Simultaneous gaze and motor imagery hybrid BCI increases single-trial detection performance: a compatible-incompatible study

1.AIM

- To develop a simultaneous hybrid brain-computer interface (BCI) that combines an event-related de-synchronization (ERD) BCI and an eye tracker, and improves performance by increasing the number of commands.

2.INTRODUCTION

- BCI provides a novel means of communication. This can be achieved by measuring electroencephalogram (EEG) signal over the sensory motor cortex of a person performing motor imagery (MI) tasks.
- However, the performance of BCI remains currently too low to be of wide practical use. A hybrid BCI system could improve the performance by combining two or more modalities such as eye tracking, and the detection of brain activity responses [1].
- Incorporating incompatible conditions between gaze direction and MI may involve errors in the hybrid BCI, while increasing the number the choices [2].

3.KEY QUESTIONS

- Do the number of command improve by combining of two different modalities?
- Does the combination of various modalities largely depend on the accuracy of each modality?
- Does the orientation between gaze and motor imagination depend on GUI experimental design?
- Does the number of choices improve in hybrid BCI?
- Do the false positive selection of eye-tracker reduce by BCI?

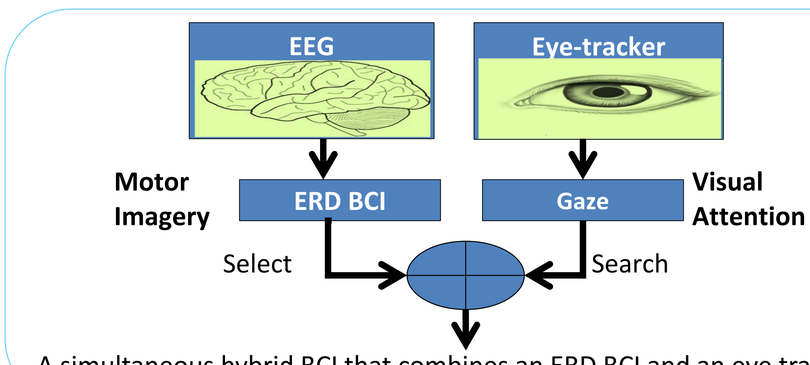
4.HYBRID BCI EXPERIMENTAL PROTOCOL

- Single-trial detection for standard, compatible and incompatible conditions, using support vector machine (SVM) classification method.
- Seven consenting healthy male subjects participated in the study.
- Three conditions varied in two classes of motor imagery and four classes of gaze for single-trial detection.
- For each subject, a session with 40 trials was recorded.

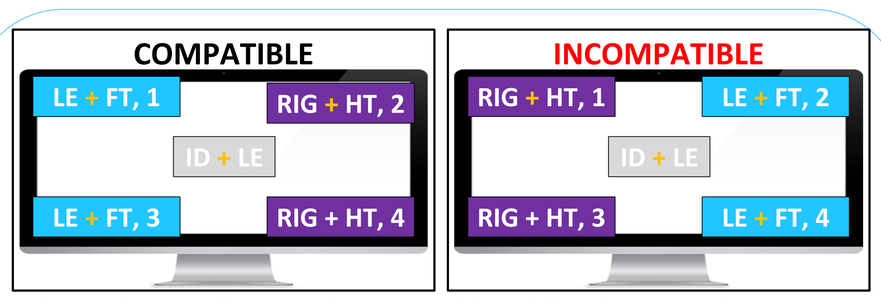
➢ Standard (LM vs RM)
➢ Compatible (LM ∩ LS) vs (RM ∩ RS)
➢ Incompatible (LM ∩ RS) vs (RM ∩ LS)

Where LM= left MI; RM = right MI; LS = left computer screen; LR = right computer screen; ∩ = combination of the two conditions.

5.HYBRID BCI MODEL



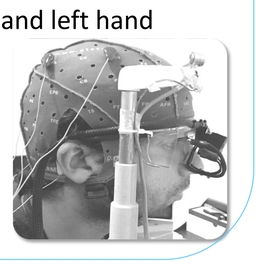
A simultaneous hybrid BCI that combines an ERD BCI and an eye tracker.

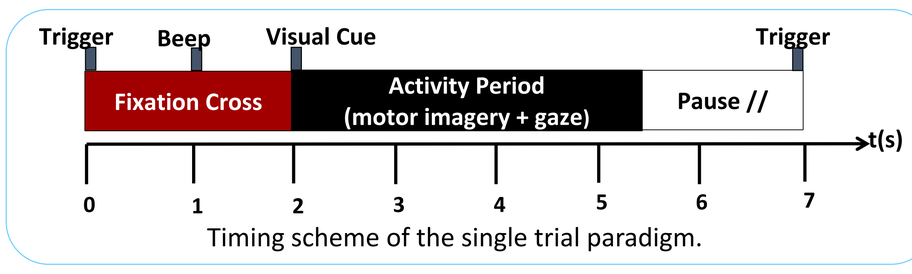


- Compatible and incompatible state of imagining right and left hand movements with four gaze coordinates (1, 2, 3, 4).

*RI+GHT / LE+FT = Stimulus that requires right / left hand MI, + = Fixation point

- The positions of the two bipolar channels (C3, C4) and eye-tracker.



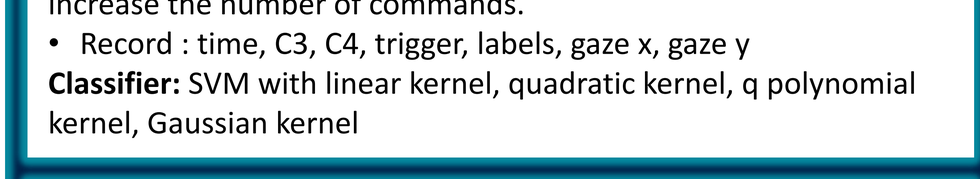


Timing scheme of the single trial paradigm.

6.SIGNAL PROCESSING AND CLASSIFICATION

Gaze

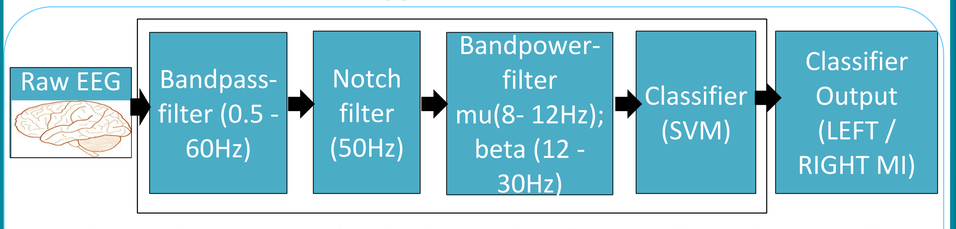
- Eye-tracker signals were digitally sampled at 128 Hz by Arrington Research Eye Tracker system.
- Record : gaze x, gaze y, time, trigger, and label indexes (1,2,3,4)



Gaze detection of four classes – (1, 2, 3, 4).

EEG

- EEG signals were digitally sampled at 128 Hz, two bipolar channels (C3 and C4).
- Record : time, C3, C4, trigger, and labels



Single-trial detection pipeline for binary classification of two classes – left and right hand MI.

Goal: to design a simultaneous gaze-MI hybrid BCI system to increase the number of commands.

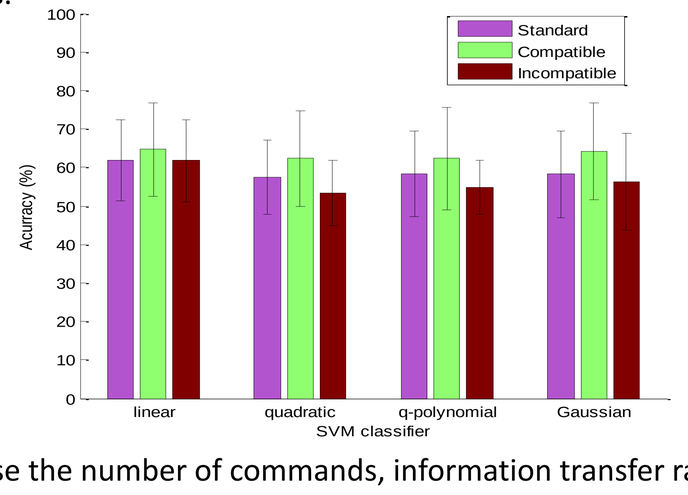
- Record : time, C3, C4, trigger, labels, gaze x, gaze y

Classifier: SVM with linear kernel, quadratic kernel, q polynomial kernel, Gaussian kernel

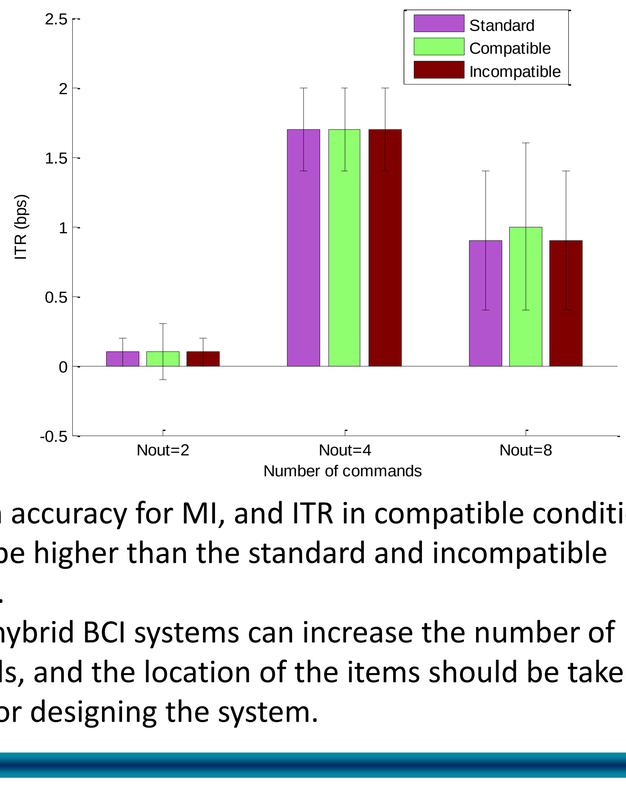
7.RESULTS

- Gaze detection performance For average and individual classes.

- Single-trial detection performance: two classes of MI and four classes of gaze in form of standard, compatible, and incompatible conditions.



- To increase the number of commands, information transfer rate (ITR) was computed in bit per symbol (bps), with the linear SVM classifier.



- The mean accuracy for MI, and ITR in compatible condition is found to be higher than the standard and incompatible condition.
- Gaze-MI hybrid BCI systems can increase the number of commands, and the location of the items should be taken into account for designing the system.

8.CONCLUSION

- A significant improvement in performance for a simultaneous gaze-MI system using a total of eight commands.
- The combination of various modalities is largely dependent on the accuracy of each modality.
- A higher accuracy for the detection of commands with the same orientation between gaze and motor imagination. Thus, this effect should be taken into account while designing gaze-MI based BCI paradigms. Specifically, the experimental design could incorporate incompatible condition if the emphasis is on having a larger number of choices despite a slight dip in accuracy.
- This hybrid BCI can also be used to reduce the false positives obtained from an eye-tracker selection paradigm by utilising motor imagery commands.

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सत्यमेव जयते

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Yogesh Kumar Meena, Girijesh Prasad Hubert Cecotti, and KongFatt Wong-Lin

Intelligent Systems Research Centre

School of Computing & Intelligent Systems

Ulster University, Derry BT48 7JL, Northern Ireland, UK

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