Gaming control using a wearable and wireless EEG-based brain-computer interface device with novel dry foam-based sensors.

Lun-De Liao et al.

Journal of Neuroengineering and Rehabilitation. (2012)

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Background

- Wireless BCI systems

Emotiv EPOC neuro-headset

Neurosky Mindset

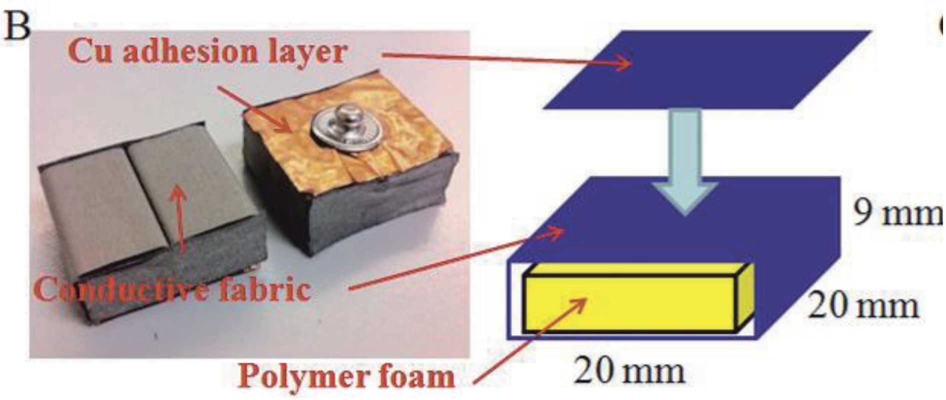
Introduction & Motivation

- Limitations of wet- and MEMS-type EEG sensors
  - Skin abrasion
  - The required used of conductive gel
  - Time-consuming, uncomfortable, and often painful
  - Degraded signal quality due to skin regeneration and drying of the conductive gel
- Goals
  - They developed a wearable, EEG-based BCI device with a novel dry foam-based sensor for gaming control.
  - A real-time focusing detection algorithm was implemented in their device to detect the real-time cognitive state of the user.

System Design

- Dry EEG sensors

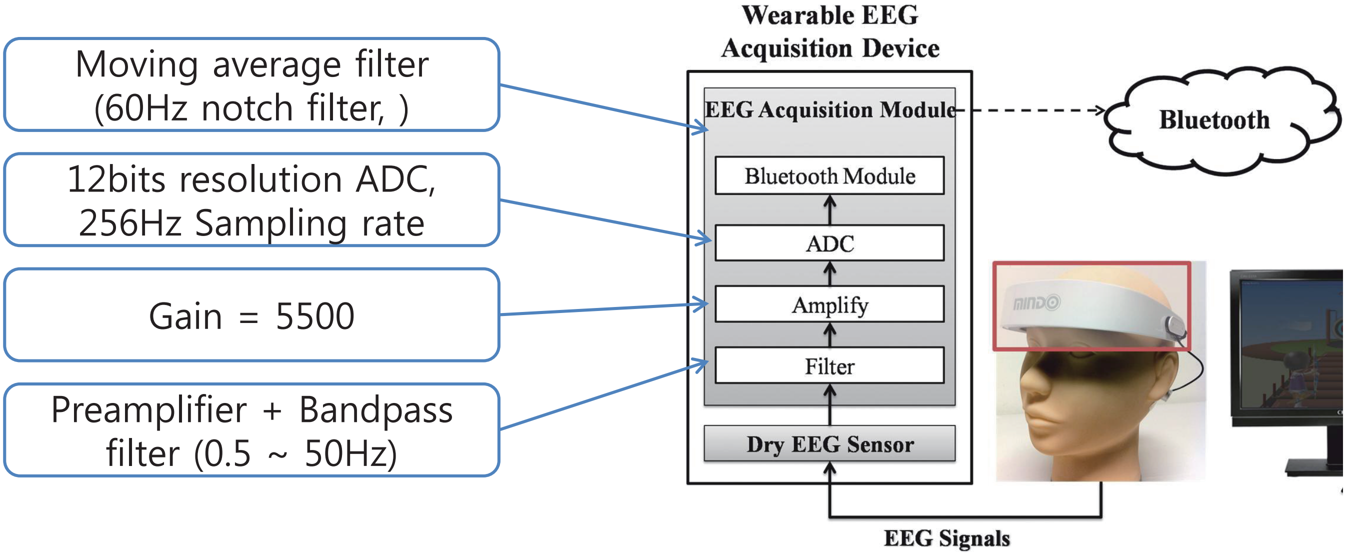
- Dry electrodes are designed by using conductive polymer foam made of a urethane material.
- Conductive foam was covered with a 0.2mm thick taffeta material.
- This was made from an electrically conductive polymer fabric and was coated with Ni/Cu on all of its surfaces.
- A 0.2-mm layer of Cu was used as an adhesion layer that was then connected to the wireless EEG acquisition module.



System Design

- Wireless EEG acquisition module

- This module was designed for acquiring EEG signals from the dry EEG sensors.
- Included components : INA2126(Texas Instruments opamp), AD8609(Analog Device opamp), MSP430(Texas Instruments microprocessor), BM0403(Unigrand Ltd., Bluetooth module)

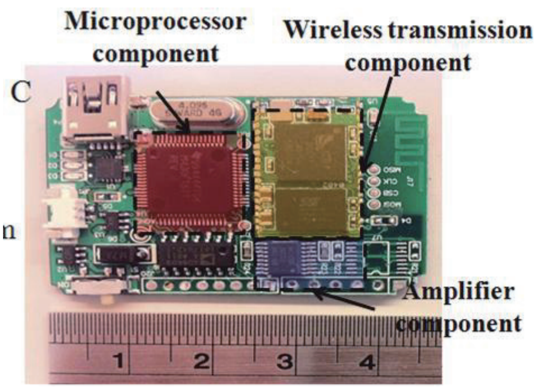


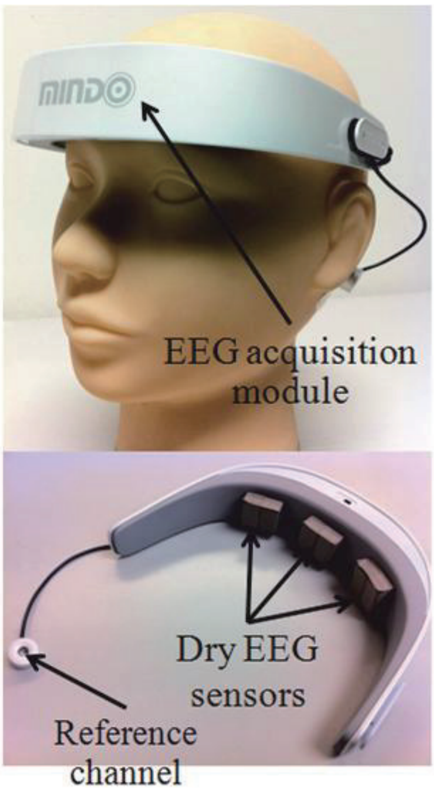
Journal Club Meeting, Dec. 04, 2012

System Design

- Wireless EEG acquisition module

- Size : 4.5 x 3 x 0.6cm3
- Power consumption : 31.58mA with a 3.7V DC power supply
- Battery life : 23 hours using a commercial 750mAh Li-ion battery.





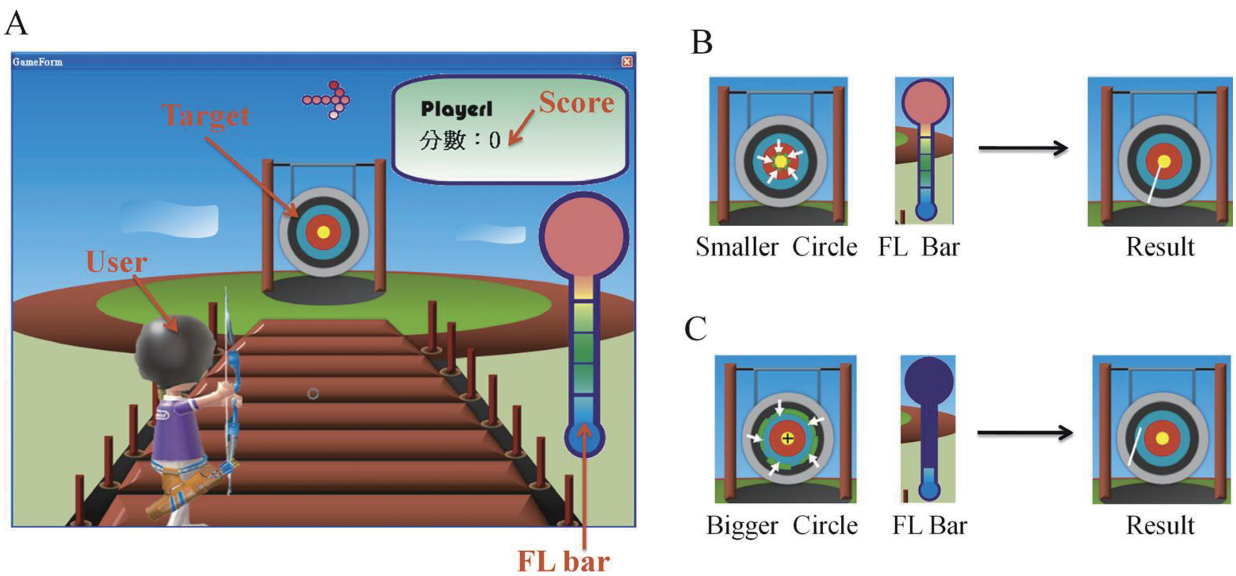
Application Design

- Archery game design

- They designed the archery game controlled by users via mental focusing feature.
- To measure the mental focusing level, they utilized the principle that the power of the alpha rhythm has a negative relationship with the mental focusing level.
- Using the focusing level(FL), they control the aiming of allows.
  - High FL : the shot was close to the center of the target – high score
  - Low FL : the shot was far from the center of the target – low score
- Game design
  - Total ten trials
  - Each trial persisted for ten seconds
  - The FL was initialized to zero for every shot.
  - The FL values were calculated every 2s.

Application Design

- Game interface



Application Design

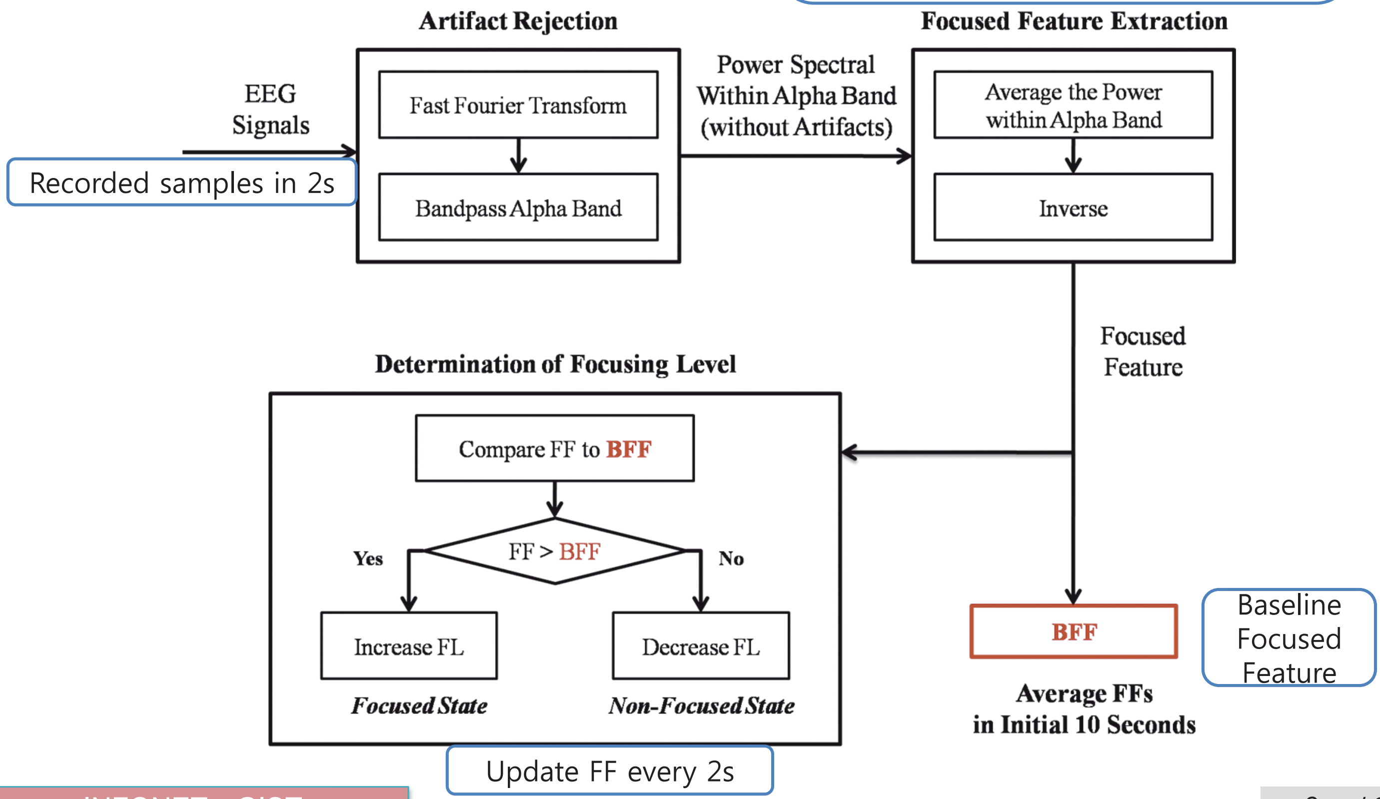
- Focusing level detection algorithm

$$X = [X_1 \quad X_2 \quad \cdots \quad X_{512}]$$

$$Y = FFT(X) = [Y_1 \quad Y_2 \quad \cdots \quad Y_{256}]$$

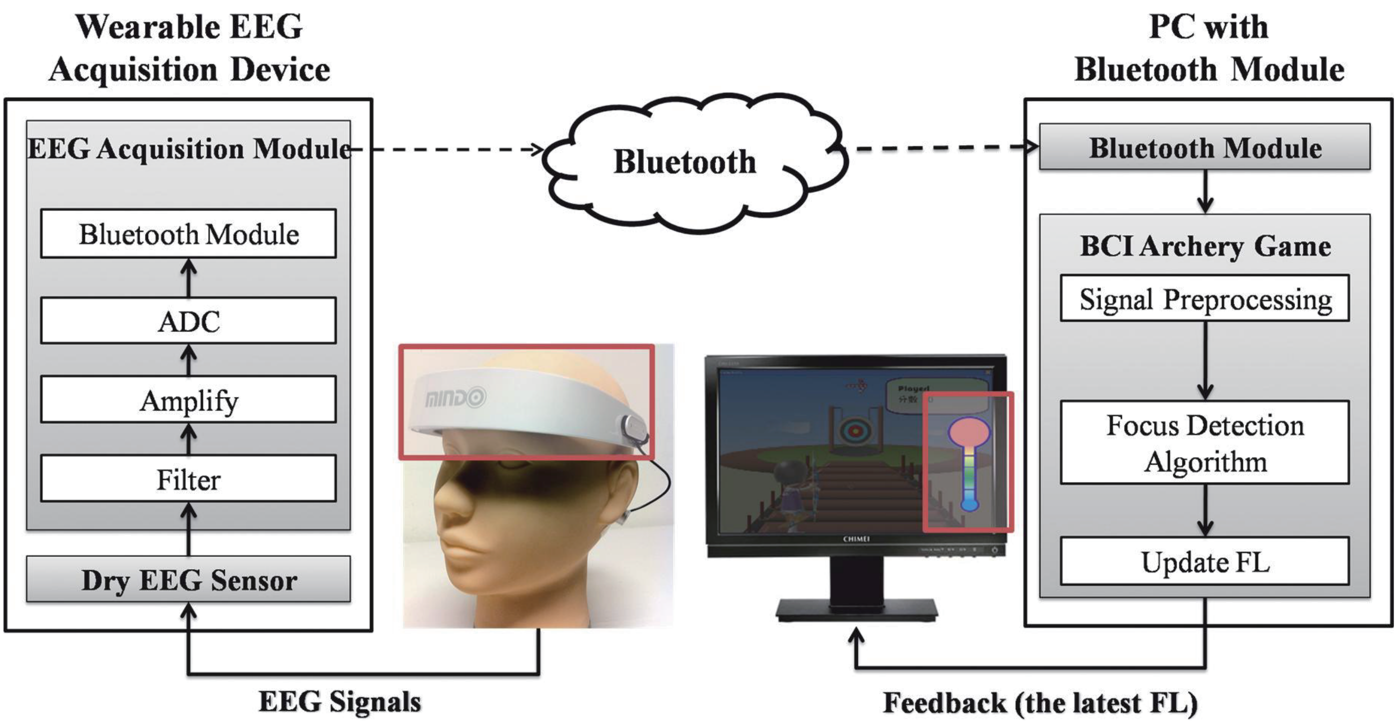
$$P_\alpha = \frac{1}{5}\sum_{n=8}^{12} Y_n$$ (Feature extraction & Averaging)

$$FF = 1 / P_\alpha$$ (Inverse)



Method

- Total system schematic



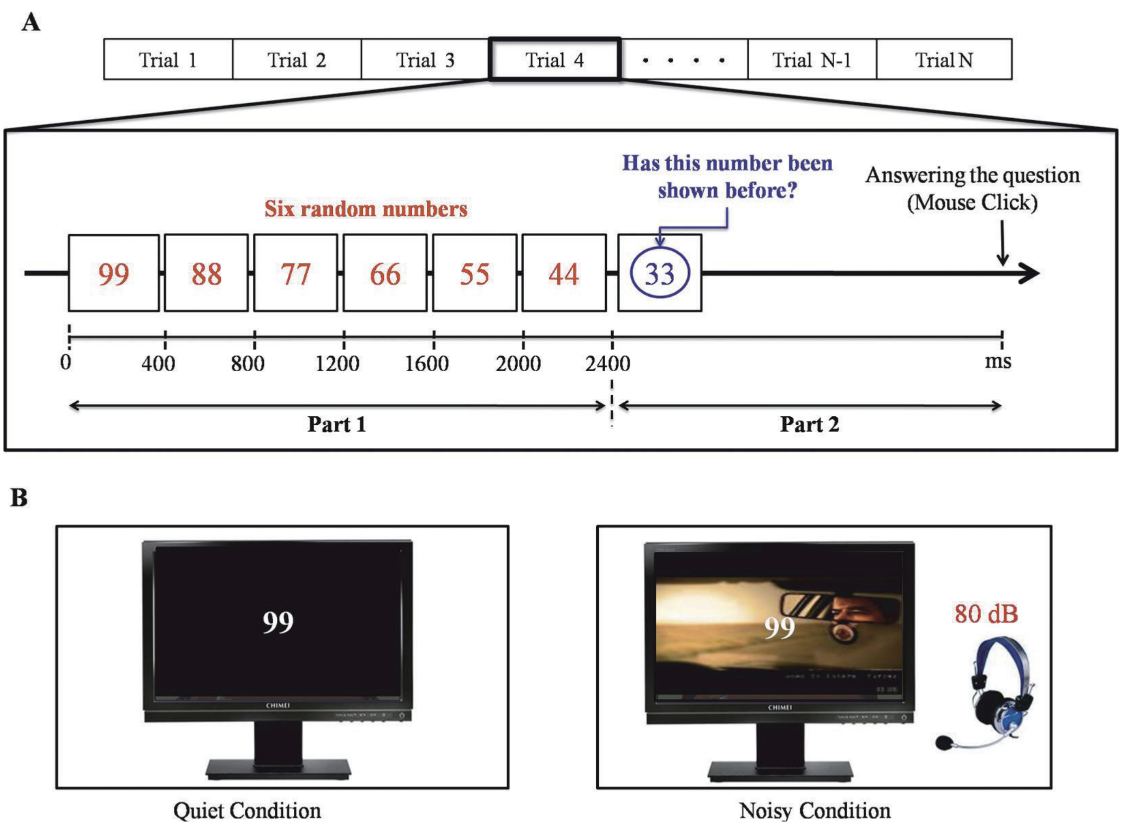
Method

- Verification of the FL algorithm

- Do the FL algorithm indicated the user's focusing level well?
- Short-term memory test
  - The user watches a rapid series of pictures over a few seconds
  - A picture is shown and the user indicate whether of not this picture had been shown before
  - Accuracy high(focused) – test in silence
  - Accuracy low(unfocused) – test under noise
- Experiment procedures
  - Six numbers were presented sequentially, each number lasts for 400ms
  - A number was presented and the user had to indicate whether or not the number had been shown before by using a mouse click
  - Trial was repeated and total 3 min
  - Quite condition vs. noisy condition
  - Average accuracy are used as an indicator to determine the user's focus level.

Method

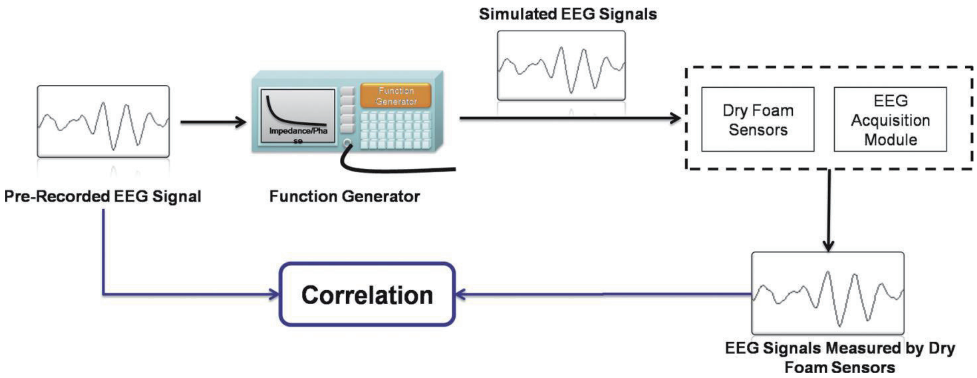
- Verification of the FL algorithm



Results

- Verification of the signal quality of the proposed dry sensor

- Experiment procedure
  - The EEG data were prerecorded using standard EEG sensors with conductive gel and were stored in a computer.
  - the EEG data were fed into a programmable function generator and were passed through a voltage divider to generate simulated human EEG signals.
  - Compare the pre-recorded EEG data and the measured EEG data using dry sensor.
- Correlation level : 97.68%



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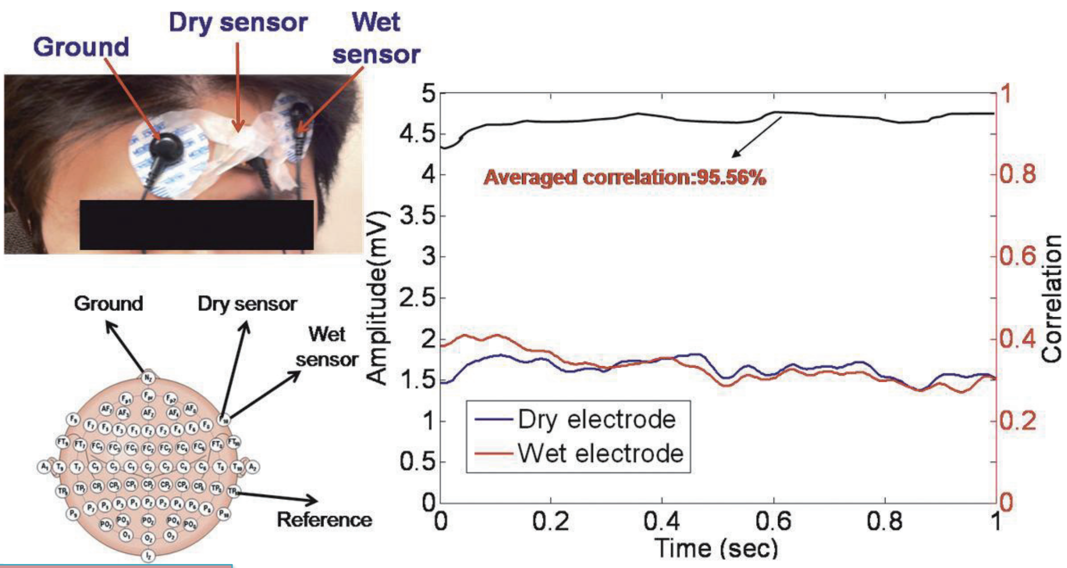
Results

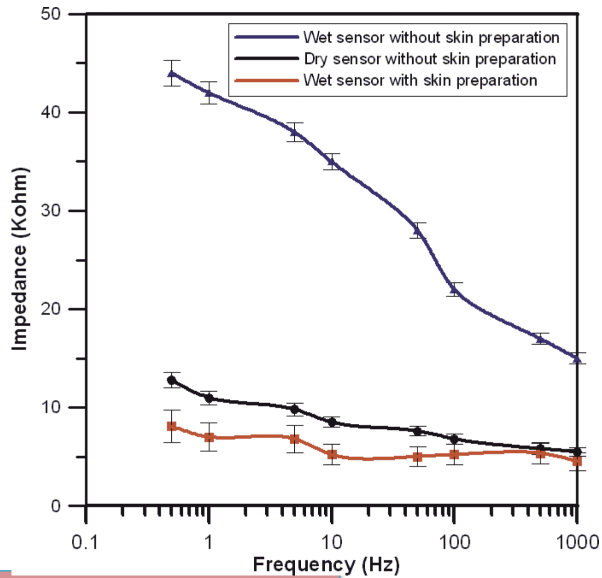
- The correlation between the conventional wet EEG sensor and the dry EEG sensor

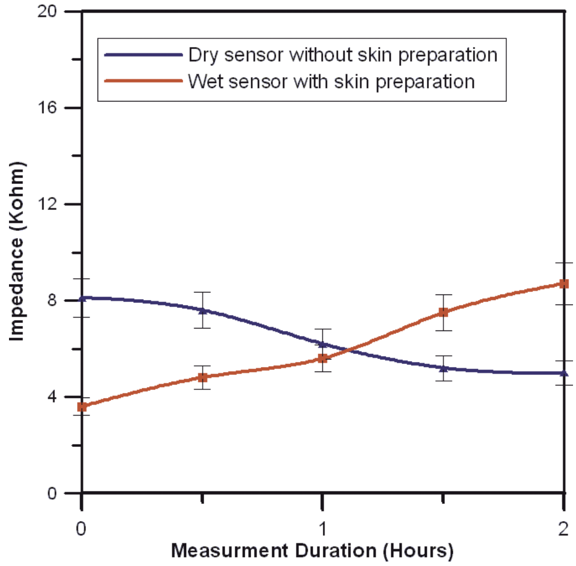
- Correlation level : typically in excess of 95.56%
- The performance of the EEG signal measurement using the dry foam-based EEG sensor was identical to that of the conventional wet EEG sensors.



Results

- Comparison of the impedance at the sensor-skin contact interfaces
  - The impedance levels between the dry EEG sensors without skin preparation and conventional wet EEG sensors with skin preparation is similar.
- Comparison of the long-term impedance variation
  - The dry sensor is more stable than wet sensor because the conductive gels are easy to dry during long-term monitoring





Results

- Relationships between short-term memory testing, FF values and gaming scores under quiet and noisy conditions

- The average accuracy of short-term memory test under two different conditions : 69.0% and 59.8%

Table 1 Results of the short-term memory experiment under quiet and noisy conditions.

	Quiet Condition			Noisy Condition			
	Total	Correct	Accuracy	Total	Correct	Accuracy	*p*-value*
Subject 1	32	24	0.750	22	14	0.636	
Subject 2	44	34	0.773	42	28	0.667	
Subject 3	41	25	0.610	47	27	0.574	
Subject 4	36	24	0.667	38	21	0.553	
Subject 5	58	35	0.603	55	32	0.582	
Subject 6	53	38	0.717	51	25	0.490	
Subject 7	53	36	0.679	54	31	0.574	
Subject 8	54	35	0.648	55	29	0.527	
Subject 9	48	35	0.729	46	31	0.674	
Subject 10	50	36	0.720	47	33	0.702	
			0.690			0.598	0.001

* Paired *t*-test.

Results

- Relationships between short-term memory testing, FF values and gaming scores under quiet and noisy conditions

- The average FF values under two different conditions : 6.94 vs. 4.64
- The users maintained a lower FF under noisy conditions than under quiet conditions because of the presence of distractions.

Table 2 Results of the FF values and gaming scores under quiet and noisy conditions.

	FF			Game Score		
	Quiet	Noisy	*p*-value*	Quiet	Noisy	*p*-value*
Subject 1	8.0	4.9		9.6	7.4	
Subject 2	8.7	4.5		8.4	7.0	
Subject 3	5.4	4.4		9.2	7.6	
Subject 4	6.1	4.2		9.0	8.2	
Subject 5	4.5	3.5		9.0	7.6	
Subject 6	8.9	4.1		9.1	6.9	
Subject 7	7.1	3.9		9.1	6.1	
Subject 8	5.9	4.6		9.1	8.1	
Subject 9	8.0	6.6		8.7	7.9	
Subject 10	6.8	5.6		9.1	7.1	
	6.940	4.642	0.0005	9.013	7.393	0.00004

* Paired *t*-test.

- Correlation test 1

- The measured FF values were significantly positively correlated to the results of the short-term memory experiment.
  - The measured FF values truly represented the user's mental focusing level.

Results

- Correlation test 2

- The game scores are positively correlated to the measured FF values.
  - the game scores are lower if the user performs the test under two different conditions.
- The FF values are an indicator of the focused state and the FL algorithm is a reliable method for measuring the user's focusing level.

Conclusion

- They proposed a wearable EEG-based BCI device with dry EEG sensors for cognitive state monitoring and demonstrated its use during EEG-based gaming control.
- Using their wearable EEG-based BCI device without conductive gel will allow users to monitor their EEG states more comfortably during daily life.
- This wearable EEG-based BCI device and the focusing level detection algorithm can be reliably used to control outside-world applications for general users or researchers.

Thank you

Discussion

- Prof. Lee
  - Check the design of our wireless BCI system?
  - What can we design the application using wireless BCI system?
- Jinteak Seong
  - How to measure the system specifications such as noise level, CMRR, and power consumption?
- Evgenii
  - How to focus in the game application?

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.

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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

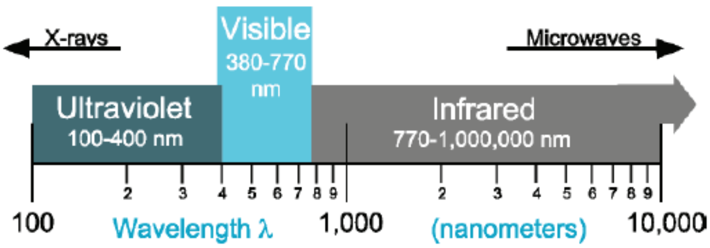
fMR

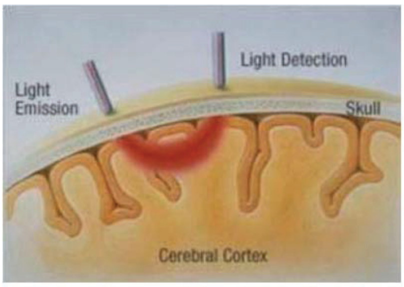
Functional near –infrared spectroscopy system

ECoG

Method

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



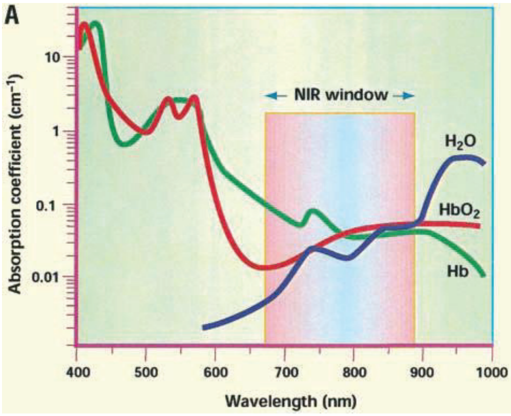


Light propagation through brain

The main principle is based on two physical phenomena. When light enters a tissu e, 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

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

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

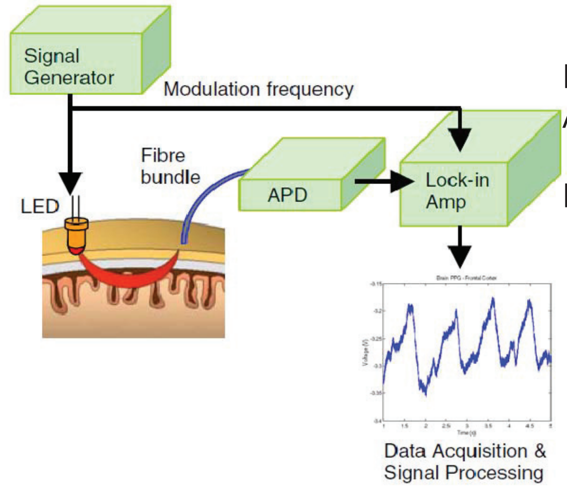


Figure 1. Components of a continuous wave NIR system.

LEDs: 760nm and 880 nm
Avalanche Photodiode (APD): Hamamatsu C5460-01
Lock-in amplifier: Signal recovery m.7265

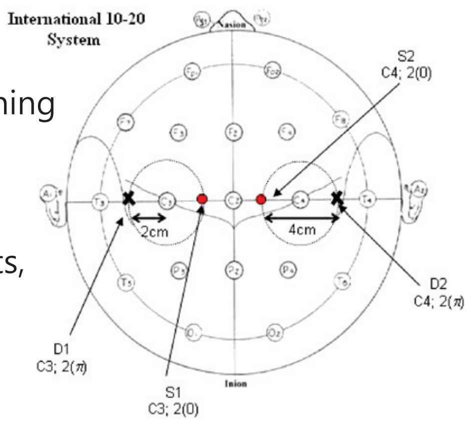
The data are recorded at a sampling rate of 100 Hz

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.

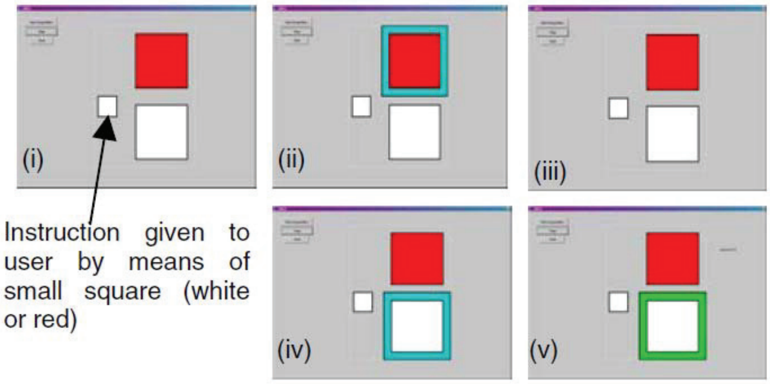


Figure 3. (i)–(v) Sequence of operations in Mindswitch.

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	

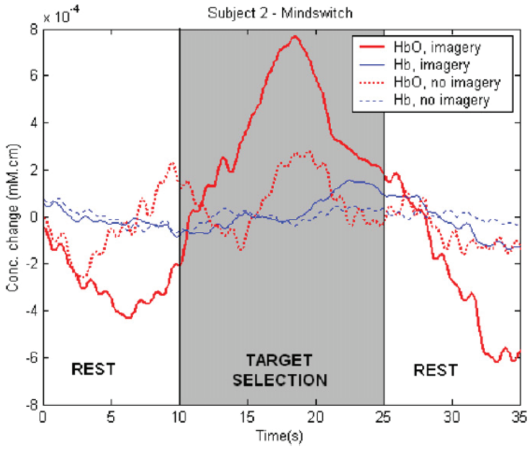


Figure 5. Subject 2—haemodynamic response measured at the right motor cortex during target selection trials. Signal has been low-pass filtered to reduce pulse artefact. Average response is shown for ten trials, i.e. one experimental run. The thicker line is the average of the ten imagery tasks and the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

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