On the Use of Brain-Computer Interfaces Outside Scientific Laboratories: Toward an Application in Domotic Environments

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What a BCI is

"Brain–computer interfaces (BCI's) give their users communication and control channels that do not depend on the brain's normal output channels of peripheral nerves and muscles."

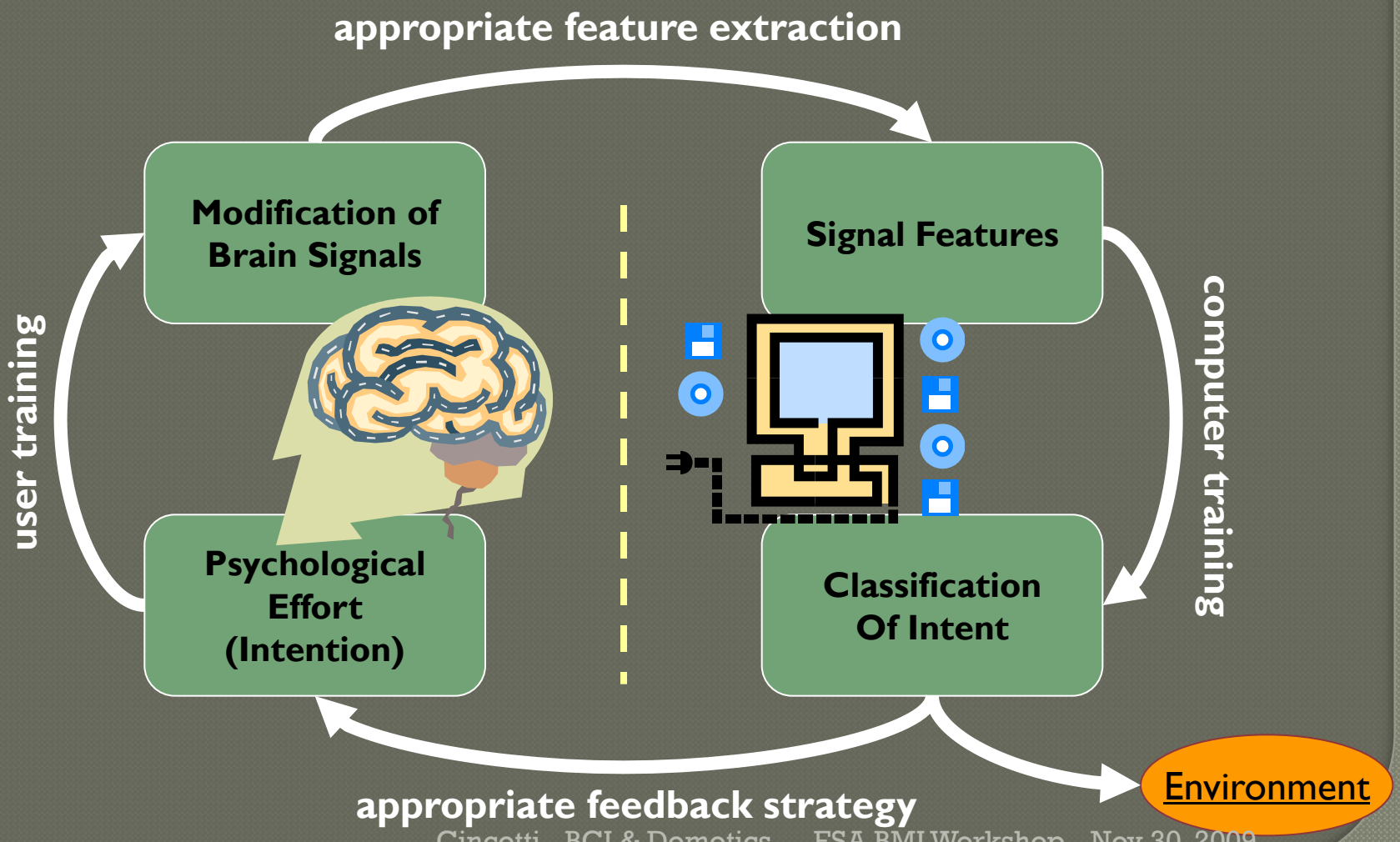
"A BCI changes the electrophysiological signals from mere reflections of CNS activity into the intended product of the activity: messages and commands that act on the world"

Wolpaw et al. 2002, clinph

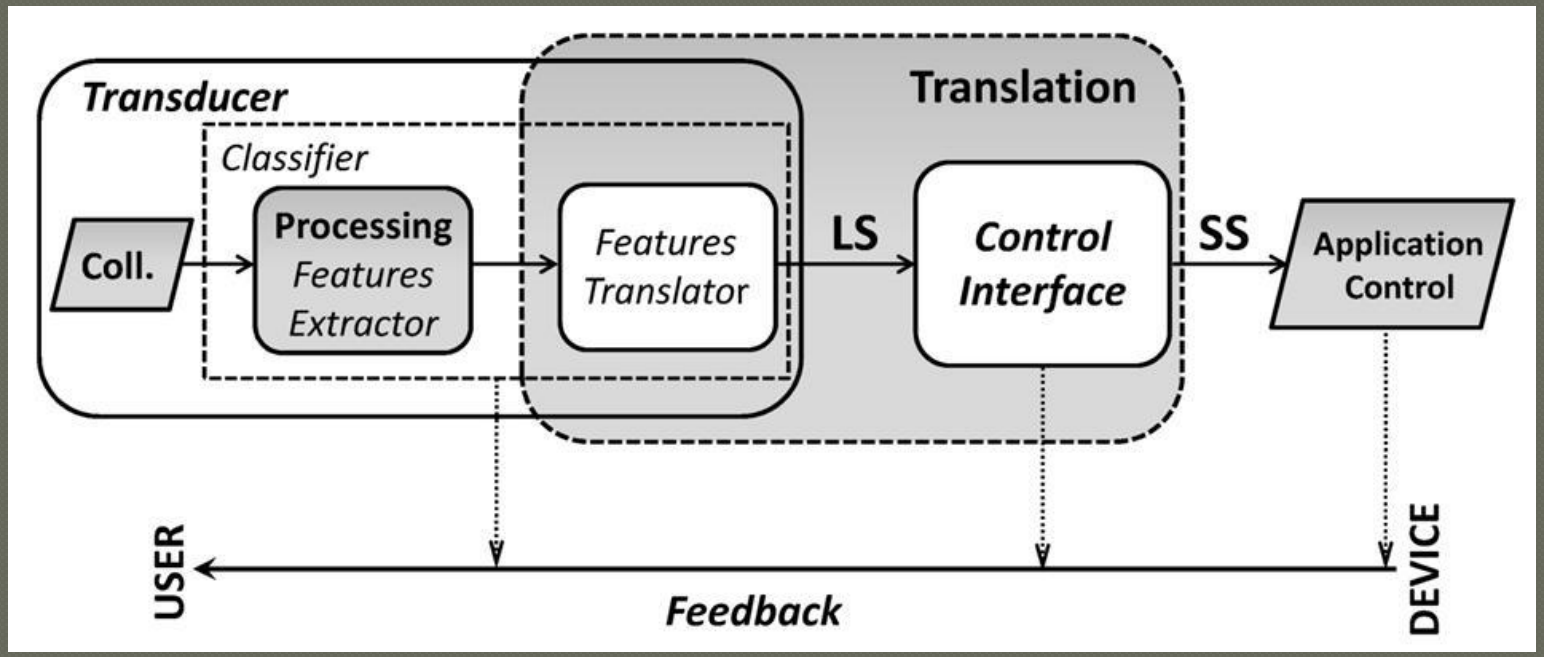
Goal of Brain-Computer Interface research is to provide:

- A new control option
  (to people with severe motor disabilities)
- Functions that normal muscular control can't address
  (to able-bodied people)

The model of BCI



The model of BCI (2)

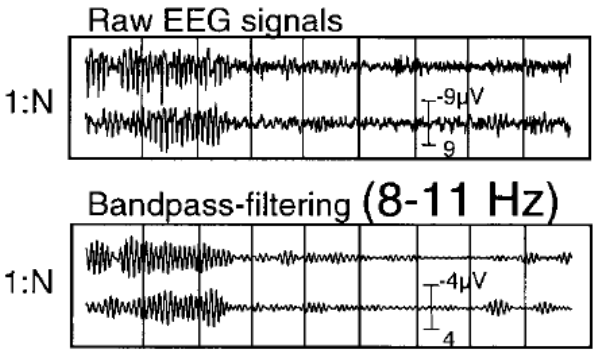


Detection of brain activity

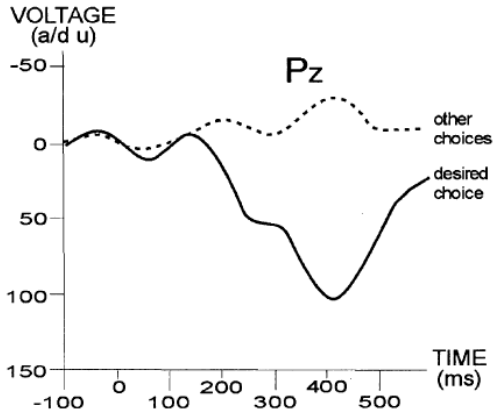
Detection of activity in the CNS

- Electrocorticography (ECoG), Intracortical potentials (microelectrodes), Depth Electrodes (SEEG), …
- Electroencephalography (EEG), Magnetoencephalography (MEG), Functional Magnetic Resonance Imaging (fMRI), Near Infrared Spectroscopy (NIRS), …

EEG features for BCIs

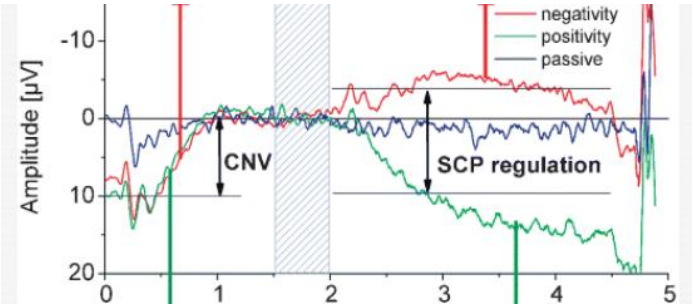


Detection of sensorimotor rhythms modulation

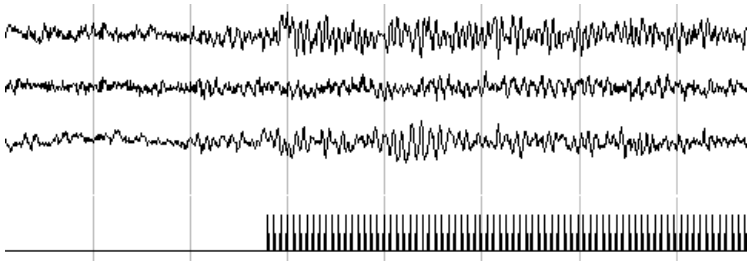


Detection of P300

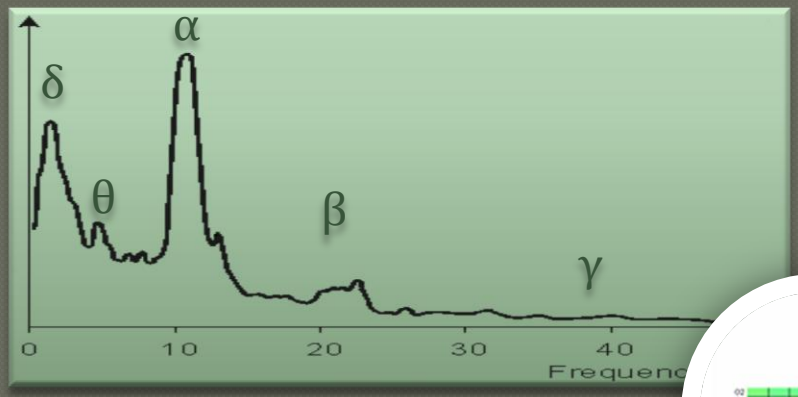
Detection of Slow Cortical Potentials

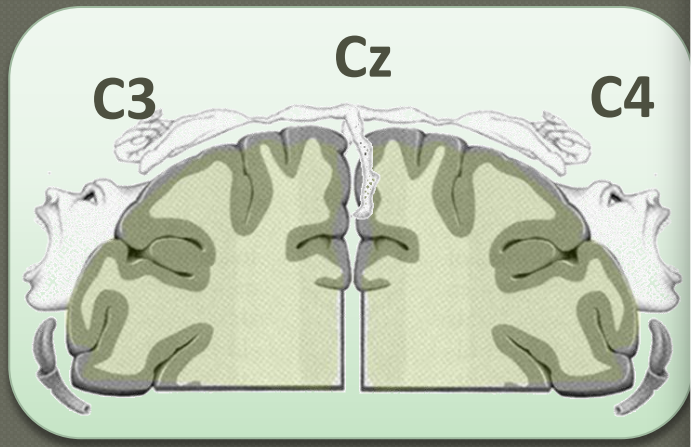


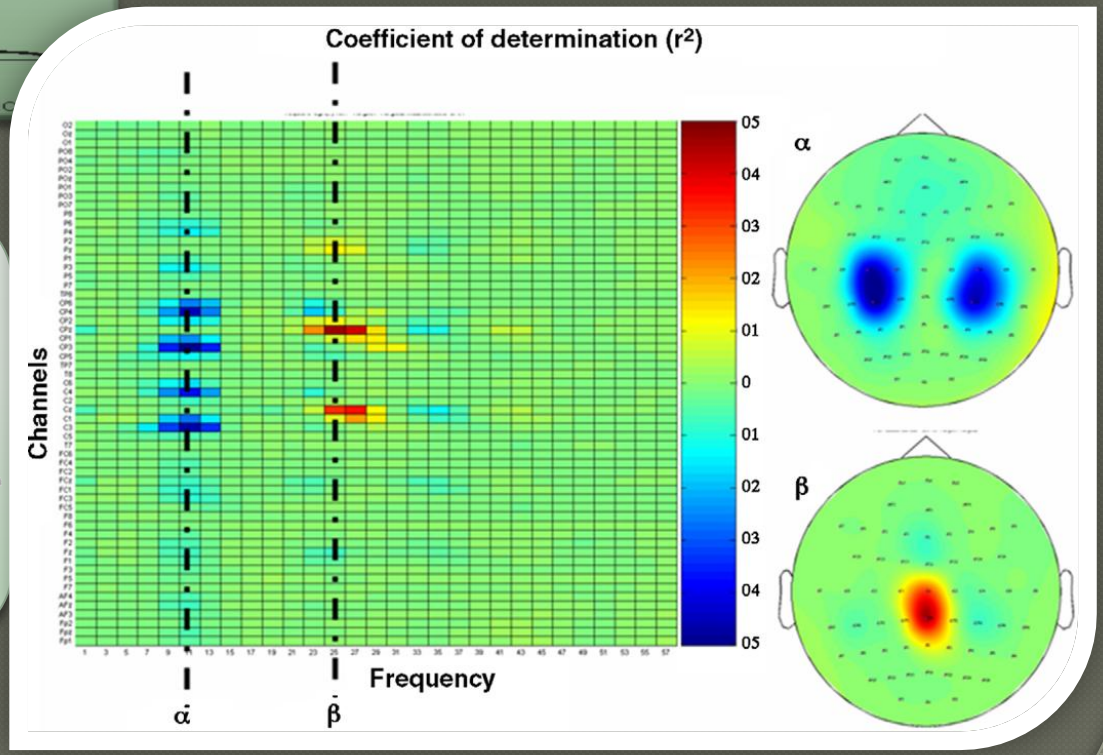
Detection of steady-state (V)EPs



Mu-Rhythm for BCI







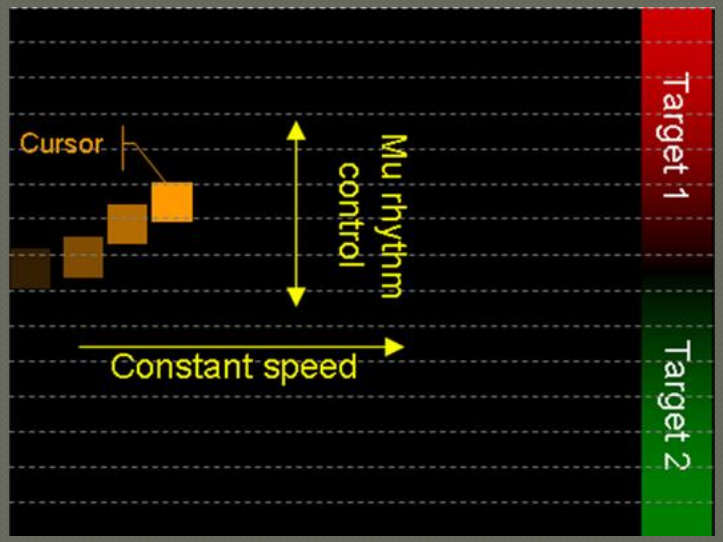
Cursor control

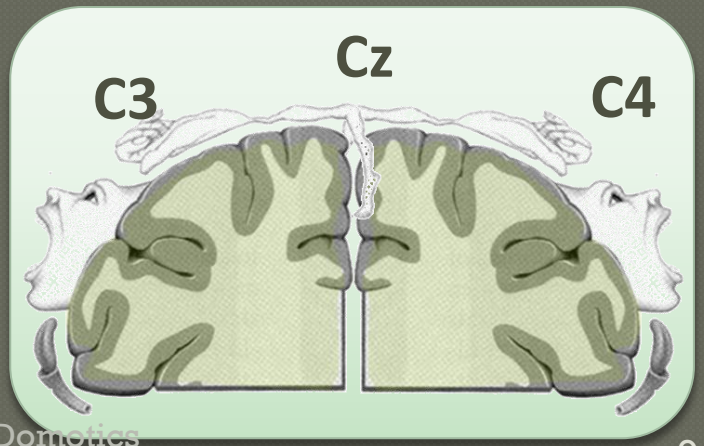
- Left vs.Right hand

$$\Delta y = S_{C3}^{\alpha} - S_{C4}^{\alpha}$$

- Upper vs. Lower limb

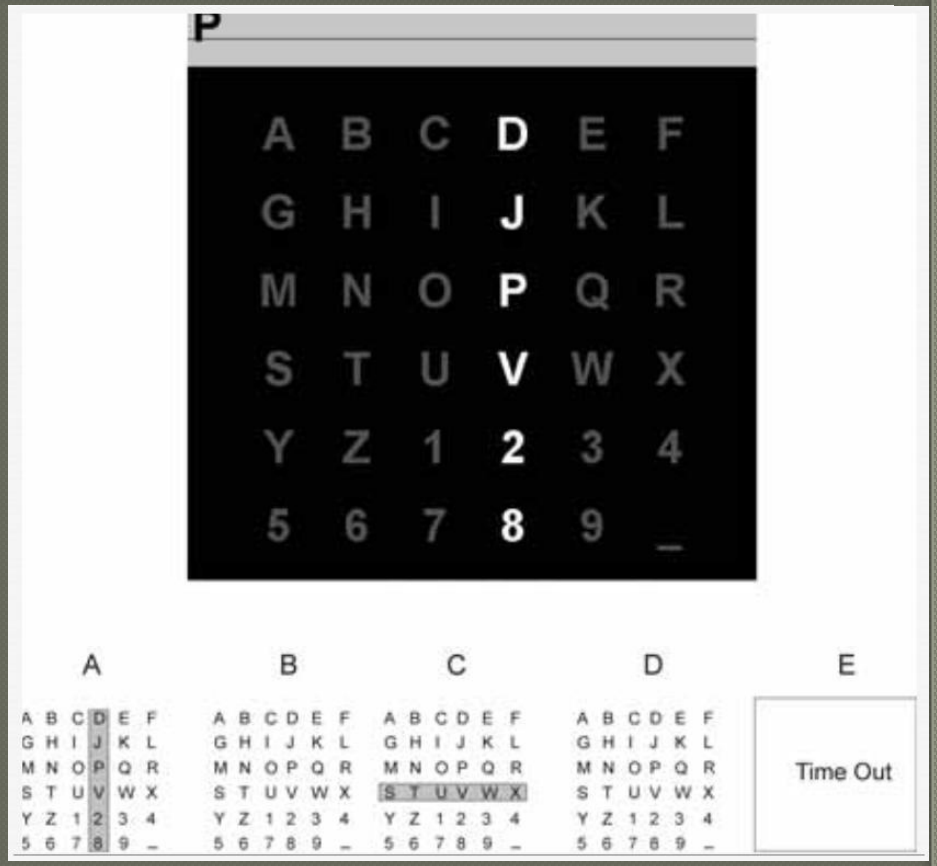
$$\Delta y = S_{Cz}^{\alpha} - \frac{1}{2}\left(S_{C3}^{\alpha} + S_{C4}^{\alpha}\right)$$





P300 Potential

- The P300 is an event-related potential, dominating at parietal electrode sites.
- P300 follows unexpected sensory stimuli or stimuli that provide task related information
- P300 speller

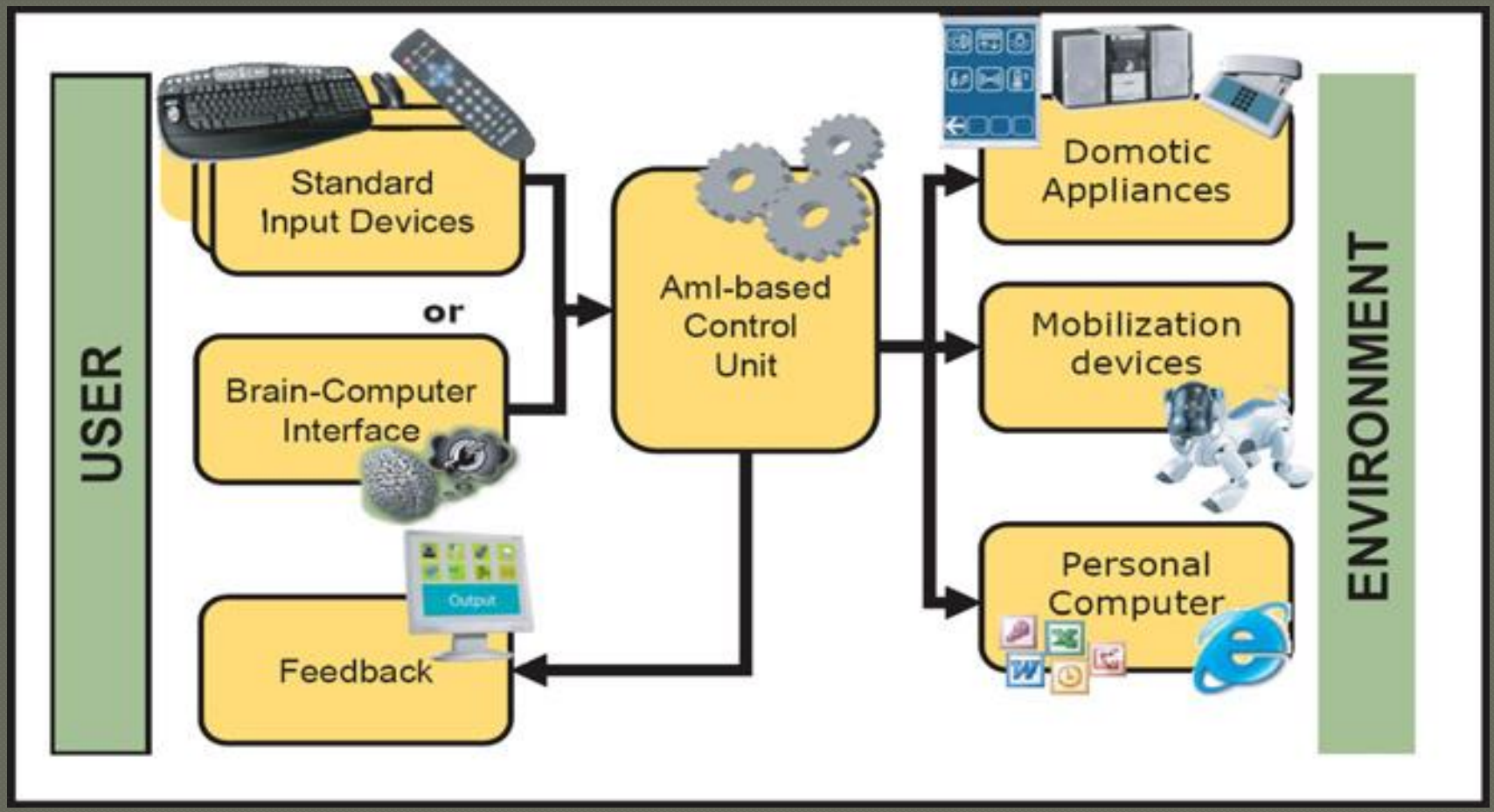


From Selllers & Donchin 2006, clinph

Domotic applications

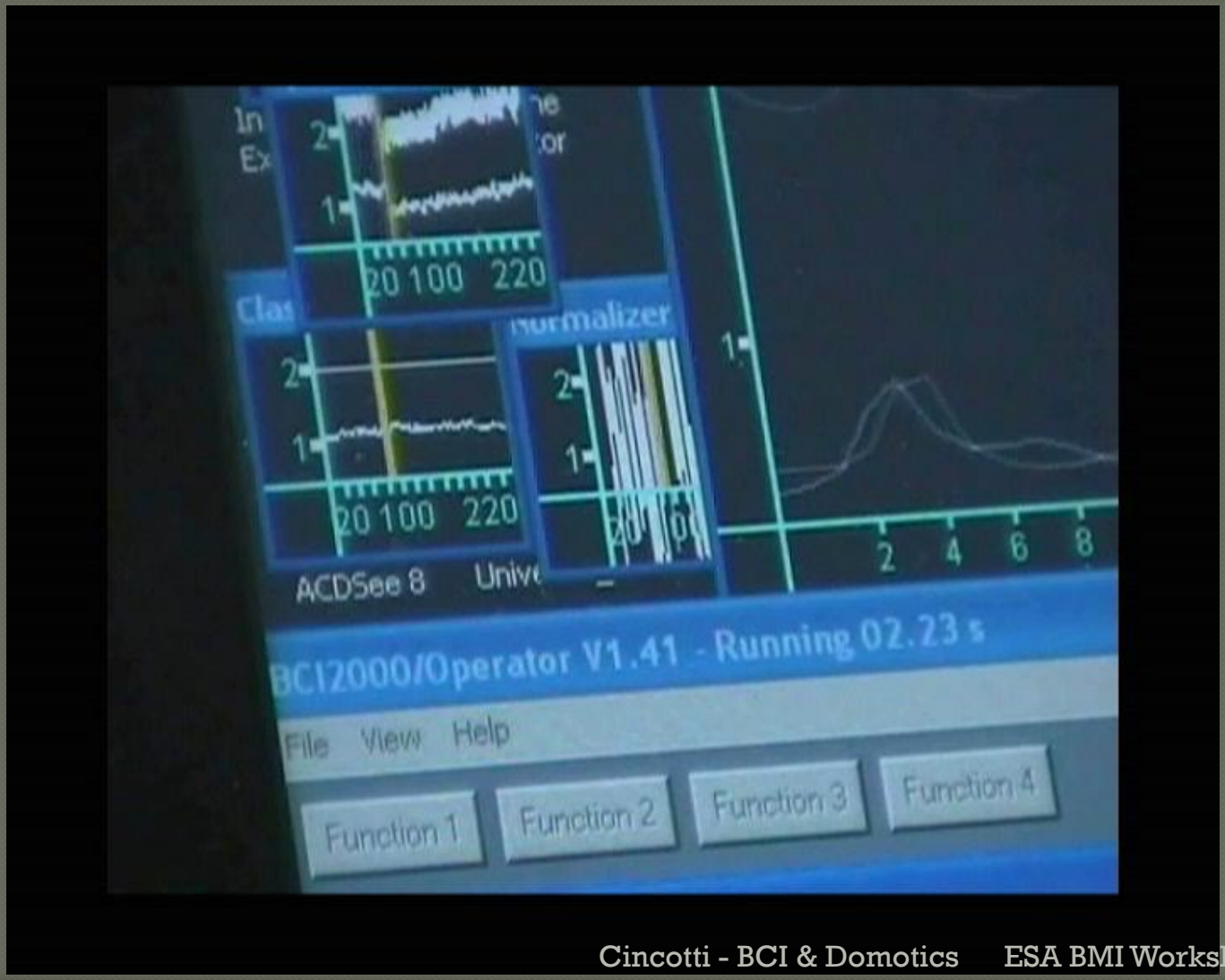
User
(Brain) Interface
(Smart) Controller
Actuators

Beyond a BCI-centric approach



Cincotti et al 2008, BRB

SMR control of a home environment



"ASPICE" Project (Italian Telethon Foundation)

P300 control of a home environment

"SM4All" Project

(FP7-ICT STREP)

P300 control of a home environment

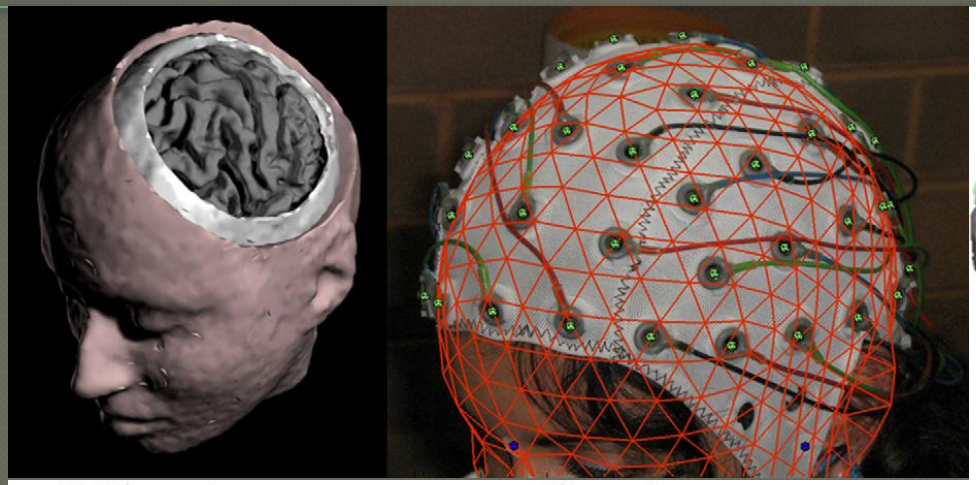
"SM4All" Project

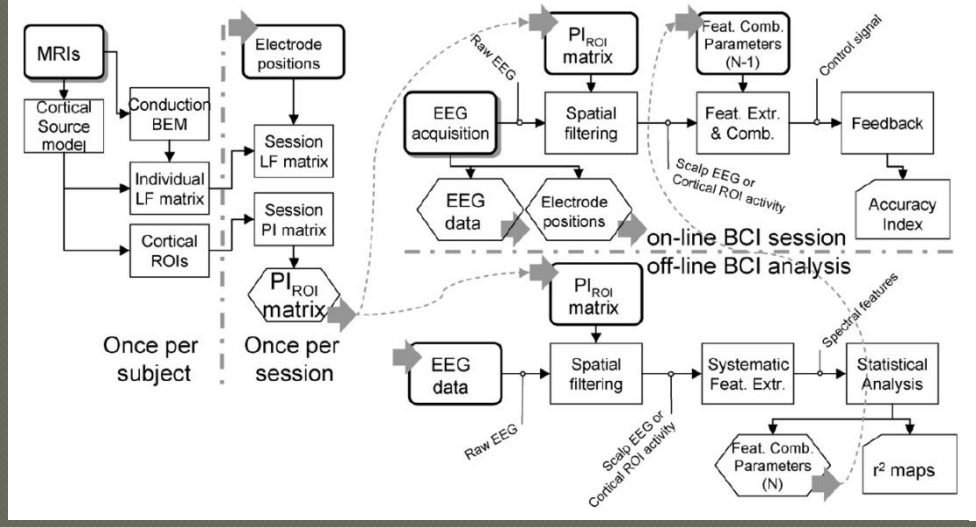
(FP7-ICT STREP)

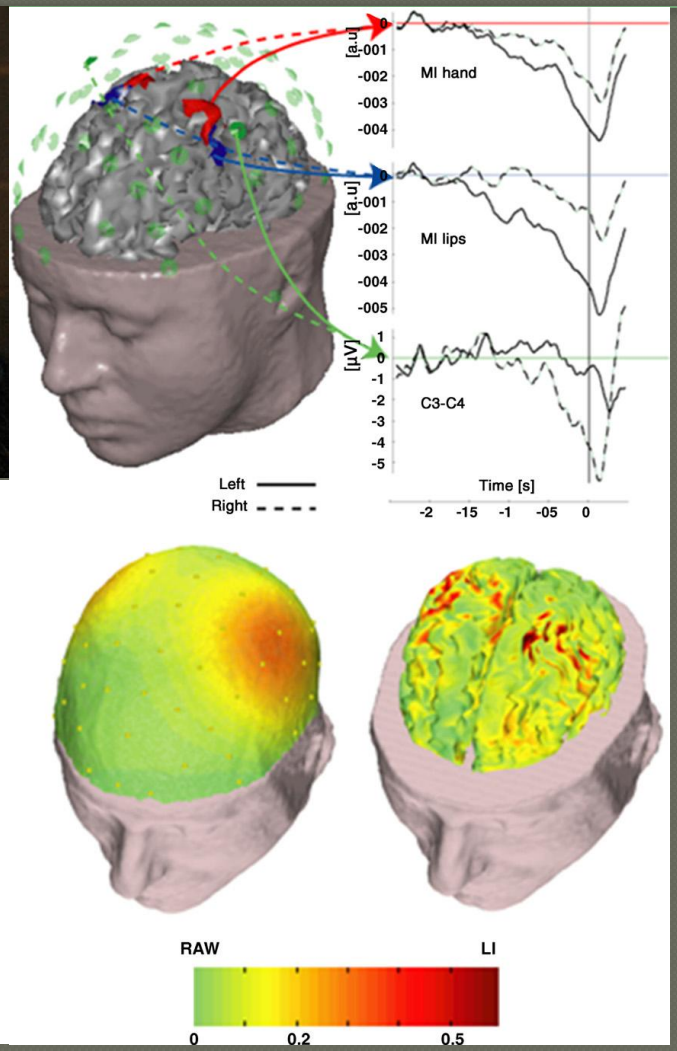
Possible improvements

Signal processing: Neuroelectrical imaging
HCI: Non-visual feedback/stimulation
…
Asynchronous control
Reduce symbolism

Neuroelectrical Source Imaging (1)

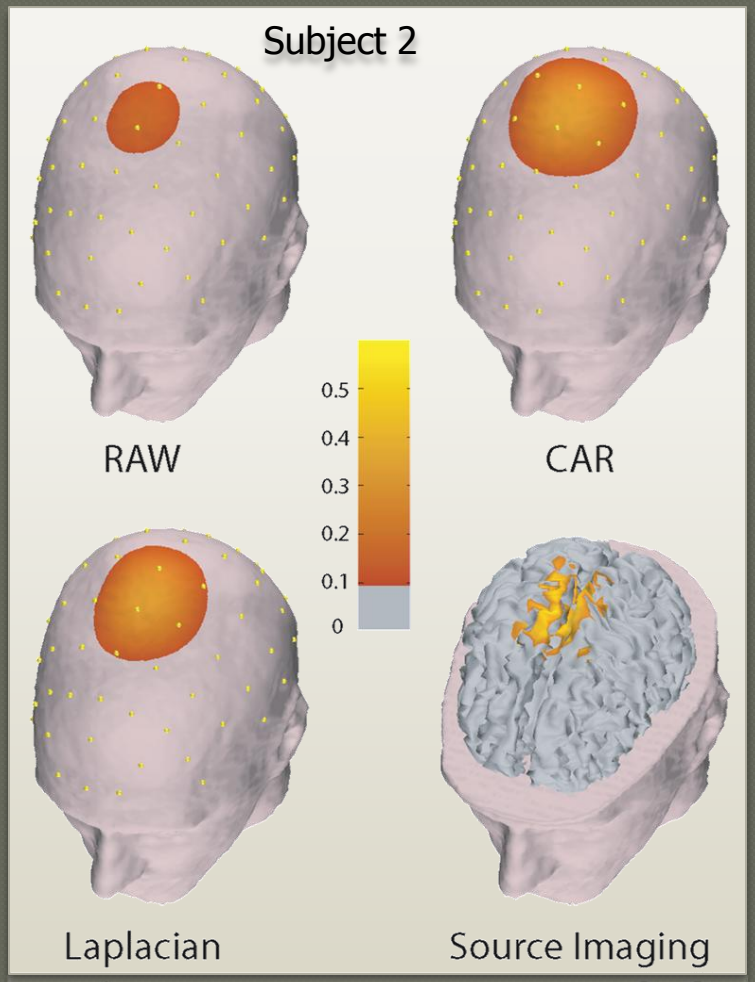


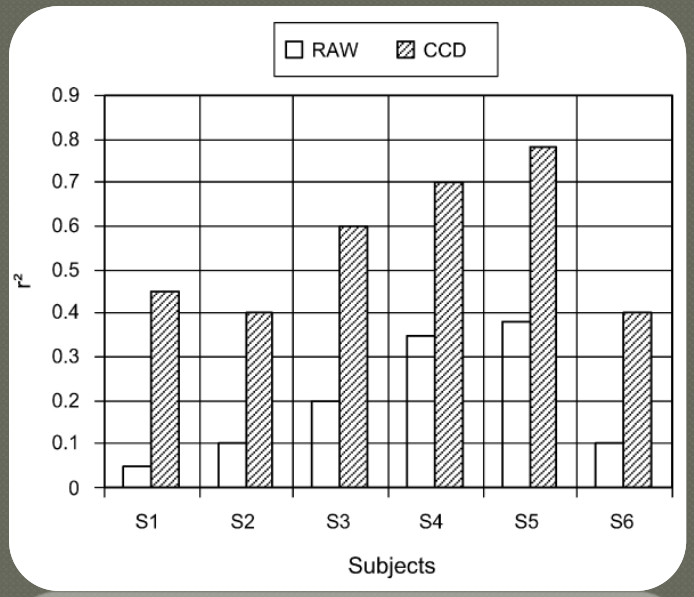




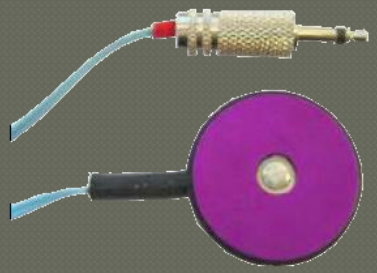
Cincotti et al 2007, JNM

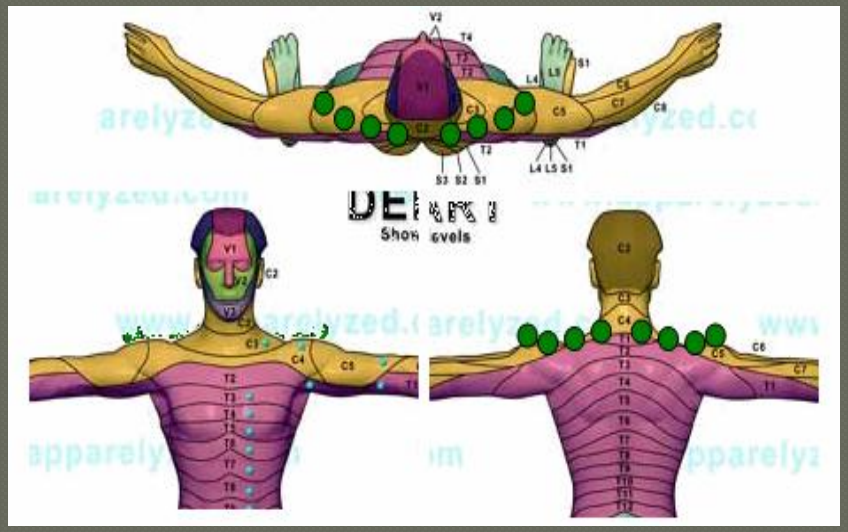
Neuroelectrical Source Imaging (2)

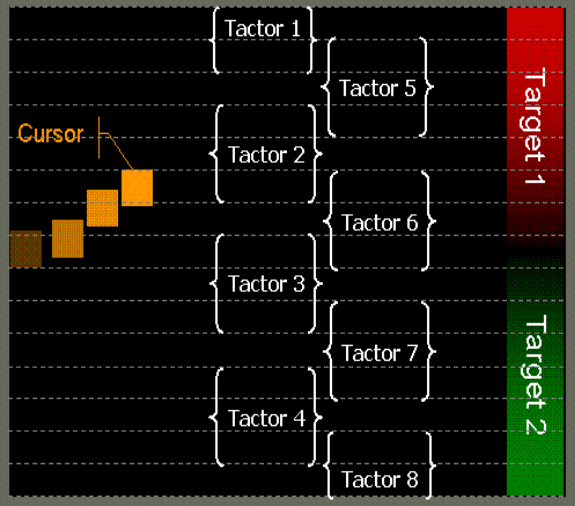




SMR Vibrotactile feedback (1)



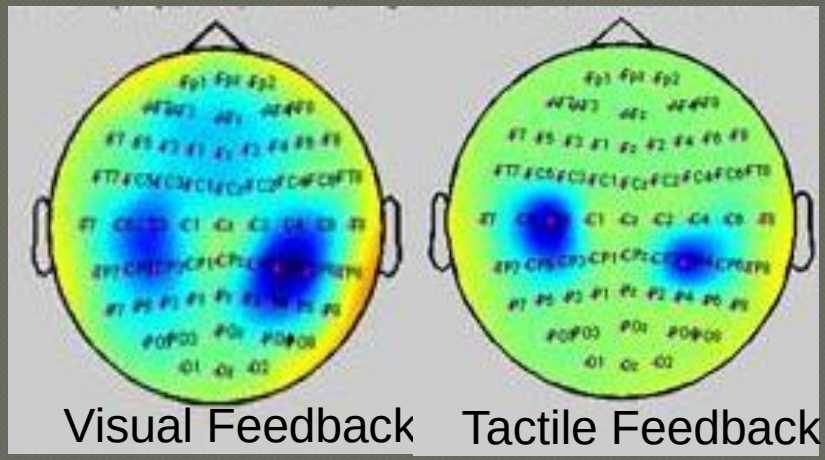


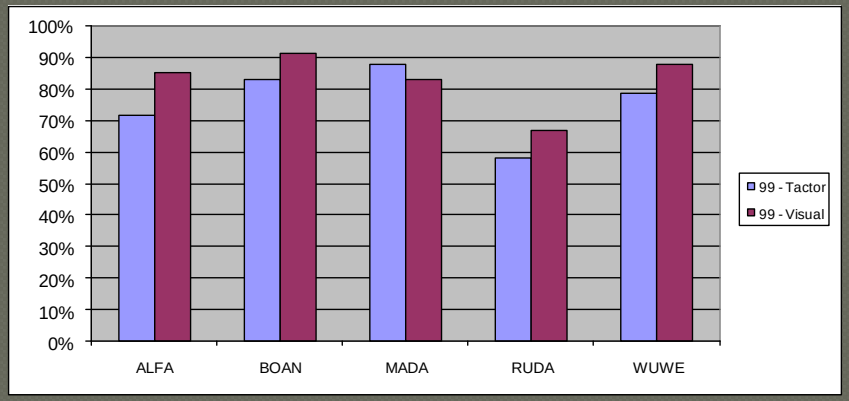


Cincotti et al 2007, CIN

SMR Vibrotactile feedback (2)

- SMR patterns are comparable
- Control performance are slightly reduced



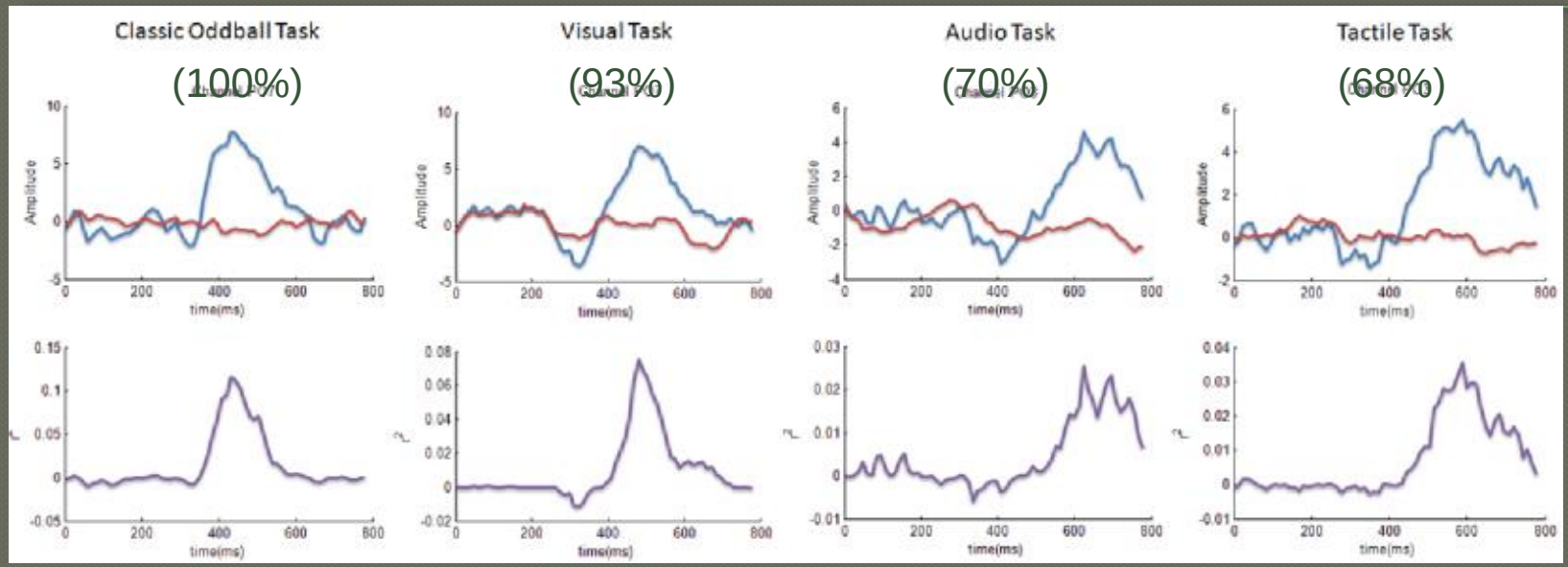


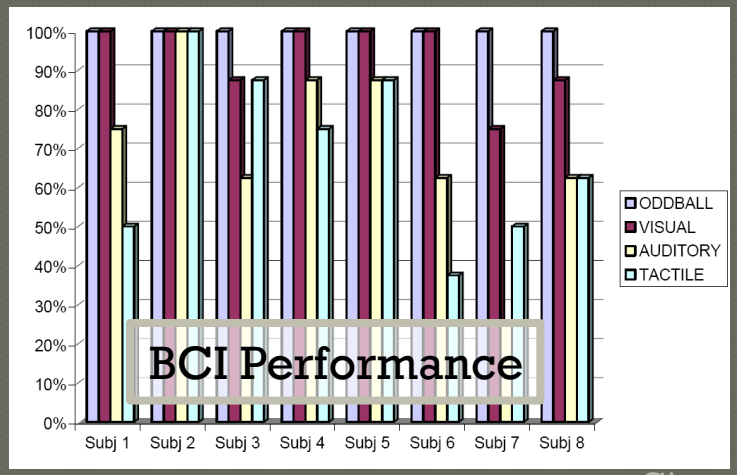
SMR Vibrotactile Feedback

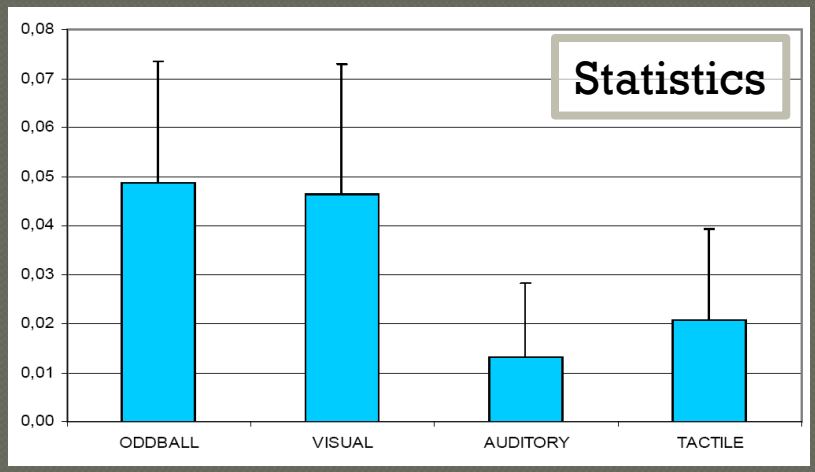
"MAIA" Project

(FP5 – STREP)

Multimodal stimulation for a P300-BCI







Aloise et al 2007, IJBEM

New challenges

- Targeted non muscular communication devices
- Non-invasive neuroprosthetics
- Non-deterministic applications (entertainment)
- Monitoring/fostering cortical plasticity

- Hybridization with muscular channels
- Asynchronous recognition of mental states (SMR, MRP, P300)
- Merging with the wider HCI fields
- Improved sensors: dry electrodes
- Standardization
- Wearable/Embedded platforms
- Evaluation metrics
- Ethics

TOBI : Tools for Brain-Computer Interaction

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