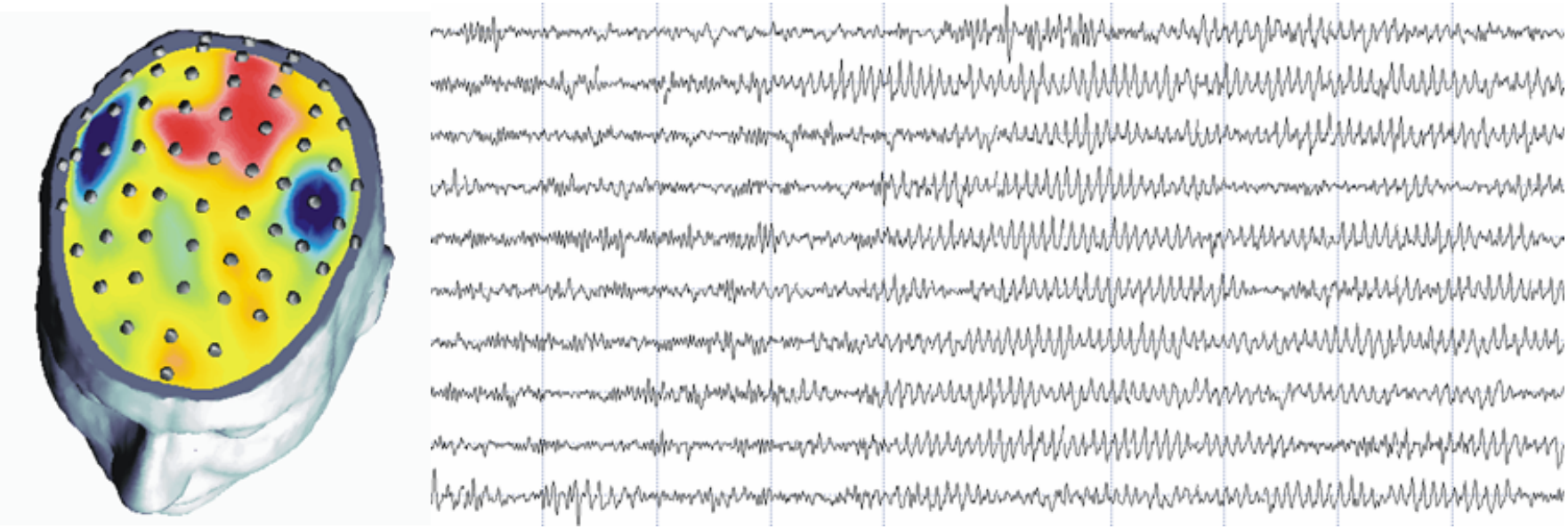
BBCI Workshop 2009, Advances in Neurotechnology, Berlin, July *8 - 10, 2009*

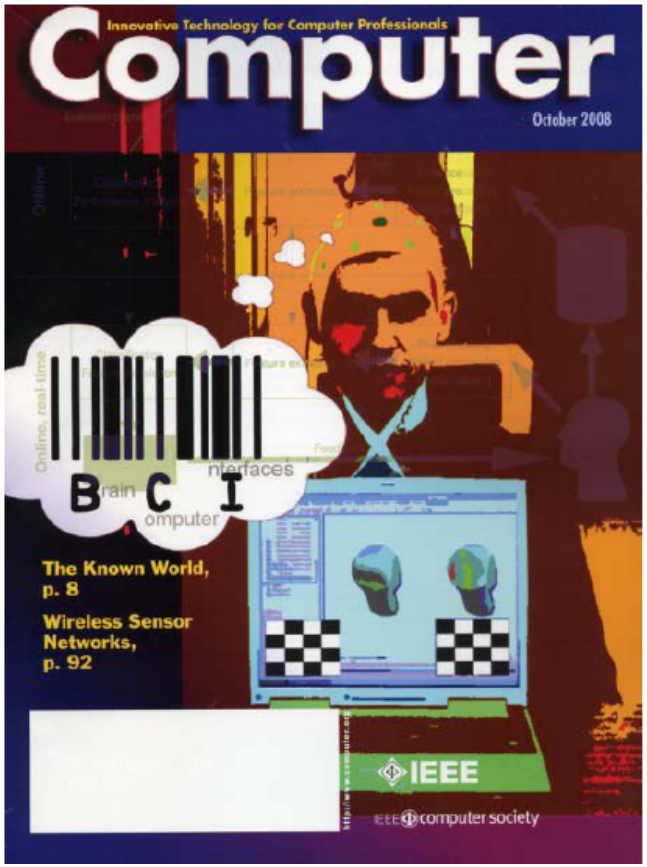


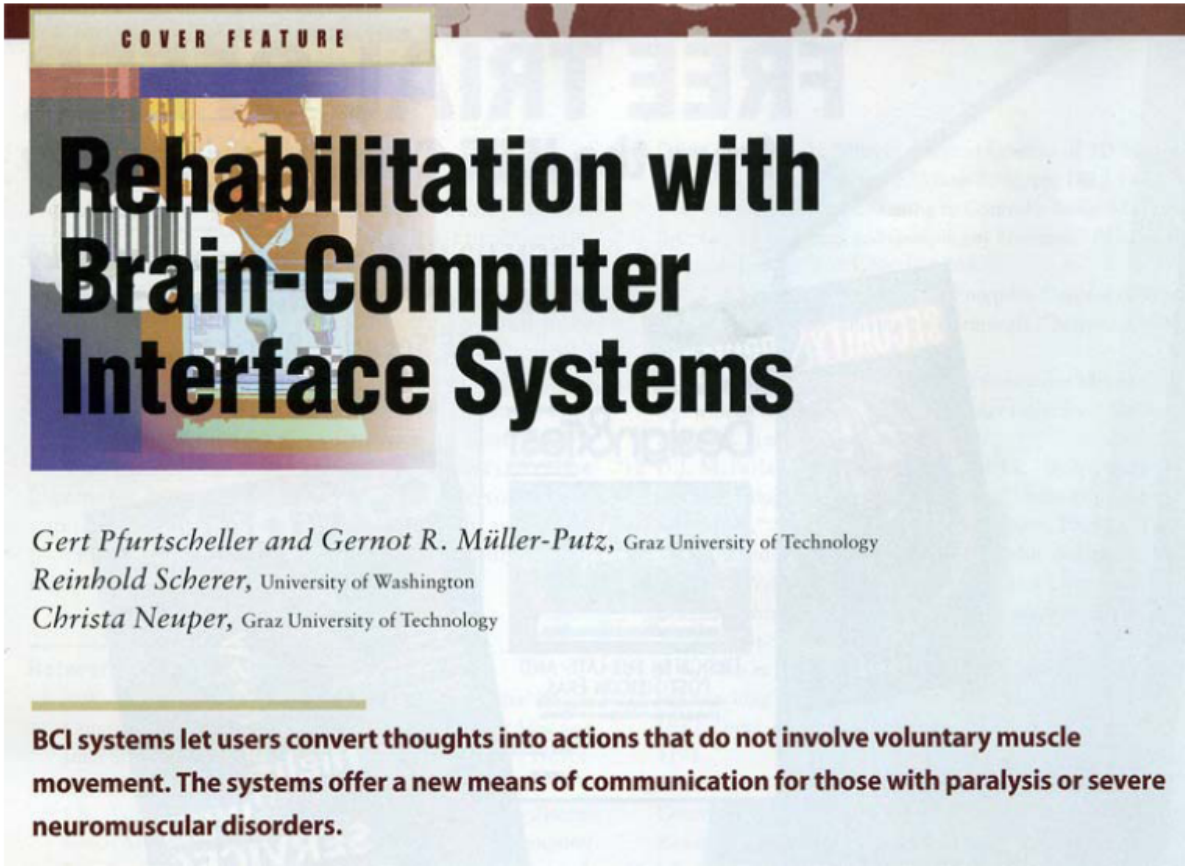
Feedback-regulated mental imagery in BCI applications: using non-invasive EEG and NIRS signals

Christa Neuper

Institute of Psychology, Neuropsychology,
University of Graz
Institute of Knowledge Discovery, BCI Lab,
Graz University of Technology

Rehabilitation with BCI-Systems

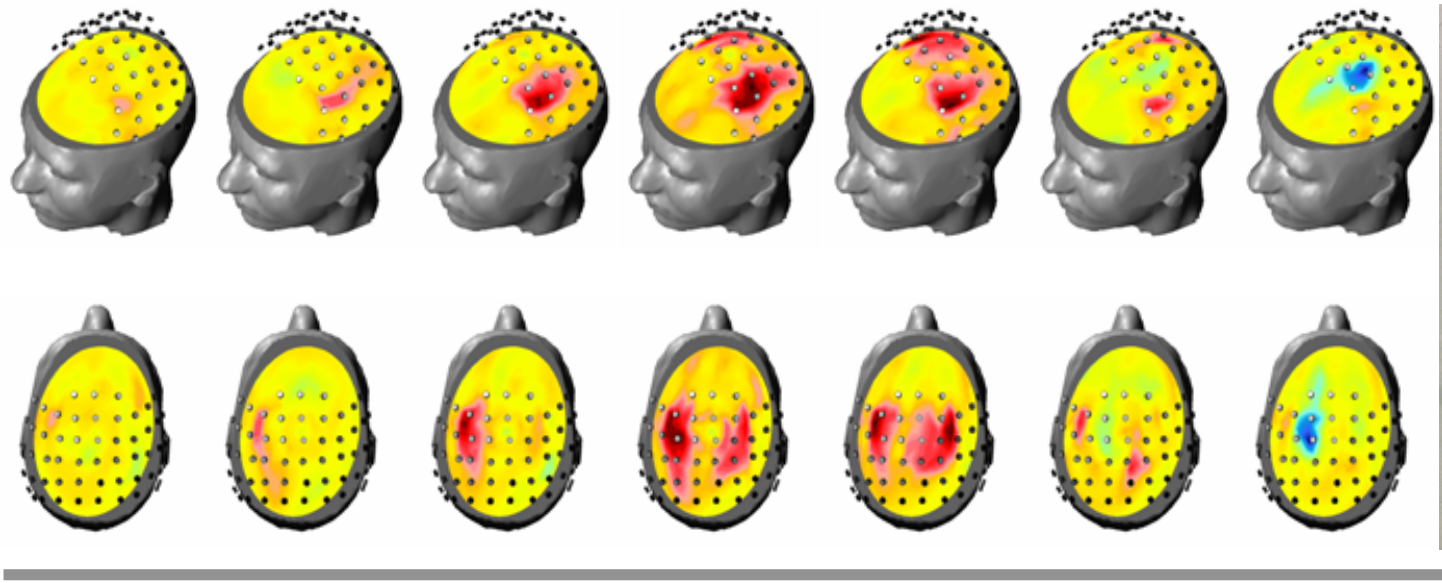


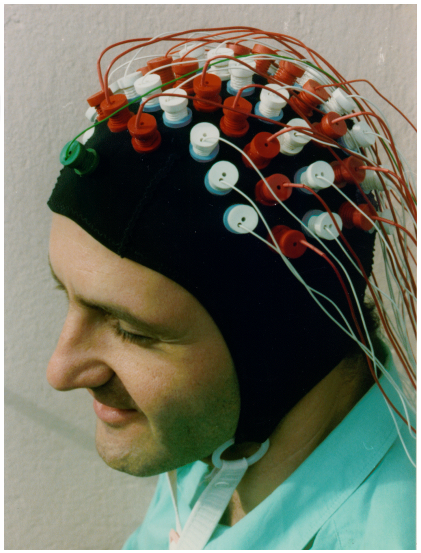


In: Computer 41 (2008) 10, p. 58 - 65

Voluntary Movement and ERD/ERS

Pfurtscheller & Neuper, 1994





-750 -500 -250 0 250 500 750

TIME (MS)

A4: 16-20 Hz

Finger movement
right hand

Activation

Deactivation

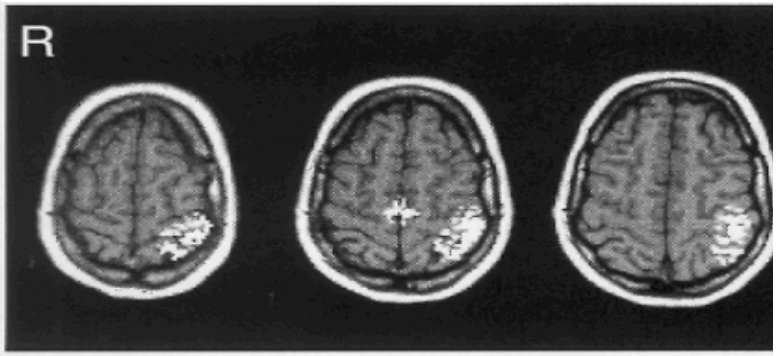
ERD

ERS

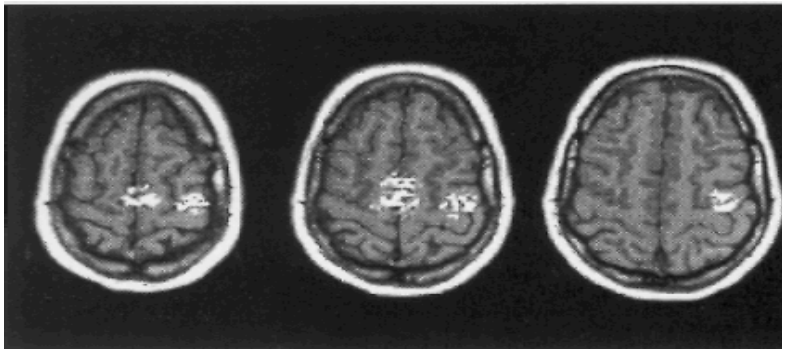
Motor Imagery as Mental Strategy

Similar neural networks (brain areas) are activated during movement execution and movement imagination.

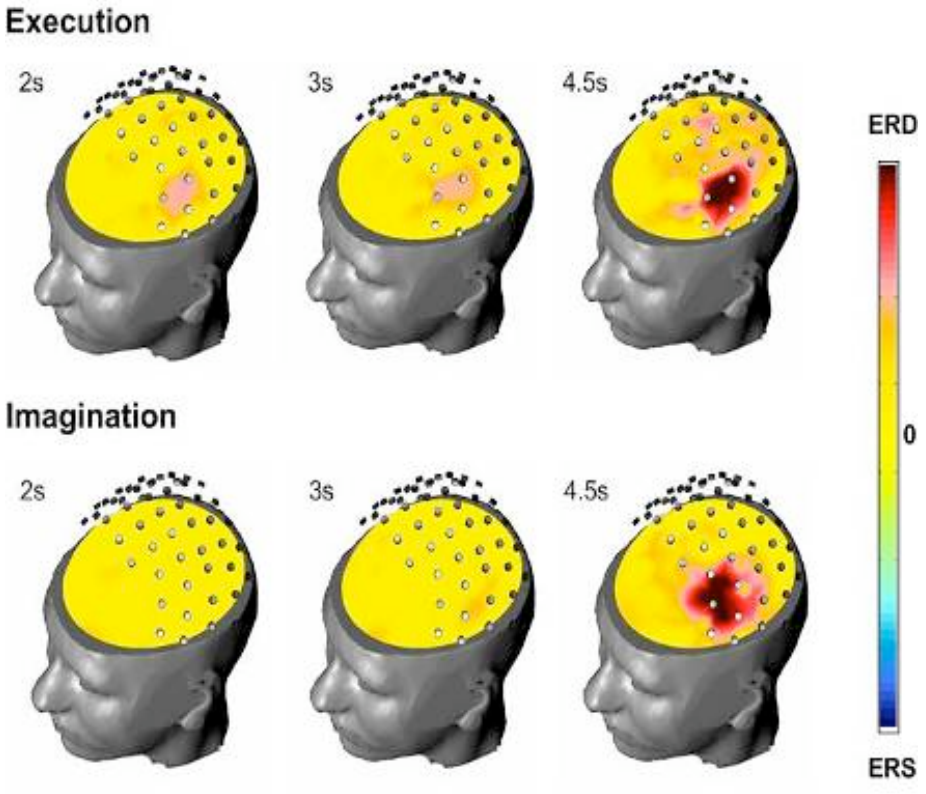
Activation during motor execution:



Activation during motor imagery:

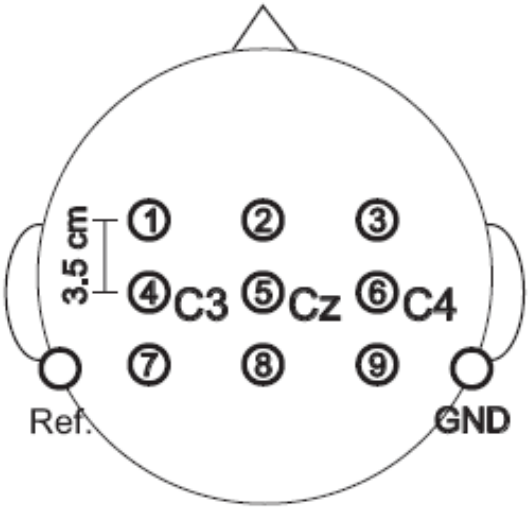


fMRI *Lotze et al. 1999*

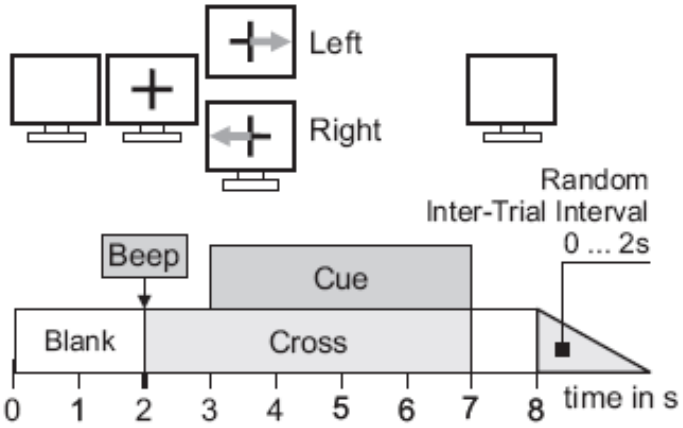


EEG *Neuper et al., 1999*

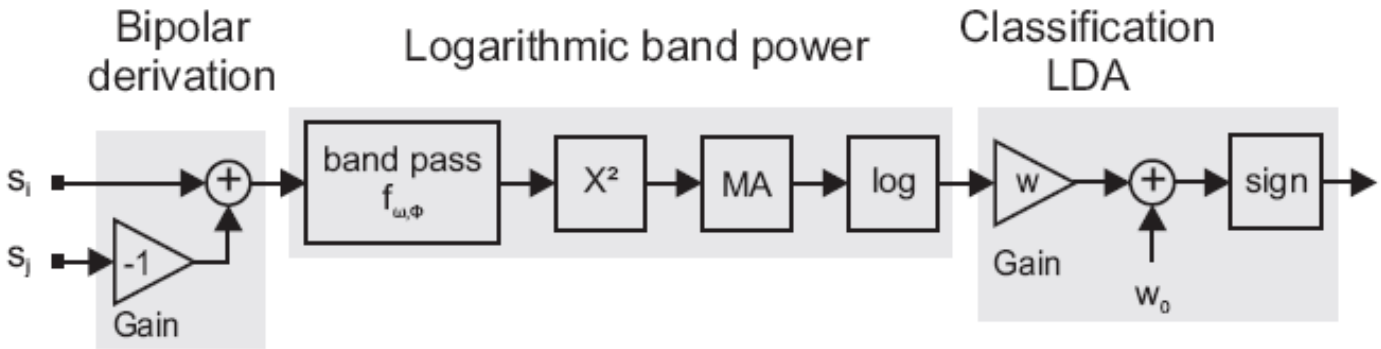
Graz-BCI: ERD/S Classification



(a)



(b)



(c)

Scherer et al., 2008

BCIs for People with Motor Disabilities

- **Motor restoration/ substitution**
  - by-pass spinal cord lesions with a BCI
  - e.g. neuroprostheses for grasping/reaching

- **Motor recovery**
  - induce plasticity by mental rehearsal of movements (motor imagery practice with feedback)
  - e.g. stroke-BCI; incl. orthosis for stroke rehabilitation

- **Use of NIRS signals for BCI feedback training**
  - implementation of NIRS-Online System
  - NIRS in combination with ERD/S

Motor Restoration

Patient T.S.:

30 years,

accident in 1998,

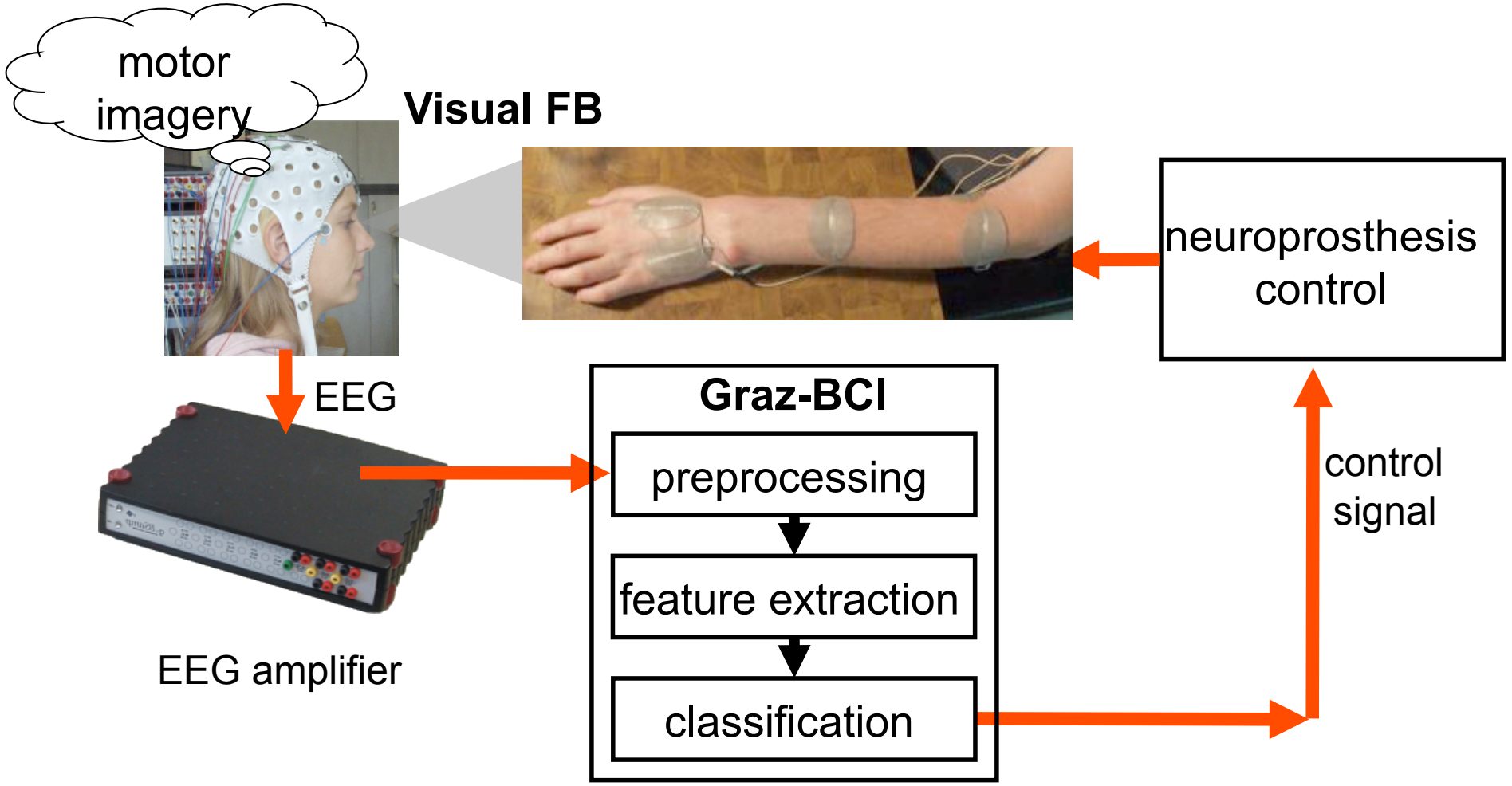
tetraplegic of level C4/C5,

residual muscle activity of left biceps

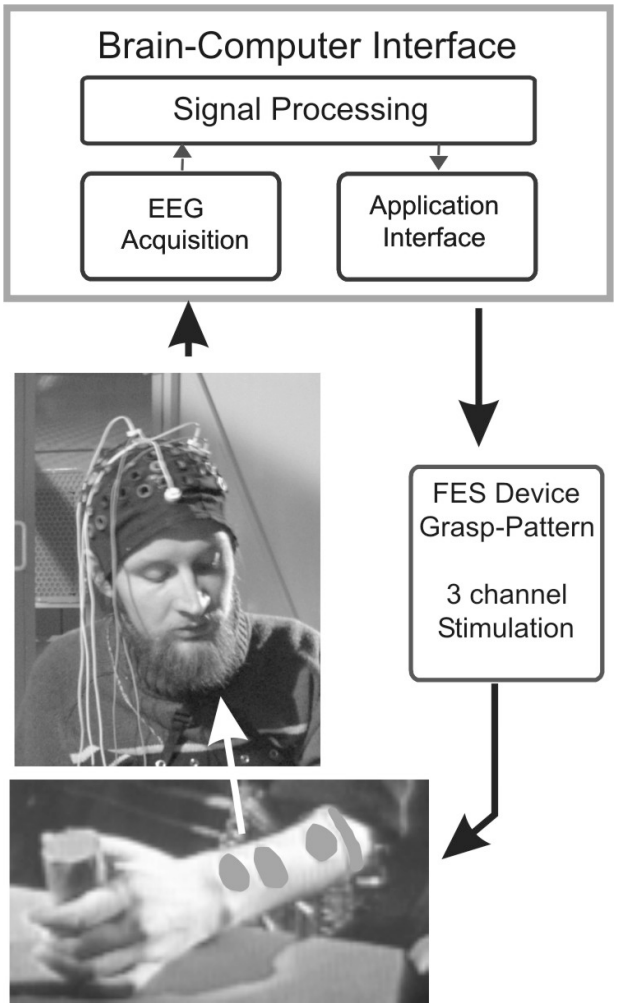
Orthopädie Heidelberg

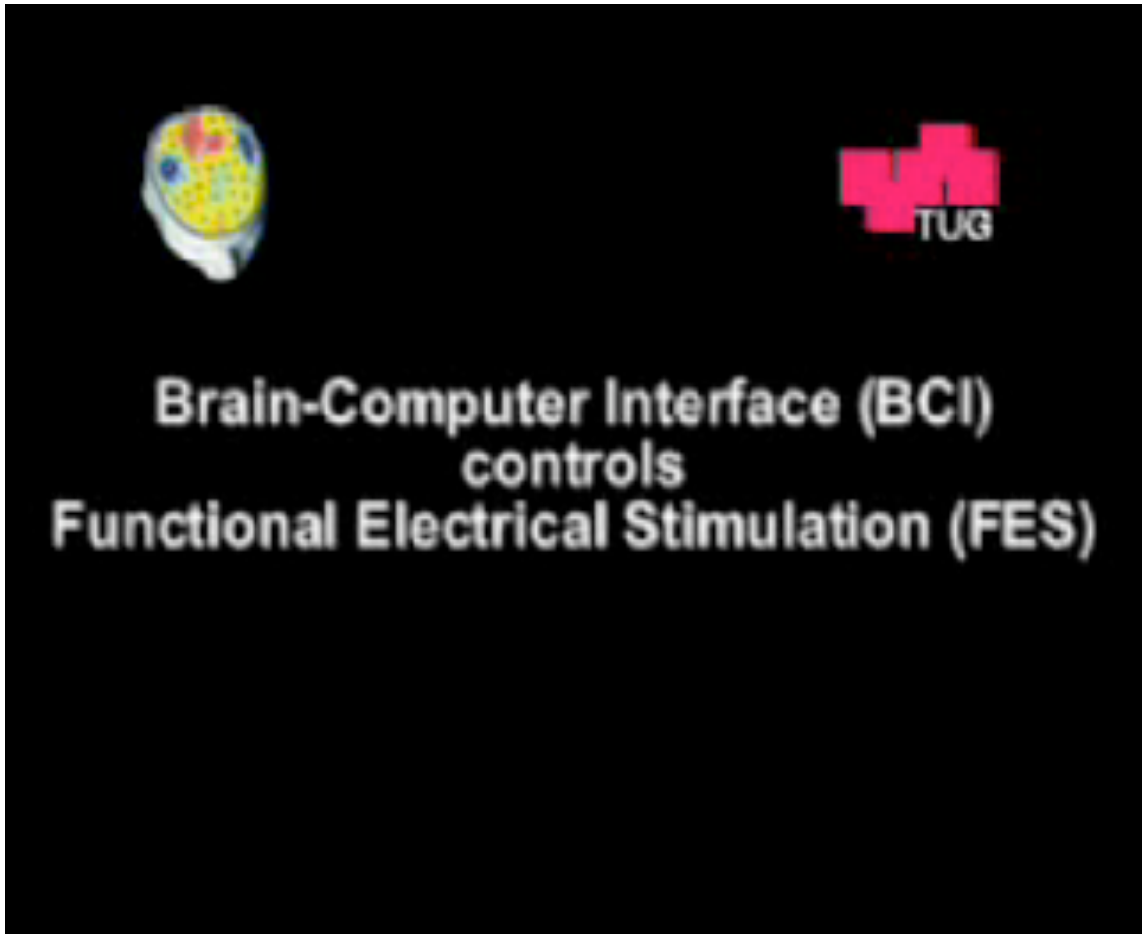
Pfurtscheller et al., 2000

BCI Control of Neuroprosthesis

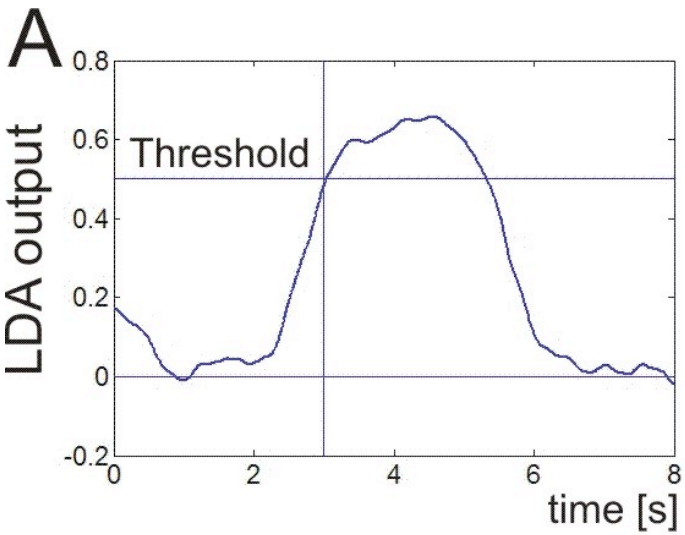


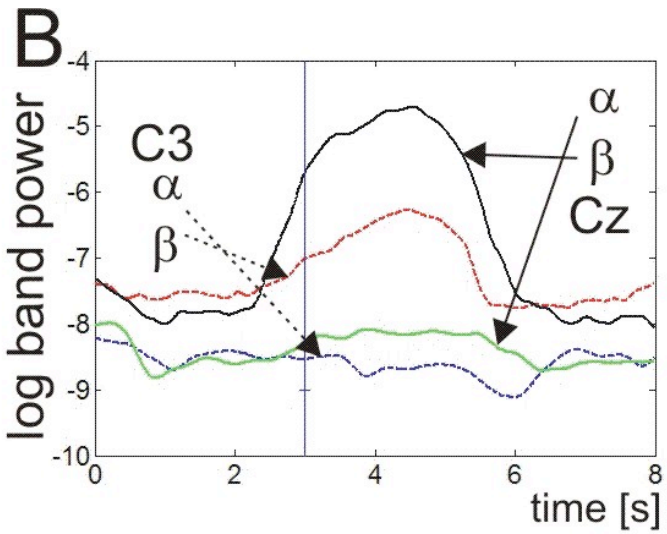
BCI Control of Neuroprosthesis

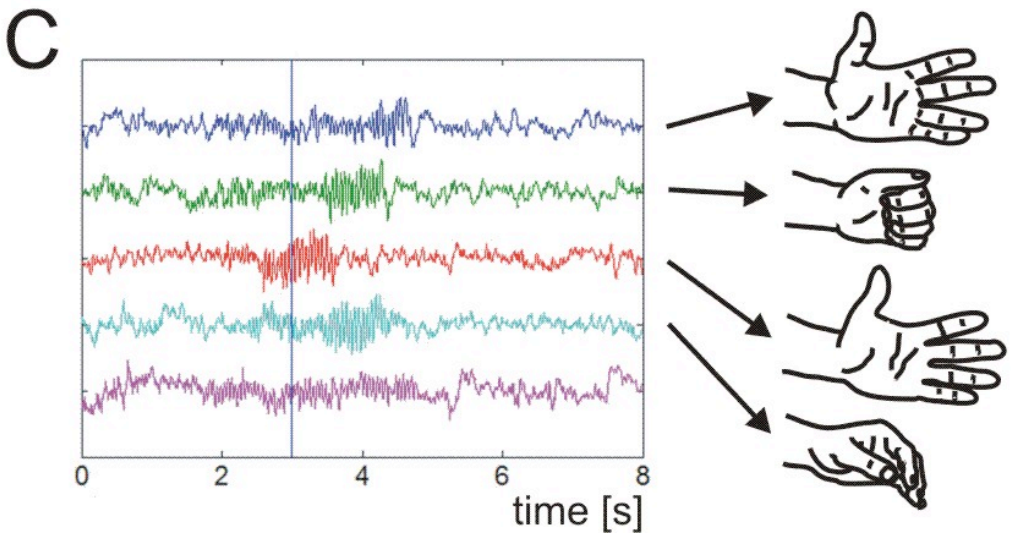


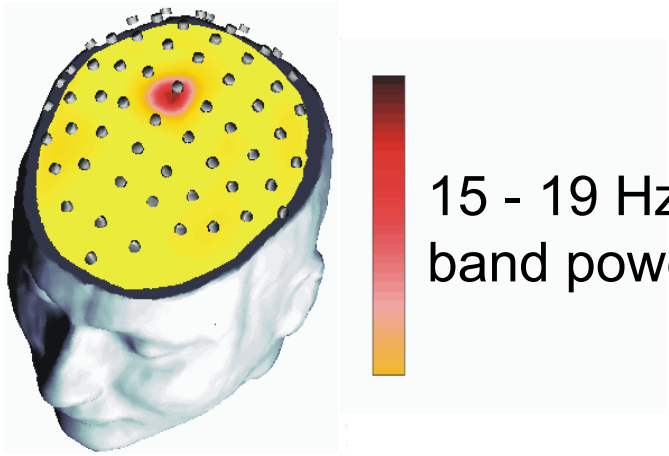


Foot Motor Imagery in Tetraplegic Patient









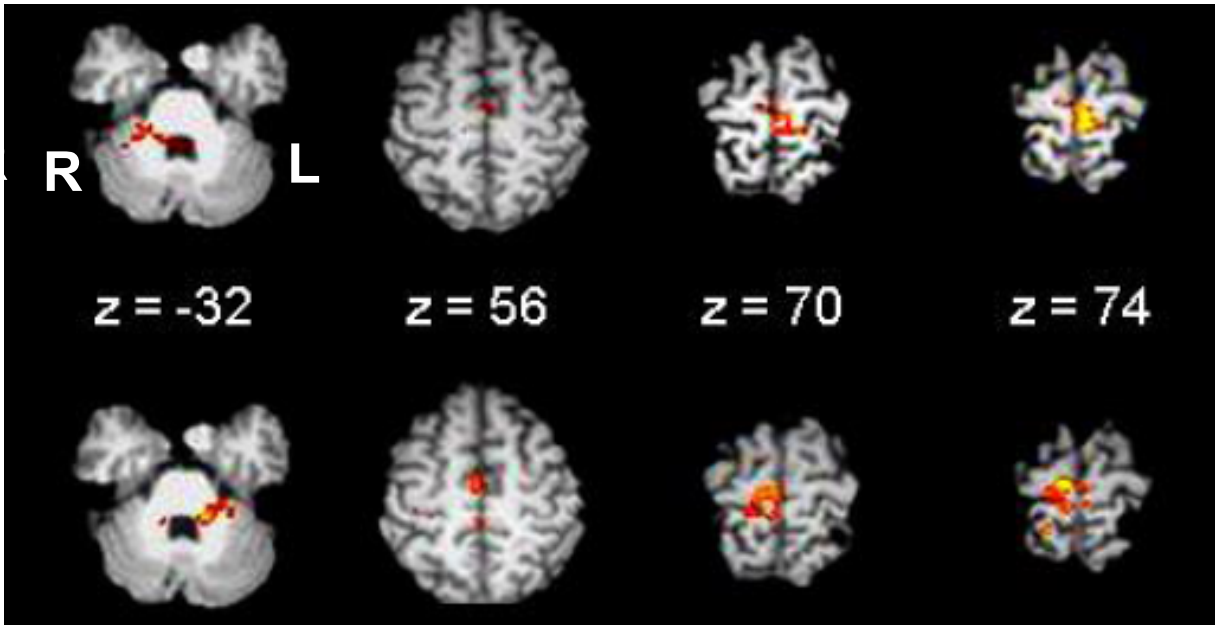
Müller-Putz et al., 2005

Foot Motor Imagery in Tetraplegic Patient

Induced beta oscillatons (15-19 Hz) close to the foot motor area are associated with a positive BOLD signal in fMRI.

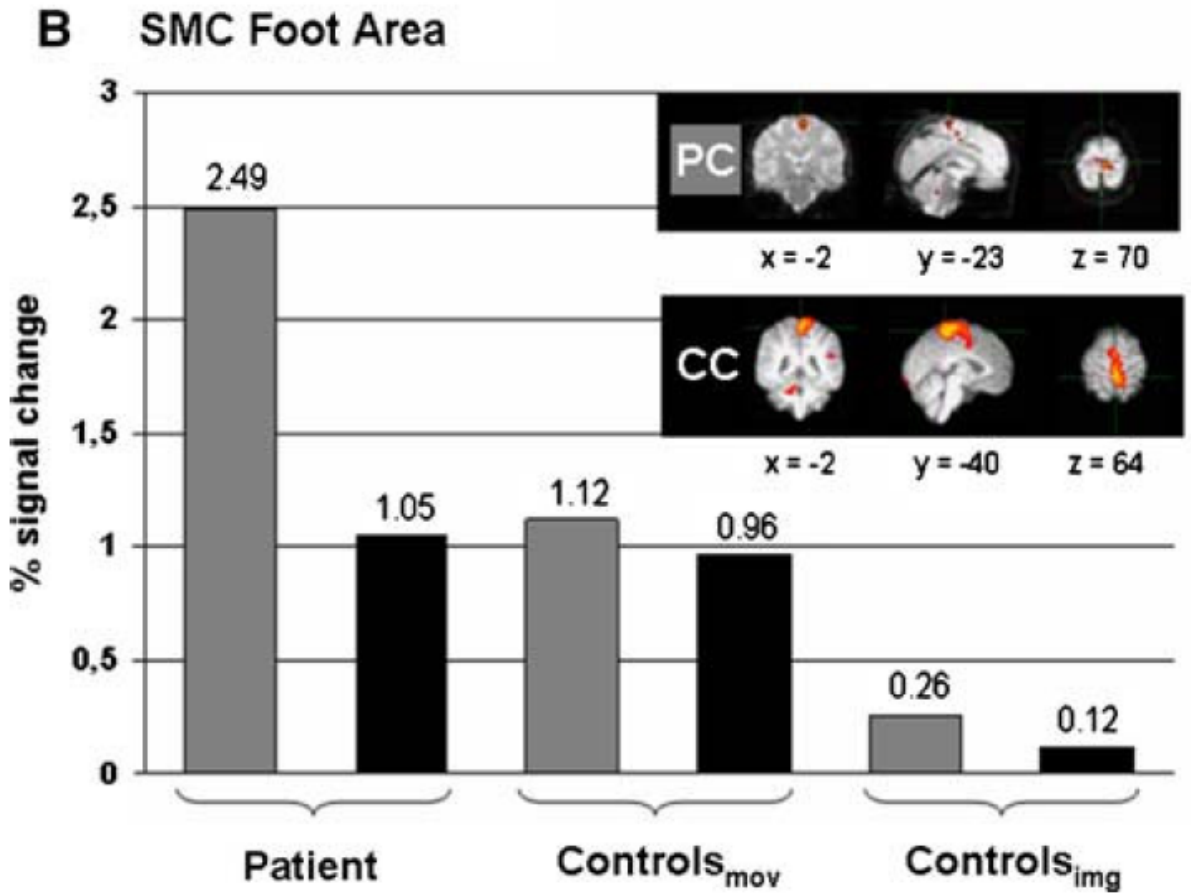
Right foot

Left foot



Enzinger et al., 2008

Foot Motor Imagery in Tetraplegic Patient



BCI training (motor imagery) may assist in maintaining access to primary sensorimotor cortex despite complete deafferentiation.

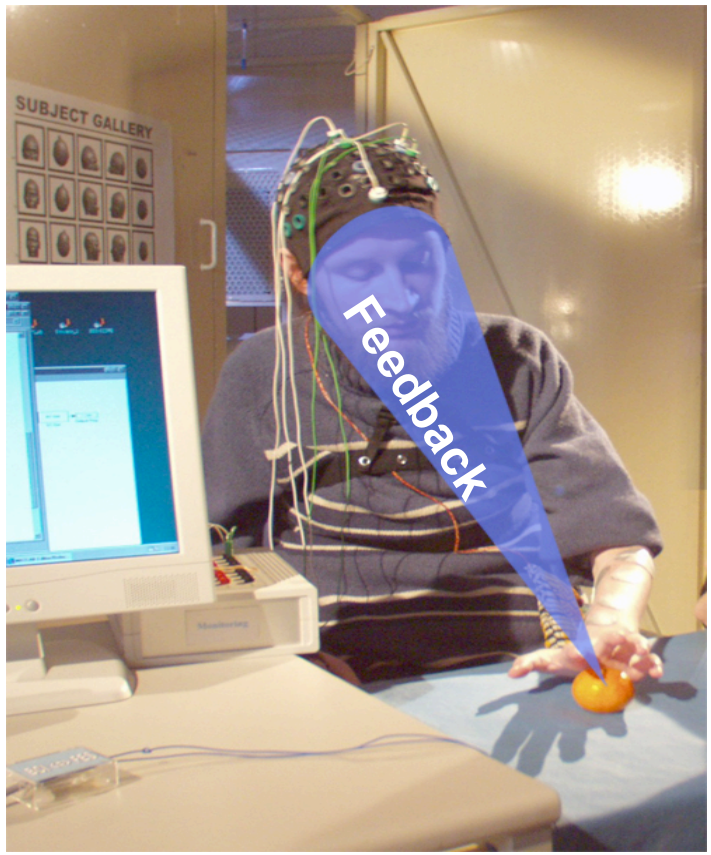
Impact of Visual Feedback

The visual display of a moving object or moving body part may influence the brain patterns involved in BCI control.

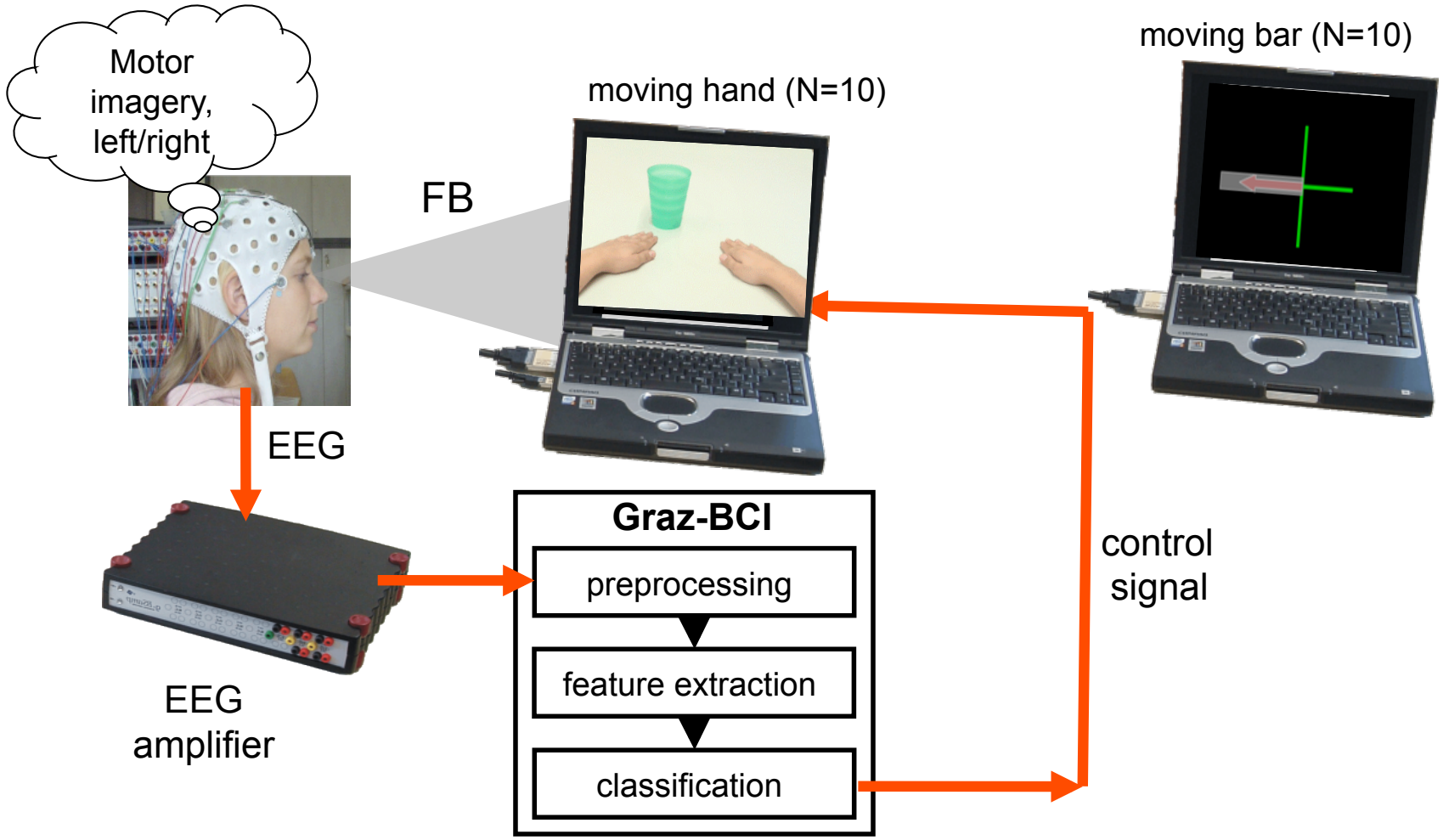
'Mirror neurons' in area F5 (monkey) respond to observation of movement.

".. there is analogy at the cortical level between the mechanisms that mediate action observation and those involved in action execution."

Rizzolatti et al., 2001

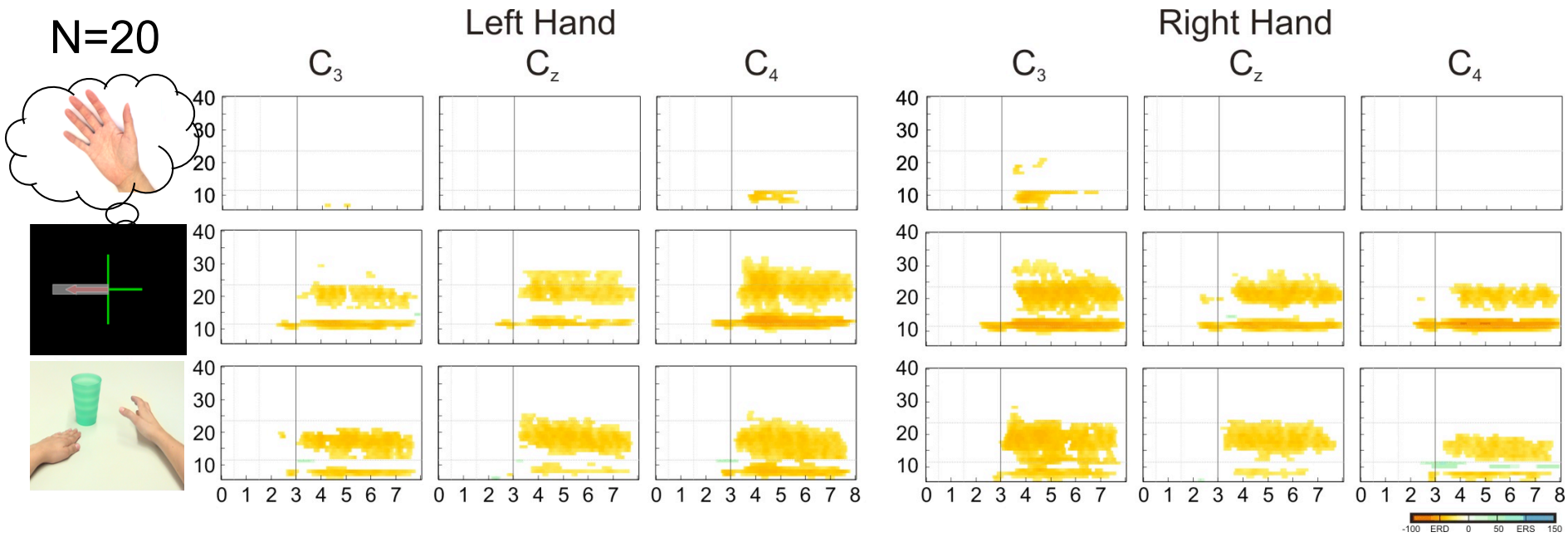


BCI Feedback Study: Grasping Hand



N =20, 4 sessions

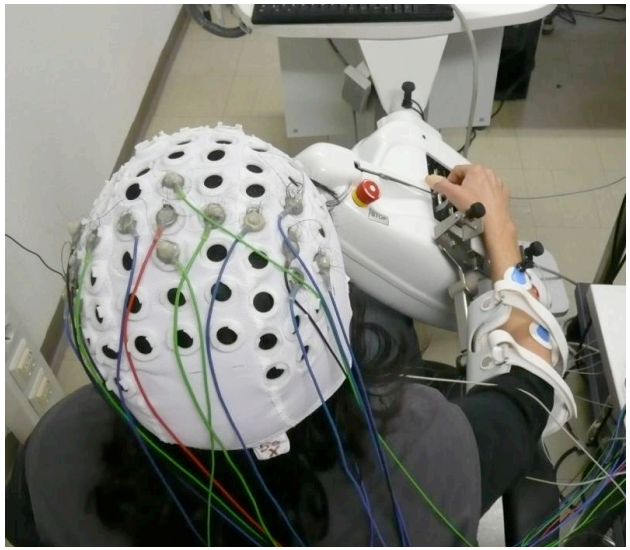
BCI Feedback Study: Abstract vs. Realistic



Visual BCI feedback clearly modulates sensorimotor EEG rhythms (compared to motor imagery without feedback). The presentation form (abstract vs. realistic) does not influence the EEG patterns and performance in a BCI, at least in initial training sessions.

Neuper et al., 2009

Motor Recovery



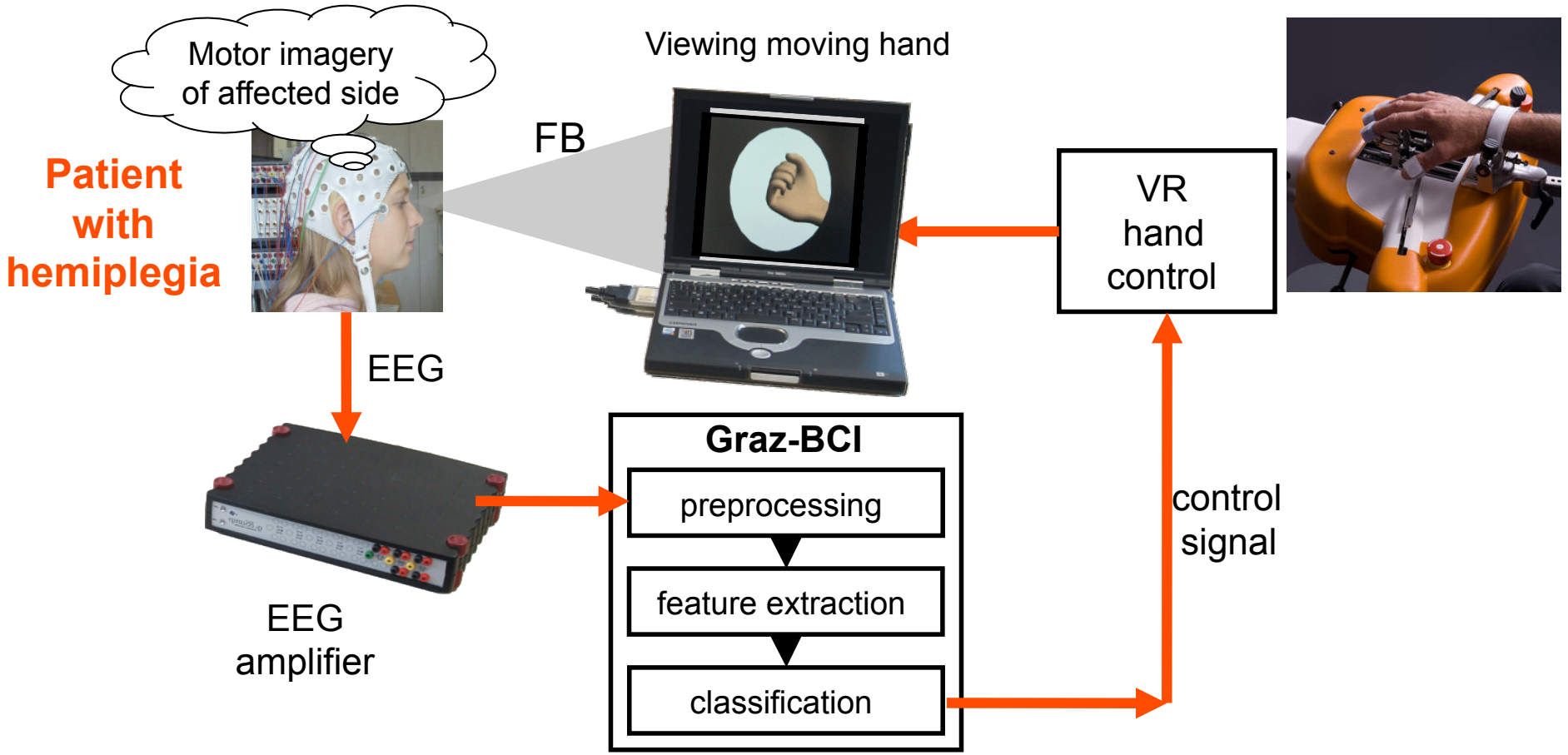
Motor Imagery: A backdoor to the motor system after stroke?

Sharma et al., Stroke, 2006

The goal is to stimulate cortical reorganization and compensatory activation of non-lesioned brain regions through motor imagery involving the paralyzed limb.

BCI-based stroke therapy

Neurofeedback training utilizing motor imagery of the paralyzed limb; the output signal of the BCI is translated into the movement of a virtual body part/ robotic device.



ERD/S Patterns in Stroke Patients

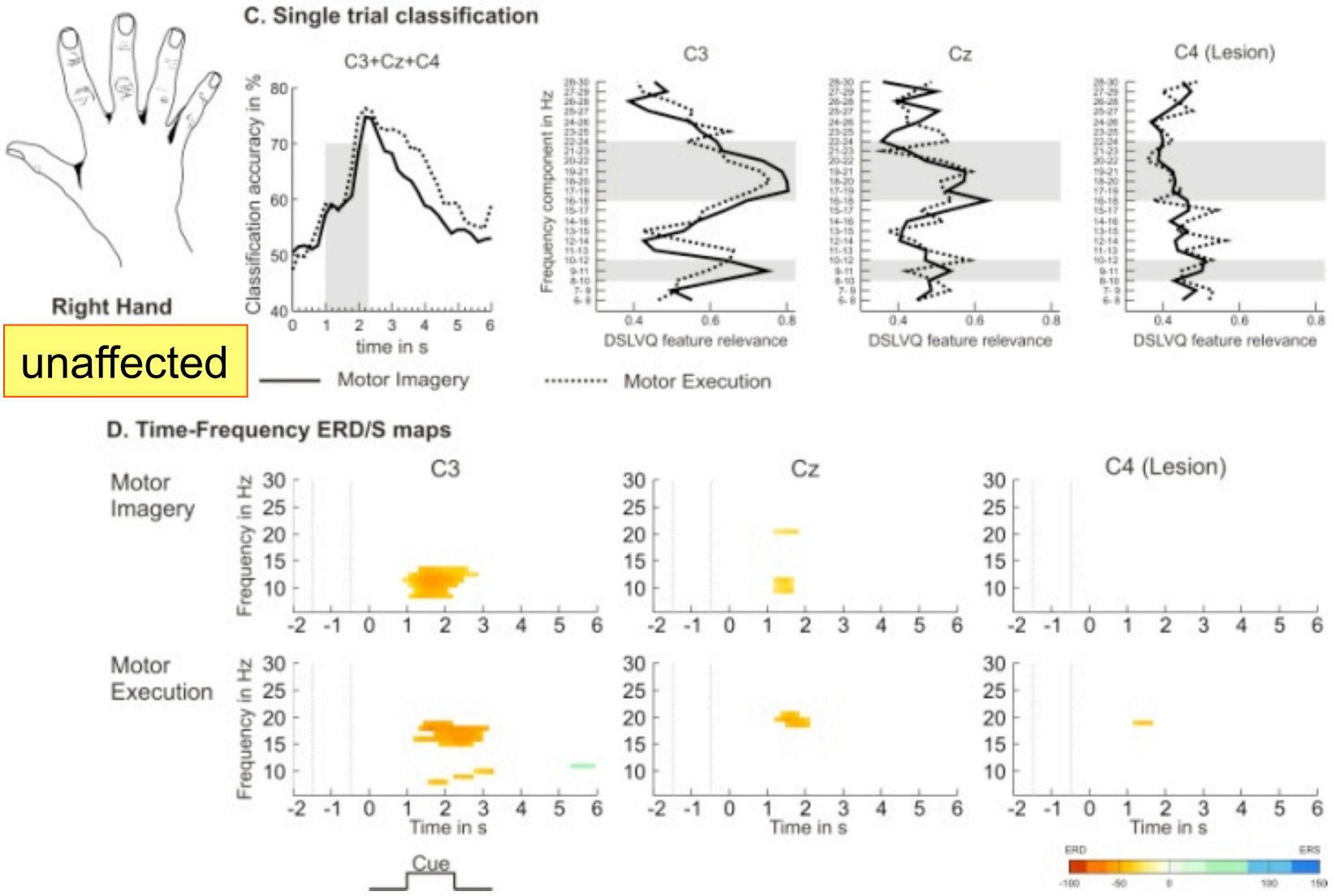
Sample of right-handed hemiparetic stroke patients, unilateral lesion (cortical/subcortical) in the right hemisphere

Id	Age	Gender	Months after stroke	Hemiparesis
s0	37	M	3	0 L
s1	57	F	23	0-1 L
s2	28	M	36	0-1 L
s3	66	M	2	3 L
s4	49	F	3	5 L
s5	41	M	28	4-5 L
s6	36	M	3	4-5 L, 5 R

L = Left, R = Right

Scherer et al., 2007

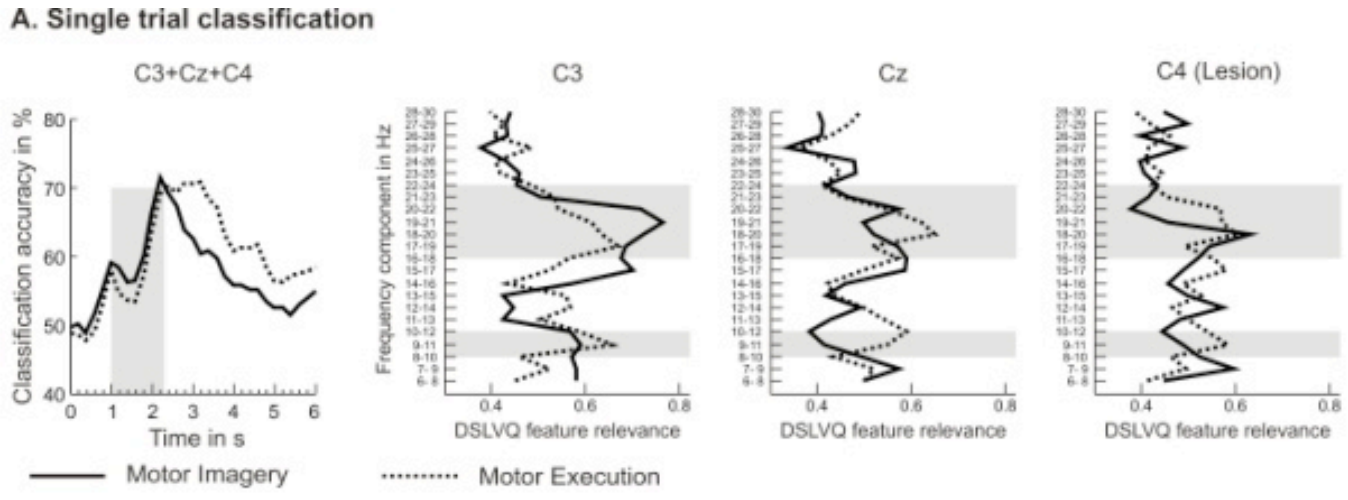
ERD/S Patterns in Stroke Patients

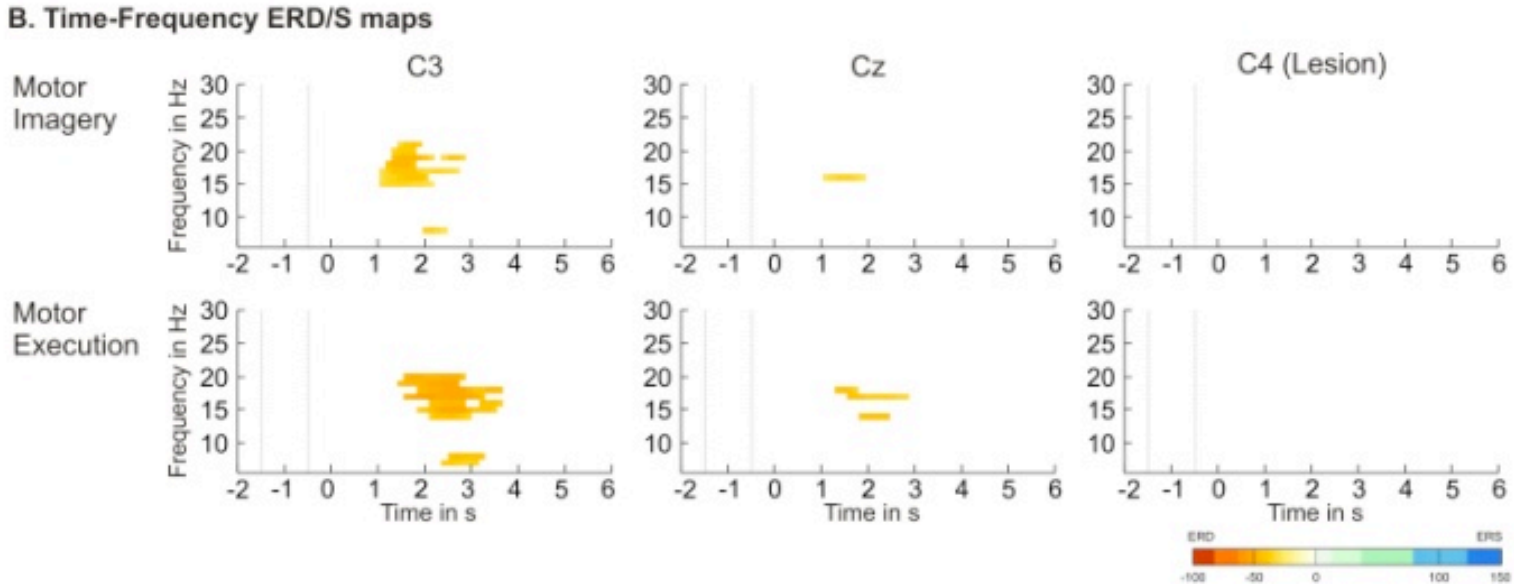


ERD/S Patterns in Stroke Patients

Left Hand

affected





ERD/S patterns during passive movement

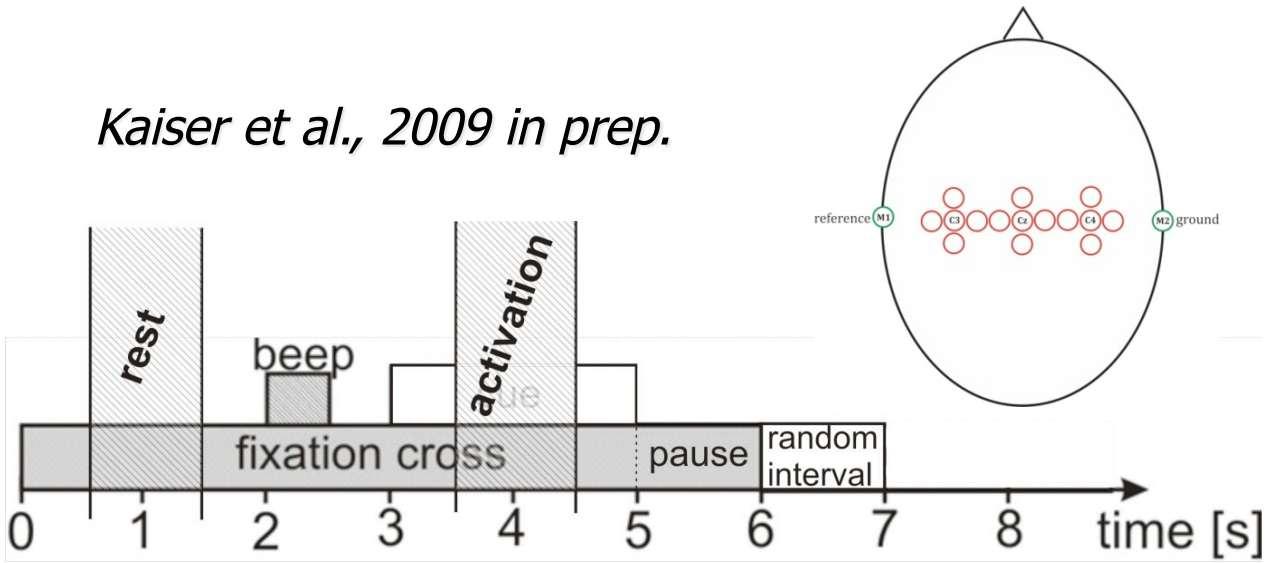
Subjects

- 15 healthy volunteers, aged between 40 and 80 years

Method

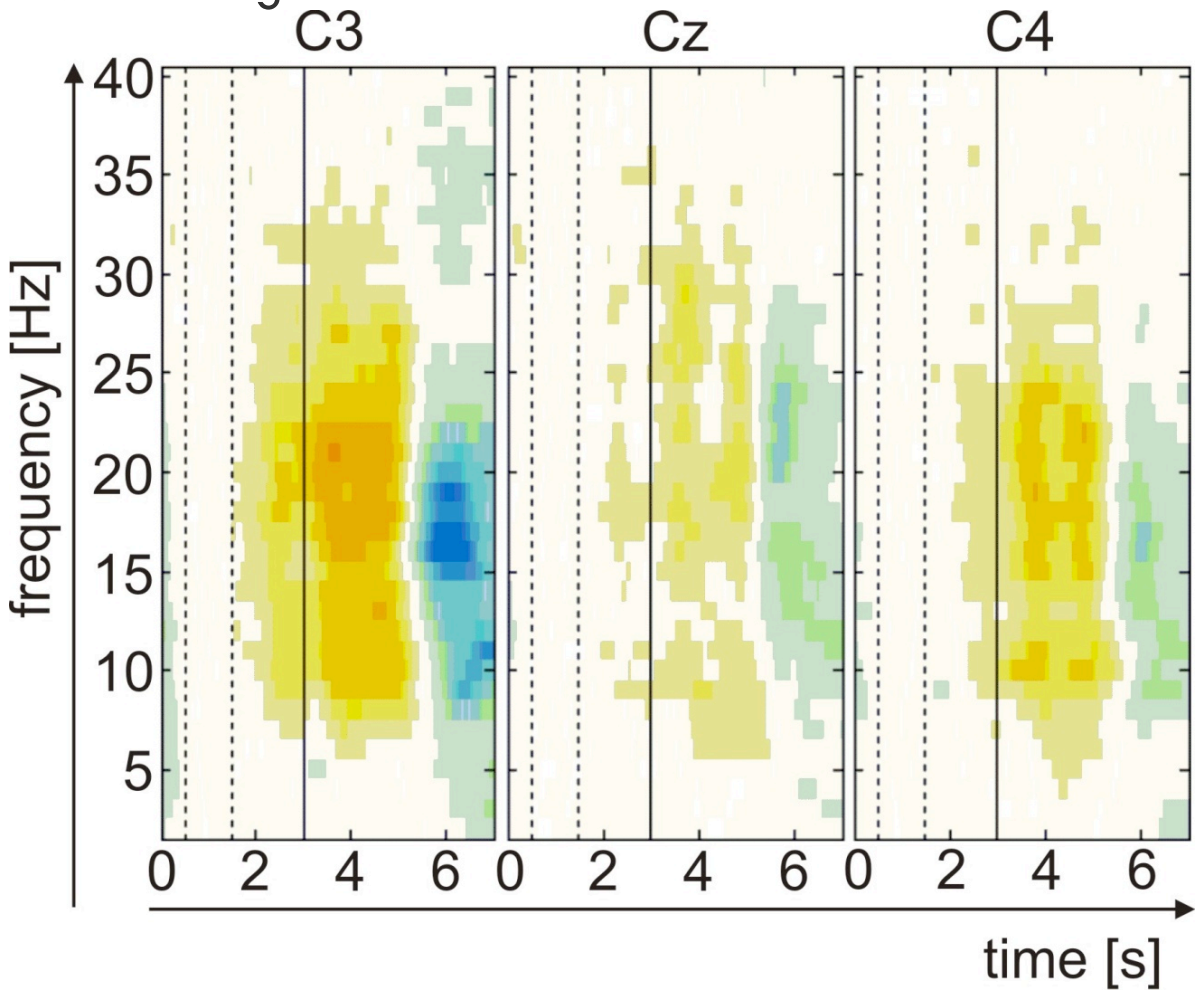
- passive movements , active movements, hand motor imagery
- Comparison of classification accuracies for detection of motor imagery

Kaiser et al., 2009 in prep.



ERD/S patterns during passive movement

passive movement right hand

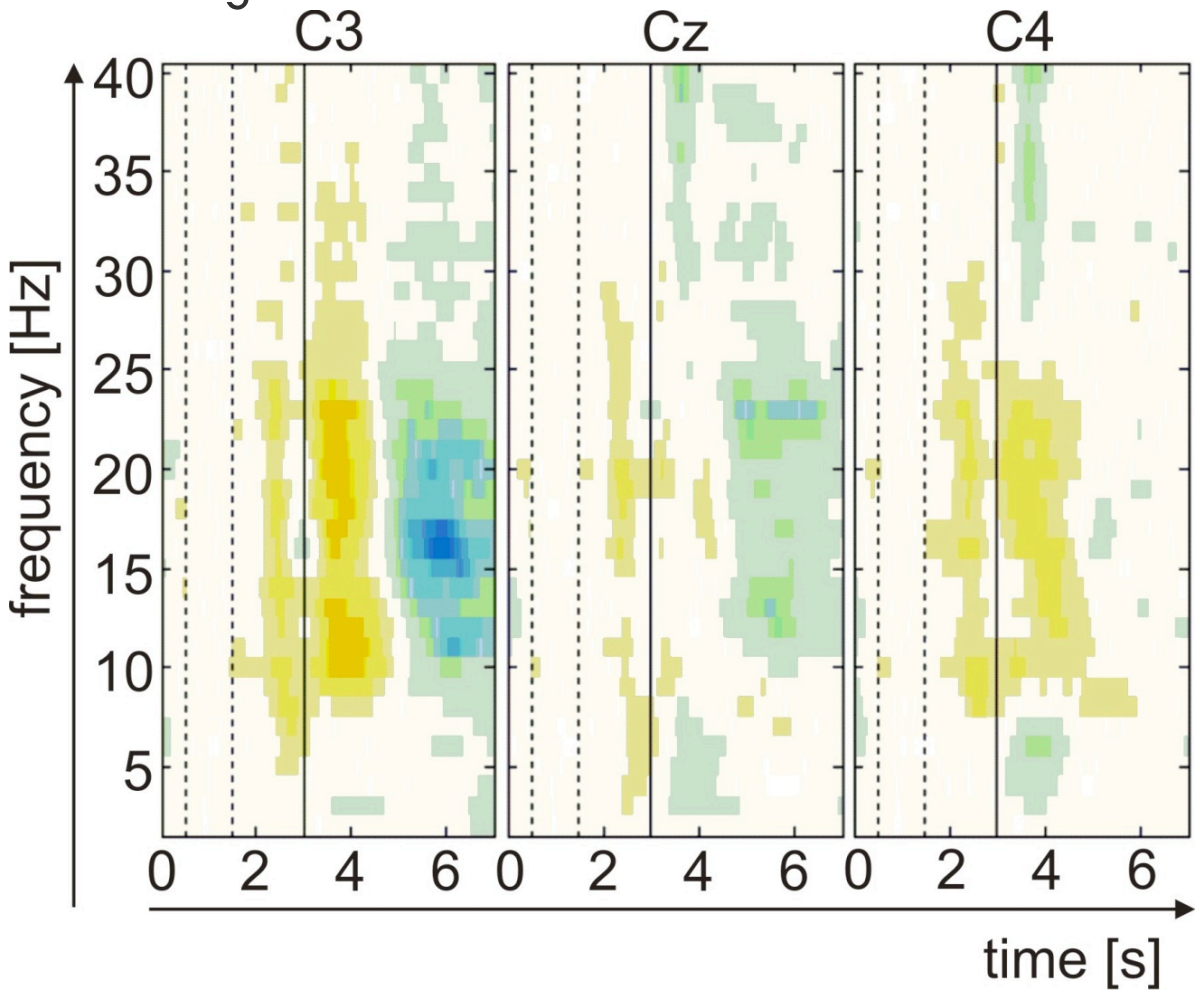


N = 15

Figure 6: grand average ERD/S map passive right hand movement

ERD/S patterns during passive movement

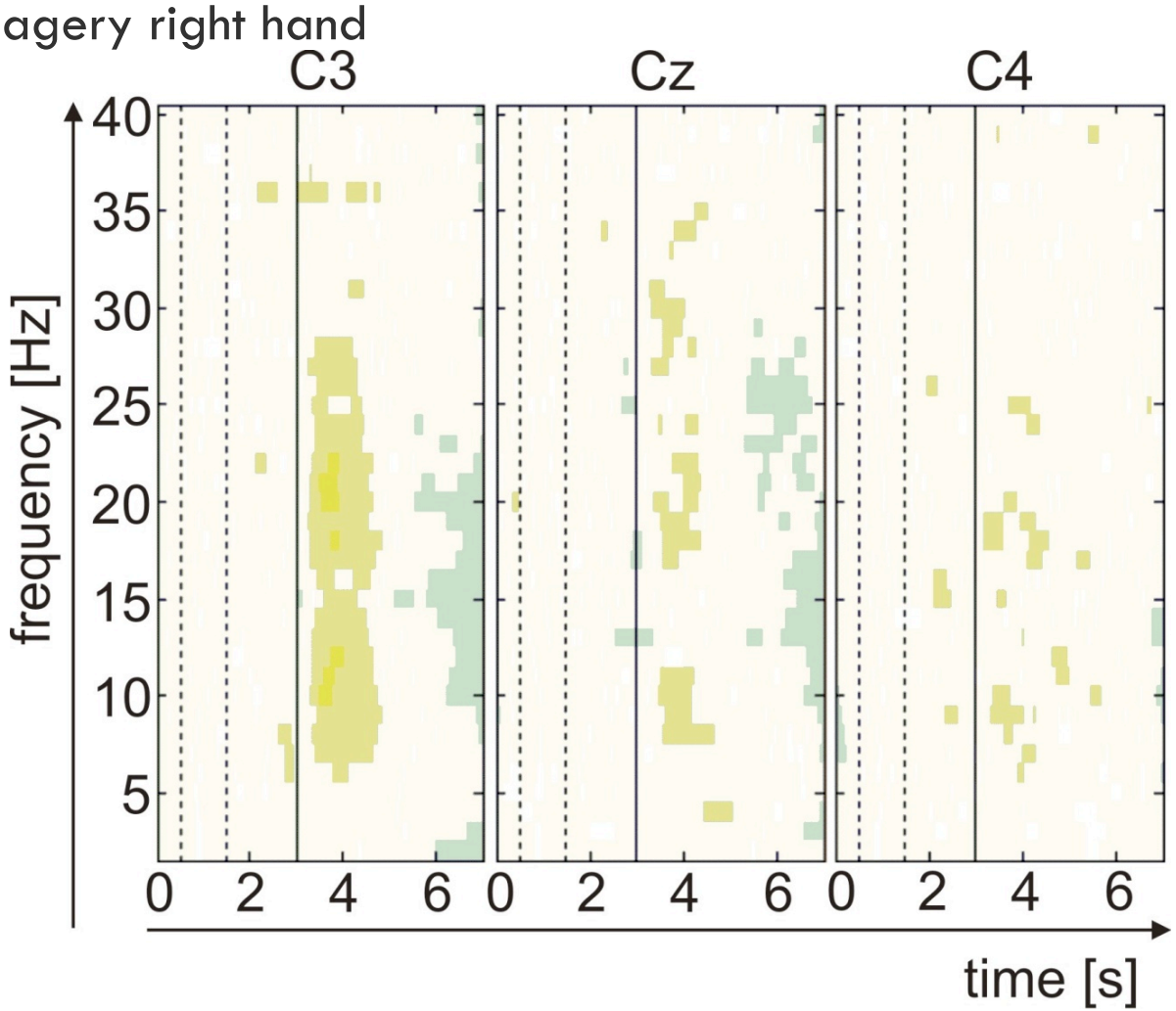
active movement right hand



N = 15

Figure 7: grand average ERD/S map active right hand movement

ERD/S patterns during passive movement

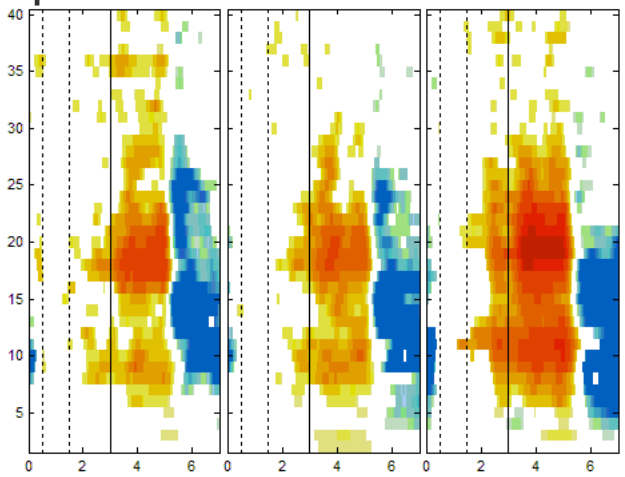


N = 15

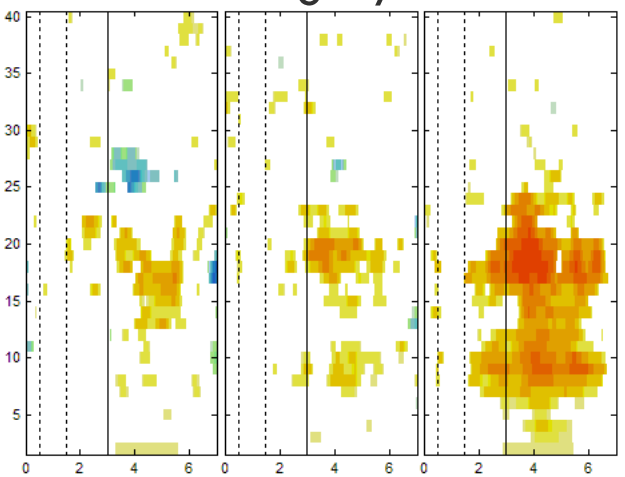
Figure 8: grand average ERD/S map right hand motor imagery

ERD/S patterns during passive movement

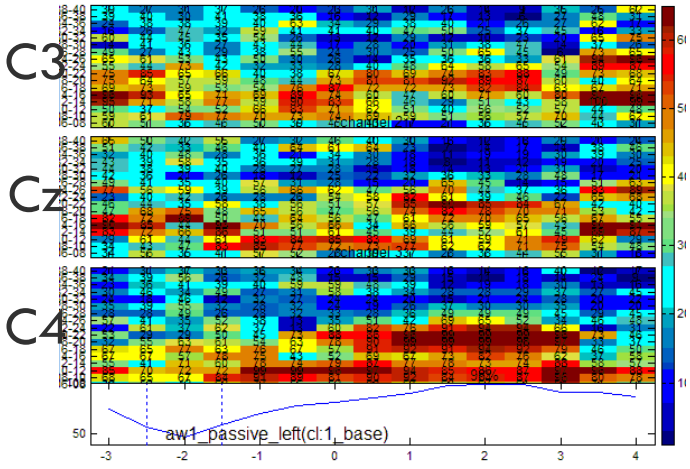
passive movement



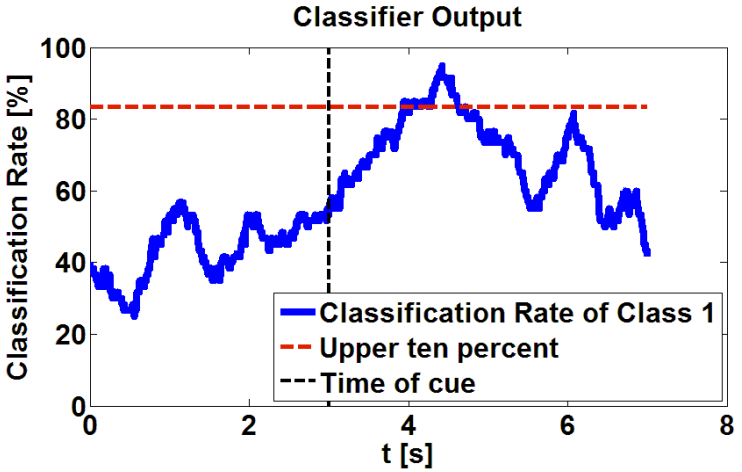
motor imagery



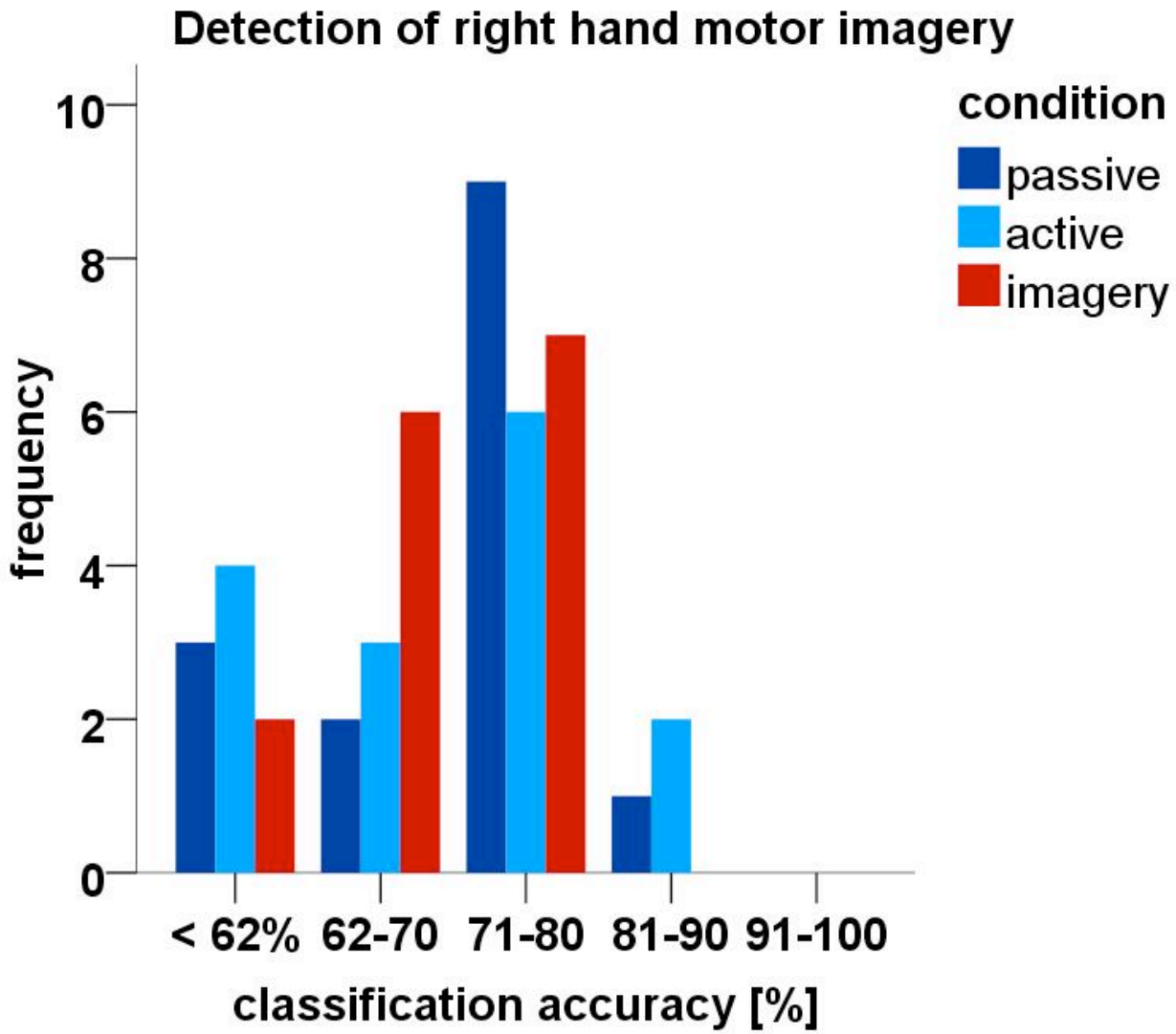
- DSLVQ map



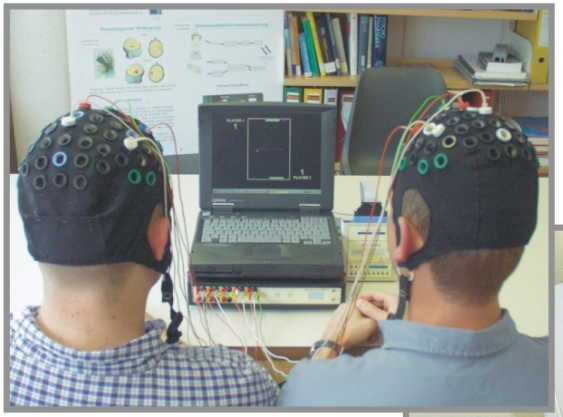
selected frequency band: C4 18-22 Hz



ERD/S patterns during passive movement



Use of NIRS signals ?



EEG-BCI

electrical potentials, EEG, ERP

MEG-BCI

magnetic fields

fMRI-BCI

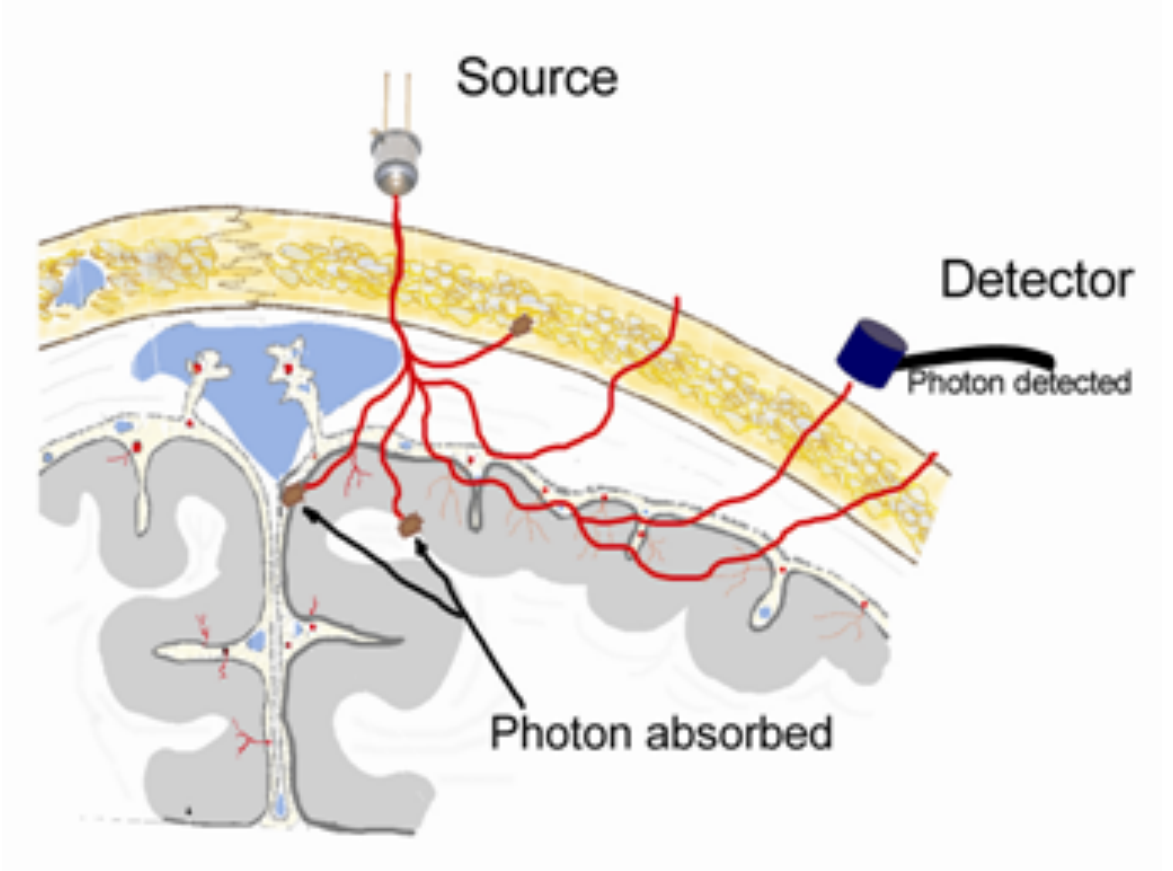
BOLD signal

Optical BCI (NIRS)

changes of
(de)oxyhemoglobin

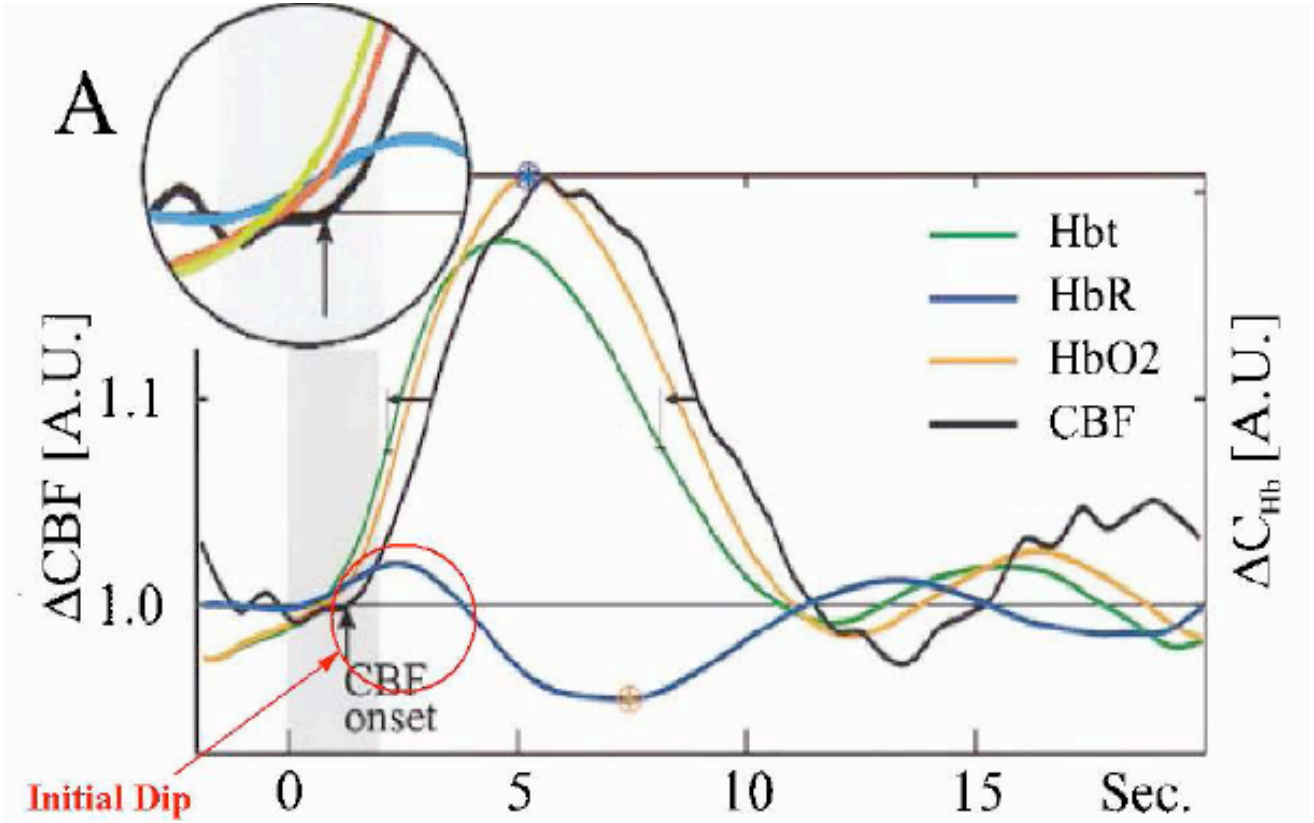
Near-Infrared Spectroscopy (NIRS)

Near-infrared spectroscopy (NIRS) is a non-invasive optical technique, suitable to assess functional activity by measuring cortical **oxygenation [HbO_2]** and **deoxygenation [Hb].**



Near-Infrared Spectroscopy (NIRS)

Typical time course of oxy- and deoxy-Hb



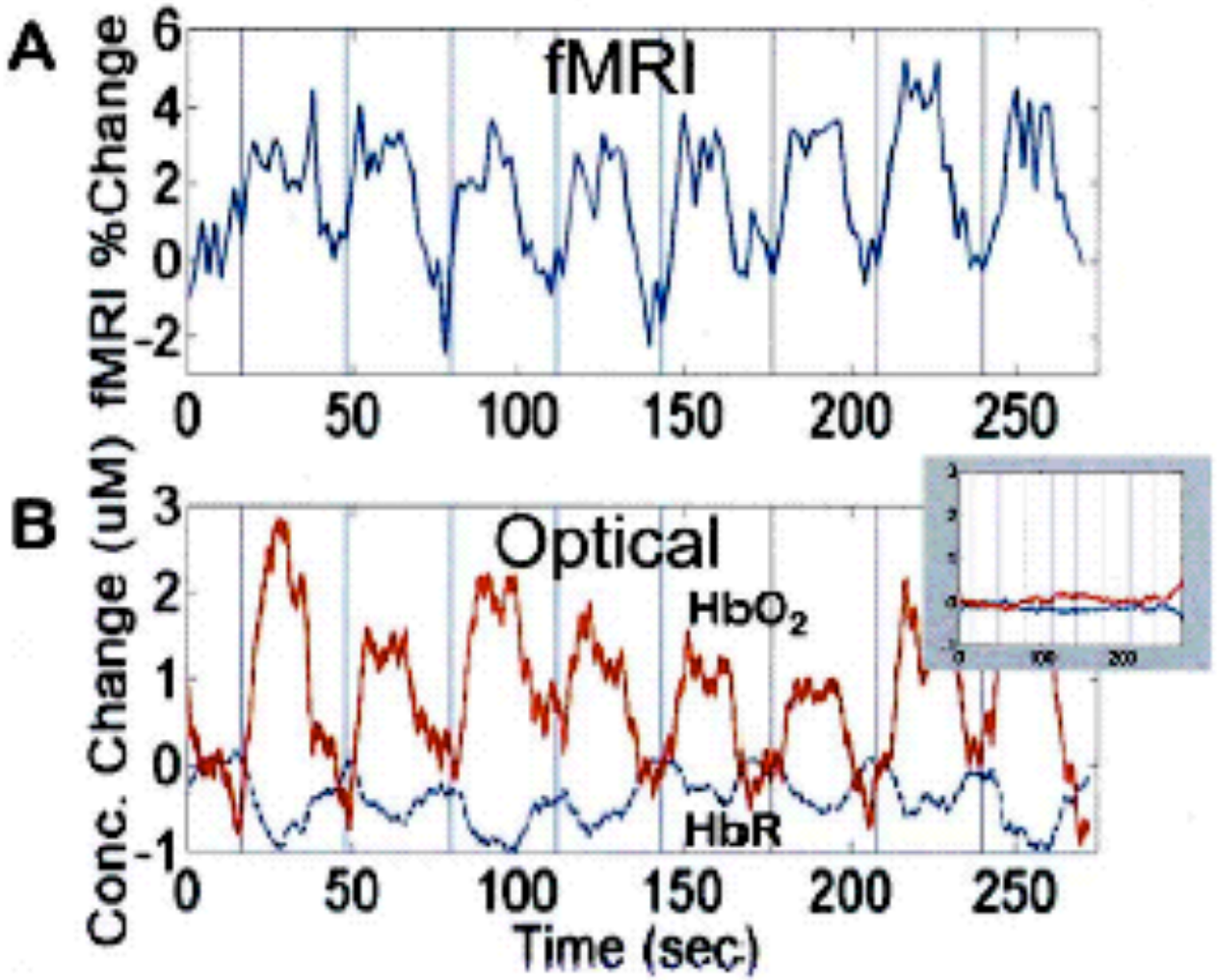
max. response after 5 – 9 s

Malonek et al. 1997

Correlation between NIRS and fMRI Signals

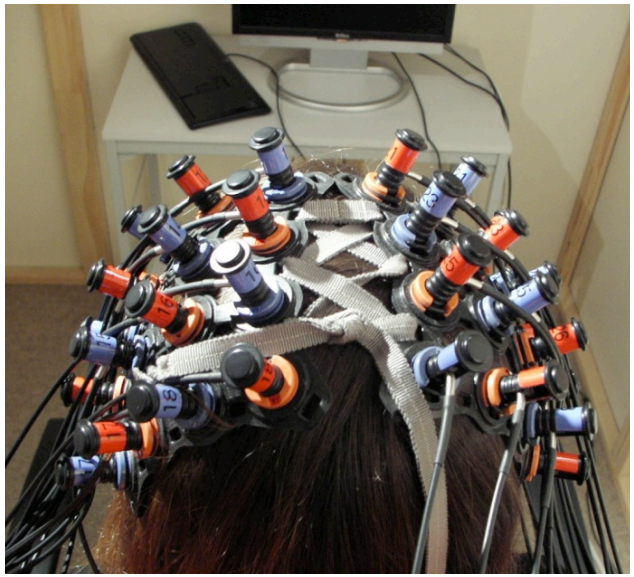
fMRI time course
for left primary motor cortex during right finger tapping vs. rest (16 s).

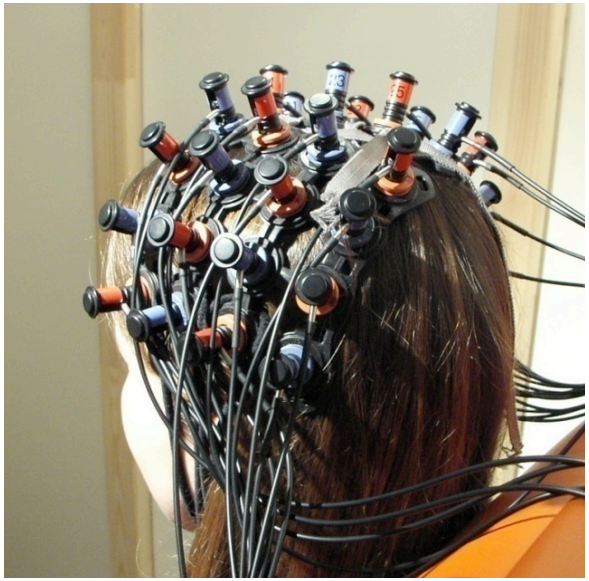
Changes in [HbO2] and [HbR]
as determined from the source-detector pair closest to the fMRI activation.



Strangman et al., 2002

NIRS Probe-Set





Emitter **Detector**

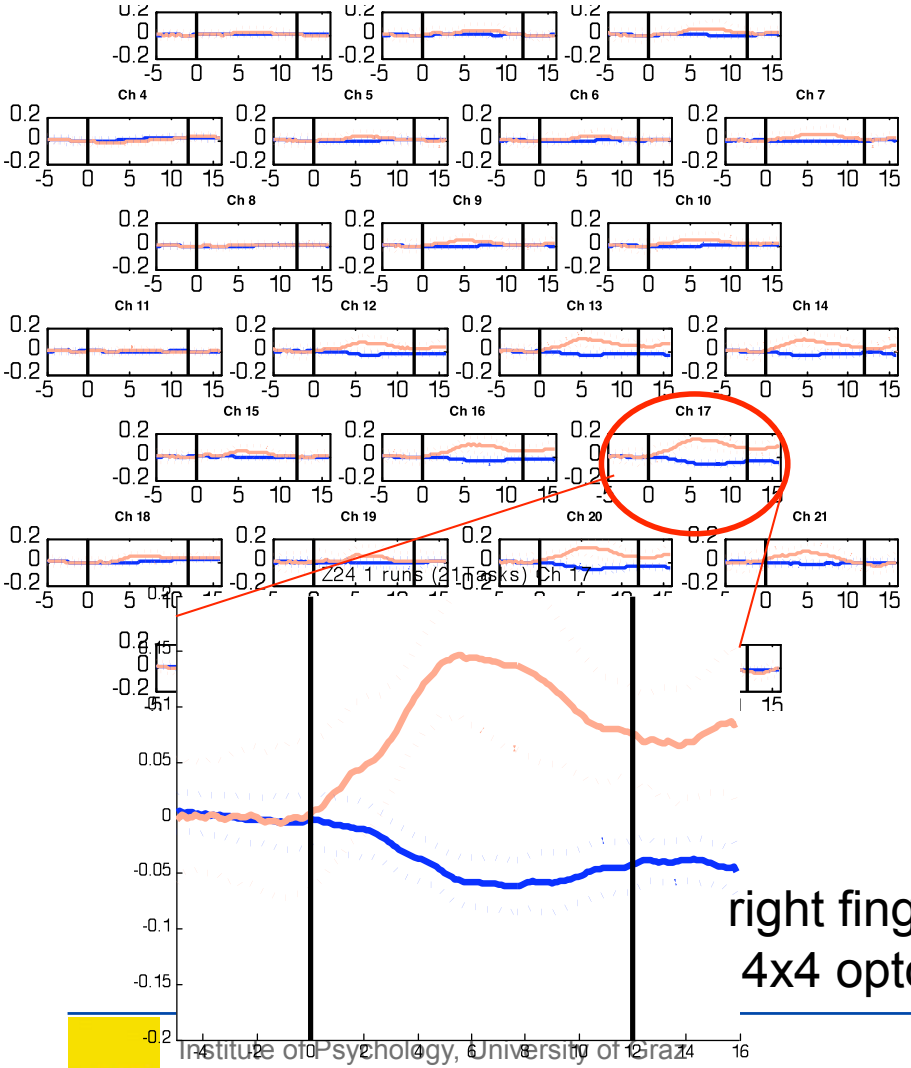
11	1	11	2	12	3	12
4		5		6		7
13	8	13	9	14	10	14
11		12	C3	13	C1	14
15	15	15	16	16	17	16
18		19		20		21
17	22	17	23	18	24	18

Cz

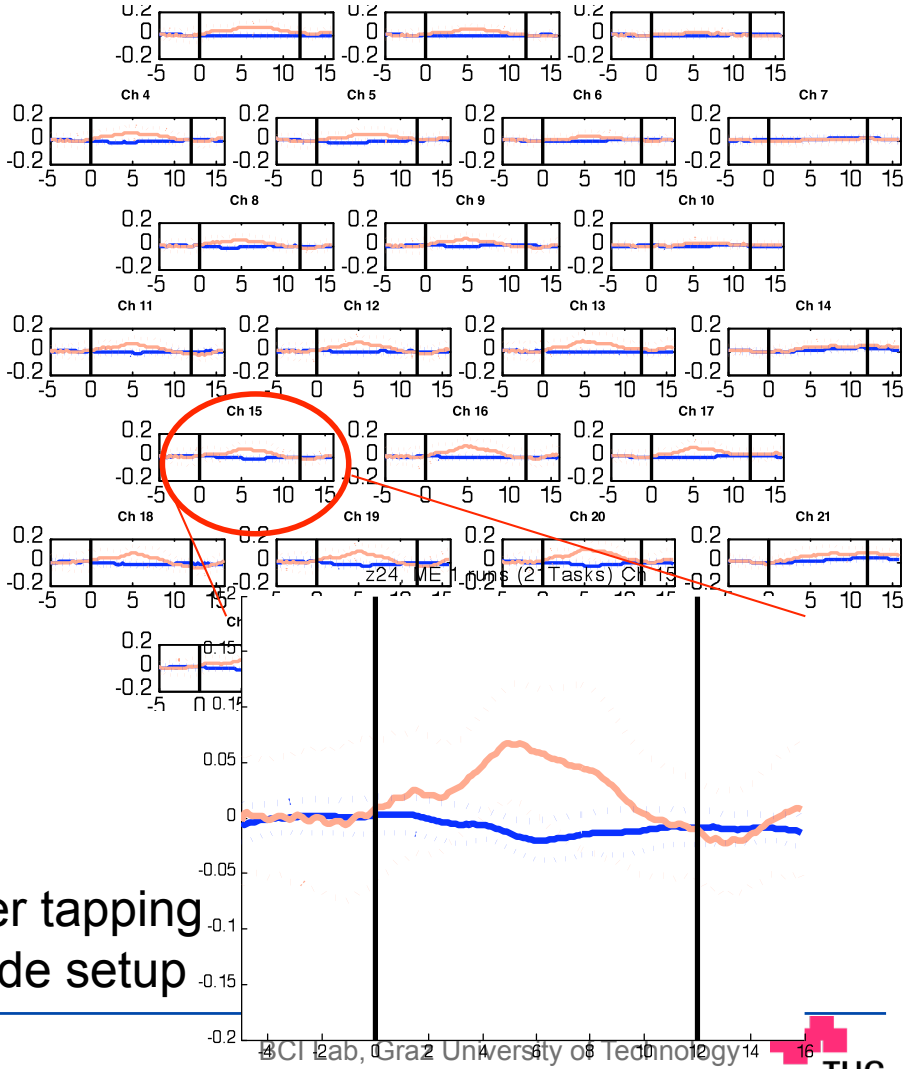
21	1	21	2	22	3	22
4		5		6		7
23	8	23	9	24	10	24
11	C2	12	C4	13		14
25	15	25	16	26	17	26
18		19		20		21
27	22	27	23	28	24	28

Motor Execution

Left hemisphere

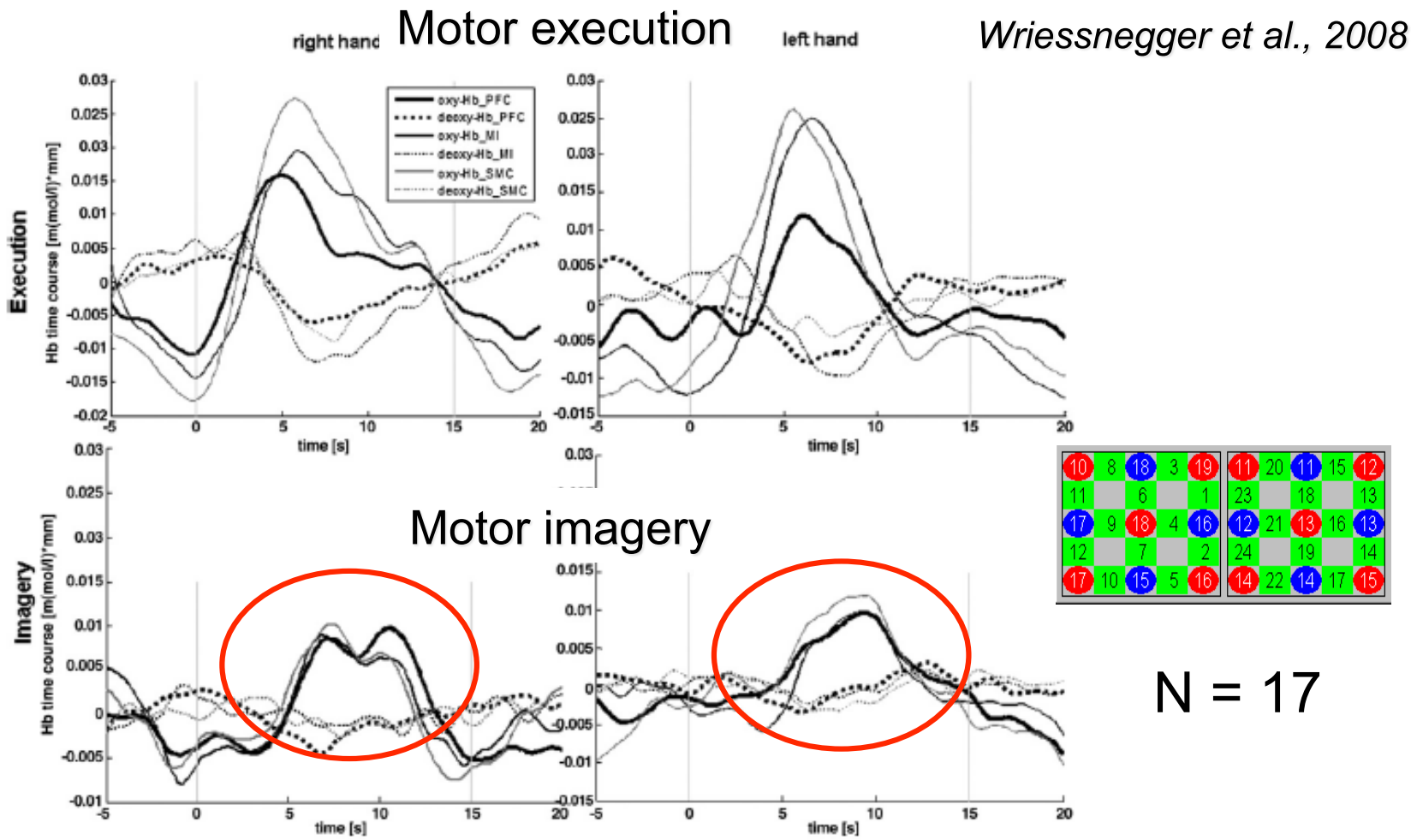


Right hemisphere



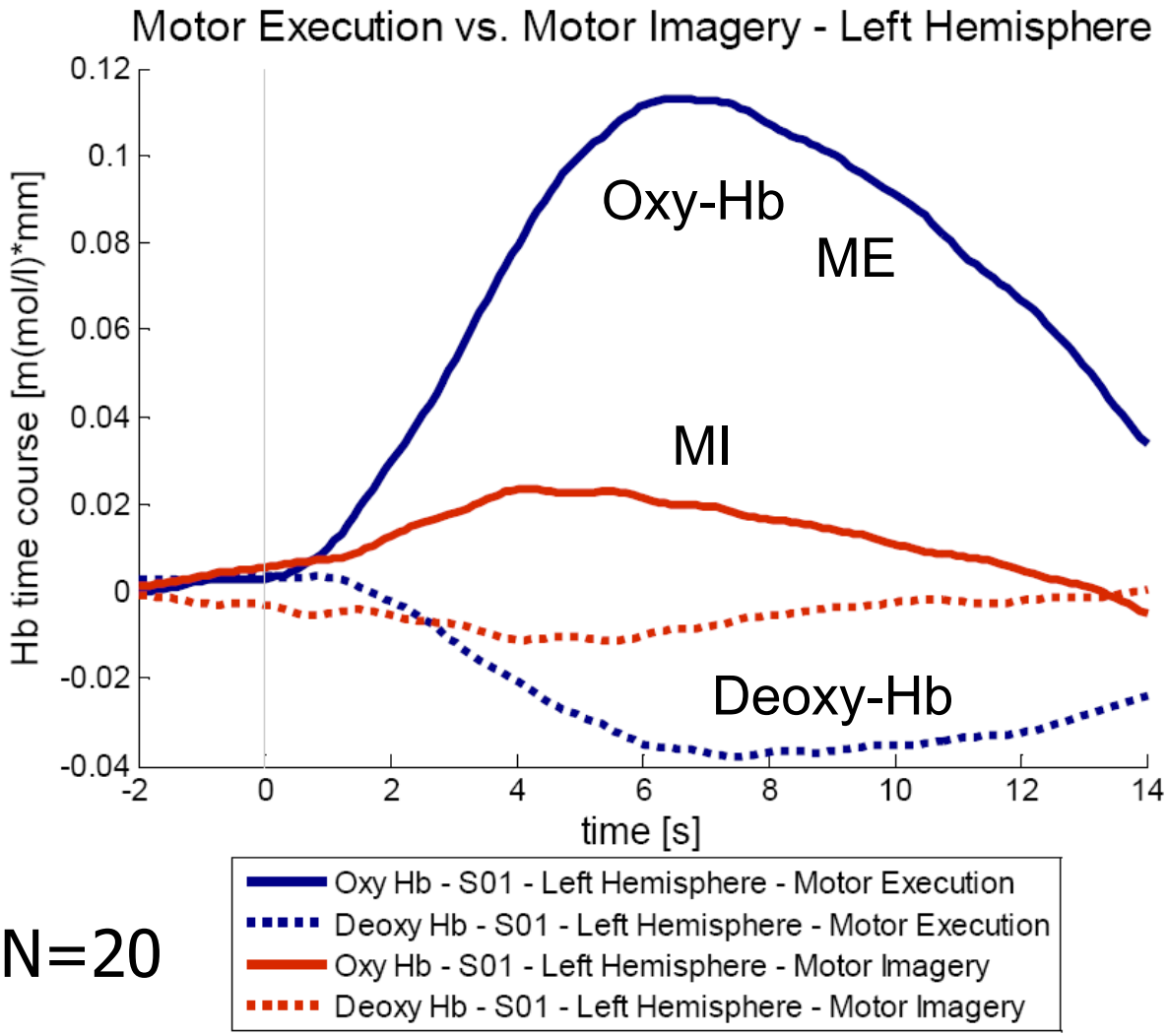
right finger tapping
4x4 optode setup

Motor Execution (ME) vs. Motor Imagery (MI)

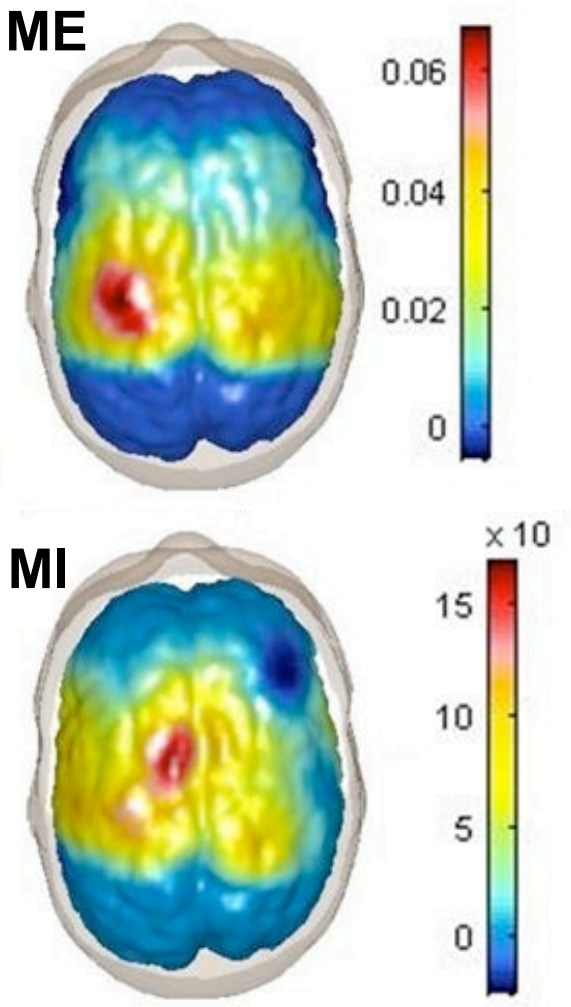


Increase of oxyhemoglobin, decrease of deoxyhemoglobin during execution **and** imagery of movements.

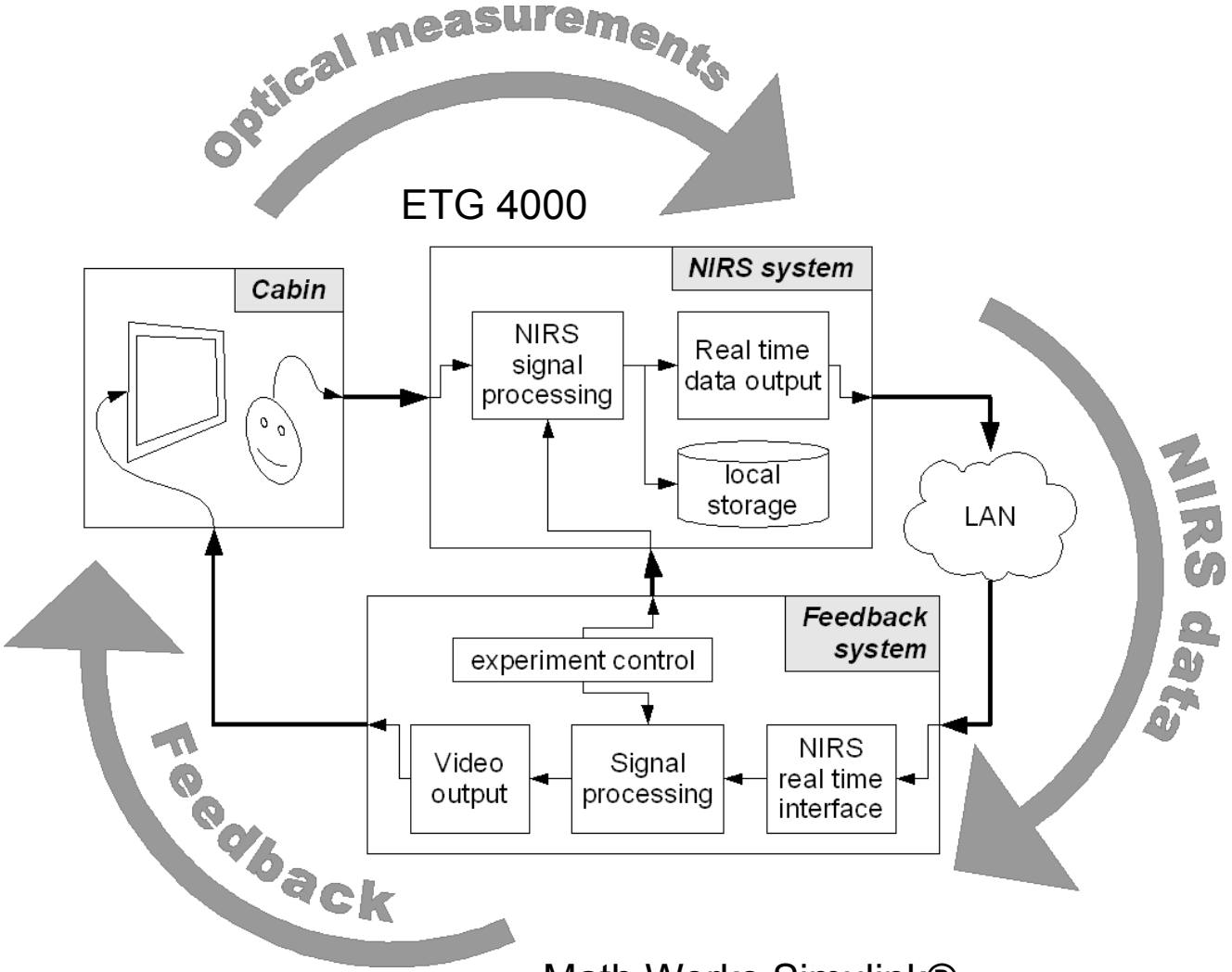
Motor Execution (ME) vs. Motor Imagery (MI)



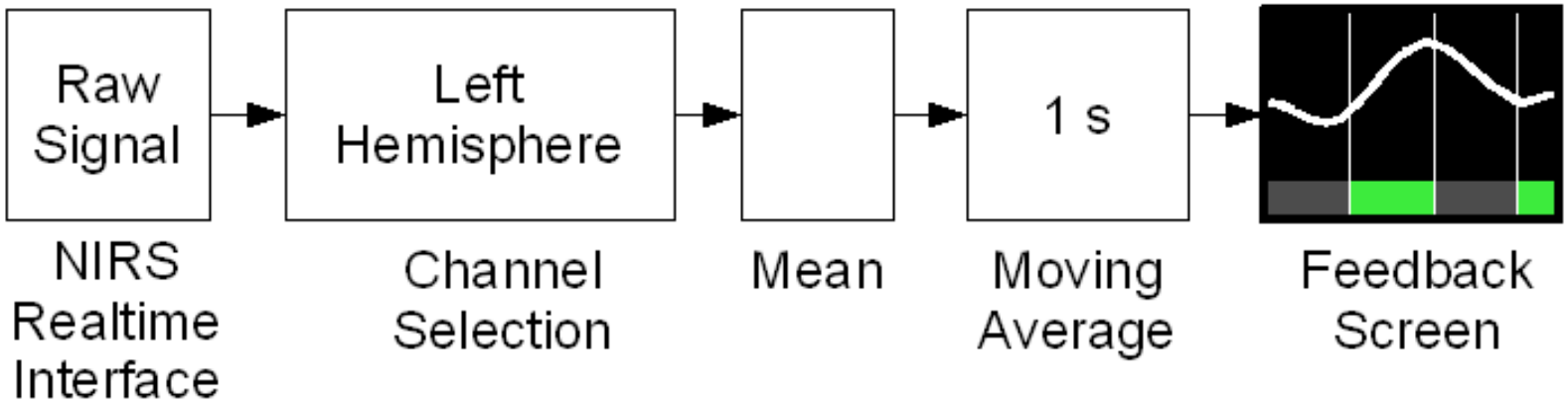
N=20



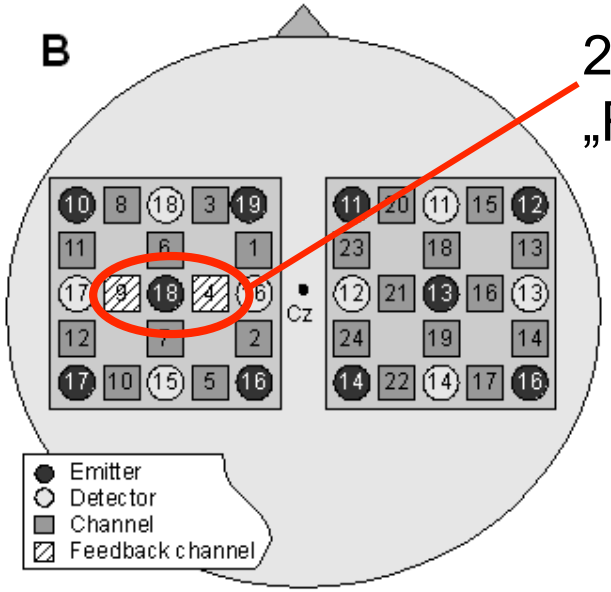
NIRS Feedback-System



NIRS Feedback: Oxy-Hb increase



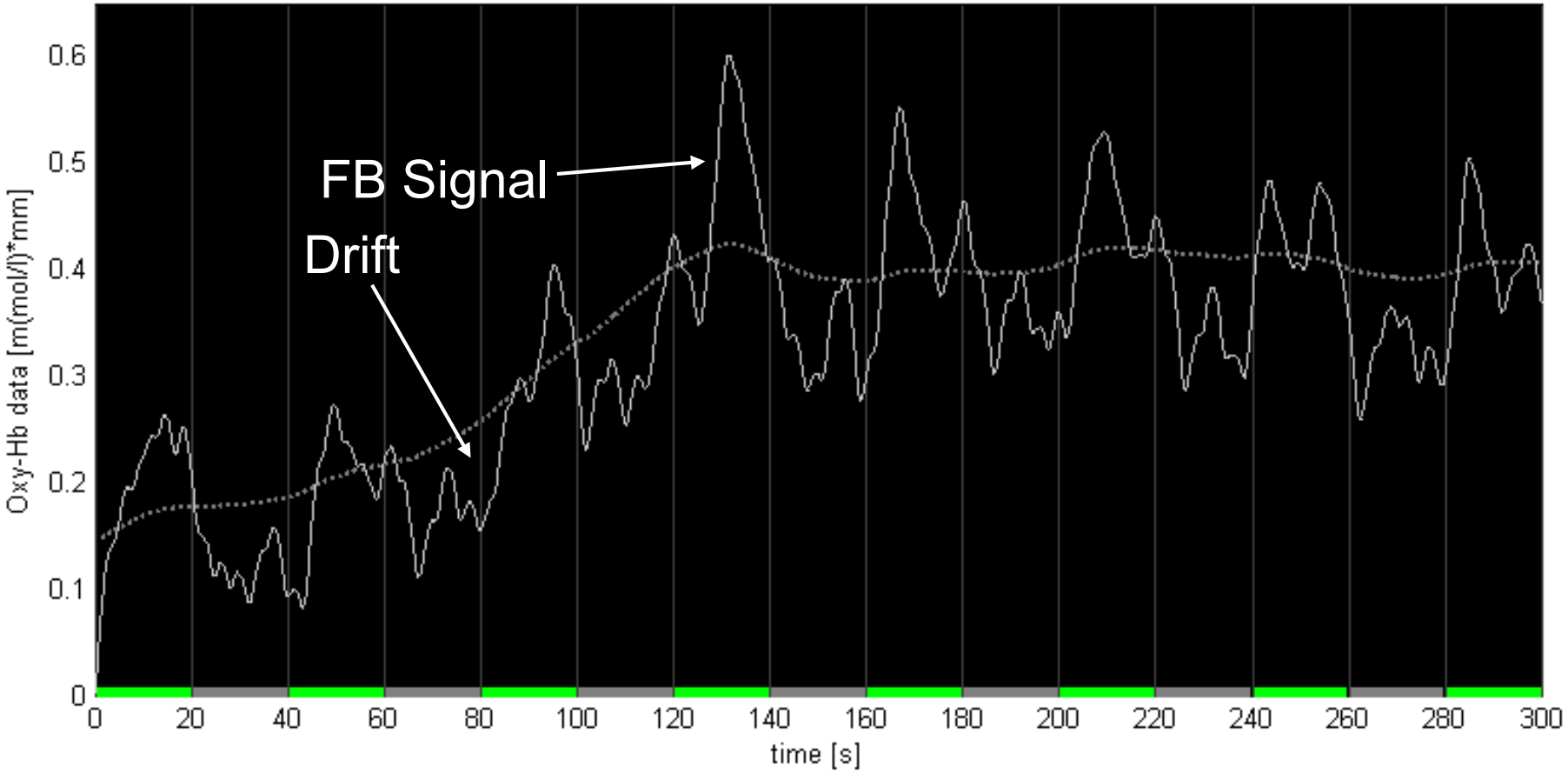
Motor imagery task with feedback (N= 8; 3 sessions)



2 FB channels
„Raw“ signal of Oxy-Hb

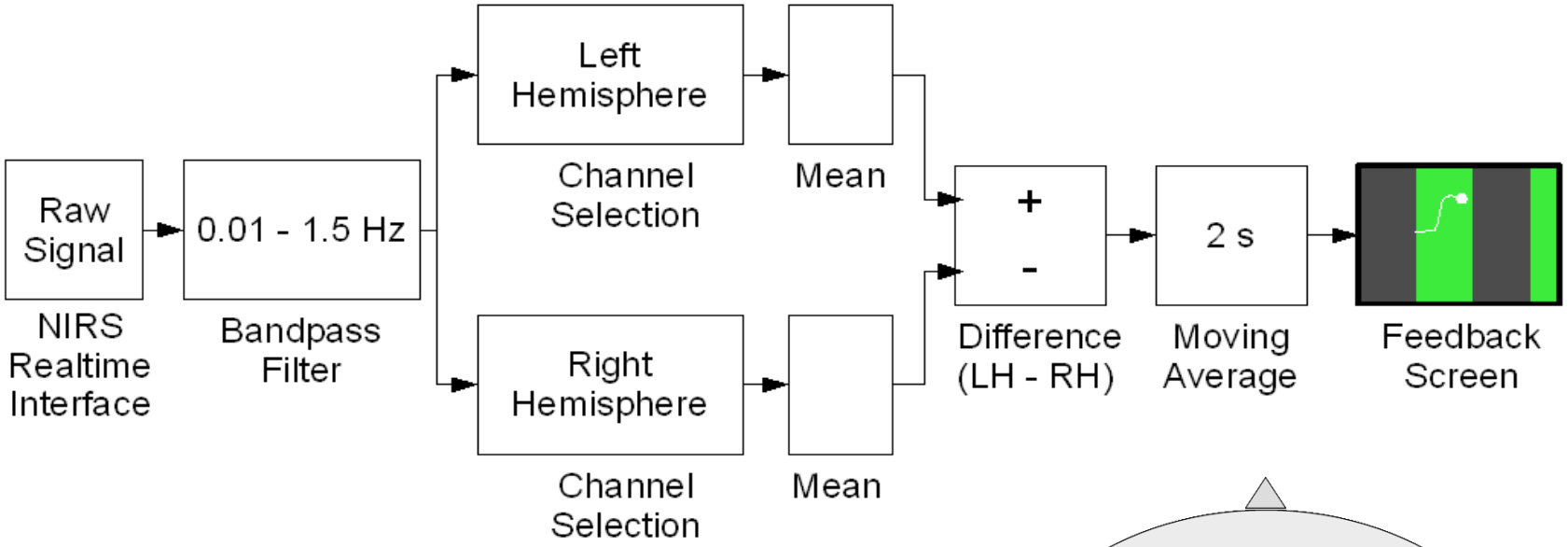
Kurzmann et al., 2008

NIRS Feedback: Oxy-Hb increase



Significant increase in Oxy-Hb in activation periods

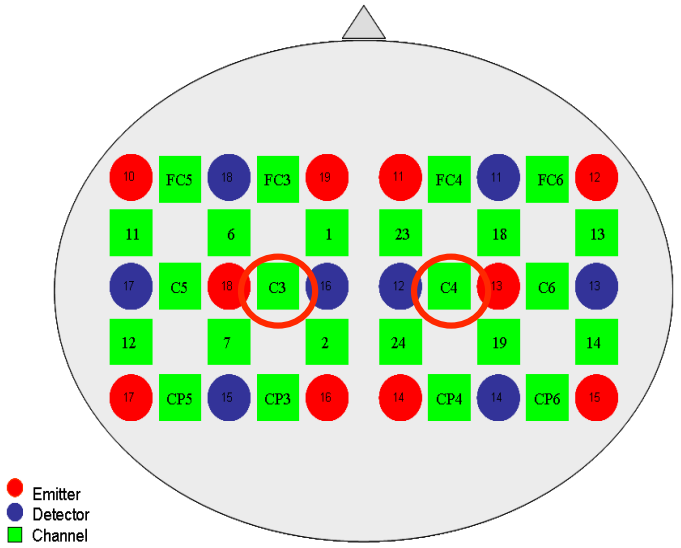
NIRS Feedback: Oxy-Hb Left-right Asymmetry



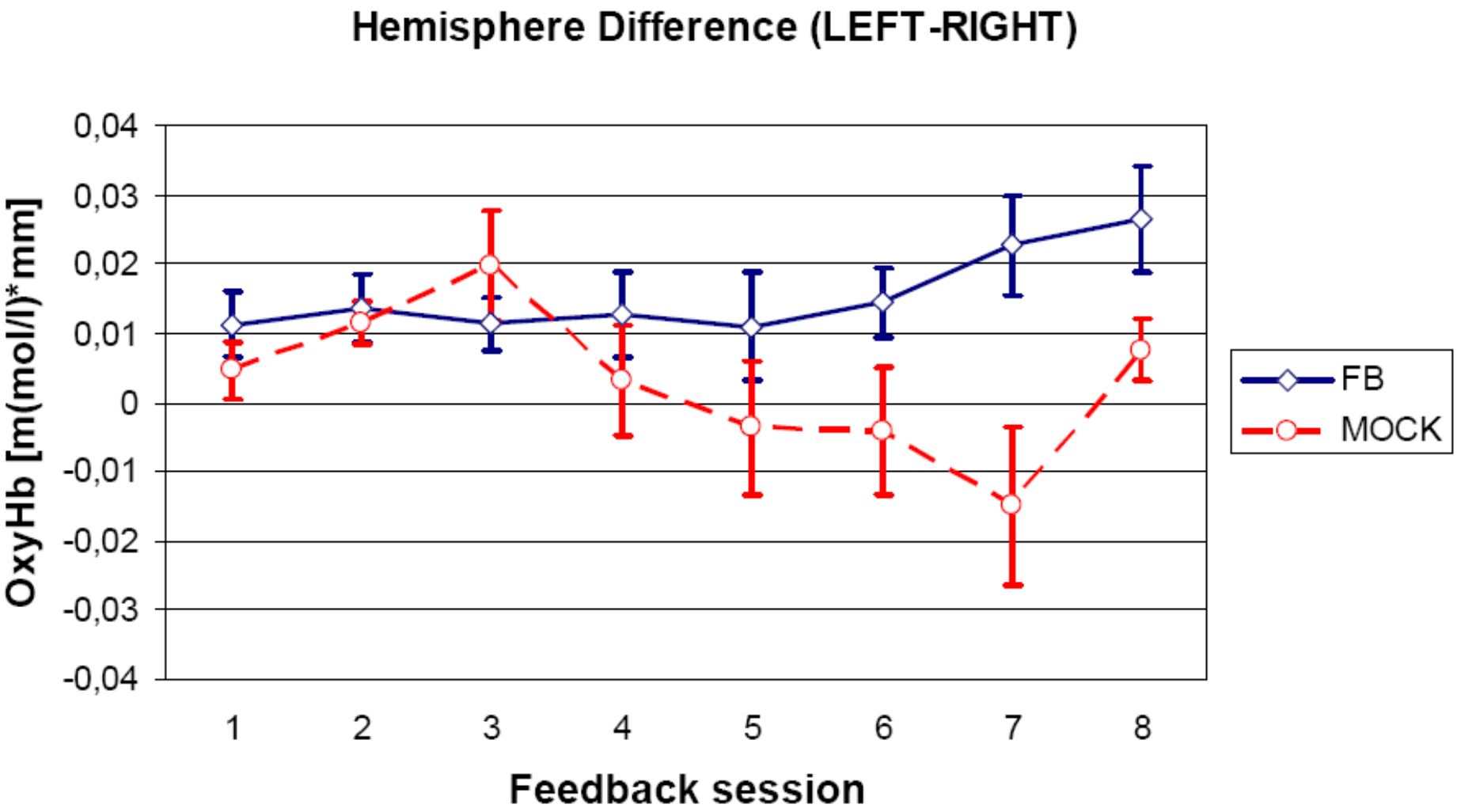
N=18, 10 sessions

2 Groups:

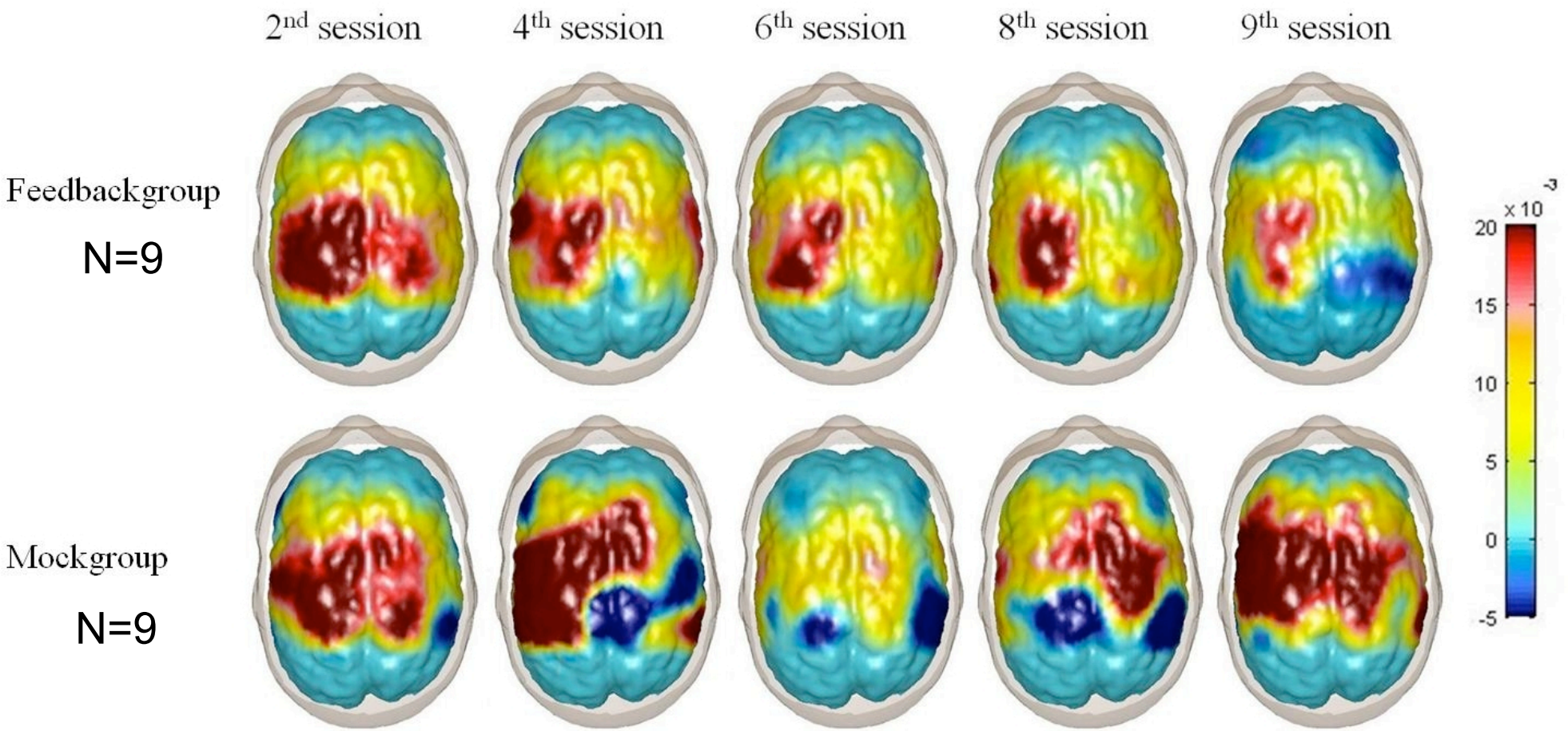
- Contingent Feedback (N=9)
- Mock Feedback (N=9)



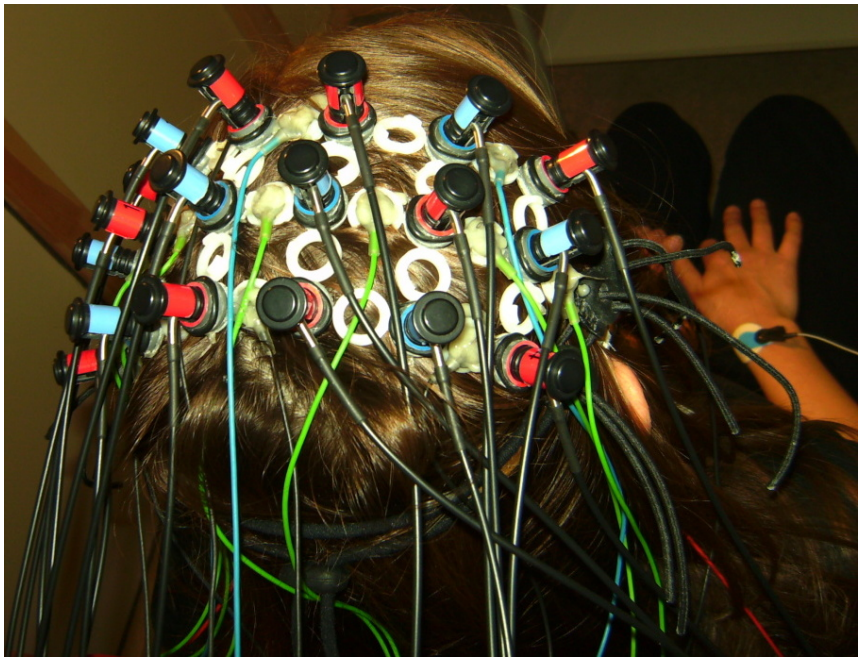
NIRS Feedback: Oxy-Hb Left-right Asymmetry

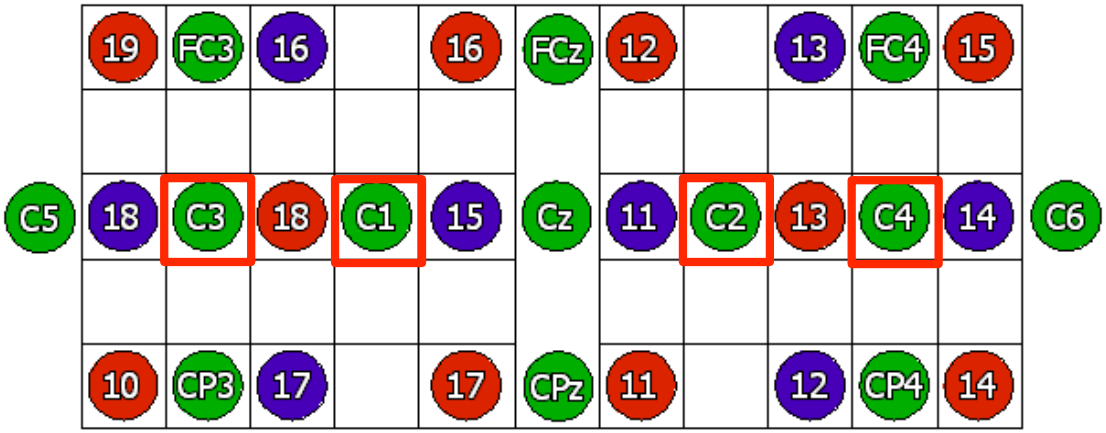


NIRS Feedback: Oxy-Hb Left-right Asymmetry



Combined EEG/NIRS recording

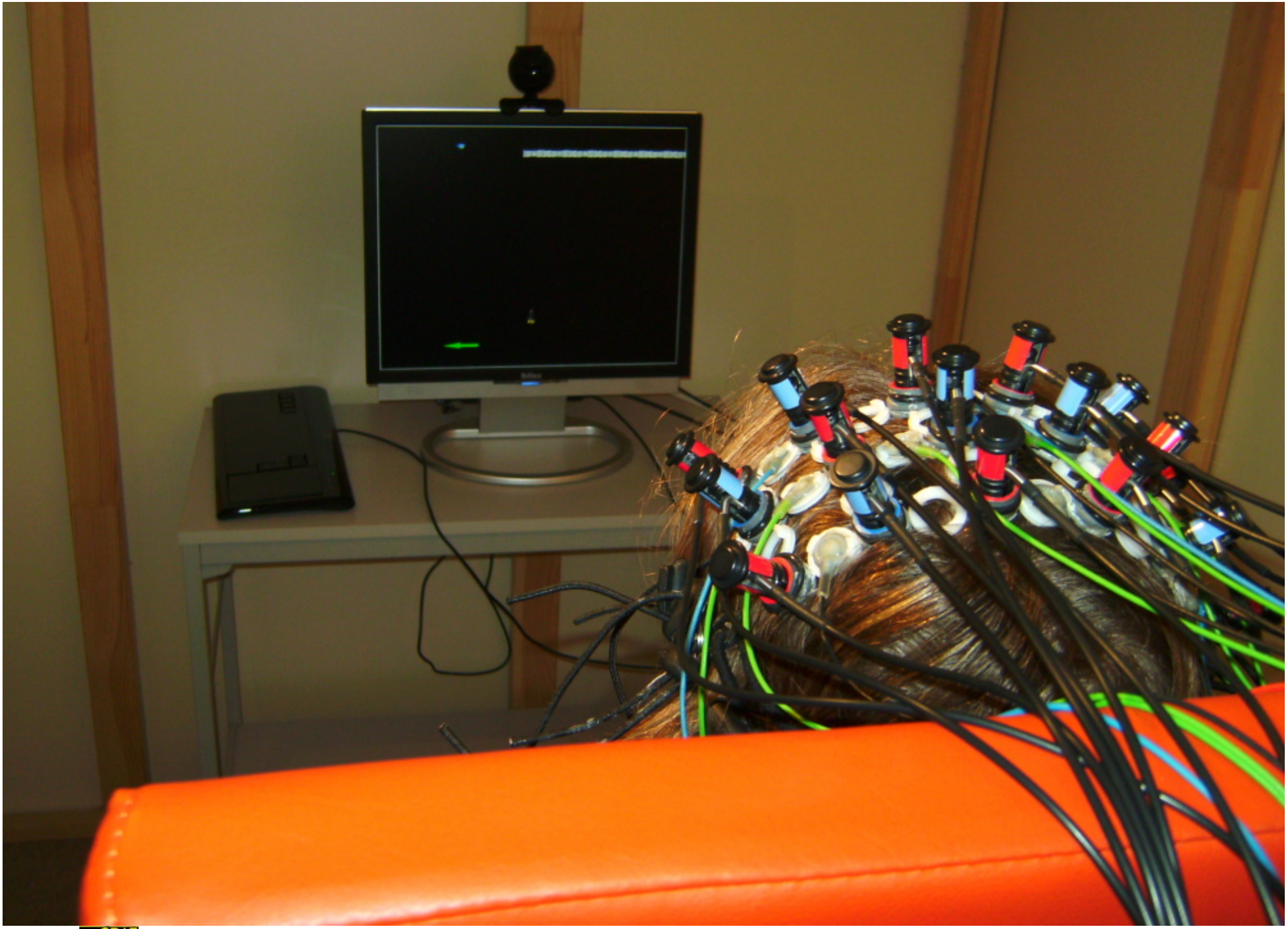




NIRS optodes: Detector

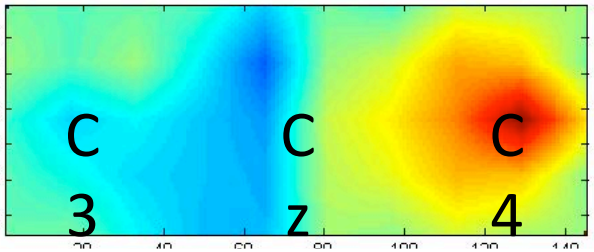
NIRS optodes: Emitter

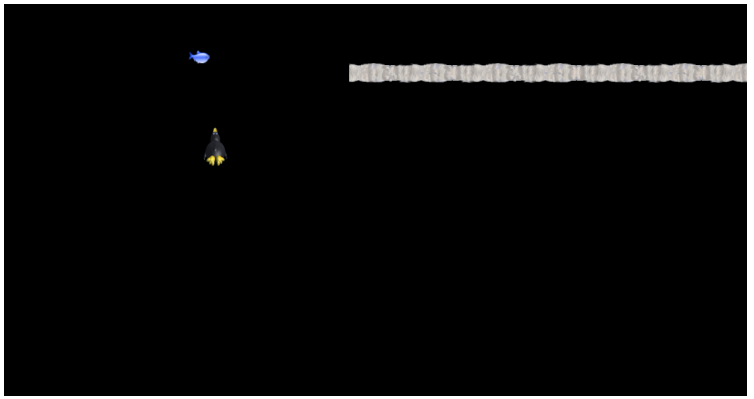
EEG electrodes


GRAZ

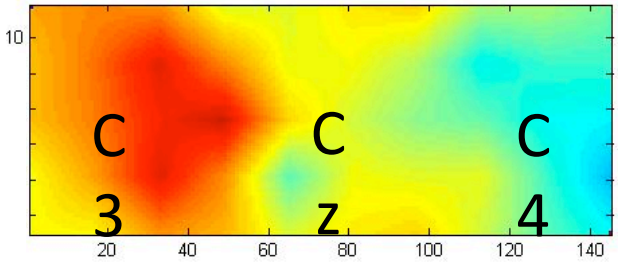
Feedback

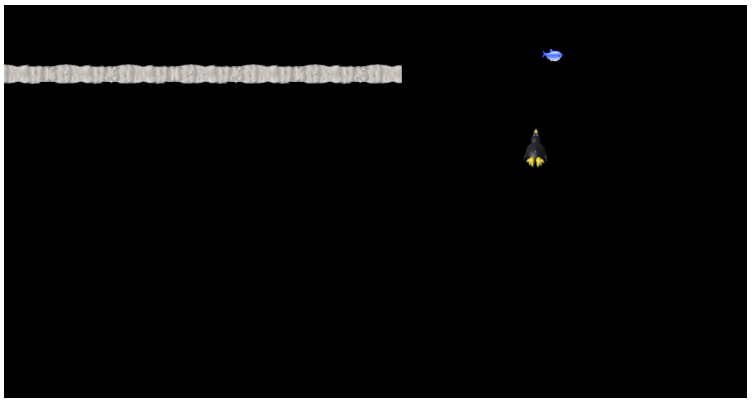
- Motor imagery – Left hand





- Motor imagery – Right hand



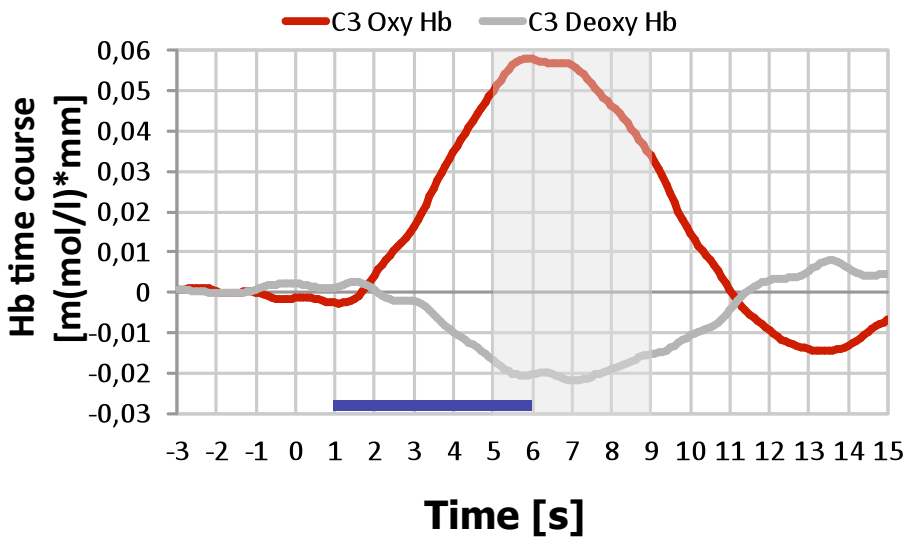


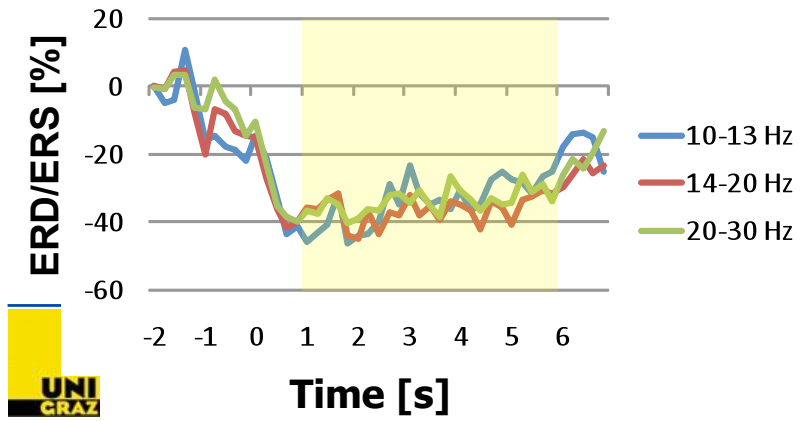
Luria finger opposition task

Motor Imagery - Session 1

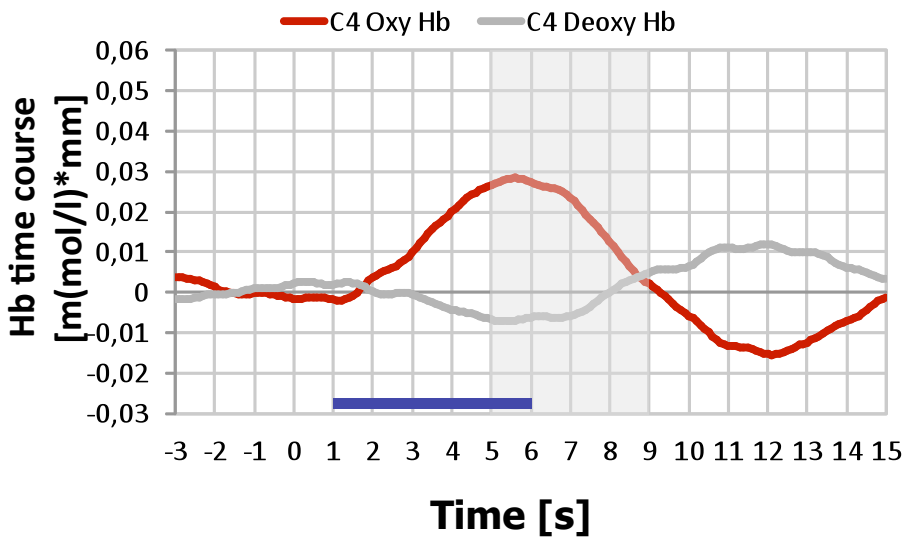
- Time course: Motor imagery – Right hand

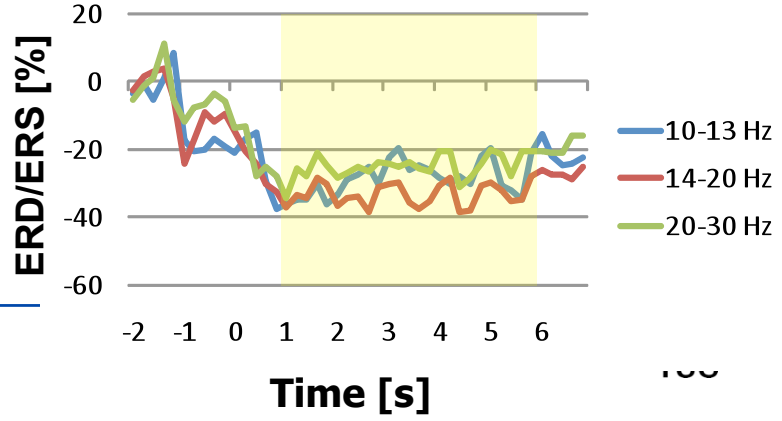
C3





C4

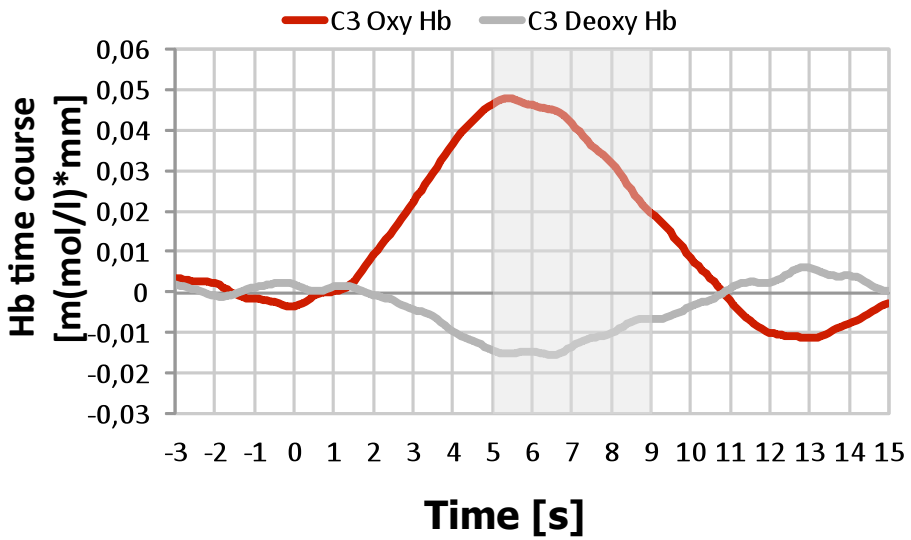


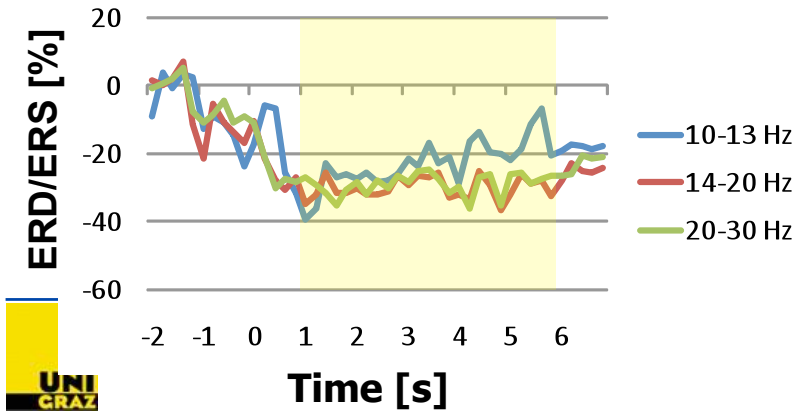


Motor Imagery - Session 1

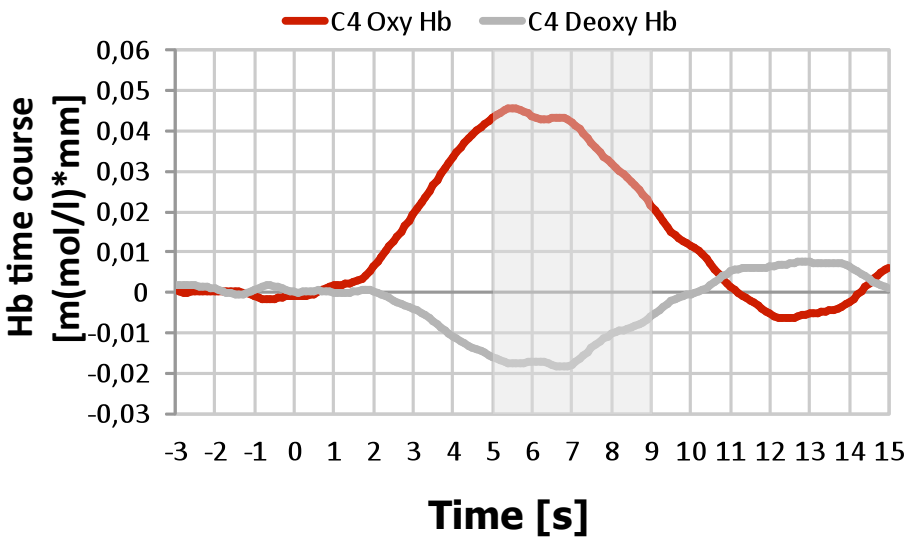
- Time course: Motor imagery – Left hand

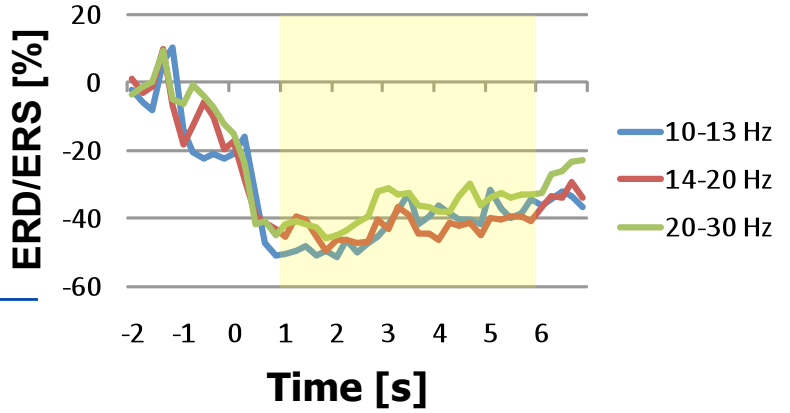
C3





C4





Session 1

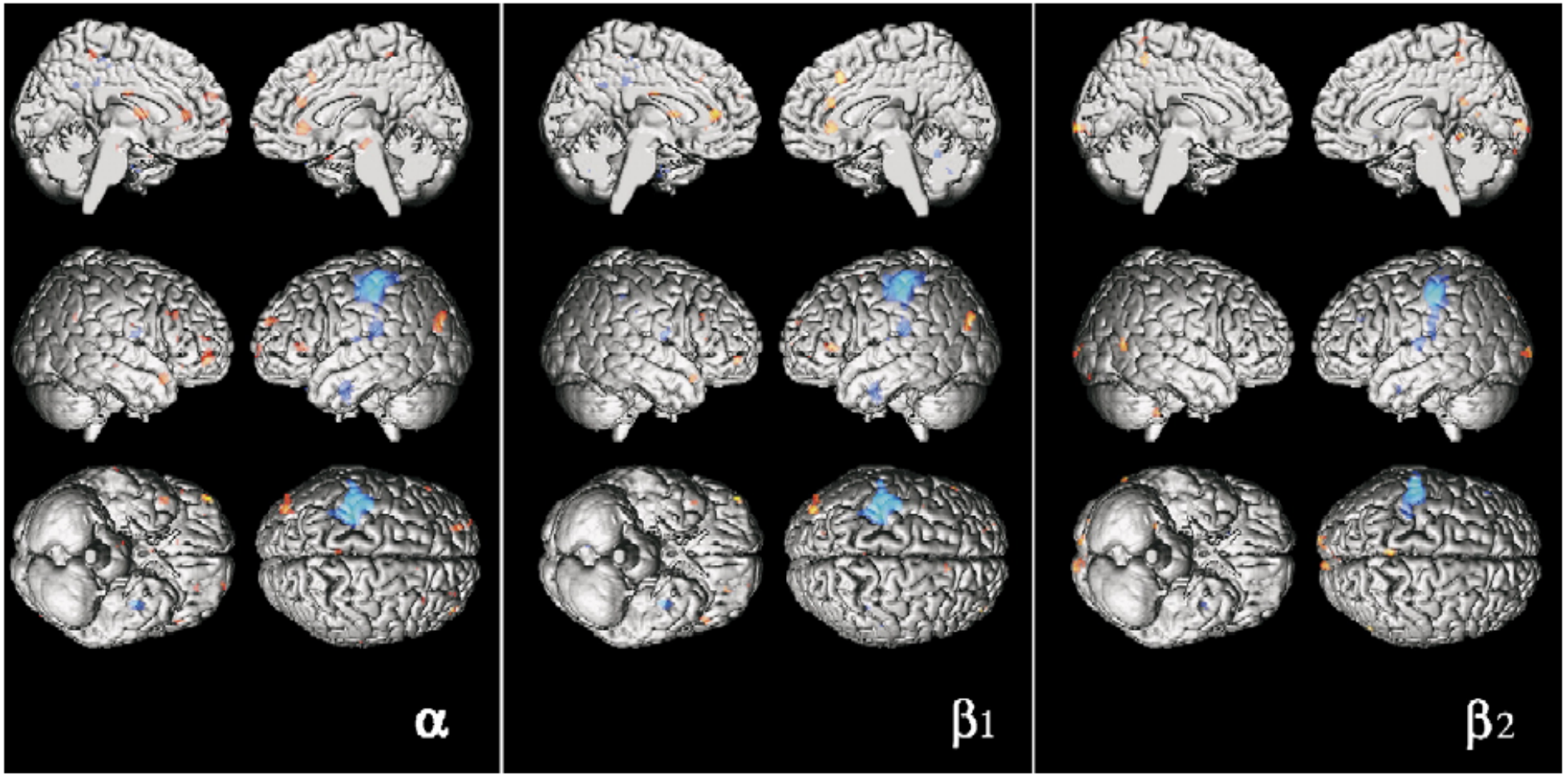
- Correlation:

Oxy Hb (mean sec 5-9) x ERD/ERS 14-20 Hz (mean sec 1-6)

			ERD/ERS 14-20 Hz			
			Motor imagery – Left hand		Motor imagery – Right hand	
			C3	C4	C3	C4
Oxy Hb	Motor imagery – Left hand	C3	-.541	-.448	-.637*	-.579*
		C4	-.378	-.305	-.479	-.481
	Motor imagery – Right	C3	-.679*	-.685*	-.638*	-.638*
		C4	-.507	-.481	-.474	-.499

rCBF/PET & Sensorimotor Rhythms

N. Oishi et al. / NeuroImage 36 (2007) 1301–1312



Take home message…

- The feasibility of noninvasive BCI-controlled devices has been proved in the past couple of years. However, longterm effects of BCI use, such as the impact of feedback on brain activity, are still widely unknown.

- Motor imagery and ERD/S-BCIs may lead to new training methodologies in neurorehabilitation, in particular after a stroke.

- Newly developed NIRS-BCIs show promise for learned regulation of brain activity and enhancement of neural plasticity.

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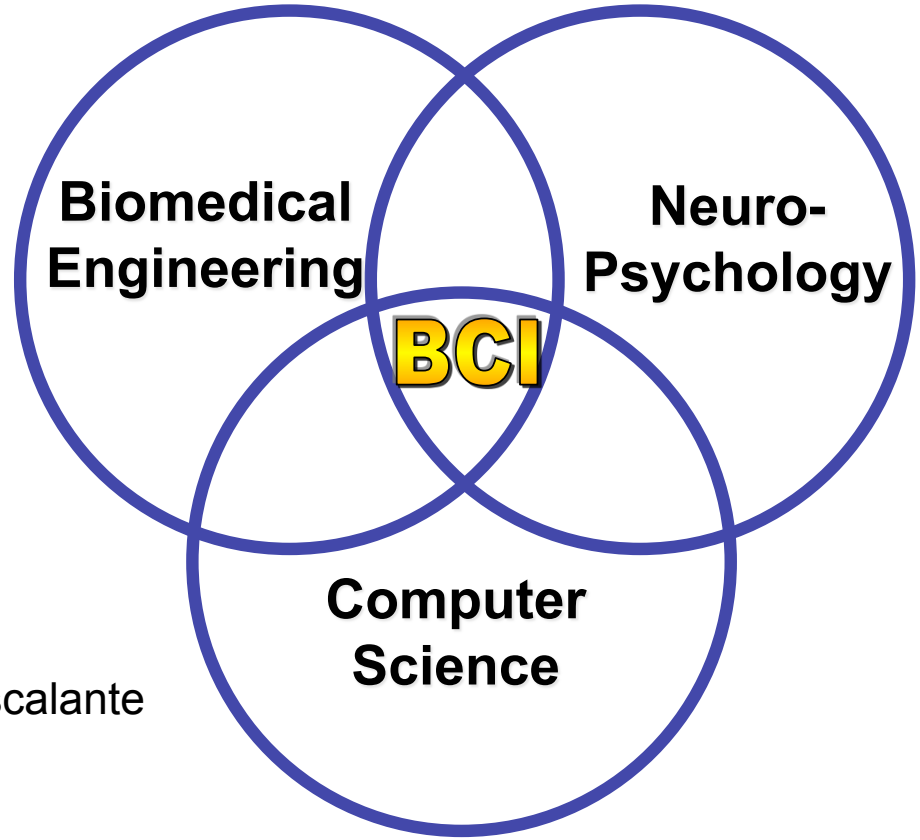

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