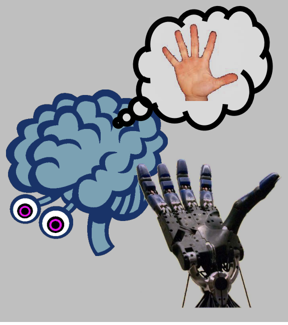
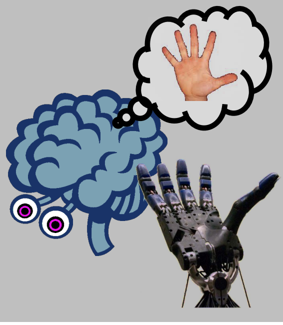


Teil V

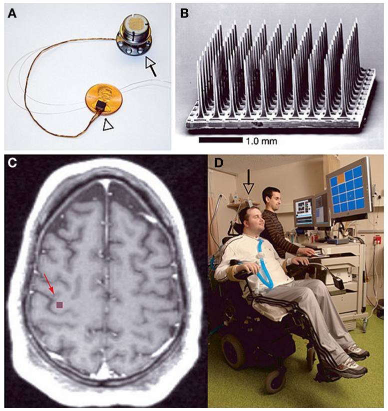
Systeme und Anwendungen

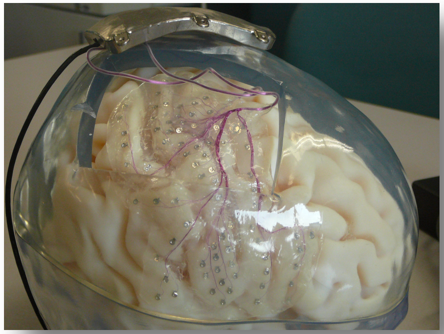
Taxonomy



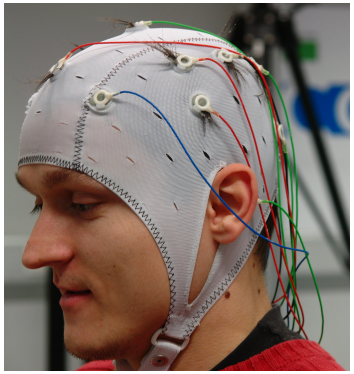
Invasive intra-cortical MEA recordings

- Controlling prosthesis, robot arms, exosceletons, etc.
- Targeting *permanently* impaired patients for restoring motor functions





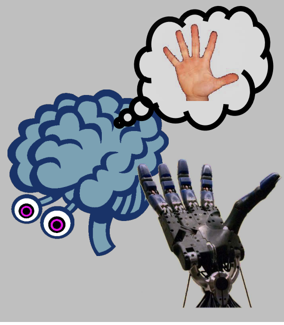
EEG



ECoG

- Often used like EEG (i.e., no regression, only discrete classification)
- Covers parts of both other approaches, like
  - Spelling
  - Prothesis, robot arms,...
- Targets patients with perminent and evt. also temporary but severe impairments.

Application Areas EEG



Active Control („traditional“)

- Spelling
- Wheelchair control
- Prosthesis
- Exosceletons

Clinical Applications

- (Motor) Rehabilitation for stroke patients
- Neurofeedback for treatment of mental disorders (e.g., ADHD, PTSD, anxiety disorders,...)
- Patients with Disorders of Consciousness

Passive Monitoring and Intervention

- Mental state, e.g., stress, vigilance, etc.

Artistic expression (patients)

- BrainPainting
- Music production

Sports

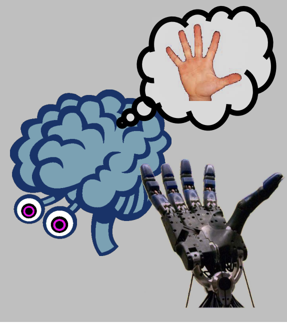
- Neurofeedback

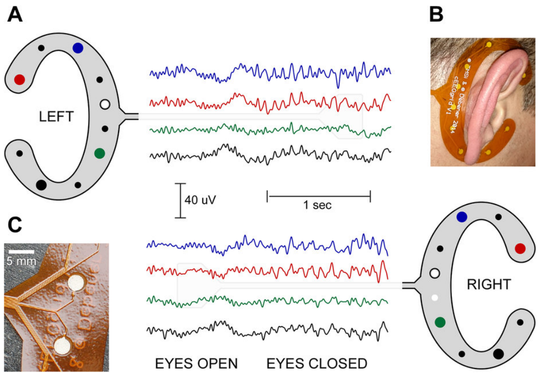
Cognitive training and (evt.) enhancement

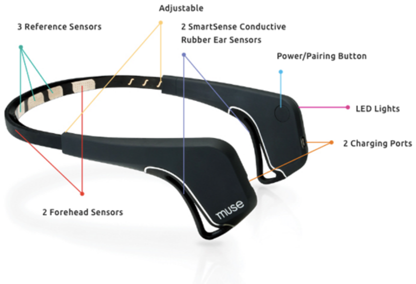
- for everybody
- E.g., combined with virtual or augmented reality

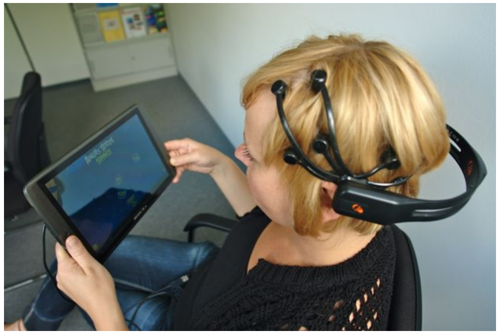
Neuromarketing

Wireless EEG Sensors

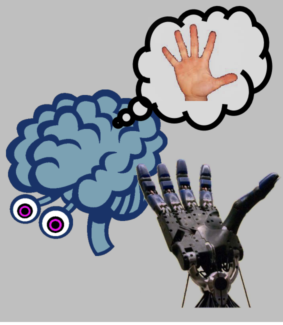




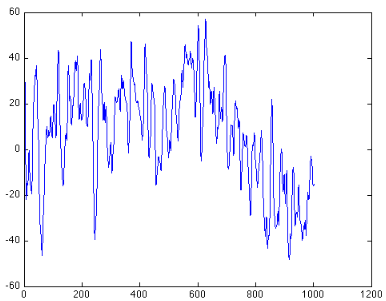




Merkmalsextraktion und Klassifikation (Feature extraction and classification)

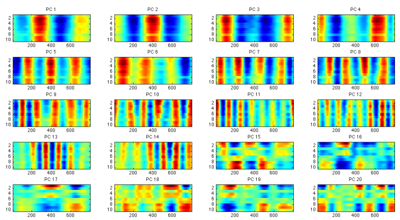


Rohdaten x



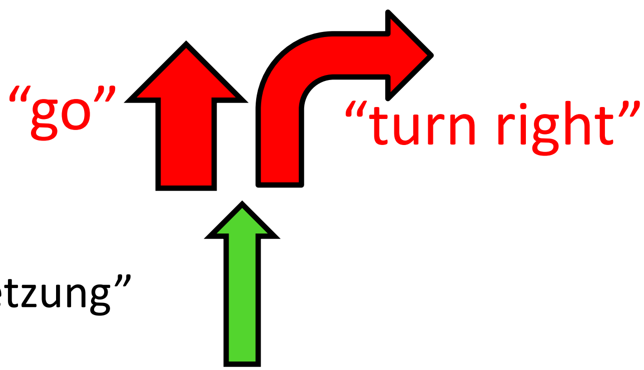
Pre-processing
Feature Extraction

Merkmal (Feature)



Klassifikator

$$f : X \to Y$$
$$\text{mit } y \in \{-1, 1\}^{*}$$

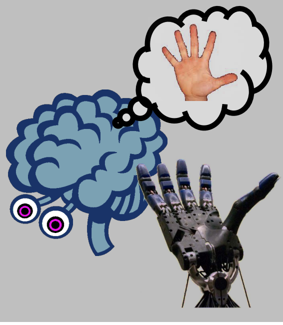


"Übersetzung"

Klassifikationsergebnis y -1 1 Label

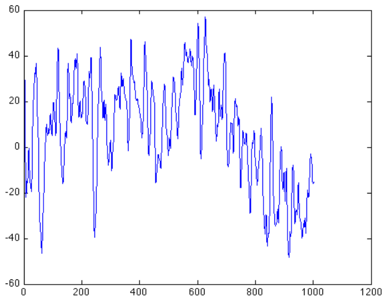
*Spezialfall binärer Klassifikator

Merkmalsextraktion und Regression
(Feature extraction and regression)

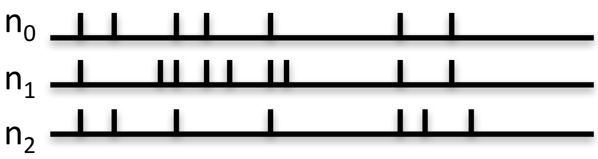


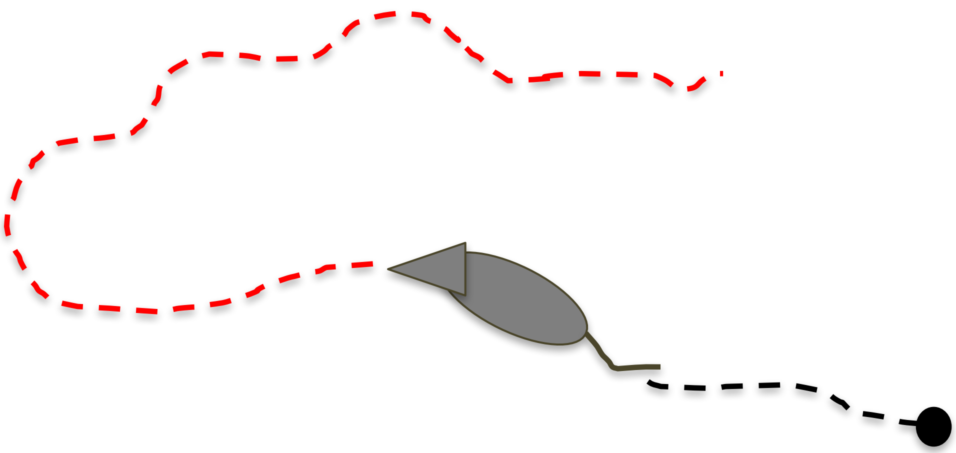
Rohdaten

Feature



Pre-processing
Feature Extraction



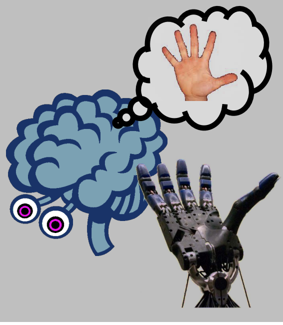


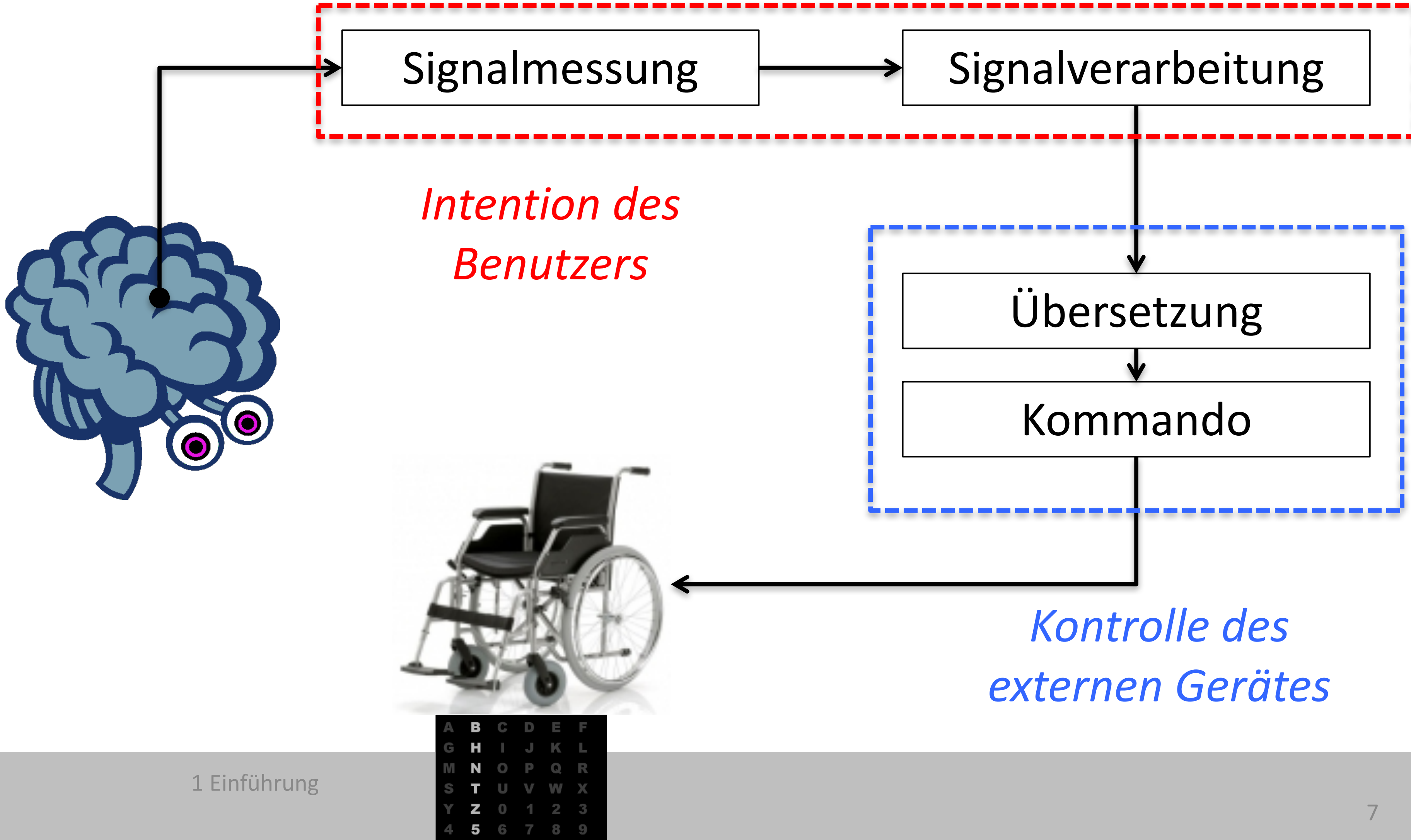
Lineares Model

$$f : X \to Y$$
$$\text{mit } y \in \mathbb{R}$$

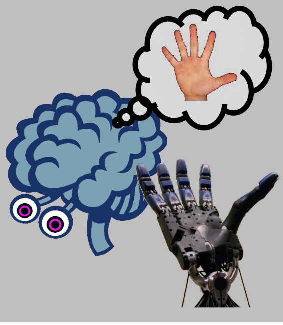
z.B. Raumkoordinaten (Trajektorie)

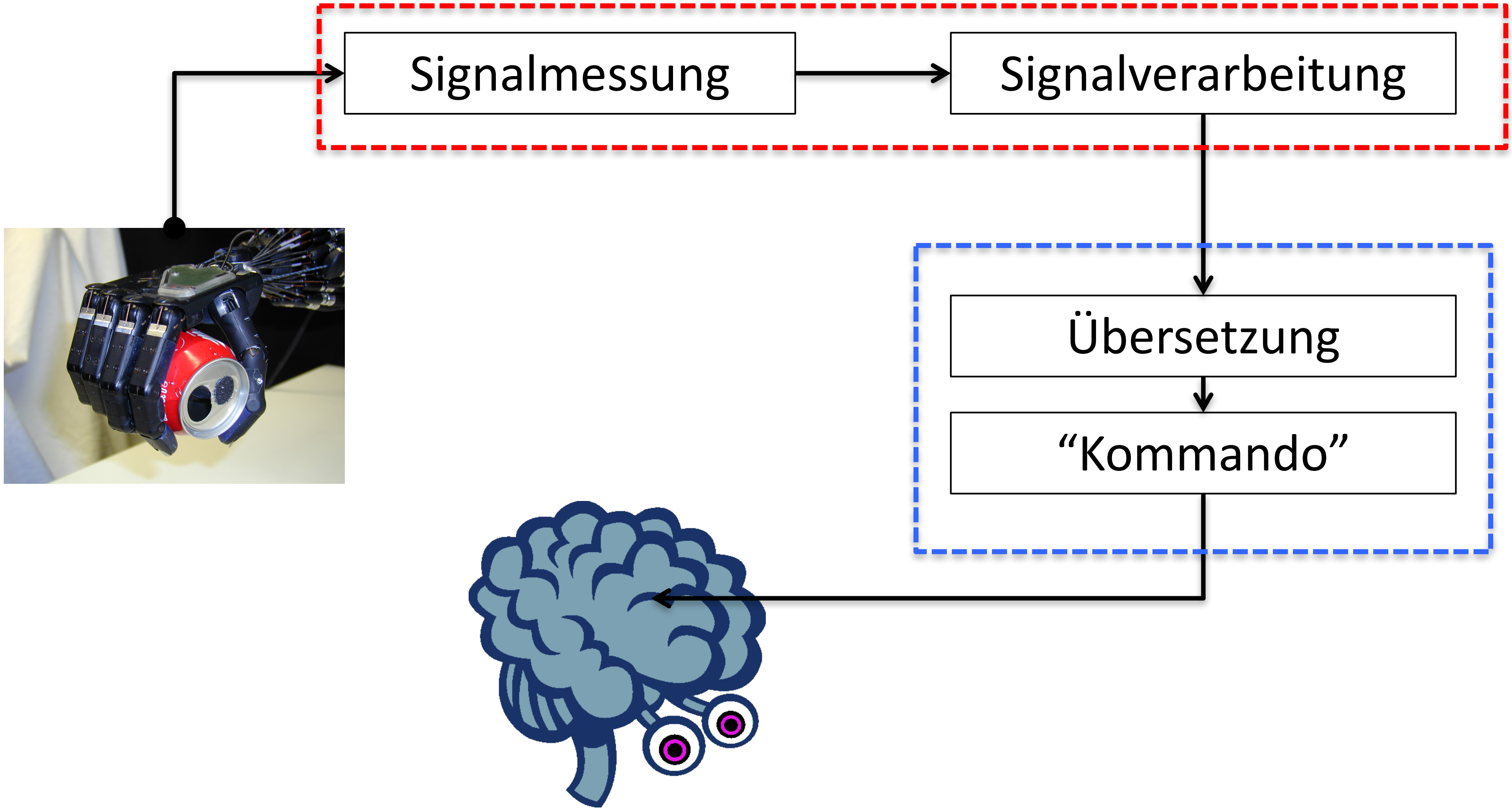
Systemkomponenten

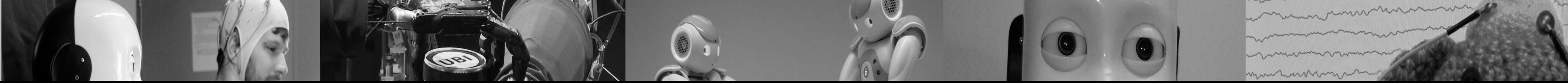




Systemkomponenten







P300-Based BCI

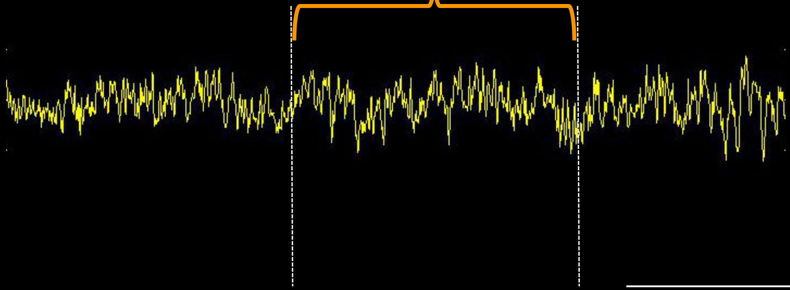
EEG

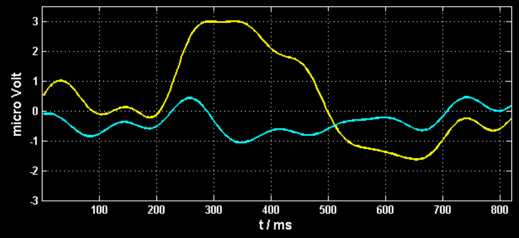
Oddball paradigm: Stimuli must be highlighted in random order, targets must be rare → evokes P300 potential

Single-trial classification

Class Label + Stimulus Index

Single-Trial Epoch



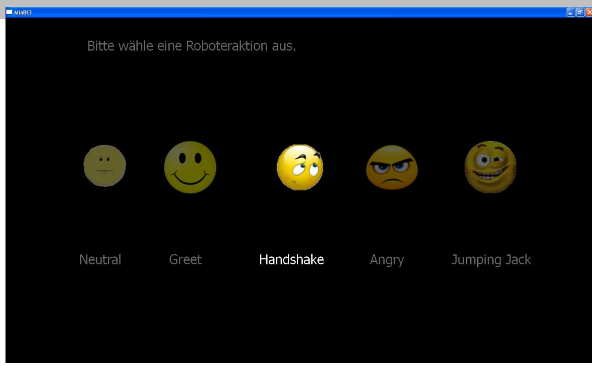


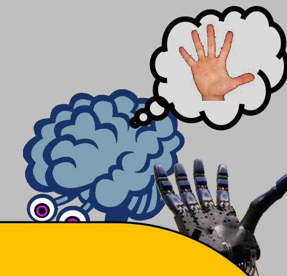
System-provided trigger and label

Averaging over trials and participants

Grand Average

System Sketch (Workshop)





EEG amplifier software
(gUSBamp)
- GUI for setting parameters
- Driver code
- Polls data from device

LSL Server
(labstreaminglayer)
- Middleware that broadcasts **data** and **timestamps** into network

MATLAB

Stimulus presentation
- Flashes stimuli in random order
- Speller matrix or sequential
- Training mode: System-defined targets for ground truth
- Test mode: Online BCI, user selects target of choice

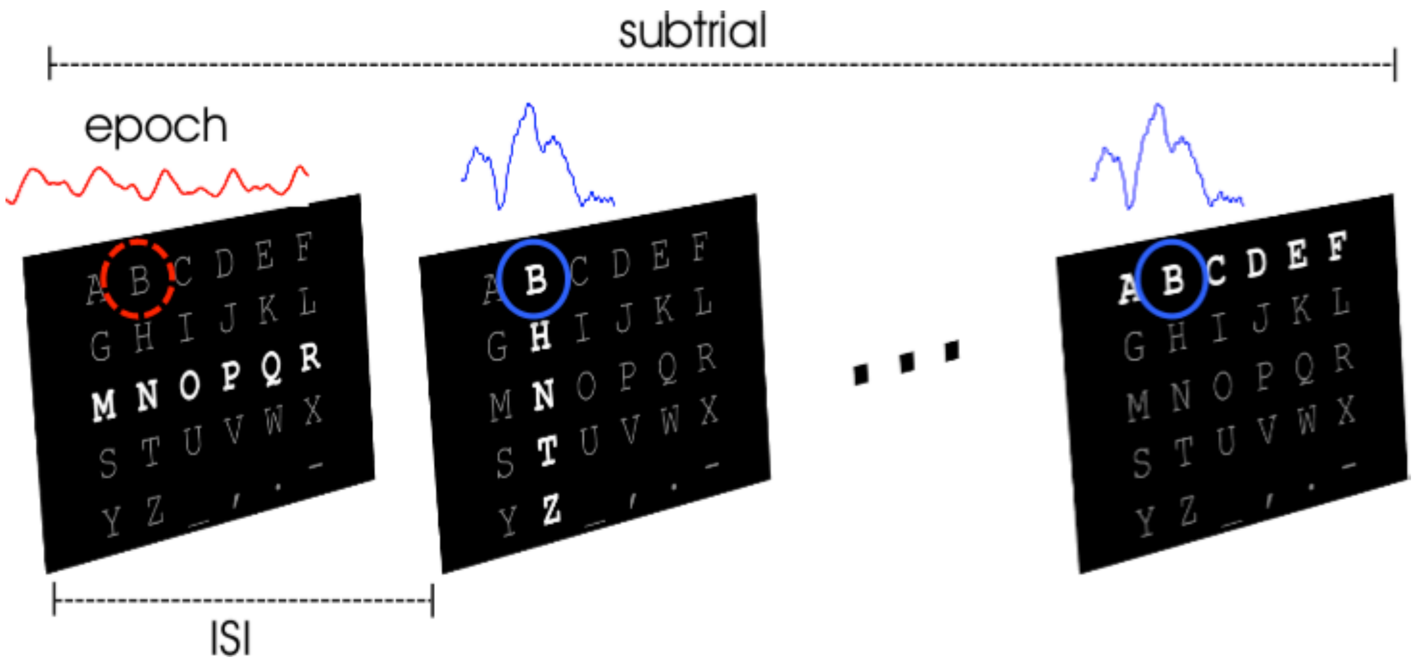
LSL Client
(labstreaminglayer)
- Receives **data** and **timestamps**

Encoding and decoding
(Training and test)
- *Segmentation*
- *Bandpass filtering*
- *Feature extraction (PCA)*
- *Classification (FDA)*

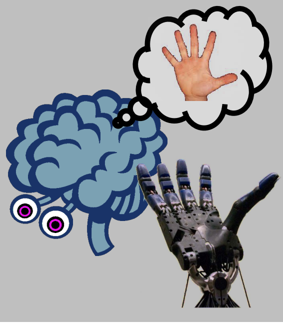
Input
- Data + timestamps (sample time)
- Stimulus flash onset timestamps
- Flash sequence (indeces)
- Target index (training)

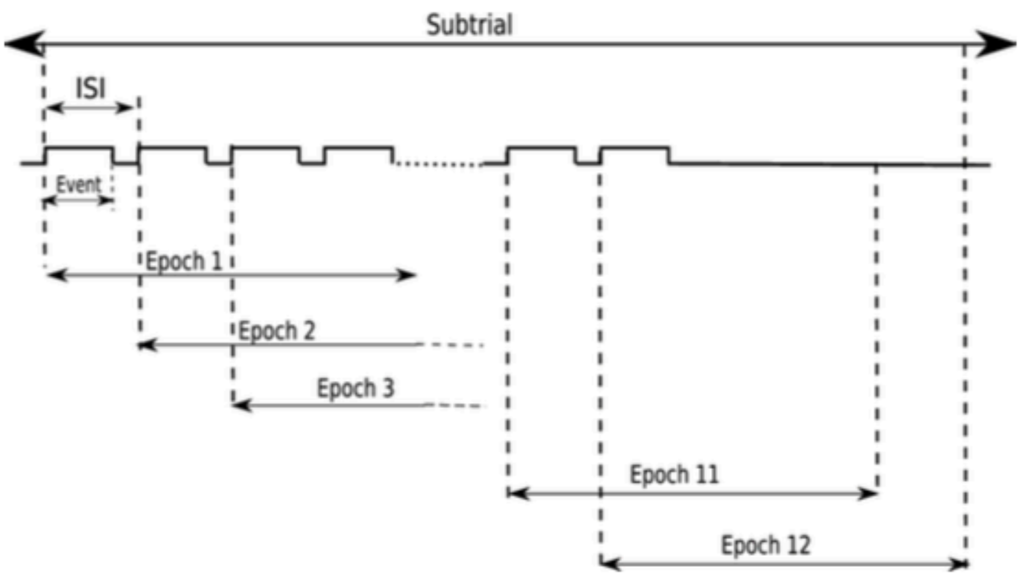
Output
- Target index (test only)
- PCA matrix, FDA.w, FDA.b (training only)
- Thresholds for dynamic subtrial limiting (training)

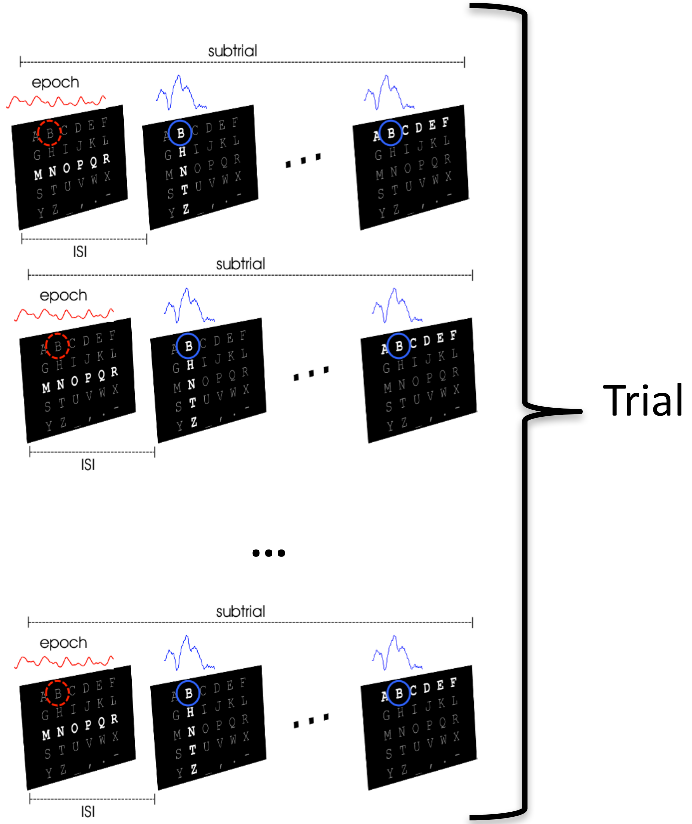
Once upon a speller…



Epoching (Segmentierung)

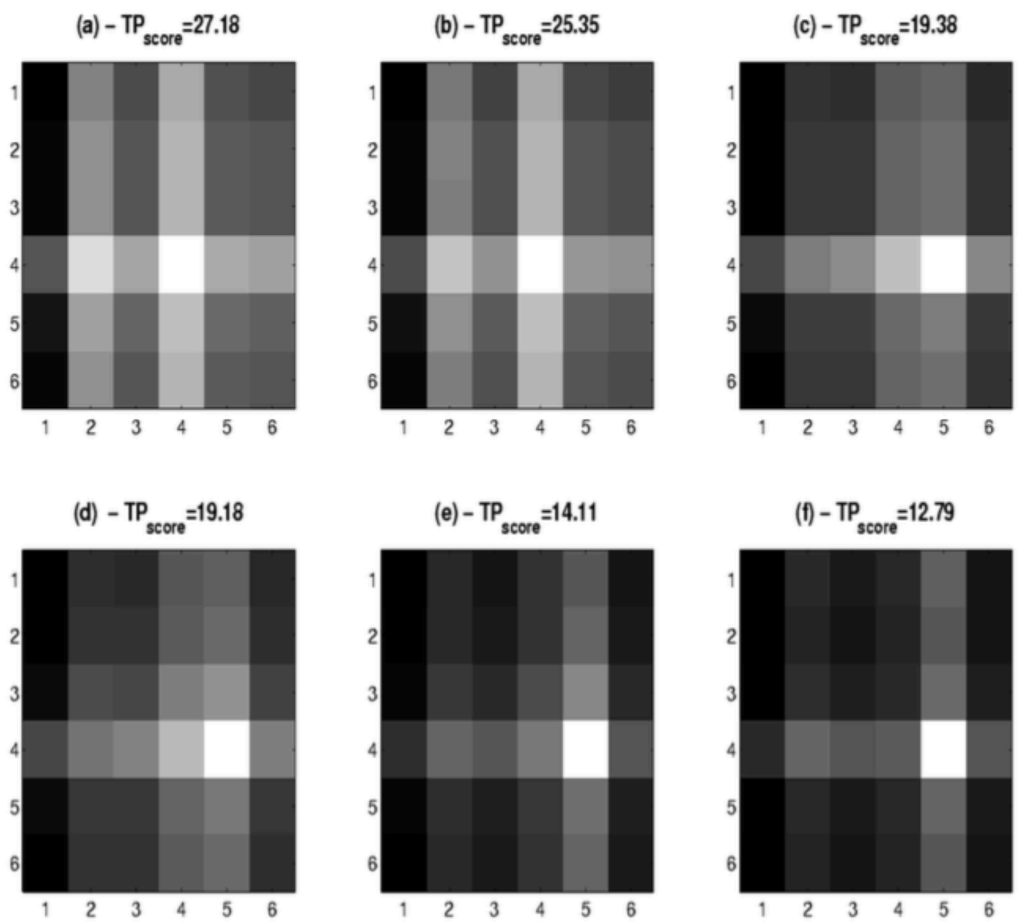






- Epochenlänge 800 ms (205 Samples)

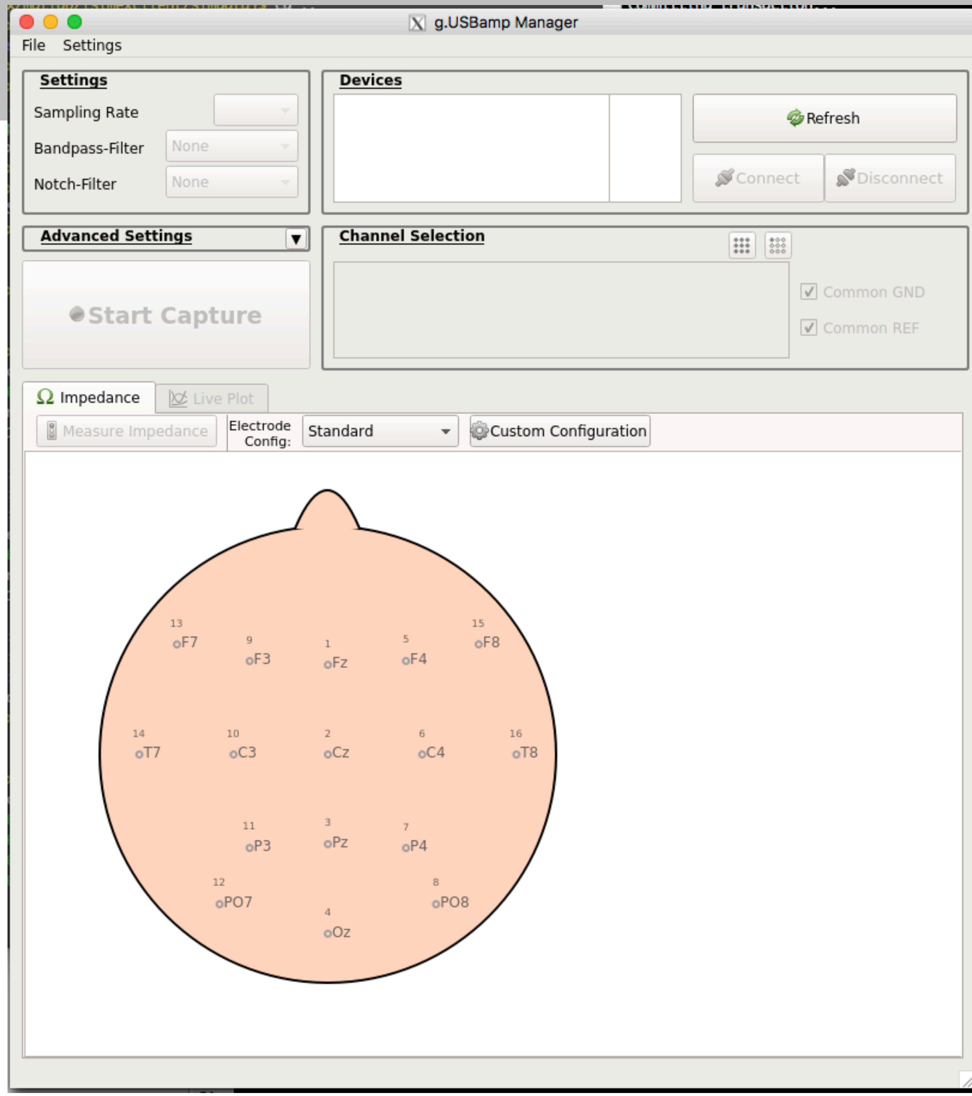
Dynamische Subtrial Limitierung



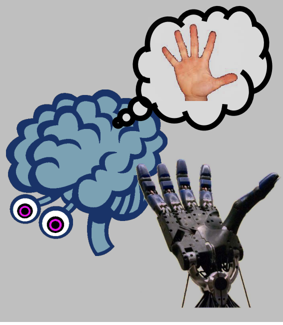
TP → True Positive Score

Wird im Training ermittelt.

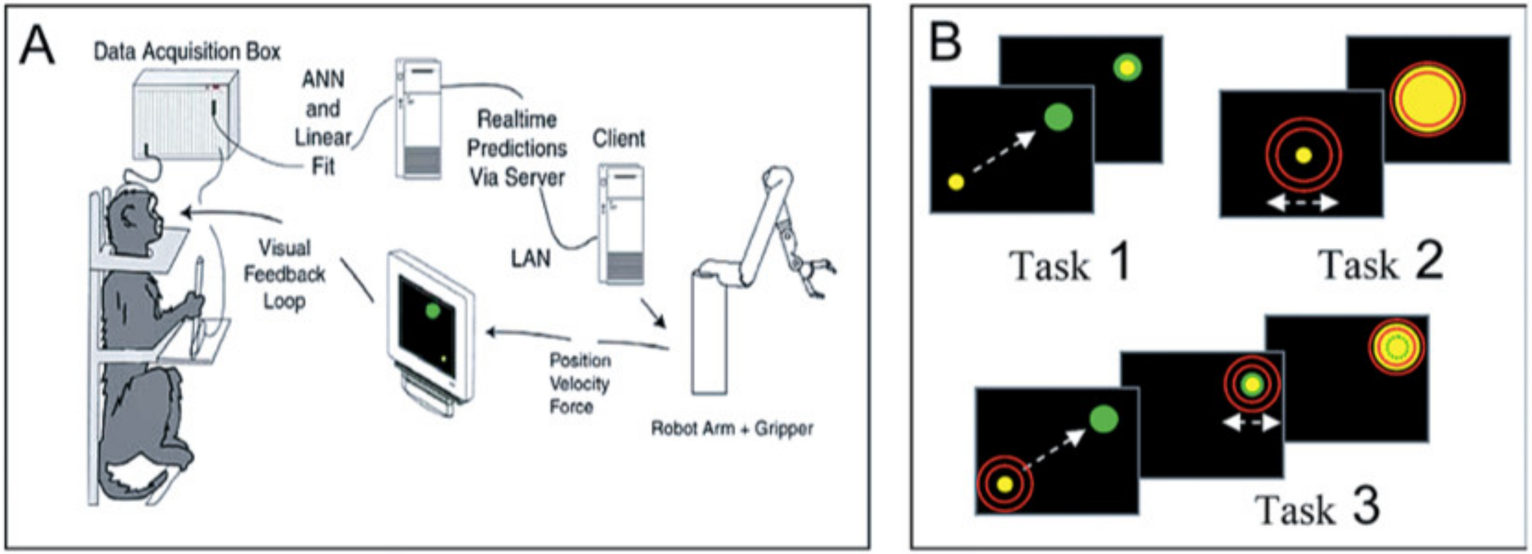
EEG amplifier software with LSL server



Invasive Systeme – Nicolis Lab Duke University (USA)

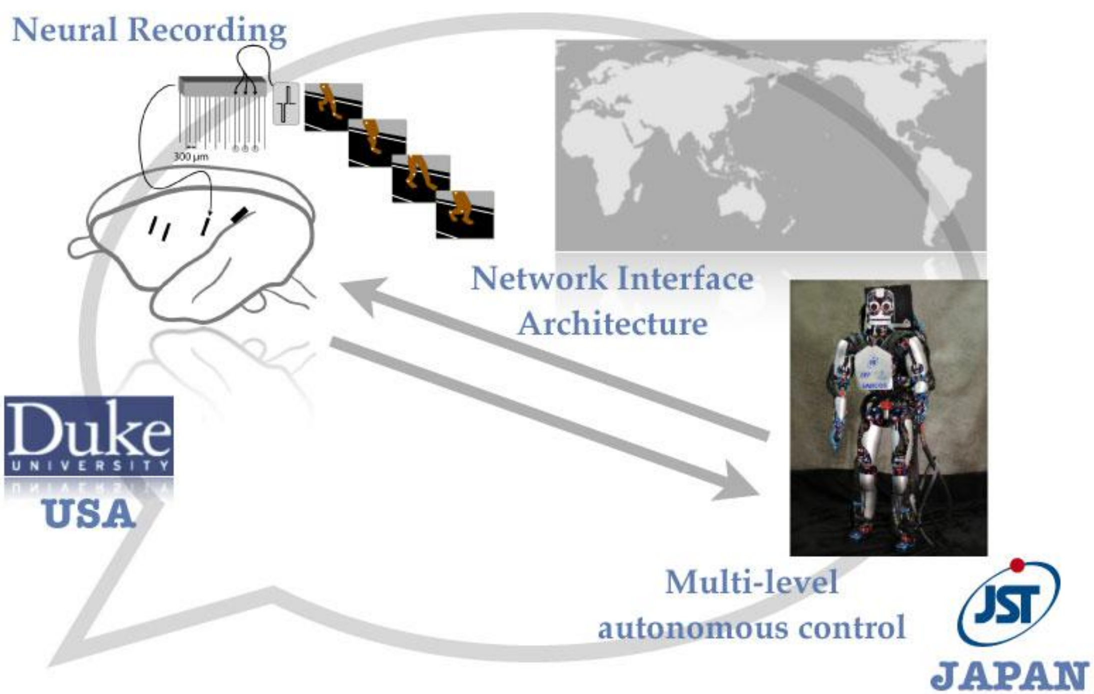


Learning to control a brain-machine interface for reaching and grasping by primates, Carmena et al., PLoS Biology, 2003

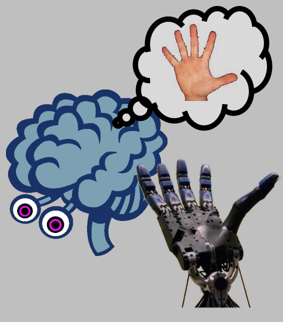


Invasive Systeme – Nicolis Lab
Duke University (USA)

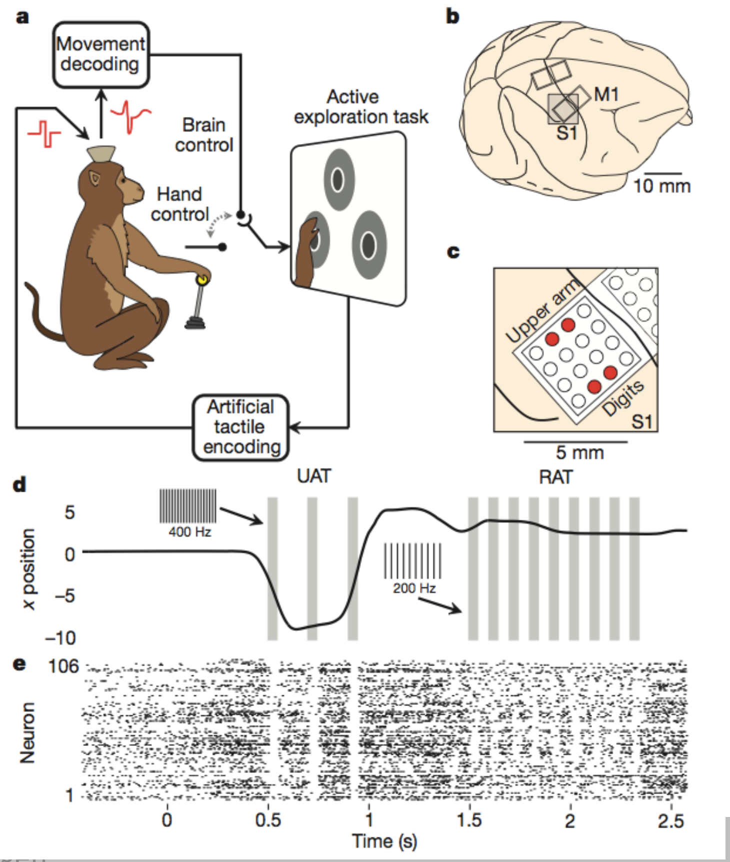
Bipedal locomotion with a humanoid robot controlled by cortical ensemble activity, Cheng et al., Society for Neuroscience 37th Annual Meeting. San Diego, CA, USA.



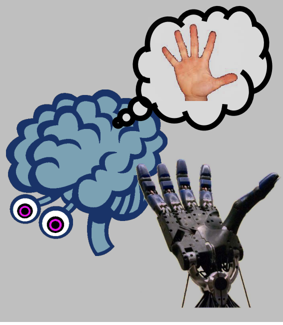
Invasive Systeme – Nicolis Lab Duke University (USA)



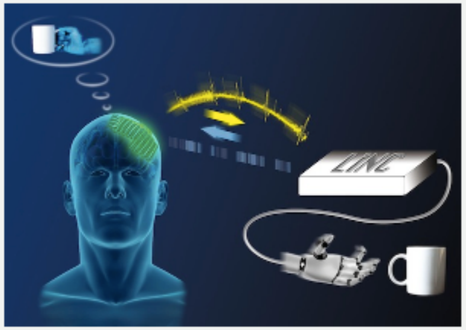
Active tactile exploration using a brain–machine–brain interface, O'Doherty et al., Nature, 2011



Bernstein Center und EXC “BrainLinks BrainTools” – Uni Freiburg



Our guide in this endeavour are two visions of intelligent neuroprosthetic device groups:



Prosthetic Limbs with Neural Control (LiNC)

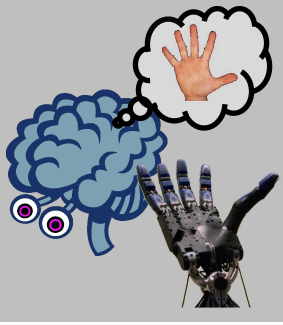
are brain-controlled assistive devices and prostheses that improve the capacity for movements in paralyzed patients and amputees, and improve the rehabilitation of patients suffering from stroke or brain trauma. LiNCs will read out a user’s conscious action goal and autonomously execute it through external actuators, for example a robotic arm. They can help patients to regain more autonomy in everyday life.

Smart Energy-Autonomous Micronodes (SEAM)

are fully implanted, autonomous devices. They work with a closed-loop feedback, recording from and stimulating the brain in cases of neurological conditions that originate from pathological network structures or activity dynamics. Epilepsy and Parkinson's disease are examples for such “diseases of dynamics”. Ideally, SEAMs will remain unperceived by the user – except for their beneficial effects.

BrainLinks-BrainTools will not work in isolation on these formidable challenges, but will be part of a strategic axis with leading international centers of neurotechnology and a dense network of dedicated Application Centers and industrial partners.

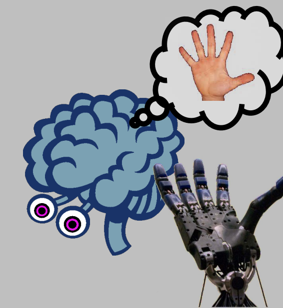
DLR (Deutsches Zentrum für Luft und Raumfahrt) mit Brown University (USA)



Reach and grasp by people with tetraplegia using a neurally controlled robotic arm, Hochberg et al., Nature, 2012

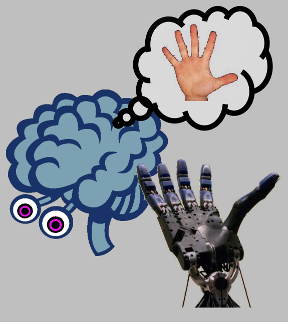
https://www.youtube.com/watch?v=QRt8QCx3BCo

BBCI – Berlin Brain Computer Interface

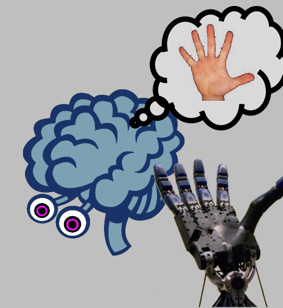


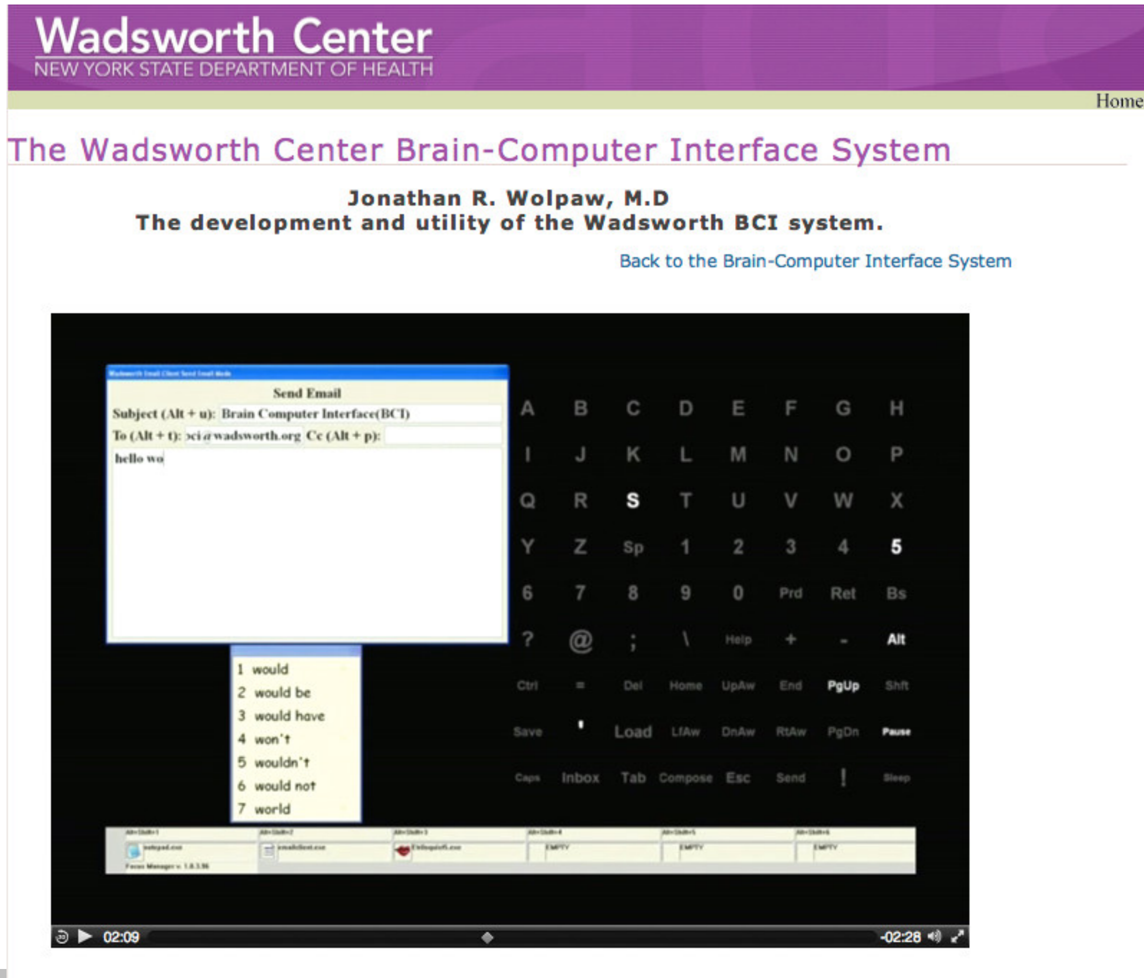
https://www.youtube.com/watch?v=ZIIffTH5D-E

TU Graz



Wadsworth Center (USA)





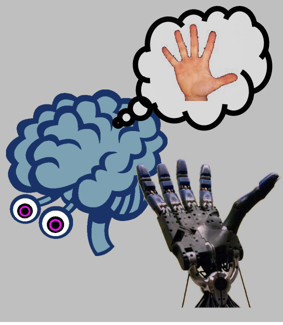
EPFL Lausanne, Schweiz

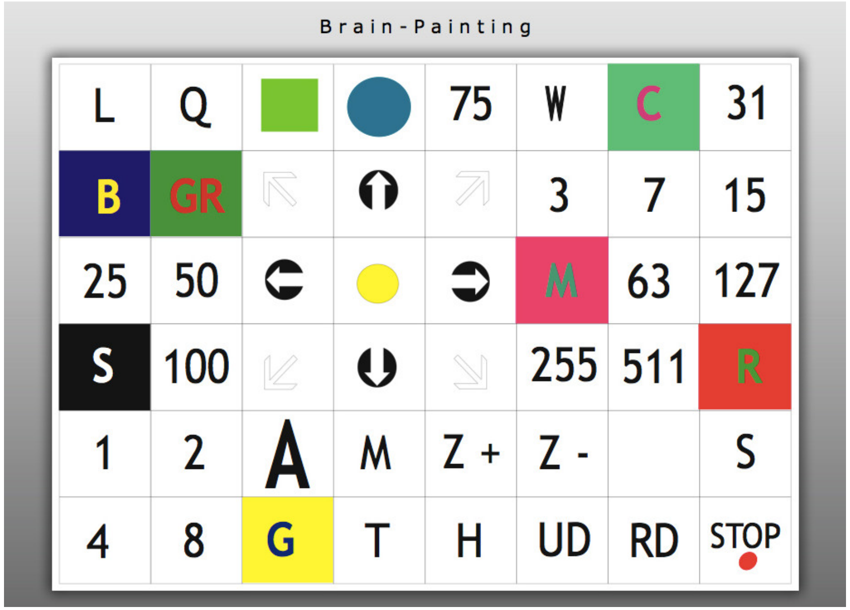
Rollstuhlkontrolle und "Shared Control" Ansatz:

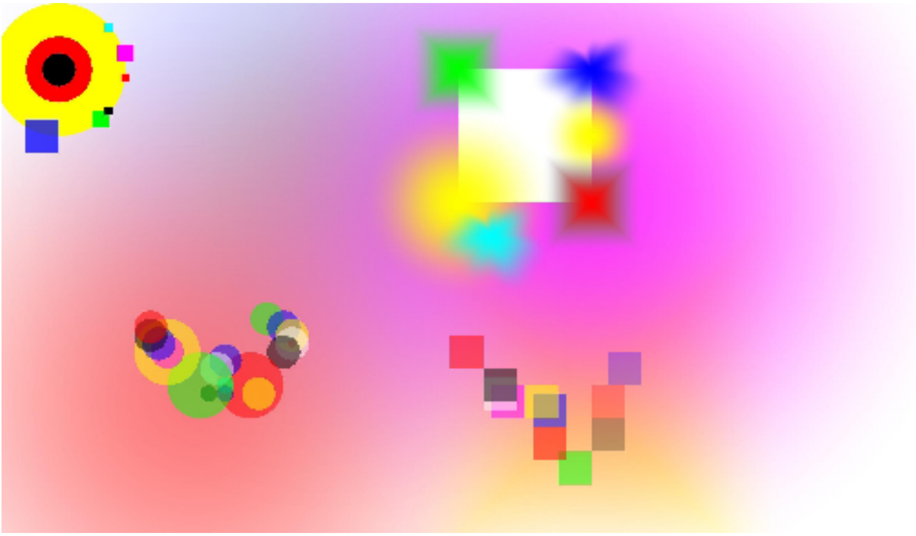
https://www.youtube.com/watch?v=The_oE_Ztm8&list=PL359957C3C6FE302C

Interessante Variante eines **passiven** BCI:

BrainPainting

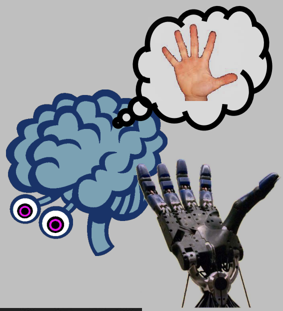






https://www.youtube.com/watch?v=LbDtHksqP98

Schlaganfall Rehabilitation



https://www.youtube.com/watch?v=9rYPS8unLpE

Exoskelett - Kontrolle

“Walk Again Project” (u.A. Miguel Nicolelis, Gordon Cheng von der TU München)

→ Motor Imagery basiert

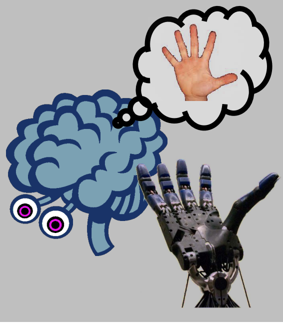
https://www.youtube.com/watch?v=inCvbDLfXBo

Korea University und TU Berlin (BBCI):

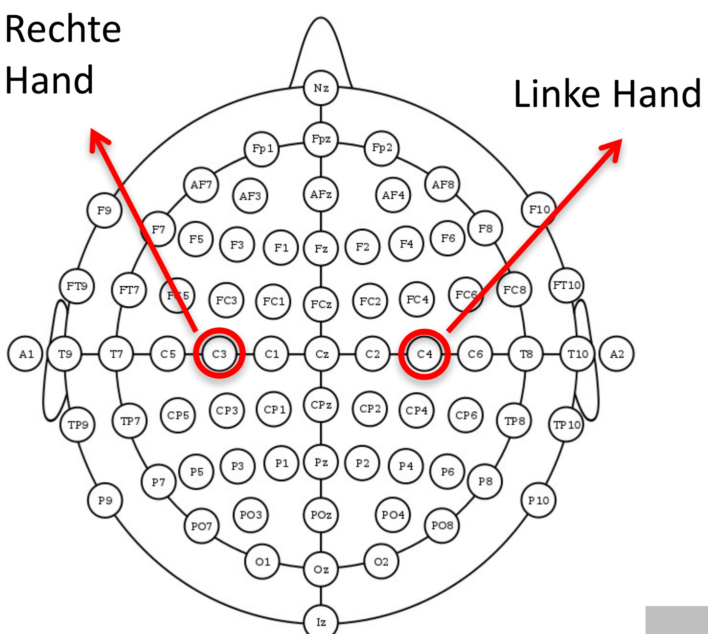
→ SSVEP - basiert

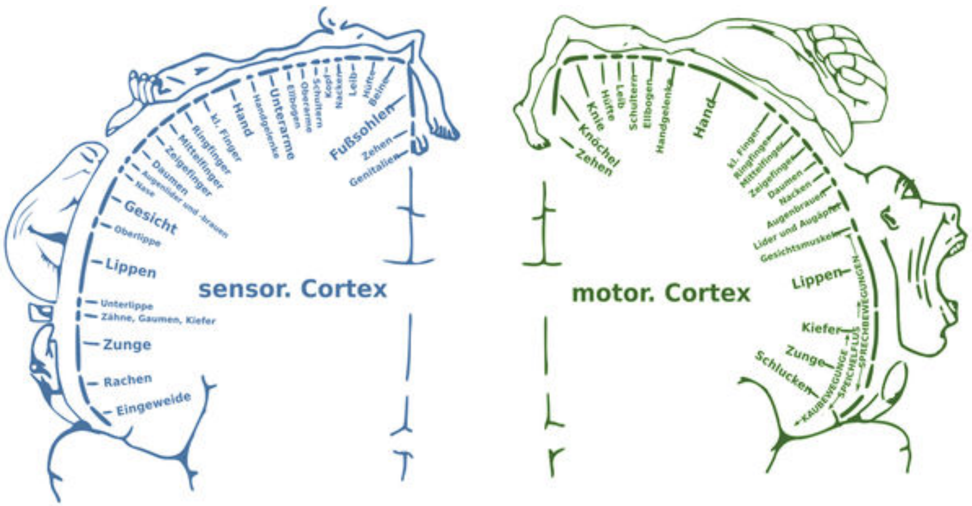
https://www.youtube.com/watch?v=jeLghZ8GASA

Motor Imagery (MI)

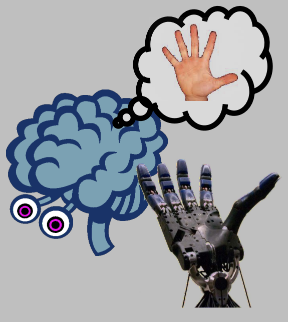


- Basiert auf dem Phänomen, dass die **reine Vorstellung** einer Bewegung zu den (annähernd) gleichen kortikalen Aktivierungsmustern führt wie eine tatsächlich ausgeführte Bewegung.
- Die Aktivierung ist Dank des “Homunculus” gut lokalisiert.





Biofeedback



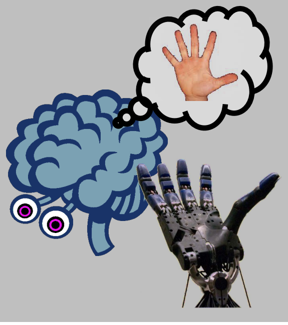
...bezeichnet eine Methode, bei der eine Person die bewusste Selbstkontrolle über bestimmte Funktionen seines Körpers erlernt

z.B. Atmung
Muskelaktivität
Herzrate

Methode: Konstante Rückmeldung (visuell oder akustisch) über die aktuelle Ausprägung der trainierten Funktion.

Neurofeedback ist somit eine Unterkategorie von Biofeedback, hier wird die Selbstkontrolle über bestimmte Hirnfunktionen / -Aktivitäten erlernt.

Operant Conditioning



Biofeedback / Neurofeedback sind Methoden, die dem Bereich der Operanten Konditionierung zuzuordnen sind.

4 Typen von Operanter Konditionierung (nach Skinner, 1950):

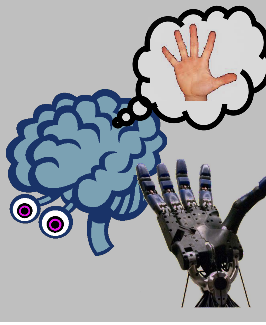
- Positive Reinforcement
- Negative Reinforcement

→ Verstärkung eines bestimmten Verhaltens

- Punishment
- Extinction

→ Vermeidung eines bestimmten Verhaltens

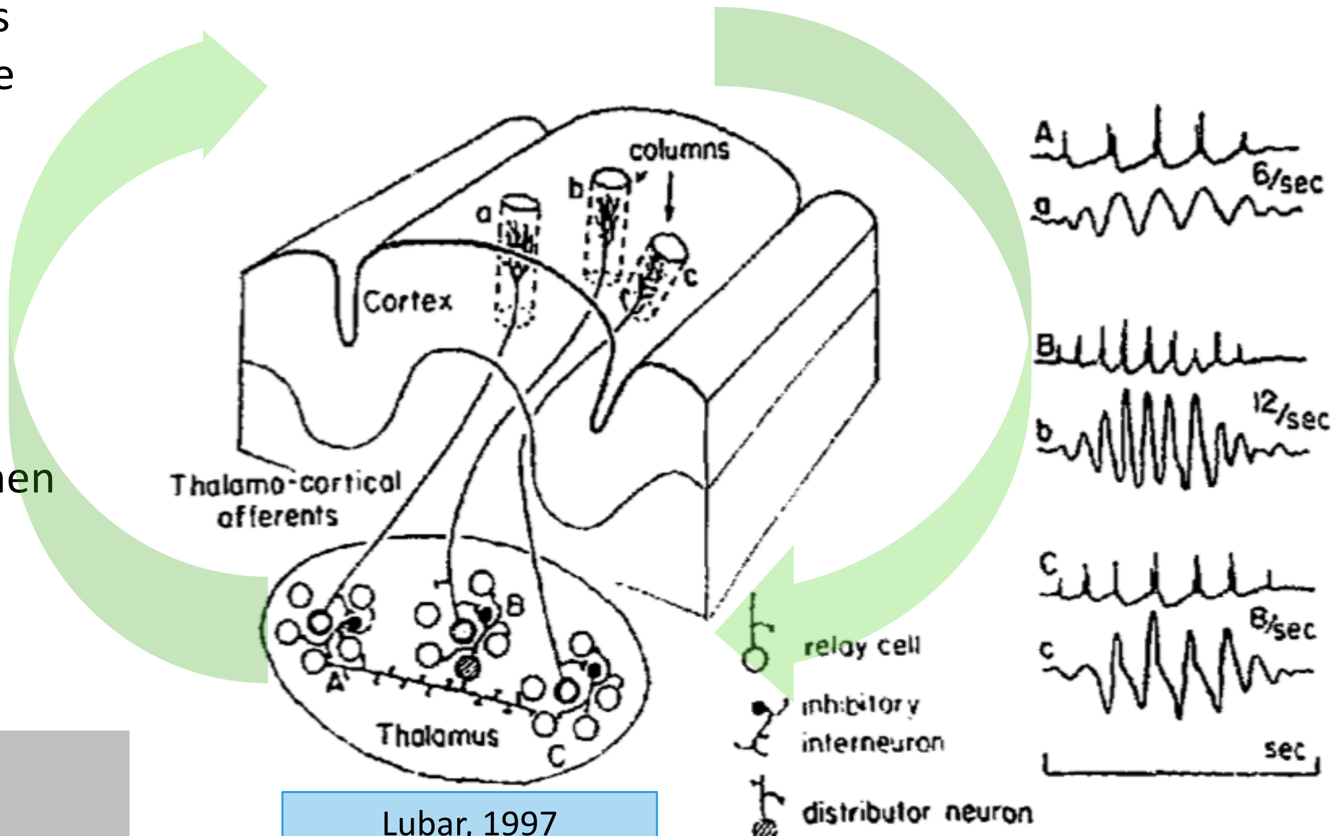
Neocortical Dynamics als Grundlage für EEG basiertes Neurofeedback



- „Taktgeber“ im Thalamus bestimmen „Rhythmus“ des Gehirns je nachdem welche corticaler Schleifen Aktiviert werden.

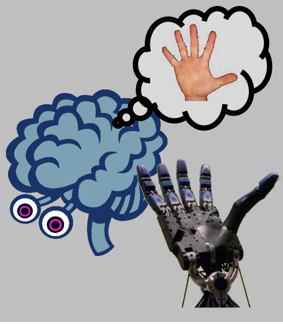
- aber auch:
Änderungen der corticalen Schleifen durch Lernen, Emotionen oder Motivationen führen zu Änderungen der Feuerrate
der Thalamus Neuronen

Thalamo-Corticale Schleife



Lubar, 1997

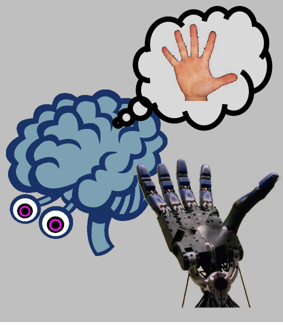
Neurofeedback als Therapie



Zur Behandlung von:

- Aufmerksamkeitsstörungen (AD[H]D)
- Epilepsie
- Post-traumatische Belastungsstörungen
- ...

AD[H]D
Attention Deficit [Hyperactivity] Disorder

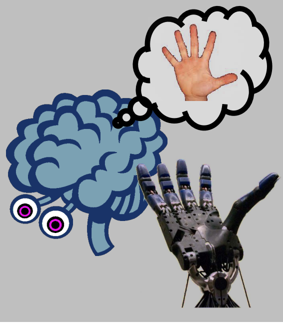


- Häufigste mentale Erkrankung bei Kindern und Jugendlichen
- Symptome:
    - Konzentrationsprobleme
    - nicht adäquates soziales Verhalten
    - „Zappelphilipp“ (Hyperaktivität)
    - „Tagträumerei“ (Hypoaktivität)

- Konsequenzen:
    - schlechte schulische Leistungen
    - Lernschwierigkeiten
    - Probleme im sozialen Umfeld
    - Enorme Belastung für Eltern, Geschwister, Lehrer

- Standard Behandlung:
    - Verhaltenstherapie
    - Medikation (Methylphenidat, „Ritalin“)

Elektrophysiologische Korrelate von ADHD



Spontan EEG:

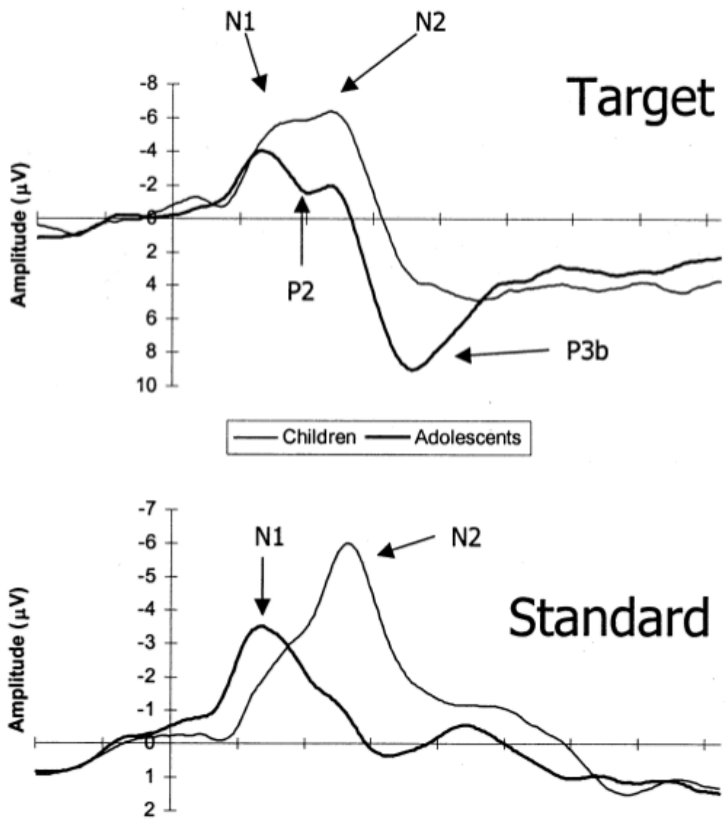
- + theta 4 – 7 Hz Übergang zum Schlafzustand
- - beta 13 – 30 Hz Wach, konzentriert, aufmerksam

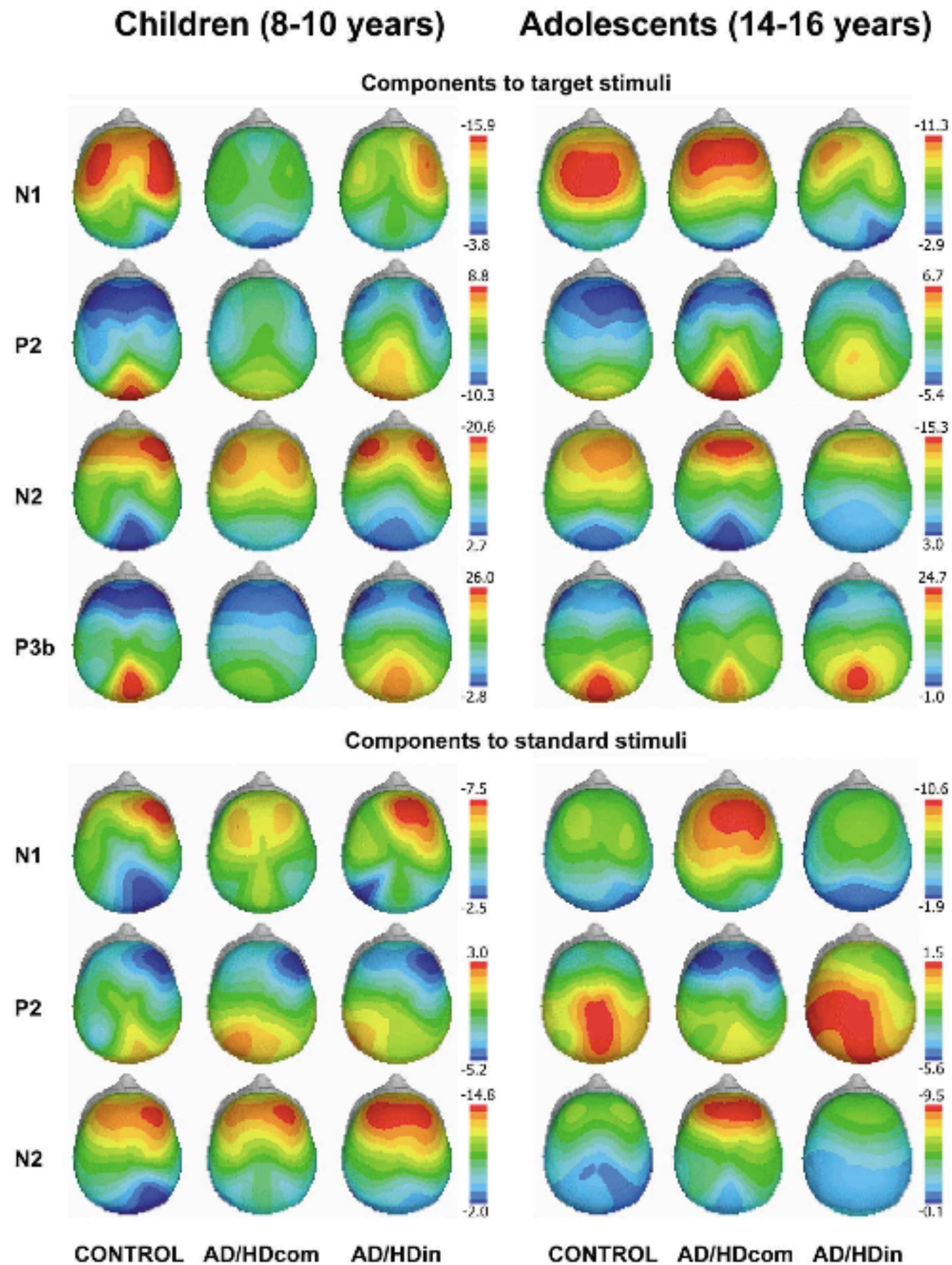
Slow Cortical Potentials (SCPs):

- + Positivierung Übergang zum Schlafzustand
- - Negativierung Lösen von mentalen Aufgaben, hohes Aufmerksamkeitslevel

Event-Related Potentials (ERPs):

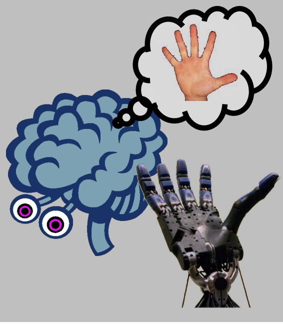
- Veränderung in Amplitude und Latenz (nächste Folie)





Barry et al., 2003

Therapieansatz



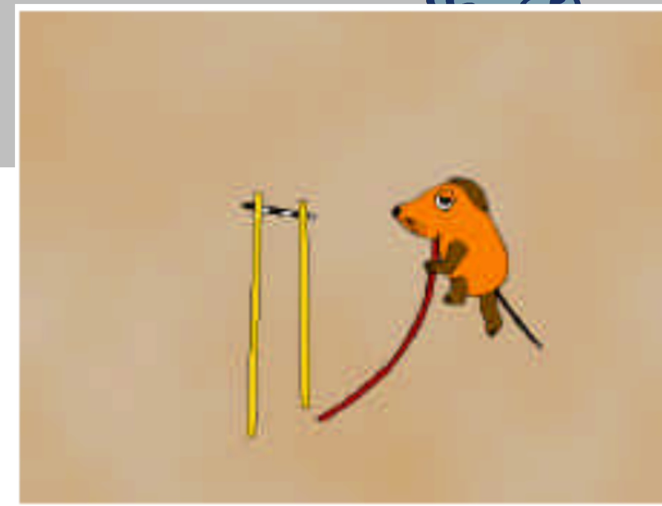
Neurofeedback Training

- theta – beta Training   Verringerung des theta Wellen Anteils bei gleichzeitiger Erhöhung des beta Anteils
  + beta / -theta

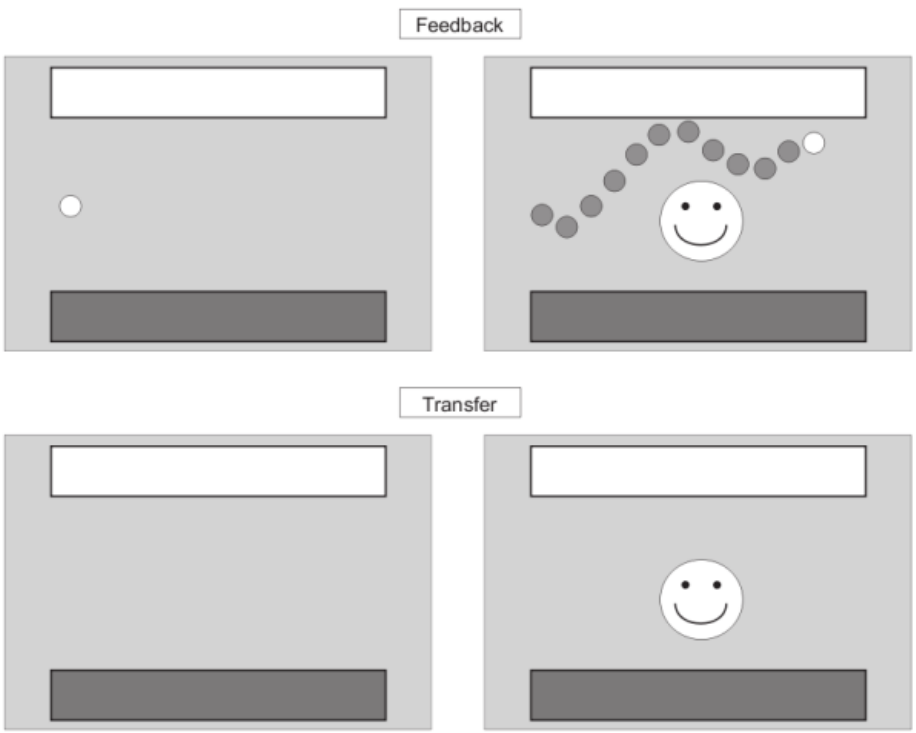
- SCP Training   Verringerung von Positivierung bei gleichzeitiger Negativierung
  + neg / - pos

- SMR (sensori-motor rhythms) Training
  Verstärkung des SMR über dem rechten SMC soll Hyperaktivität verringern

Systeme

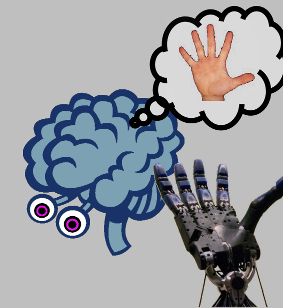


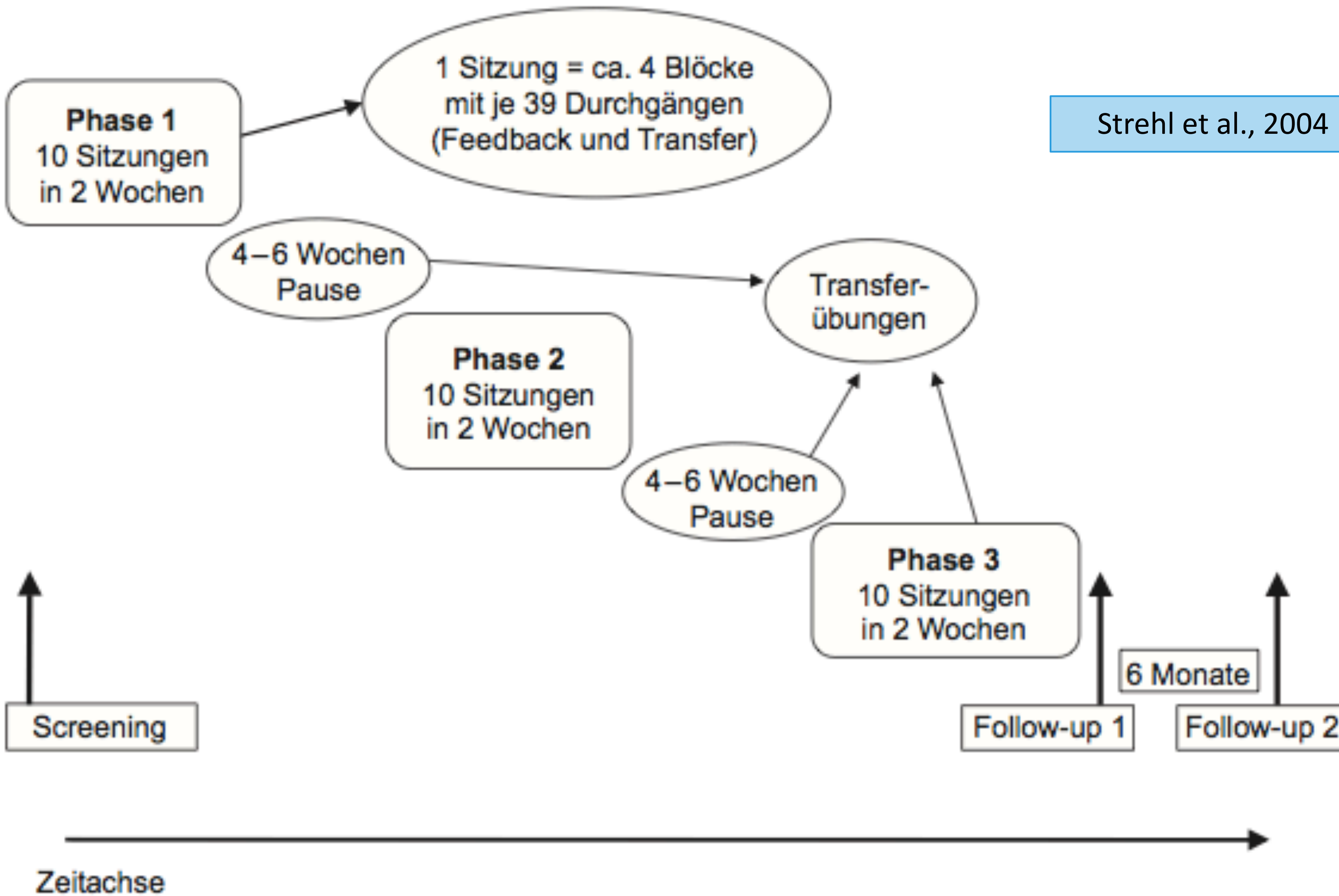
Thought Translation Device – TTD
Universität Tübingen



GöFi
Universität Göttingen

Trainingsphasen

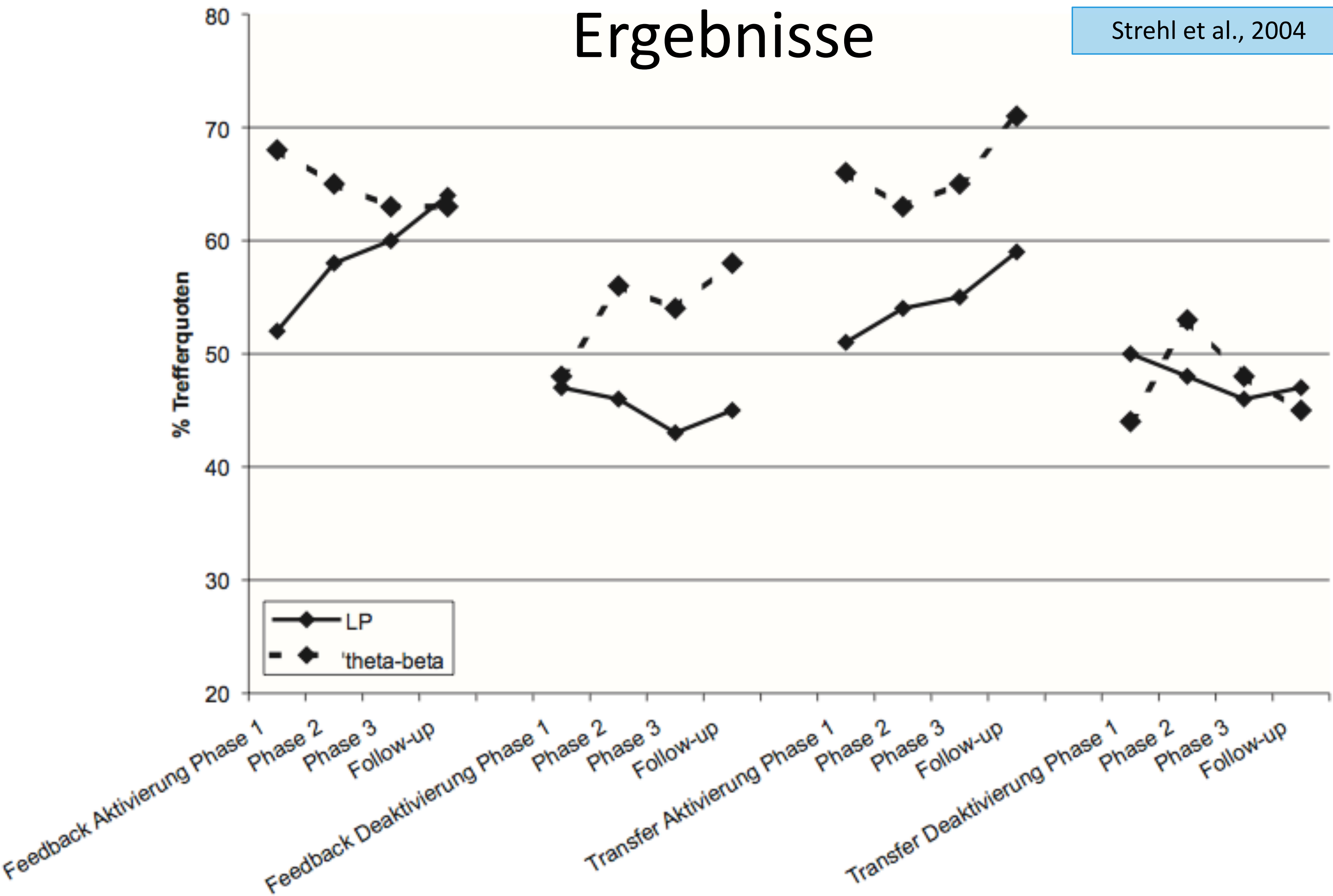




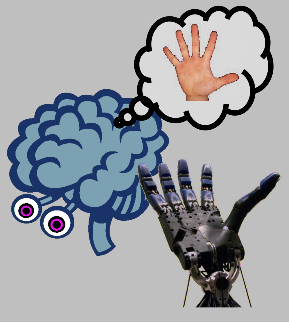
Strehl et al., 2004

Ergebnisse

Strehl et al., 2004



Ergebnisse



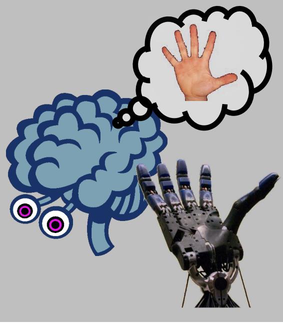
Verbesserung bei den Symptomen

- Hyperaktivität
- Impulsivität
- Sozialverhalten
- Verbesserungen bei Tests zur Aufmerksamkeitsprüfung

- Besserungen auch bei Nachuntersuchungen 6 Monate später messbar

- Teilweise vergleichbare Resultate wie durch Mediktion

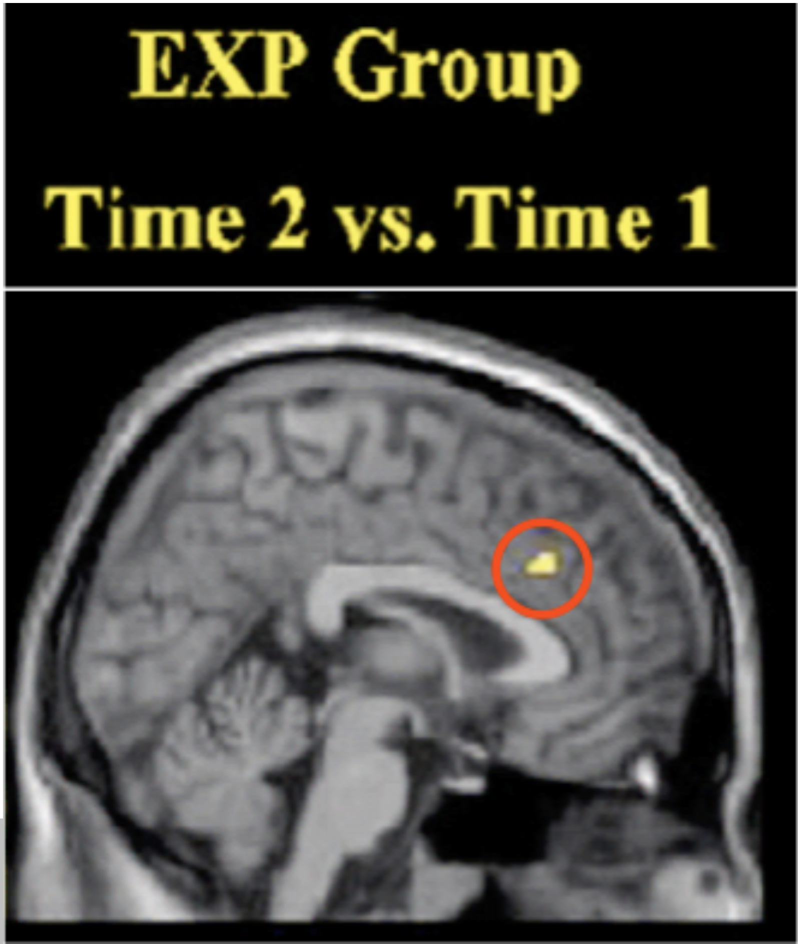
fMRI Untersuchungen



ADHD:
schlechtere Aktivierung des anterioren cingulären Cortex (ACC).

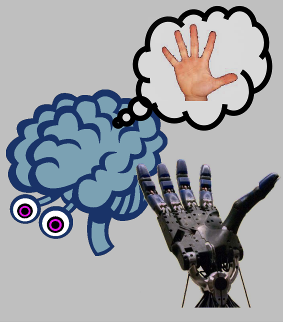
Steht für
- selektive Aufmerksamkeit
- Impulskontrolle

Nach Neurofeedback Training
- normalisierte ACC Funktion
- bessere Impulskontrolle



Levesque et al., 2006

Open Source Software – OpenVIBE



Screenshots