Studying brain function with near infrared spectroscopy concurrently with electroencephalography

**Abstract:** In this study, the P300 endogenous evoked response was generated in human subjects using an auditory oddball paradigm while concurrently monitoring the hemodynamic response both topographically and temporally with near-infrared spectroscopy (NIRS). The NIRS measurements demonstrated a hemodynamic change in the frontal-temporal cortex within the first few seconds after the appearance of the electrical potential (P300).

**Introduction:** Near-infrared spectroscopy (NIRS) and electroencephalography (EEG) are non-invasive imaging modalities with the ability to give complementary information about the functioning of the brain. Concurrent NIRS and EEG have been used to investigate the synchronized activity of neurons and the subsequent hemodynamic response in human subjects[1-5]. In particular, Richard et al found that hemodynamic responses associated with the “oddball” auditory stimulus had a latency of approximately 100 ms and occurred in close proximity to the areas of peak electrical activity[6], while Silvina et al detected NIRS signal and event-related potentials simultaneously during a semantic processing task[2]. These previous studies suggest that there is some kind of coupling between evoked potentials, representing electrophysiological responses, and the NIRS signals, representing hemodynamic and metabolic responses[3,4].

There is potential to use combined electrical and optical evoked responses to identify the neuronal activation and corresponding hemodynamic response temporally and spatially. To explore this potential, in this study we have concurrently collected evoked potentials and optical responses (related to hemodynamic changes) associated with cognitive tasks (oddball paradigm) using a specially-designed opto-electrical helmet worn by the subject.

**Instrumentation for concurrent electrical and optical recordings:** The block diagram of the experimental setup, the optical diagram, and a detail of the EEG-NIRS helmet are shown in the figure on the left. The EEG equipment for the measurement of the event-related potentials (ERP) is based on a NuAmps, a 40-channel digital EEG amplifier running SCAN 4.3, a software system designed to acquire and analyze amplified EEG data. Stimulus is provided by STIM, a software environment for custom stimulus and task design as well as presentation (all from NeuroScan Inc., Abbotsford, Australia). The acquisition rate of the digital EEG was 1000 Hz with digital filtering applied in the post-analyser. Each one of the 40 electrodes was applied with an impedance below 5 kΩ. The evoked potential was extracted from the continuous EEG file by averaging epochs of the EEG surrounding the stimulus locked auditory stimulus.

The optical system used in these studies is a frequency domain optical spectrometer from SSi, Inc., Champaign, IL (Duraspec™) comprising 2 PMT-based detector channels, 16 laser diodes coupled to optical fibers (8 at a wavelength = 690 nm, and 8 at = 830 nm), and internally modulated at 110 Hz. The acquisition rate of the optical system was set to 7812 Hz. Striker optical source fibers and two optical detectors are embedded into a standard 40-channel EEG cap (NeuroScan Inc., Abbotsford, Australia) to allow simultaneous recording of EEG and NIRS data.

**Data analysis:** EEG: Following routine artifact rejection and baseline DC correction, the EEG data were averaged for rare and common cases of the tone, starting 100 ms before each stimulus and lasting 400 ms after. The average wave of the rare stimuli and the common stimuli are shown for further analysis with the waveforms presented topographically at each of the 45 electrode positions with reference to a linked ear reference. The P300 wave is seen in the “oddball” paradigm.

**Optical detector fiber**

**Optical illumination fiber**

**EEG electrode**

**Protocol:** The subject (an adult male age 24 years of age) is asked to sit comfortably in a chair wearing bilateral ear phones. Half minute of baseline optical data is acquired, then subject hears 50 consecutive tones (20 m in length) with its intervals in between them. Among these 50 tones, 10 are high-pitch tones (2000 Hz), representing the rare cases. The other 40 tones are low-pitch tones (1000 Hz), representing the common cases. The high-pitch and low-pitch tones are mixed randomly. The subject was asked to press a button (with his right finger) when he hears the rare cases and to otherwise be quiet and relaxed.

**References:**


