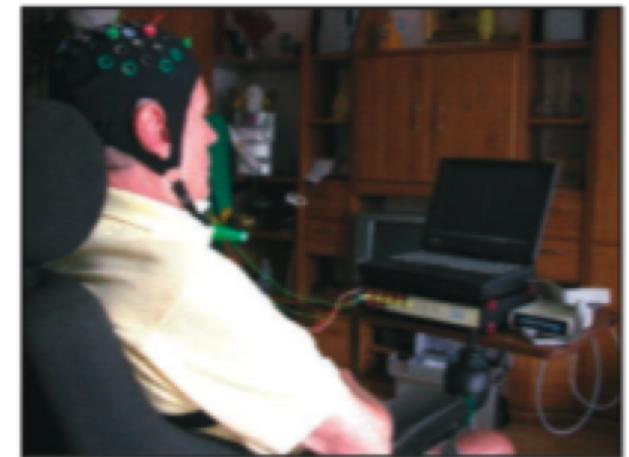
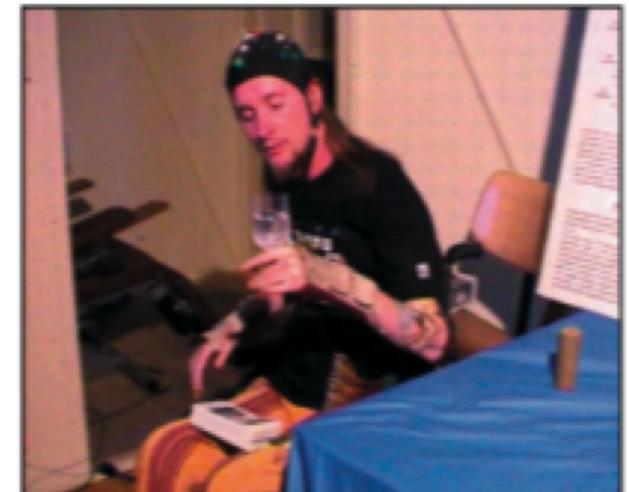


# Imagined movement based BCI



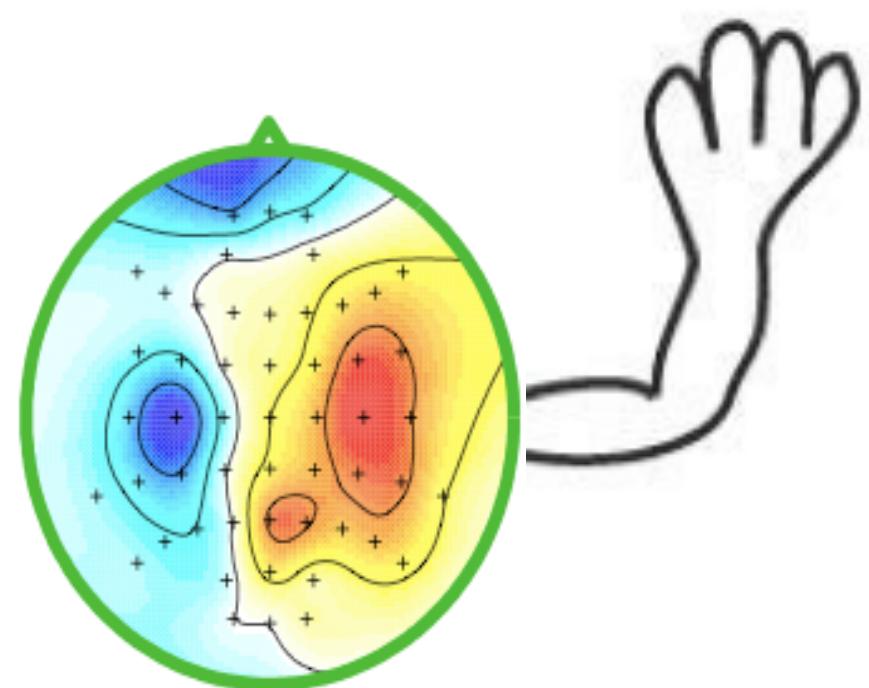
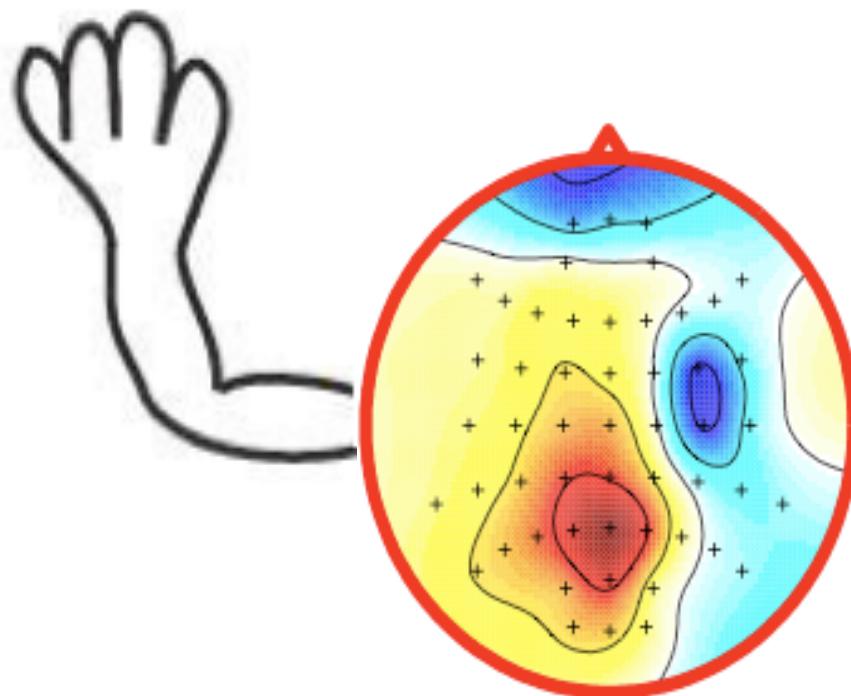
Introduction  
Brain-Computer Interfacing



05-10-2010  
Moniek Lijster

# Active BCI

User actively performs a BCI specific task



# Outline

Key paper: Blankertz et al., 2010

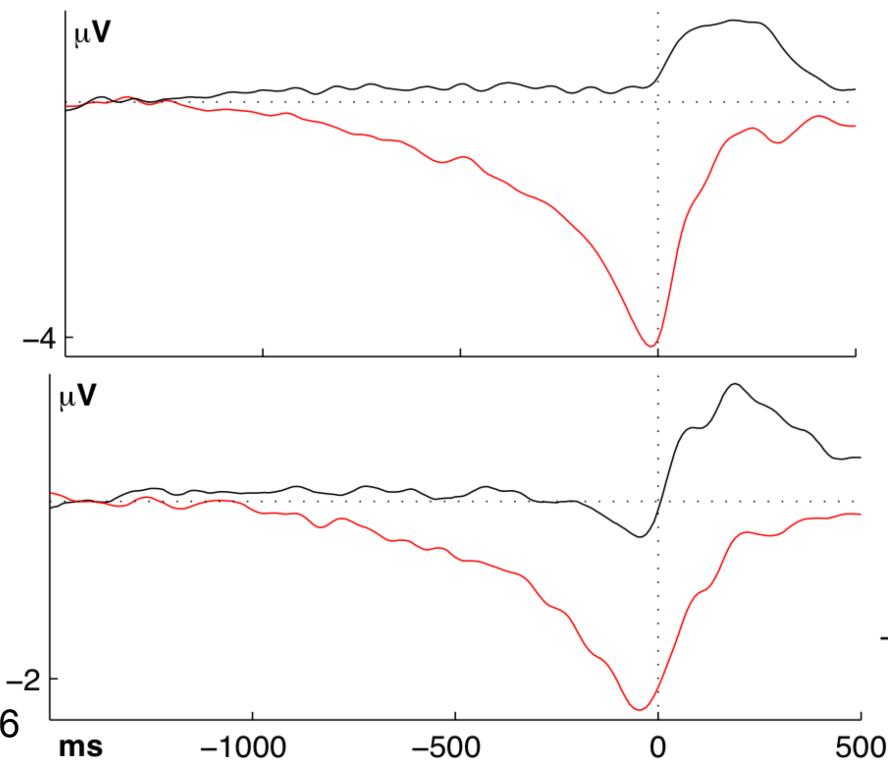
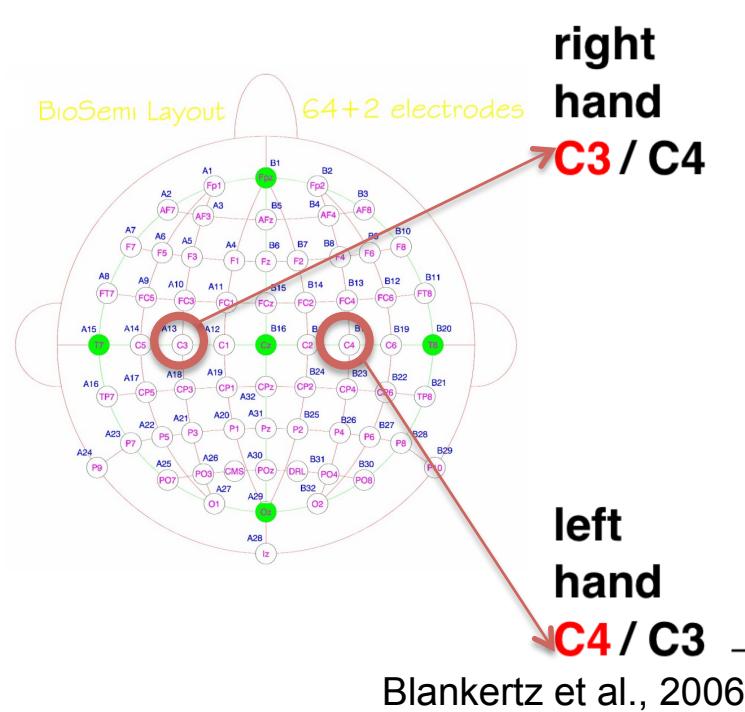
- Brain signatures of motor imagery
- Motor imagery paradigm
- Current research
- Research @ CAI
- Application in patients

# Outline

- Brain signatures of motor imagery
  - Readiness Potential (RP) or Bereitschaftspotential
  - Event-Related (De)Synchronization (ERD/ERS)
- Motor imagery paradigm
- Current research
- Research @ CAI
- Application in patients

# Readiness Potential (RP)

Negative deflection of the EEG over contralateral primary motor cortex during motor preparation that peaks about movement onset (evoked)



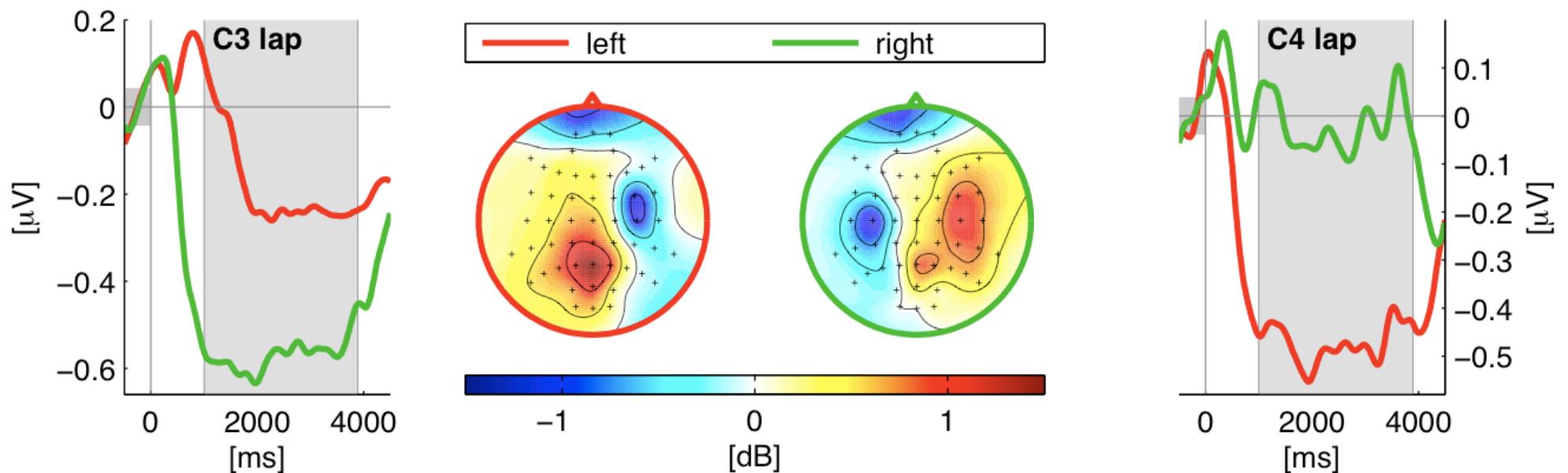
# Event-Related (De)Synchronization

De-/increase of power of the EEG signal in a given frequency band relative to baseline → induced response

# ERD/ERS in sensorimotor rhythms

- Classic example: modulation of power in  $\mu$  (8 - 12 Hz) and  $\beta$  (13 - 28 Hz) frequency bands
- During movement: ERD over contralateral motor cortices
- After movement: ERS over contralateral motor cortices (so-called  $\beta$ -rebound)

# Also works for motor imagery!

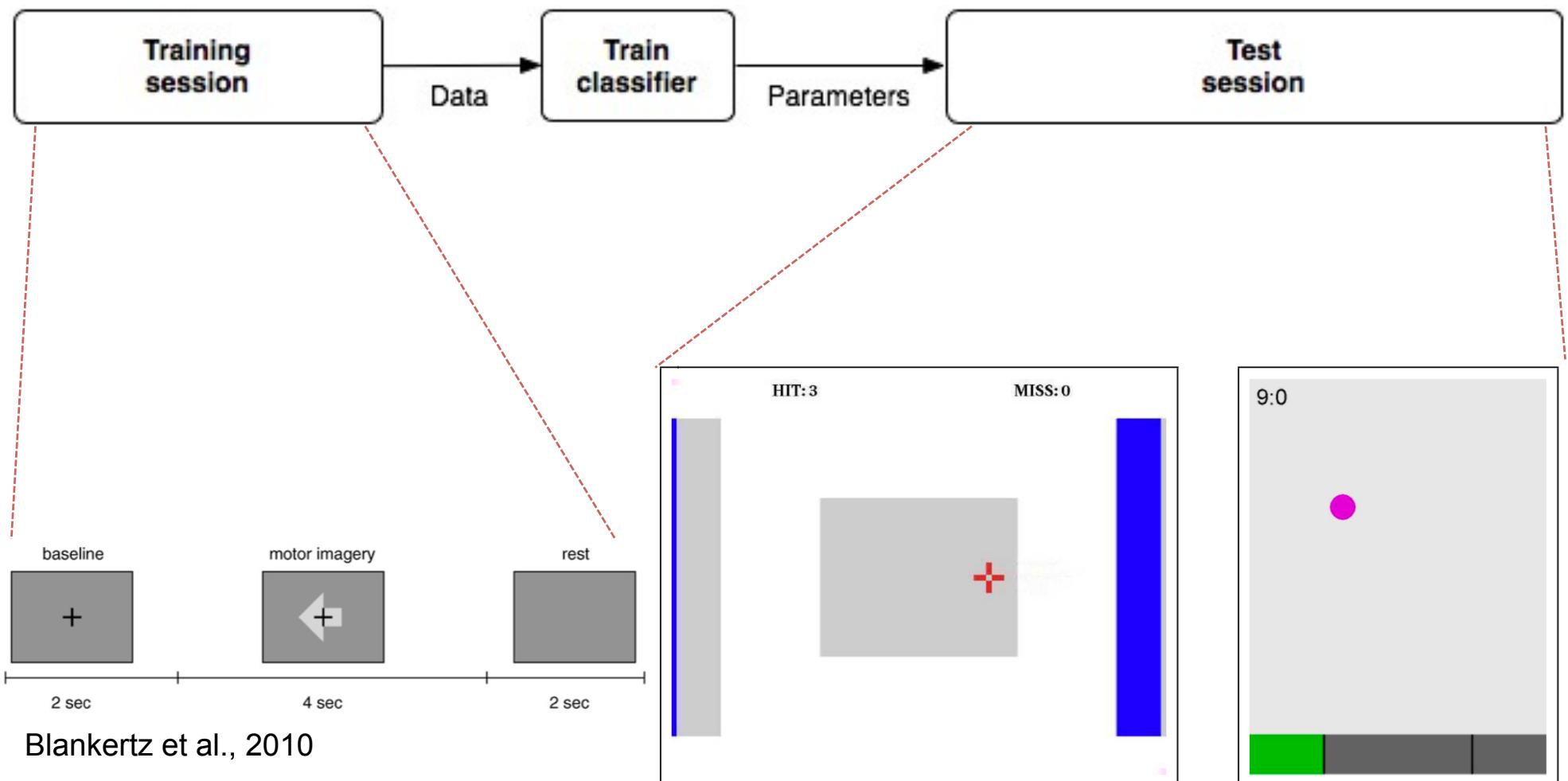


Blankertz et al., 2008

# Outline

- Brain signatures of motor imagery
- Motor imagery paradigm
  - The paradigm
  - Characteristics
- Current research
- Research @ CAI
- Application in patients

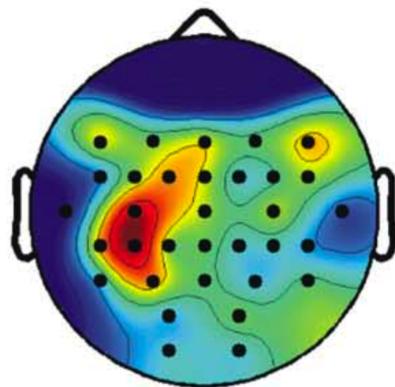
# Motor imagery paradigm



# Modes of motor imagery

## Kinesthetic

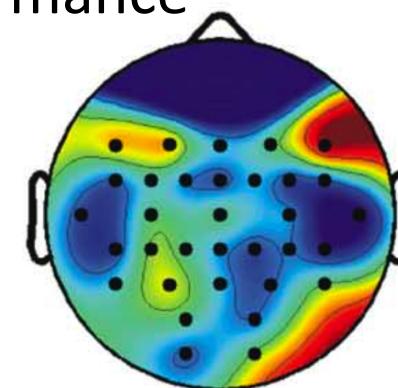
- Imagine you performing the movement
- High classification performance



→ Works better in BCI !

## Visual

- Imagine you watching someone else performing the movement
- Low classification performance



# Other characteristics

- Speed (fast / slow) and type (extension / rotation) of movement → only speed matters in classification Gu et al., 2009
- Duration → more ERD lateralization in brief movements compared to continuous movements Nam et al., 2010

# Outline

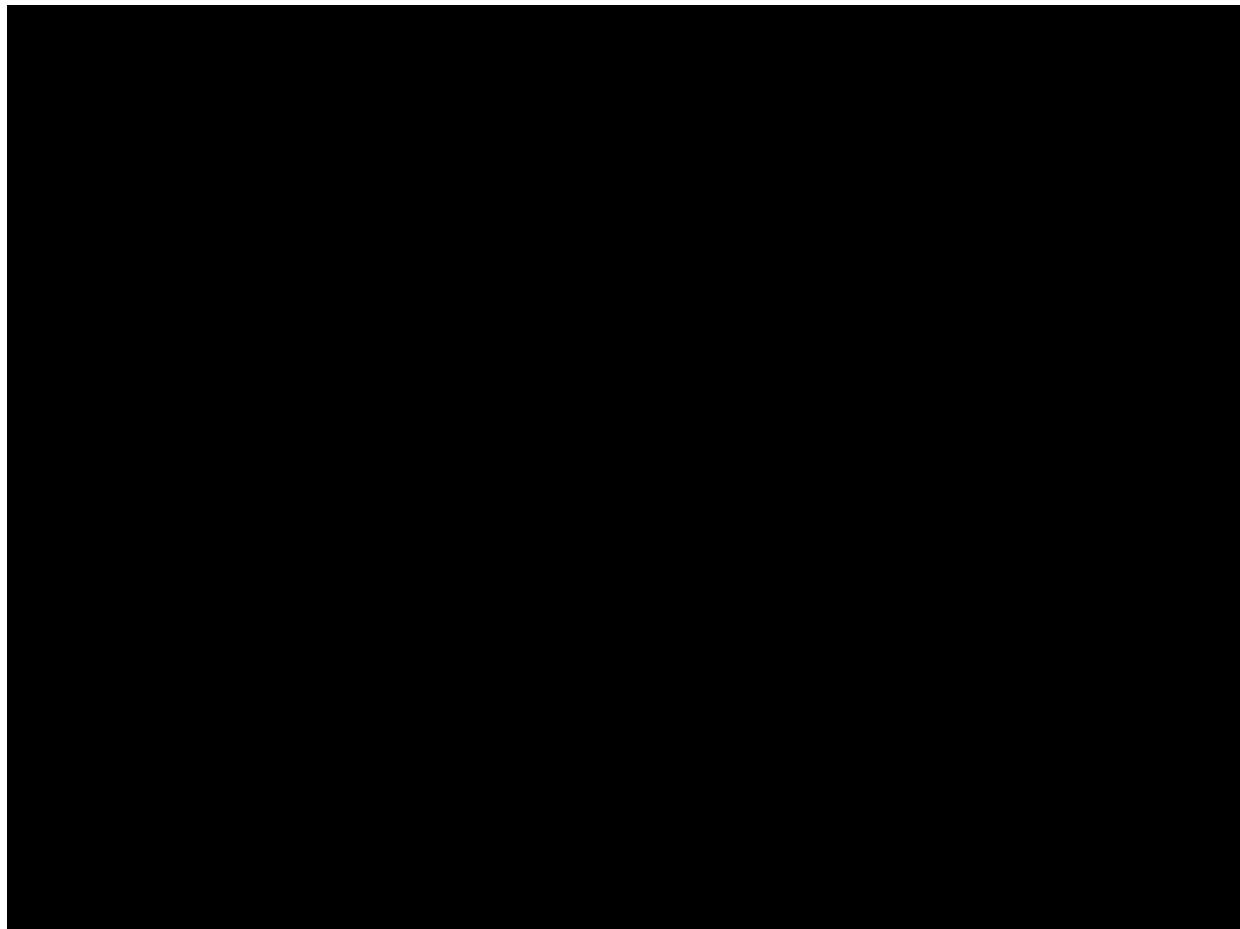
- Brain signatures of motor imagery
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- Current research: Graz, Wadsworth and Berlin
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# Graz BCI

- One of the first “online” BCI systems introduced 20 years ago
- Applications:
  - Functional Electrical Stimulation
  - Neuroprosthesis
  - Navigation in Virtual Reality

# Functional Electrical Stimulation

- Foot movement imagery → burst in  $\beta$  power



# Navigation through virtual reality

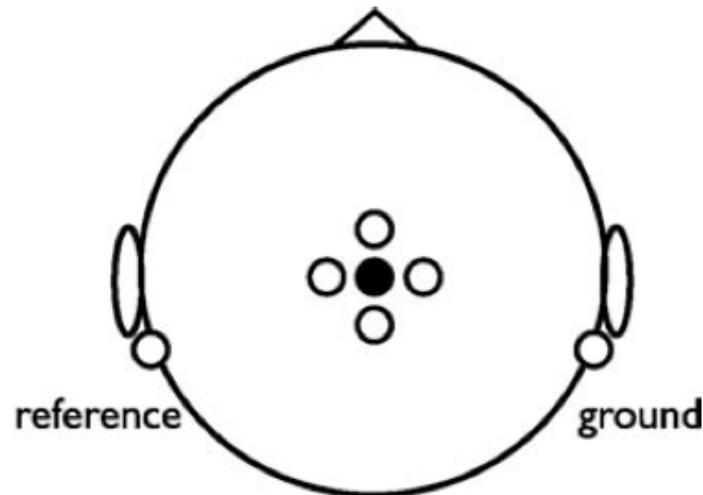
- Navigation through virtual world
- Use of Google Earth
- Avatars in street

Leeb et al., 2007

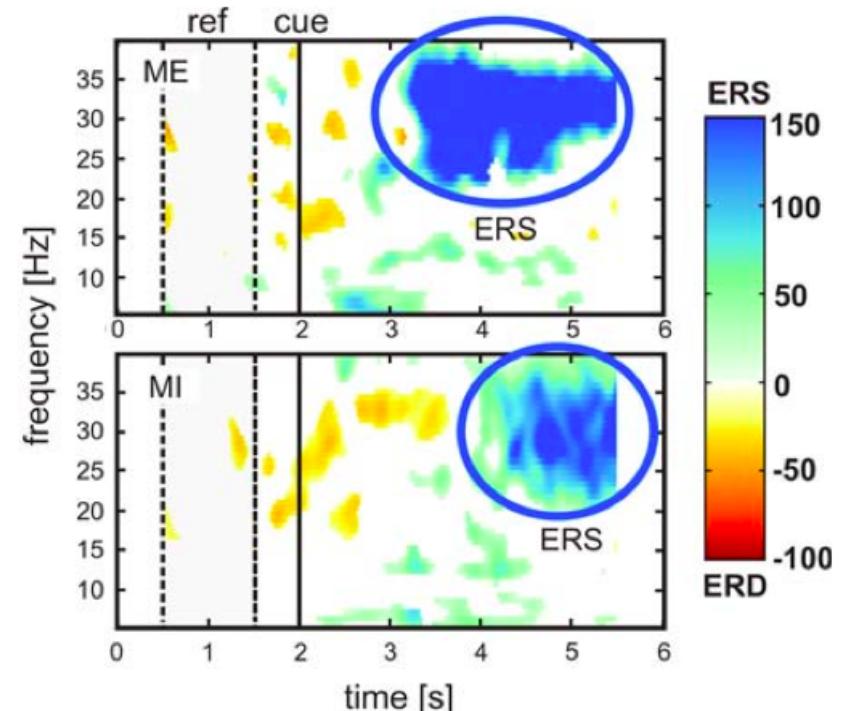


EEG-based "walking"  
of a tetraplegic  
in virtual reality

# Brain Switch



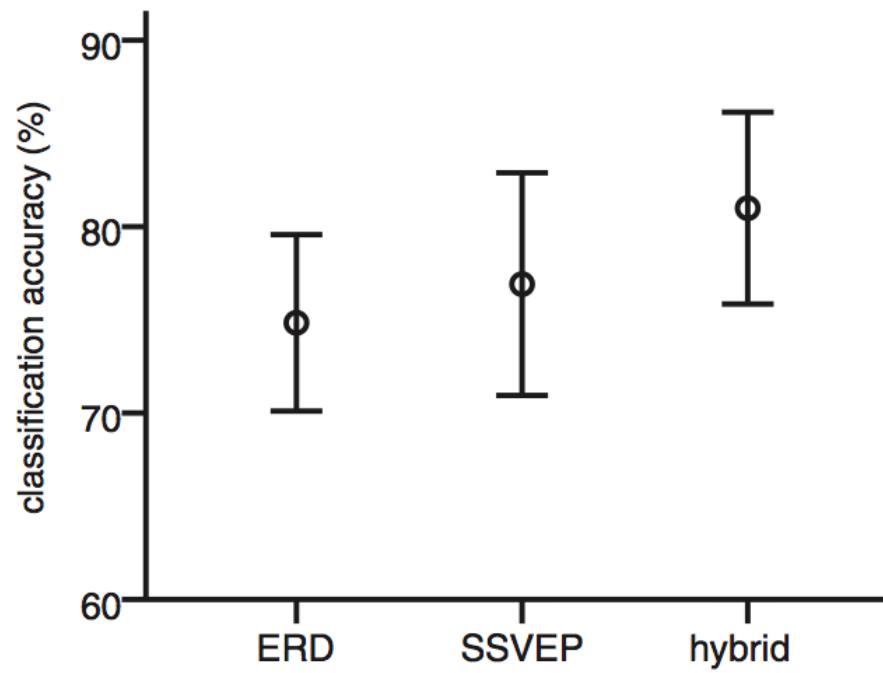
- Brisk foot movement
- Asynchronous
- Train classifier on motor execution, but classify imagery
- > 80% performance



Müller-Putz et al., 2010; Solis-Escalante et al., 2010

# Hybrid BCI

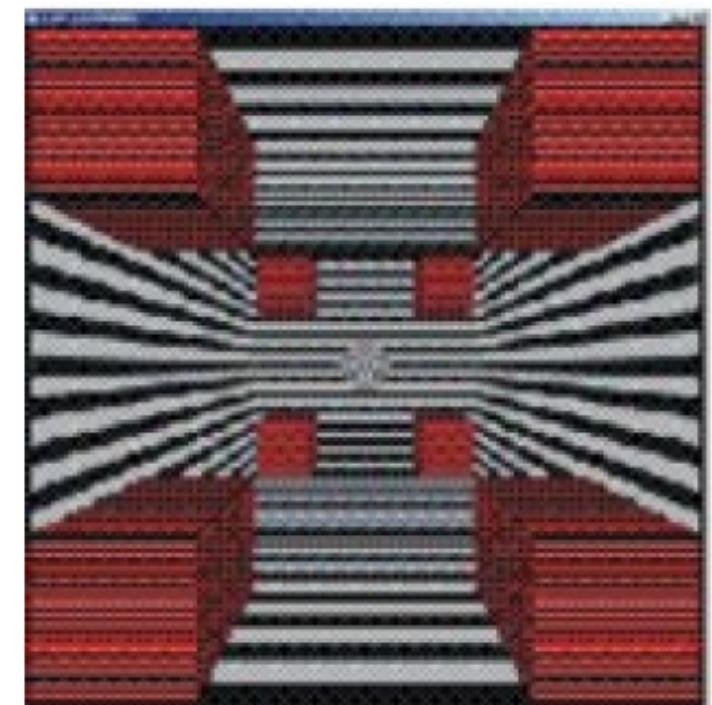
- ERD versus SSVEPs versus both Allison 2010



# Wadsworth Center

- Implicit learning: modulate amplitude of mu and beta rhythms Wolpaw & McFarland 2004
  - Subjects report to initially use motor imagery
- Cursor control: weighted combination of left/right mu and beta amplitude

# 2D and 3D control



McFarland et al., 2008 & 2010

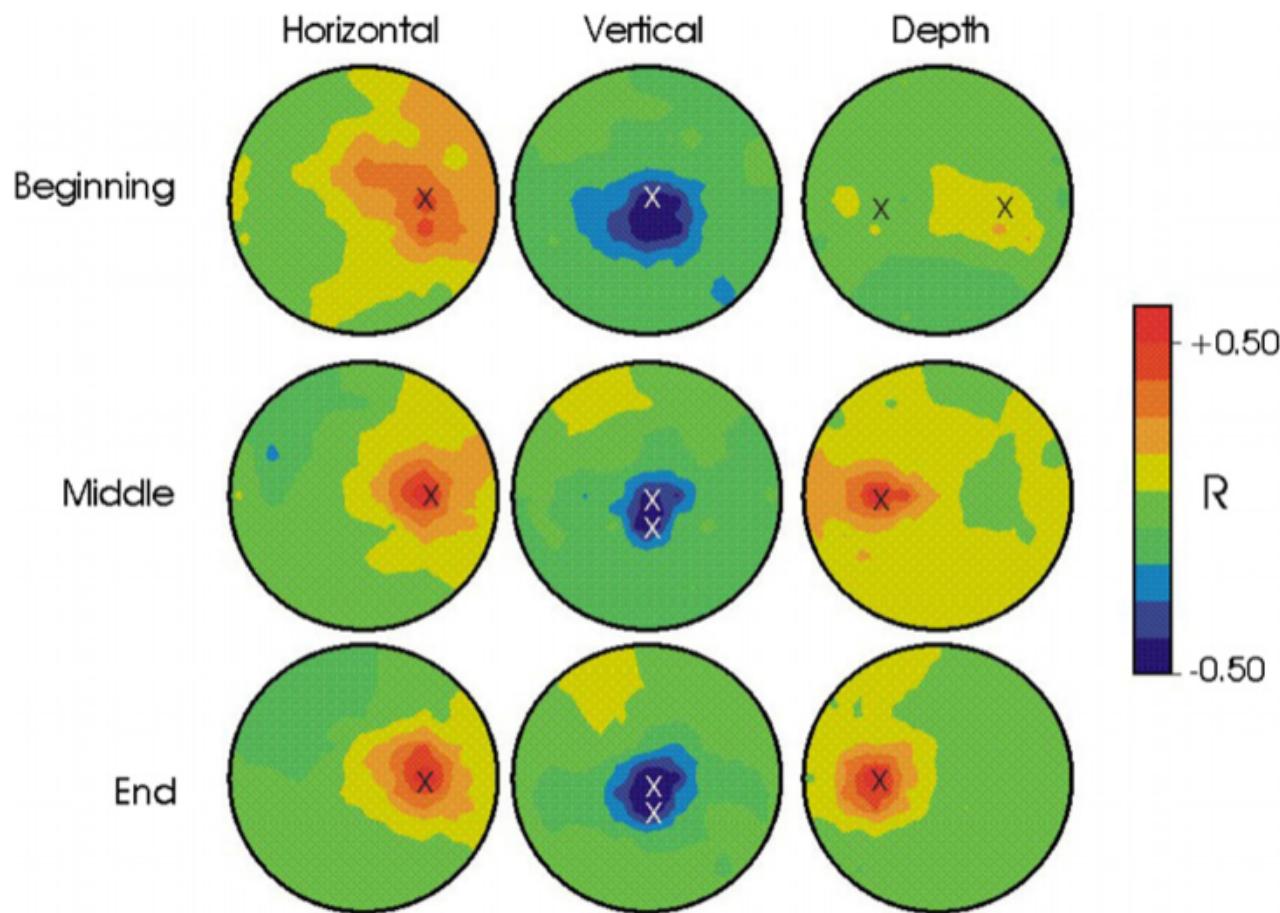
# 2D control

- First learned 1D control in horizontal and vertical directions separately
- Target selection: ERS over left sensorimotor cortex
- Then: move and select **5-15h training**



- **59 – 88% accuracy** McFarland et al., 2008

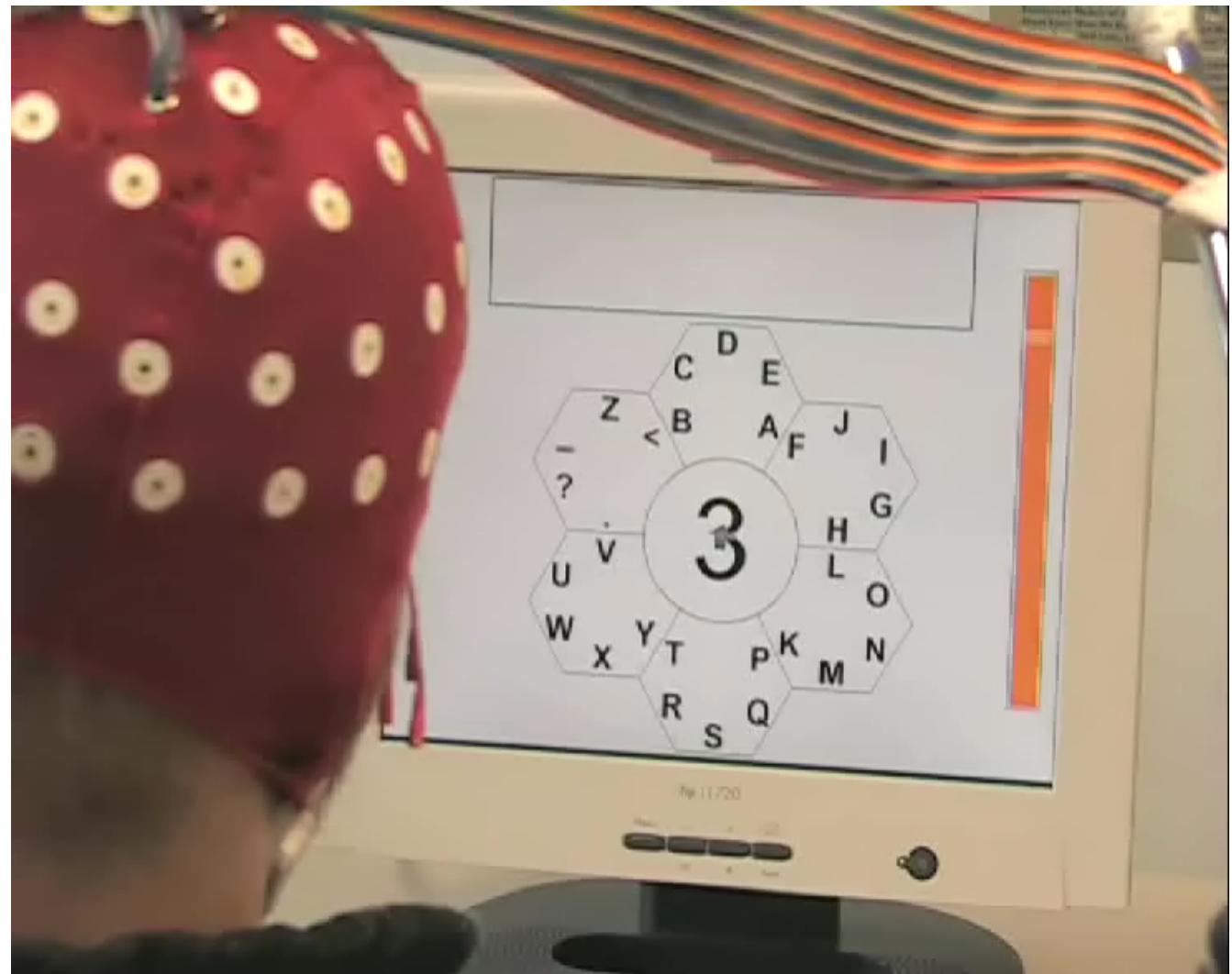
# 3D control



McFarland et al., 2010

# Berlin BCI (BBCI)

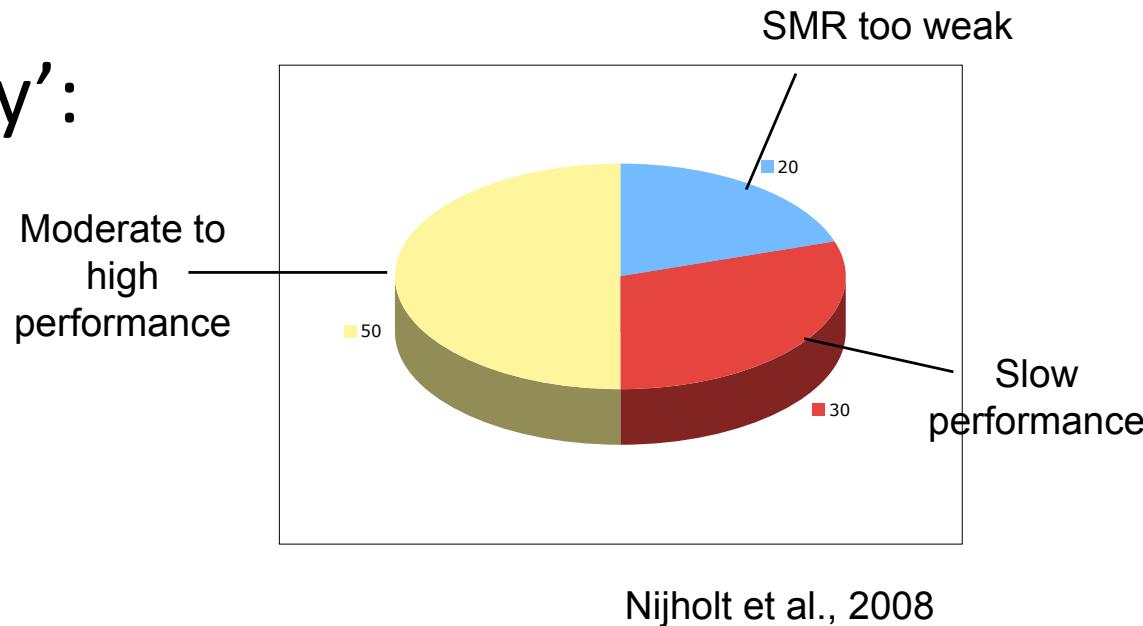
- Hex-o-Spell



Blankertz et al., 2006

# Current research Berlin

- ‘Illiteracy’:

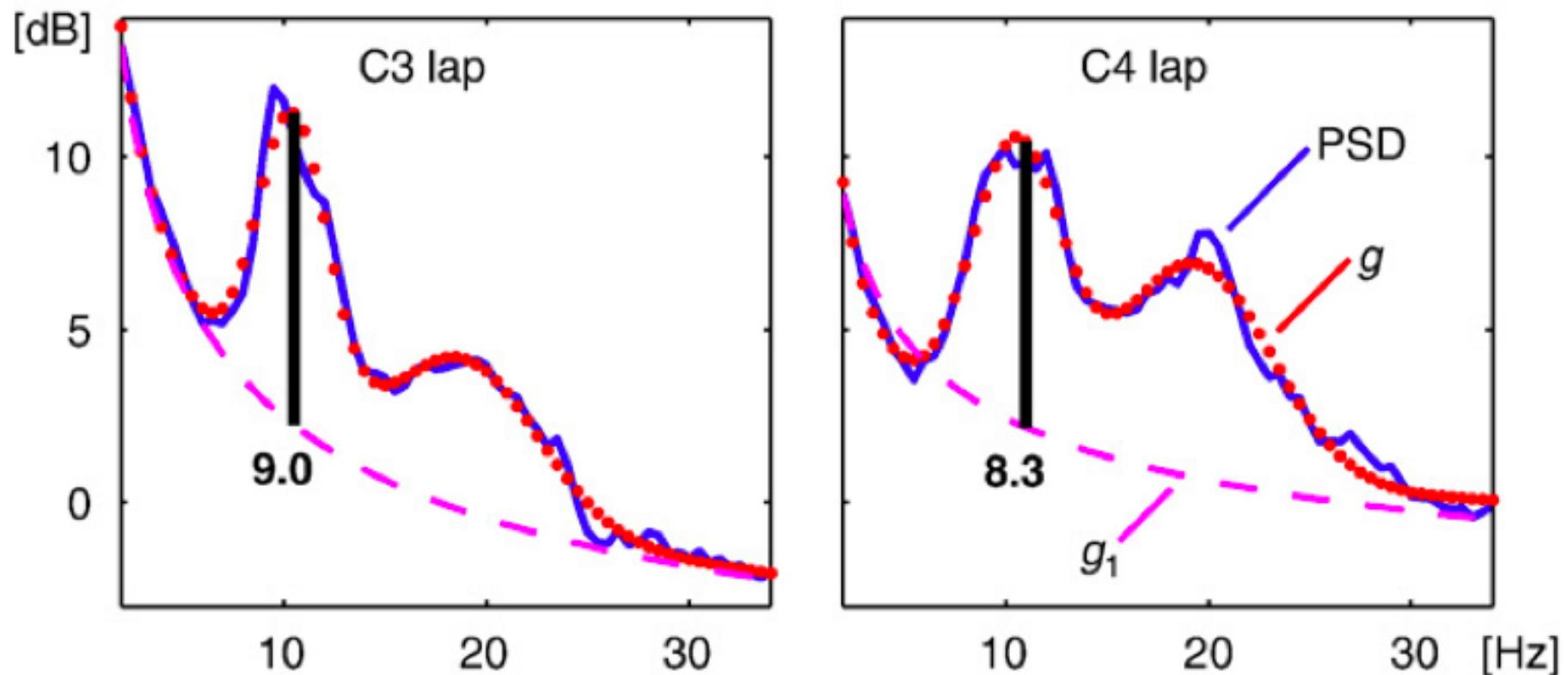


- Predict SMR-based performance to ....:
  - ... avoid costly BCI training of illiterates
  - ... investigate neural mechanisms of illiteracy and inter-subject variability

# Predictor SMR-based performance

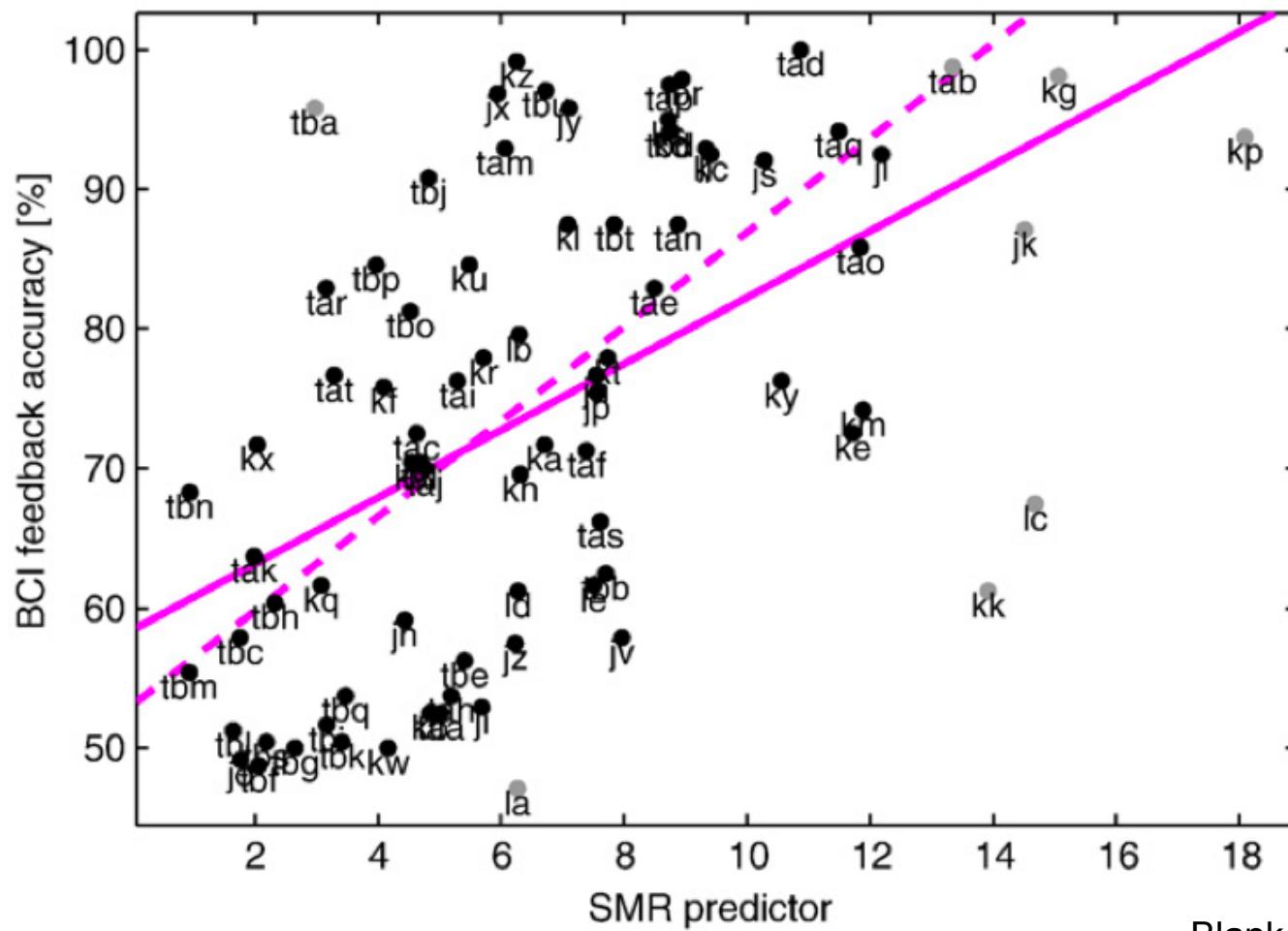
- Before BCI training: relax with eyes open
- Large subject population ( $n = 80$ )

Blankertz et al., 2010



# Predictor SMR-based performance

- Mean accuracy: 74.4%

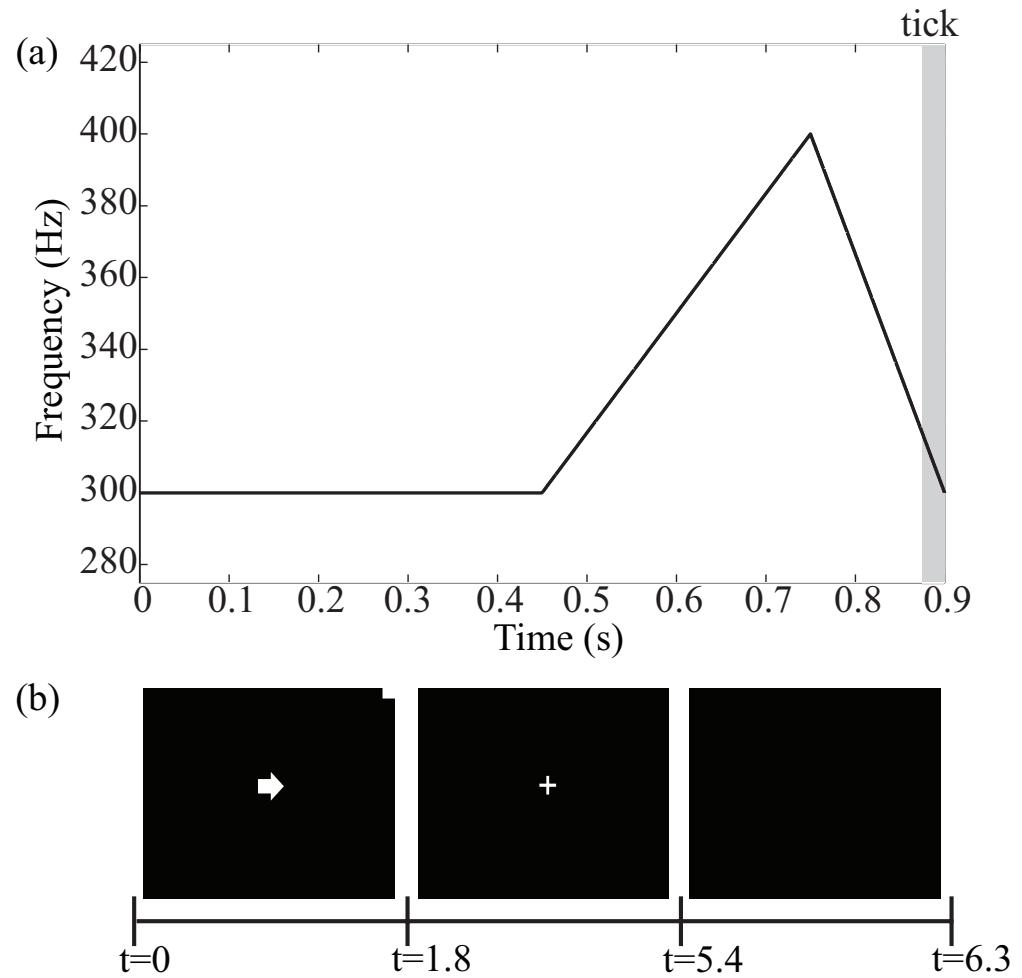


# Outline

- Brain signatures of motor imagery
- Motor imagery paradigm
- Current research
- **Research @ CAI: time-locked hand tapping and variability**
- Application in patients

# Current research at CAI

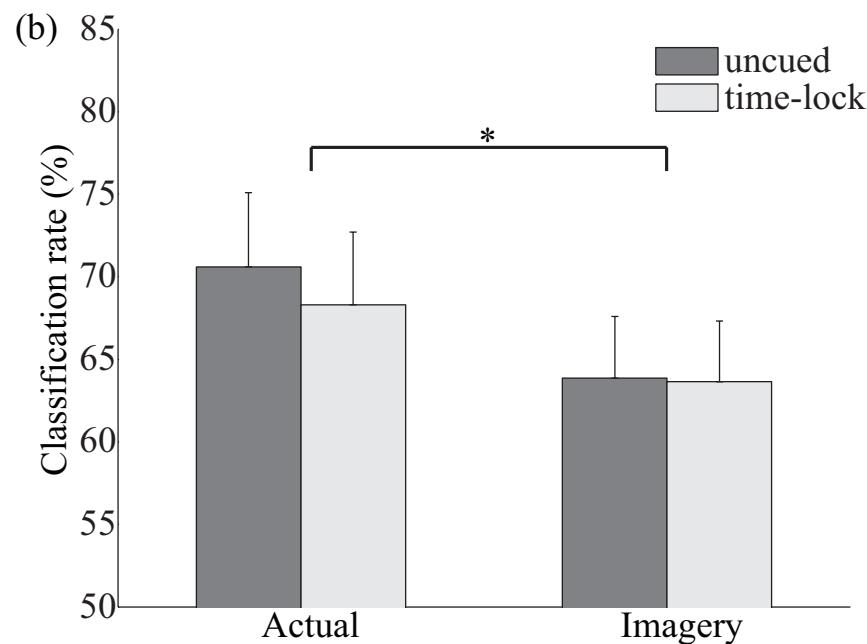
- Introduce an external auditory cue → hybrid BCI
  - Know imagined movement timing → increase detectability
  - Increase vividness of imagery Heremans et al., 2009
- 12 Subjects executed/imagined left and right hand motion with and without auditory cue



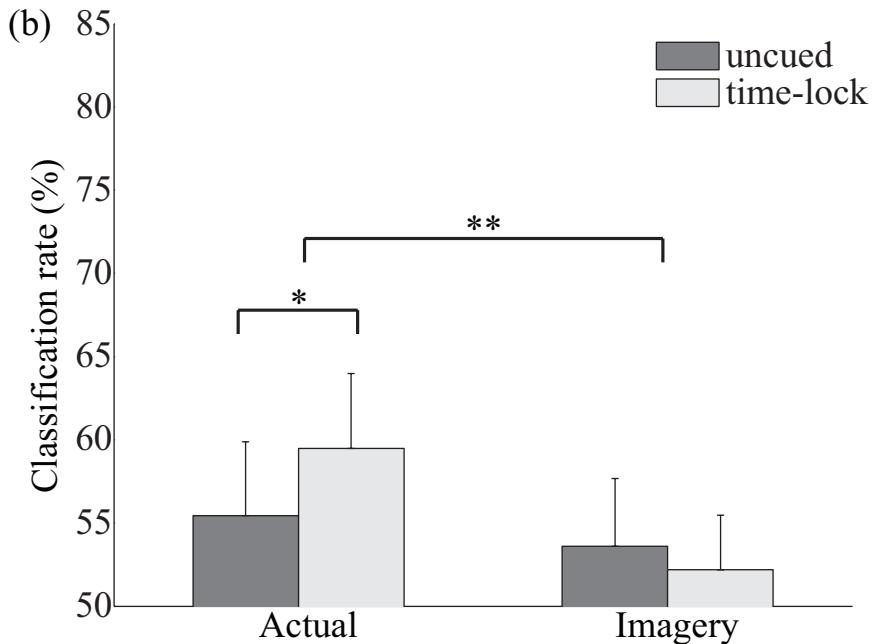
Lijster et al., in prep

# Time-locked hand tapping

## ERD/ERS



## RP



→ Subjects reported increased vividness of imagery with external cue

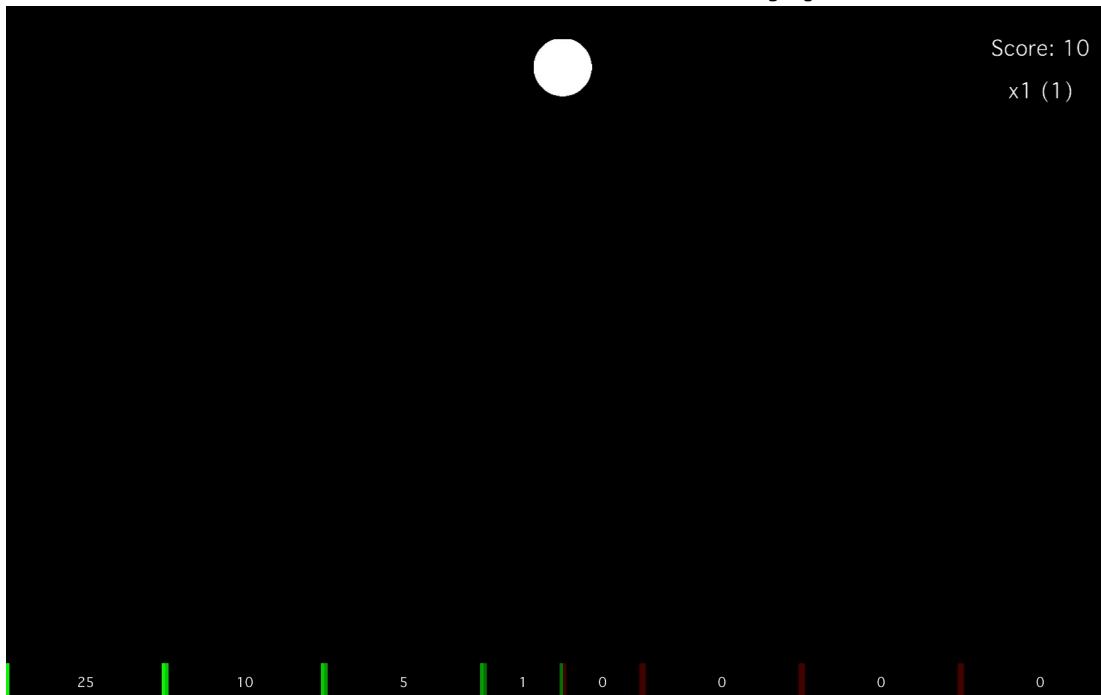
# Characterize variabilities in BCI

- Large degree of variability in BCI data
  - Inter-user variability
  - Inter-session variability
  - User learning
  - Feedback dependent variability
  - Non-stationarity of brain signals within sessions

→ Non-functioning BCIs

# Use motor imagery as paradigm

- Goal → Characterize these variabilities using modern analysis methods
- Large scale experiments → Multi-session, long experiments, test different types of feedback



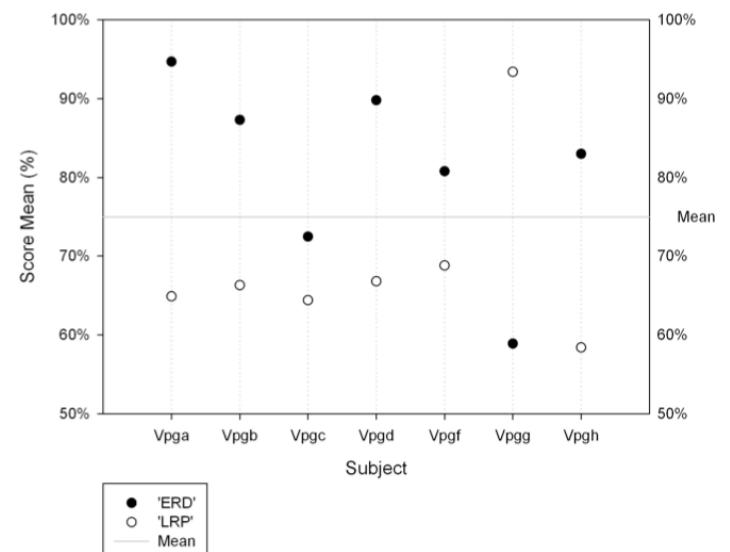
Roijendijk et al., in prep

# Outline

- Brain signatures of motor imagery
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- Current research: Graz, Wadsworth and Berlin
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# Patient applications

- Both motor imagery and attempted movement → small-scale studies e.g., Conradi et al., 2009
- Motor programs of SCI patients intact Hotz-Boendermaker 2008, but not all studies can find ERD/ ERS features Kauhanen et al., 2007; Gourab & Schmit, 2010
- Completely locked-in Kübler & Birbaumer, 2008



# Summary

- ERD/ERS widely used as brain signal for BCI
- Mostly elicited by motor imagery
- Several research groups work on motor imagery based BCIs, e.g. hybrid BCI and brain switch, prediction of illiteracy, 3D control
- Currently, CAI works on a time-locked motor imagery paradigm and BCI variability
- Patient applications need more research

# Papers

- Required:
  - Blankertz, B., Sanelli, C., Halder, S., Hammer, E.M., Kübler, A., Müller, K.R., Curio, G. and Dickhaus, T. (2010). Neurophysiological predictor of SMR-based BCI performance. *NeuroImage*, 51, 1303-1309.
- Additional:
  - Pfurtscheller, G., & Lopes Da Silva, F.H.L. (1999). Event-related EEG/MEG synchronization and desynchronization: basic principles. *Clinical Neurophysiology*, 110, 1842-1857.