Concurrent Time-Resolved Near-Infrared Spectroscopy and fMRI Measurements of Visually Stimulated Humans

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Introduction: Near-infrared spectroscopy (NIRS) allows to determine changes in oxy- and deoxy-hemoglobin concentrations in the human head non-invasively. In contrast to NIRS using cw light, time-domain NIRS using short (ps) laser pulses provide depth resolution by recording distributions of times of flight of diffusely reflected photons. In this way cerebral signals can be separated from those of overlying tissue [1]. For the first time, time-resolved NIRS has been co-registered with fMRI using newly developed, MR-compatible, time-domain NIRS instrumentation.

Methods: So far, two healthy subjects were investigated in a 3T Bruker scanner, using 8 Hz radial checkerboard visual stimulation, and a T2*-weighted EPI sequence. The heads of the volunteers were resting on a surface coil, which also held a 6 mm thick silicone plate (see Fig.1 left). Three transmitting optical fibers and four receiving fiber bundles were mounted on this plate. Three diode lasers with average power of less than 10 mW at 664, 760, and 826 nm were connected to the transmitting fibers illuminating a single 3 mm wide spot on the back of the volunteer's head. The fiber bundles being in contact with the skin collected the diffusely remitted light at an inter-optode (transmitting fiber-receiving fiber bundle) distance of 3 cm, and guided the light to separate photomultiplier tubes of three time correlated single photon counting channels.

Results: fMRI contrast maps with a resolution of 2.8 x 2.8 x 1.6 mm^3 were obtained showing activation in the visual cortex (Fig.1 right). In a multimodal measurement with 20 stimulation cycles within 20 minutes one of the two subjects showed significant stimulation contrast in NIRS data. Fig. 2 depicts the diffusely reflected intensity (total photon counts) at two wavelengths averaged over 20 cycles. During stimulation absorption at 664 nm is reduced due to decreased deoxy-hemoglobin concentration also seen by BOLD-fMRI. The TOF variance, weighting deeper (2 cm) layers of the head, is affected at 826 nm only. Although the four receiver bundles cover an area of 4cm x 4cm our experiments indicate that the initial optode positioning has to be optimized. After recording preliminary fMRI maps the head will be moved to maximize light penetration of the activated volume.

Conclusion: A novel setup for co-registration of time-resolved NIRS and fMRI has been developed and successfully tested. This will provide new insights into the mechanisms of hemodynamic response and will improve analysis of optical data by using MR-results as prior knowledge.

References: [1] Liebert A, et al (2004). Appl Opt 43:3037-47

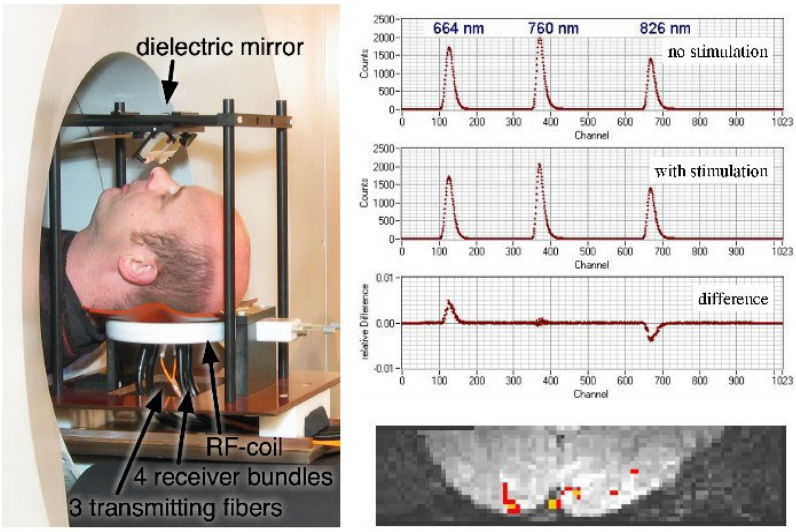

Fig.1: apparatus for concurrent time-resolved NIRS and fMRI (left), NIRS data (top right) and 3 tesla fMRI data (bottom right) after visual stimulation

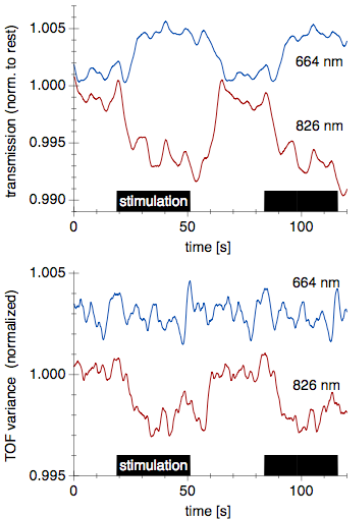

Fig.2: response to stimulation of diffusely reflected intensity (top) and TOF variance (bottom)