Engineering, neural engineering, and measuring the brain

Engineering and science

- Design tools, systems, or machines
- Manipulate the environment as primary goal
- Oriented towards products and implementation
- Applied

- Identify phenomena, objects, or patterns
- Manipulate environment to look for pattern or effect
- Oriented towards knowledge and (scientific) theory
- Basic (fundamental)

Major fields of engineering

- Chemical/molecular
- **Materials**
- Civil
- Environmental
- Geotechnical
- Petroleum/mining
- Structural
- Acoustic
- Sport
- **Computer science**
- Telecommunications
- **Electrical**
- **Mechanical**
- Consumer products
- Food
- Military
- Vehicle/transportation
- Aerospace
- Agricultural
- **Biological/biomedical**
- **Nanoengineering**
- Energy/power plant
- Nuclear
- Textile
- And more…

3

What's in a design?

- Goal
- User base
- User's needs and situation
- Design obstacles – size, weight, material, etc.
- Financial obstacles – manufacture, adoption
- Intermediate steps or designs
- Risks, known issues, defects, or other liabilities
- Time to design and make

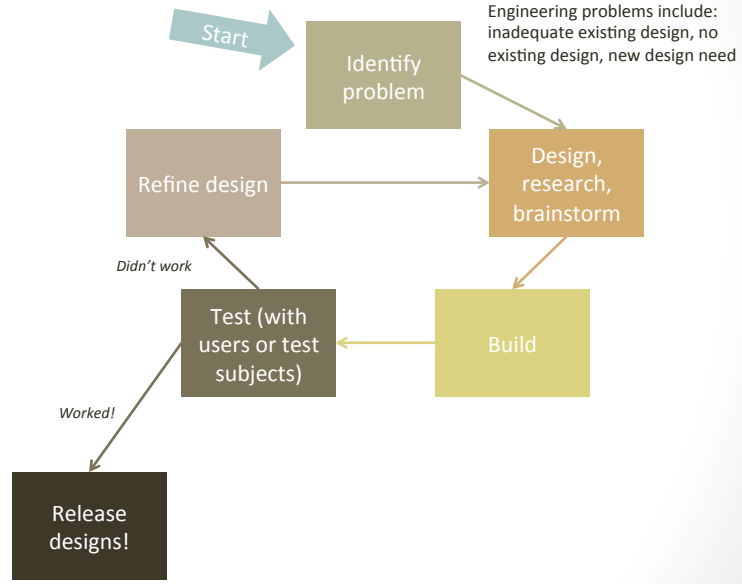
4

Why are neural engineering designs special or unusual?

- Extremely diverse user base – injury type, age, capability
- End-user input and adaptability
- Medical feasibility, training for care providers
- FDA approvals – up to 10 years
- Cost – insurance?
- Maintenance
- Number of users
- Nervous system challenges

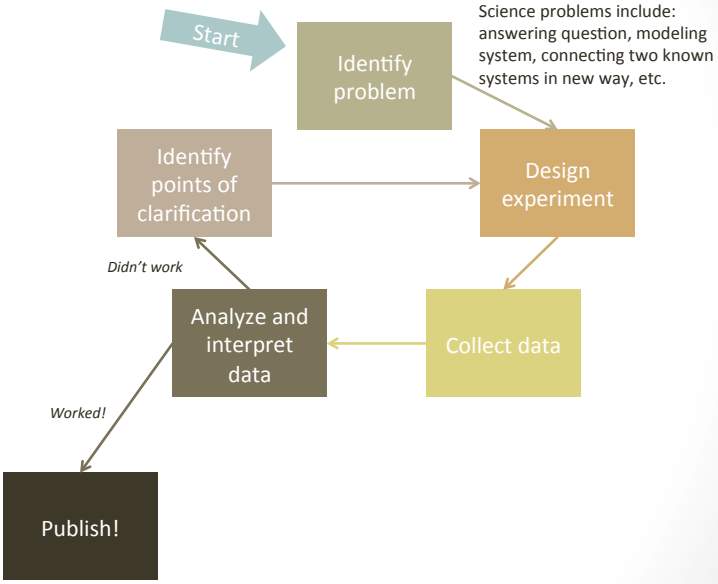
5

Cycle of engineering



6

Cycle of science



7

NEURAL ENGINEERING TODAY

8

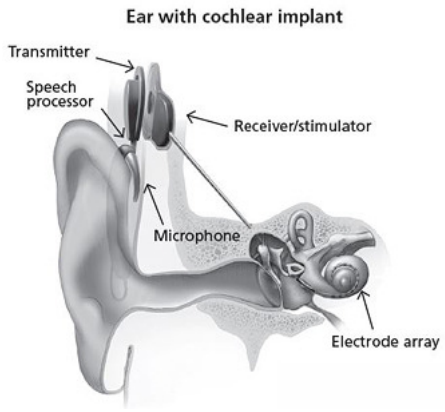
Parts of a brain-computer interface

- Sensors – own body
- Sensors – environment
- Encoding system (e.g. stimulating electrodes)
- Recording system (e.g. implanted electrodes)
- End effector (whatever user controls)
- Processing unit
- Encoding and/or decoding software
- Power source
- Case, implant site if applicable

- Method of measuring usefulness

9

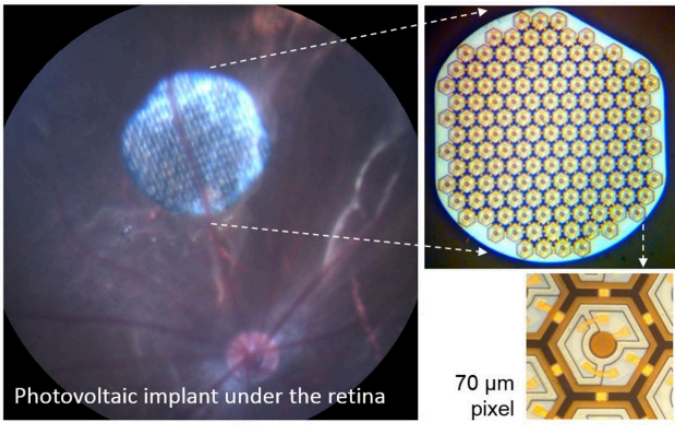
Cochlear implants



10

NIDCD

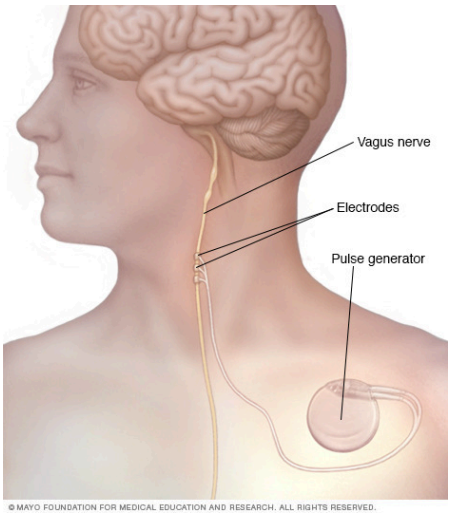
Retinal implants



11

Palanker

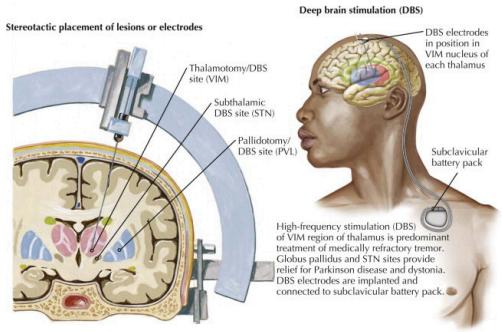
Vagus nerve stimulation



12

Mayo Clinic

Deep brain stimulation (DBS)



13

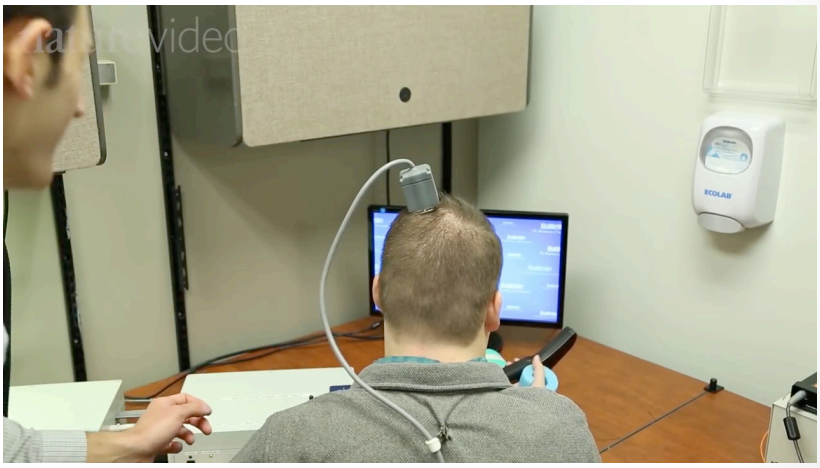
Jones

DBS in action

14

Ric Robinson

Muscle reanimation



15

Nature/Ohio State

Prosthetic control

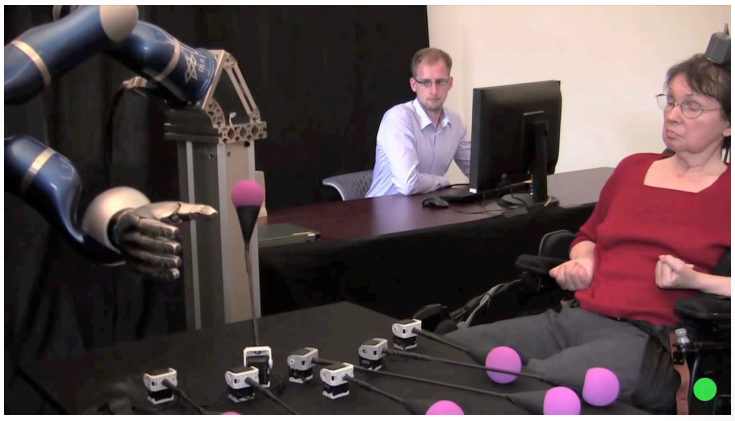
16

Darpa/Rehabilitation Institute of Chicago

Prosthetic control

Johns Hopkins

External effector control



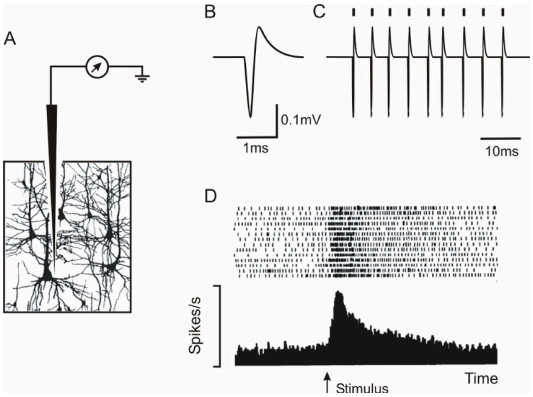
Braingate/Brown University

Orthotics and exoskeletons

Steele lab

TOOLS FOR RECORDING FROM BRAIN AND BODY

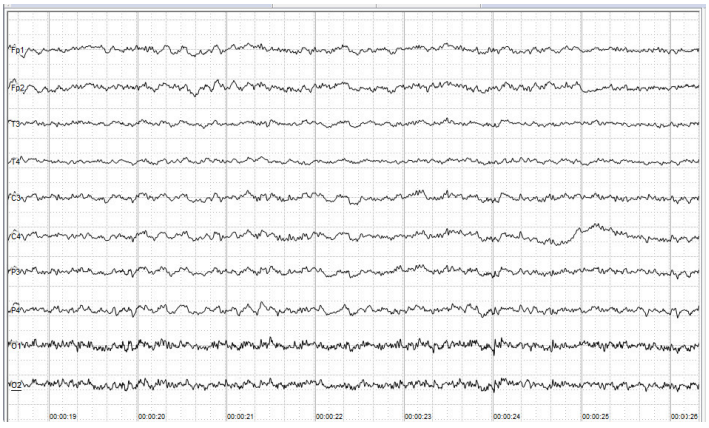
Single unit recordings



21

Ludvig

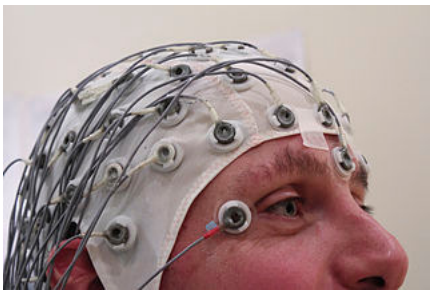
Electrical signals in the brain



22

wikipedia

Electroencephalography - EEG

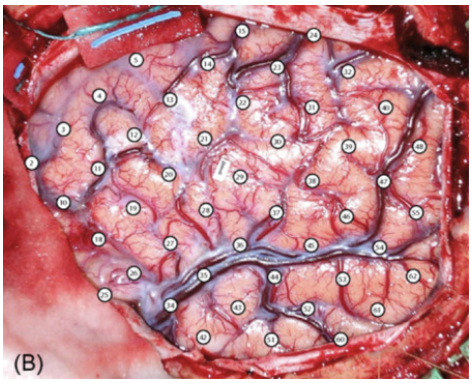


Wikipedia

- Pros
  - Cheap
  - Easy
  - Non-invasive
  - Easy to get
- Cons
  - Low resolution
  - High noise
  - Doesn't work well with excessive movement, hair, water
  - Low consistency in day-to-day electrode placement

23

Electrocorticography - ECoG

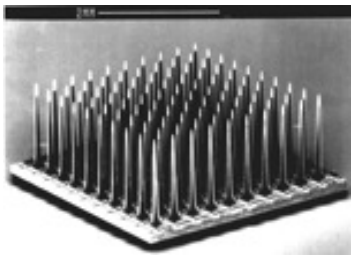


Miller 2009

- Pros
  - Low noise
  - Higher resolution
  - Easy
  - Can be in place for many days
  - Is already used (though not for BCIs)
- Cons
  - Invasive
  - Expensive
  - Resolution not high enough for some uses

24

Penetrating microelectrodes

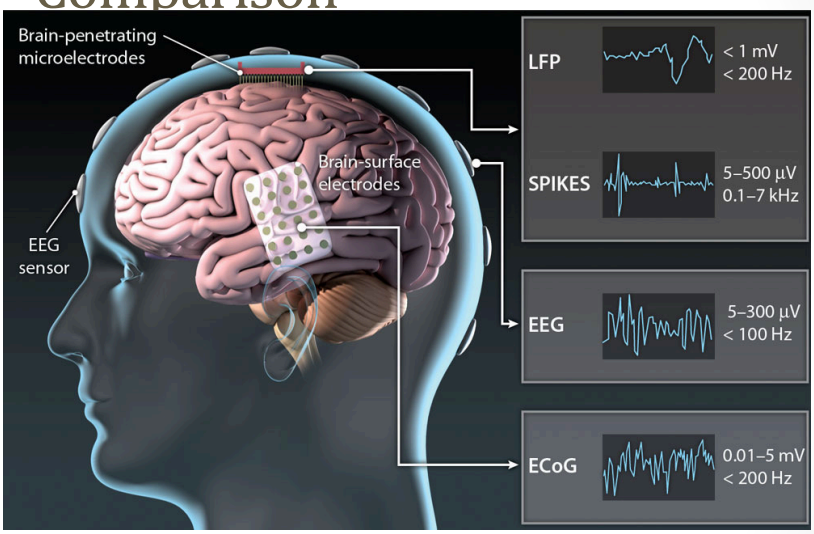


- Pros
  - Extremely high spatial resolution
  - Best BCI control in existing trials
- Cons
  - Low spatial coverage
  - Highly invasive
  - Expensive and difficult to place
  - Electrodes cause scarring and degrade

25

Kindlmann

Comparison



26

Thakor

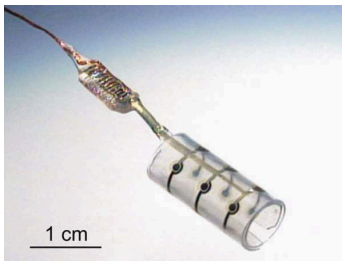
MRI

- Pros
  - Easy to access
  - High spatial resolution
  - Access to deep structures
  - Non invasive
  - Good for research on anatomy-> function
- Cons
  - Cannot be used in practical BCIs
  - Slow time resolution
  - Indirect measure of brain activity

27

Cedars Sinai

Nerve cuff



- Pros
  - Minimally invasive (no brain surgery)
  - Specific
  - Relatively inexpensive
  - Stimulate and record
- Cons
  - Won't work if nerves or limb too damaged
  - Won't work if spinal cord damage
  - Can only control one target per cuff

28

Hassler