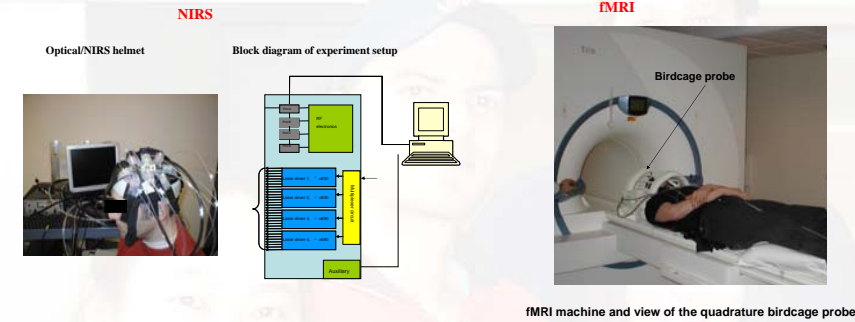


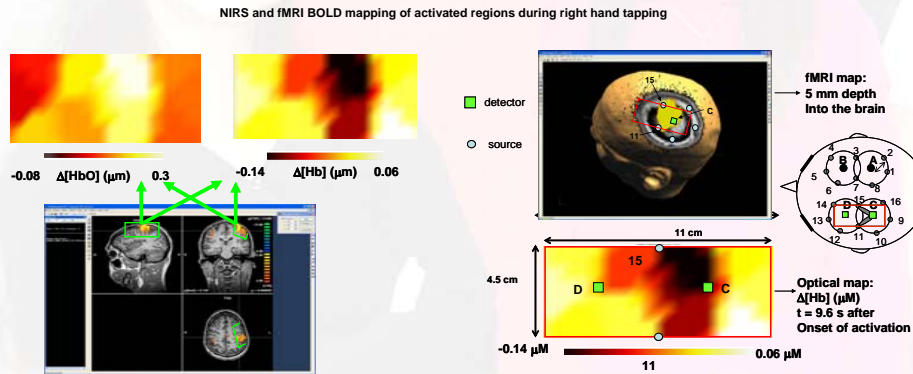
Experimental protocol & data analysis for concurrent fMRI-NIRS

Functional magnetic resonance imaging (fMRI) is performed on a 3 Tesla Siemens Trio whole body magnetic resonance scanner (Siemens Medical Systems, Erlangen, Germany). A quadrature birdcage probe, open at both ends and with a removable top section, is used to allow the optical fibers to be placed on the subject's head without significant bending. After localization and shimming, a series of fMRI images are acquired. Image parameters are as follows: gradient echo EPI, TE/TR=30/2020ms, 64x64 image matrix, full k-space acquisition, FOV 220x220, 30 interleaved coronal slices (RL readout), 3mm thick, 0mm gap, with the slice stack centered on the motor strip. 120 time points are acquired after 12 dummy shots. Images are saved in DICOM format and processed using Brain Voyager QX (Brain Innovations B.V., Maastricht, The Netherlands). The update rate of fMRI data is 0.5 Hz. The optical experimental setup is a frequency-domain tissue imager (Imagent, ISS, Inc., Champaign, IL) comprising sixteen laser sources at 690 nm and sixteen laser sources at 830 nm (average power about 1 mW) and four optical detectors (photomultiplier tubes, Hamamatsu Photonics R928). The laser diodes are modulated at a frequency $f = 110$ MHz, and are coupled to optical fibers 400 μm in core diameter and 10 m long. The subject (30 years old healthy male) lies motionless inside the magnet. One minute of baseline optical and fMRI data are acquired. Afterwards six cycles of 20 sec right hand tapping and 20 sec of rest are carried out by the subject while simultaneous NIRS and fMRI data are acquired. The optical data are filtered to cut off the lower ($< .0125$ Hz) and higher frequencies ($> .1$ Hz), averaged over the six cycles (folding average) and then analyzed by using modified Lambert-Beer law for the change of oxy and deoxy hemoglobin. Temporal trends and spatial mapping are obtained for both NIRS and fMRI.

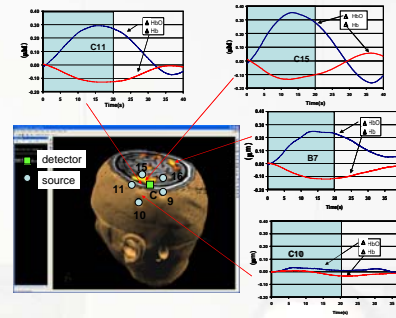
Experimental setup



Spatial Correlation

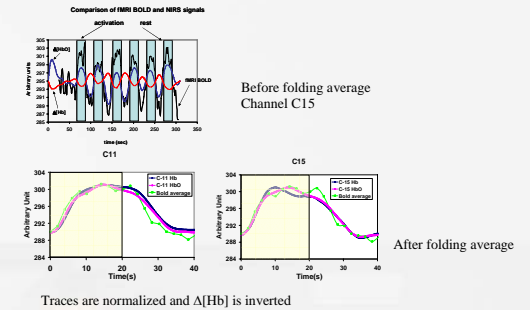


NIRS signal: temporal trends from different channels

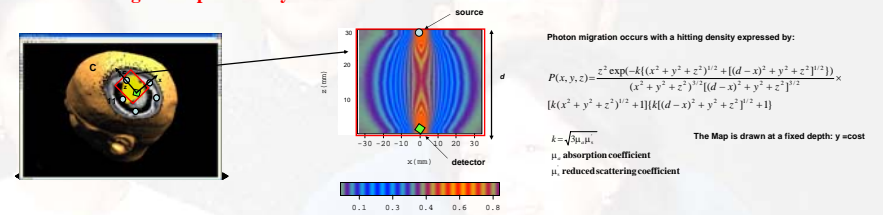


NIRS-fMRI: temporal correlation

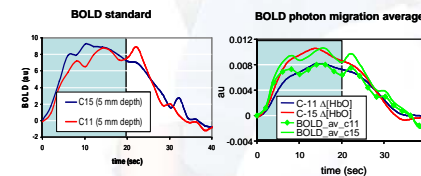
Correlation between $\Delta[\text{Hb}]$, $\Delta[\text{HbO}]$ (NIRS), and BOLD (fMRI) signals



Photon migration probability distribution



Comparison of fMRI-BOLD before and after using the photon distribution



While the standard BOLD signals calculated at two different locations, (C15 and C11) do not show any noticeable difference (left figure), those calculated by using the photon probability distribution have different maxima, that correlate with the maxima of $\Delta[\text{HbO}]$.

Summary

We have presented preliminary results on simultaneous NIRS-EEG and NIRS-fMRI data acquisition for the study of functional imaging of the brain under hand tapping task. The comparison of NIRS-fMRI shows a good correlation between BOLD signal and both $\Delta[\text{Hb}]$ and $\Delta[\text{HbO}]$ measured with NIRS at the area of activation. A smaller activation on the side ipsi-lateral to the tapping hand is present in the fMRI maps and also on the optical data (data not shown). We have shown some preliminary results about a new way of comparing NIRS and fMRI data. We suggested that in fMRI data analysis the BOLD signal should not be calculated as a simple average of the activated voxels, but it should reflect the photon density probability distribution between source and detector. In the example shown above the BOLD signal calculated from two different locations scales as the change in Oxy-hemoglobin.

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