Brain Computer Interface for communication and control

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Human computer interfaces

- In the classical Star Wars third movie (the return of Jedi) Darth Vader reveals a connection between his neural system and the computer

- Today, such high level of integration between man and machine seems really yet too far from the common practice

Overview of the presentation

- ☞Definition of a Brain Computer Interface
- ☞Principal neurophysiological signals that can be used to do the job
- ☞The most active research groups in the BCI field and their achievements
- ☞Future trends

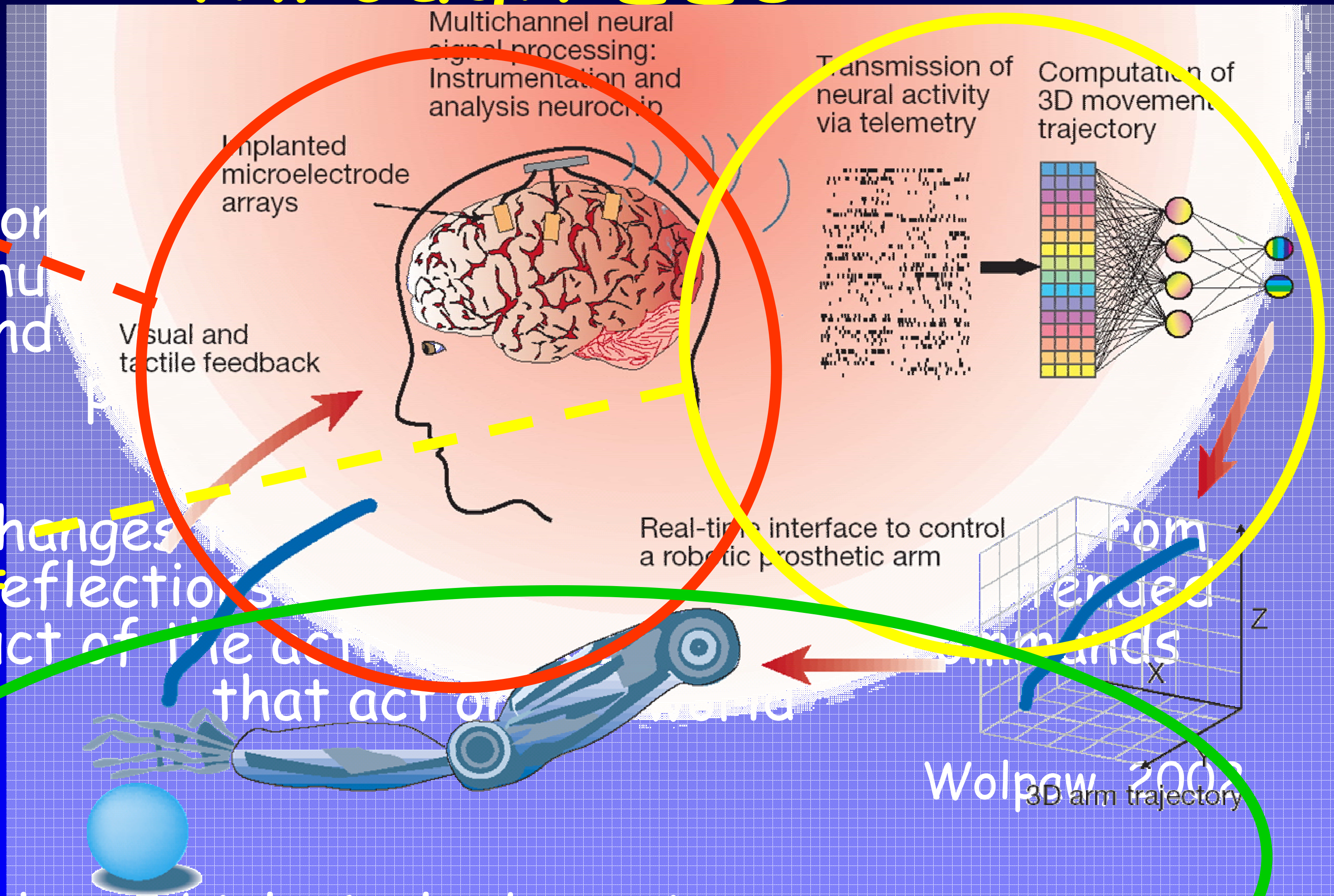
Nicolelis, Nature 200

Brain-Computer communication through EEG

Acquisition or estimation of the cortical activity

Actuation in the real world

Processing and classification of cortical signals



Wolpaw, 2002

☞ Feedback and biological adaptation

Nicolelis, Nature 2001

The most downloaded paper from Clinical Neurophysiology

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Clinical Neurophysiology 113 (2002) 767–791

www.elsevier.com/locate/clinph

Invited review

Brain–computer interfaces for communication and control

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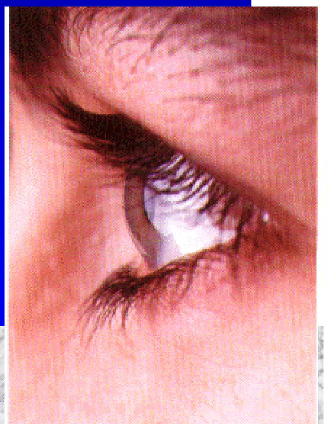
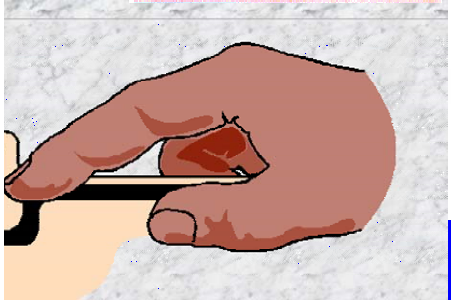
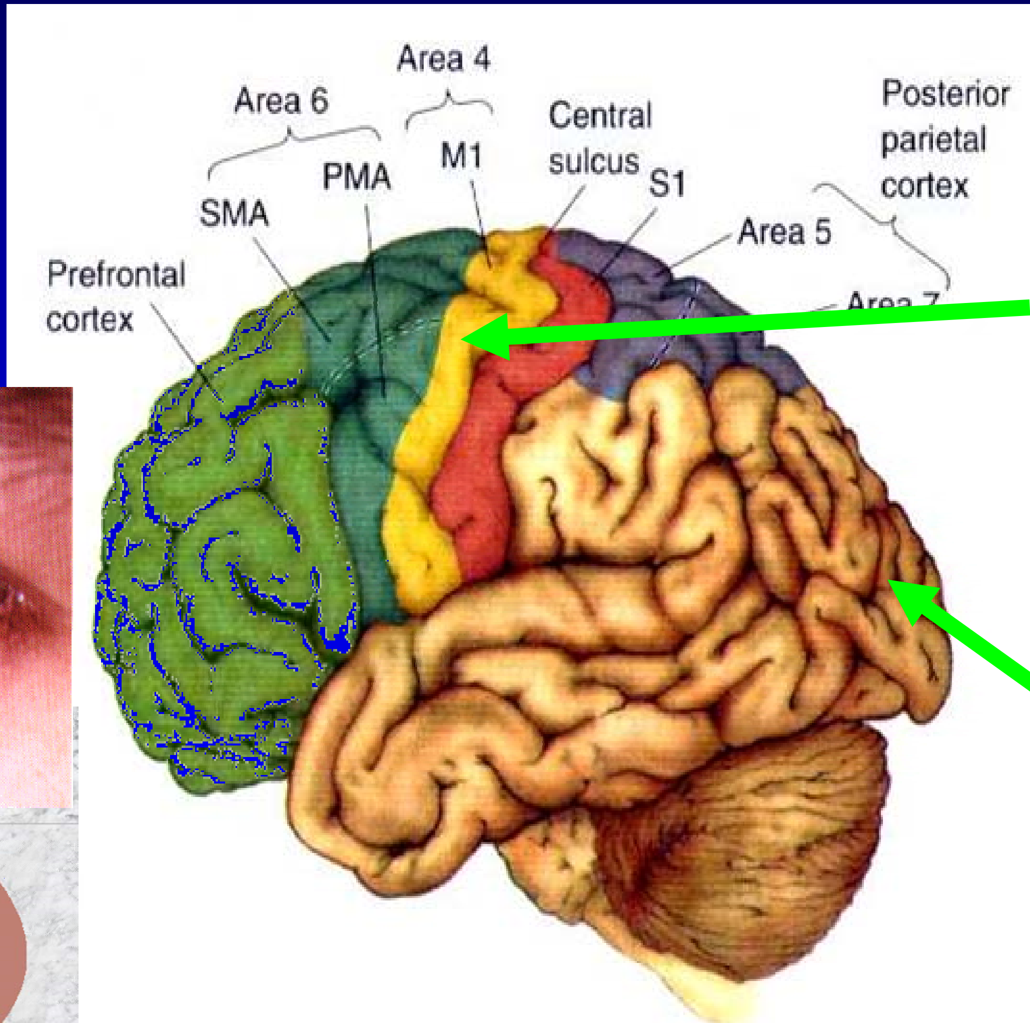
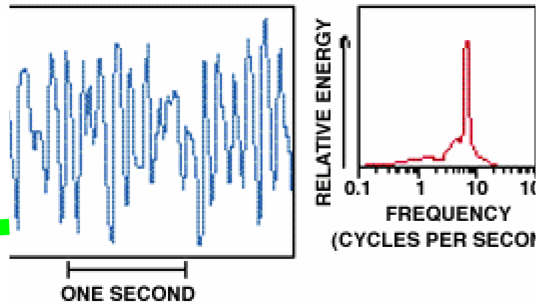
Variations of EEG waves are correlated with some mental states

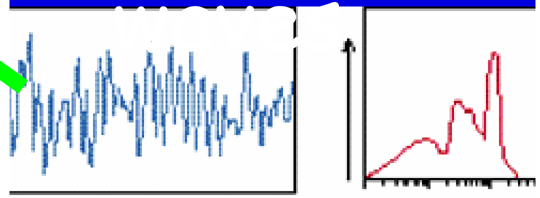






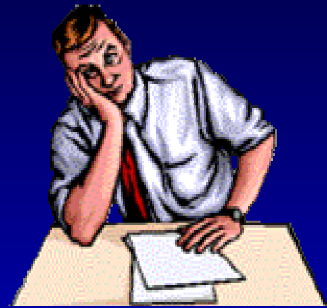


8-12 Hertz, mu EEG

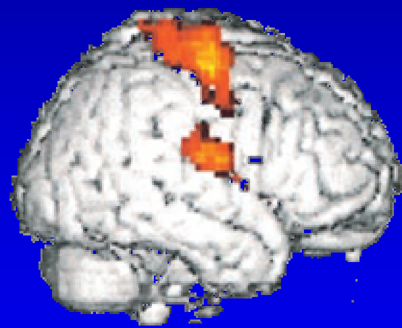


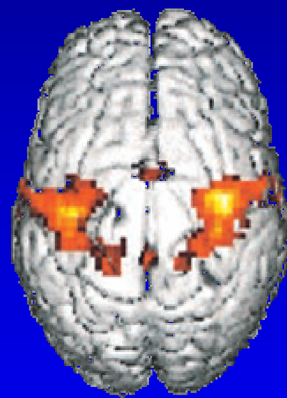
8-12 Hertz, alpha EEG waves

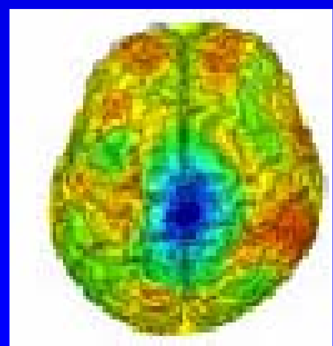
Movement-related thoughts elicited specific cortical patterns

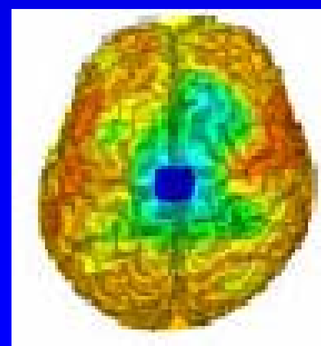


- ☞ Neuroscientific studies with fMRI have demonstrated that motor and parietal areas are involved in the imagination of the limb movements
- ☞ Several EEG studies have been also demonstrated that imagined movements elicited desynchronization patterns different for right and left movement imaginations



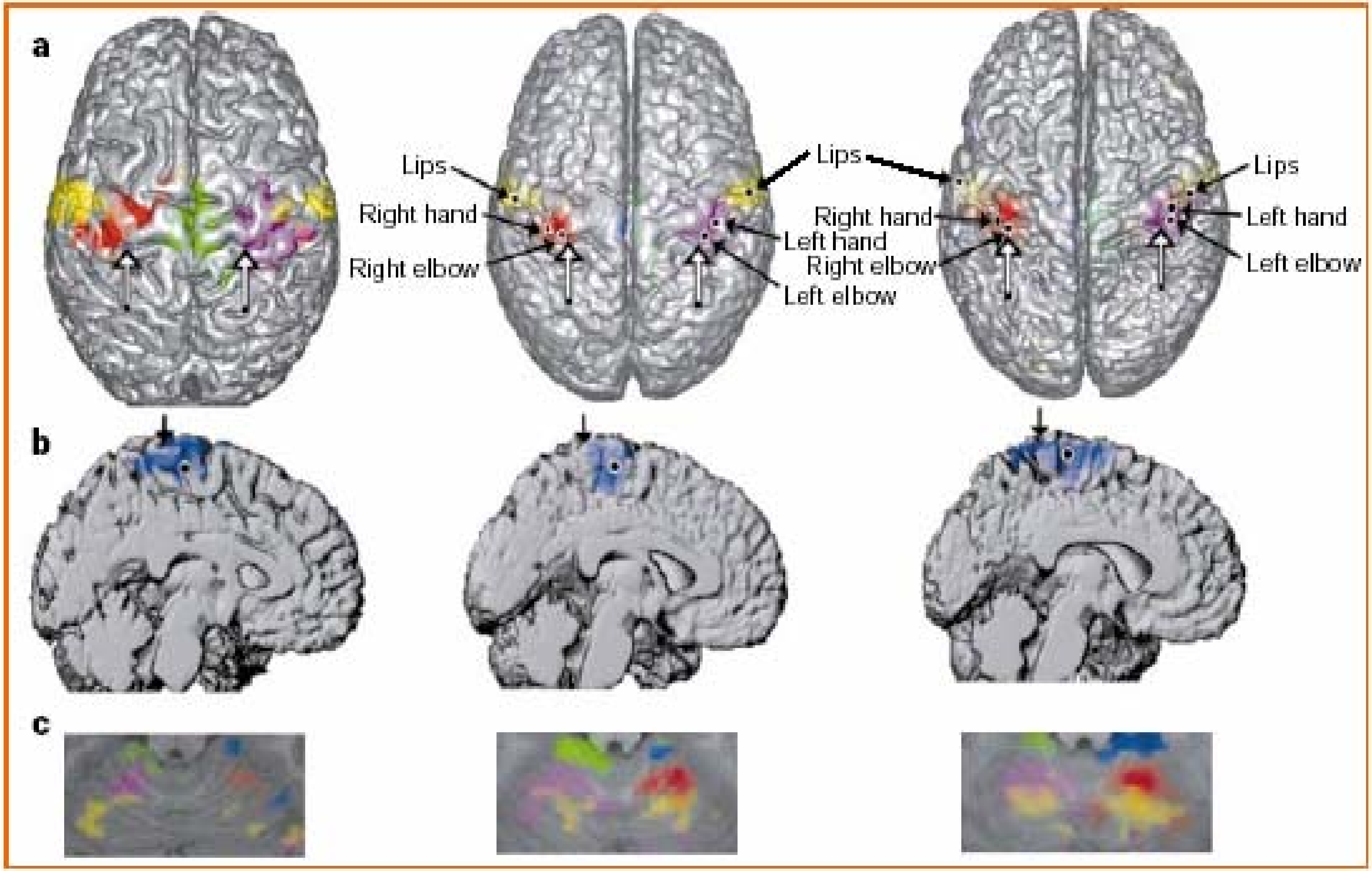






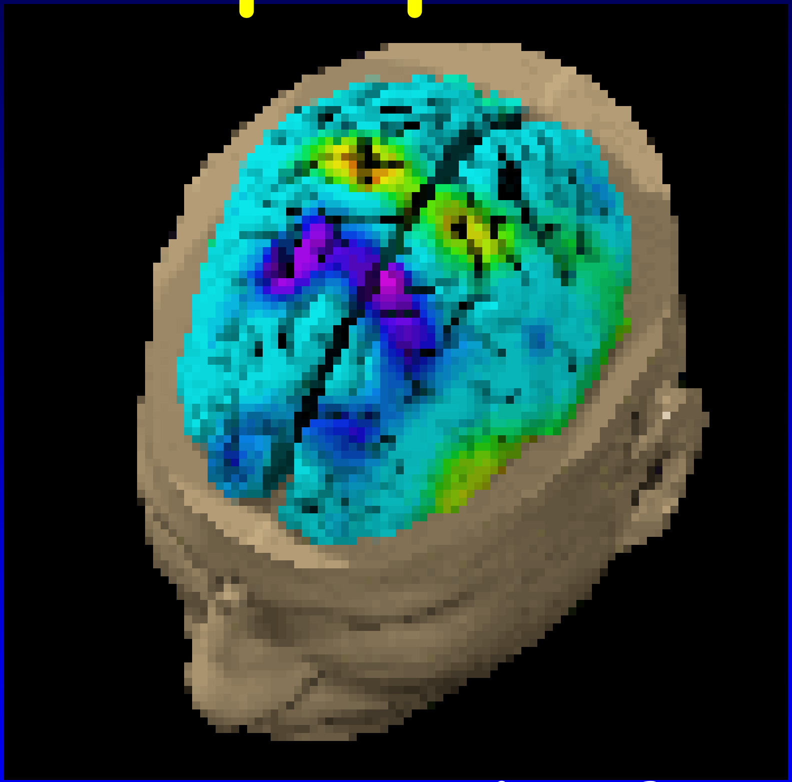
Imagined left movement Executed left movement

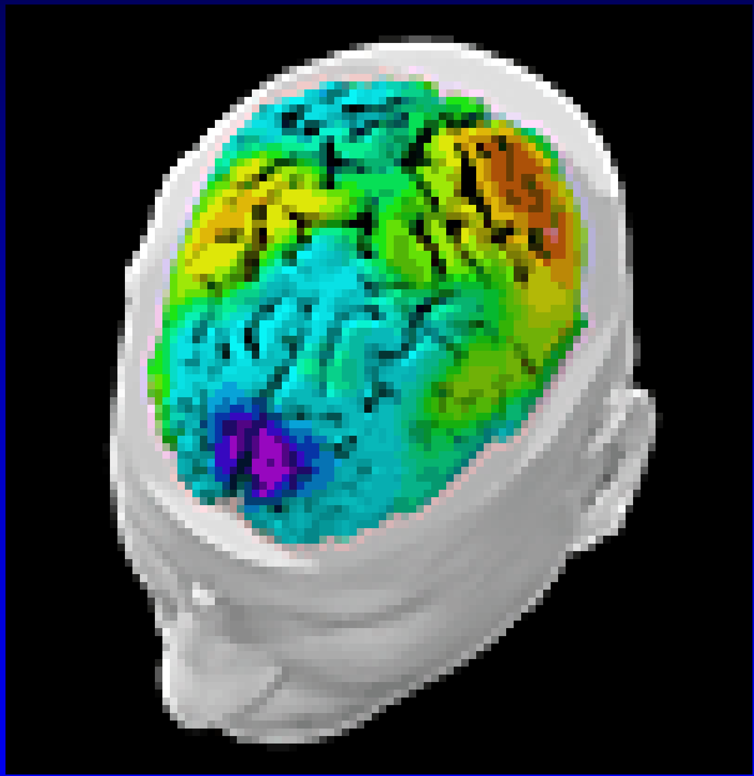
Motor cortical activity in tetraplegics



Shoam et al., Nature, vol 413, 2001

A closer look into the brain dynamics underlying the movement preparation and execution





MRPs Right finger movement alpha ERD

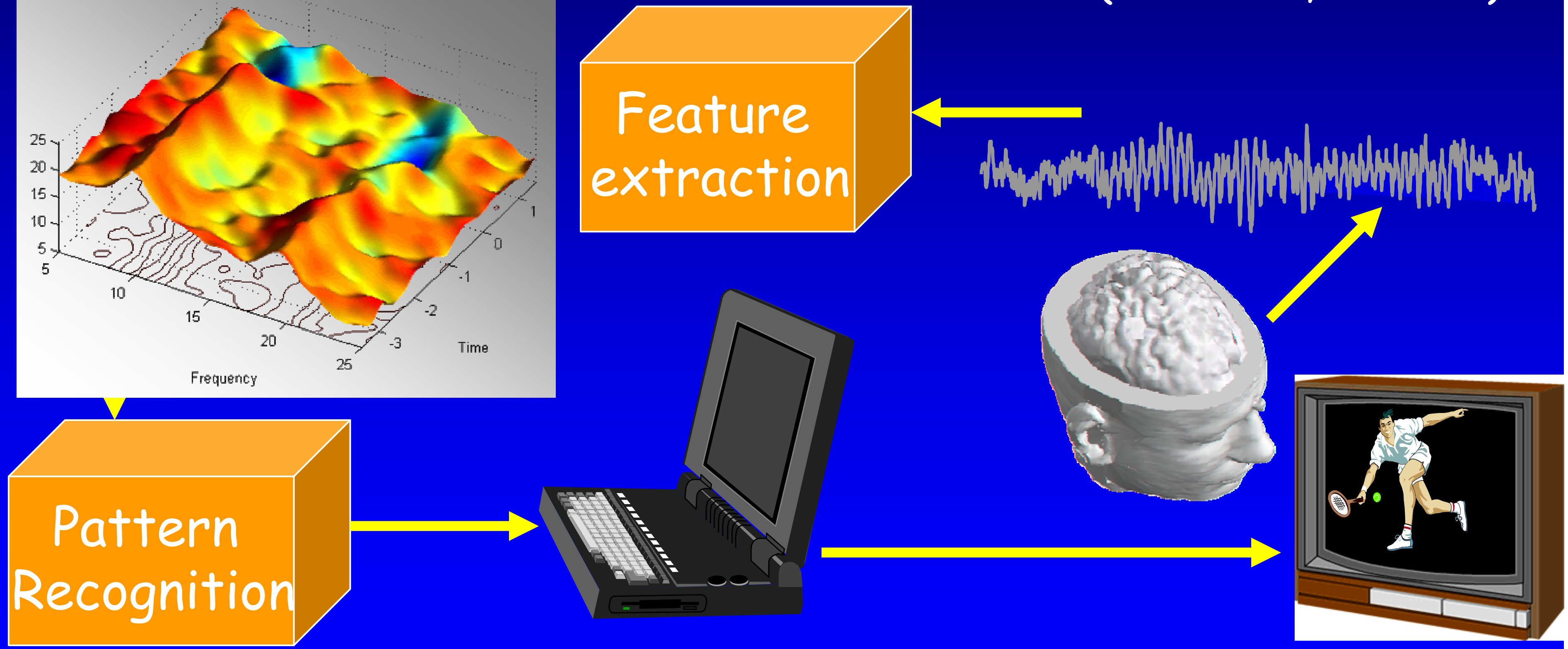
From –1 before (movie start) to +0.1 sec post-movement

Where: centro-parietal scalp area

On the use of neurophysiological signals to control devices

- Time-dependent features
  - Times series values
- Frequency dependent features

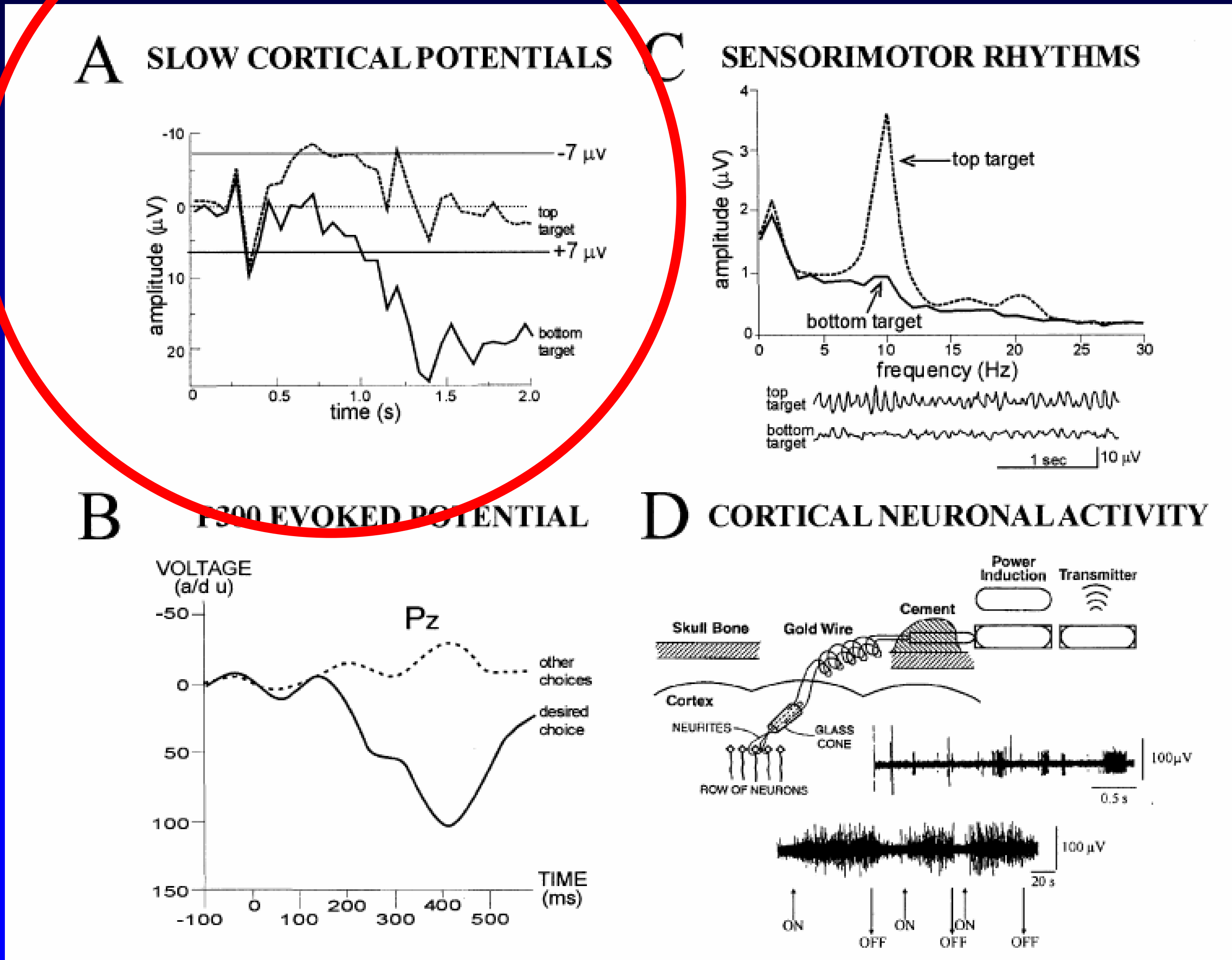
EEG, EMG, EOG
- Quality of sensors
- SNR (EMG >>10, EEG $\approx$ 1)



- LDA, MDA
- Non linear classifier

Actuators

Present-days BCIs



Threshold classifiers for the Brain Computer Interface (Tubingen)

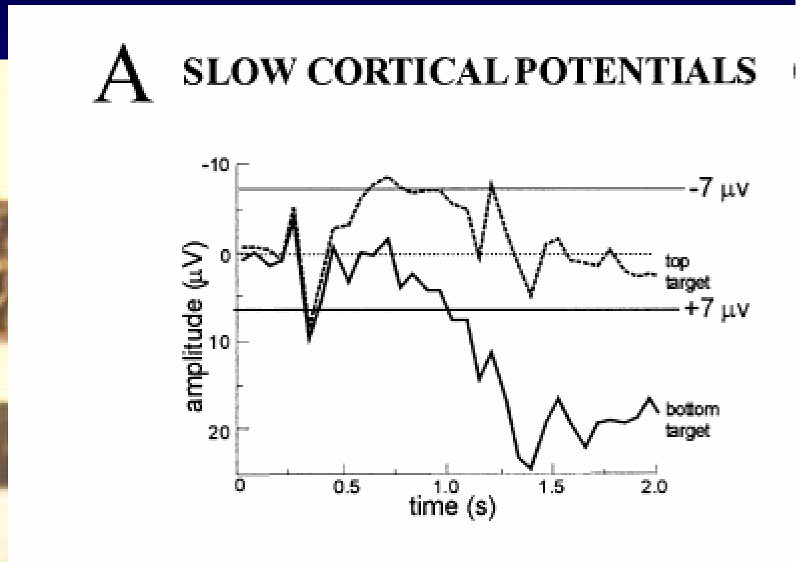
Eberhard Karls
Universität
Tübingen

Institute of Medical Psychology and Behavioural Neurobiology
Department chair: Prof. Niels Birbaumer

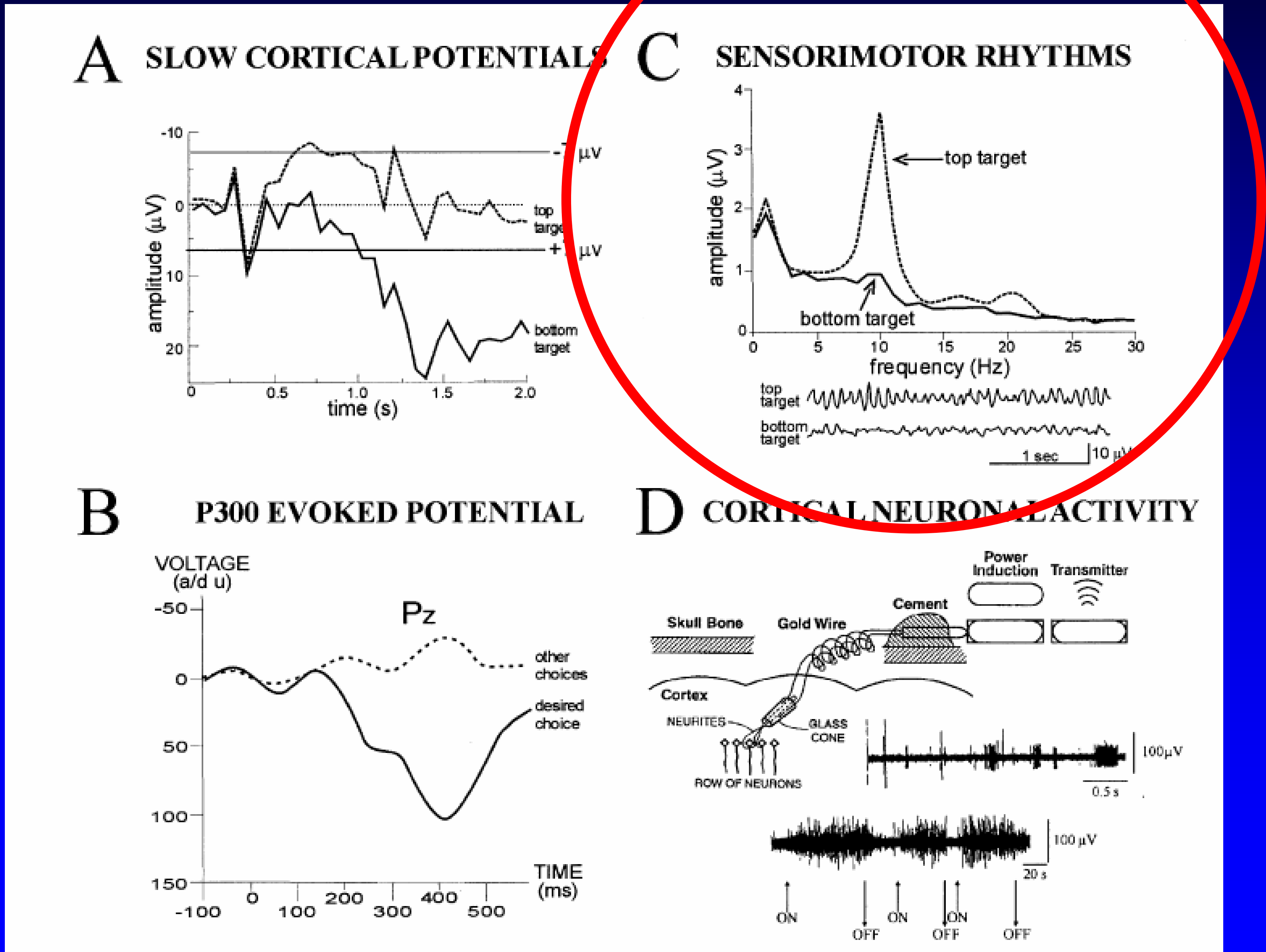
Dr. Andrea Kübler - biologist

Nicola Neumann - psychologist
Slavica Coric - assistant
Dr. Thilo Hinterberger - physicist
Dr. Jochen Kaiser - psychologist
Dr. Boris Kotchoubey - psychologist, physician
Dr. Jouri Perelmouter - mathematician

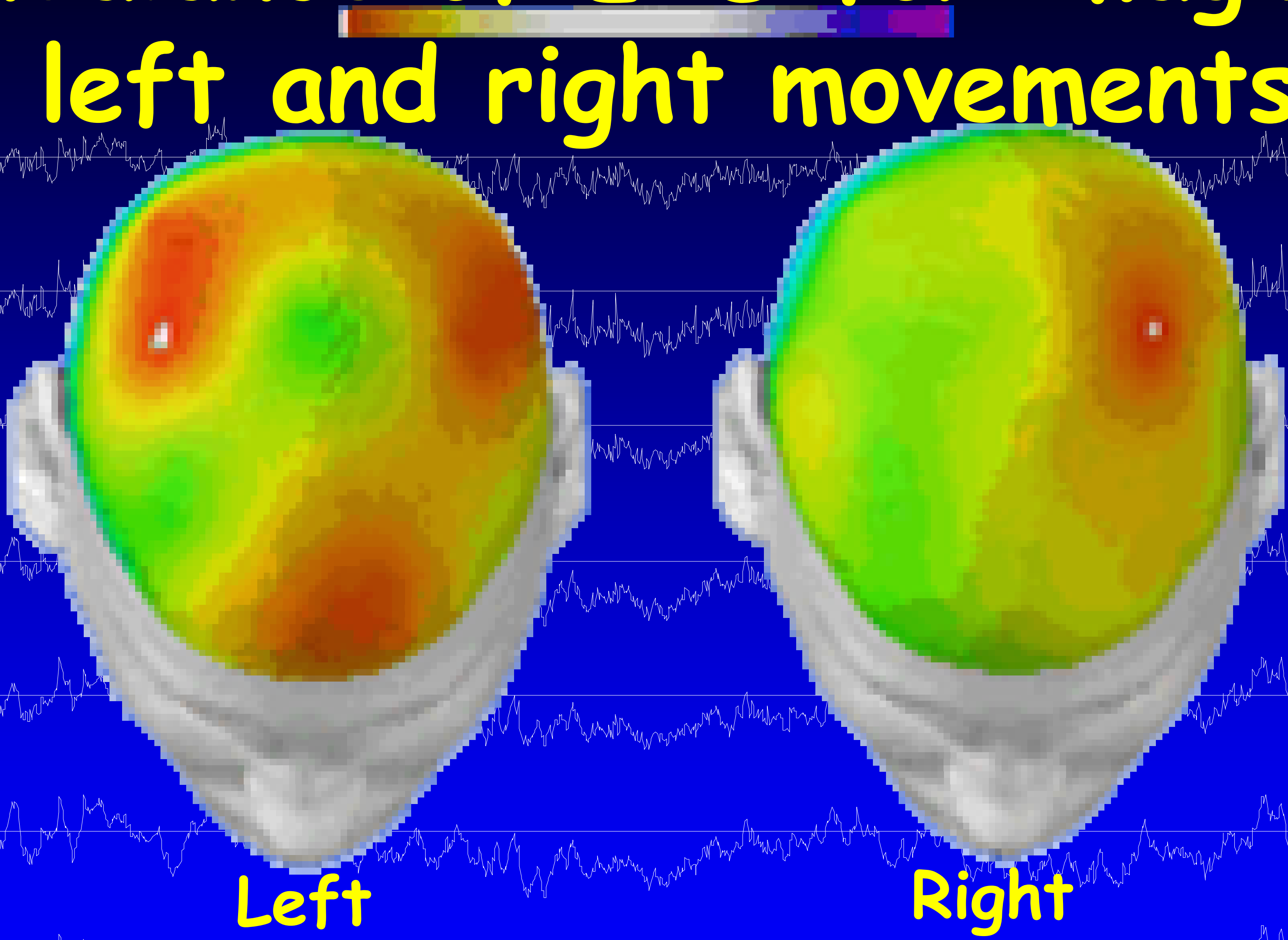
Patient HPS using the Thought Translation Device

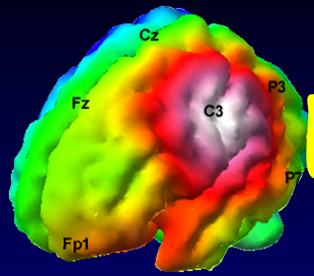


Present-days BCIs



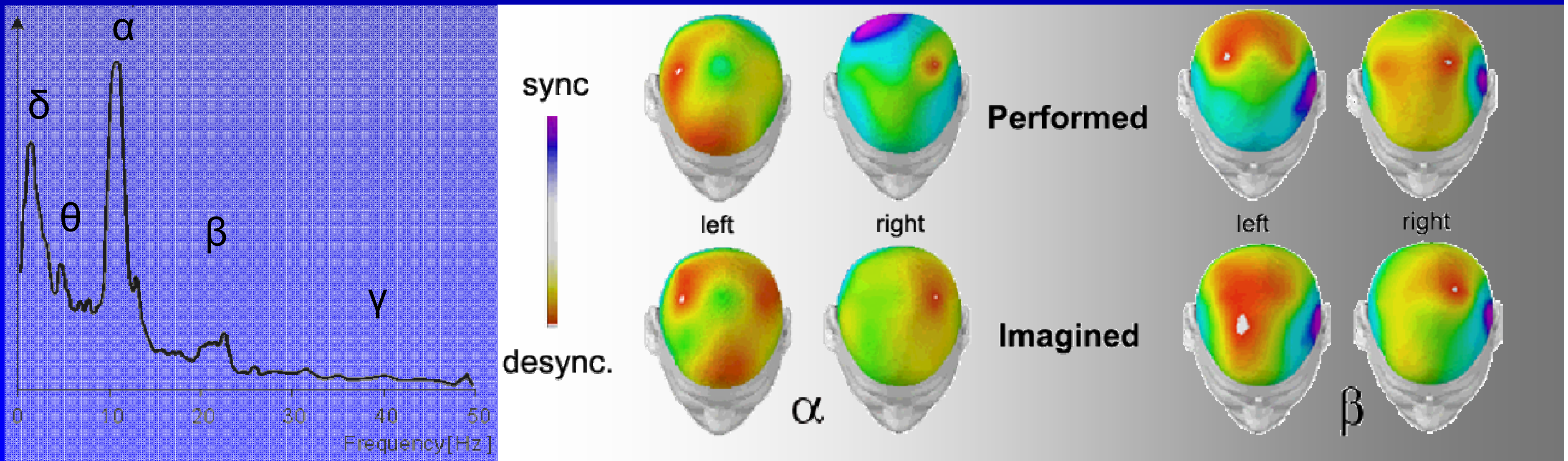
Unbalance of ERD for imagined left and right movements





EEG patterns related to cognitive tasks

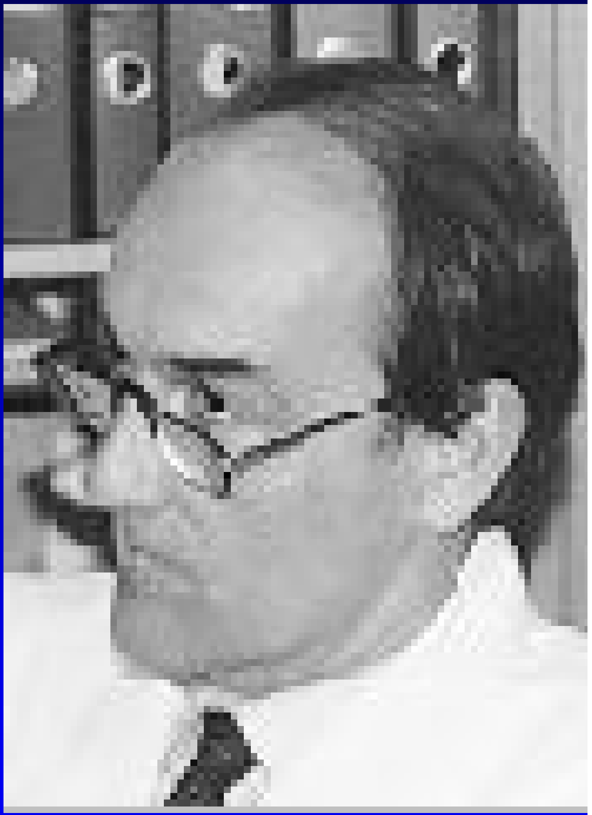
- Power spectrum increase/decrease of EEG data recorded when subject imagines or performs a movement of his middle finger.



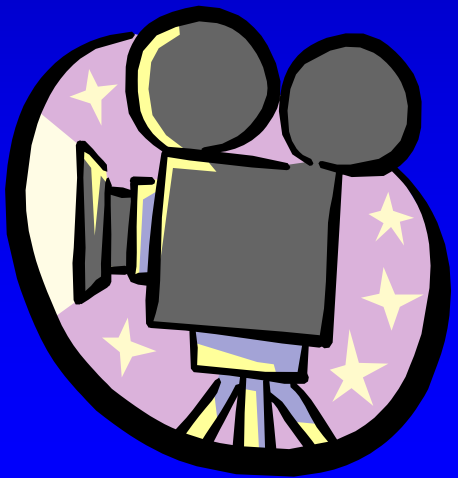
Babiloni et al., IEEE Tr. Rehab. Eng., 2000

Brain Computer Interfaces at the Graz University

Prof. Gert Pfurtscheller



Mu-rhythms pattern recognition by linear and non linear classifiers



The Adaptive Brain Interface

Maria Grazia Marciani
Donatella Mattia
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Josep Mouriño
Marco Franzè

JOINT RESEARCH CENTRE
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Markus Varsta
Jukka Heikkonen
Kimmo Kaski

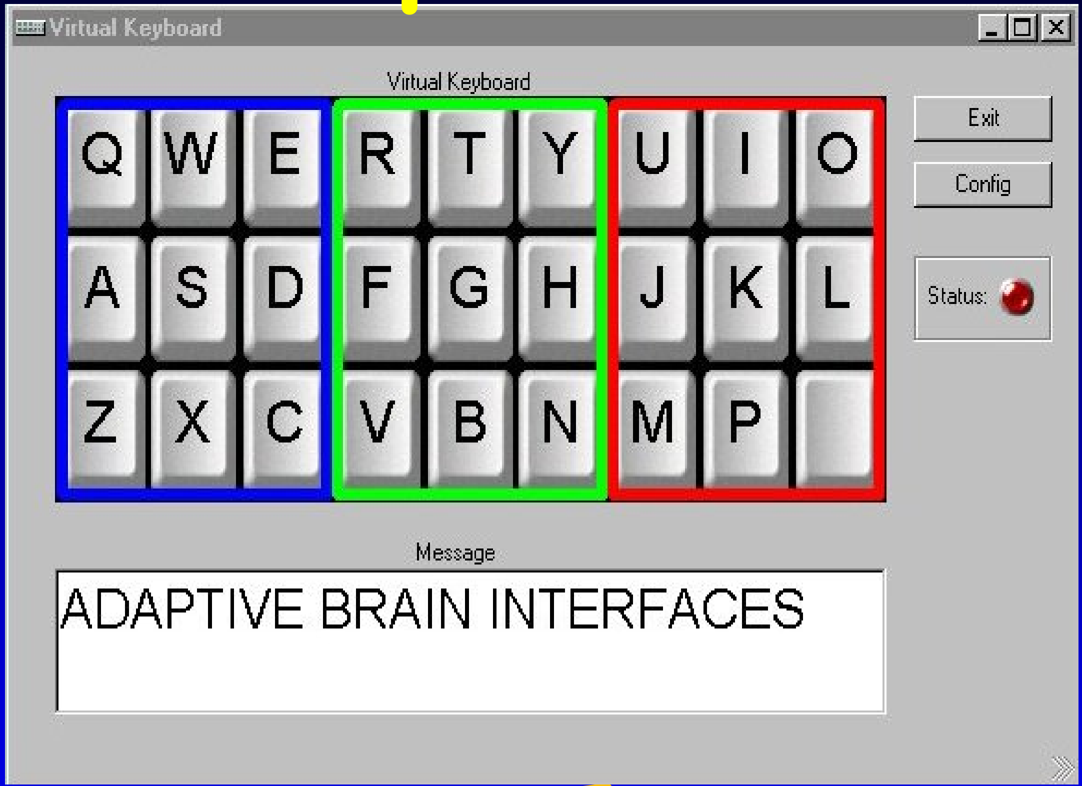
Fabio Topani
Adriano Palenga
Fabrizio Grassi

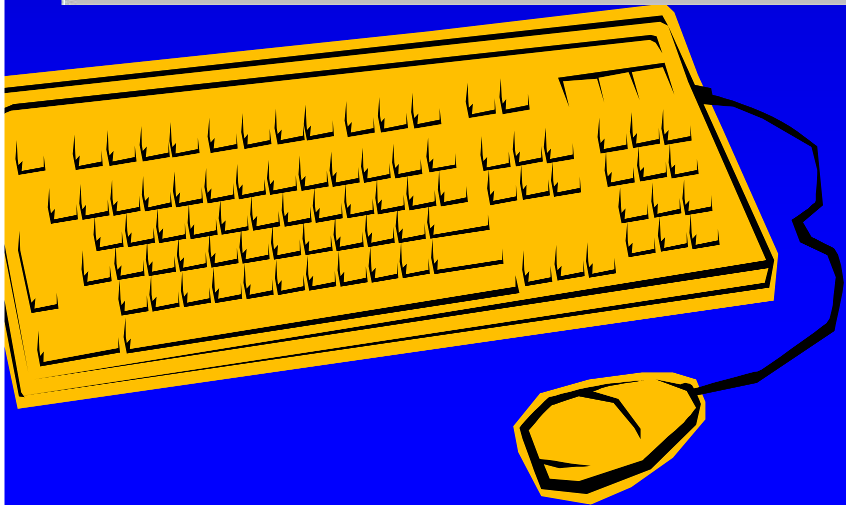
fase Sistemi Srl

ABI Training

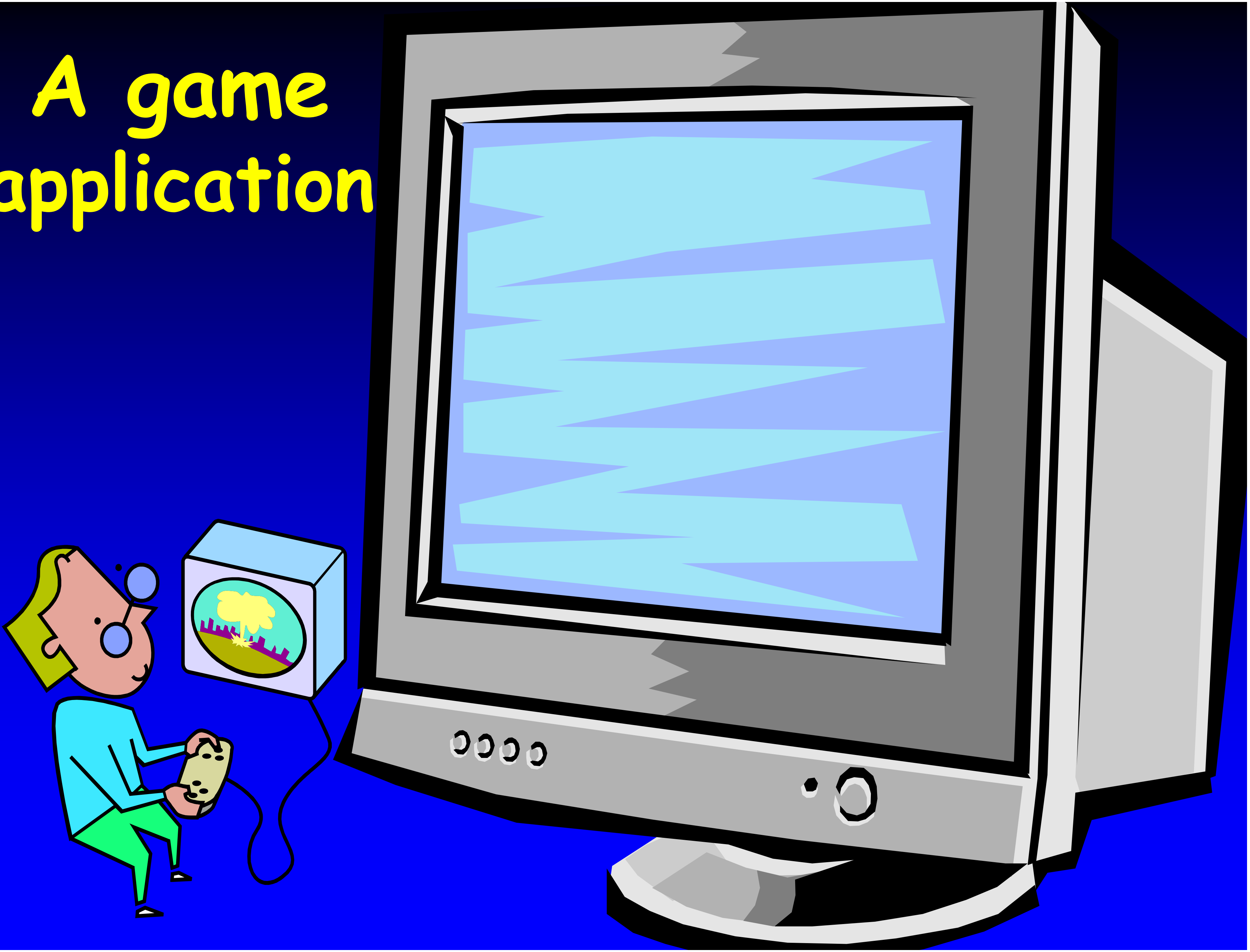
6.40-7.30

Brain-operated Virtual Keyboard





A game application



Finalist to the Descartes prize 2001

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The Descartes Prize

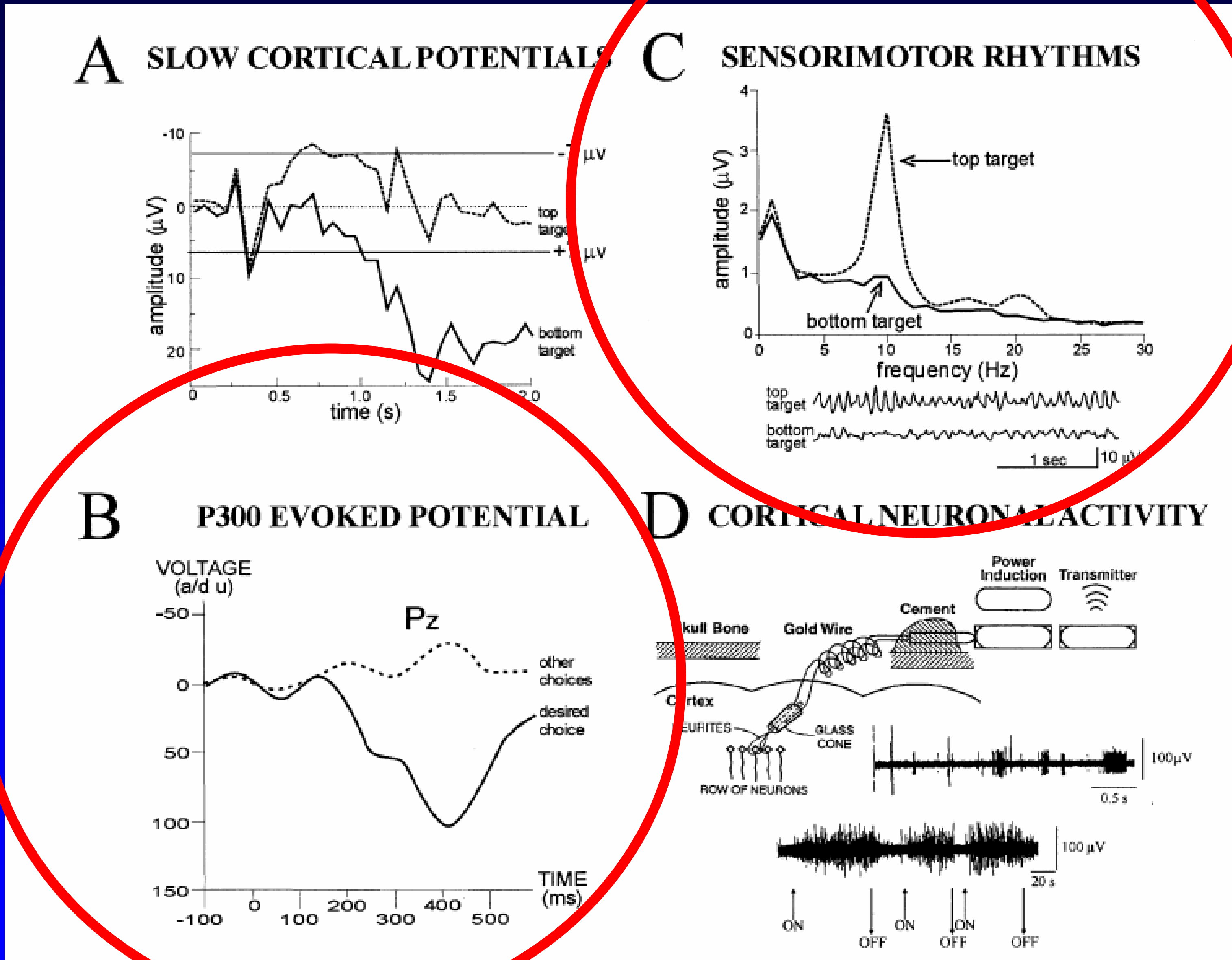
The Descartes Prize 2001 > Finalists 2001 > Adaptive brain interfaces (ABI)

Adaptive Brain Interfaces (ABI)

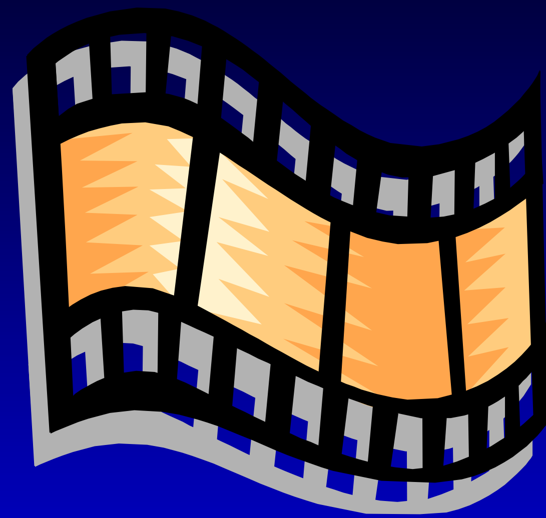
The Motivation

In today's fast paced world, information and communication technologies are dramatically transforming our society. Access to new emerging technologies can be taken for granted. Unfortunately, not everyone can enjoy their benefits on equal terms. People with severe physical disabilities are practically excluded. But, what if they could communicate their wishes or control electronic appliances merely by thinking? This is promise of the ABI project (http://sta.jrc.it/abi) that aims at augmenting human capabilities by enabling people to interact with computers through conscious control of their thoughts after a short training period.

Present-days BCIs

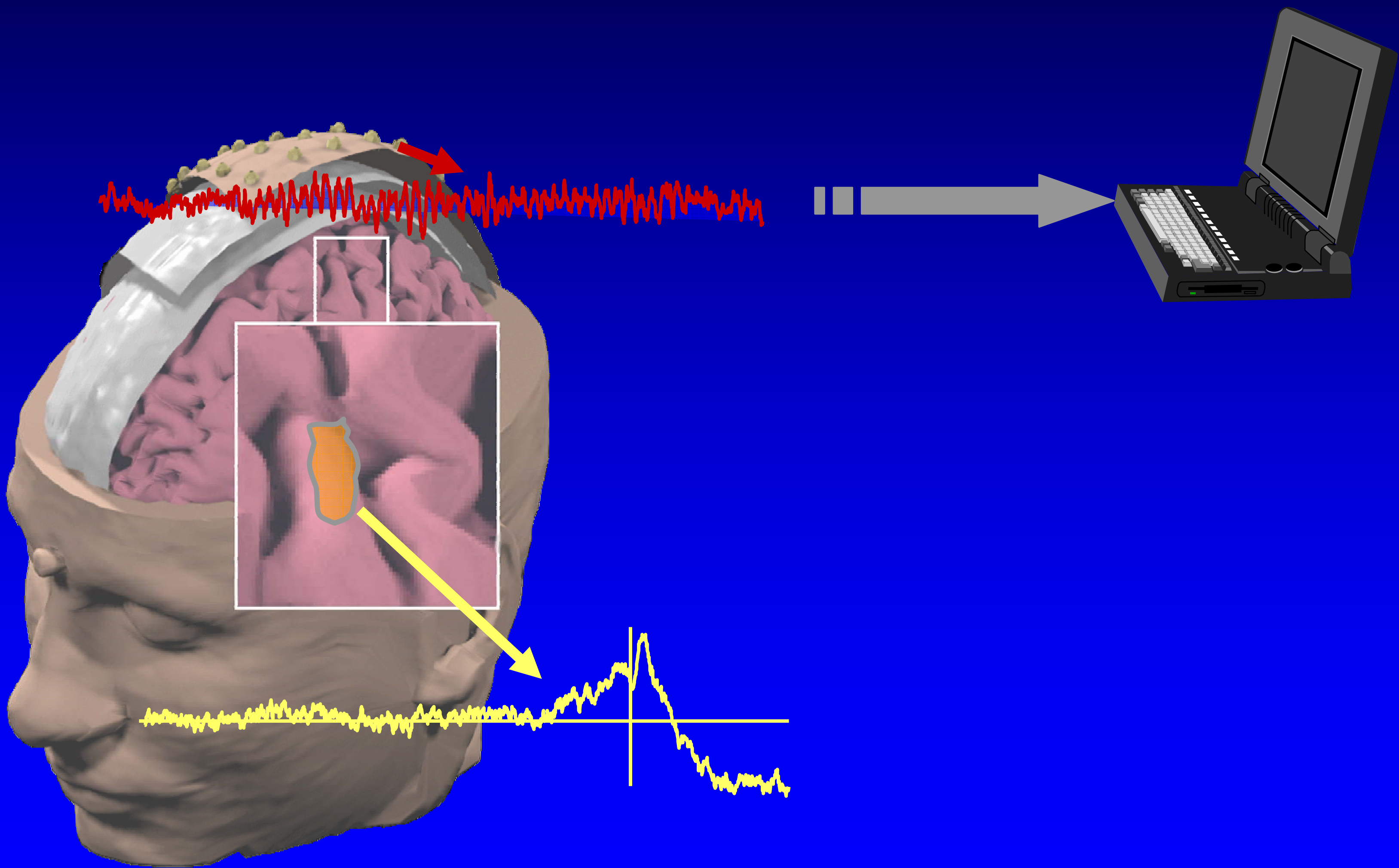


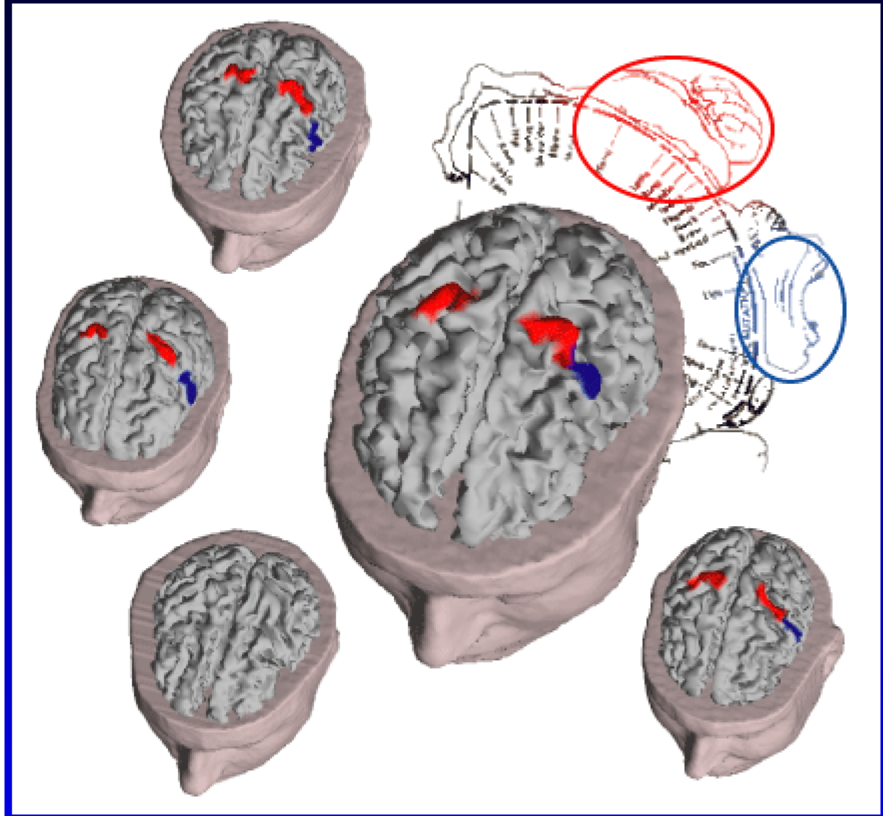
Wolpaw's Wadsworth Center

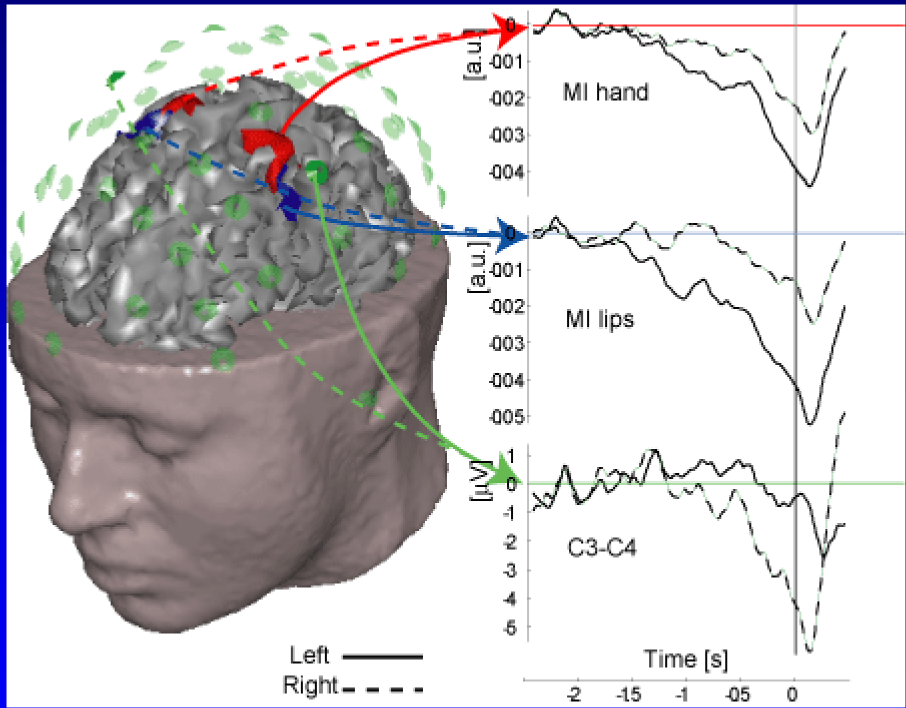


- Spelling device (2.25)
- Aid screen
- P300 spelling device

BCI controlled by estimated cortical activity



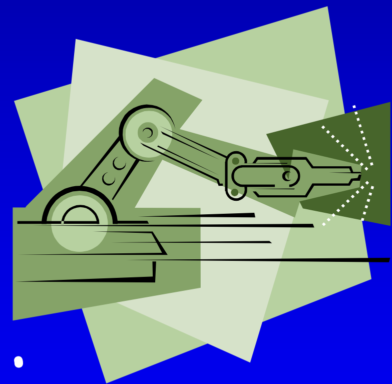




MI hand
MI lips
C3-C4
[a.u.]
0
-001
-002
-003
-004
-005
[µV]
1
0
-1
-2
-3
-4
-5
Left
Right
Time [s]
-2
-15
-1
-05
0

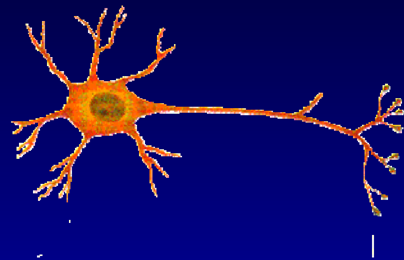
Future trends: increase awareness of controlled devices

- BCI is a slow communication channel
  - Best performance with virtual keyboard: 3 characters per minute

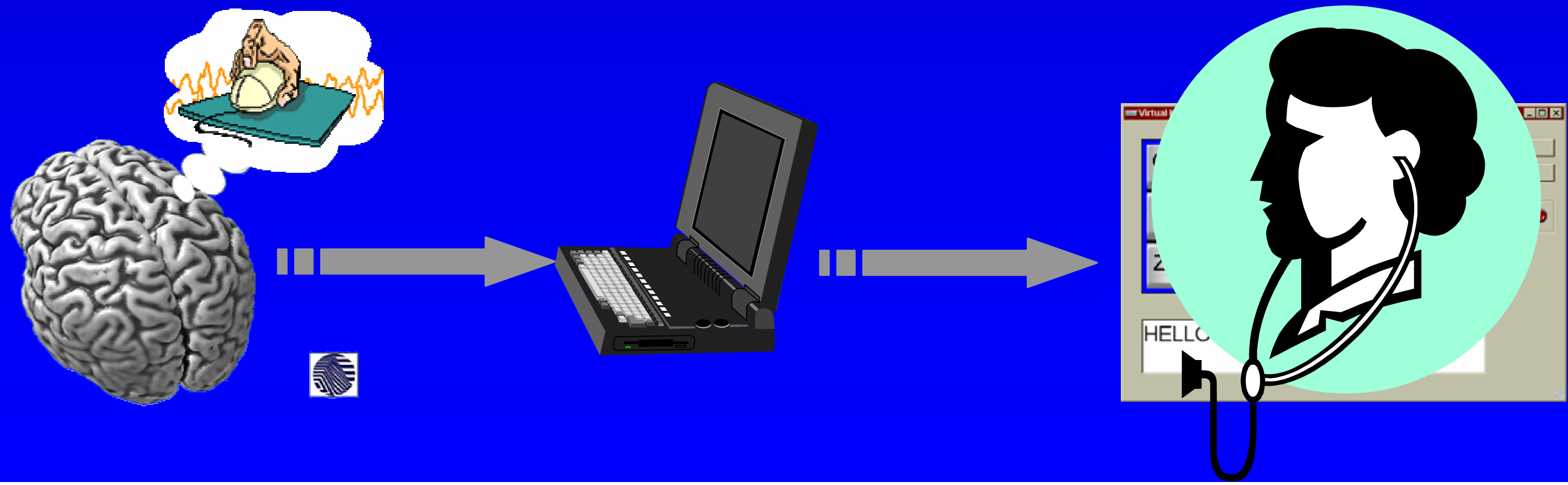


- Need for "smart" devices, e.g.:
  - T9 programs for SMS on cellular phones
  - Trajectory aware weelchairs or robotic arms

EEG Based BCI in rehabilitation



- Focus: degree of Autonomy
  - Partially restoring the abilities, mostly using alternative strategies
  - Communication aid-> Controlling device
- Focus: degree of Functional Recovery
  - Tuning of the rehabilitation actions to maximize level of recovery
  - Cortical plasticity->Rehabilitation device



Future trends

- Identification of those signals, whether evoked p[illegible]e[illegible]als, spontaneous rhythms, or neuronal firing rates, [illegible] best able to control independent of activity in c[illegible] motor output pathways;
- Development of training methods for helping users to gain and maintain that control
- Delineation of the best algorithms for translating these signals into device commands;
- Identification and elimination of artifacts such as electromyographic and electro-oculographic activity;
- Adoption of precise and objective procedures for evaluating BCI performance;
- Identification of appropriate BCI applications and appropriate matching of applications and users
- Attention to factors that affect user acceptance of augmentative technology, including ease of use, cosmesis, and provision of those communication and control capacities that are most important to the user