Multi-Decision Detection Using EEG-NIRS Based Hybrid Brain-Computer Interface (BCI)

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Introduction:

Brain-computer interface (BCI) is a technique by which brain signals are used for the control of external devices. Electroencephalography (EEG) and functional-near infrared spectroscopy (fNIRS) are most common non-invasive BCI techniques. The neuronal firing from the brain is detected by EEG (Turnip et al. 2011), whereas the brain activity in NIRS is detected by measuring the absorption of near infrared (NIR) light which is associated to the concentration changes of oxy- (HbO) and deoxy-hemoglobin (HbR) (Hu et al. 2010, Hu et al. 2013, Naseer and Hong 2013, Kamran and Hong 2013, Santosa et al. 2013). Both modalities have the advantages of being low cost and portable. The simultaneous use of the two modalities results in better brain signal acquisition and classification (Fazli et al. 2012). In this research we have used the hybrid EEG-NIRS system on visual and prefrontal brain region to acquire two different set of control signals for patients with locked-in syndrome (LIS) with high classification accuracy. Support vector machines (SVM) is used for classification and results show that multiple signals for decision making can be acquired using the hybrid modality

Methods:

The NIRS system (Portalite, Artinis Medical Solutions, Netherlands) used in this experiment, utilizes two wave lengths of 760 and 830 nm. A single channel was used on the subjects from the source-detector combination. The location of the prefrontal activation region was predetermined before the start of the experiment. The sampling frequency used for signal acquisition was 5 Hz. The source transmits incident light in NIR range at the mentioned wavelength on the scalp and the detector detects the reflected light. The absorption coefficients of HbO and HbR are known for NIR lights, therefore modified Beer-Lambert law was used to convert the intensity of incident and detected light into HbO and HbR. Two Ag/AgCl EEG electrodes were utilized to extract visual-related brain activity by placing electrodes on O1 and O2 location on occipital lobe of the brain using the International 10-20 System. The sampling rate was set at 256 Hz and signals were band filtered between 12-50 Hz. The EEG-NIRS channel configuration is shown in Fig. 1. Four subjects (age 25~30) participated in the experiment consisting of two sessions with a single session of 5 minutes for each subject. The duration of rest in each session was 20 seconds and activation of 10 seconds. The subjects were shown direction signs (i.e., left and right) and were asked to perform mental counting from 39 downward if indicated direction is right and blink five times if the indication is left, for any other indication the subjects were asked to relax.

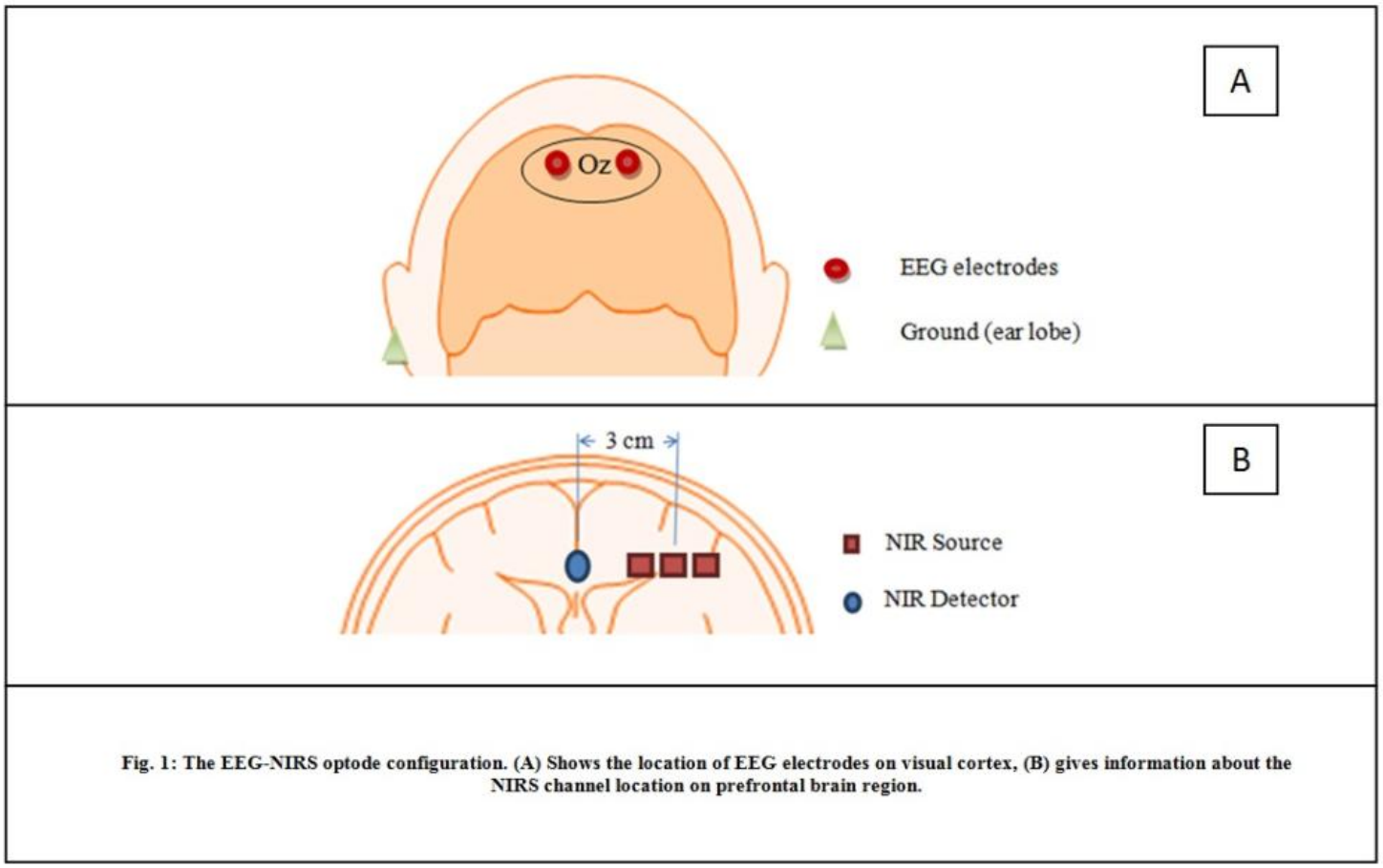


Fig. 1: The EEG-NIRS optode configuration. (A) Shows the location of EEG electrodes on visual cortex, (B) gives information about the NIRS channel location on prefrontal brain region.

Results:

The two different classes of signal obtained are shown in Fig. 2. The rest state was selected as a common reference for the two modalities whereas the activation states of the frontal and occipital lobe were used as control commands for BCI. It was observed that upon activation, HbO level increases in region of interest of brain due to increase in the neuronal firing. The average classification accuracy for the subjects was computed using SVM (Hu et al. 2013, Naseer et al. 2013) which was found to be 85% for the prefrontal and 90% for the visual cortex region. The classification for Subject 2 and accuracies of all are shown in Fig. 3. The results show that the method is suitable for LIS patients, however results can be improved by further investigation using more subjects.

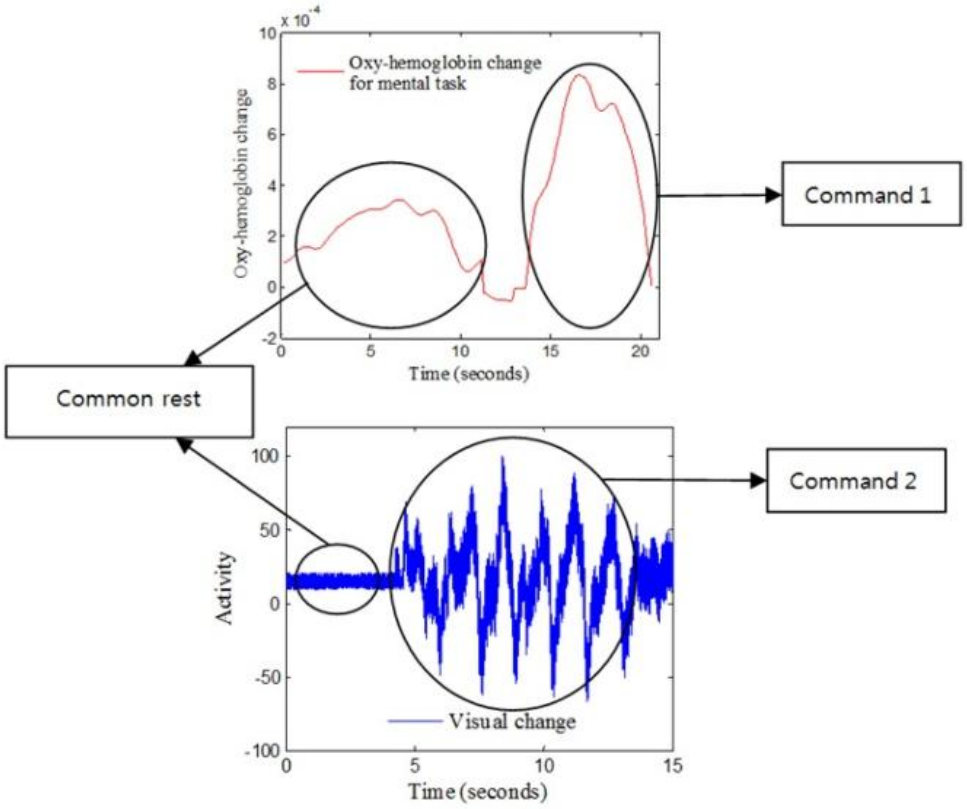
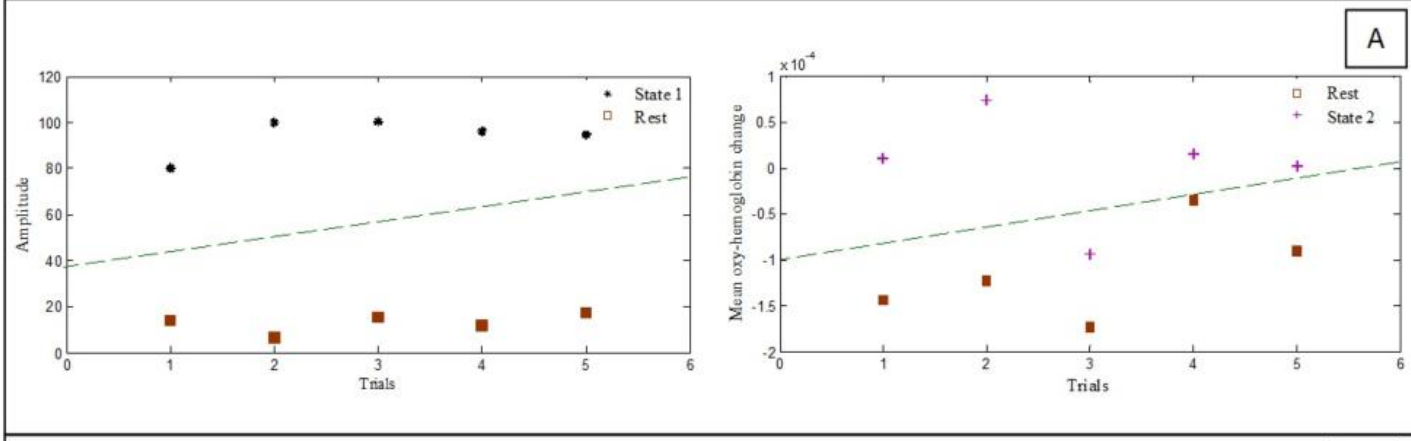


Fig. 2: Prefrontal and visual brain signals. HbO change is observed from prefrontal region and neuronal firing in micro-volts is detected from visual cortex.



B

Subject No.	EEG classification accuracy (%)	NIRS classification accuracy (%)
1	90	90
2	95	90
3	90	80
4	85	80
Mean	90±4.1	85±5.6

Fig. 3: Classification and accuracies. (A) Classification of two activities for subject 2. State 1 is the signal form EEG in micro-volts and state 2 is the NIRS signal change in micro-mol. (B) Classification accuracies of four subjects using EEG and NIRS

Conclusions:

A hybrid EEG-NIRS based system was designed to acquire multiple signals from the brain for control command acquisition using prefrontal and visual activities and a common threshold on rest state was set between the moralities. The classification accuracies show the paradigm is suitable for BCI and can be used to detect more than one decision command for patients with LIS.

Imaging Methods:

Optical Imaging/NIRS

Abstract Information

Would you accept an oral presentation if your abstract is selected for an oral session?

Yes

Please indicate below if your study was a "resting state" or "task-activation" study.

Task-activation

Healthy subjects only or patients (note that patient studies may also involve healthy subjects):

Healthy subjects

Internal Review Board (IRB) or Animal Use and Care Committee (AUCC) Approval. Please indicate approval below. Please note: Failure to have IRB or AUCC approval, if applicable will lead to automatic rejection of abstract.

Not applicable

Please indicate which method was used in your research:

EEG/ERP

Optical Imaging

For human MRI, what field strength scanner do you use?

If Other, please list - NA

What post processing software packages do you use?

Other, Please list - NIRS-SPM, MATLAB

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