Brain Computer Interfaces as Stroke Rehabilitation Tools:

Optimization of current strategies

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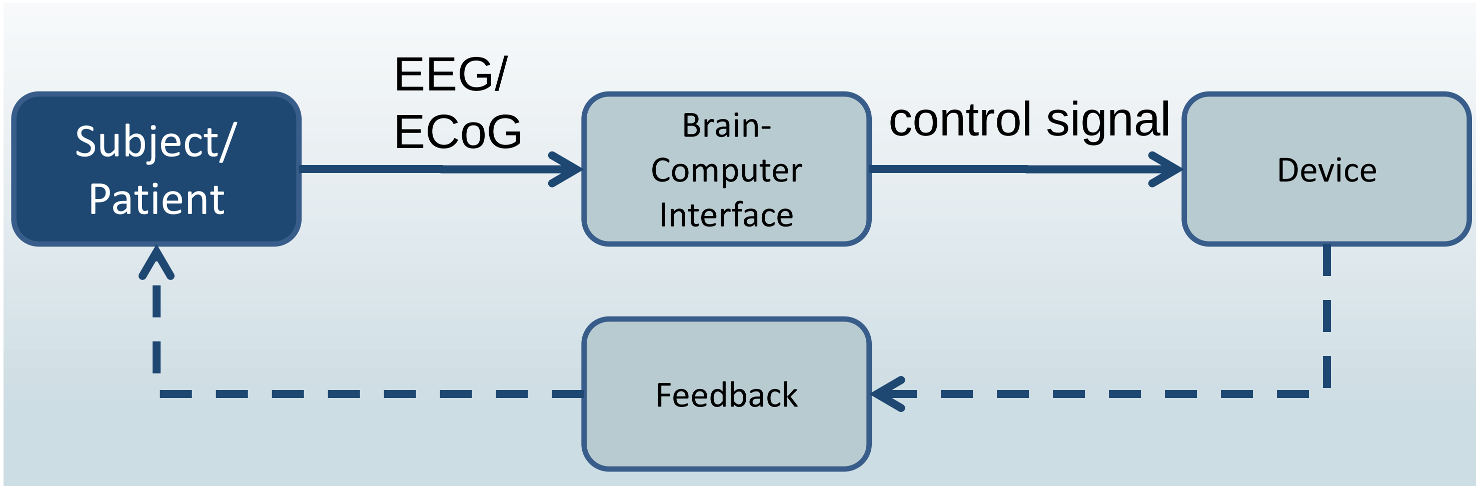
Brain-Computer-Interface (BCI)



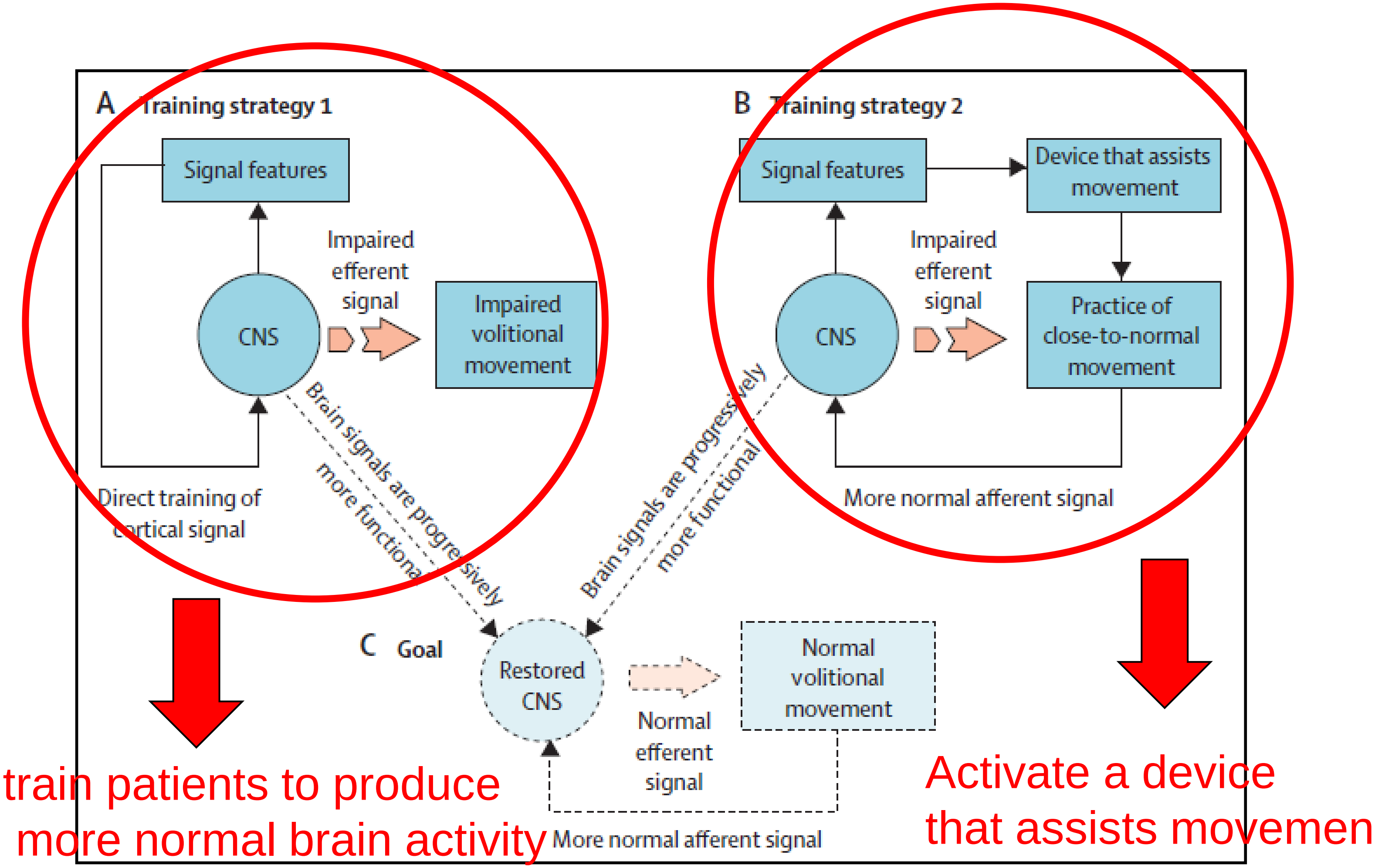
"A system for **controlling a device** e.g. computer, wheelchair or a neuroprothesis by human intention which does not depend on the brain's normal output pathways of peripheral nerves and muscles" [Wolpaw et al., 2002].

HCI – Human Computer Interface

DBI – Direct Brain Interface (University of Michigan)

TTD – Thought Translation Device (University of Tübingen)

BCIs to help stroke survivors



Daly, J. J. & Wolpaw, J. R. ***Brain-computer interfaces in neurological rehabilitation***; The Lancet Neurology, 2008, 7, 1032-1043

Stroke Rehabilitation

Motor imagery (MI) based rehabilitation was proven to be an effective therapy.

Andrea Zimmermann-Schlatter, Corina Schuster, Milo A Puhan, Ewa Siekierka and Johann Steurer. ***Efficacy of motor imagery in post-stroke rehabilitation: a systematic review***; Journal of NeuroEngineering and Rehabilitation

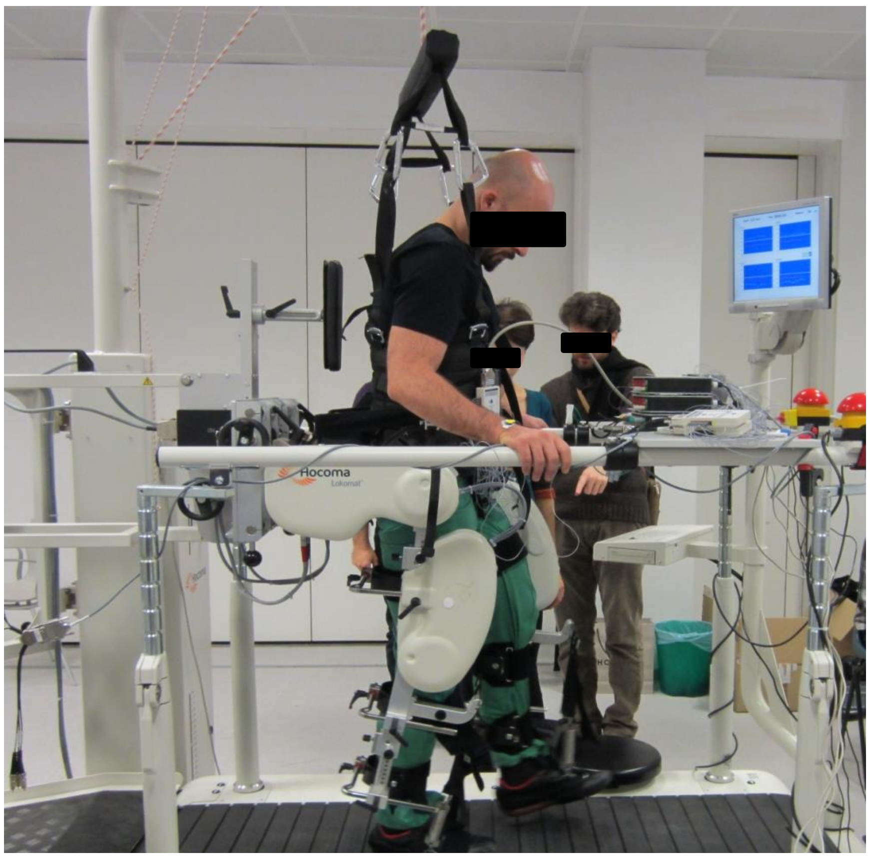
Stroke Rehabilitation

Neurological rehabilitation via robotic devices shows promising results in clinical trials.

Video

Stroke Rehabilitation

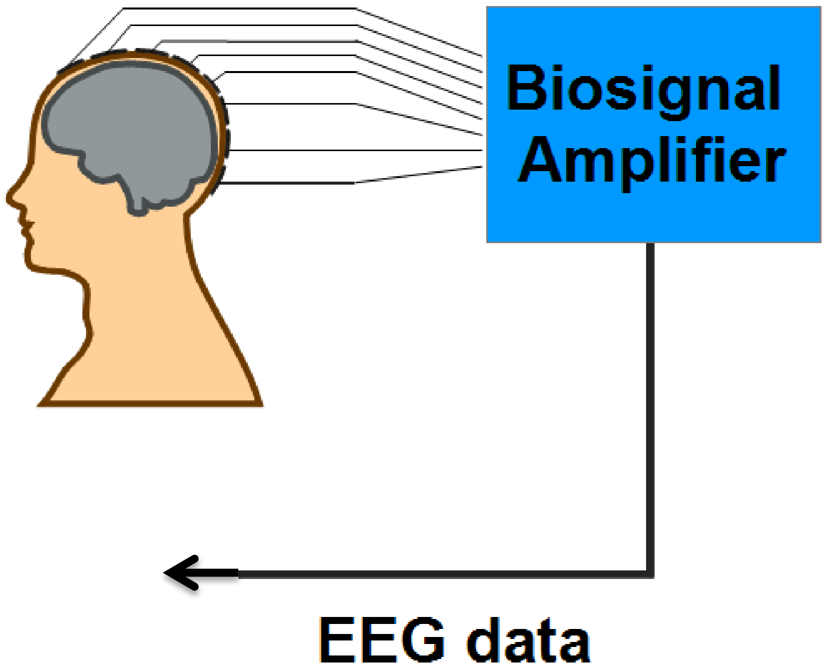
The **logical next step** **combines** the two approaches into an integrative rehabilitation strategy.



How to induce brain plasticity?

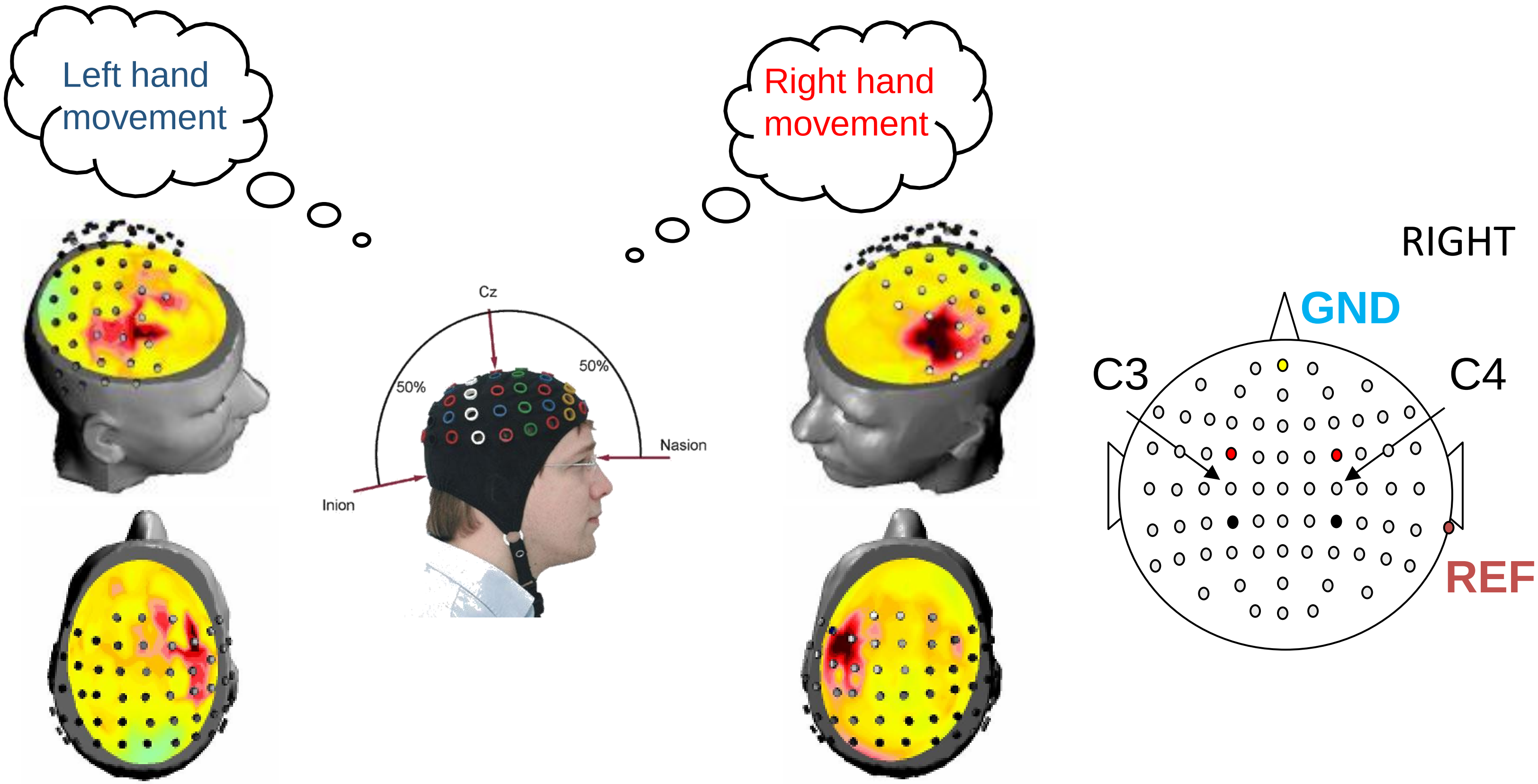
Close the feedback loop and induce "Hebbian plasticity"

?



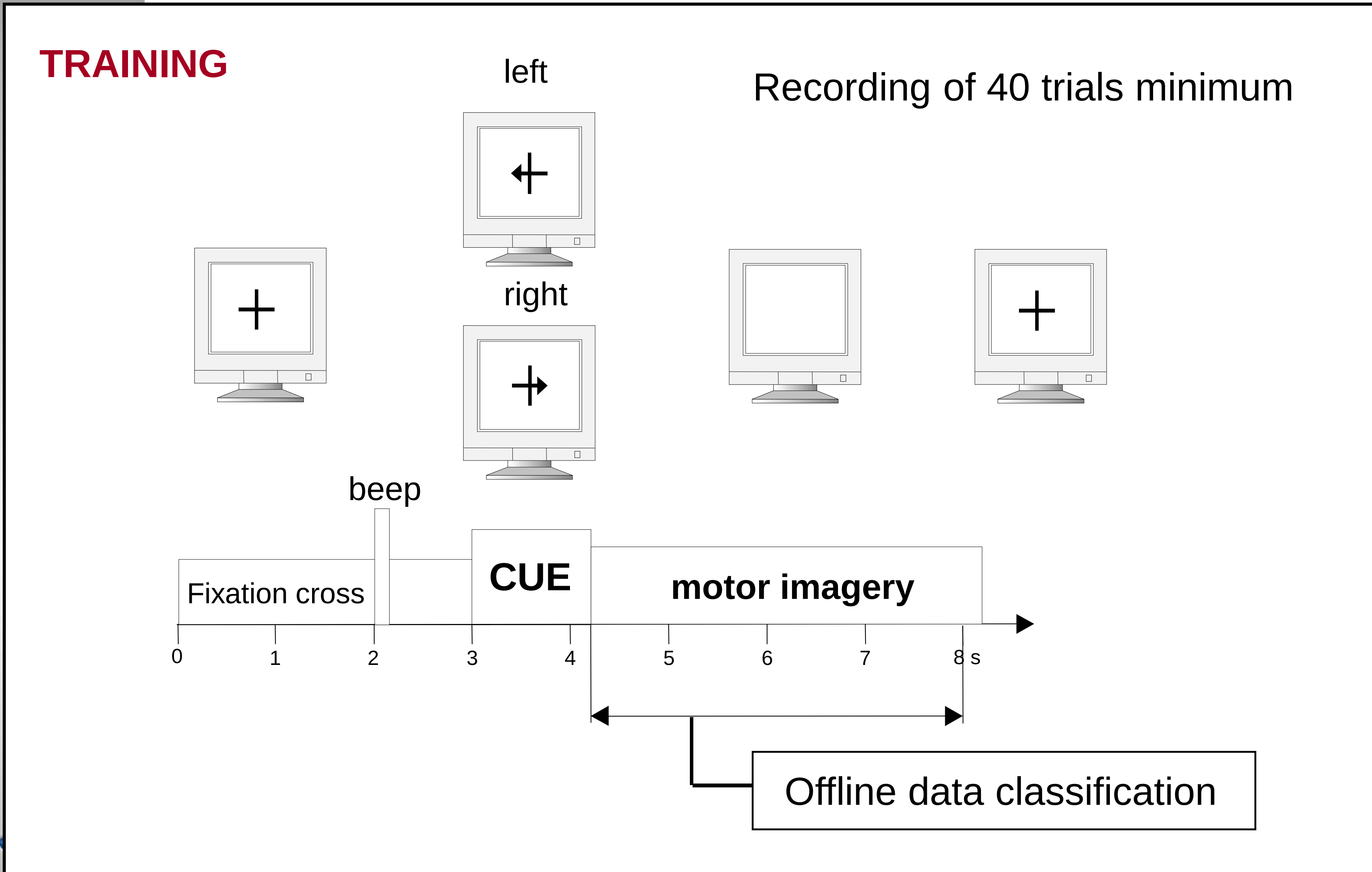
"Cells that fire together, wire together."

Physiological Background – why does it work

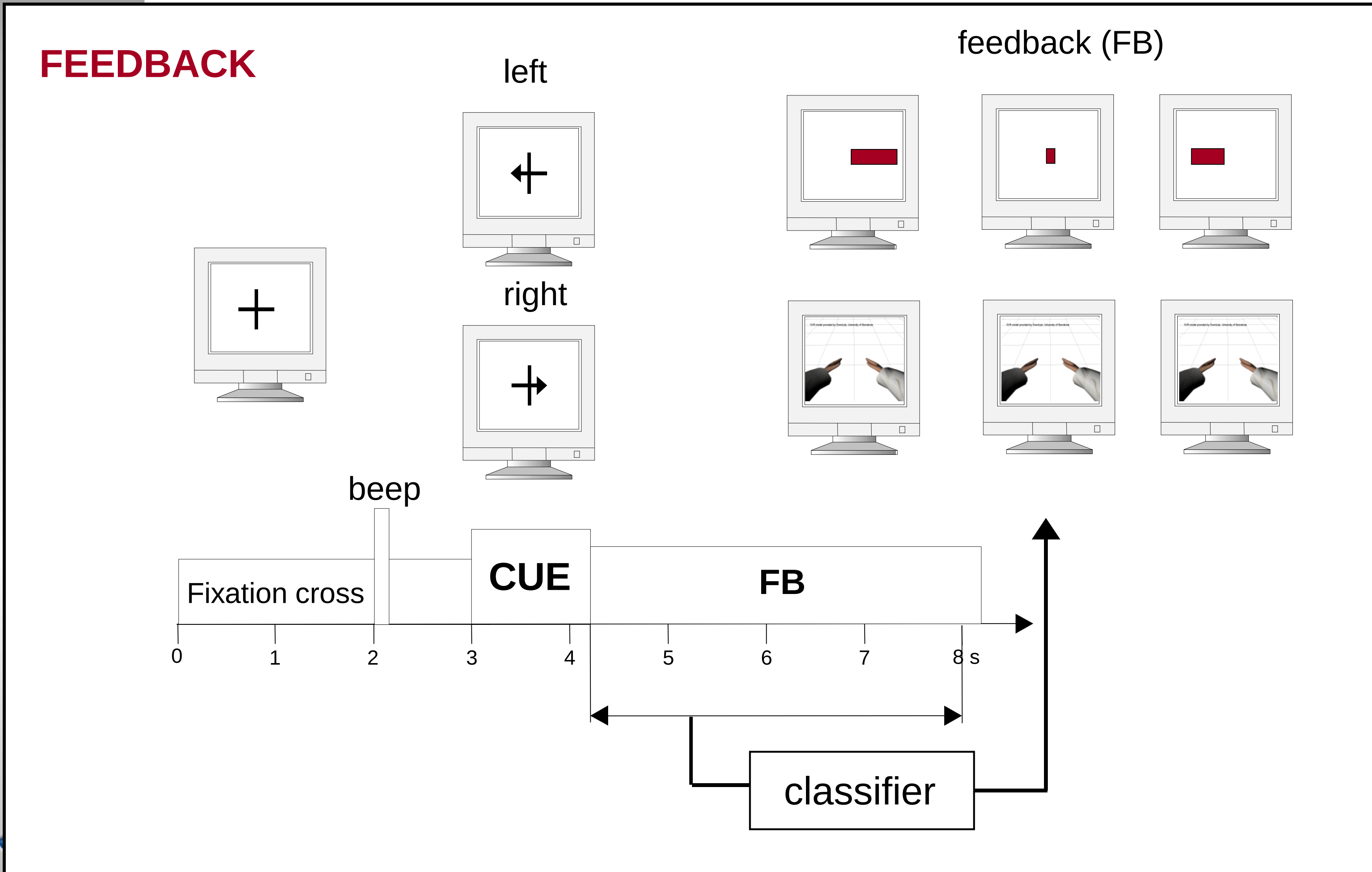


Imagination of hand movement causes an ERD which is used to classify the side of movement. The desynchronization occurs in motor and related areas of the brain. Therefore, for analyzing and classifying ERD-patterns the electrodes must be placed close to sensorimotor areas.

Paradigm for motor imagery BCI experiment



Paradigm for motor imagery BCI experiment



Right/Left hand motor imagery with Common Spatial Patterns - principle

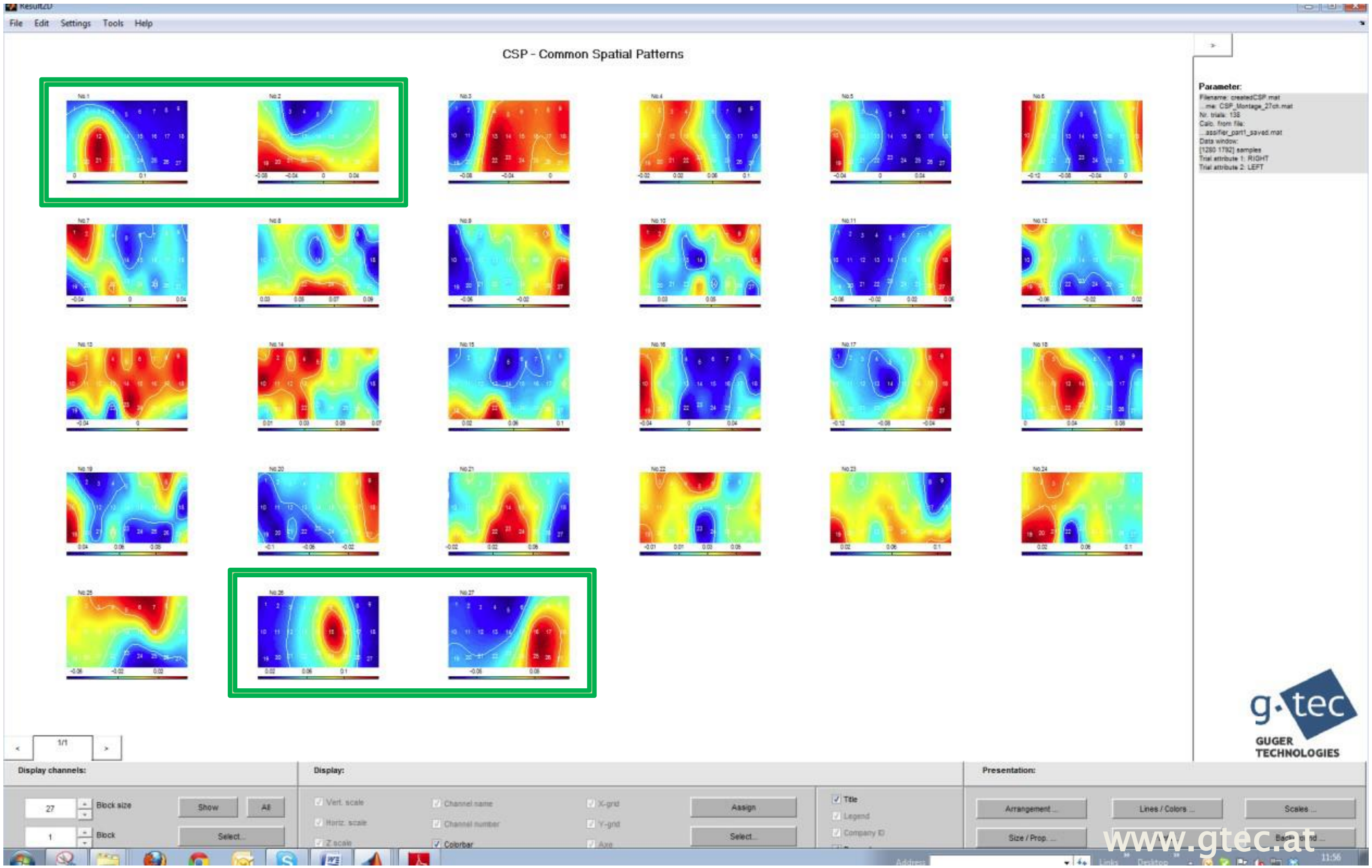
- Common Spatial Patterns weight each electrode according to the importance to the discrimination task.

$$\vec{w}^* = \underset{\vec{w} \in \mathbb{R}^N}{\operatorname{argmax}} \left\{ \frac{\vec{w}^{\mathrm{T}} R_{\vec{x}|c_1} \vec{w}}{\vec{w}^{\mathrm{T}} R_{\vec{x}|c_2} \vec{w}} \right\}$$

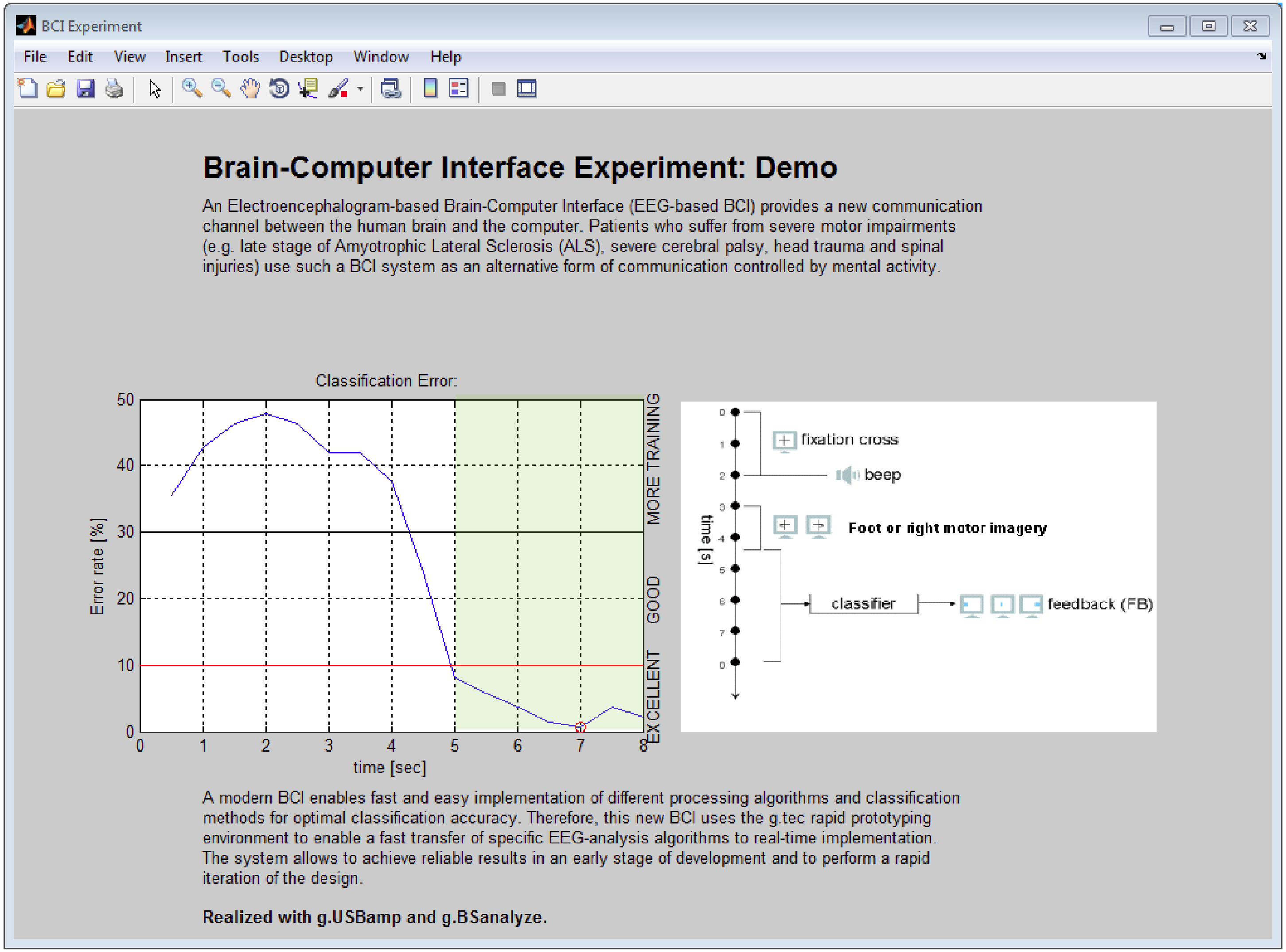
$R_{\vec{x}|c_1}, R_{\vec{x}|c_2}$ the covariance matrices of $\vec{x}$ given c_1, c_2

- The difference between left and right population is maximized.
- CSPs reflect the EEG source distribution.
- Setup of 4 CSPs: influence of electrode montage, sensitive to artifacts.
- The spatial filter suppresses artifacts.
- Variance calculation of 1 second segments -> fast feedback.

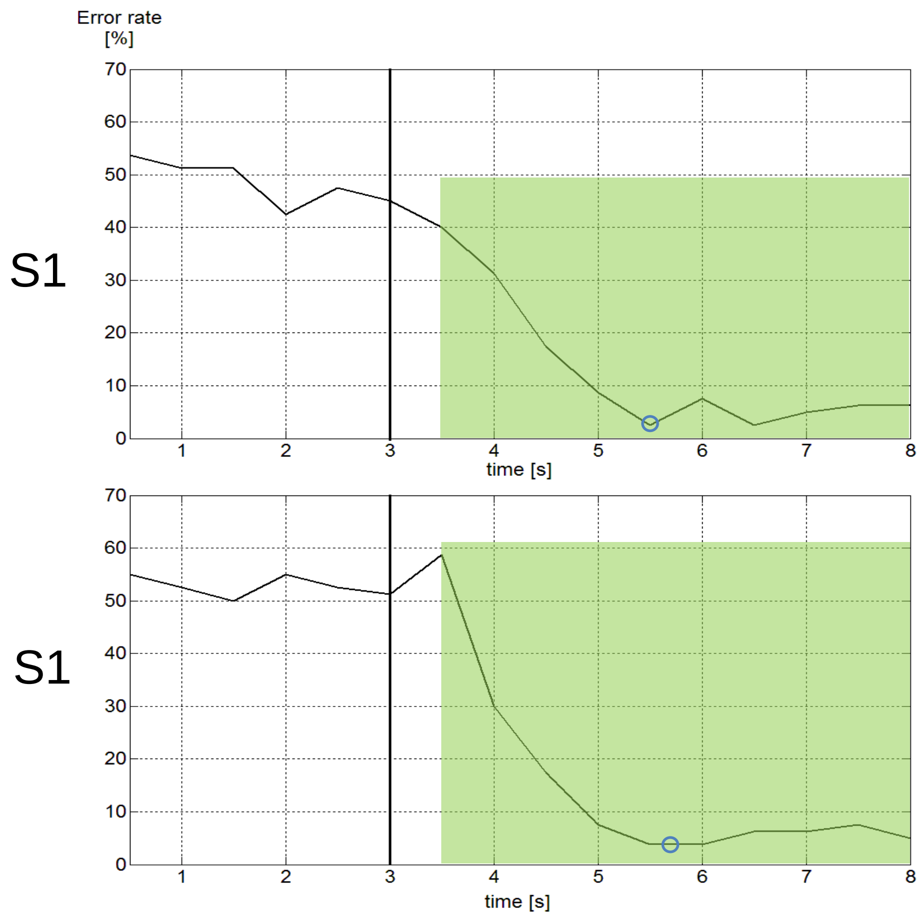
Right/Left hand motor imagery with Common Spatial Patterns: live experiment



Classification expected



Comparison bar-FB and VR-FB



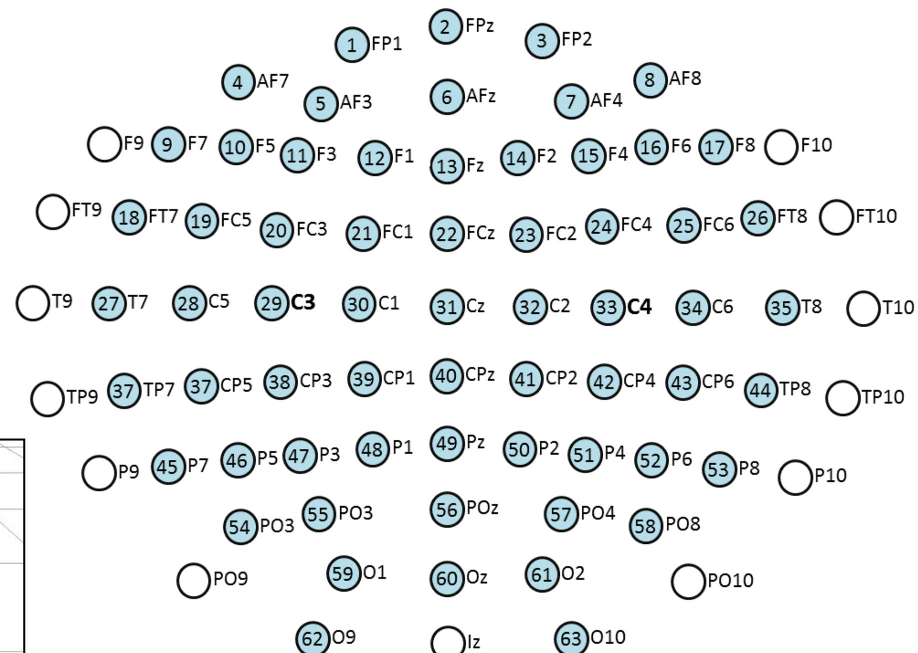
Mean

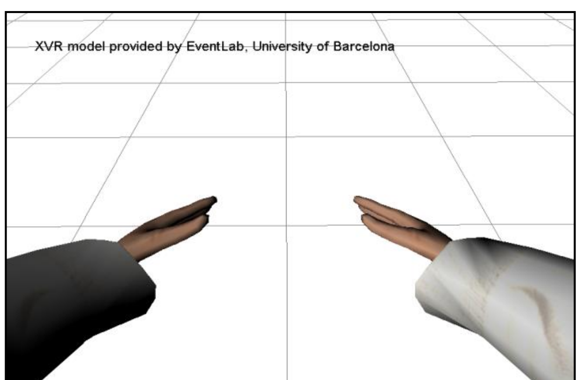
Min

Error rate from the two feedback runs for S1. The vertical bar indicates the cue onset.

Study

Test of a generic set of Common Spatial Patterns (CSP) and Linear Discriminant Analysis (LDA), for Motor Imagery (MI) - Brain-Computer Interfaces with stroke patients.





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Methods:

- Eleven healthy subjects did EEG recordings with 64 EEG channels.
- Users were instructed to imagine right or left hand movement according to the arrow presented.
- All healthy test users performed one session, consisting of 80 trials.
- A general classifier and CSP feature vector was calculated using data of this 11 subjects.
- The test was done over 11 healthy and 11 stroke patients.
- For check long term effect 5 stroke patients perform 4^{th} more sessions.

Mean accuracy rates of the two groups participating in the VR paradigm

	Healthy	Stroke		
Session #	1	1	1	4
Participants	11	11	5	5
Mean Acc.	63.77	60.67	59.7	72.48
SD	16.52	13.05	6.08	8.45

Results from 80 trials. The first number shows the mean error rate beginning from 3.5 seconds until 8 seconds. The number in parenthesis shows the minimum error rate within this time.

Conclusions

- Generic CSP and LDA classifier can be used for healthy persons and also for stroke patients for MI training.
    - Time is reduced -> keep motivation and ability of control

- Five stroke patients that participated to more training sessions, increased their accuracy from 59,70% up to 72,48%.

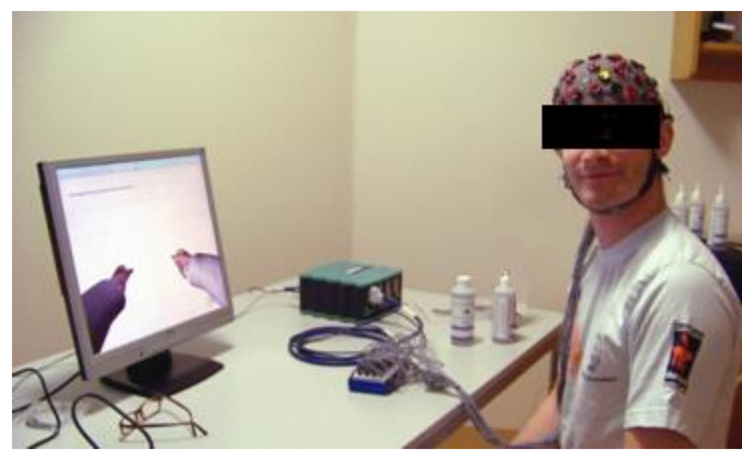
- Difference accuracy between healthy users and stroke patients is only about 3% on average.

Krzeszowice Rehabilitation Center, Poland

- Testing motor imagery in stroke patients.

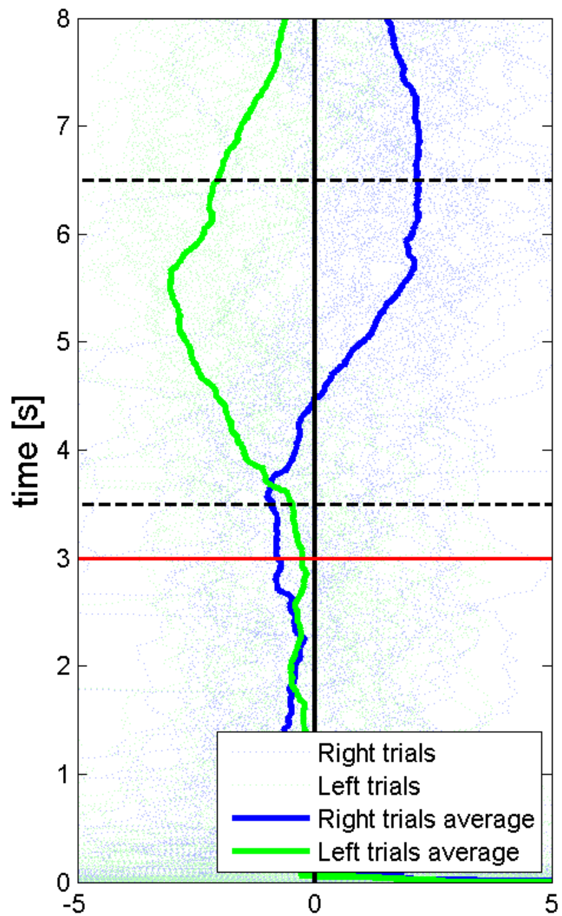
- Study changes of ERD curves in stroke.

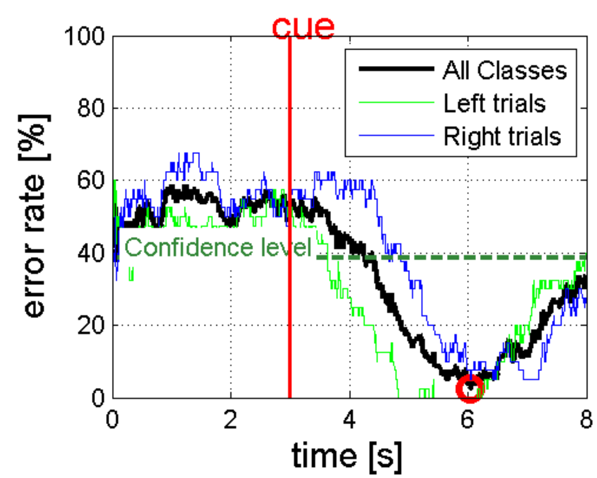
- Prove if stroke patients can control MI – BCI.



Results, classifier same session

If enough runs performed to divide data into test runs (for calculating classifier and spatial filters) and test data, some patients able to achieve very high accuracies.



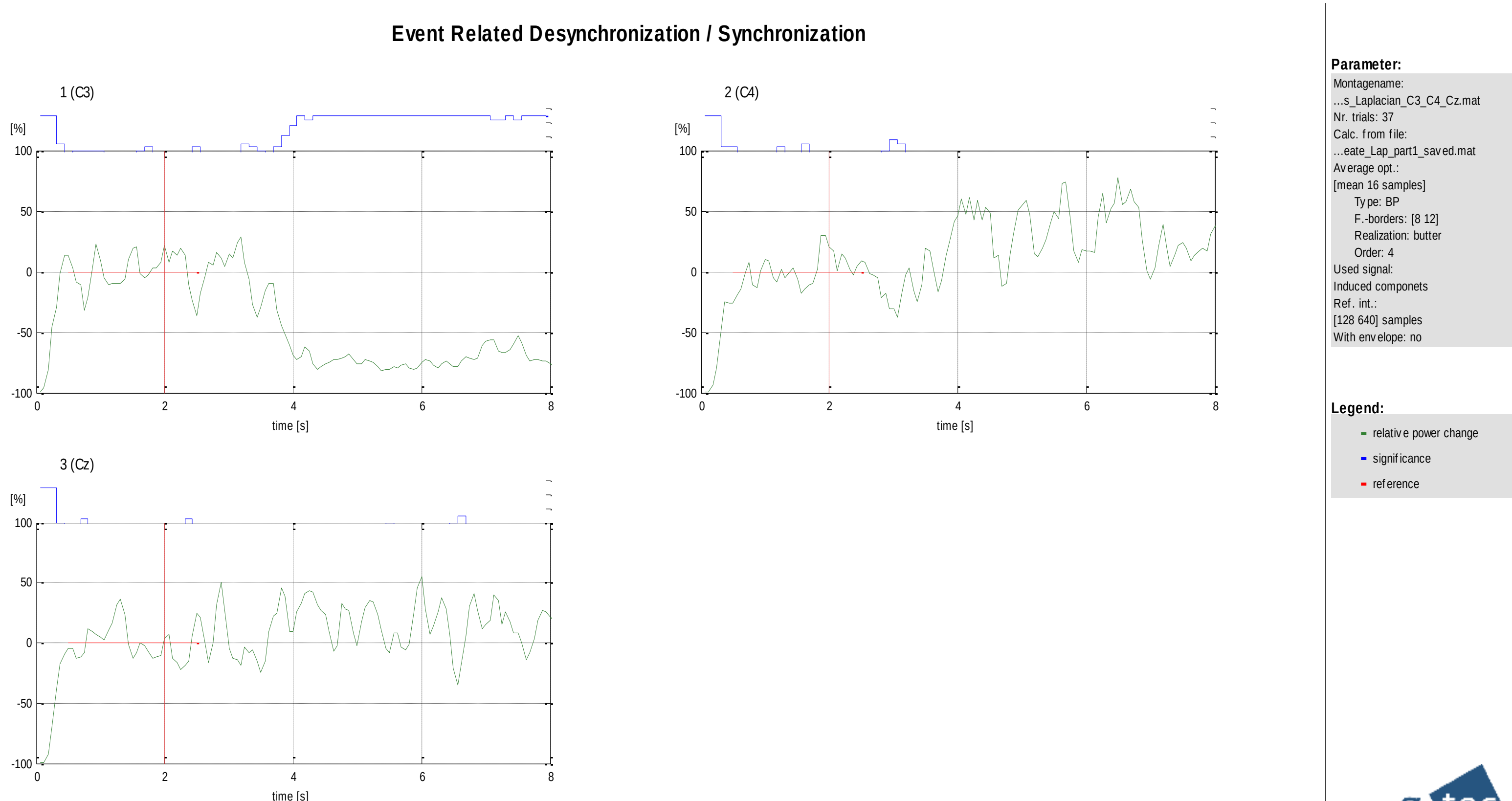


Min. Error = 2.5%
Mean Error = 14.5% (from second 5 to
Number of trials = 80
Alpha = 0.05
Confidence level = 38.6%

Calculating ERD over time

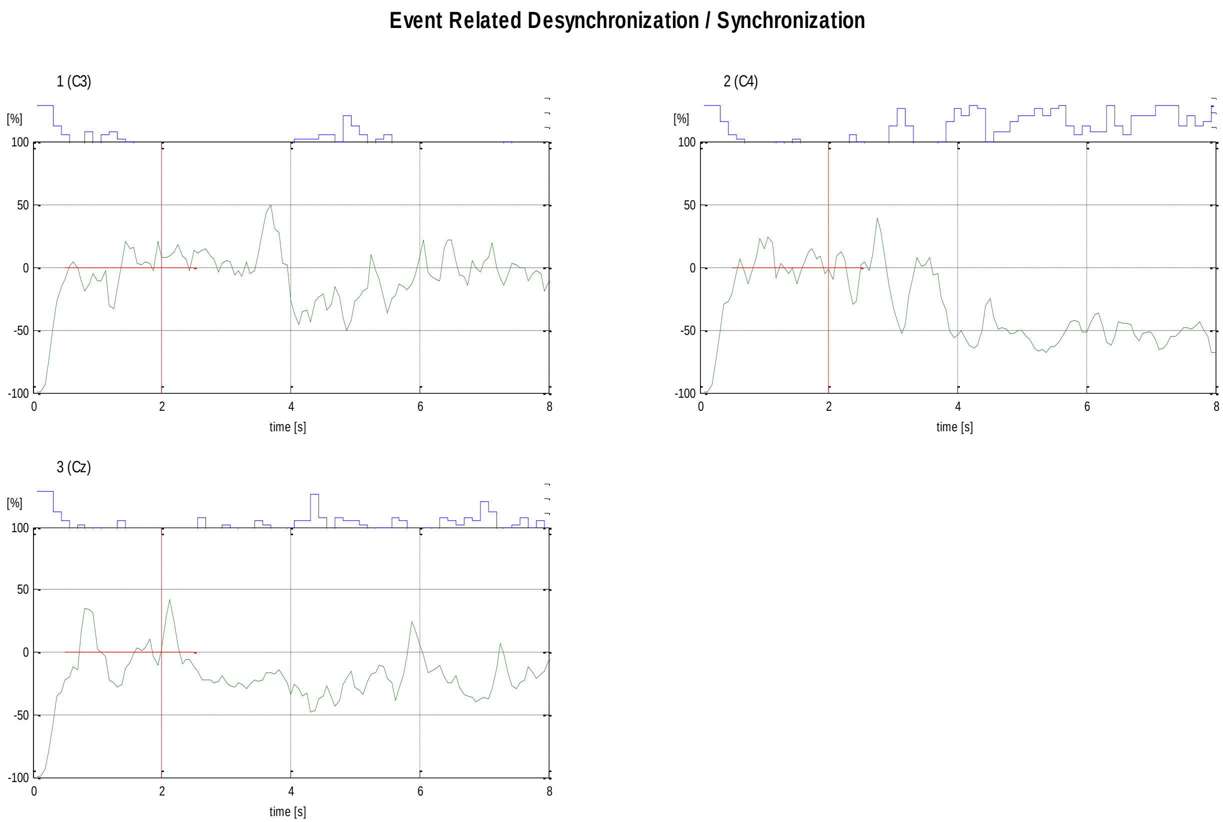
? ERD in stroke survivors is significantly lower

Right trials – good performer



Calculating ERD over time

Left trials – good performer



Parameter:

Montagename:
...s_Laplacian_C3_C4_Cz.mat
Nr. trials: 34
Calc. from file:
...eate_Lap_part1_saved.mat
Average opt.:
[mean 16 samples]
Type: BP
F.-borders: [8 12]
Realization: butter
Order: 4
Used signal:
Induced componets
Ref. int.:
[128 640] samples
With envelope: no

Legend:

- relative power change
- significance
- reference

Next Steps

g.REHAbci with robotic feedback

Lectures

for training & teaching

g.tec introduces lectures for biosignal recording and analysis. They are divided into a first part which contains the theoretical background, hands-on examples and several tasks to solve and a second part which contains only the solutions for the tasks. The lectures allow researchers to get a quick start in the specific field and to perform already state of the art experiments after just a few hours. The lectures are also perfectly suited for teaching because of the separation of tasks and solution manuals.

	LECTURE 1: THE ELECTROENCEPHALOGRAM	LECTURE 2: THE BRAIN-COMPUTER INTERFACE	LECTURE 3: THE ELECTROCARDIOGRAM	LECTURE 4: EVOKED POTENTIALS
Average time to perform the lecture:	450 min	465 min	700 min	330 min
Pages of lecture:	47	89	58	65
Pages of solutions for lecture:	24	28	71	24

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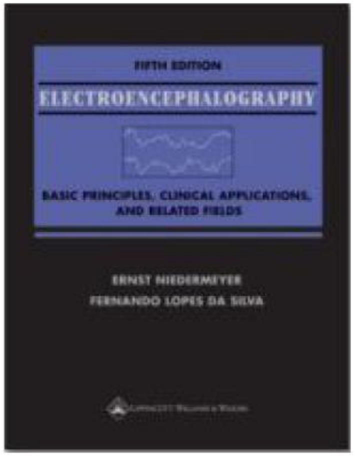

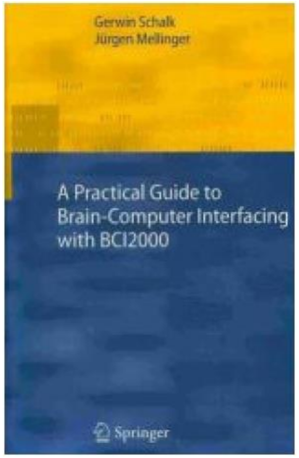

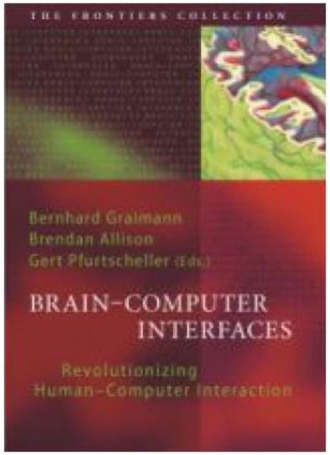

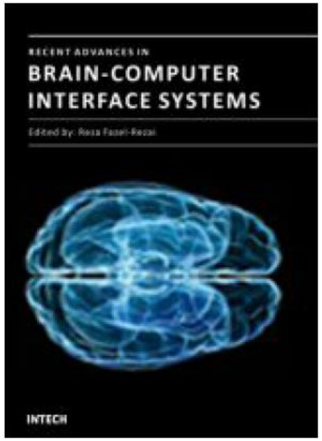

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