Responses to Median Nerve Stimulation as Recorded by Simultaneous Diffuse Optical Imaging and Magnetoencephalography

POSTER
162 W-PM

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Our goal is to study the neurovascular coupling by recording the evoked magnetic fields and hemodynamic responses simultaneously. We used parametrically varied electrical median nerve stimulation on four adults and measured neuronal signals using magnetoencephalography (MEG) and hemodynamic signals using diffuse optical imaging (DOI). We found that both responses mainly came from the same region of the brain and the hemodynamic signals could be predicted well using a linear model and the MEG response amplitude.

The measurement setup

DOI system

- ✓ 18 laser diode sources (690 & 830 nm) frequency encoded
- ✓ 16 parallel APD detectors
- ✓ Detector's output is digitized at ~40kHz on-line, individual source signals obtained off-line by infinite-impulse-response filters
- ✓ Acquisition time per image (16x18 channels) can be as short as 10ms

TechEn Inc., Milford, MA. http://www.nirsoptix.com

Paradigm

- o The median nerve of the right wrist was stimulated using a multicondition event-related design
- o The current was set slightly above motor threshold < 15 mA
- o Pulses of 0.2 ms duration were used
- o 4 Hz stimulus frequency within trains
- o Train lengths 1s, 2s, 3s, or 4s depending on condition
- o we repeated 4-6 6 min runs in each subject
- o about 35 trains per run

Stimulation electrodes attached to the right arm

MEG system

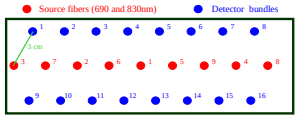
- ✓306-channel VectorView system (Elekta Neuromag Oy, Helsinki, Finland)
- ✓Data acquisition was set at 1 kHz per channel
- ✓ Band-pass filtering with pass-band between 0.01 Hz and 250 Hz
- ✓ Off-line averaging was used because of the relatively long stimulus trains

306-channel VectorView MEG system with magnetically shielded room. The optical fibers and go through a hole in the shielded room and are conneted to the DOI instrument outside the room

Design of the DOI probe

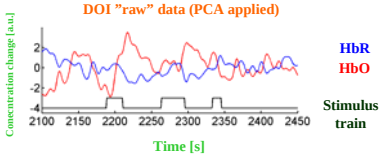
- o The DOI probe was designed to fit within a 1 cm thick gap between the subject and the MEG dewar
- o Probe is made from flexible straps and thin optode tips into which the fibers are bent in a 90-degree angle
- o All materials used are non-magnetic
- o The probe covers about 50% of the left hemisphere

DOI probe geometry

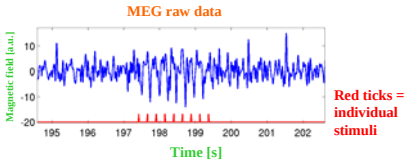


What do the acquired signals look like?

DOI "raw" data (PCA applied)



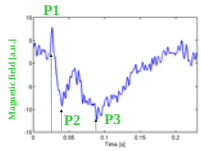
MEG raw data



DOI and MEG signal processing

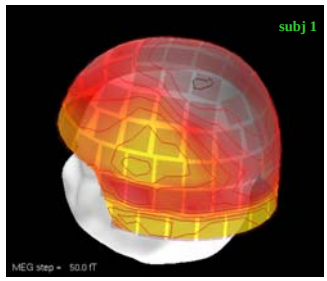
- o Bandpass filtering from 0.02 Hz to 0.8 Hz was applied to the optical data to remove slow trends and attenuate the heart beat
- o We applied principal component analysis (PCA) to filter out systemic oscillations in the optical data so that a localized response can be identified. 1-2 largest principal components were removed in both HbR and HbO
- o The MEG data shown is filtered from 3 Hz to 40 Hz
- o In the combined MEG-DOI measurement, the optical data suffers from motion artifacts more than in a regular measurement
- o The 1 cm additional distance between the top of the head and the dewar reduces the SNR of MEG responses
- o To obtain averaged responses to the four conditions, deconvolution is used in the case of the DOI data, and regular averaging for the MEG data

Typical averaged response from a single MEG channel on the somatosensory cortex

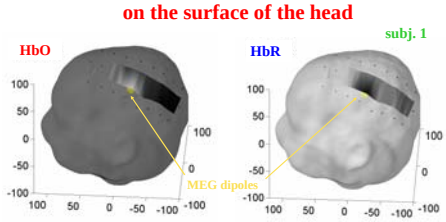


We looked at the three peaks of the somatosensory response which take place approximately at 25ms (P1), 40ms (P2), and 85ms (P3) post-stimulus

Magnetic field pattern corresponding to the second peak on the surface of the head



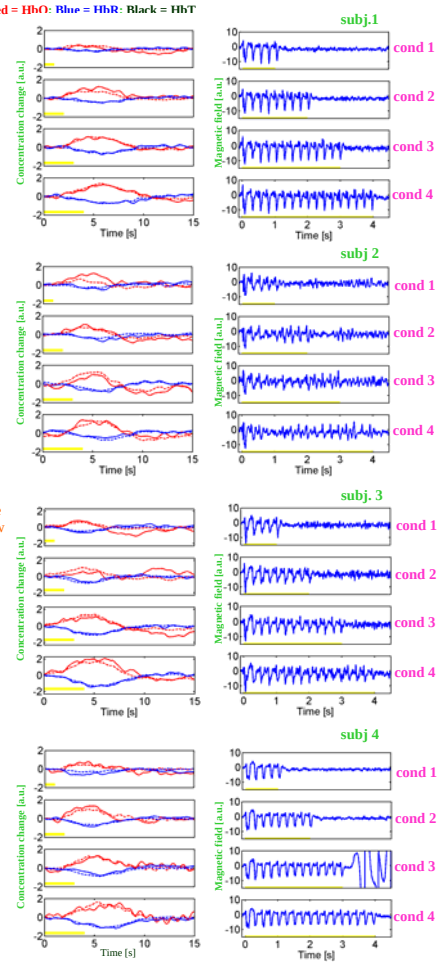
DOI activation maps displayed on the surface of the head



HbO (left) and HbR (right) concentration changes as grayscale maps on the surface of the head. The head surface was reconstructed using anatomical MRI. In the HbO image, the activated area is light gray (increase in HbO),while in the HbR image, the activated area is shown with dark gray (decrease in HbR). The yellow dots indicate 25 ms and 40 ms dipole locations. The spatial agreement is good.

Results

DOI and MEG responses by condition



- o The hemodynamic responses to each of the four conditions were determined using deconvolution and are shown on the right using solid line notation. The MEG data were converted into 10 Hz response amplitude time series which was then used in the deconvolution to obtain the hemodynamic response function (HRF).
- o The dashed lines on thehemodinamic graph illustrate the prediction made by the linear model (HRF) and the MEG response amplitude time series
- o Coefficients of determination (R^2 values) were calculated to compare how well the MEG and linear model predict the hemodynamic responses corresponding to the four conditions

✓In all subjects, the hemodynamic response peak amplitude, latency and area grow as a function of increasing train duration. The predicted responses also show this behaviour

✓The MEG responses to stimulus trains show some habituation in all subjects

✓ The response to the first stimulus of each train is markedly greater than responses to the subsequent stimuli.

Different MEG response characteristics (P1, P2, etc) were used to predict the hemodynamic responses

The corresponding R^2 values for each subject are shown in the Tables below

R^2 values for HbO

Subject	P1	P2	P1-P2	Area	P3	Area L	Unity
1	0.79	0.79	0.78	0.79	0.79	0.79	0.79
2	0.69	0.70	0.71	0.70	0.70	0.70	0.70
3	0.62	0.61	0.58	0.59	0.60	0.58	0.62
4	0.72	0.72	0.73	0.72	0.72	0.72	0.71
Mean	0.71	0.71	0.70	0.70	0.70	0.70	0.70

R^2 for predicted vs.measured HbO and HbR responses using a linear HRF model and one of the following characteristic of the evoked MEG response: P1, P2, P3 amplitude, max-min (P1-P2), the response area within time interval of 15-65ms, the response within 15-105ms (area L), or unity (= the stimulus trigger)

R^2 values for HbR

Subject	P1	P2	P1-P2	Area	P3	Area L	Unity
1	0.88	0.88	0.85	0.87	0.87	0.87	0.88
2	0.72	0.68	0.73	0.66	0.69	0.68	0.69
3	0.88	0.87	0.85	0.86	0.87	0.85	0.87
4	0.71	0.69	0.72	0.70	0.70	0.71	0.70
Mean	0.80	0.78	0.79	0.77	0.78	0.78	0.78

All of the properties derived from the MEG response predicted the hemodynamic responses for the four conditions with similar accuracy. No statistically significant differences were observed between the predictions based on the stimulus trigger and properties of the MEG response. HbR responses were predicted better than HbO responses. In this paradigm, a linear model was found to be adequate.

Summary

✓ DOI and MEG event-related responses can be recorded simultaneously in adult humans

✓ The hemodynamic response and the magnetic dipole corresponded to the same area of the brain

✓ The MEG P1 peak amplitude with a linear model was able to explain 80% of the variance in the HbR response and 71% of the variance in the HbO response

Acknowledgments

The authors would like to thank Deirdre Foxe, G W Krauss, and Shalini Nagdir for their help with the measurements and probe design

Funded by NIH R01-EB001954, P41RR14075, the MIND Institute, and the Athinoula A. Martinos Center for Biomedical Imaging