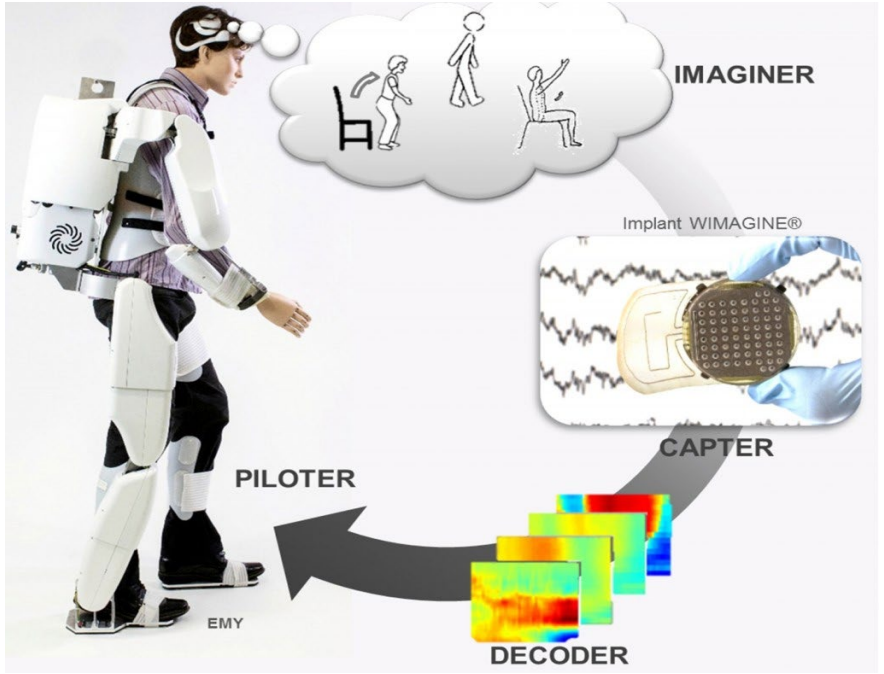








Brain computer interfacing for rehab and communication

Strahinja Dosen

DTHS seminar

Nov 2022

NEUROREHABILITATION SYSTEMS

HOME /

PEOPLE RESEARCH PUBLICATIONS CONTACT US

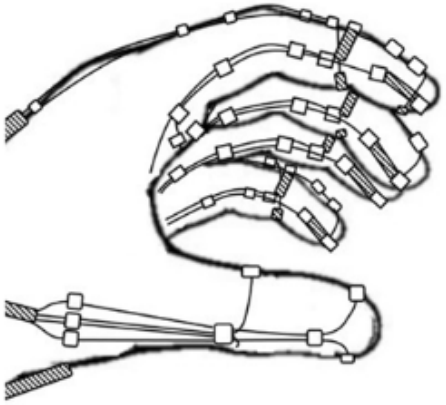
Welcome to the home page of the Neurorehabilitation Systems Research Group of Aalborg University!

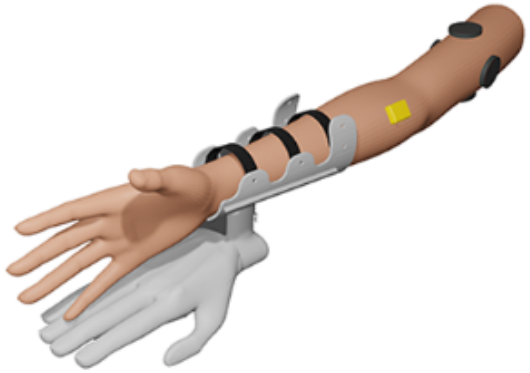
WHO ARE WE?

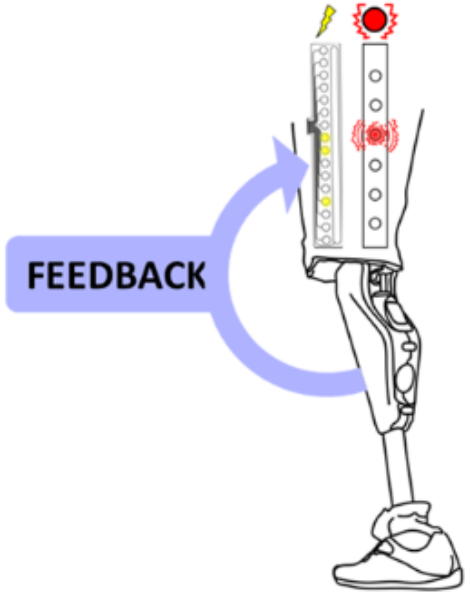
We are an interdisciplinary group that aims at developing and evaluating methods and technologies to assist patients with lost or impaired sensory-motor functions. We strive to translate the insights from human neurophysiology and computational neuroscience into effective biomimetic neurorehabilitation systems.

OUR RESEARCH – WHAT WE DO

Our focus is on improving the effectiveness of robotic prostheses, exoskeletons, and functional electrical stimulation systems and on providing a better user experience when interacting with these devices. For example, we explore novel methods to allow intuitive and dexterous control and transmit artificial somatosensory feedback so that the users can seamlessly operate as well as "feel" their bionic limbs. We also investigate assistive technologies that can be used for the training and improved mobility of elderly, diseased and injured people.







- 3 faculty positions
- 3 Postdocs
- 8 Ph.D. students

European Commission

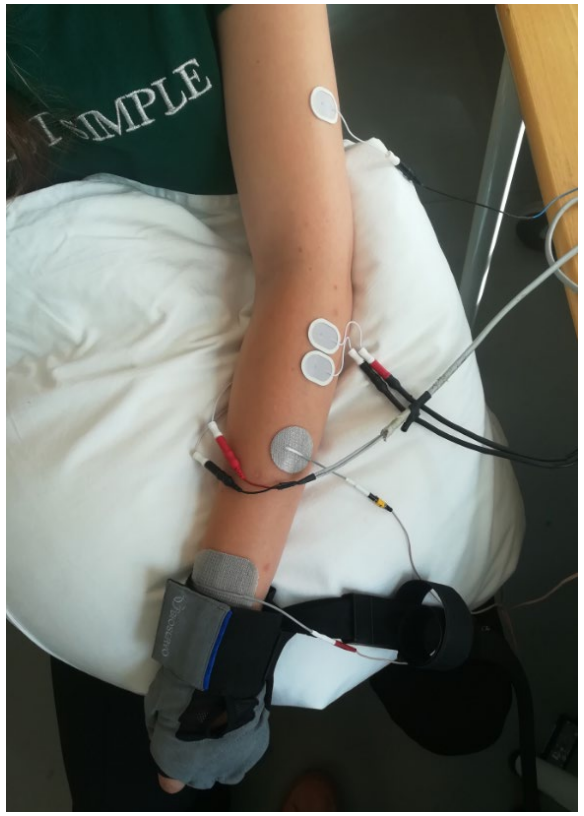
HORIZON 2020

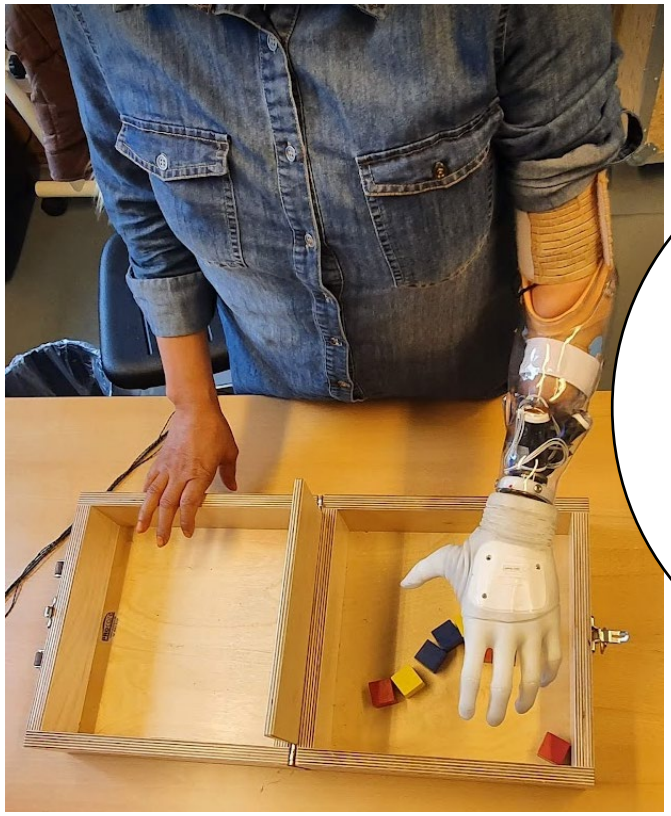
INDEPENDENT RESEARCH FUND DENMARK

Innovation Fund Denmark

Group for Neurorehabilitation Systems





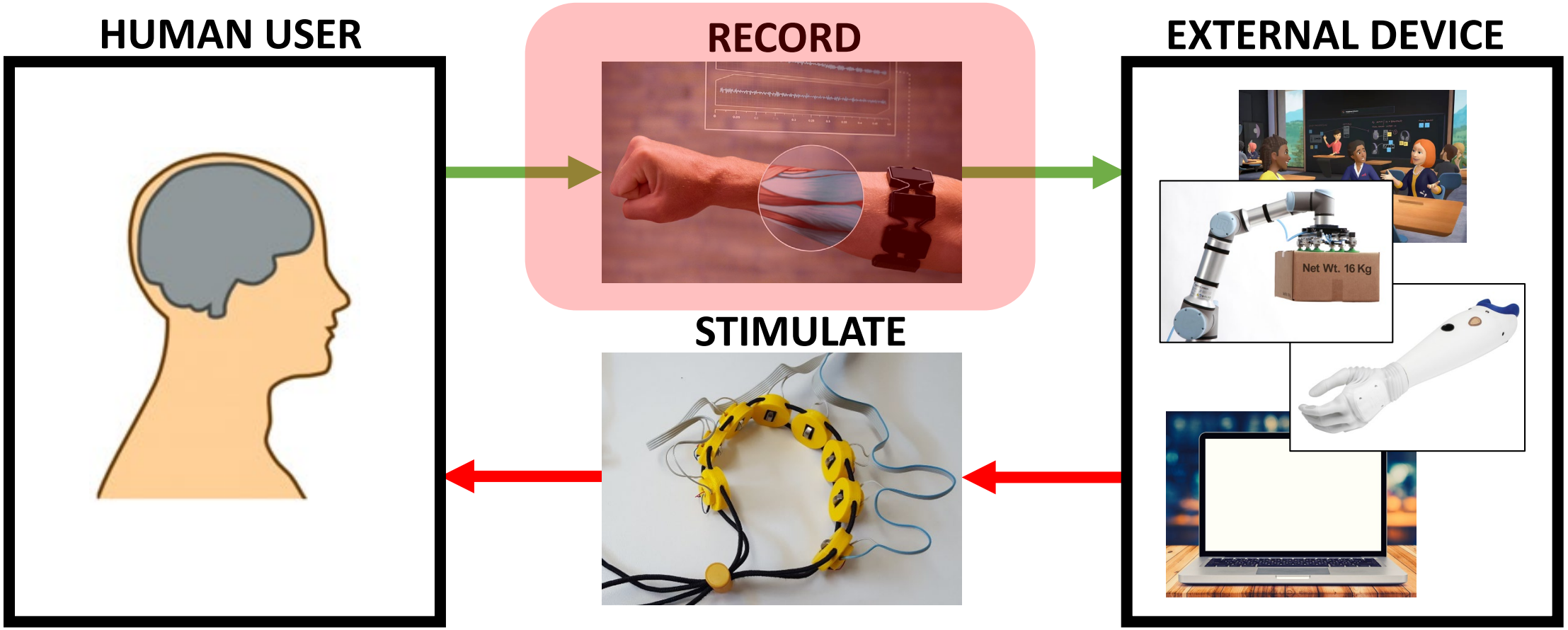




www.neurorehabsystems.aau.dk

https://vbn.aau.dk/en/organisations/neurorehabilitation-systems

Human-machine interfacing:
Connecting humans to the external devices



J. W. Sensinger and S. Dosen, "A Review of Sensory Feedback in Upper-Limb Prostheses From the Perspective of Human Motor Control," *Front Neurosci*, Jun. 2020.

Translating user signals into commands







Connecting brain to external devices

Mind reading

Thought control

Forbes

AI

Brain-Computer Interfaces And Mind Control Move One Step Closer To Becoming Reality

Simon Chandler Former Contributor

I'm a journalist covering emerging tech and its effects on society.

Sep 24, 2019, 10:35am EDT

NORDJYSKE

Science Fiction: De hjælper lammede patienter med at flytte ting ved tankens kraft

Nordjyske læger og ingeniører er sammen om epokegørende forskning, der bringer lammet motorik fra tanke til handling



Strahinja Dosen iført hætten, der gør det muligt at styre ved hjælp af tankens kraft - til gavn for patienter med lammelser. *Foto: Torben Hansen*

MEDTECH

Separating science from sci-fi: Battelle's Justin Sanchez on balancing the buzz of brain-computer interfaces

By **Andrea Park** · Sep 2, 2021 08:30am

executives | implant | medical device | Neurology

European Commission

Search

Horizon

The EU Research & Innovation Magazine

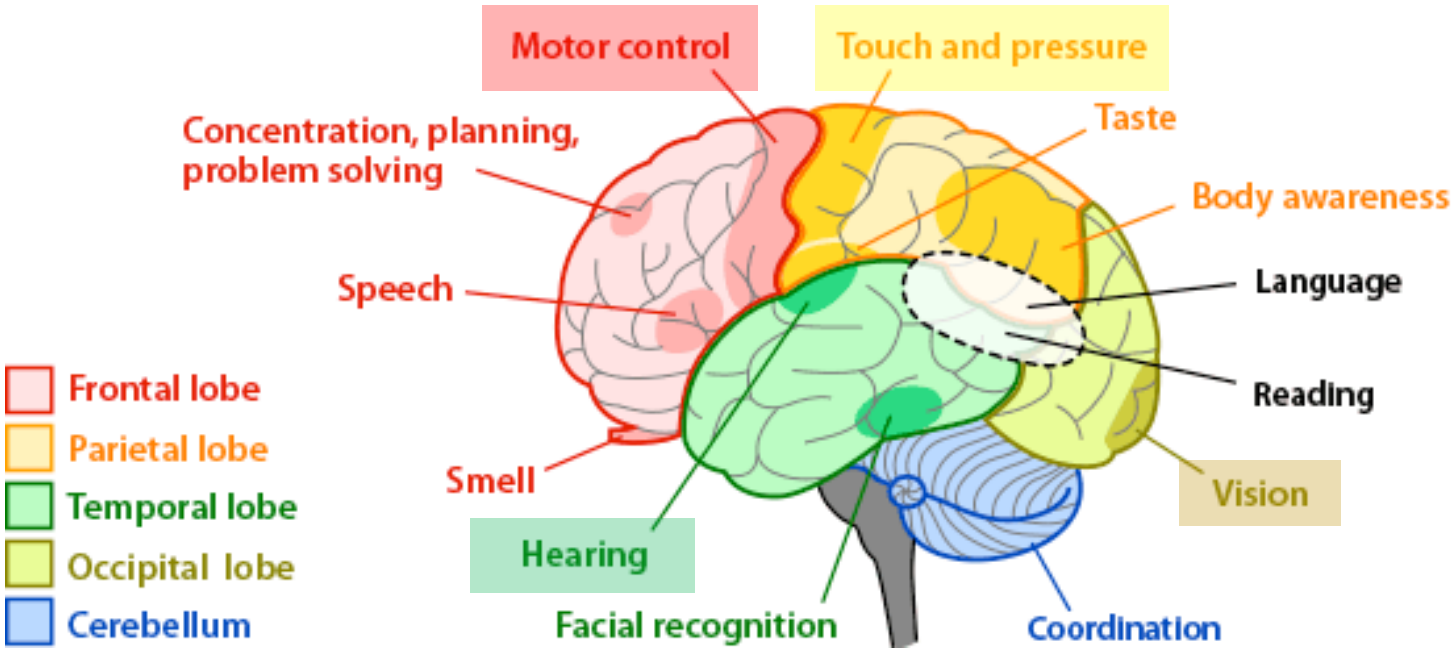
HOME | VIEWS | TOPICS | VIDEOS | ABOUT

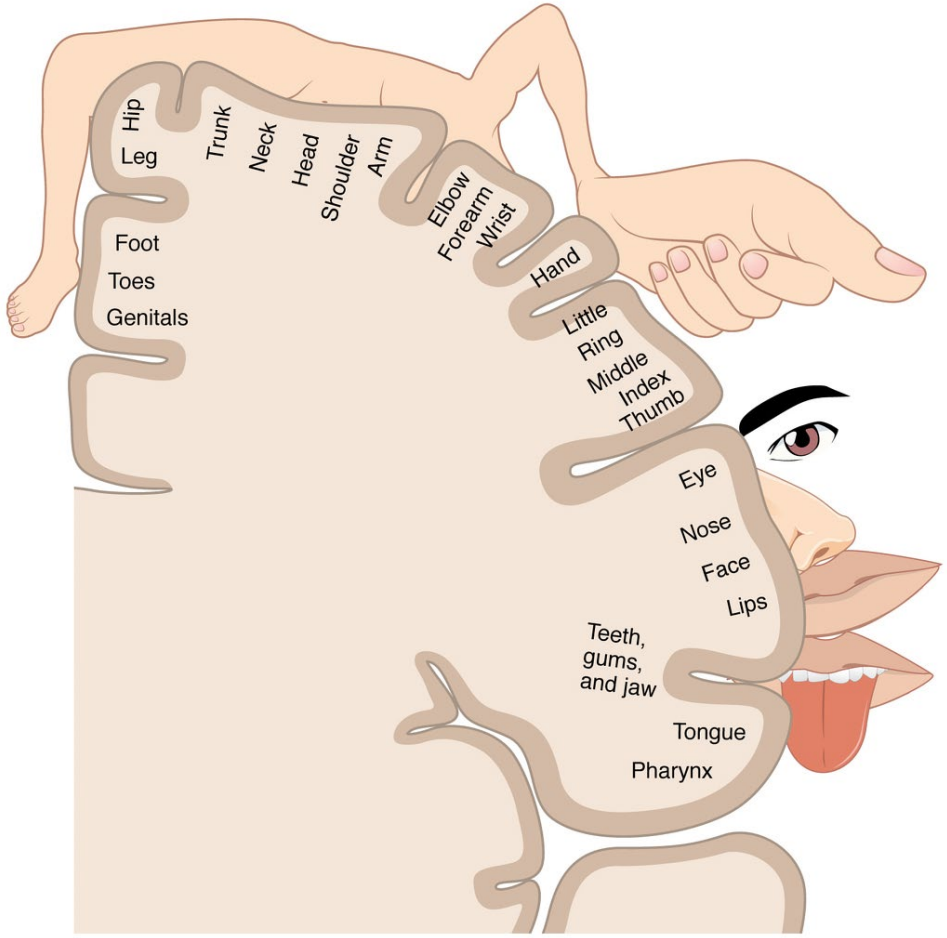
ICT | INDUSTRY | FRONTIER RESEARCH

REPUBLISH

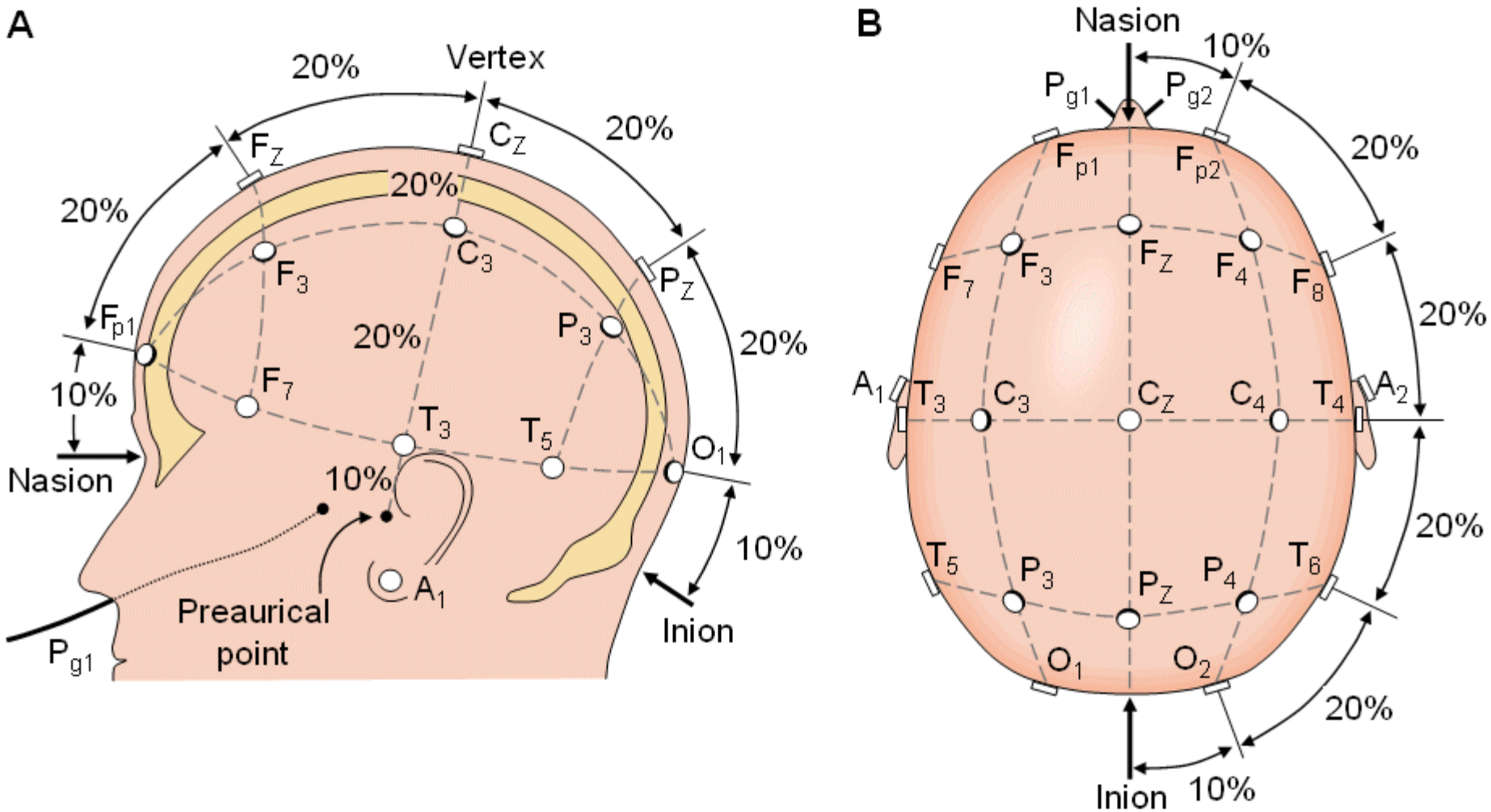
Brain-controlled computers are becoming a reality, but major hurdles remain

Brain areas and functions



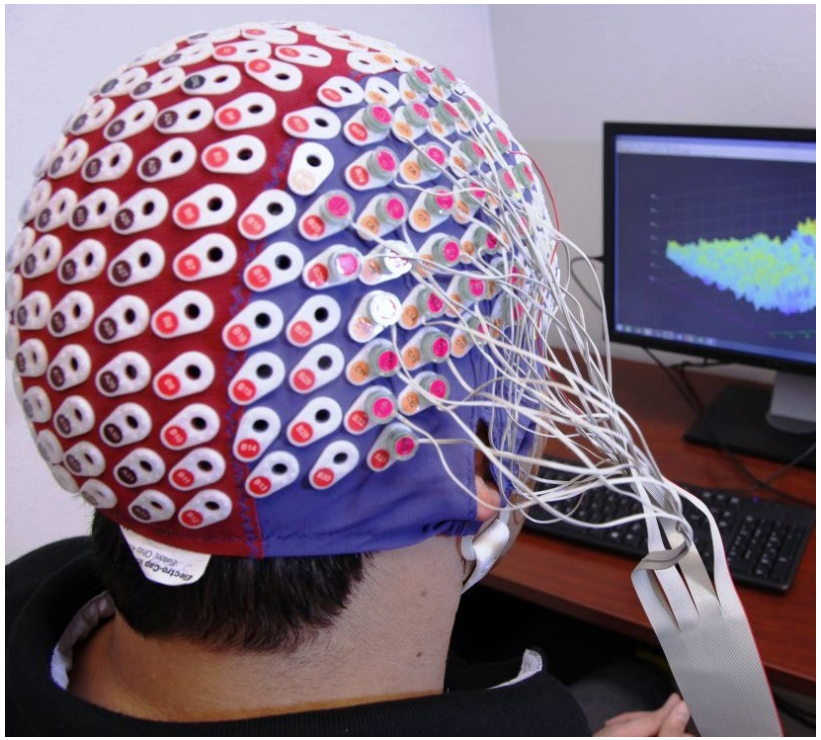


Electroencephalography (EEG)
Standard 10-20 configuration

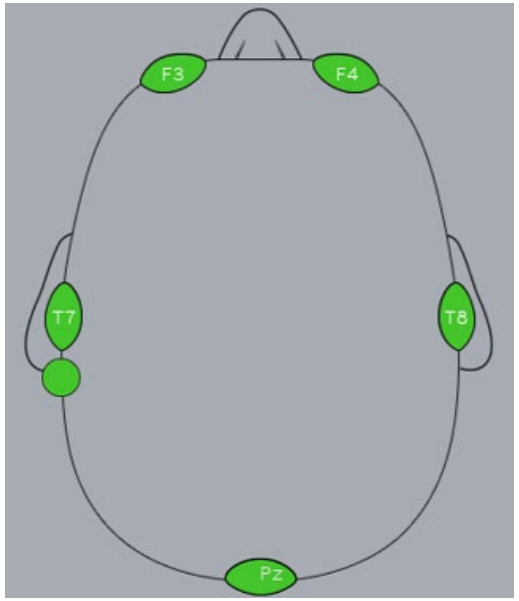


Electroencephalography (EEG)









www.emotiv.com

EEG cap and electrodes



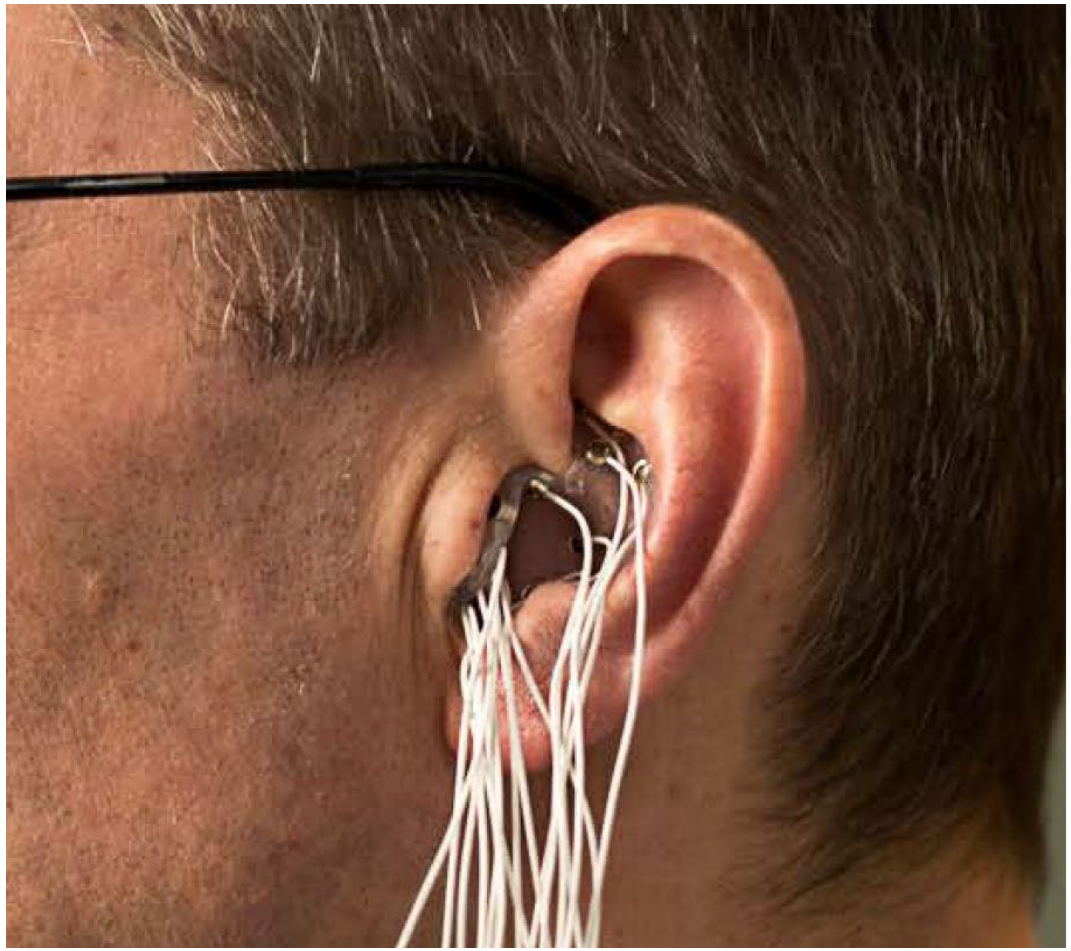


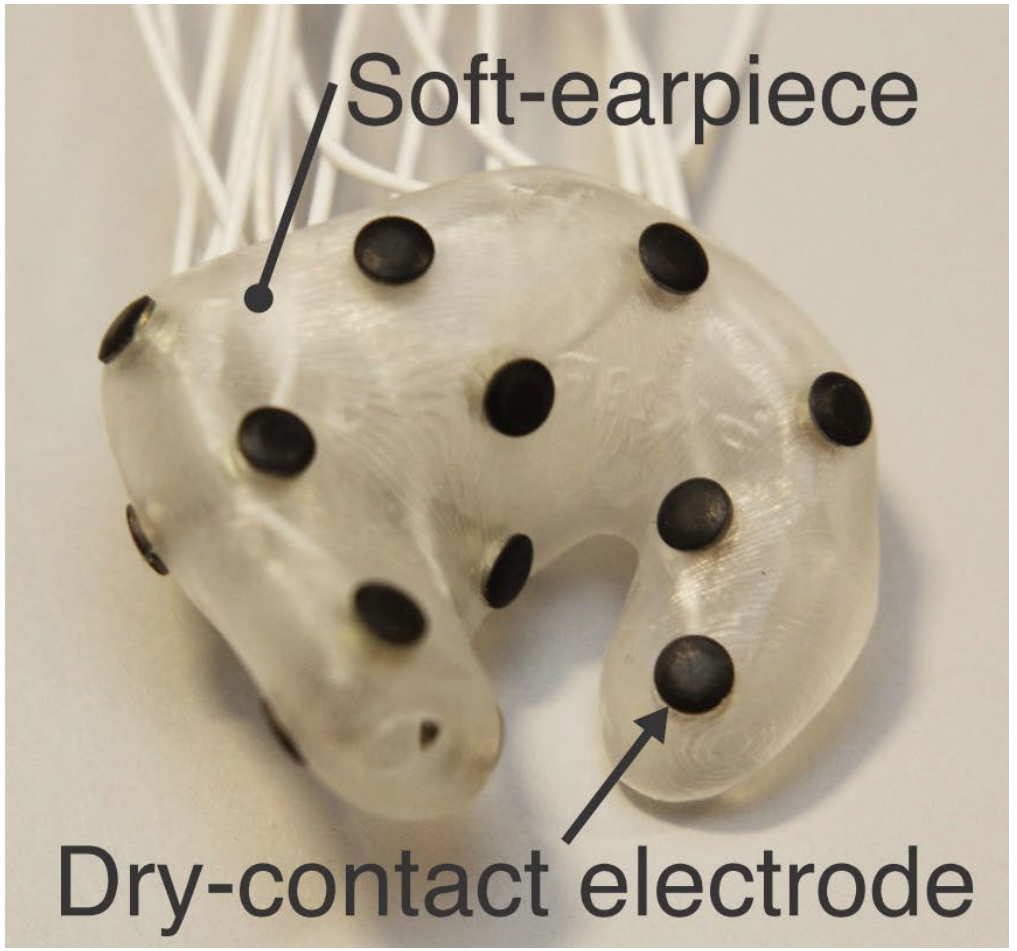






EEG from ear electrodes



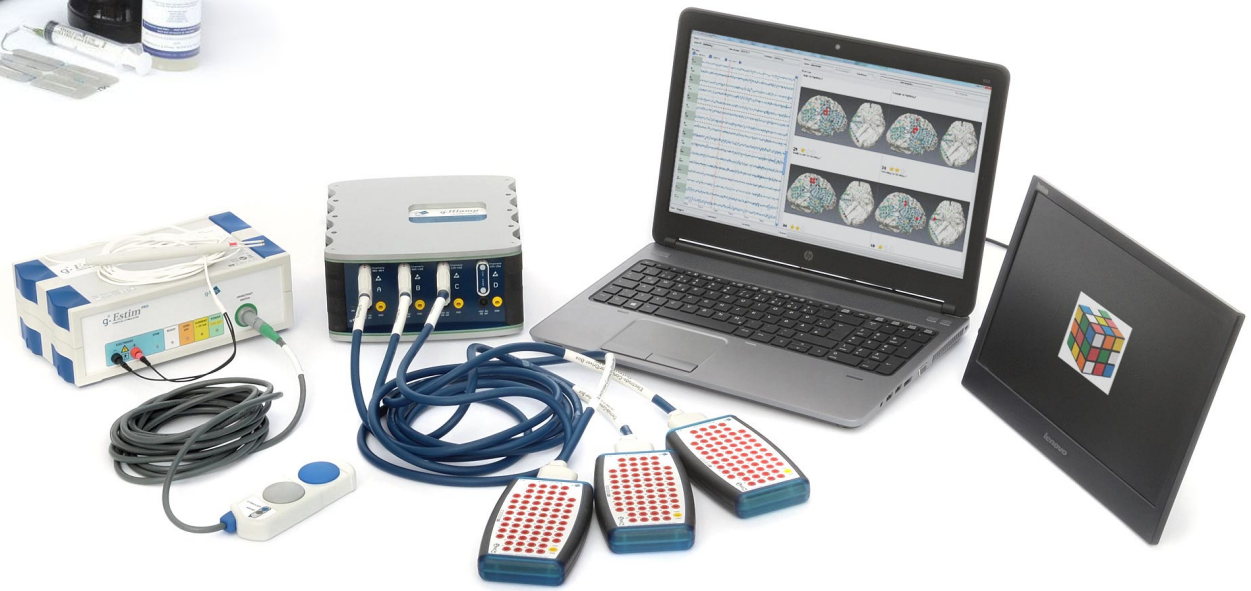


Kappel, Simon L. et al. 2018 *IEEE Trans Biomed Eng*

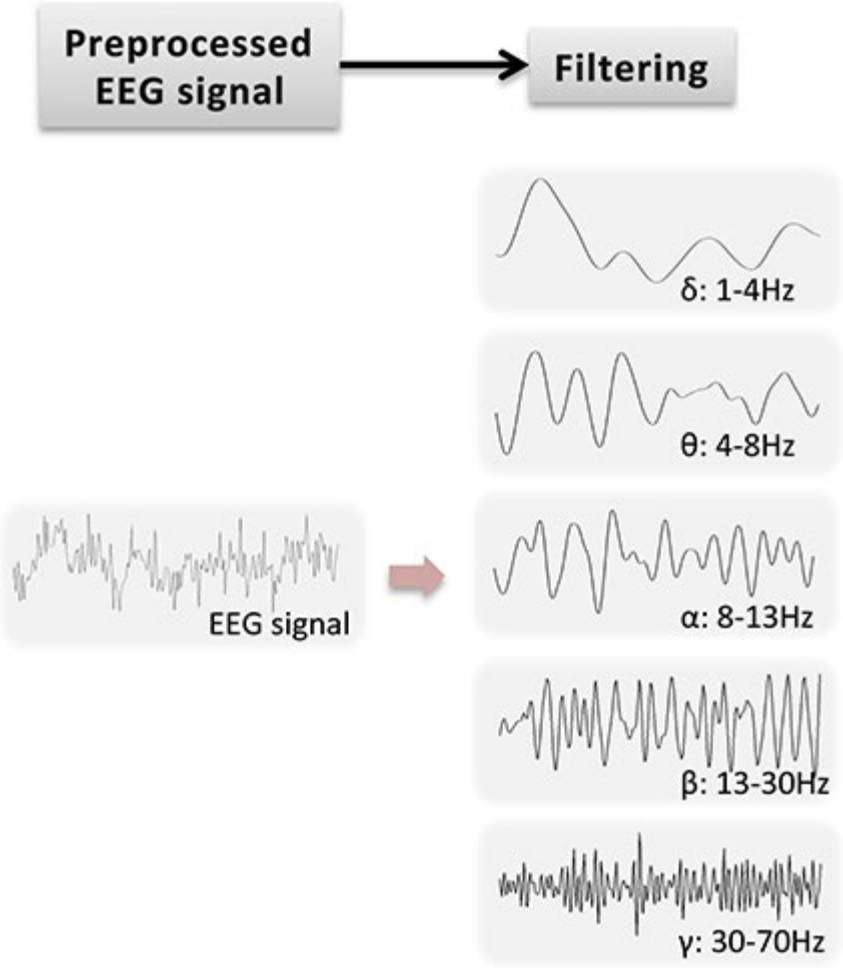
EEG amplifiers and stimulus generators





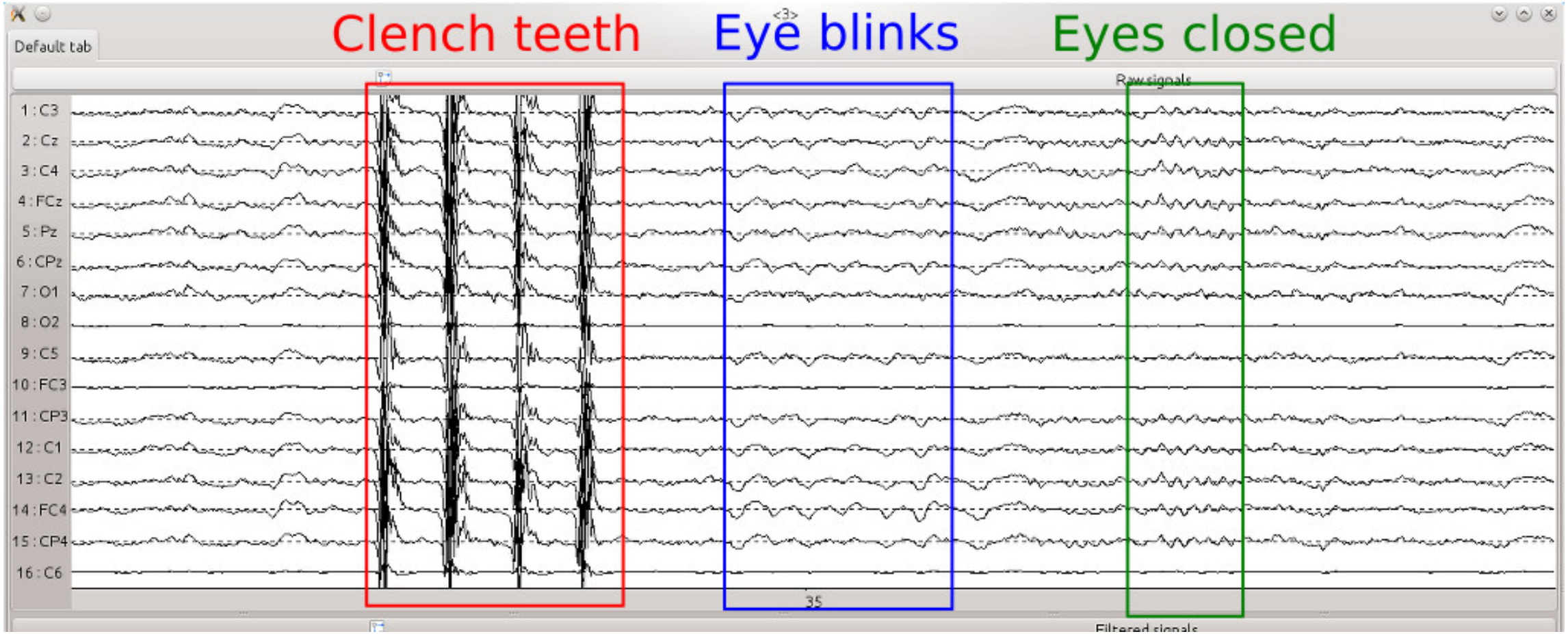


EEG signal components



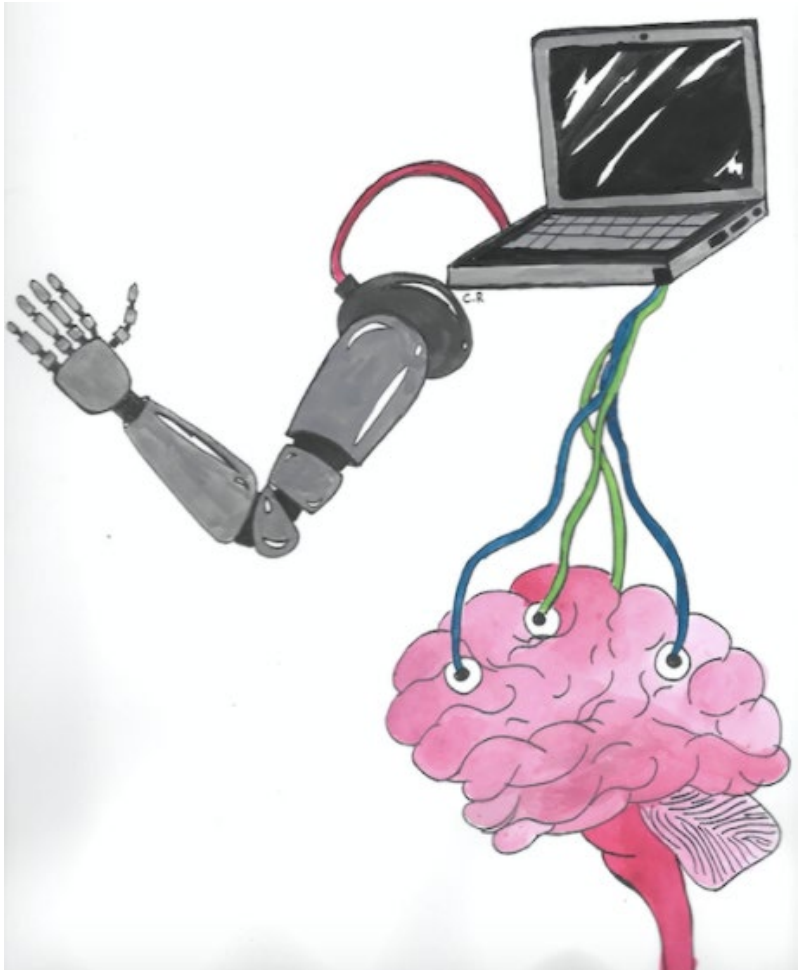
Type	Amp [uV]	Freq. [Hz]	State
Delta	50-200	1-4	Deep sleep
Theta	30-100	4-8	Sleep/wake, meditation
Alpha	10-40	8-13	Occipital region, Relaxed awareness, eyes closed
Beta	15-30	13-30	Wake, active thinking, attention, frontal and central regions
Gamma	5-20	30-70	Still speculative

EEG recording is very sensitive!

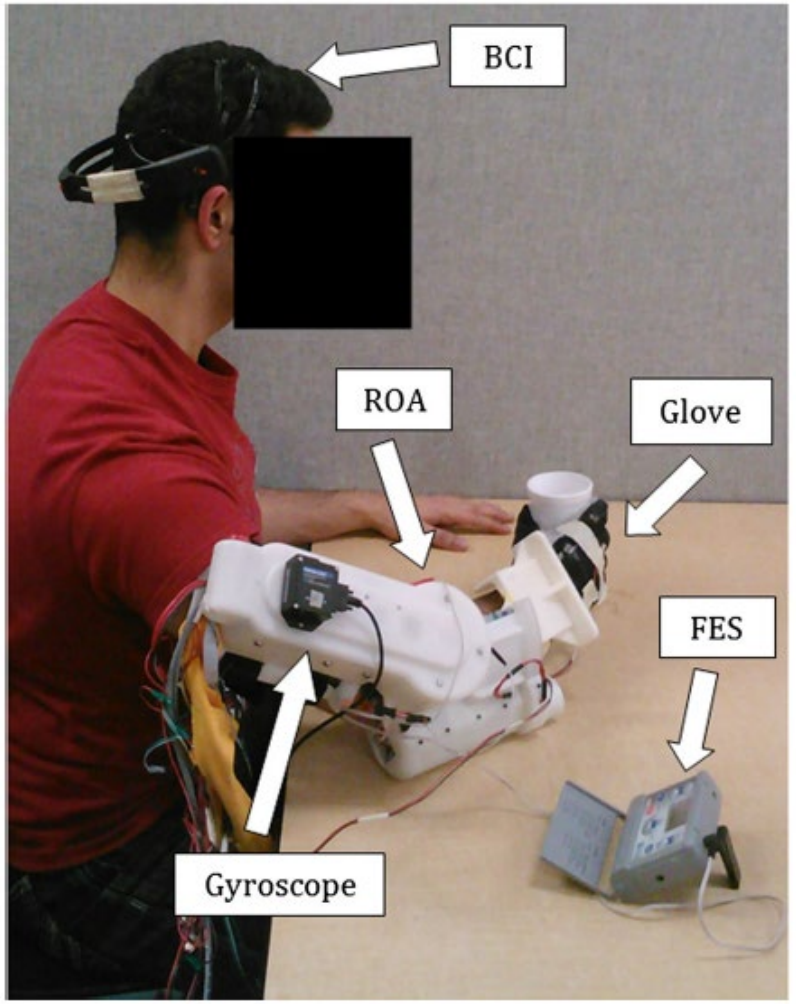


www.openbci.com

Brain computer interface



www.mcgilldaily.com



Looned et al., J NeuroEng Rehab, 2014



www.reuters.com

What is desired versus what is possible



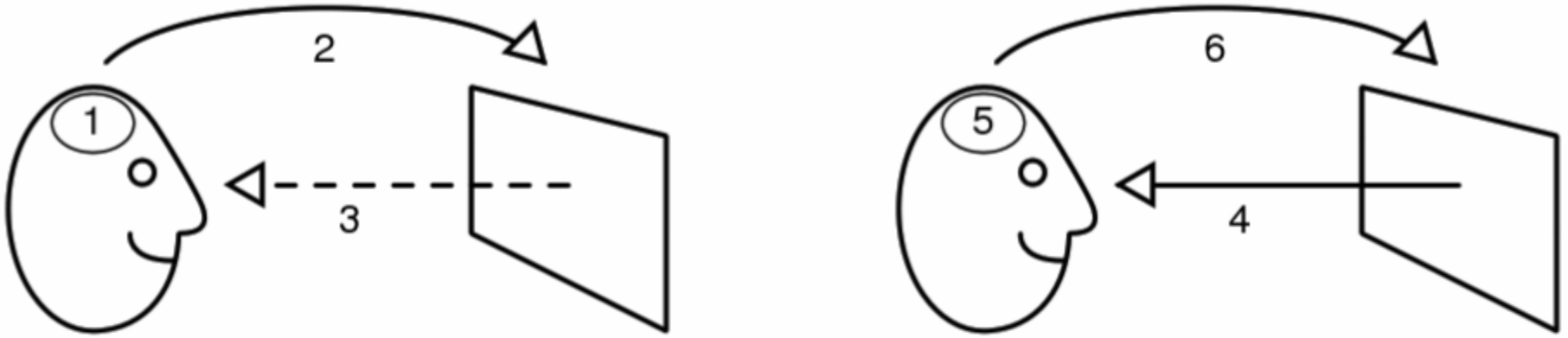
FIFA World Cup 2014







Brain computer interface



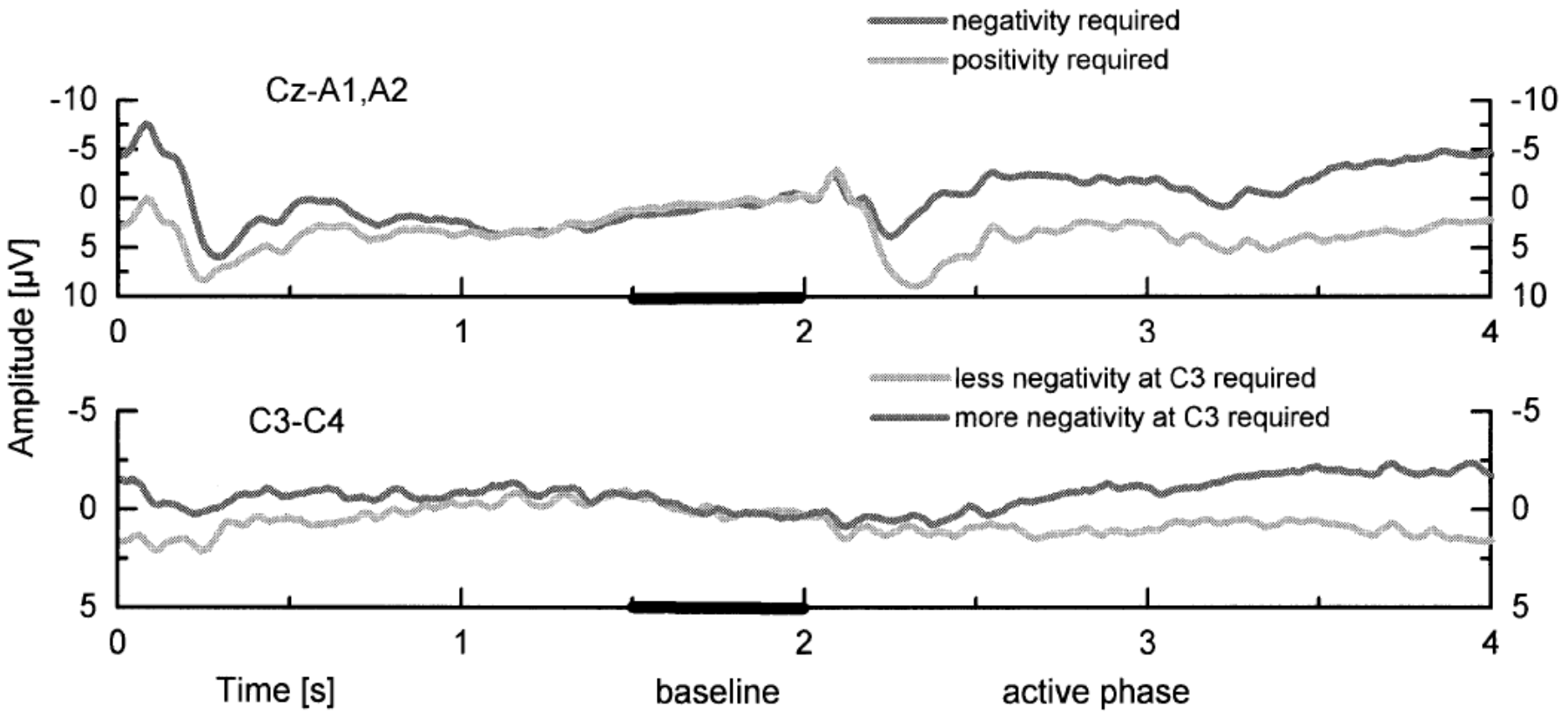
a) Active BCI

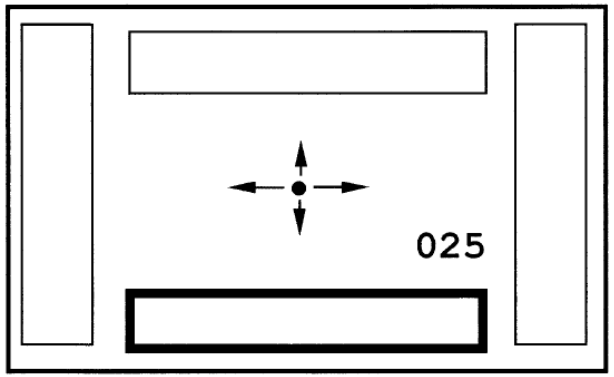
b) Reactive BCI

Figure 4.1. *Active versus reactive BCI. a) In an active BCI, the user spontaneously modifies his or her mental state (1). The system detects this variation (2). It then possibly sends informative feedback (3). b) In a reactive BCI, the system stimulates the user (4), whose brain reacts to certain stimuli (5), thus producing a modification in mental state eventually detected by the system (6)*

Laurent et al., Brain Computer Interfaces: Methods, Applications and Perspectives, John Wiley & Sons, 2016

Slow cortical potentials (SCP)





Kübler et al., Experimental Brain Research, 1999

Movement-related synchronization and desynchronization (ERD and ERS)

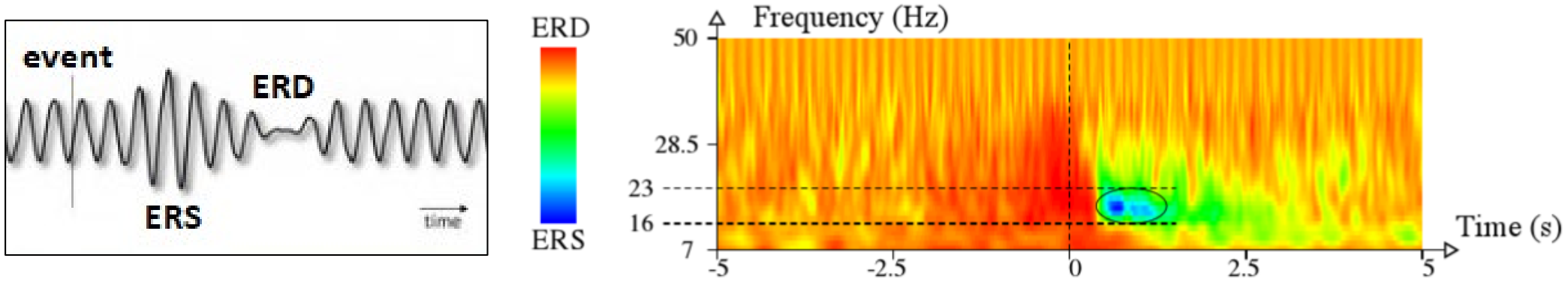
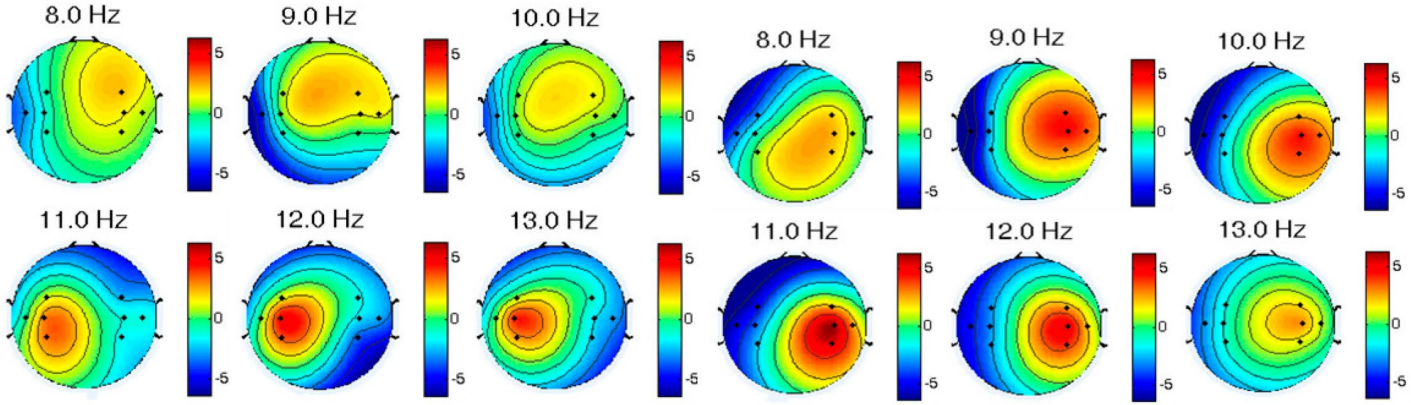


Figure 4.3. *Desynchronization and synchronization related to the event. Spectrogram (time-frequency representation) of an EEG signal recorded directly above the motor area during movement. Event-related desynchronization (ERD) begins both in the mu (8–12 Hz) and beta (13–30 Hz) ranges. ERD in the mu range is produced for about 1 s after the end of movement. On the other hand, only 500 ms after the end of movement an event-related synchronization appears in the beta range. This "beta rebound" is located in the figure's ellipse. For a color version of this figure, see www.iste.co.uk/clerc/interfaces1.zip*

Laurent et al., Brain Computer Interfaces: Methods, Applications and Perspectives, John Wiley & Sons, 2016

Detecting movement attempt / imagination



(a) Left hand motor imagery

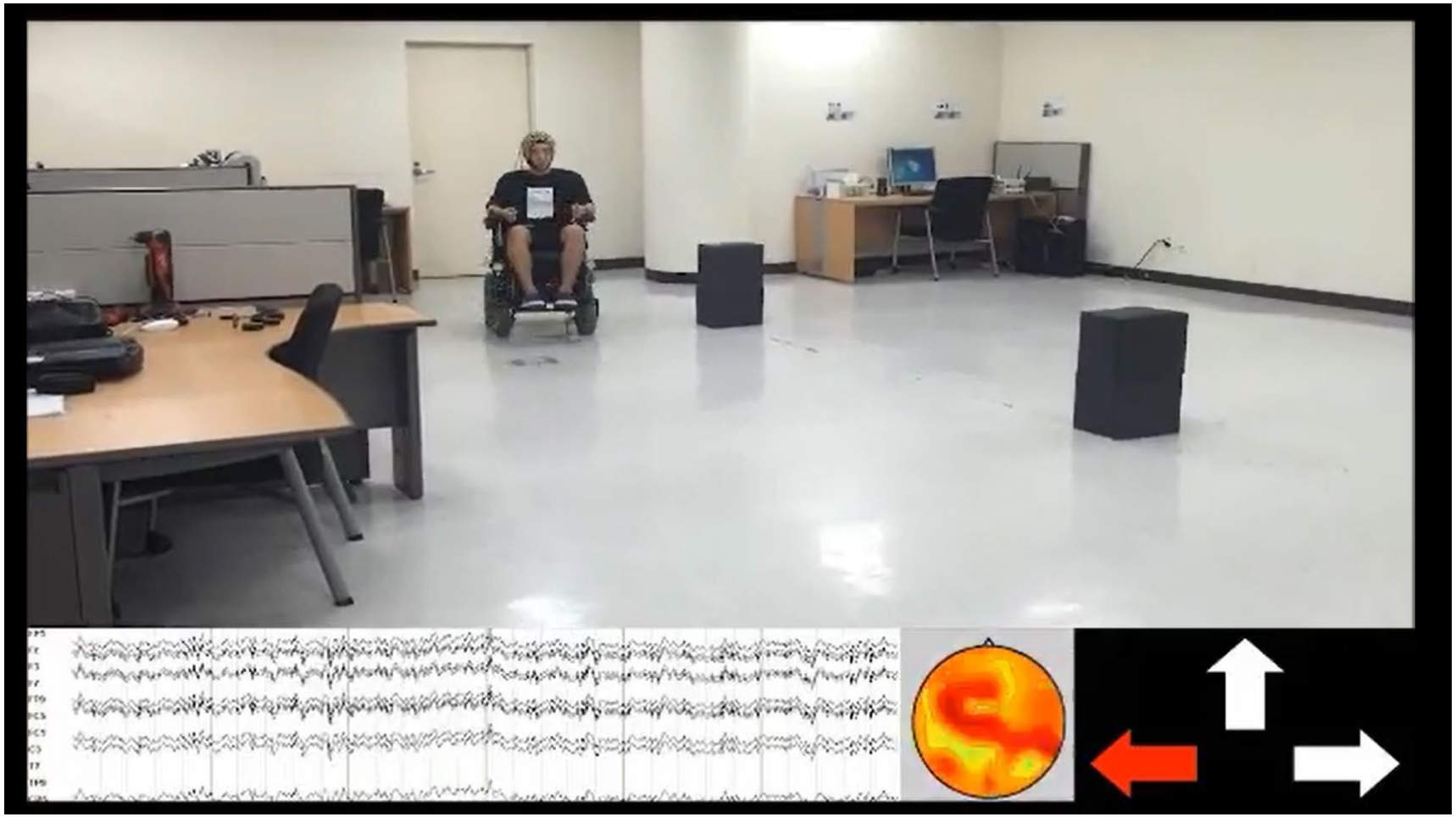
(b) Right hand motor imagery

(c) Both hands motor imagery

(d) Both hands relax imagery

Xu, B.; Li, W.; He, X.; Wei, Z.; Zhang, D.; Wu, C.; Song, A. Motor Imagery Based Continuous Teleoperation Robot Control with Tactile Feedback. Electronics 2020, 9, 174.

Mind control wheelchair



https://www.youtube.com/watch?v=V_Z5wnX9BDg

Detecting the focus of attention using P300 potential



Emotiv & Wadsworth Center

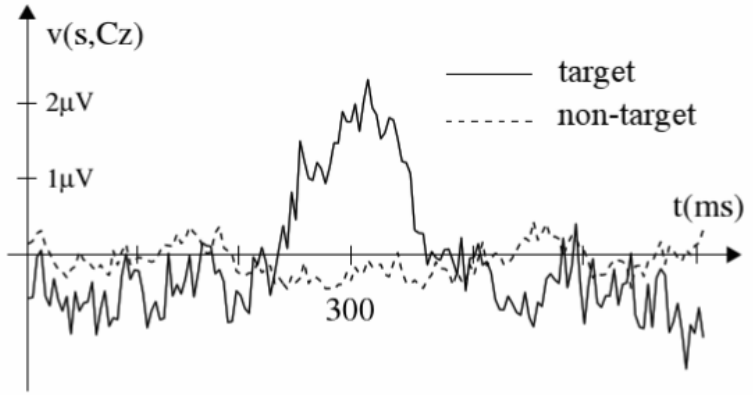
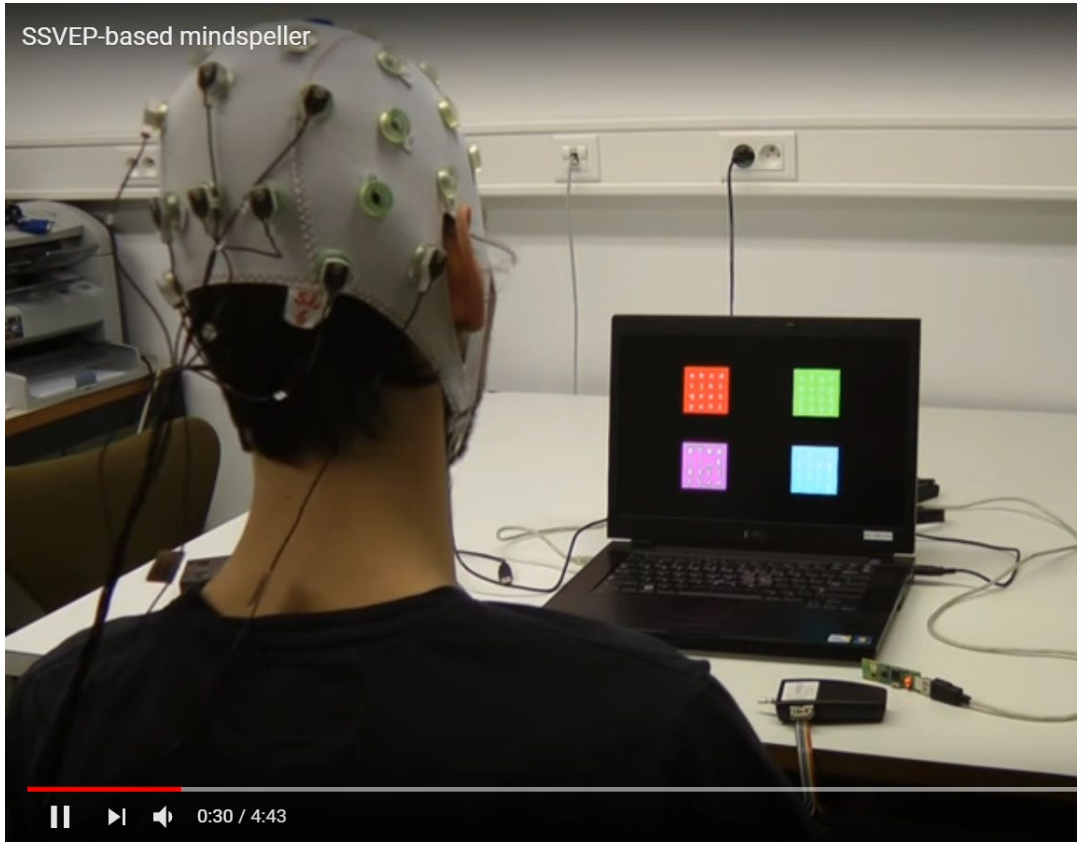


Figure 4.5. *Endogenous P3b potential. EEG readings recorded on a Cz electrode in response to target stimuli (continuous line) and to standard stimuli (dotted line), averaged over 60 recording in each case. We can observe an increase in potential in the neighborhood of 300 ms after a target stimulus*

Laurent et al., Brain Computer Interfaces: Methods, Applications and Perspectives, John Wiley & Sons, 2016

Detecting the focus of attention
Steady-state visually evoked potentials



Nikolay Chumerin

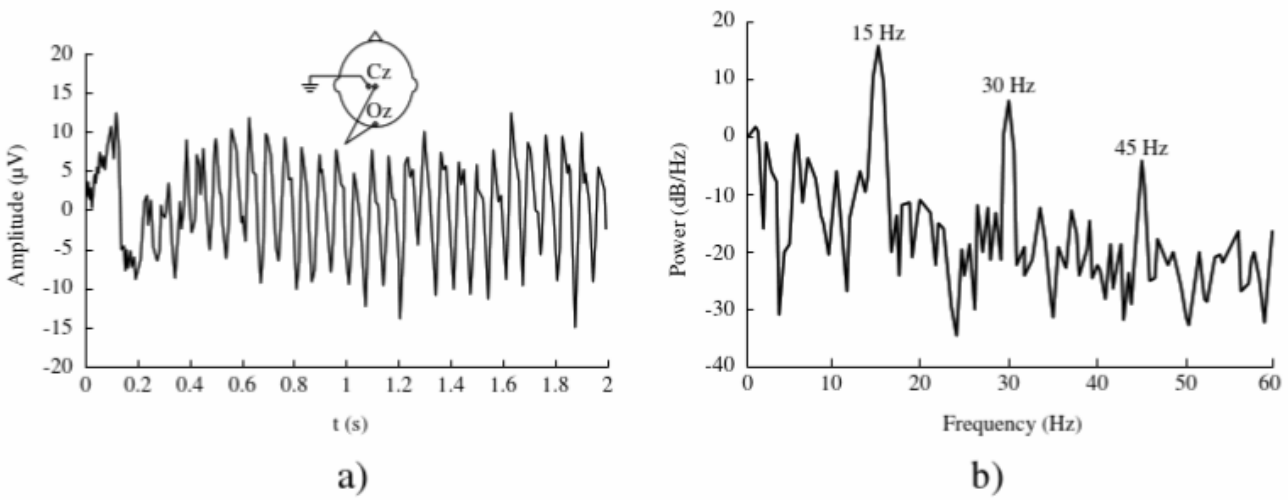
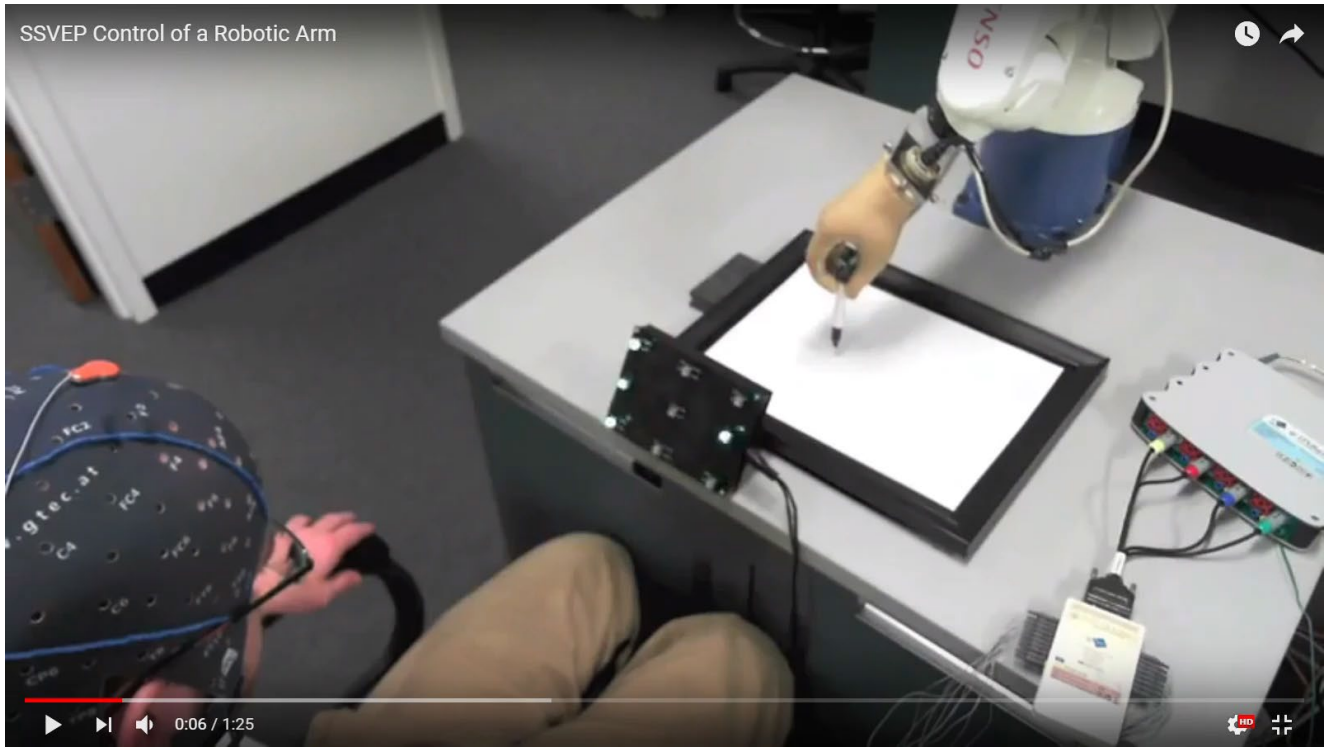


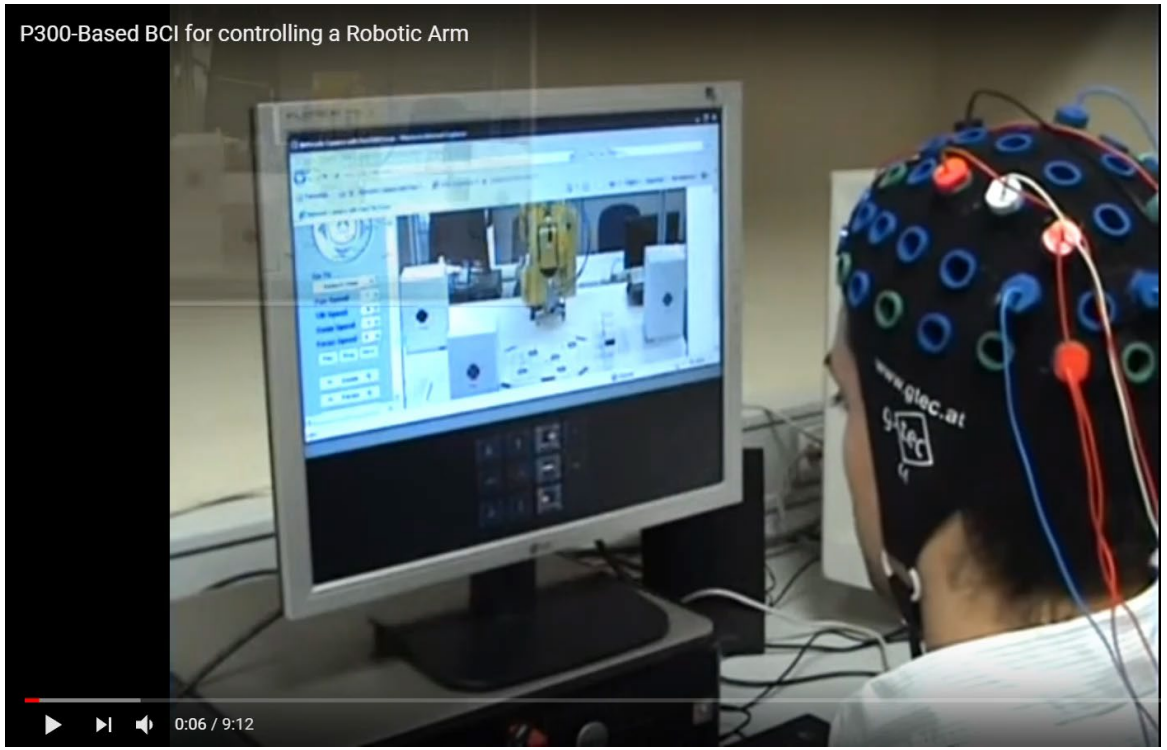
Figure 4.4. *EEG measured on a bipolar derivation on positions Oz and Cz during visual stimulation at a frequency of 15 Hz. a) Signal averaged on 10 experiments synchronized at the beginning of the stimulus. The transitory phase is clearly visible before the emergence of the steady-state protocol. b) Power spectrum for that same signal, showing a peak for the fundamental frequency – which is identical to that of the stimulus – and several other peaks for its harmonics. Figure reproduced from [ZHU 10]*

Laurent et al., Brain Computer Interfaces: Methods, Applications and Perspectives, John Wiley & Sons, 2016

Online robot control



g.tec Medical Engineering and ASPEN Lab, Old Dominion University



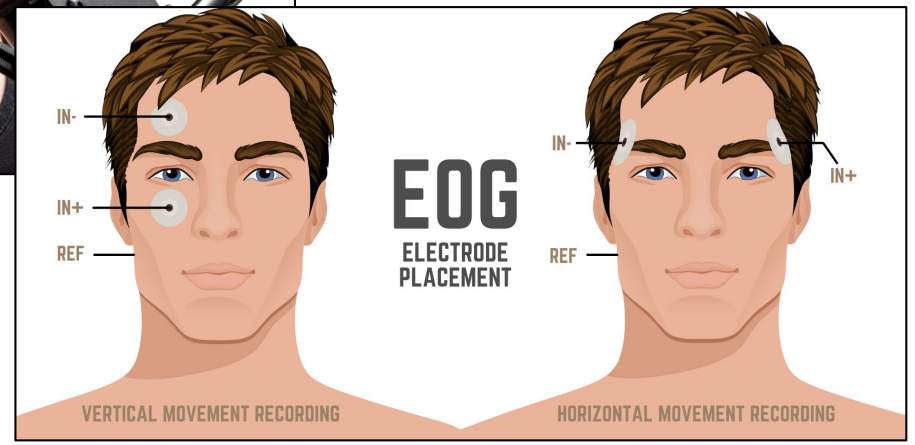
VR2-nBio Lab, Universidad Miguel Hernandez de Elche

BCI versus other control methods









BCI to assist highly disabled patients

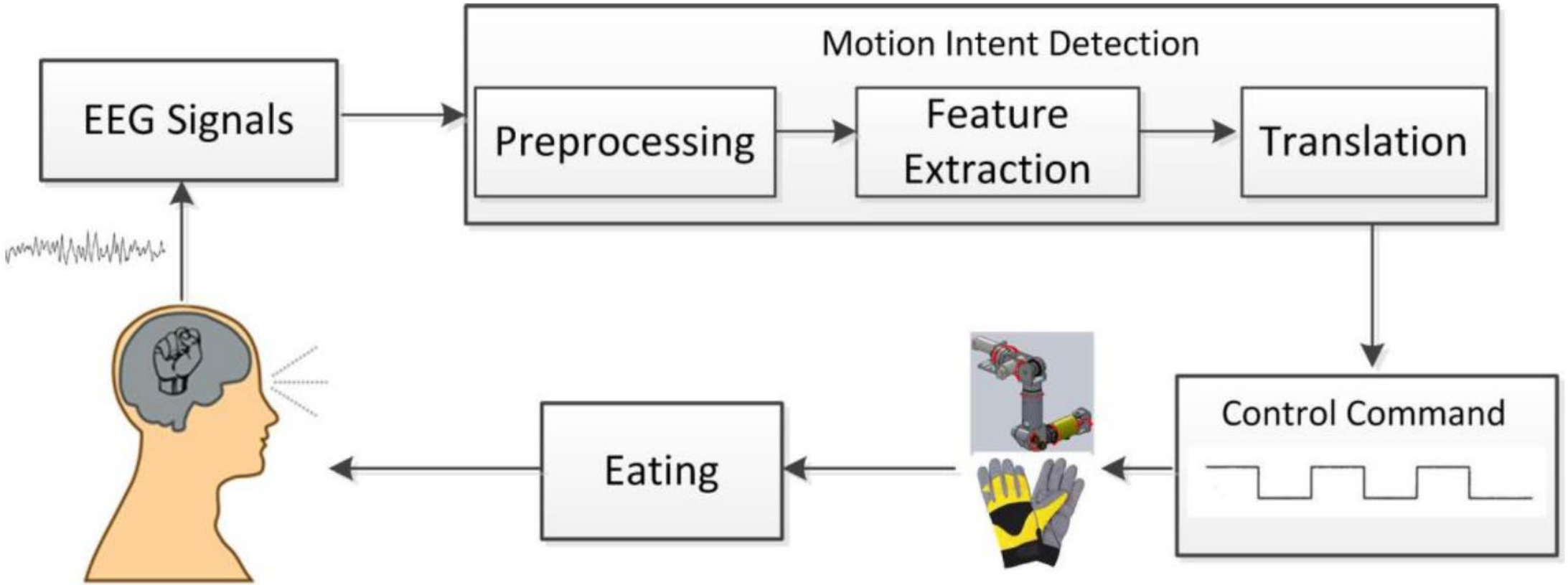


Amyotrophic
Lateral
Sclerosis

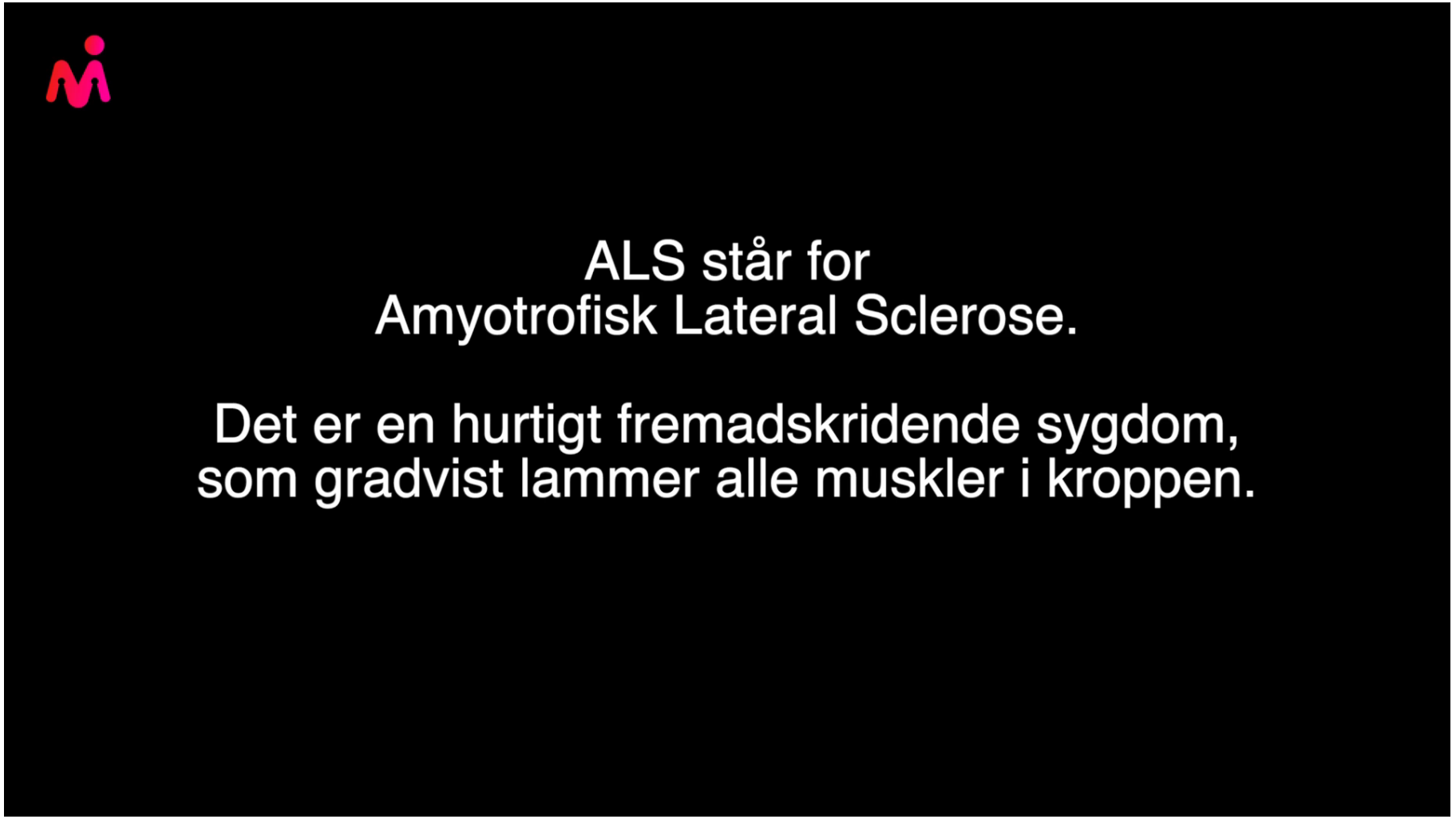




REMAP project



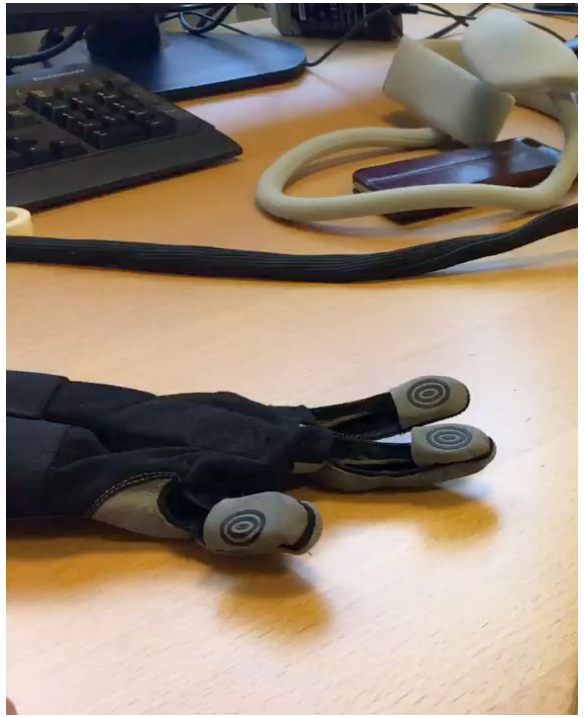
The hands are very often first affected



Courtesy of Muskelsvindfonden

REMAP project
AAU, AU, Muskelsvindfonden



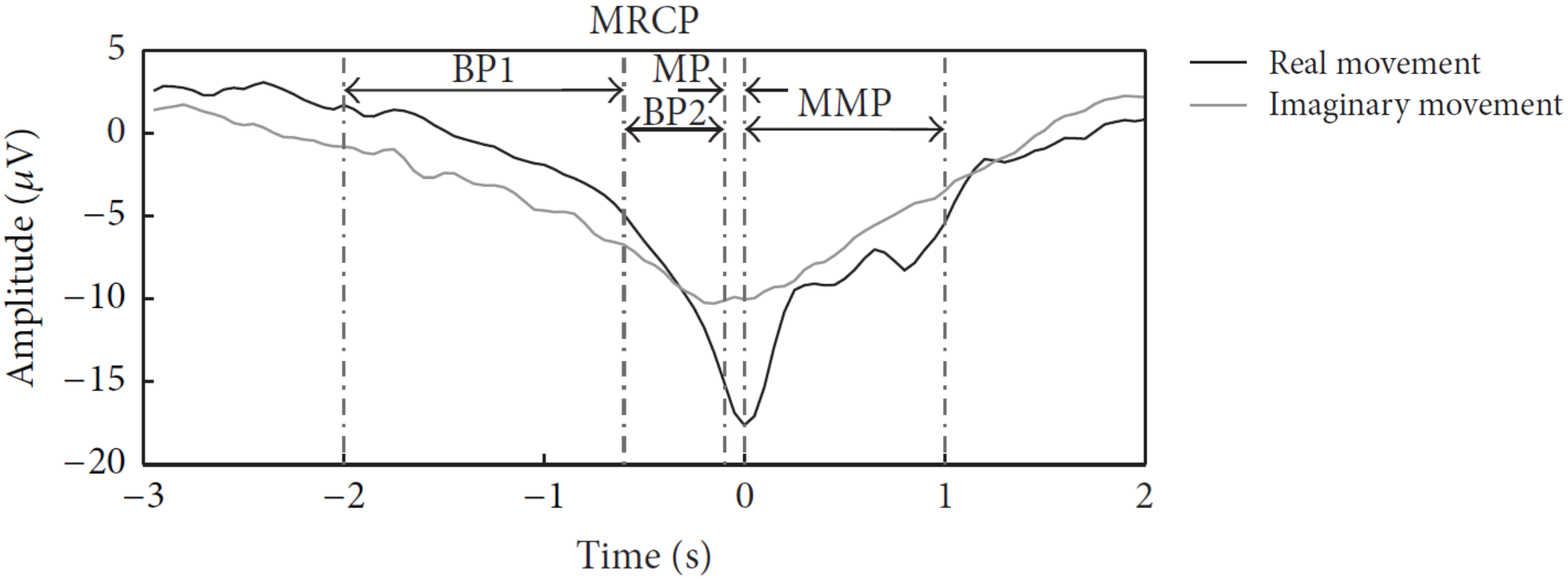




AARHUS UNIVERSITY

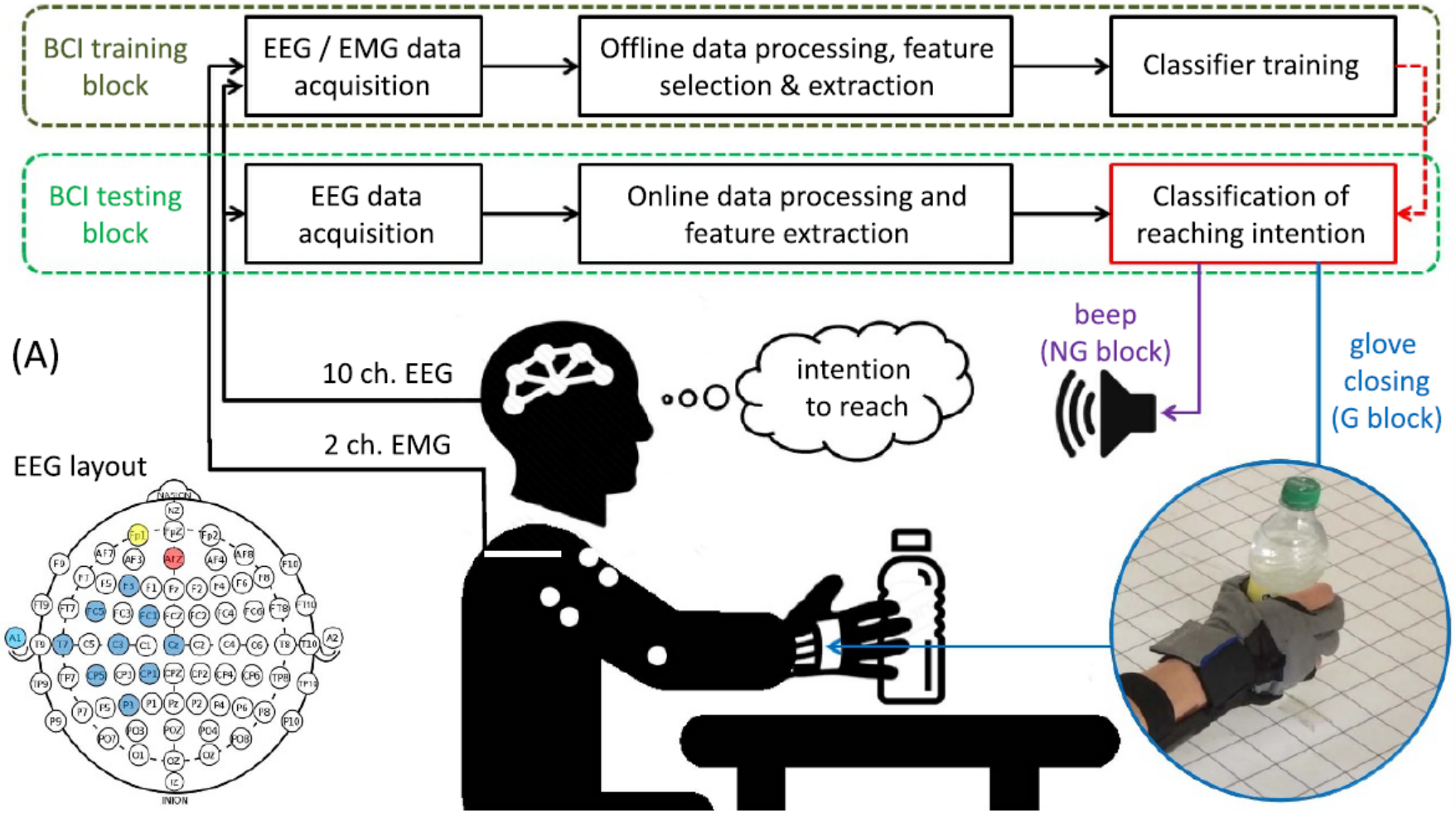
MUSKELSVINDFONDEN
plads til forskelle!

Movement-related cortical potential (MRCP)



Shakeel et al., Computational and Mathematical Methods in Medicine, 2015

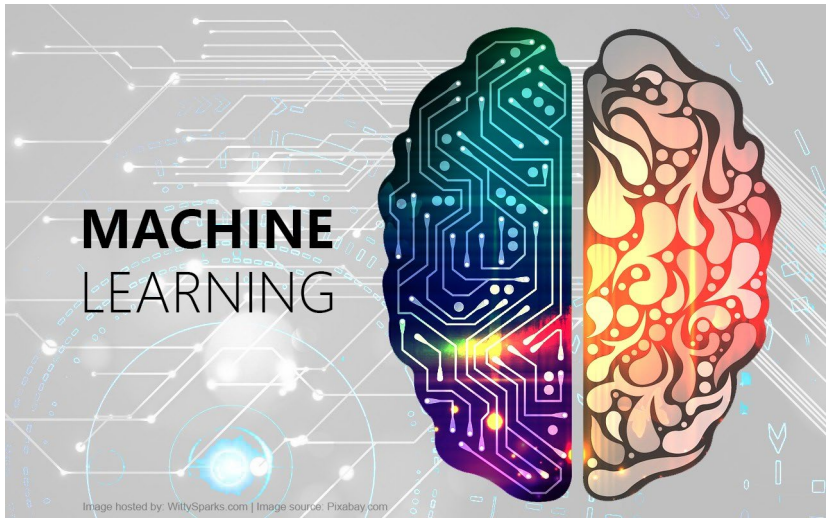
Online control using machine learning



A. M. Savić, S. Aliakbaryhosseinabadi, J. U. Blicher, D. Farina, N. Mrachacz-Kersting, and S. Dosen, "Online control of an assistive active glove by slow cortical signals in patients with amyotrophic lateral sclerosis," *J. Neural Eng.*, vol. 18, no. 4, p. 046085, Aug. 2021.

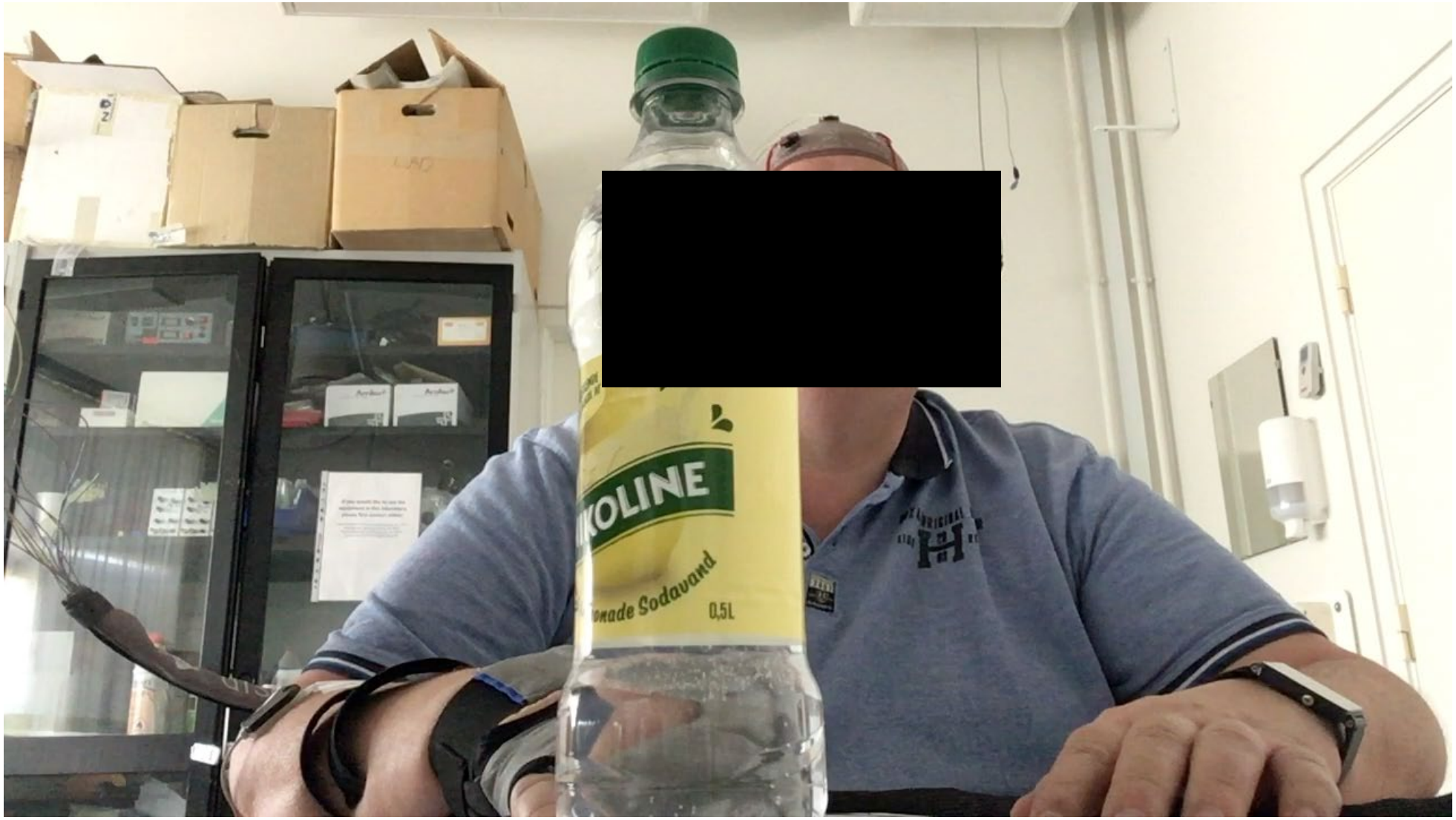
Collecting the training data



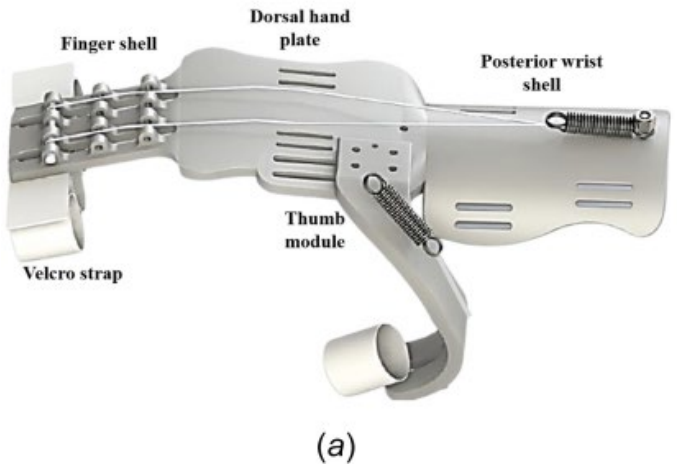




Online glove control using BCI



Exoskeleton for passive extension



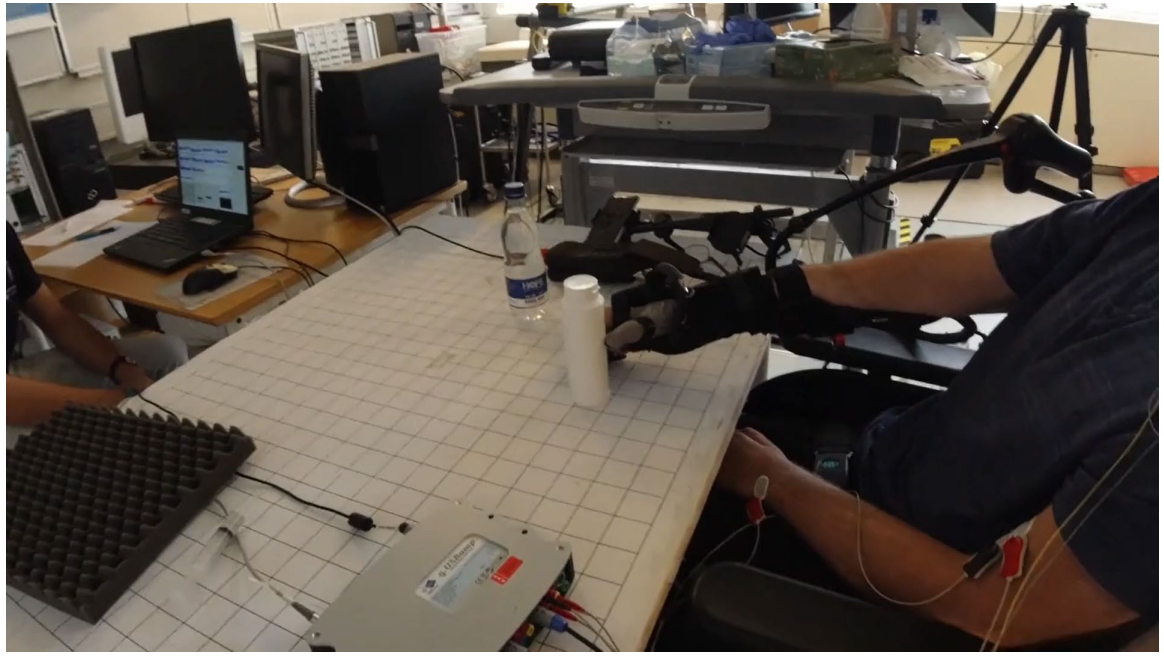
(a)



Restoring grasping in a highly-disabled patient

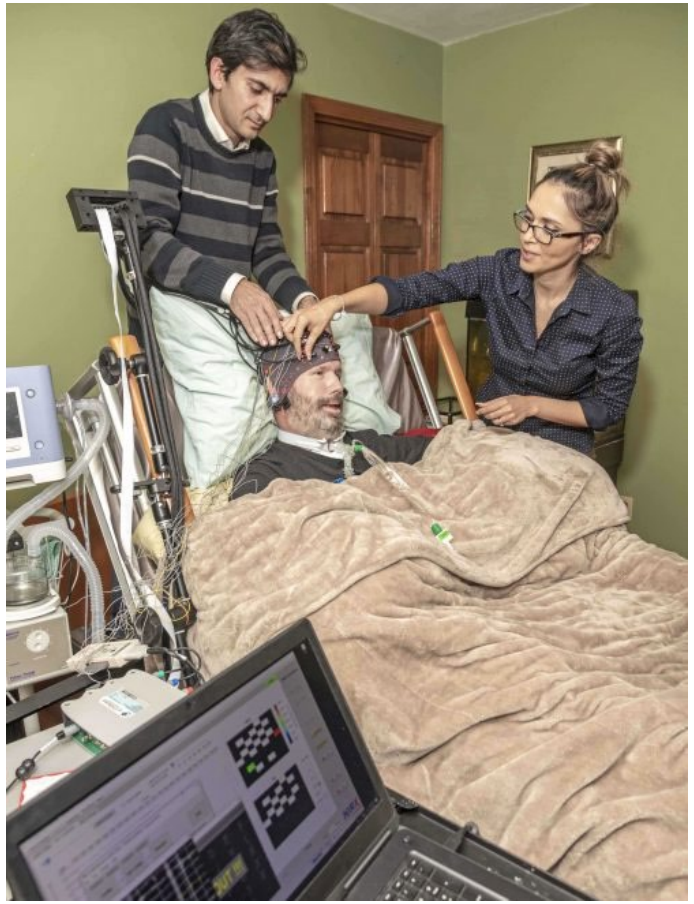


Courtesy of Muskelsvindfonden



S. Aliakbaryhosseinabadi, S. Dosen, A. M. Savic, J. Blicher, D. Farina, and N. Mrachacz-Kersting, “Participant-specific classifier tuning increases the performance of hand movement detection from EEG in patients with amyotrophic lateral sclerosis,” *J. Neural Eng.*, vol. 18, no. 5, p. 056023, Oct. 2021.

Using a REMAP system for communication



- Early state of the disease: using REMAP system to control the glove and assist grasping
- EEG signals are collected and the system becomes better in recognizing
- Patient becomes better in triggering the system
- Locked in phase: using the system to communicate (hand opening ~ YES / mouse click)

REMAP project

- https://muskelsvindfonden.dk/artikler/velfaerdsteknologi-hvis-mennesker-med-lammelser-kunne-gaa-ved-tankens-kraft/
- https://www.dr.dk/nyheder/indland/lammet-mand-bevaeger-haanden-ved-tankens-kraft
- https://www.dr.dk/drtv/se/21-soendag_-adidas-danske-chef-har-en-boen-til-kansleren_275962



Natalie Kersting



Susan Aliakbary



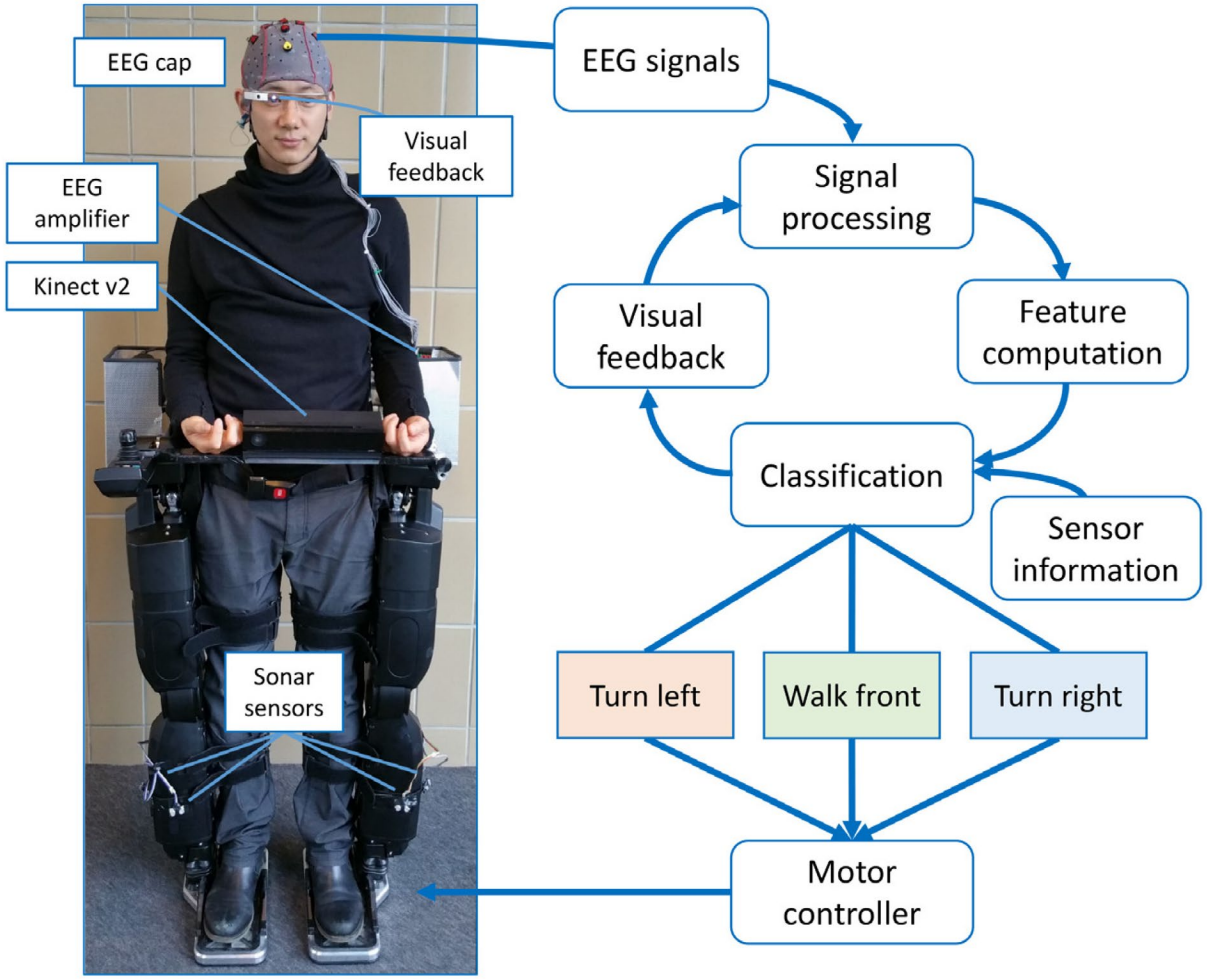
Jakob Blicher

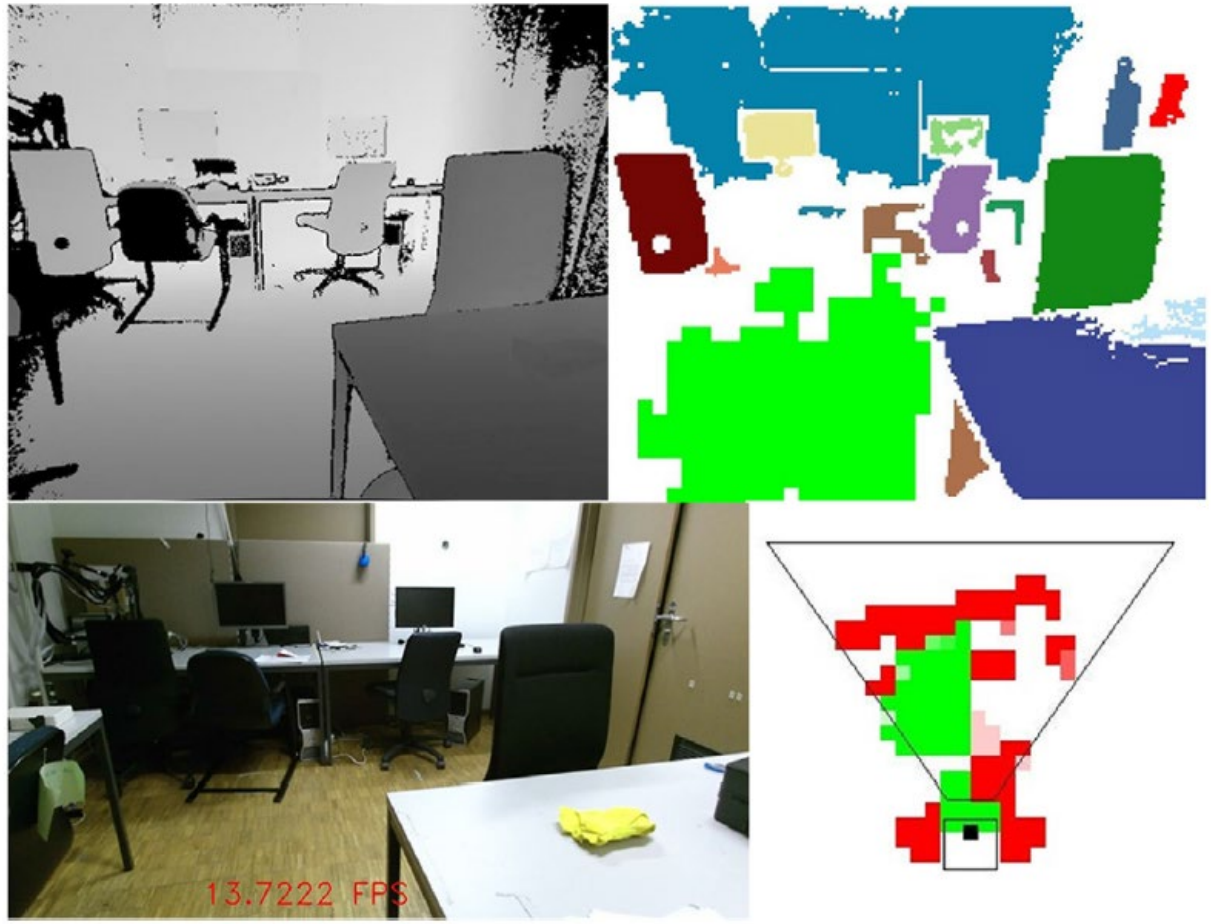
AD NYE VEJE
AALBORG UNIVERSITET

AARHUS
UNIVERSITY

MUSKELSVINDFONDEN
plads til forskelle!

BCI for an exoskeleton to restore walking





Lee et al., Robotics and Autonomous Systems, 2017

BCI control of a lower limb exo

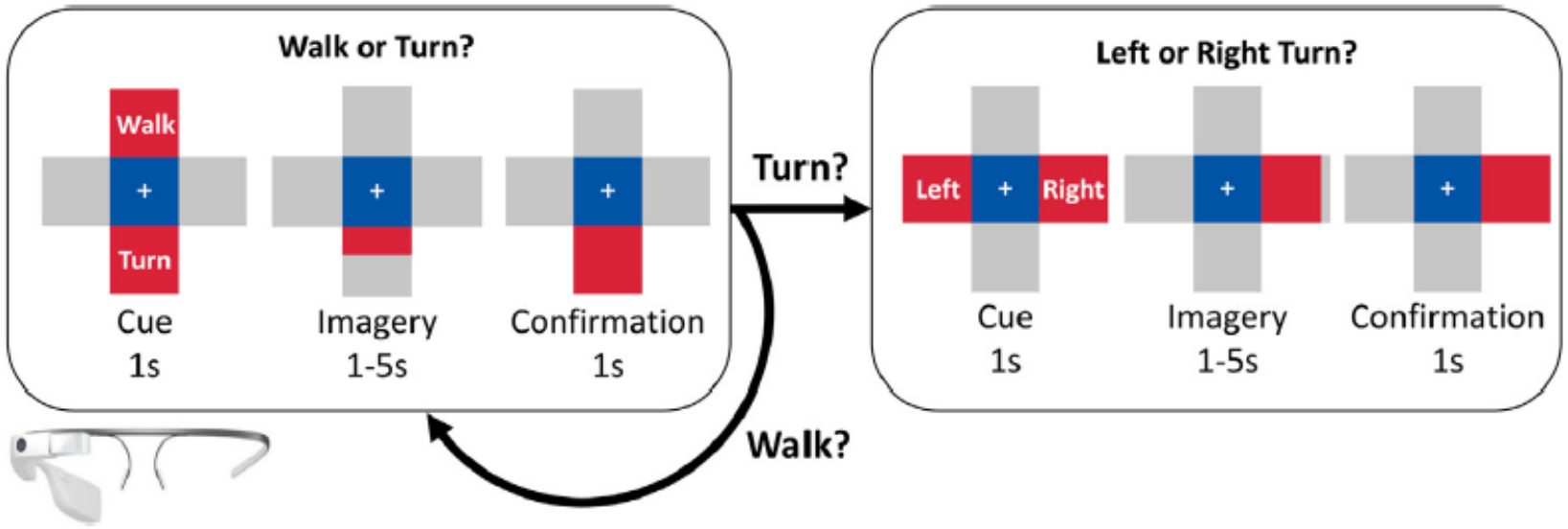
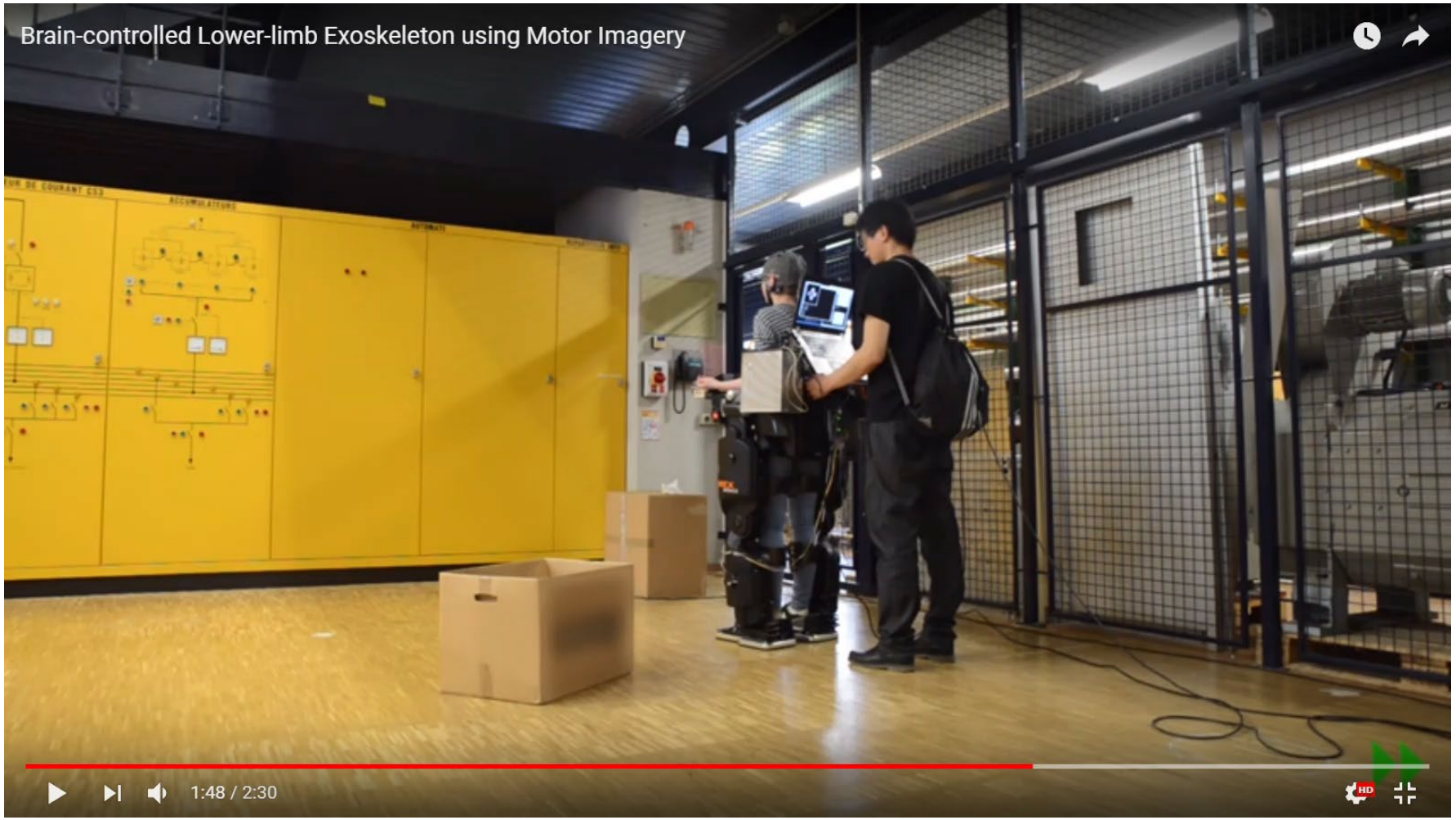


Fig. 2. A cascaded binary classification protocol. This is the visual feedback that a user sees on the see-through screen. The *Walk vs Turn* classification is performed during the first stage. If the red bar reaches either the top or remains in the upper area after timeout (5s), a walk motor command is delivered to the robot. Otherwise, *Turn* intention is detected and *Left vs Right* classification is performed. It has the same behavior as in the first classification step except that the bar moves left or right.

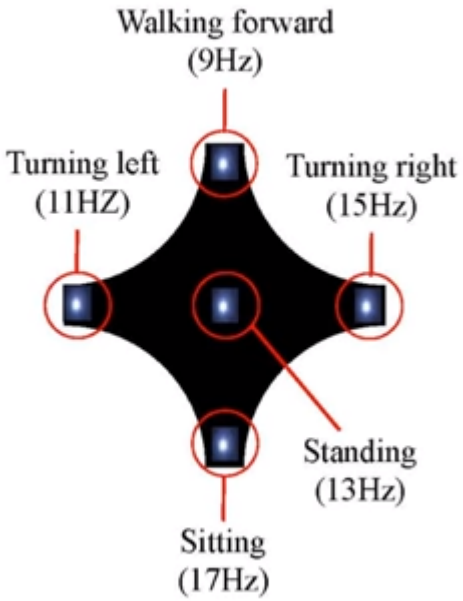
Lee et al., Robotics and Autonomous Systems, 2017

BCI control of lower limb exo



Lee et al., Robotics and Autonomous Systems, 2017

Lower limb exo controlled using SSVEP





Pattern Recognition Lab., Dept. of Brain and Cognitive Engineering, Korea University

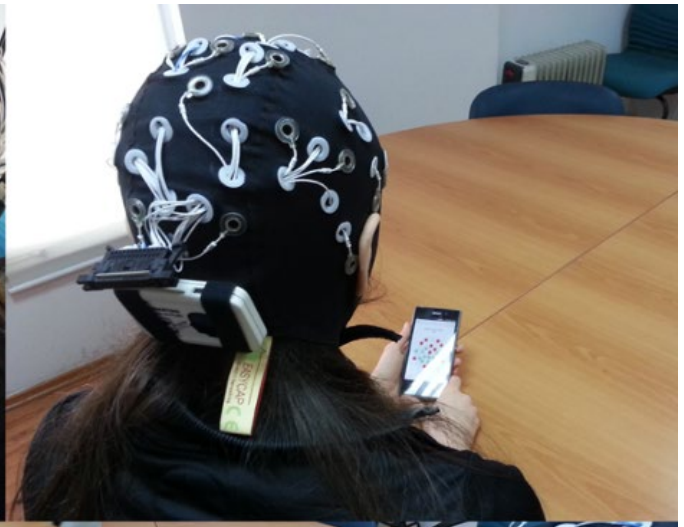
Wearable EEG systems

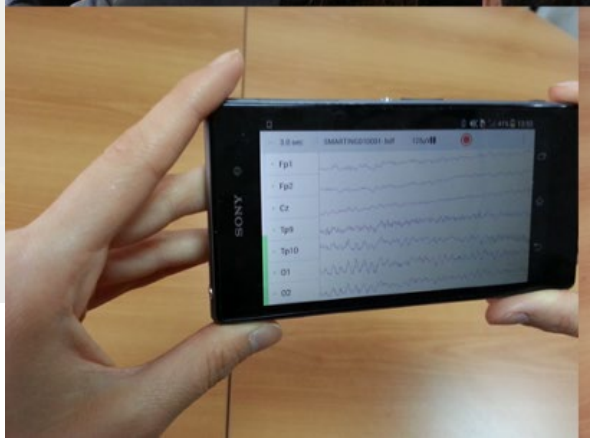


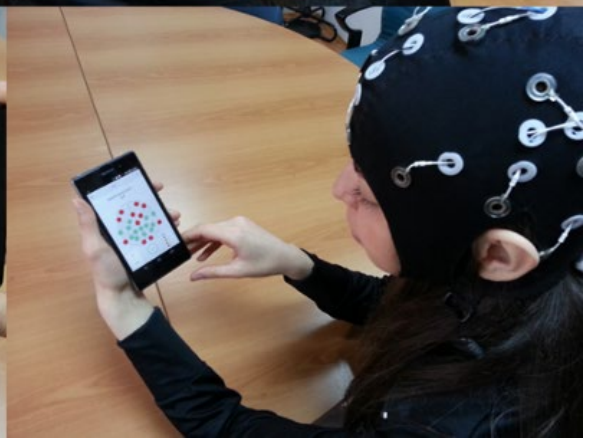
Bitbrain

mbt



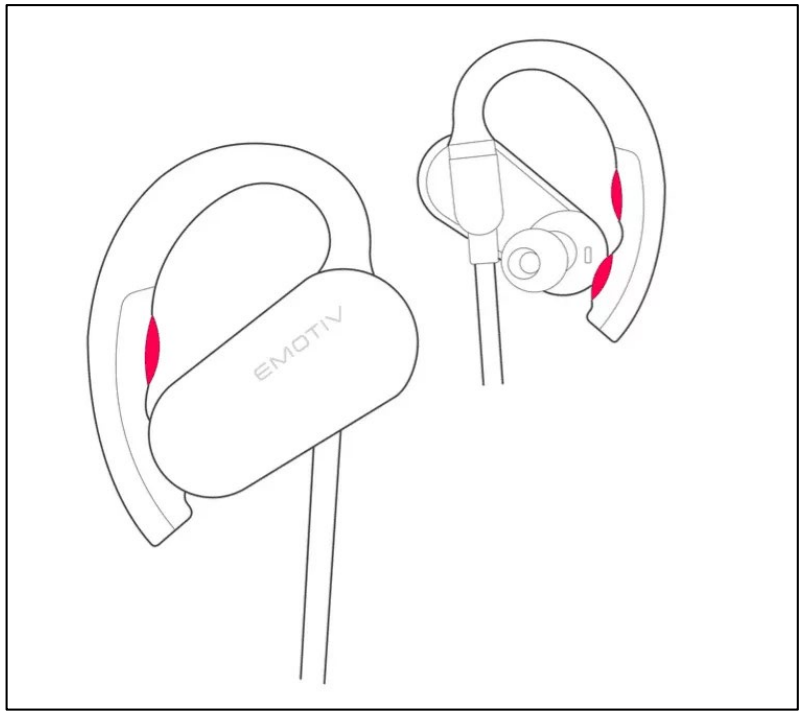






Emotive



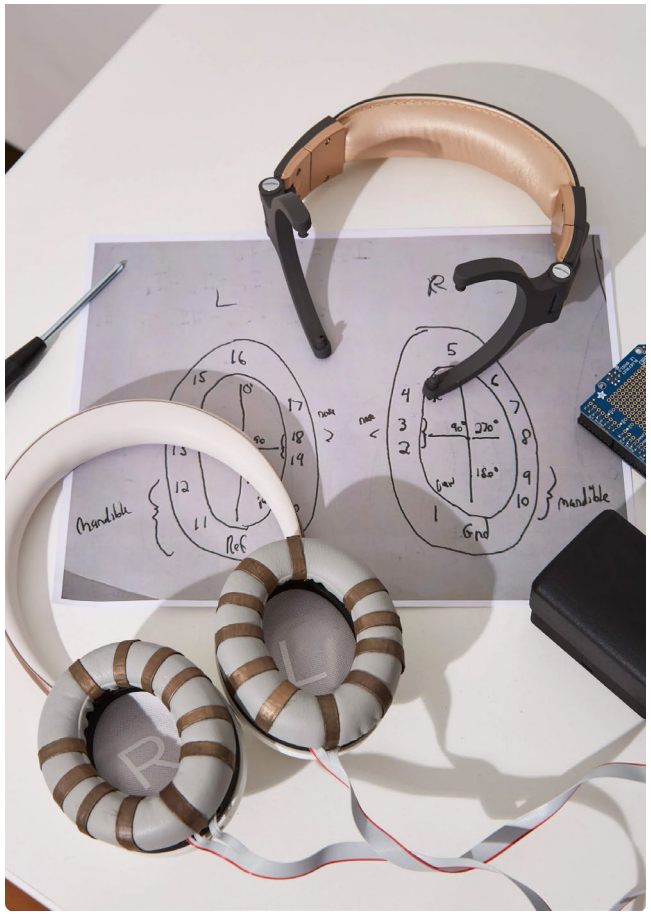




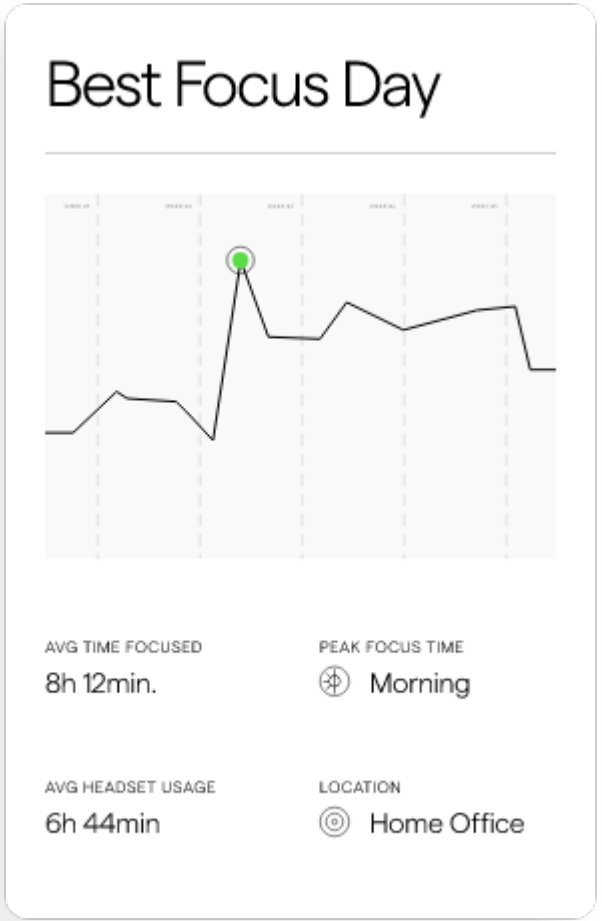
Emotive: monitoring stress and attention



Neurable

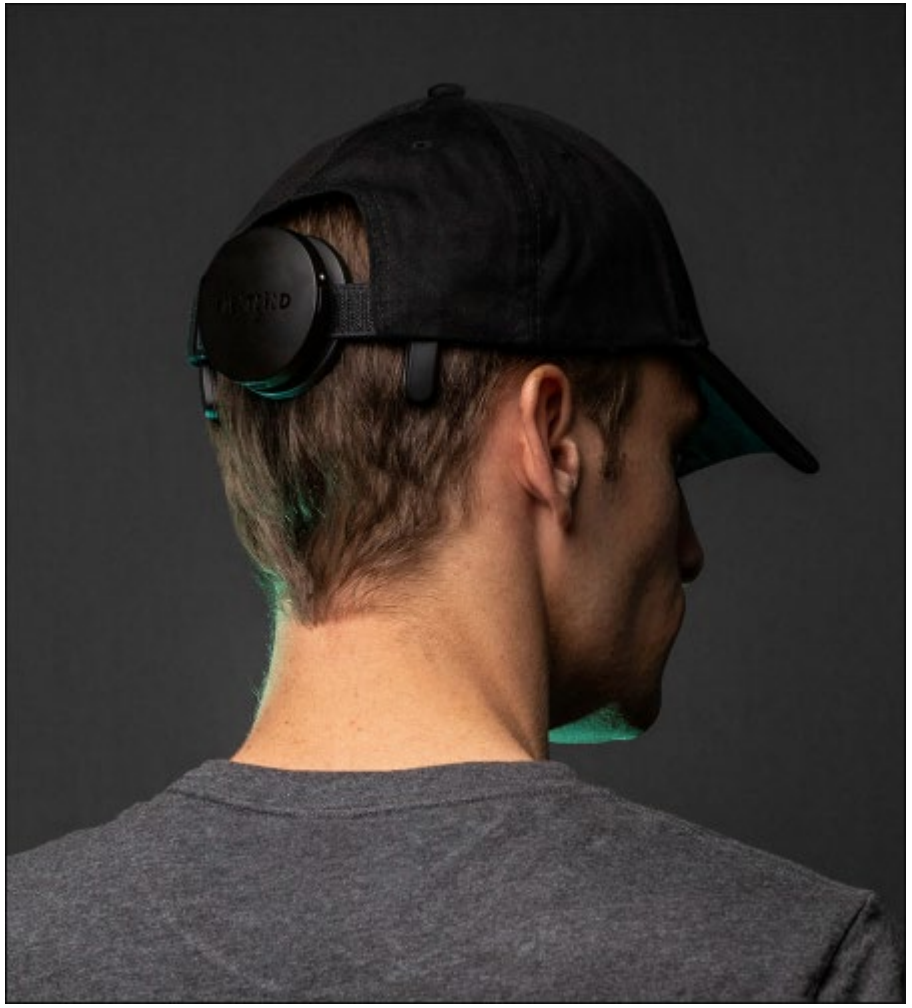

L
R
Mandible
Mandible
Ref
Gnd




Best Focus Day
AVG TIME FOCUSED
8h 12min.
PEAK FOCUS TIME
Morning
AVG HEADSET USAGE
6h 44min
LOCATION
Home Office

Next mind

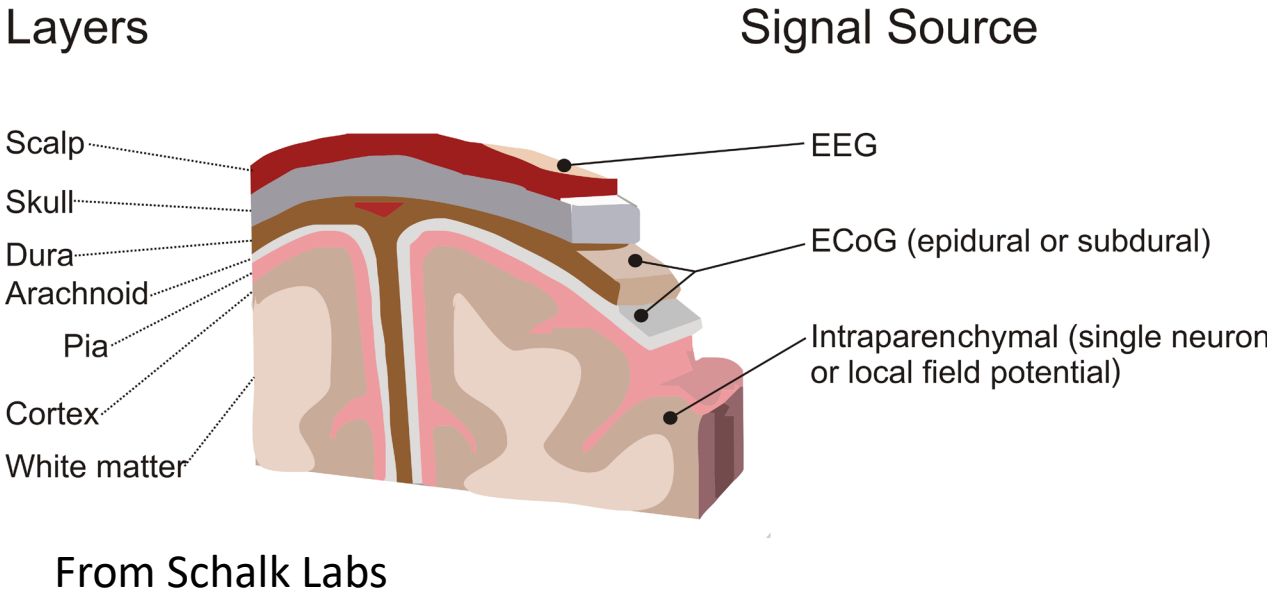




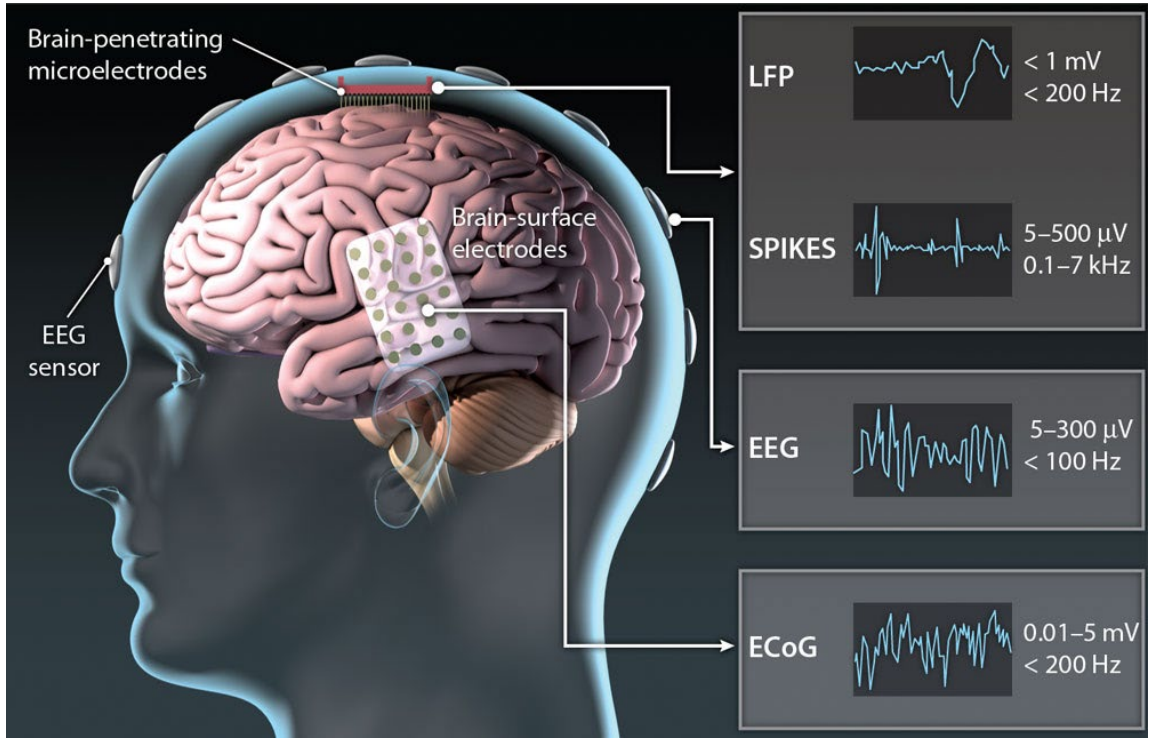
Next mind



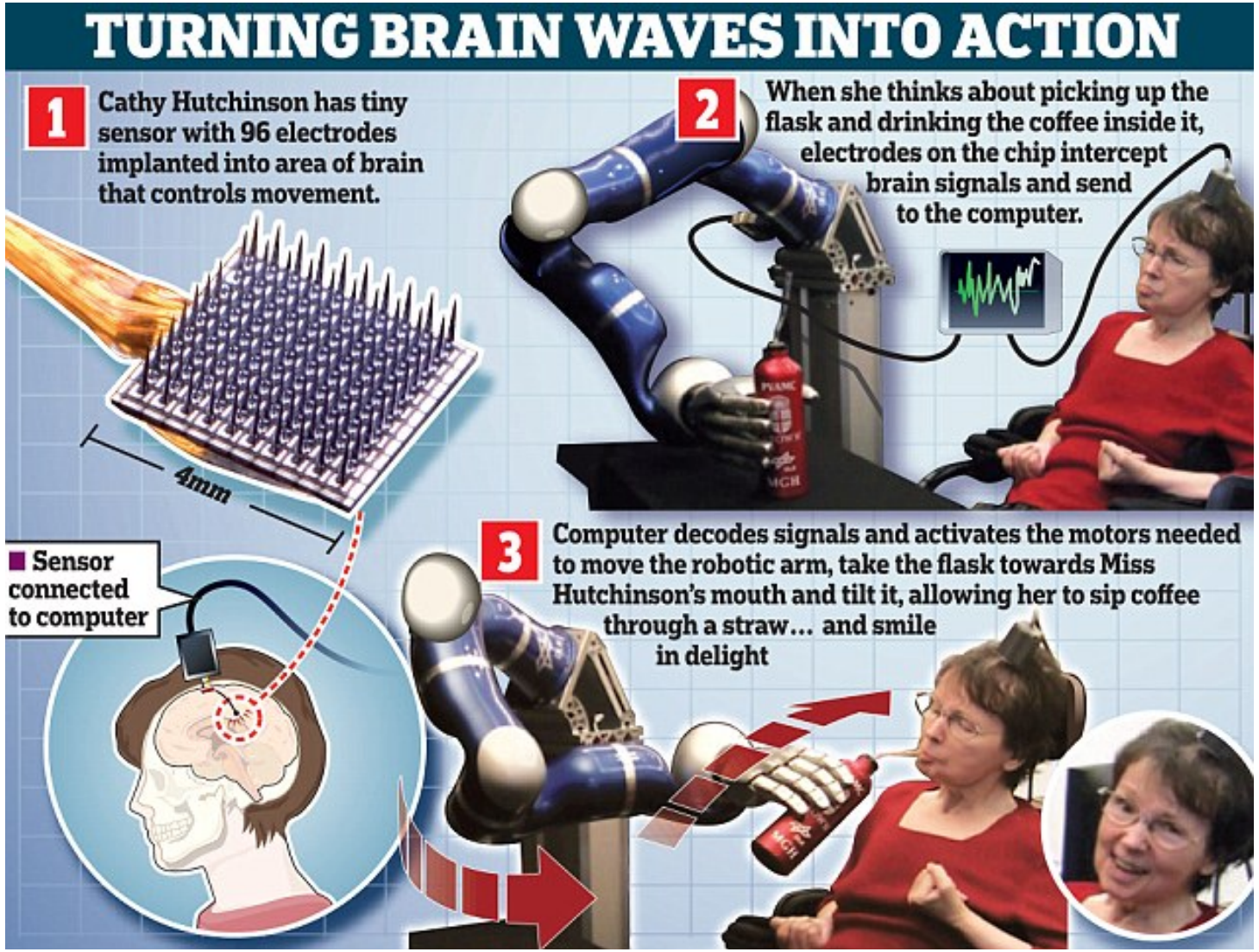
Invasive recording of brain signals



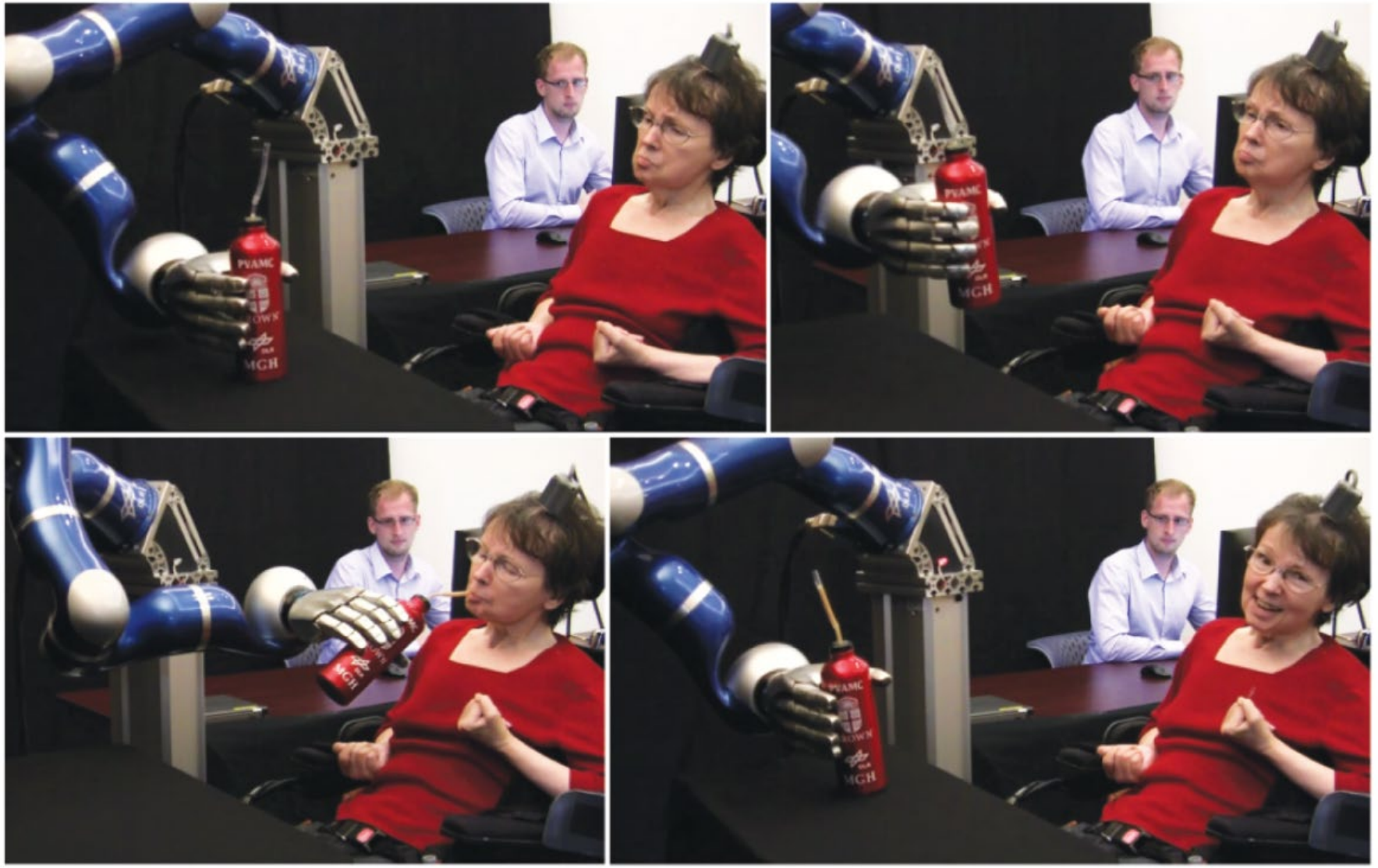
From Schalk Labs



BrainGate project

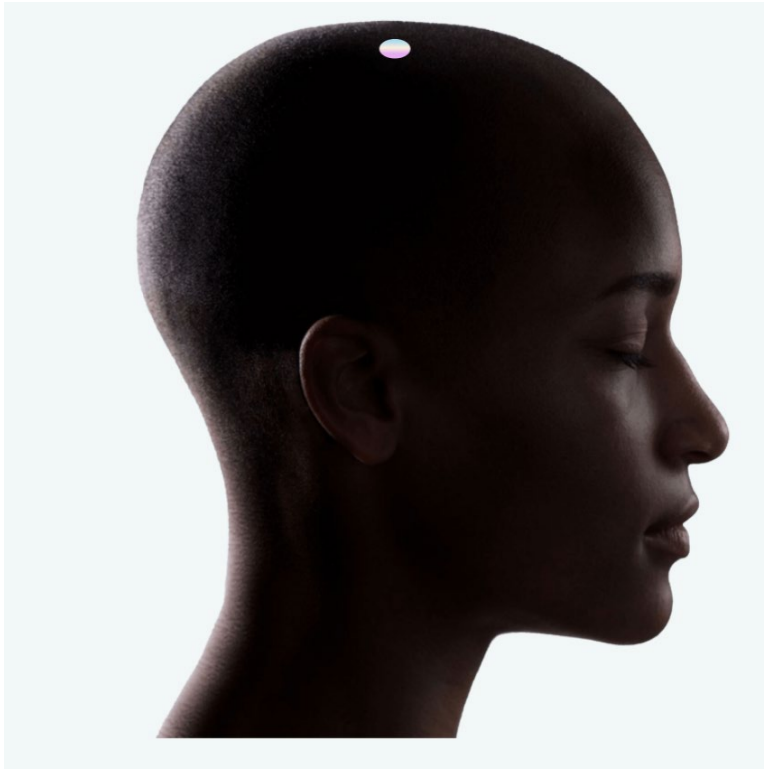


Functional task: reaching and drinking

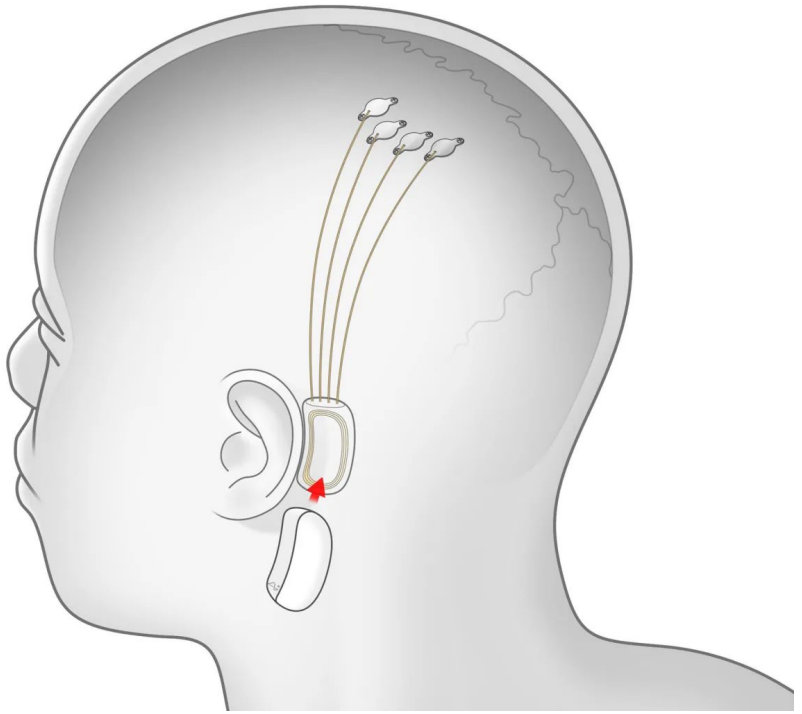


Hochberg, Nature Letters, 2012

Elon Mask: Neuralink



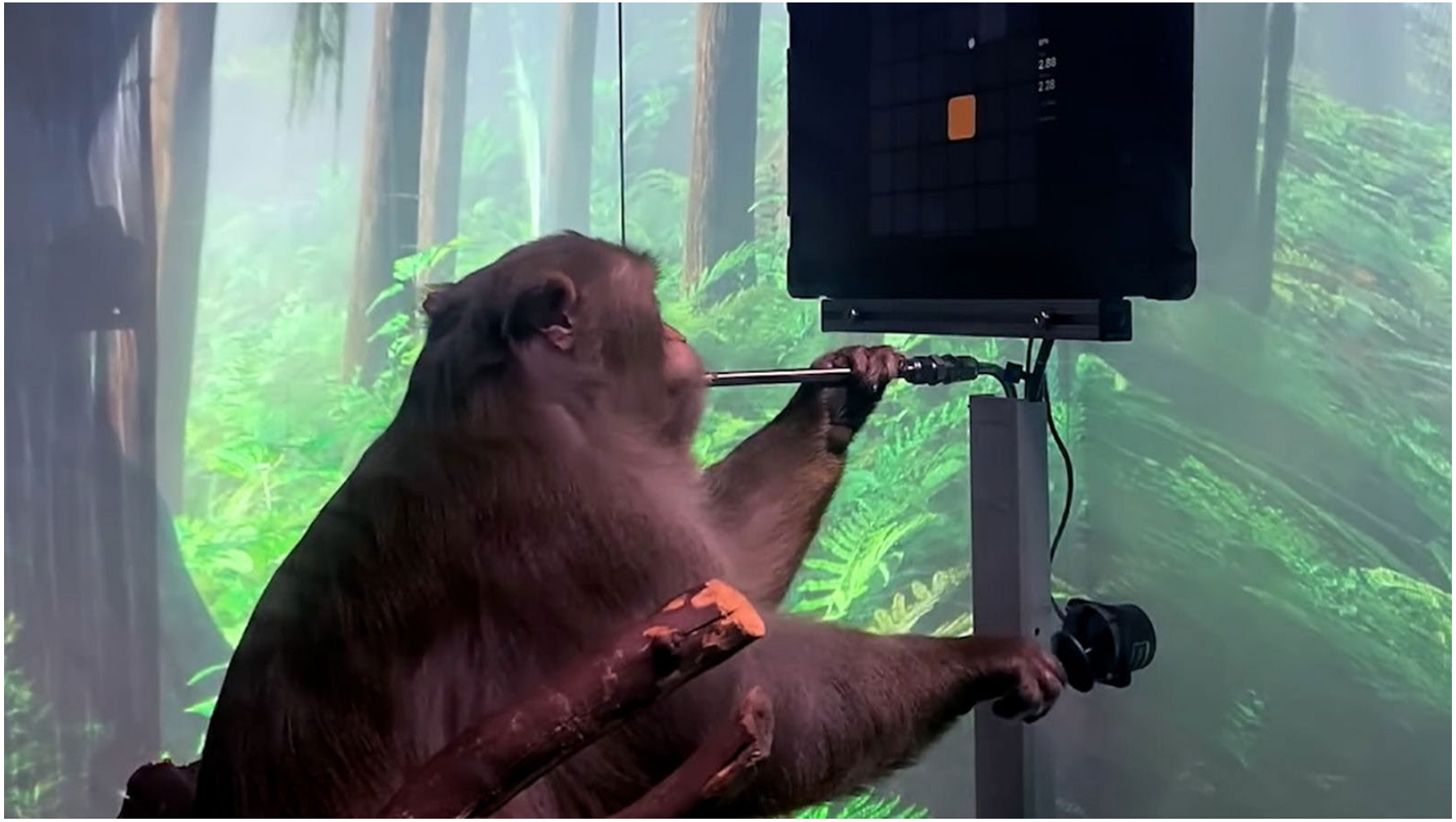




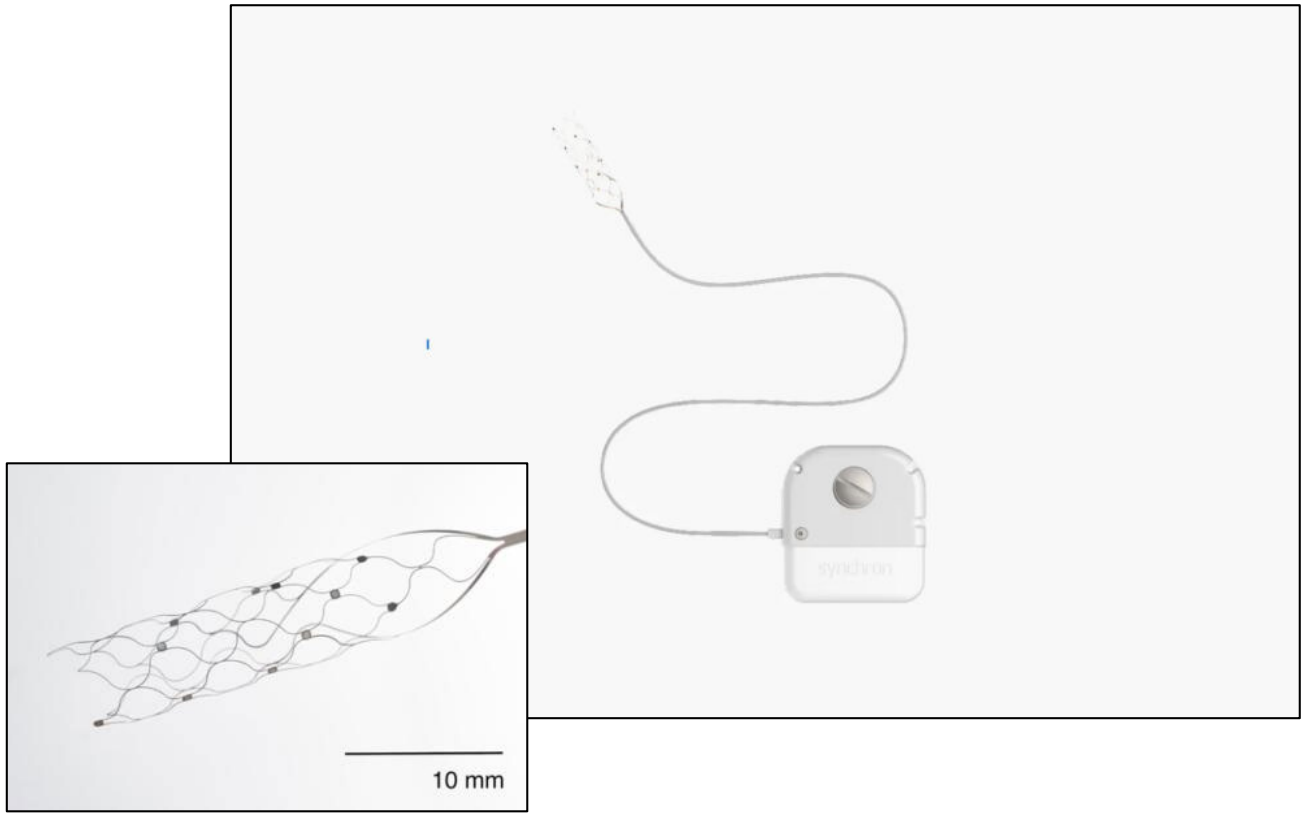
Neuralink: tests in animals

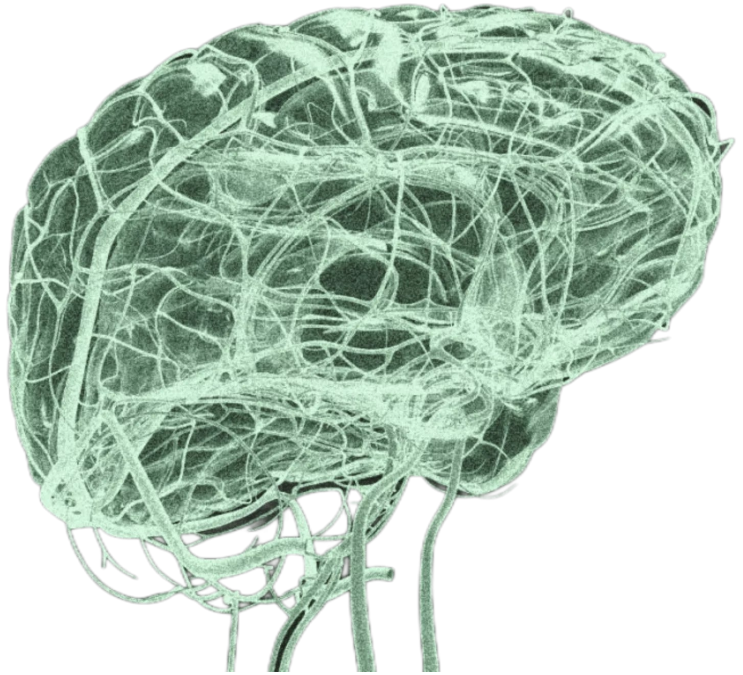


Neuralink: tests in monkeys



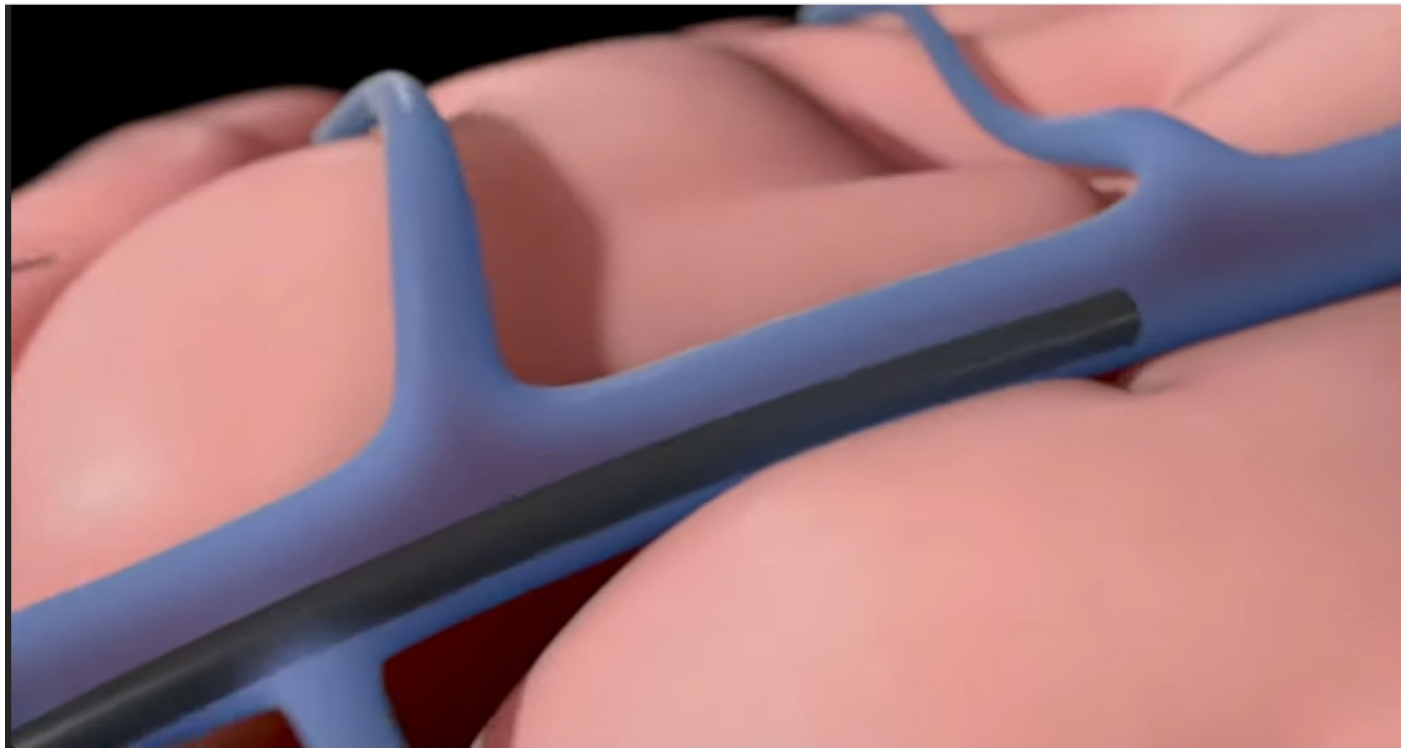
Endovascular electrodes: Synchrone





Endovascular electrodes: implantation

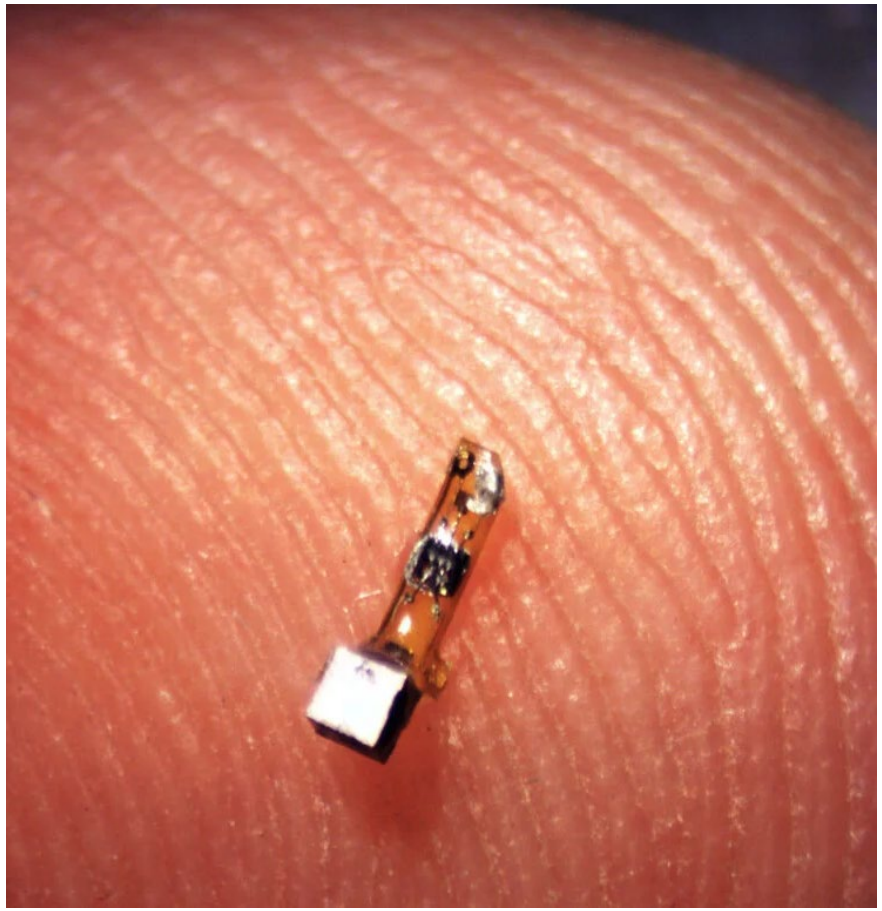


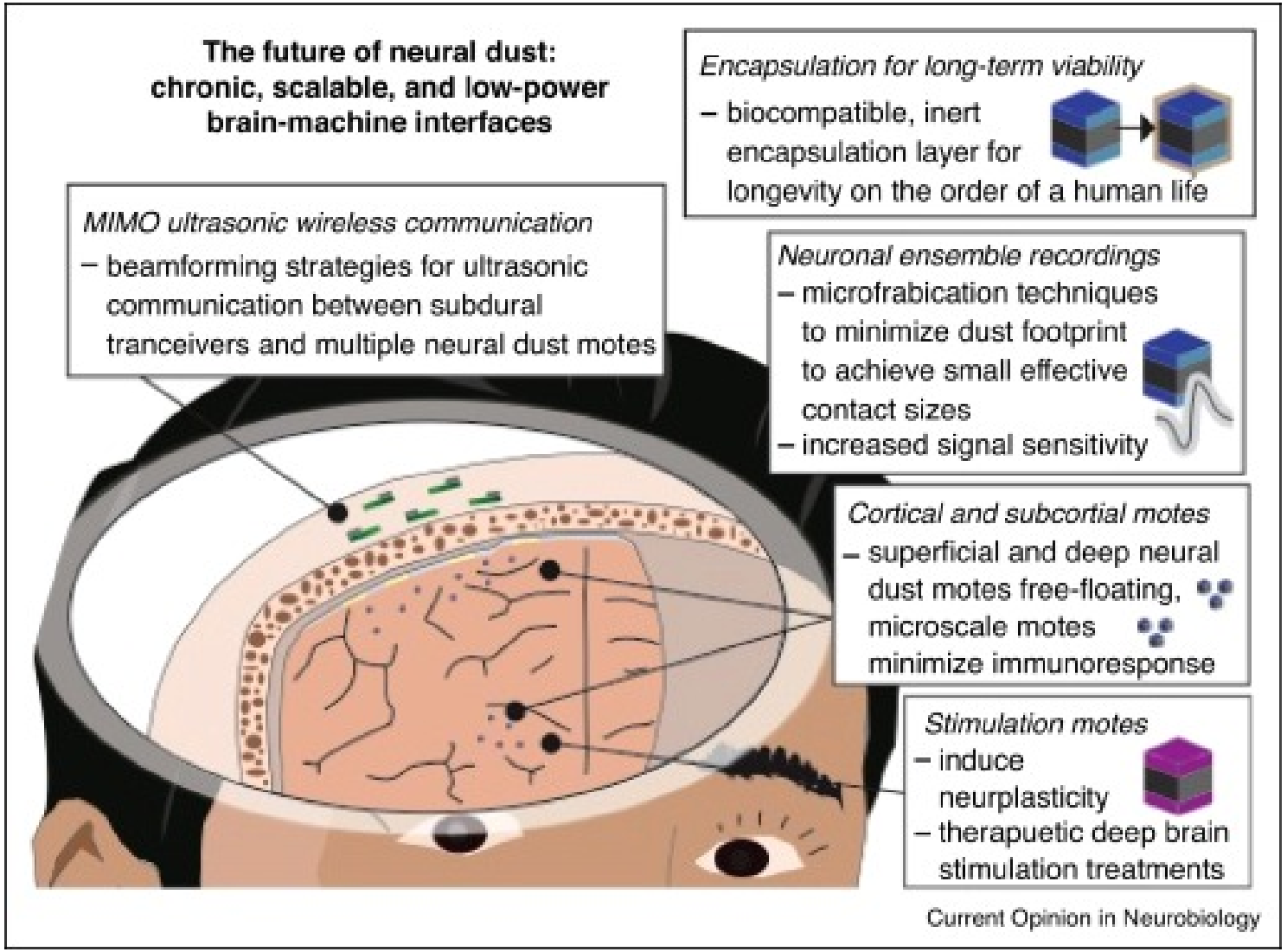


Endovascular electrodes: function restoration



Neural dust




The future of neural dust:
chronic, scalable, and low-power
brain-machine interfaces
Encapsulation for long-term viability
– biocompatible, inert encapsulation layer for longevity on the order of a human life
MIMO ultrasonic wireless communication
– beamforming strategies for ultrasonic communication between subdural tranceivers and multiple neural dust motes
Neuronal ensemble recordings
– microfrabication techniques to minimize dust footprint to achieve small effective contact sizes
– increased signal sensitivity
Cortical and subcortial motes
– superficial and deep neural dust motes free-floating, microscale motes minimize immunoresponse
Stimulation motes
– induce neurplasticity
– therapuetic deep brain stimulation treatments
Current Opinion in Neurobiology



Conclusions

- Brain machine interfacing is a fascinating field with many recent and future technological developments
- There is a clear tradeoff between functionality and easy of application
- Practical and ergonomic systems can deliver only simple functions
- Laboratory systems are advanced but confined to the lab
- Invasive systems can provide complex functions but they require surgical procedure
- Very useful in patients with a high level of disability

