Brain-computer interface using a simplified functional near-infrared spectroscopy system

Coyle SM et al.

J. Neural Eng.4 (2007)

Presenter : Evgenii Kim

GIST, Dept. of Information and Communication.

Gwangju Institute of
Science and Technology

Outline

- Introduction

- Methods

  – NIRS-the optical signal

  – Functional NIRS measurement and instrumentation

  – Functional NIRS-BCI system design

  – Optode design and placement

  – Software

  – Experimental procedure

  – Data processing and classification

- Results
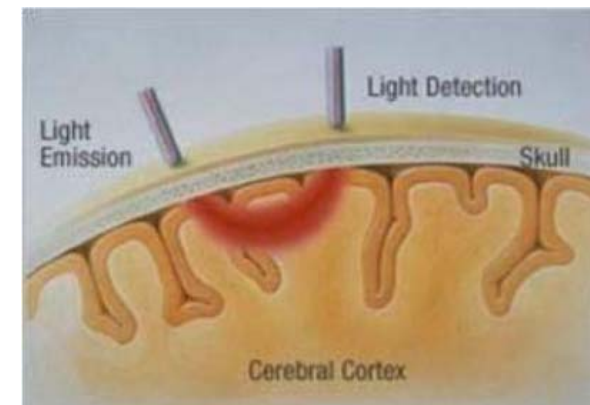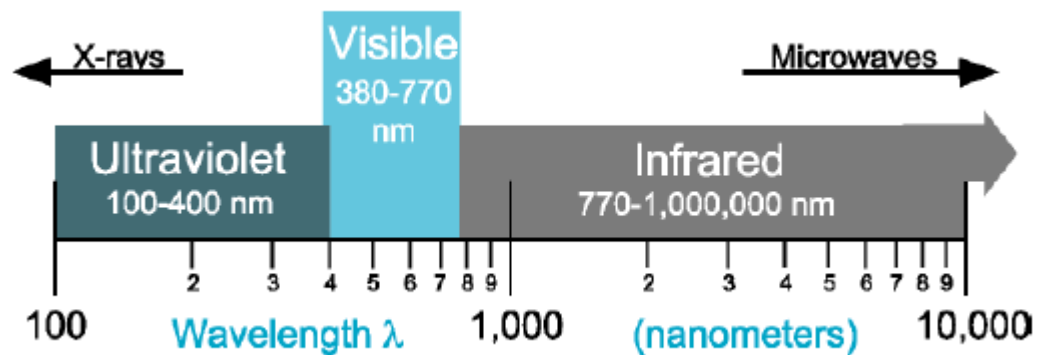
- Conclusions

Introduction

fMRI

Functional near –infrared spectroscopy system

ECoG

Method

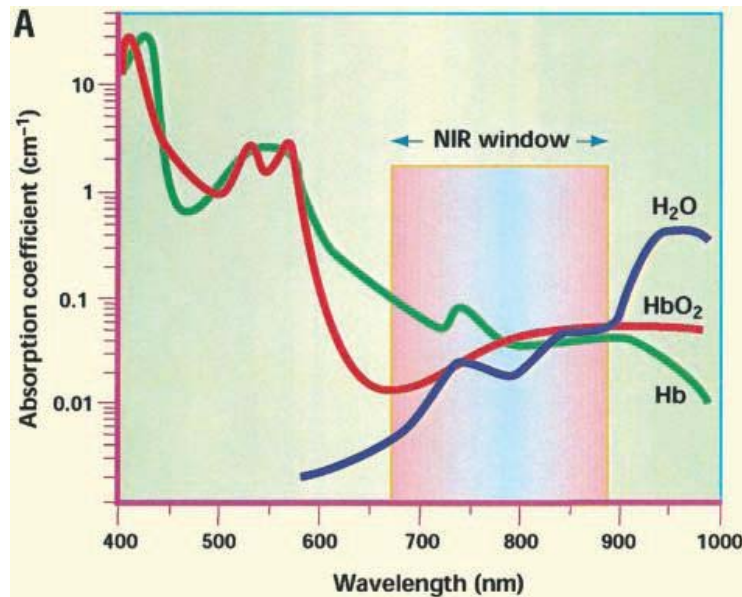Infrared light is composed of a broad range of electromagnetic waves from 770 nm to 1 mm.

Light propagation through brain

The main principle is based on two physical phenomena. When light enters a tissue, its propagation in mainly governed by light *absorption* and *scattering*.

Method

- Beer-Lambert law

$$A = \log_{10} \frac{I_o}{I} = \mu_a L$$

where I_o is incident light intensity

I is the transmitted light intensity

A is attenuation

L is the optical path length

$\mu_a = \varepsilon.c.$ is the absorption coefficient

$$\mu_a{}^{\lambda 1} = \varepsilon_{Hb}^{\lambda 1} Hb + \varepsilon_{HbO2}^{\lambda 1} HbO2$$

ε is the specific extinction coefficient of the absorber
c is the concentration of absorbing compound in solution

$$\begin{pmatrix} Hb \\ HbO2 \end{pmatrix} = \frac{1}{L} \begin{pmatrix} \varepsilon_{Hb}^{\lambda 1} & \varepsilon_{HbO2}^{\lambda 1} \\ \varepsilon_{Hb}^{\lambda 2} & \varepsilon_{HbO2}^{\lambda 2} \\ \vdots & \vdots \\ \varepsilon_{Hb}^{\lambda n} & \varepsilon_{HbO2}^{\lambda n} \end{pmatrix}^{-1} \overline{\begin{pmatrix} A^{\lambda 1} \\ A^{\lambda 2} \\ \vdots \\ A^{\lambda n} \end{pmatrix}}$$

Method

- fNIRS measurement and instrumentation

Functional NIRS measurements are made using one of the three methods:

- Continuous wave (CW)
- Time-resolved (TR)
- Frequency domain (FD)

In CW systems, light is emitted at constant amplitude. Light coming out from the tissue is collected by a detector or detectors.

If more than one wavelenght is used, a relative change of chromophore concentrations can be calculated.

CW systems are comparatively easy to build and acquire data fast.

Method

- fNIRS-BCI system design

Figure 1. Components of a continuous wave NIR system.
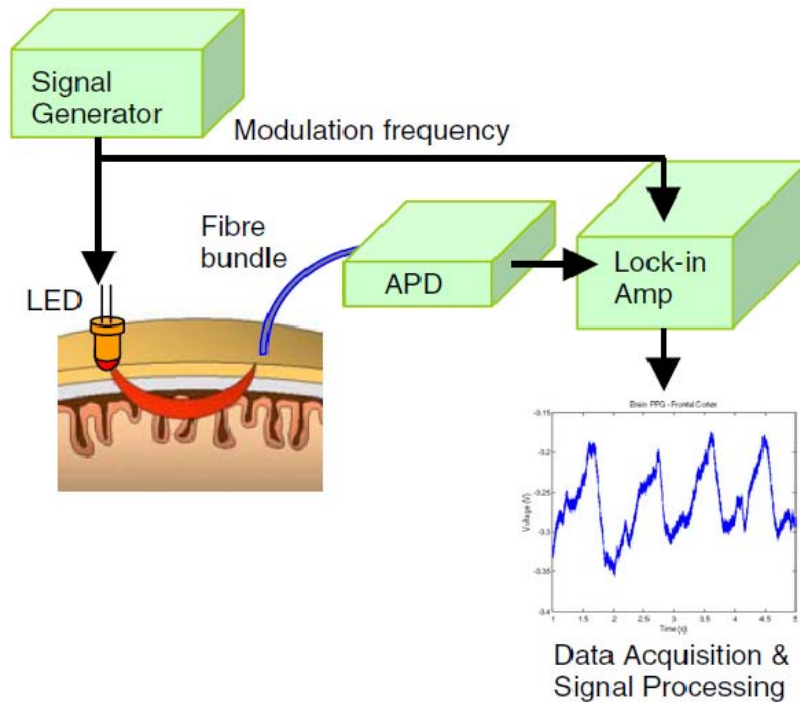
LEDs: 760nm and 880 nm
Avalanche Photodiode (APD):
Hamamatsu C5460-01
Lock-in amplifier: Signal recovery m.7265

The data are recorded at a sampling
rate of 100 Hz

Lock-in amplifier is a type of amplifier that can extract a signal with a known carrier wave from an extremely noisy environment

Method

The challenge is to ensure rigid optode positioning while still allowing for subject comfort.

Solutions to date include modified cycle helmets, thermoplastic moulded to the contours of each subject's head, spring-loaded fibres attached to semirigid plastic forms and fibres embedded in rubber forms.
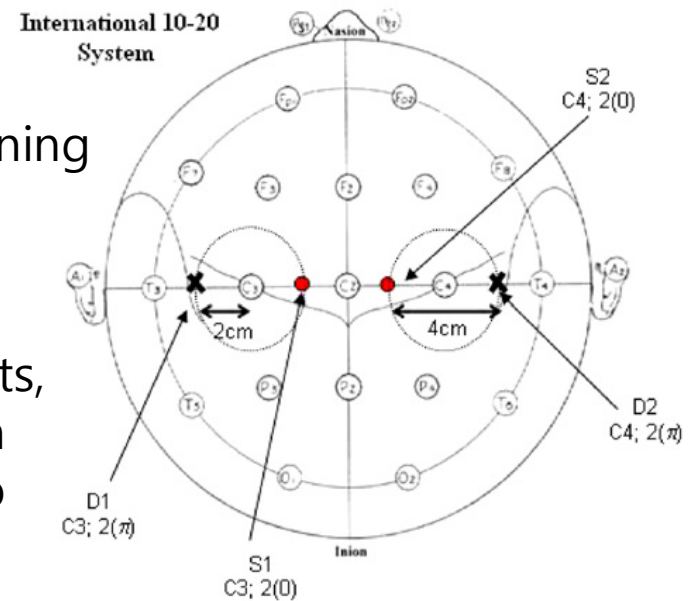
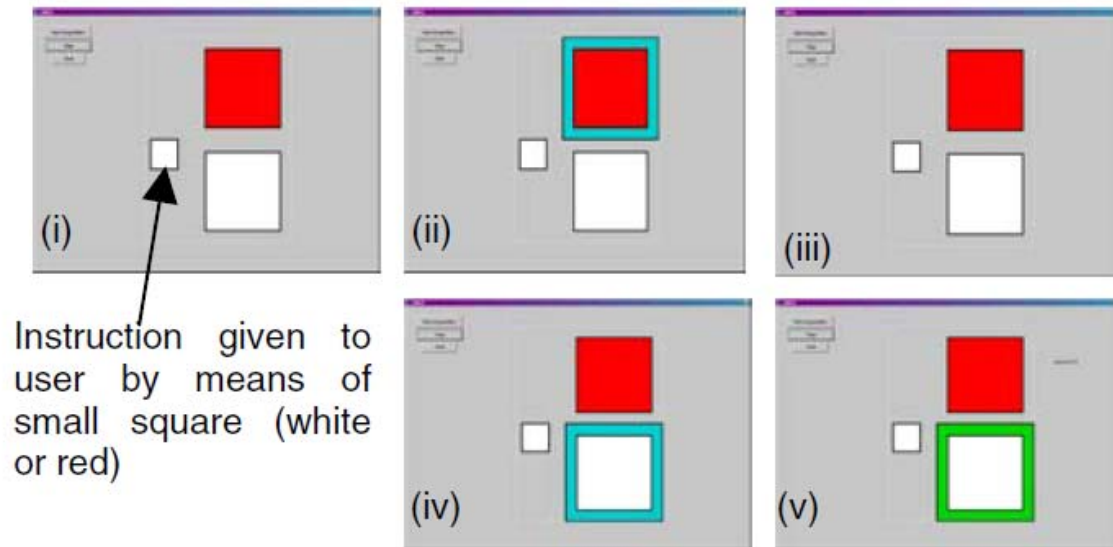The positions of a source (S1) and detector (D1) placed 4 cm Apart.

Method

Experimental procedure

In this work, they applied fNIRs to MI-based BCI

Three healthy subjects participated
in this experiment.

Instruction given to
user by means of
small square (white
or red)

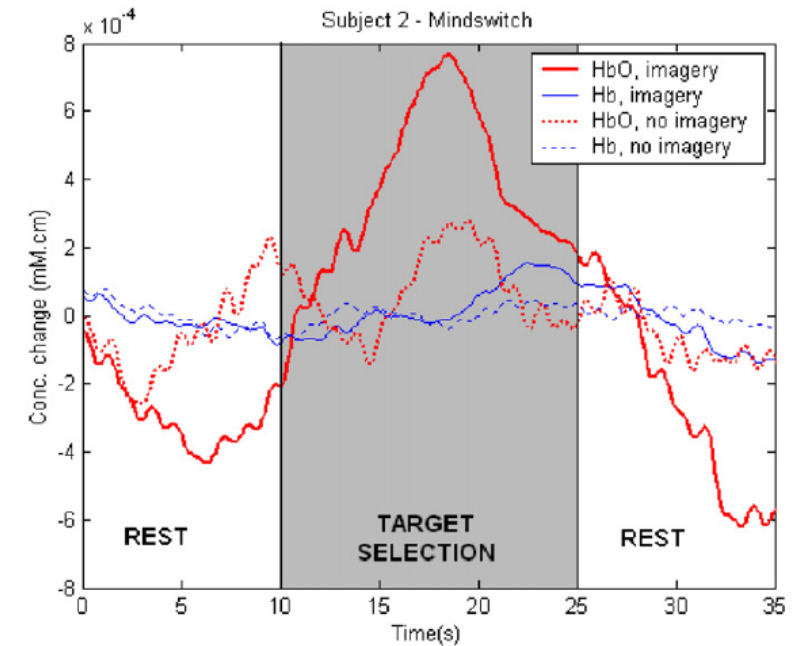**Figure 3.** (i)–(v) Sequence of operations in Mindswitch.

Method

Experimental procedure

The total time of a target takes 1 min:

- The first 15 s is a resting period, establishing a baseline condition. In the last 5 s of this period, a command is given to the user by means of a small coloured square indicating which target must be selected.

- In the next 15 s the upper target, the red square, is highlighted. If the user wishes to select the highlighted target, he∕she must perform imagery tasks during this time.

- The following 15 s is another rest state allowing the HbO signal to return to baseline if necessary.

- During the next 15 s the lower target is highlighted, and again the user may perform imagery if the highlighted target is desired.

- Rest follows, with the decision being presented to the user and the score updated (number of correct trials∕total number of trials).

Results

		Red target red selected ✓	Red target white selected ×	White target white selected ✓	White target red selected ×	Accuracy
Subject 1	Avg.	0.74	–	0.40	0.33	90%
Exp. 1	St. Dev.	0.36	–	0.22	–	
	No. of trials	4	0	5	1	
Exp. 2	Avg.	0.62	0.39	0.41	–	80%
	St. Dev.	0.50	0.48	0.19	–	
	No. of trials	2	2	6	0	
Exp. 3	Avg.	0.41	–	0.52	0.57	80%
	St. Dev.	0.19	–	0.20	0.27	
	No. of trials	2	0	6	2	
Exp. 4	Avg.	0.24	0.22	0.34	0.22	70%
	St. Dev.	0.02	0.13	0.19	–	
	No. of trials	2	2	5	1	
Exp. 5	Avg.	0.08	0.22	0.34	0.22	70%
	St. Dev.	0.04	0.13	0.19	–	
	No. of trials	2	2	5	1	
Exp. 6	Avg.	0.79	–	0.22	0.01	80%
	St. Dev.	0.49	–	0.07	–	
	No. of trials	4	0	5	1	
Subject 2	Avg.	0.47	0.41	0.43	–	90%
Exp. 1	St. Dev.	0.40	–	0.29	–	
	No. of trials	3	1	6	0	
Subject 3	Avg.	0.35	0.25	0.16	0.17	70%
Exp. 1	St. Dev.	–	0.12	0.09	–	
	No. of trials	1	2	6	1	
Exp. 2	Avg.	1.11	–	0.66	0.67	90%
	St. Dev.	0.24	–	0.45	–	
	No. of trials	3	0	6	1	

Figure 5. Subject 2—haemodynamic response measured at the right motor cortex during target selection trials. Signal has been low-pass filtered to reduce pulse artefact. Average response is shown for ten trials, i.e. one experimental run. The thicker line is the average of the ten imagery tasks and the thinner line the average of the ten epochs when no imagery was performed.

Conclusion

They have shown how a simplified fNIRS device designed to detect hemodynamic responses arising from mental imagery processes can be used in BCIs.

- The advantages of optical systems: safety

                                                                        accessibility

                                                                        non-invasiveness.

Discussion

Because, in this work, they didn't consider location of source, the special resolution is not high. But maybe using the source localization technique we can increase a performance of fNIR system.

THANK YOU