Virginia Commonwealth University

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An EEG-Based Natural BCI for Volitional 2-D Cursor Control

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EEG & BCI Laboratory

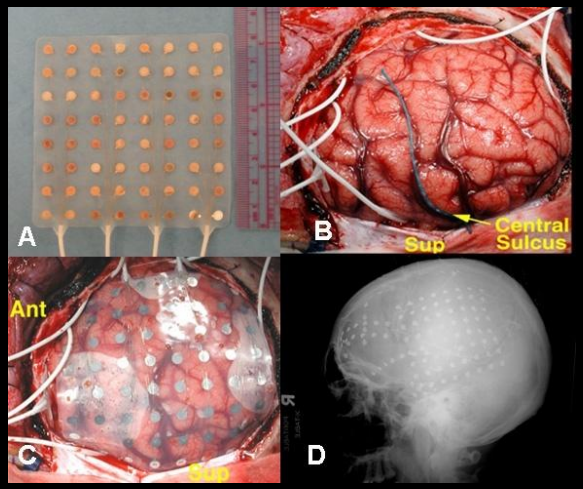
Critical challenge for BCI?

- BCI Purpose: direct brain control.
- BCI & Volition
- Brain signal:
  - Reliably decode subject's volition: high Signal-to-Noise Ratio (SNR) is required

Signal Methods

Invasive BCI

- Pros
  - Better SNR
- Cons
  - Clinical threshold
  - Technical difficulties



http://labs.seas.wustl.edu/bme/dmoran/Research/BCI.htm

Non-invasive BCI

- Pros
  - Easy to use
- Cons
  - Low signal-to-noise ratio: large variance

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Rhythm Regulation

To increase SNR (reduce variance): EEG rhythm regulation (Wolpaw and McFarland, 2004)

However, the artificial regulation requires:

- Long-term training
- Much attention & mental effort: fatigue
  - may no longer be able to regulate

Paralyzed patients

- may not be able to learn
- easily get fatigued (Birbaumer, 2006)

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Our solution

Natural BCI associated with movement intention

- No need to learn
- Less mental effort

Human movement intention with natural behavior

- ERD (Event-Related Desynchronization): power decrease , during movement (widely used in BCI).
- ERS (Event-Related Synchronization): power increase , post-movement (novel augmentative feature).
- ERD/ERS: motor imagery (available).

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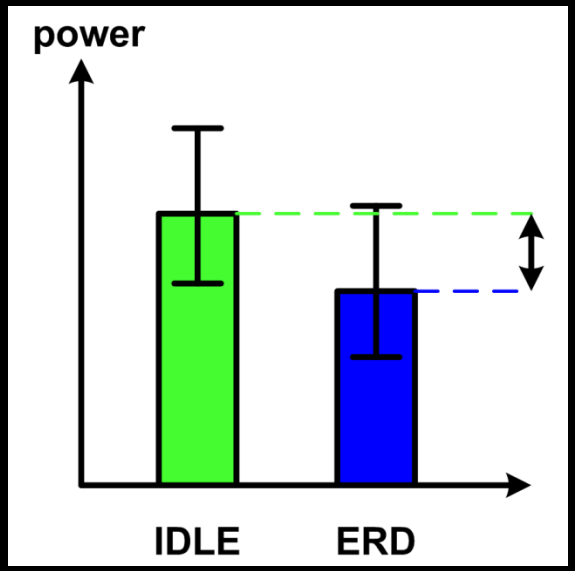
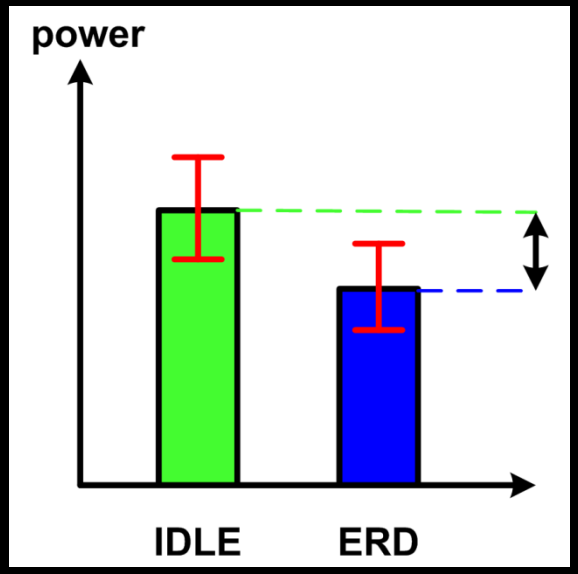
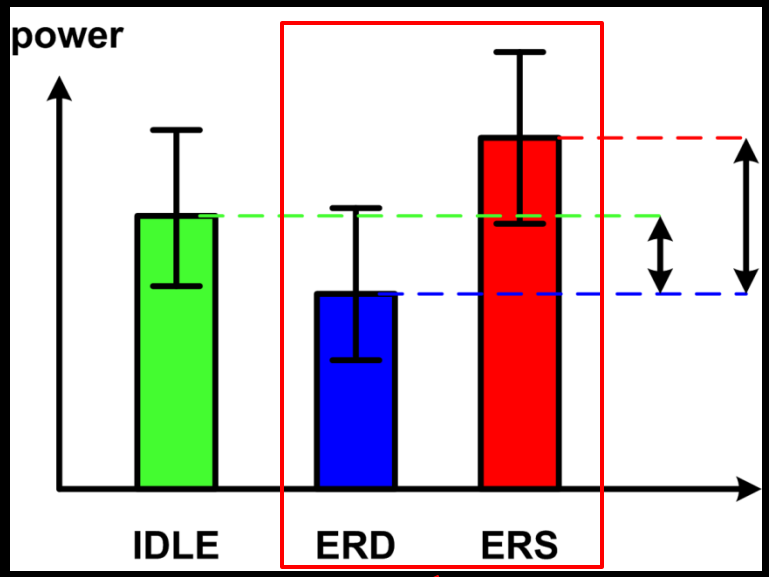


Identify ERD from IDLE
Large variance



Dr. Wolpaw's group
Identify ERD from IDLE
Regulate rhythm
Reduce variance



1. Increase mean difference

2. Natural; no training needed

Our solution, differentiate ERD from ERS

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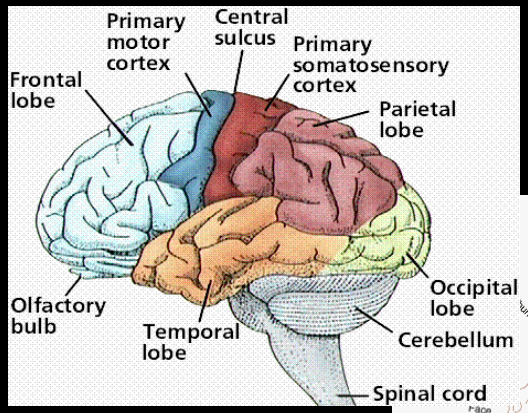
ERD/ERS was tested successful for binary control .
(Bai, O., et al., 2008)

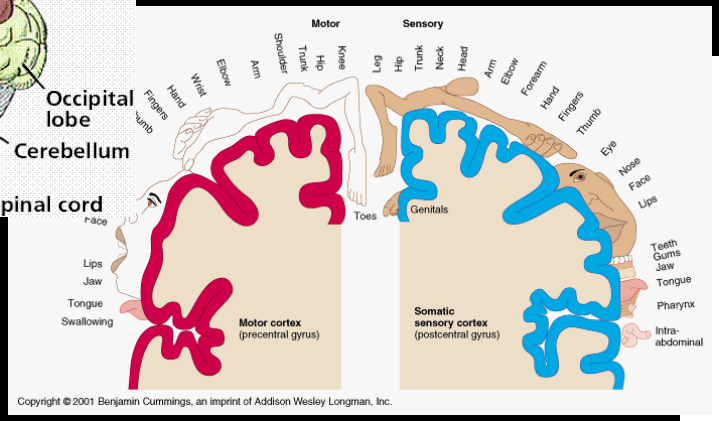
New Challenge

Does it support four directional cursor control in 2-D plane?

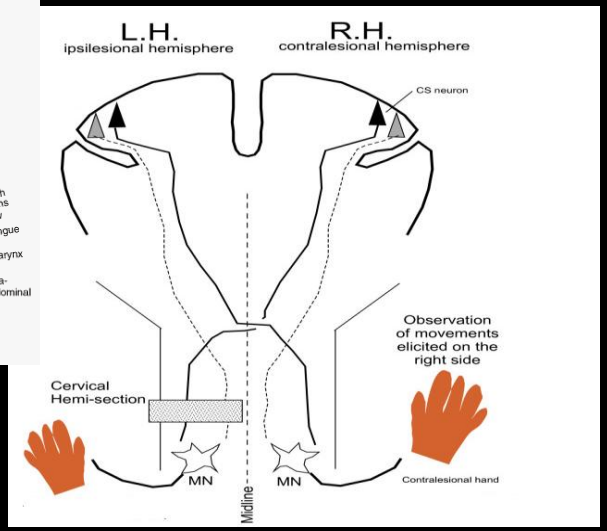
Physiological rationale



For Physical/ Imaginary movements



Hand movement- Motor cortex



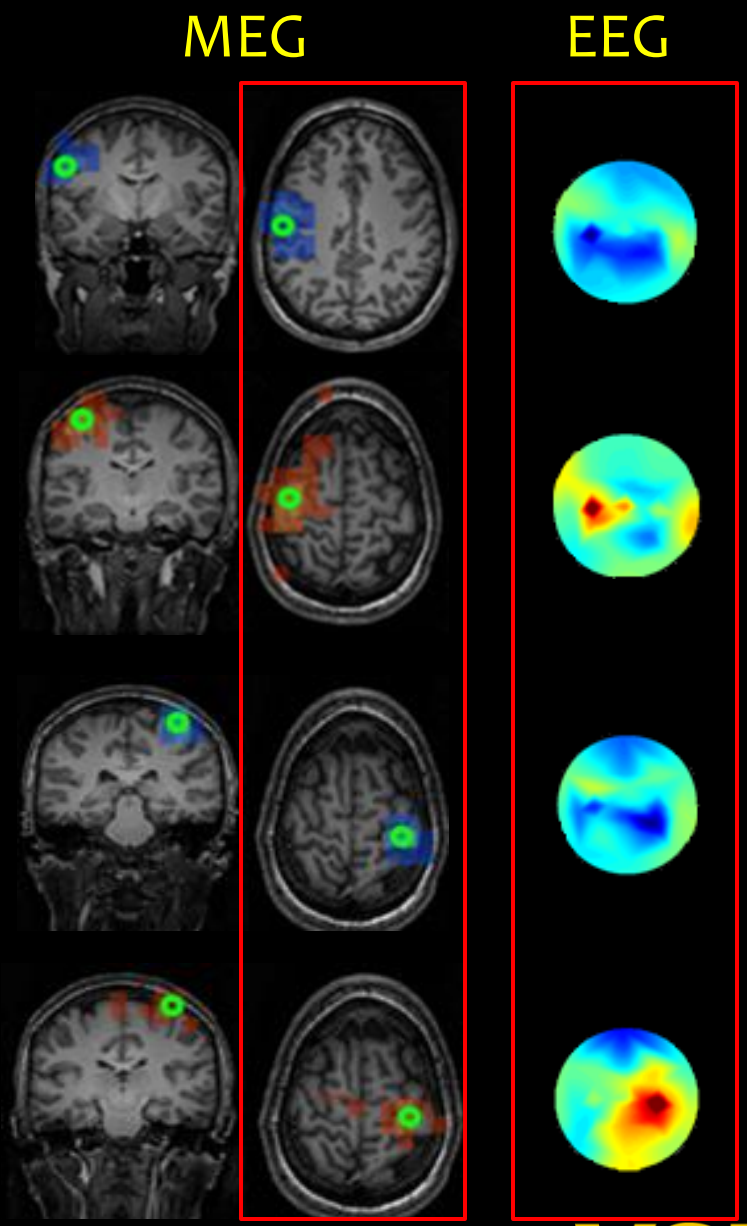
Contralateral control

Right hand:

- During movement-LERD
- After movement-LERS

Left hand:

- During movement-RERD
- After movement-RERS



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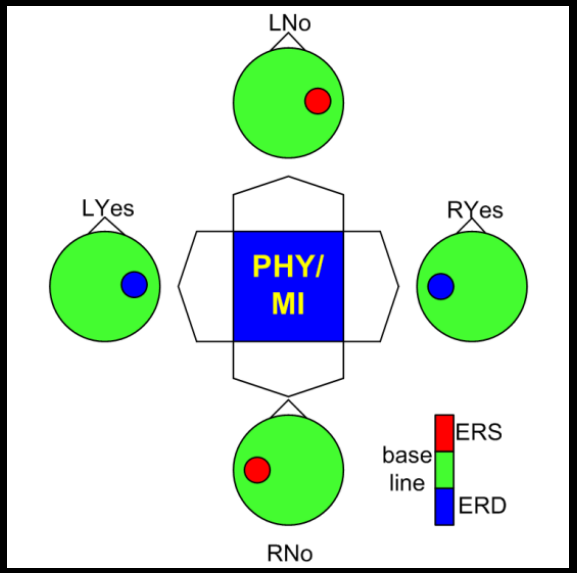
Rationale for 2D cursor control

Right **ERS**

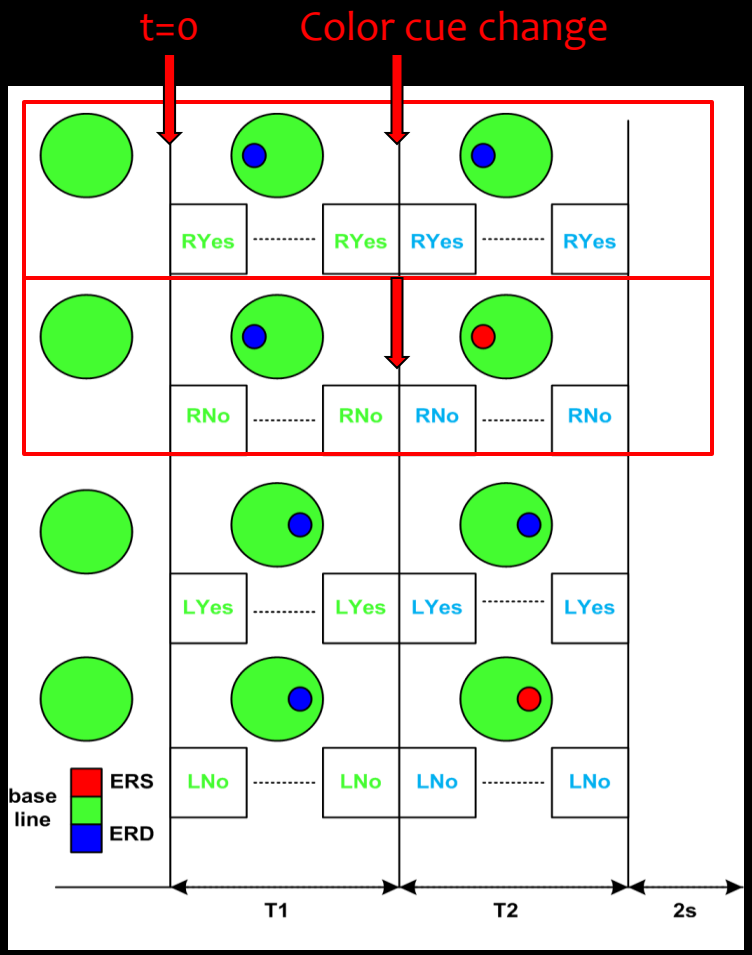
Right **ERD**



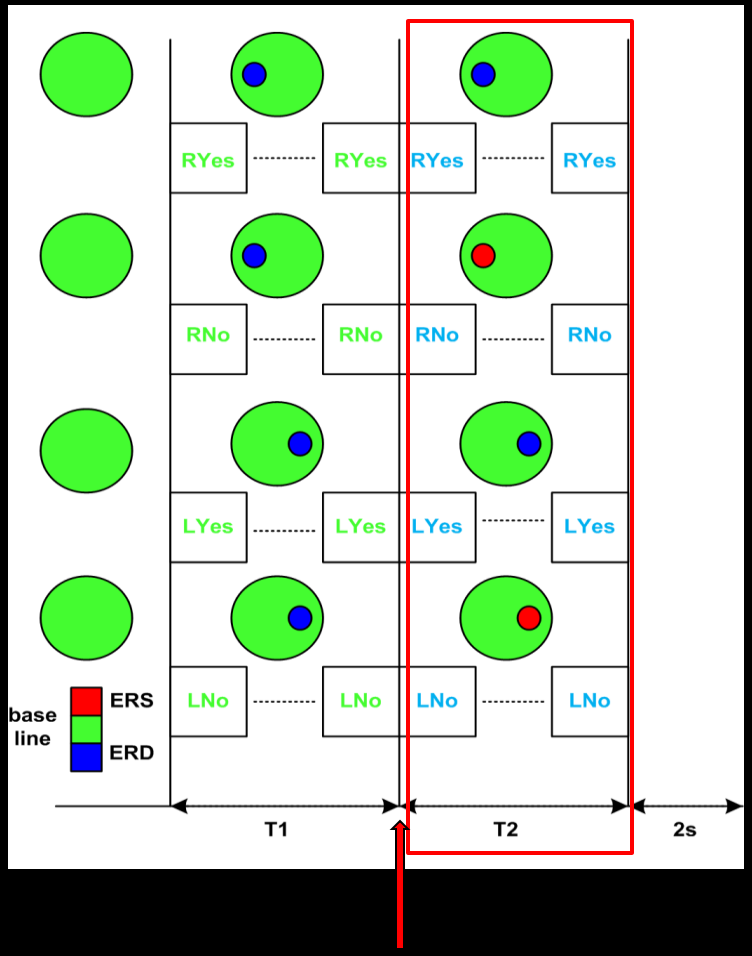
Left **ERD**

Left **ERS**

Online calibration



Online calibration



Left ERD

Left ERS

Right ERD

Right ERS

Color cue change

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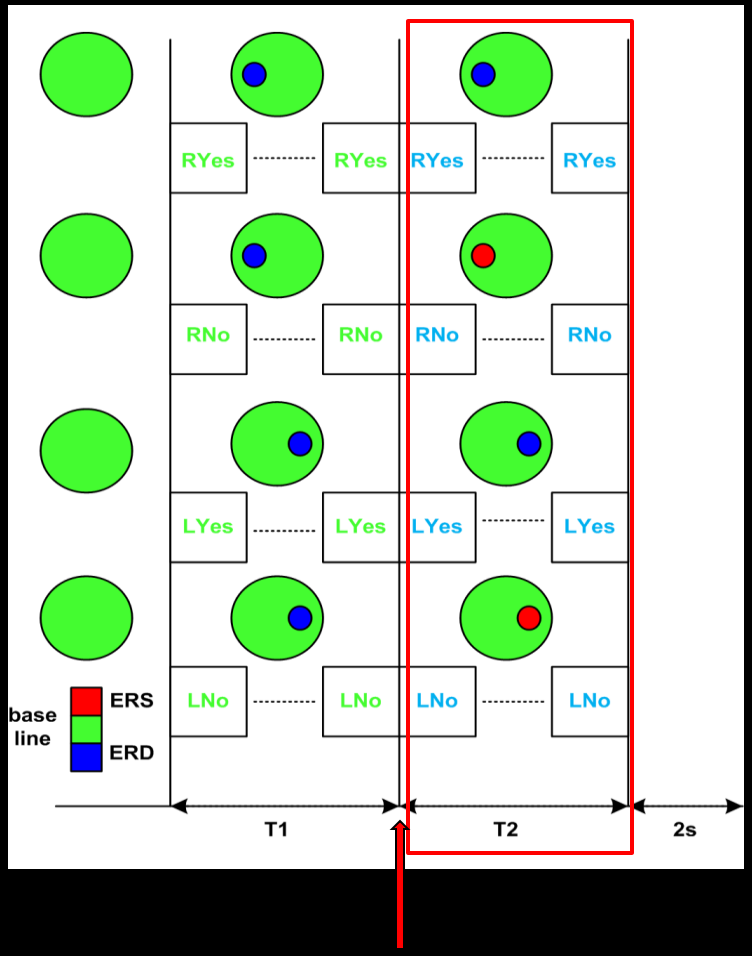
Online calibration

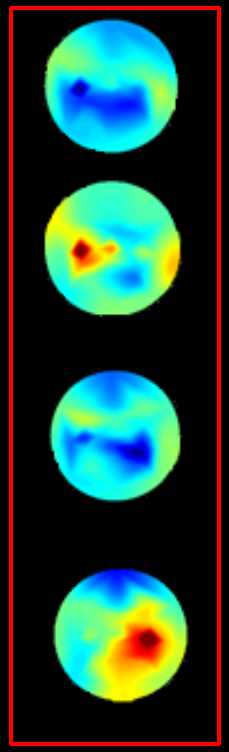


Left ERD

Left ERS

Right ERD

Right ERS



Color cue change

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Computational Methods for Online Control

Spatial filtering

- Surface Laplacian Derivation (SLD)

Temporal filtering

- Power Spectral Density (PSD) estimation

Feature extraction

- Empirical selection: Channel & frequency band restriction
- Bhattacharyya distance

Classification

- Decision Tree Classifier (DTC)

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Online 2-D Cursor Control Game

Performance of Natural BCI for 2-D Control

- Physical movement, average performances for S1, S2, S3, S5: 92%, 85%, 81%, 84% (overall: 85.5%±4.65%)
- motor imagery, 73%±5.97% for S1, 59.2%±3.63% for S2

  (offline results: 10 fold cross-validation)

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Summary

- Users can achieve robust BCI control without long-term training by using natural behavior
- Higher dimensional BCI control is possible to be realized with appropriate signal processing methods
- BCI will provide great opportunities for various patients with neurological disease to improve their quality of life

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Thank You!