

Bench philosophy (7): Discovering brain activity with Near Infrared Spectroscopy

Candling the Brain

An old dream of mankind is to read the thoughts of another person. There have been many ideas in history on how to study the thoughts of a human being, which have led to the creation of mind machines or lie detectors. However, we are far away from reading a mind like a paperback but some techniques used today are well established and have quite an impact on understanding the brain.

Spectroscopy may be defined, as the study of the interaction between light and matter (<http://en.wikipedia.org/wiki/Spectroscopy>). There are a couple of spectroscopic methods to study the structure and function of an object. Some of them e.g. mass spectroscopy harm the object or they interact with it and change its properties. Special care is needed for *in vivo* studies. Usually, they are performed with one of the following methods: Visible Spectroscopy, Infrared Spectroscopy, Thermal Infrared Spectroscopy, Nuclear Magnetic Spectroscopy, Photoemission Spectroscopy, X-RAY, Raman Spectroscopy or Inelastic Neutron Scattering.

Looking for the perfect method

To study not only the properties but also the dynamic processes in living tissues, methods like Electroencephalography (EEG), Magnetic Encephalography (MEG), Positron Emission Tomography (PET), and Nuclear Magnetic Resonance (NMR) are applied. Harming and destruction of the object may be tolerated in material studies. For *in vivo* studies, however, the interference with the living object should be kept as minimal as possible. Ionising methods such as X-ray or radioactive tracers, for example, may have long-term consequences for a patient, like cancer. Others such as NMR are accompanied with discomfort for the patient and are therefore not suitable for the investigation of a child's brain function. A perfect method for *in vivo* studies would



NIRS optode in action



have the following features:

- Minimal invasive for the patient (object)
- Cheap
- Good reproducibility
- Harmless for the scientist

Old method – newly discovered

Near Infrared Spectroscopy (NIRS) comes very close to meeting these requirements. Long before the pharmaceutical and chemical industries discovered NIRS, the agricultural industry applied it to examine the water and fat concentration in crops or to determine alcohol levels in wine. Pharmacists use NIRS to check the ingredients of their products even through the package while chemists define the termination of reactions, e.g. esterification, hydrolysis or hydrogenation with NIRS. In medicine NIRS applications are used for non-invasive medical diagnostics like oximetry or measuring blood sugar concentrations. It is also applied to detect brain functions by measuring the levels of blood haemoglobin (Hb). Even astronomers use NIRS. They look for molecules like titanium oxide or cyanide in the universe with NIRS to classify cool stars.

NIRS is an absorption spectroscopic method, which tracks the loss of light intensity. The penetrancy of NIRS is higher than that of infrared light. One of NIRS' main

benefits, however, is the ability to track the redox potential of Hb and oxygenated HbO₂ in the brain (F.F. Jobsis, Non-invasive infrared monitoring of cerebral and myocardial sufficiency and circulatory parameters. *Science*, 198, 1264, 1977).

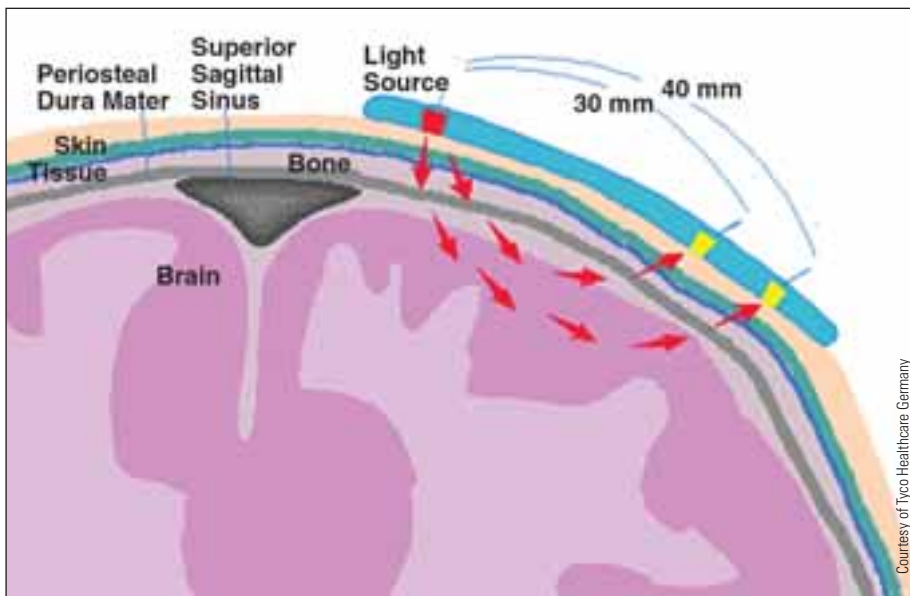
Easy to use and not invasive

Fritz Haverkamp's group at the Children's Hospital Medical Centre of the University of Bonn studies the higher intellectual functions and associated brain activities in special areas of the central nervous system (cns) in children. In order to do this, they have searched for a minimal invasive method providing valid data connected with brain activities especially in the pre-frontal cortex (PFC). This part of the brain is mainly associated with executive brain functions. Methods like NMR spectra are well established, however, too invasive in children. Therefore the Haverkamp group uses NIRS as an alternative method for analysing children's brain activities. NIRS is easy to use and does not harm the child's brain. Furthermore, it is less invasive and less expensive than other methods.

The brain's activity can be measured in terms of the BOLD response (Blood depend-



Matthias Faix with NIRS receiving unit attached to his forehead



Scheme showing the “banana shaped” path of Near Infrared photons through the brain

ant oxygenation). This oxidation process reflects cortical activities e.g. during cognitive processes. NIRS measures the underlying cytochrome c activities. Hence, the brain's cellular activity is correlated by a trackable change in the absorption of NIRS.

Transparent skull

During the NIRS experiment, special light sources attached to the patient's head emit light between 730 nm and 804 nm (see picture) and detectors measure the amount of light passing through the skull. In fact, NIRS is a kind of brain-photometer. The wavelengths are set to the maximum absorbance of Hb or HbO₂, so the redox status of a particular part of the brain can be surveyed. The main advantage of NIRS is the skull's transparency for near infrared light and its ability to visualise developments in the brain. The only limitation is the depth of the tissue that should not exceed 2.5 cm but this is perfectly suited for studies of the PFC.

NIRS measurements are pretty fast because only two optodes need to be fixed to the temporal frontal section of the skull, in contrast to 32 electrodes in EEG measurements. Actually, the probands forget that they are wearing NIRS optodes. This is an important detail because the proband's undisturbed concentration is important whilst testing higher order brain functions.

How valid is this method? According to studies by the manufacturer of the NIRS equipment in use (INVOS), there is a reproduction quality of 5%. For brain studies an absolute change in the oxygenation status is irrelevant, as they focus purely on the

change of oxygenation in correlation with the working brain.

The NIRS apparatus delivered by the manufacturer is equipped with a serial interface. Haverkamp's group has built an additional interface between the detection machine and a normal usb-equipped computer. This enables them to track the deltas of the oxygenation status in real time while triggering functions on the computer. They can, for example, follow brain activities with NIRS while a proband is working on the Hanoi Problem or the Wisconsin Sorting Card Test.

They also plan to study the development of the brain with NIRS, to detect problems in child development at an early stage. A special focus is set on children aged between 6 and 8 months, for whom EEG data already exists. The comparison of event-related signals in conjunction with subjective figures (known as “Kanizsa squares”) may lead into a new mass diagnostic in early childhood. The combination of real time brain tracking and problems presented by a computer may not only help in detecting problems in a developing brain but also to train patients to sustain good health for a longer period of time.

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Fancy composing an installment of “Bench Philosophy”?

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