A Wearable Multi-Channel NIRS Imaging System for Brain Imaging in Freely Moving Subjects

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NIRX ENLIGHTENING INNOVATION

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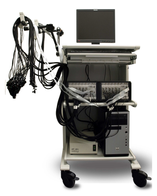
Bernstein Focus: Neurotechnology Berlin

New Wearable Multi-Channel NIRS System

Probably most of the NIRS setups employed in neuroscientific research still offer a restrained setting, because typically, in sum rather heavy and not very flexible fiberoptic cables tie the subjects to a more or less stationary instrument. While restrained settings with a portable but stationary instrument might be well feasible for bedside monitoring, they hamper imaging in a more natural environment, e.g. outside the laboratory, during sports or physical therapy, when social interactions between subjects are required or when imaging children.

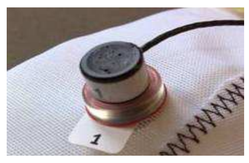


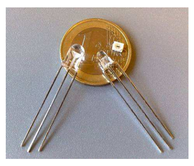
• <u>with direct illumination:</u>
8 dual-wavelength light emitting diodes (L760/850-36 by Epitex Inc., Japan)

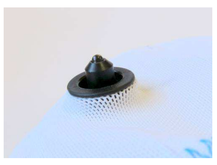
• <u>with active optical sensors (AOS):</u>
8 self-designed AOS each with a 12-mm segment of plastic optical fiber (POF, 3-mm OD, NA = 0.50, type NT53-833 by Edmund Optics, Barrington, NJ, USA) guiding the received light to a Si photo diode (PD, BPW34, Siemens, Germany) housed in an internally shielded enclosure that contains active amplification (10-MΩ transimpedance amplifier)

• <u>wearable 103 mm x 43 mm x 167 mm main part</u>:
containing data acquisition (NI-USB 6216, National Instruments, Austin, TX, USA (NI)), LED and AOS circuitry. Data transfer and power supply are realized though 2 USB 2.0 connections.

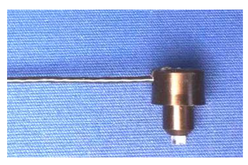
LED Illumination

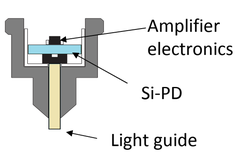






Active Optical Sensor





Complete wearable NIRS system

Abstract:

We present a miniaturized, portable diffuse optical NIR imaging system that allows multi-channel brain imaging in freely moving subjects and lends itself readily to general-purpose large-area imaging of brain activity. The performance of the instrument is demonstrated on N=7 subjects in a hand gripping motor paradigm on a bicycle performed during three conditions: (i) outdoor bicycle riding, (ii) indoor bicycle ergometer pedaling and (iii) rest. To the best of our knowledge, this is the first demonstration of functional NIRS brain imaging during an outdoor activity in a real life environment.

Experimental Design

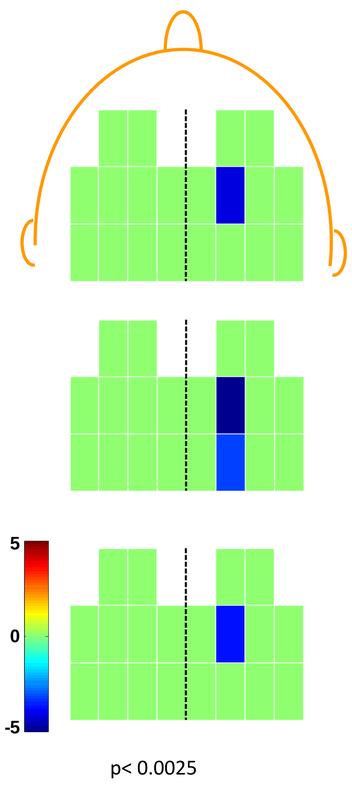
• We measured 8 subjects performing 10 repetitions of a self-paced left hand gripping motor task (20 sec gripping followed by 40 sec of rest) on a bike during (i) outdoor bicycle riding, (ii) indoor pedaling or (iii) rest. Auditory commands 'start' and 'stop' were issued via earphones by the control laptop to indicate onset and cessation of left-hand motion on a dummy hand brake lever mounted to the handle bar .
•The optodes were arranged in two groups of four sources and four detectors each clustered around positions C3 and C4 according to the extended international EEG 10-20 system. The inter-optode distance between neighboring source-detector-pairs was 25±3 mm. A secondary fabric cap worn over the optical probes served to improve probe-tissue-contact and to provide stabilization against motion artifacts.

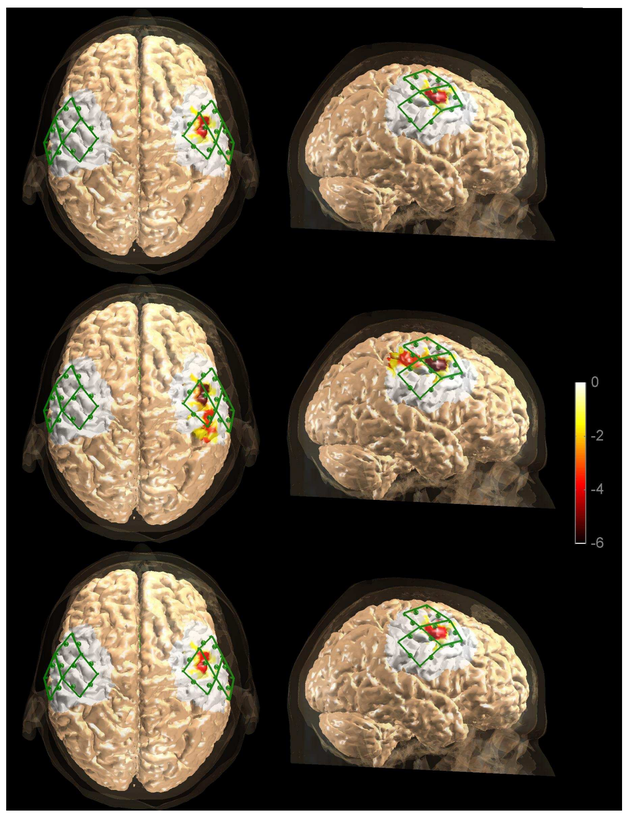
Data processing

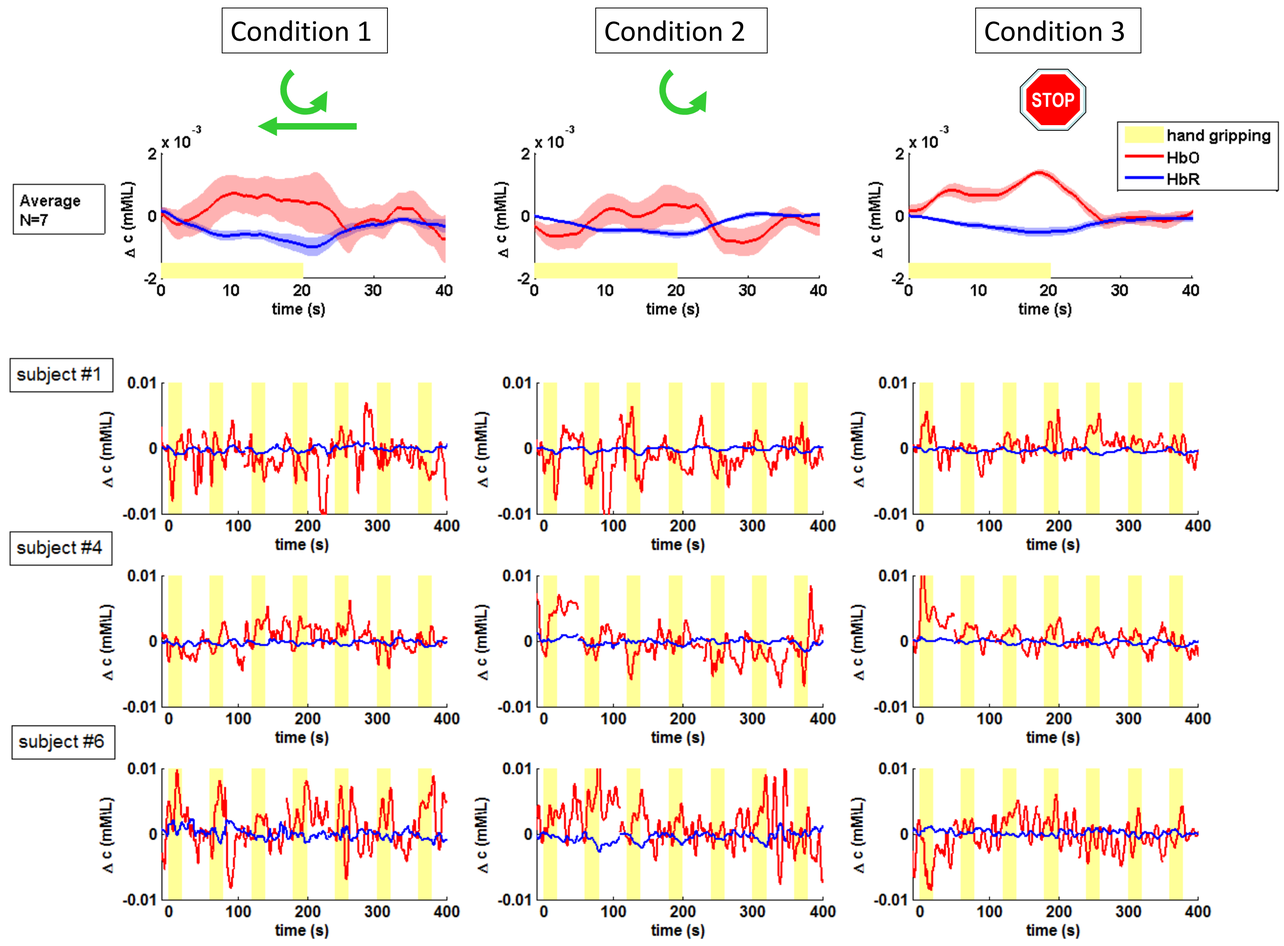
- Reconstruction of relative HbO/ HbR-Changes with modified Beer-Lambert law
- Filter: 0.1Hz notch, 0.011- 0.2 Hz butterworth bandpass
- Baseline: Average over all time points
- Trials Rejection: on average < 1 trail/condition; after visual inspection
- Subjects rejected: 1, severe artefacts due to optode displacement during bicycling
- Time Courses: average over all trials and subjects, standard error of mean
- Activation Maps: one-sided t-test of mean ΔHbR decrease 8-20 sec after stimulus onset

Results & Conclusion

Condition







Topographic mapping of all NIRS channels. Left: Experimental conditions. Middle: Topographic mapping of all measurement channels with a significant relative HbR decrease 8-20 sec after stimulus onset.color coded with their corresponding *t*-value after Bonferroni-Correction for multiple comparison (p<0.0025). Right: Channel projection onto a representative cortical surface map (normalized in MNI space) using the 10-20 EEG electrode system. Optodes and measurement positions are indicated in green.

Reconstructed oxygenation changes. Top row: Mean relative HbO (red) and HbR (blue) concentration changes averaged over 7 subjects during during the hand gripping motor task while outside bicycle riding (left), inside pedaling on a stationary bike (middle) and inside resting on a stationary bike (right) (*t* = 0 s marks clenching onset; yellow: 20-s activation period). Rows 2-4: single subject time courses of relative HbO and HbR changes in all three conditions (yellow: 20-s activation period)

The results reveal a focal activation to left hand clenching by the relative HbR decrease over the contralateral motor cortex. The averaged time courses show the prototypical increase in HbO and decrease in HbR in response to neural activation. No significant differences between the three conditions were found, however, HbR decrease appears to be stronger during outdoor bicycle riding than compared to the resting condition. The resulting activation pattern to left hand clenching during bike riding demonstrate the feasibility of our compact NIRS device for realistic studies in the fields. To the best of our knowledge, this is the first demonstration of functional NIRS brain imaging during an outdoor activity in a real life environment. Truly portable and miniaturized NIRS systems open new perspectives to study sensory or cognitive paradigms in realistic environments and furthermore promise clinical uses as a monitoring tool in neuro-rehabilitation and intensive care units.

References

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[2] C.H.Schmitz, M.Loecker, J.M.Lasker, A.H.Hielscher, R.L.Barbour. Instrumentation for fast functional optical tomography. *Rev. Sci. Instrum.* . 2002;73(2)

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