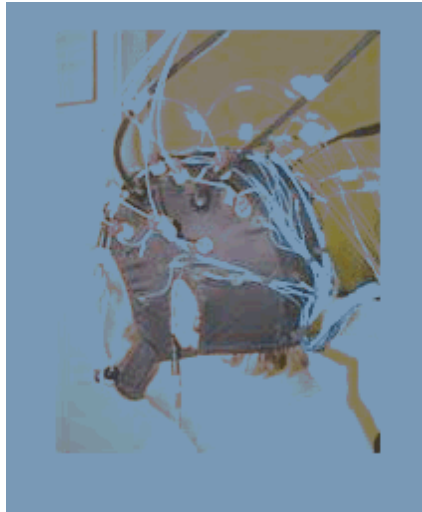


Concurrent recordings of electrical evoked potentials and near-infrared responses to brain activation



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Near-infrared spectroscopy (NIRS) and electroencephalography (EEG)

Functional studies of near-infrared spectroscopy (NIRS) are based on the strong absorption of hemoglobin in the near-infrared spectral region (molar extinction coefficient of $\sim 2,000 \text{ cm}^{-1} \text{ M}^{-1}$ at 800 nm), and to the different shape of the near-infrared absorption spectra of oxy-hemoglobin and deoxy-hemoglobin. Once the near-infrared light is delivered to the scalp by a source fiber, the light is scattered by the tissues and partially absorbed by chromophores such as water, lipids, and cytochrome oxidase, but mostly by the hemoglobin. The amount of light received by a detecting fiber, which is placed about 3 cm away from the source fiber, can be used to examine the hemodynamic response of the cortex of the brain between the source and detector fibers.

Electroencephalography (EEG) recordings provide information on the electrical activity occurring in the brain. This can be used to measure evoked potentials associated with specific functional activities [Menon *et al.*, 1997; Teplan *et al.*, 2002].

Both NIRS and EEG are non-invasive imaging modalities, and they have the ability to provide complementary information about the functioning of the brain. Concurrent NIRS and EEG have been used to investigate the synchronized activities of neurons and the subsequent hemodynamic response in human subjects [Opitz *et al.*, 1999; Kennan *et al.*, 2002]. Furthermore, the detection of well-established electrical evoked potentials can give information on whether a given stimulation has elicited a desired response, and then NIRS can be used to localize it or characterize the hemodynamic pattern associated with it.

P300 and N100

A well documented event-related potential in the brain is the P300 in response to an auditory oddball stimulus [Picton, 1992; Polich 2003]. This evoked potential has a latency of about 300ms following oddball stimuli (i.e. rare events such as a high-pitch sound that are randomly presented amidst common events such as low-pitch sounds). Another well-known

evoked potential, the N100, corresponds to auditory stimulus and is observed in response to both rare and common stimuli.

Data collection

Optical source fibers and optical detector fibers are embedded into a standard 40-channel EEG cap to allow for simultaneous recording of EEG and NIRS data (see Figure 1). The data is collected during a protocol in which the subject is presented with a series of sounds, many low-pitch and a few high-pitch. The high-pitch sounds are the oddball stimuli, while the low-pitch sounds are the common stimuli.

Figure 3 shows the time evolution of a cerebral map of electrical signals, in which one can identify the P300 and N100 evoked potentials as measured with our optical/electrical helmet. Figure 4 shows the optical response to the oddball stimuli, consisting of an increase in the concentrations of oxy-hemoglobin and a decrease in the concentration of deoxy-hemoglobin, which are broadly accepted as the trademark of cortical activation [Villringer *et al.*, 1993; Villringer and Chance, 1997].

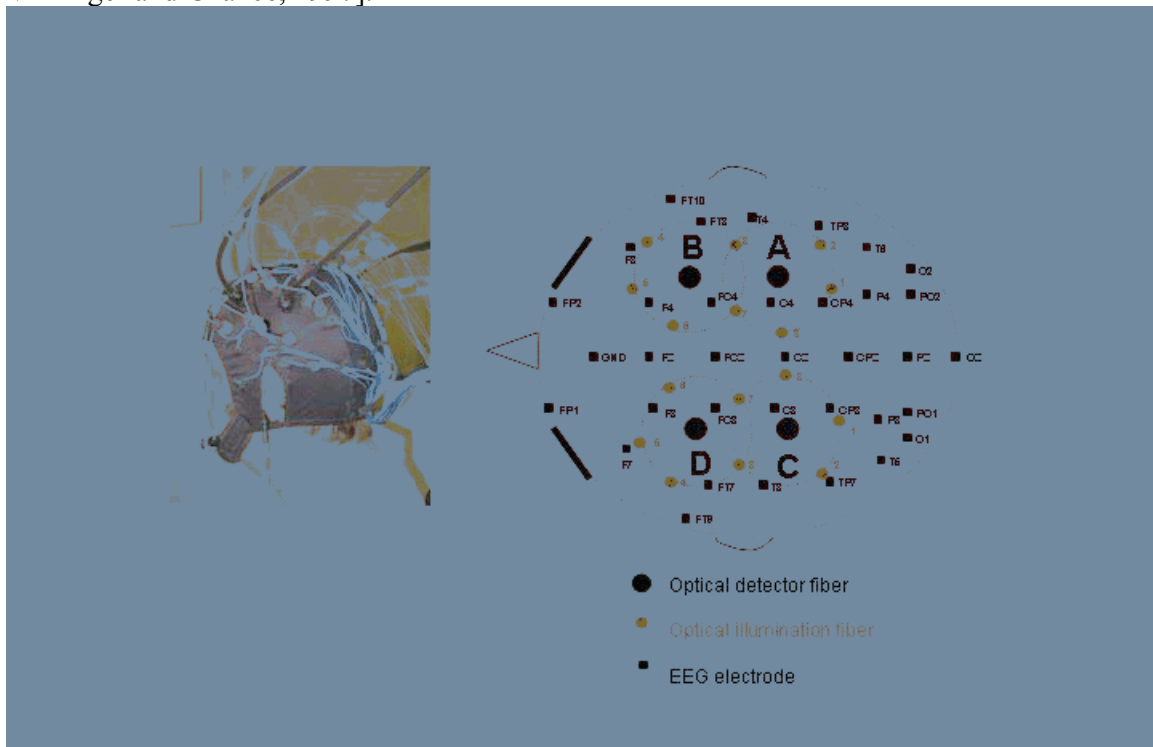


Fig. 1. Photograph and top view of the helmet containing the optical source-detector matrix for NIRS and the electrodes for EEG.

Protocol
 00.511.522.5020406080100120140
 Time(s) Stimulus Auditory Stimulus
 Beeps Boops Time slot to average each beep for NIRS
 Time slot to average after each beep for EEG (500ms)
 250 Oddball Common cases Similar process has been conducted for the
 common stimulus. Time slot to average for oddballs in NIRS (20s)
 Time slot to average for oddballs in EEG (20s)

Fig. 2. Stimulation protocol, showing the high-pitch sounds (oddball stimuli) amidst the more common low-pitch sounds (common cases).

Fig. 3. Average temporal evolution of spatial maps of evoked potentials for the oddballs. The blue area that peaks at about 100ms corresponds to the negative N100, whereas the red area that appears around 300ms is indicative of the positive P300 evoked potential.

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. 4. Hemodynamic responses to oddball stimuli (blue lines) and common stimuli (fuchsia lines) recorded by detector B and source 3 (see Fig. 1). The increase in oxyhemoglobin and decrease in deoxy-hemoglobin observed in response to oddball stimuli is associated with brain activity.

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