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

**Coyle SM et al.**

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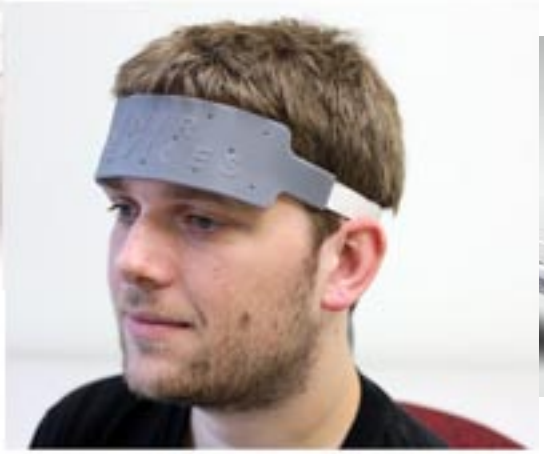
# Introduction

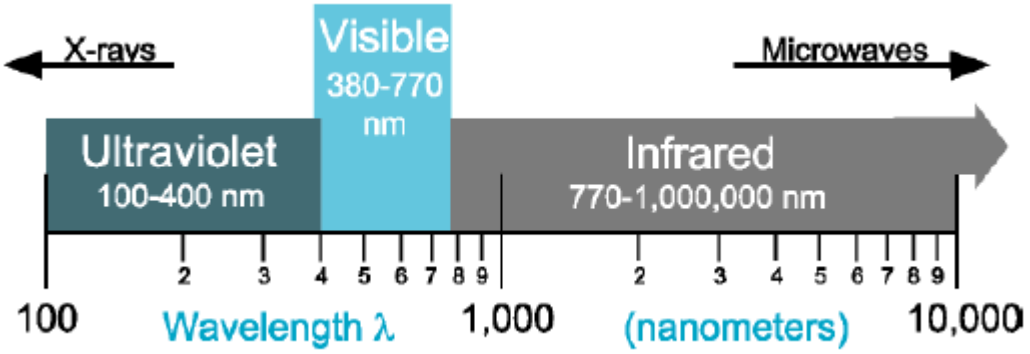
fMF

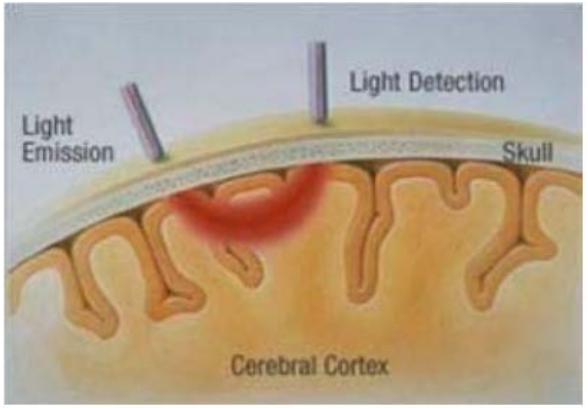
Functional near –infrared spectroscopy system

ECoG

# Method

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



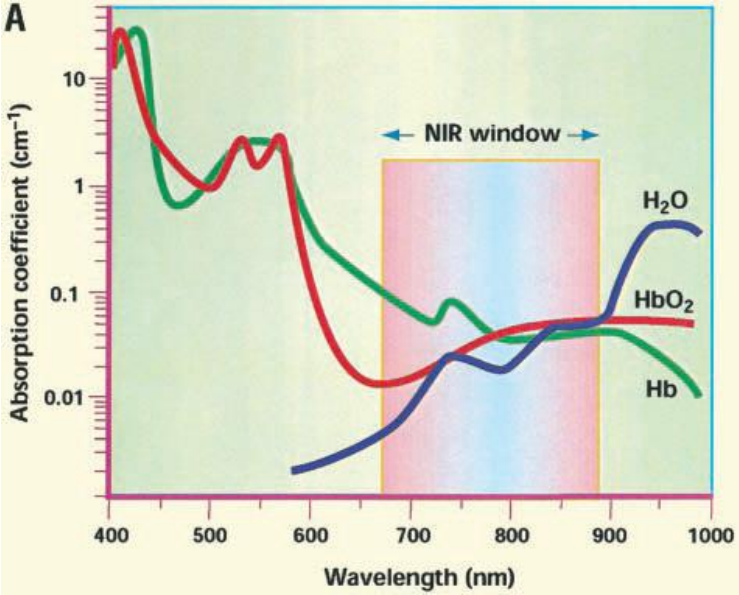




Light propagation through brain

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

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

$\varepsilon$ is the specific extinction coefficient of the absorber

$c$ is the concentration of absorbing compound in solution

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

# 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)

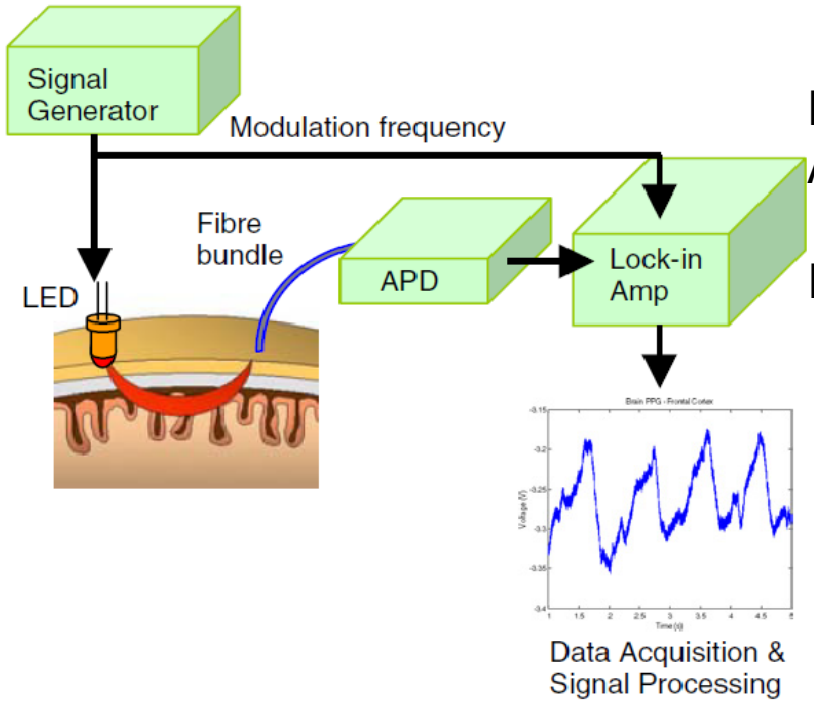
In CW systems, light is emitted at constant amplitude. Light coming out from the tissue is collected by a detector or detectors.

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




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

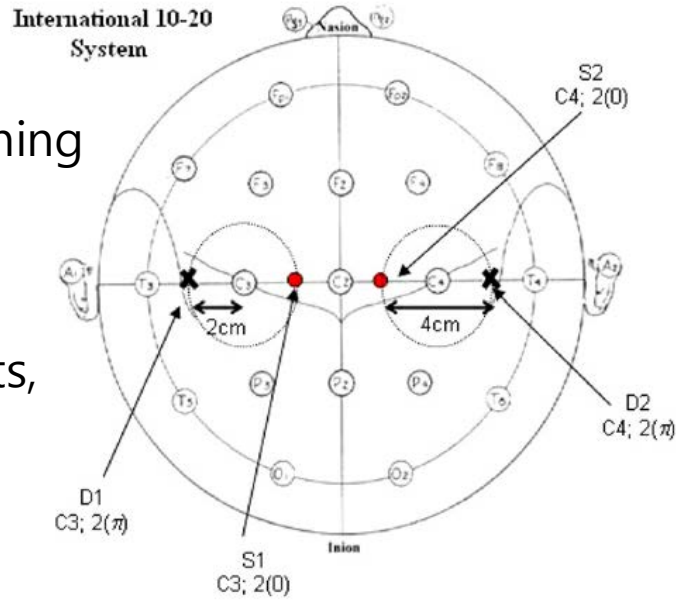
**Figure 1.** Components of a continuous wave NIR system.

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.

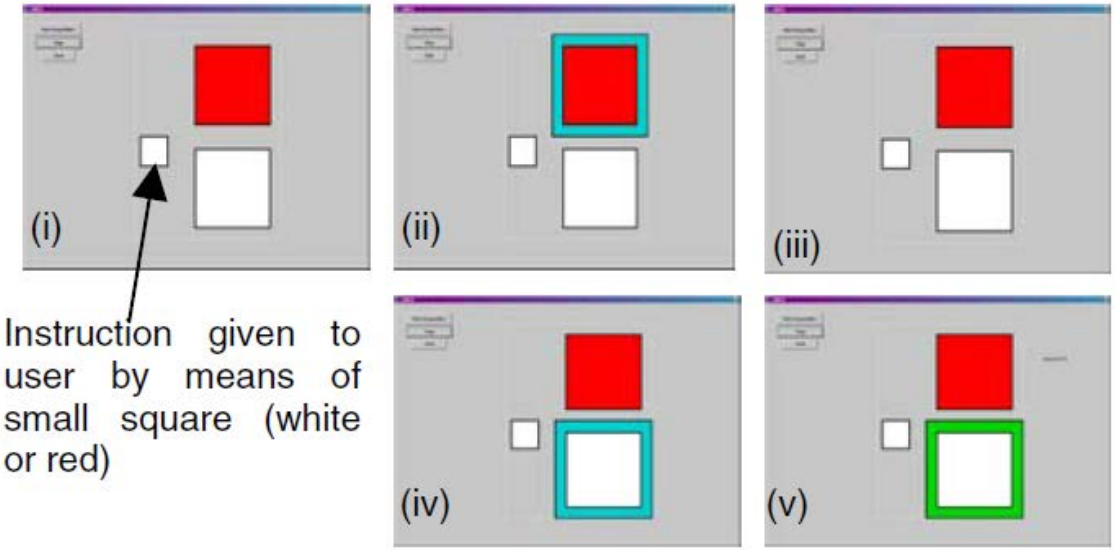



**Figure 3.** (i)–(v) Sequence of operations in Mindswitch.

# 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 sm all coloured square indicating which target must be selected.
- In the next 15 s the upper target, the red square, is highlighted. If the us er 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 | |

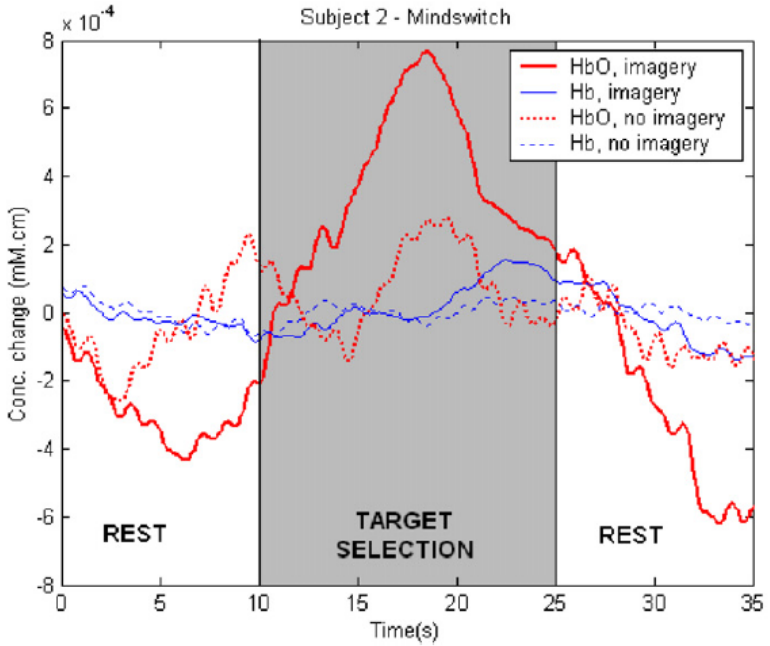



**Figure 5.** Subject 2—haemodynamic response measured at the right motor cortex during target selection trials. Signal has been low-pass filtered to reduce pulse artefact. Average response is shown for ten trials, i.e. one experimental run. The thicker line is the average of the ten imagery tasks and 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.

# THANK YOU