Biophotonic Methods for Brain-Computer Interfaces

C. Soraghan[1,3], F. Matthews[4], C. Markham[3], B.A. Pearlmutter[4] and T. Ward[2]
Department of Experimental Physics, Department of Electronic Engineering,
Department of Computer Science, Hamilton Institute,
NUI Maynooth, Co. Kildare
christopher.j.soraghan@nuim.ie

Summary

A brain-computer interface (BCI) is a system that allows a user to communicate with the external world through thought processes alone. A Near-Infrared Spectroscopy (NIRS) based BCI or Optical BCI (OBCI) intends to detect volitional mental states non-invasively, in-vivo, via optical interrogation methods. NIR light pervades to a depth of ~2cm, successfully penetrating the scalp, skull, further cranial layers, and cortical tissue. Under the influence of volitional neuronal excitation, the cortical tissue’s optical properties serve to absorb and scatter the impending incident light, which can be detected and classified as an ‘attempt’ by the subject to control some augmentative device. The absorption and scattering of most intermediate layers and chromophores are assumed constant and therefore do not affect the qualitative varying haemodynamic concentrations of interest. Overall, the BCI research field is attempting to mitigate the affects of such neurodegenerative diseases such as Amyotrophic Lateral Sclerosis. Construction of the device can be broken into hardware, software, ambient control and subject preparation. Each of these modules is further broken into pre-processing and post-processing. Finally, visual feedback aids in improving performance over time as subjects learn to control their cranial haemodynamics. Indeed, such control has been used over the last decade for the purpose of relieving the affects of such disorders as ADD. Hemoencephalography (HEG) has been used in biofeedback, also having its origins in NIRS, to essentially teach the subjects to control the haemodynamics of their frontal lobe.

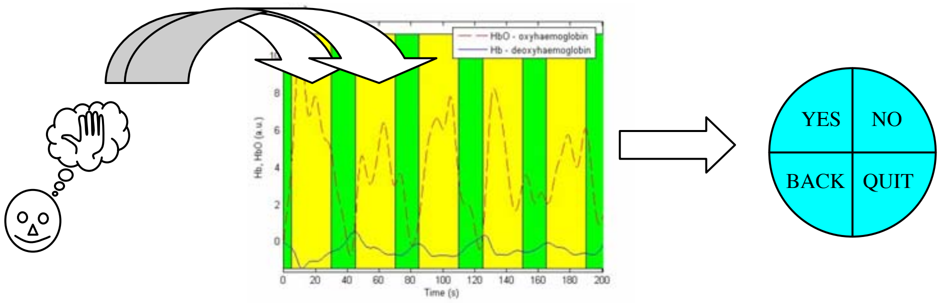

Figure 1: Mental volitional effort by the subject induces an increase in oxyhaemoglobin and a decrease in deoxyhaemoglobin. This is used to classify the intent and in turn is used to control a device or select from a list.

In choosing the hardware there are many factors that need to be considered. The correct choice of detector and source with their accessories and optics are very important. The main consideration is the overall signal-to-noise ratio with the simple mechanical coupling of the optics to the subject being most pertinent and frail. For the detector the main concerns are noise-equivalent-power (NEP), quantum efficiency, spectral response, gain, and minimum detection limit. For the source, wavelength selection, safety, beam angle, full-width half maximum (FWHM), and output power are carefully considered. Indeed, commercial NIRS systems have not employed the most efficient wavelengths, thus portraying the advantage of developing a custom-made malleable device. Other considerations in hardware include demodulation, where a small signal buried in noise has to be recovered. With the shear increase in power of software-based systems, there is a possibility of developing software-based demodulation and other signal processing techniques, increasing flexibility and improved real-time control. The applications explored for such a NIRS-BCI device thus far have been in simple gaming, stroke rehabilitation, BCI control and biofeedback.