A. Korik[1*], L. Hay[2A], P. L. Choo[2B], S. J. Gilbert[3], M. Grealy[2B], A. Duffy[2A], D. Coyle[1]

[1] Intelligent Systems Research Centre, Ulster University, Derry, U.K.
[2A] Design, Manufacture and Engineering Management, University of Strathclyde, Glasgow, U.K.
[2B] School of Psychological Sciences and Health, University of Strathclyde, Glasgow, U.K.
[3] Institute of Cognitive Neuroscience, University College London, London, U.K.

Faculty of Computing, Engineering & the Built Environment

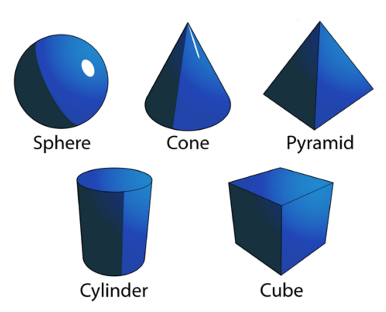
Primitive Shape Imagery Classification from Electroencephalography

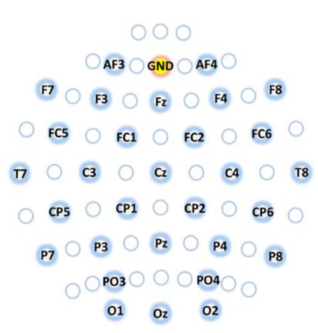
Introduction

- BCIs augment traditional interfaces for human-computer interaction and provide alternative communication devices that may enable the physically impaired to work.
- Imagined object / shape classification from electroencephalography (EEG) may lead, for example, to enhanced tools for fields such as engineering, design, and the visual arts.
- Evidence to support such a proposition from non-invasive neuroimaging techniques to date has mainly involved functional magnetic resonance tomography (fMRI) [1] indicating that visual perception and mental imagery show similar brain activity patterns [2] and, although the primary visual cortex has an important role in mental imagery and perception, the occipito-temporal cortex also encodes sensory, semantic and emotional properties during shape imagery [3].
- We investigate if five imagined primitive shapes (sphere, cone, pyramid, cylinder, cube) can be classified from EEG using filter bank common spatial patterns (FBCSP) [4].

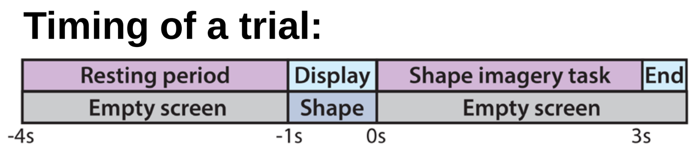
Experimental setup

- The analysis performed on two datasets (using the same experimental protocol)
  - Experiment 1: 10 subjects / 1 session
  - Experiment 2: 3 subjects / 3 session
- Each session involved 72 trials / shape: 3 runs, 4 blocks/run, 30 trials/block (total)
- EEG recorded on 30 channels as presented

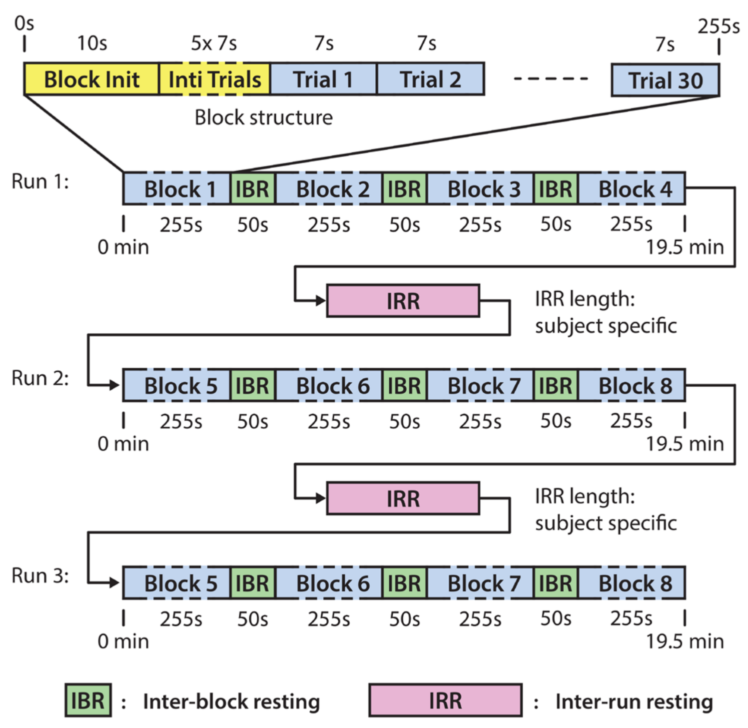




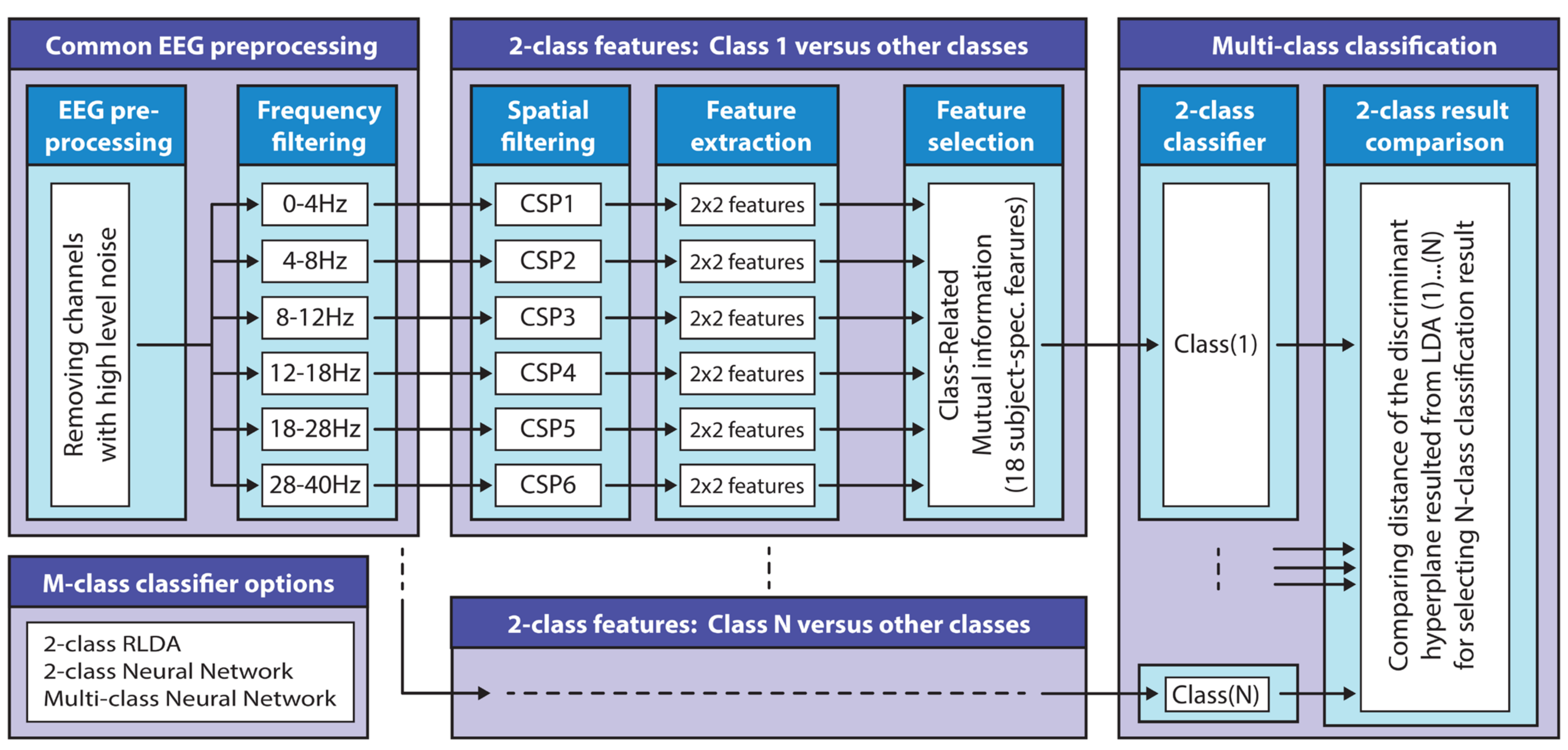
Timing of a trial:



Experimental protocol:



Methods: Filter Bank Common Spatial Patterns



Decoding accuracy (DA) was tested for 3 different multi-class classifier options

Selected method (base on test DA): multiple 2-class classifier based RLDA architecture

Cross validation

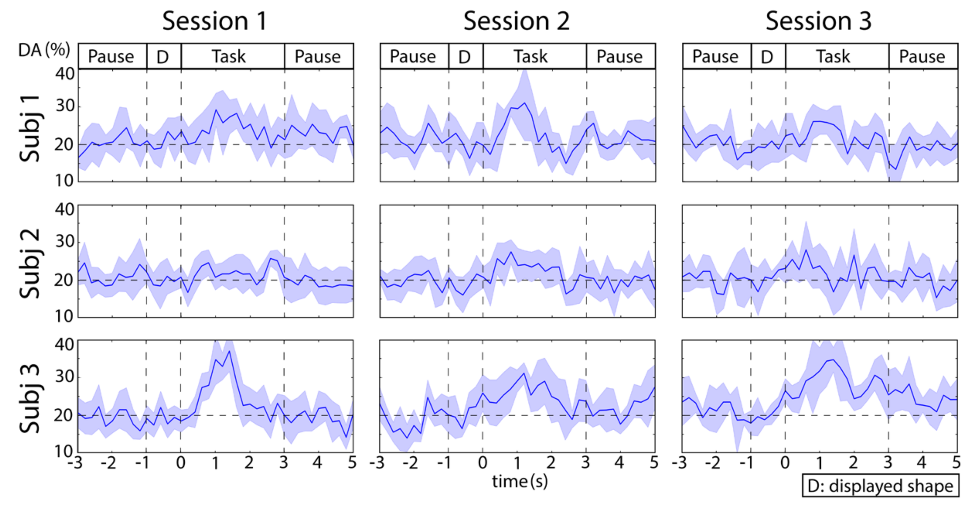
- 6 fold inner-outer (nested) CV
- Wilcoxon non-parametric test

Method validation

Performance of the applied method was tested with BCI Competition IV dataset 2a [6].

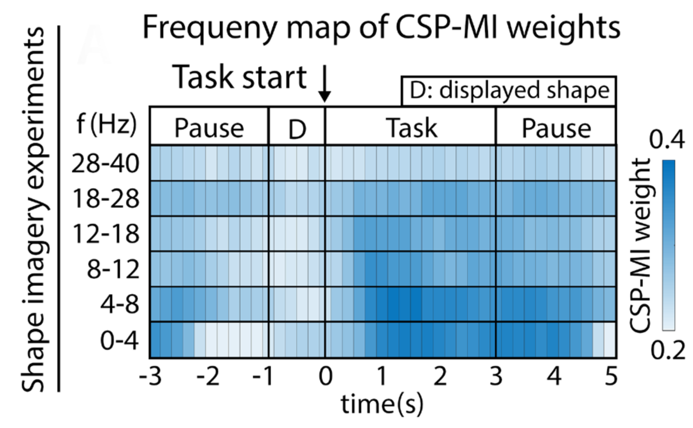
Results

Decoding accuracy (DA) from shape experiment 2



- DA~20% chance level prior to (-1s) display period.
- DA peak ~1s after onset of the shape imagery task.

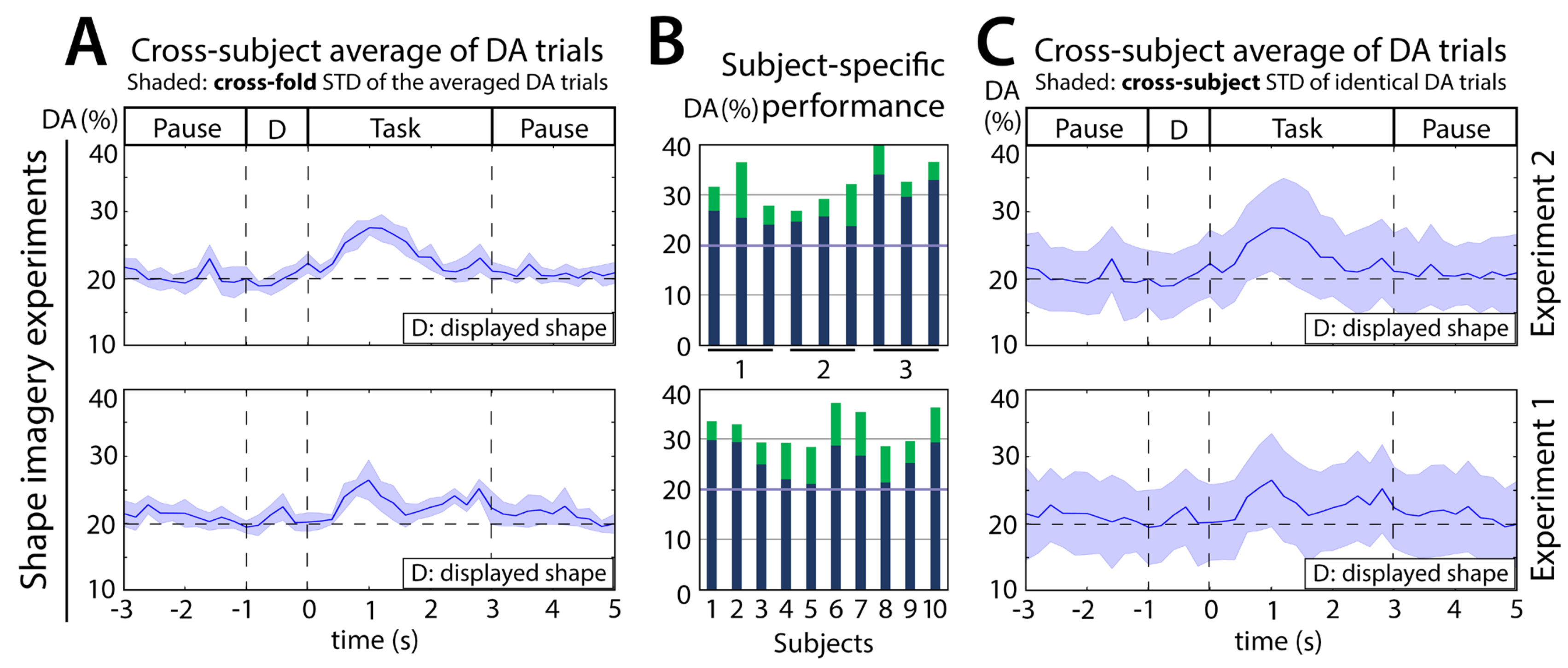
Frequency analysis (used subjects selected with DA>30% from exp1 and 2)



CSP-MI weight pattern indicates:

- Increased task-related neural activity in 0-4Hz (delta) and 4-8Hz (theta) bands.
- CSP-MI weight peak and DA peak obtained at the same time.

Cross-subject decoding accuracy (method stability vs. subject performance)

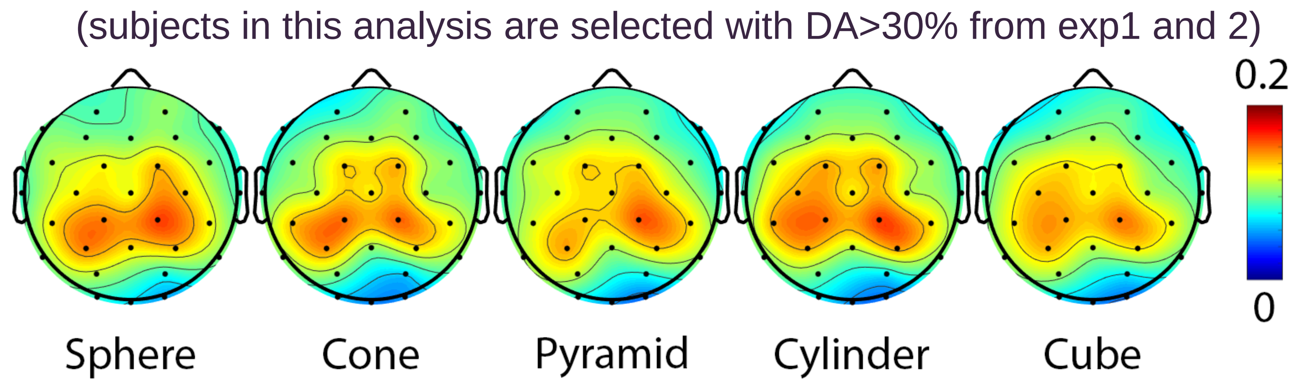


- STD of cross-subject average DA in 6 folds CV confirmed the stability of the method *(Fig A)*.
- Single-subject peak DAs are plotted *(Fig B)*.
- Individual DA varied in a wide range *(Fig C)*.

Topographical analysis (spatial distribution of CSP and MI weights at time of peak accuracy)

Shape imagery task

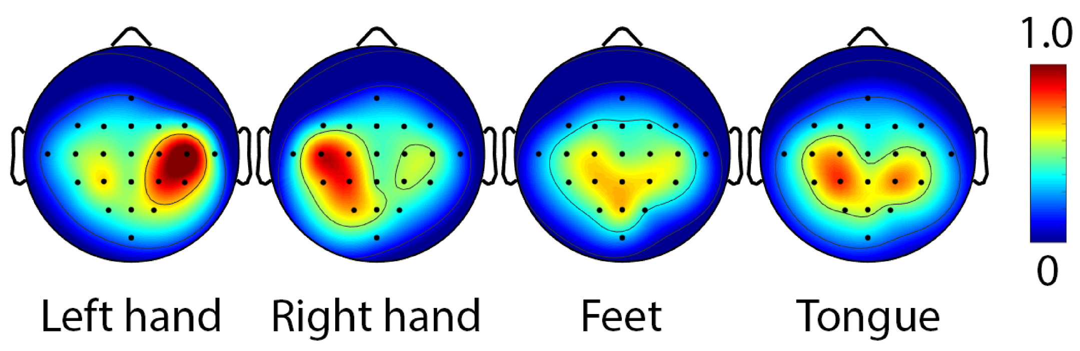
(subjects in this analysis are selected with DA>30% from exp1 and 2)



- CSP-MI weighs show shape-related neural activity in centro-parietal and occipito-temporal cortex.
- Spatial pattern of CSP-MI weights show similar distribution for mental imagery of different shapes.

Motor imagery task (a comparison to shape imagery)

(subjects in this analysis are selected with DA>75% from BCI Competition IV. Dataset 2a)



- High spatial separability of CSP-MI weights detected in SMA & M1 for different motor-imagery tasks
- This result explains the high level of DA achieved for motor-imagery task classification during our method validation process (4-class DA_{mean}~75%, DA_{max}~90%, chance level 25%).

Result summary: We achieved significantly higher DA for imagined shape classification as the chance level prior to the display period (5-class DA_{mean}~28%, DA_{max}~37%, chance level 20%) despite imagery of different shapes activating similar cortical areas. CSP-MI weights indicated task-related neural activity in occipito-temporal & parietal cortex in low frequency (delta & theta) bands. Limitation: visual perception of display shapes may effect results. Real-time feedback of shape imagery may enhance accuracy.

Significance

Only the second study of shape imagery classification from EEG [5].

Multi-session online experiment with real-time feedback of task performance may improved DA.

References

Supported by the UK EPSRC grant nos. EP/M01214X/1 & EP/M012123/1

[1] T. Horikawa et. al, Nat. Commun., vol. 8, no. May, pp. 1–15, 2015.
[2] G. Ganis, et al., Cogn. Brain Res., vol.20, no.2, pp.226–41, 2004.
[3] D. J. Mitchell et al., Sci. Rep., vol. 6, p. 20232, 2016.
[4] K. K. Ang, et. al., 2008 IEEE Int. Jt. Conf. Neural Net., pp. 2390–97, 2008.
[5] E. T. Esfahani et al., CAD Comput. Aided Des., vol. 44, no. 10, pp. 1011–19, 2012.