BCI-Brain Computer Interface

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Introduction

Improved computing capabilities:
Real time signal processing.

Advances in analysis of brain signals:
Characteristic and function

Brain-computer interface isn’t a Science-fiction.

Introduction

Definition: BCI (Brain-computer interface) is a direct communication pathway between a brain (in a broader sense central nervus system (CNS)) and an external device.

BCIs are often directed at researching, mapping, assisting, augmenting, or repairing human cognitive or sensory-motor functions.

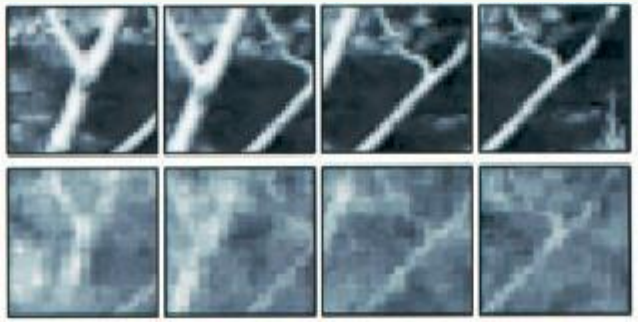
BCI differs from:

- Neuromodulation, because it allows for bidirectional information flow.
- A system that simply records and analyses brain signals and does not provide the results of the analysis to the user in a real-time interactive way.

History

- 1969: presented for the first time that monkeys could learn to control the deflection of a biofeedback meter arm with neural activity
- 1970: established that monkeys could quickly learn to voluntarily control the firing rates of individual and multiple neurons in the primary motor cortex if they were rewarded for generating appropriate patterns of neural activity.
- In the 1980s researchers found a mathematical relationship between the electrical responses of single motor cortex neurons in rhesus monkeys and the direction in which they moved their arms (based on a cosine function).
- 1977: scientists presented noninvasive EEG control of a cursor-like graphical object on a computer screen. The demonstration was movement in a maze.

History

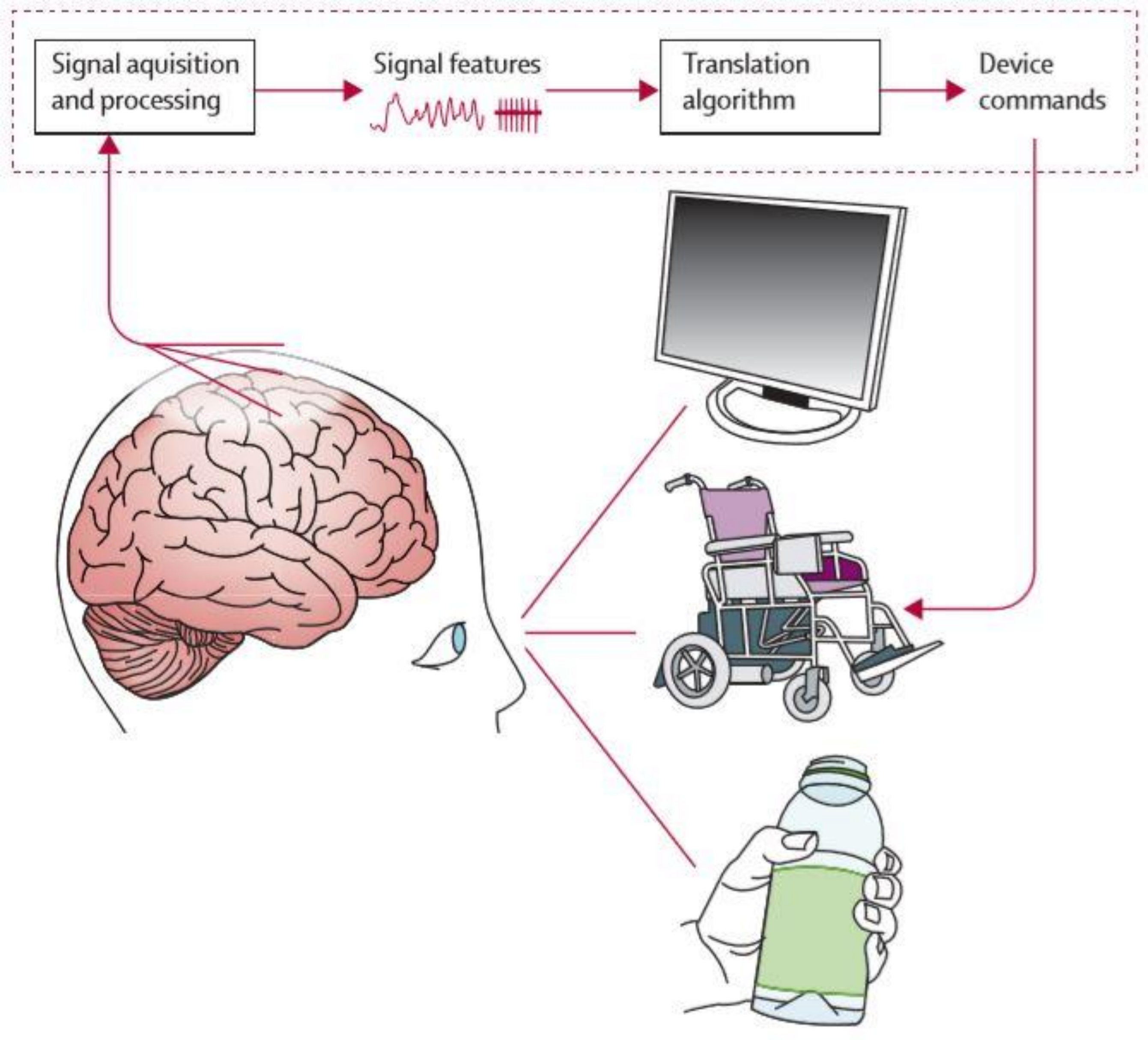


- 1977: first cochlear implant.
- 1988: a report was given on noninvasive EEG control of a physical object, a robot. The experiment described was EEG control of multiple start-stop-restart of the robot movement, along an arbitrary trajectory defined by a line drawn on a floor.
- 1999: decoded neuronal firings to reproduce images seen by cats.
- 2002: the earliest commercial uses of BCIs were the repairation/restoration of damaged sight of human (blinded during adulthood).
- 2005: a human controls a robotic arm by thinking about moving his hand as well as a computer cursor, lights and TV. (*motor neuroprosthetics*)

How it works

1. Electrophysiological signals are obtained.
2. The signals are analysed to derive particular signal features (for example: amplitudes of event-related potentials, EEG rhythms, firing rates of single neurons, or firing pattern of neurons)
3. Features are translated into commands.
4. The commands operate an output device.
5. The subject get a feedback (see/feel the effect of her/his activity).

It is a learning process which takes time.



How it works

Difficulties:

- The algorithm must accommodate spontaneous variations in the user's range of control, such as those due to diurnal change or exhaustion.
- The translation algorithm should also be able to accommodate and advance improvements in the control of the user. Thus, if the user's range of control improves from 1–5 μV to 1–8 μV, the algorithm should use this improvement to increase the speed and precision of cursor movement.
- The ongoing dependence on the mutual adaptation of the user to the system and the system to the user is a basic principle of BCI operation. Proper management of this adaptation is one of the most difficult and important challenges of BCI research and development.

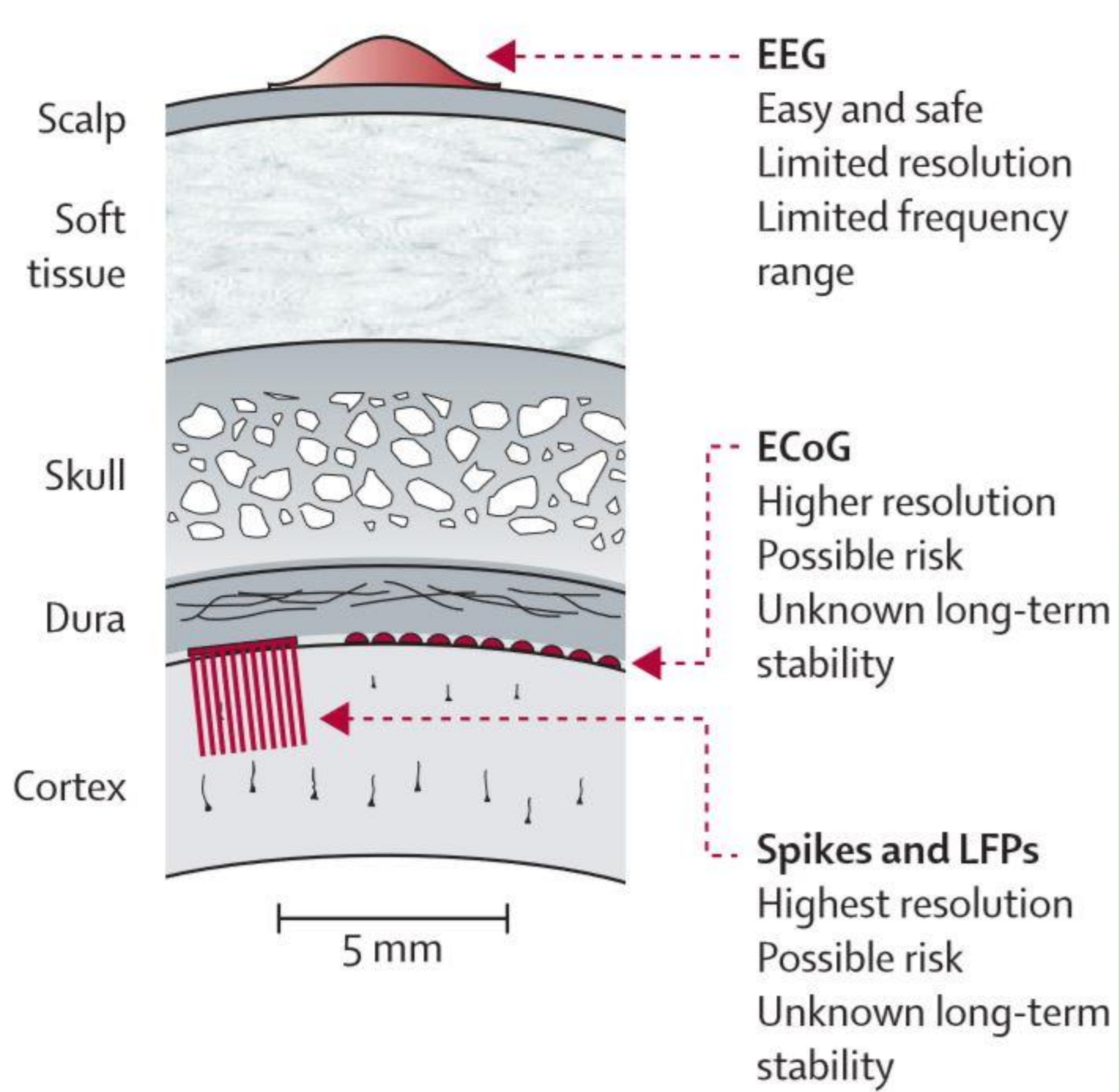
Signals

Brain signals can be detected and measured in many ways:

- fMRI (functional Magnetic Resonance Imaging)
- fPET (functional pozitron emission tomography)
- MEG (MagneticEncephaloGraphy)
- fNIR (functional Near-InfraRed imaging)
- EEG (ElectroEncephaloGraphy)

Expensive, complex, and limited real-time capabilities

EEG versions

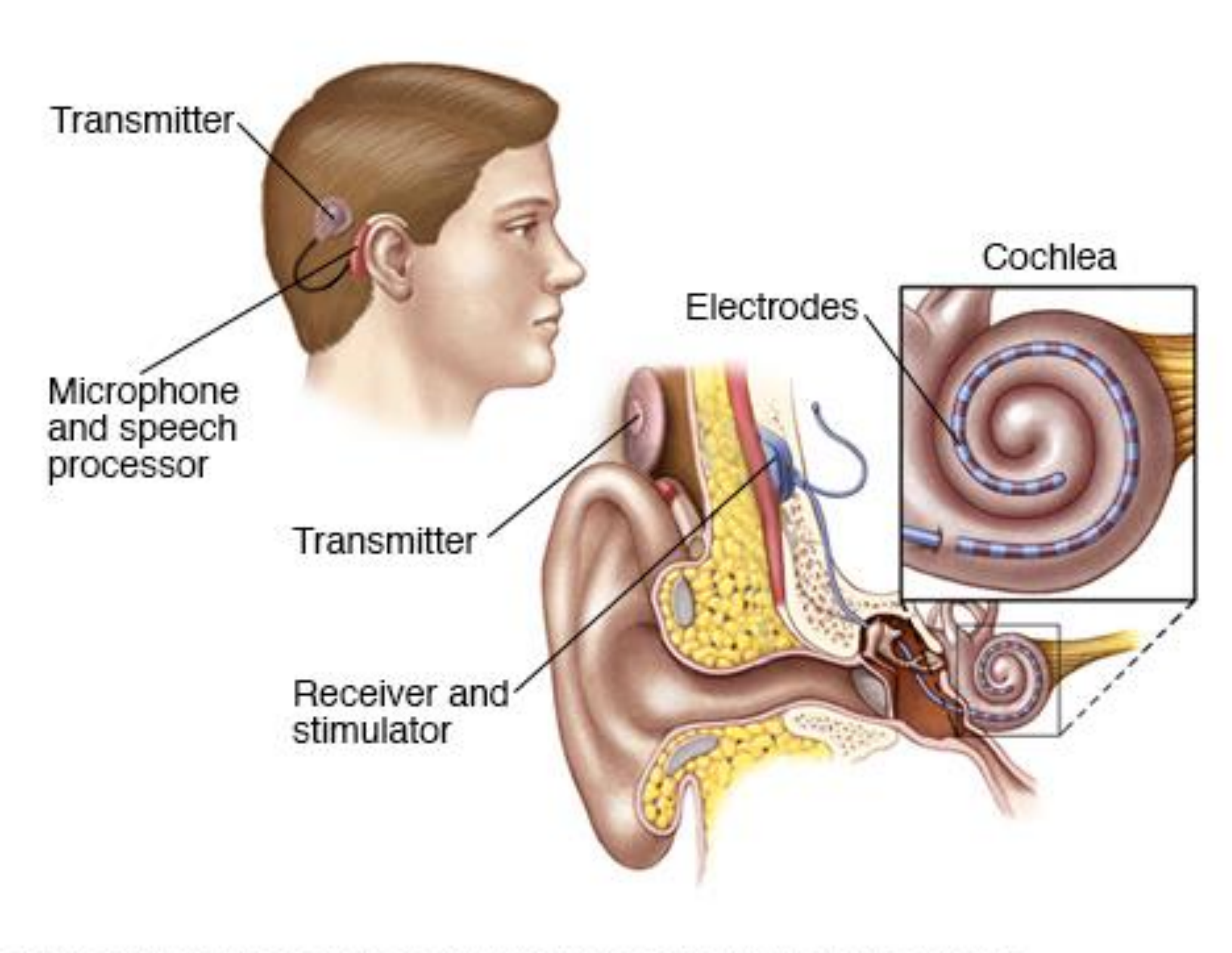


Application: cochlear implant

- Hair cell prosthesis
- Neuroprosthetics: using artifical devices to replace the function of sensory organ (in this case hearing).
- The implant transforms the sounds into an electric signal and directly stimulates the VIII cranial nerve.
- Solution, if classical hearing aids fail to help. Why?

Application: cochlear implant

- To function, it requires the VIII cranial nerve, the auditory cortex healthy, and anatomically correct cochlea. (Don’t need outer ear: auricle, ear canal. Middle ear: eardrum, hearing bones. Inner ear: functional cochlea)
- In case of innate deafness is the best, if the implantation takes place before the patiant betrays his/her second year of life (due to the acceptable development of the auditory cortex).



Application: intelligent prosthesis

- Bionic arm/leg
- An EEG-based BCI system allows to control a hand prosthesis by imagination of the movement.
- It can help disabled people affected by neuromuscular disorders such as multiple sclerosis (MS) or amyotrophic lateral sclerosis (ALS), brain or spinal cord injury, Myasthenia gravis or brainstem stroke.
- Bionic arms/legs often use myoelectric signal detection.

Application: intelligent prosthesis

- I found a paper with a simple implementation.
- They use Neurosky Mindwave EEG Headset, ThinkGear Matlab modul, Arduino, and a 3D printed hand.
- They can distinguish three commands from one signal. (open, close, pinch)
- More detectors → more commands
- Nowadays: with EEG hat there are operable robotic arms with many degrees of freedom.
- The next stage: people would like to make the arm a sensitive part of the body.
- Video: https://www.youtube.com/watch?v=w6QEGeIKHw0

Application: Gaming

- There are many games that we can control with our mind.
- It is good because it is fun, and people love fun. 🡐 money from game publishers.
- I think that combined with virtual reality it will be really great experience.
- Flipper: https://www.youtube.com/watch?v=ZIIffTH5D-E
- Car game: https://www.youtube.com/watch?v=HUra6i_UCZE
- World of Warcraft: https://www.youtube.com/watch?v=jXpjRwPQC5Q

Ethical considerations:

- personal responsibility and its possible constraints (e.g. who is responsible for erroneous actions with a neuroprosthesis),
- blurring of the division between human and machine
- therapeutic applications and the issue of surpassing human biological limits,
- mind-reading and privacy,
- mind-control.

Thank you!

References:

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