Simultaneous Optical Tomography (OT) and fMRI with and without Task Activation

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Introduction

Correlation analysis of low-frequency fluctuations in (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 [1]. One of the limitations OT is the low spatial resolution. To overcome this limitation, dense probe arrays had been used in the above pioneering study.

Full head coverage is desirable in order to avoid that analysis is constrained to specific networks. Here, we assess whether a sparser topographical sampling still yields results that are comparable to the 'gold standard' of resting-state network assessment, i.e. fMRI.

We used a subset of optical fibers in a typical grid (2-3 cm inter-optode distance, Figure 1) covering both motor cortices [2]. This grid can be extended to whole head coverage, without interfering the subject's comfort.

Aim of our study:
We performed a simultaneous OT and fMRI measurement [3] during a finger tapping task and open eyes rest to investigate functional connectivity analysis for topographical OT data.

Figure 1

OT sensors as worn by the subject inside the fMRI head coil. A standard EEG cap is used to position the sensors on the head.

Methods

Materials

2 subjects participated in the experiment, one is shown.
Task consisted of 10 min open-eyes rest, followed by a block-designed finger tapping task
fMRI data acquisition: 3T MAGNETON TIM Trio (Siemens); 300 volumes (TR 2 s) rest and 510 volumes (TR 1 s) finger tapping
OT data acquisition: NIRScout 816 (NIRx Medizintechnik); 8 sources, 16 detectors, 26 channels, sampling frequency 6.25 Hz

Task dependent data processing

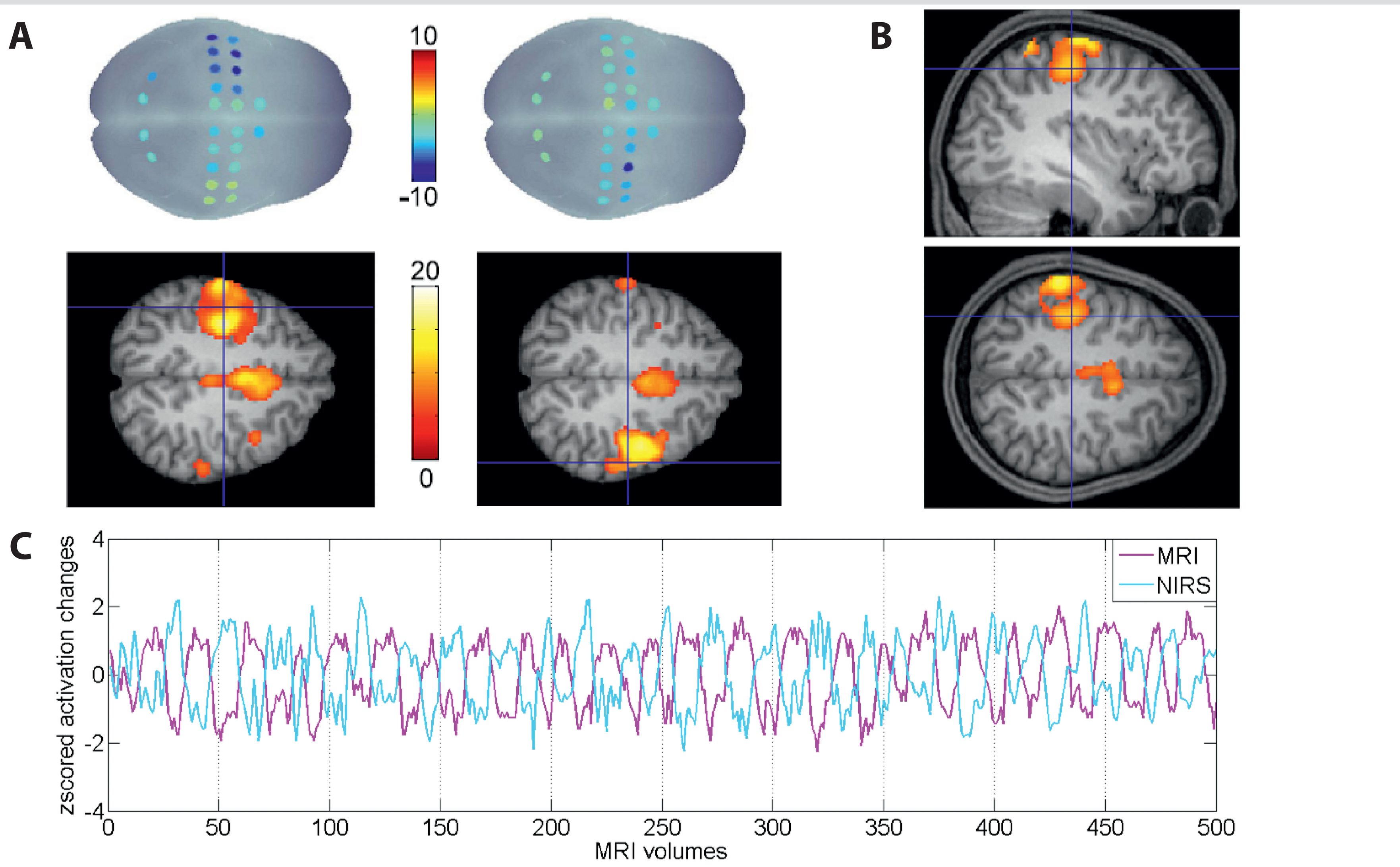
We calculated a GLM for fMRI and OT separately. This provided us with the t-values for left and right finger tapping (Figure 2A). The time course for right finger tapping was extracted from the OT channel showing maximal activity. We used this as a regressor for the fMRI data (Figure 2B) and calculated the correlation coefficient between this and the time course showing maximal activity in fMRI data (Figure 2C).

Task independent data processing

As a first attempt, the OT raw time course of the peak channel was extracted from resting state data and used as a seed channel for correlation analysis in OT (Figure 3) and as a regressor for resting-state fMRI (Figure 4).

Results

Figure 2



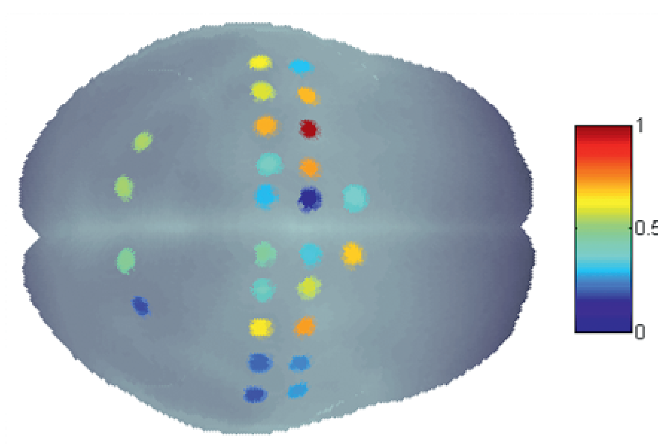
A Statistical results for deoxy-hemoglobin in OT (top row) and BOLD-fMRI (bottom row) using right and left finger tapping. Note that high activation is coded in blue (negative t-values) in the OT maps. The fMRI results show associated regions of the motor system ($p < 0.05$, corrected).
B OT peak channel data taken as regressor for fMRI analysis ($p < 0.001$, corrected).
C Time courses in the peak voxel/channel for deoxy-hemoglobin in OT and fMRI are anti-correlated with a correlation coefficient of -0.8.

As expected, the finger tapping task shows a very strong effect in OT and fMRI (Figure 2A). Using the OT channel with maximum effect in right finger tapping as a regressor in the fMRI data (Figure 2B) shows not only primary motor but also supplementary motor area. However, the correlation between OT and fMRI time courses is very high (Figure 2C). This proves an overall reliability of our data.

Functional connectivity analysis shows a compliant pattern in the OT data. Taking a right motor seed channel leads to correlations in bilateral motor cortices (inter-hemispheric correlation) and supplementary motor area (Figure 3).

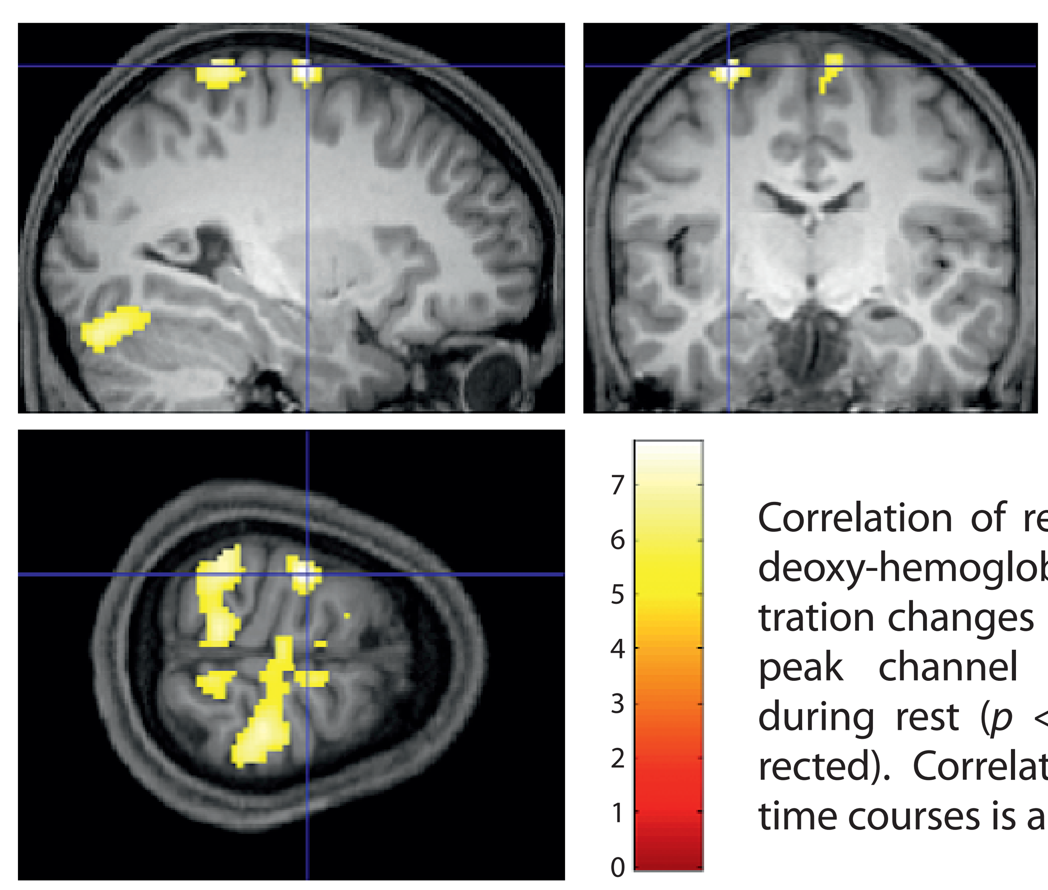
Furthermore, the same pattern shows up in resting-state fMRI, using the time course of a right motor OT channel as a regressor in fMRI data (Figure 4). But the correlation coefficient is much smaller than in the finger tapping task.

Figure 3



Correlation of resting state deoxy-hemoglobin concentration changes. The peak channel for right finger tapping was used as seed (deep red).

Figure 4



Correlation of resting state deoxy-hemoglobin concentration changes in the right peak channel with fMRI during rest ($p < 0.05$, corrected). Correlation of the time courses is around -0.5.

Conclusion

Our data proofs the concept of functional connectivity analysis for OT, especially for sparse setups. This opens this research field for OT setups with full head coverage. And thereby to a number of resting state networks like visual, attentive and default-mode network which are connected to diseases and cognition [4]. Due to its easy applicability, OT may thereby develop into a tool for functional connectivity studies in subjects or patients not suited for fMRI experiments (like newborns and deep-brain stimulated patients).

Furthermore, this data set allows the investigation of low frequencies as measured by OT and fMRI and attempts to correct the signals for global fluctuations, superficial artifacts and physiological noise.

References
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Abbreviations
OT – optical tomography
fMRI – functional magnetic resonance imaging
BOLD – blood-oxygen level dependent

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