Brain-Machine Interfaces

Technology and Potential

Esben Kran

Brain-machine interfaces

1. Brain-machine interfaces
2. The Past
3. The Present
4. The Future

Brain-machine interfaces

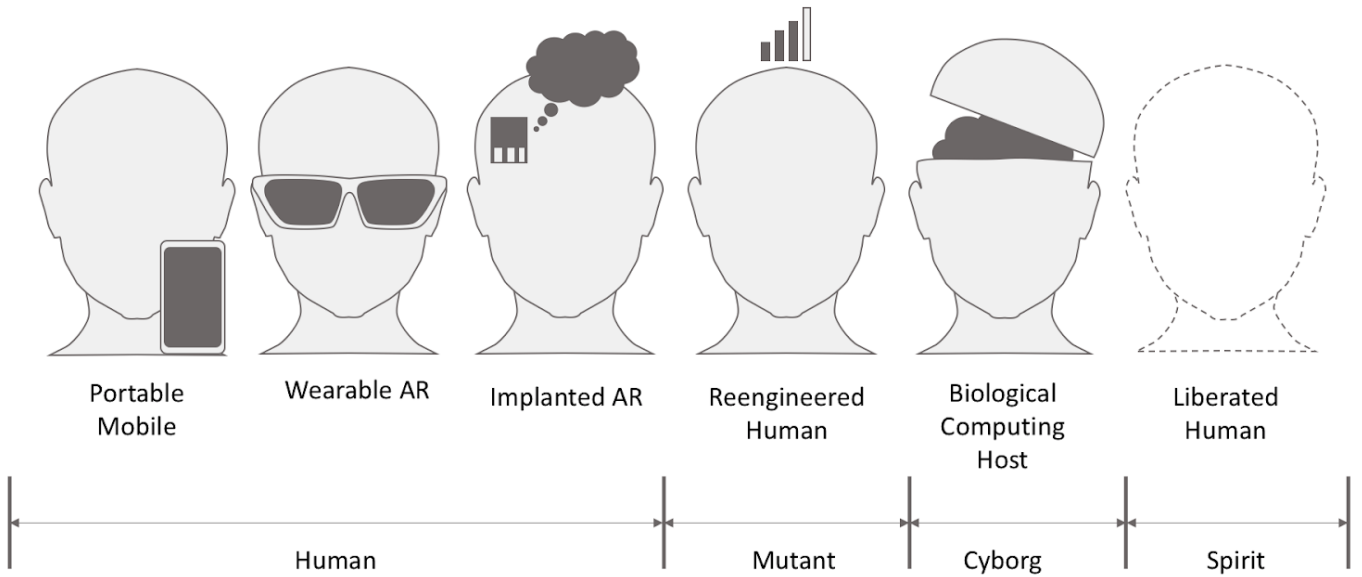
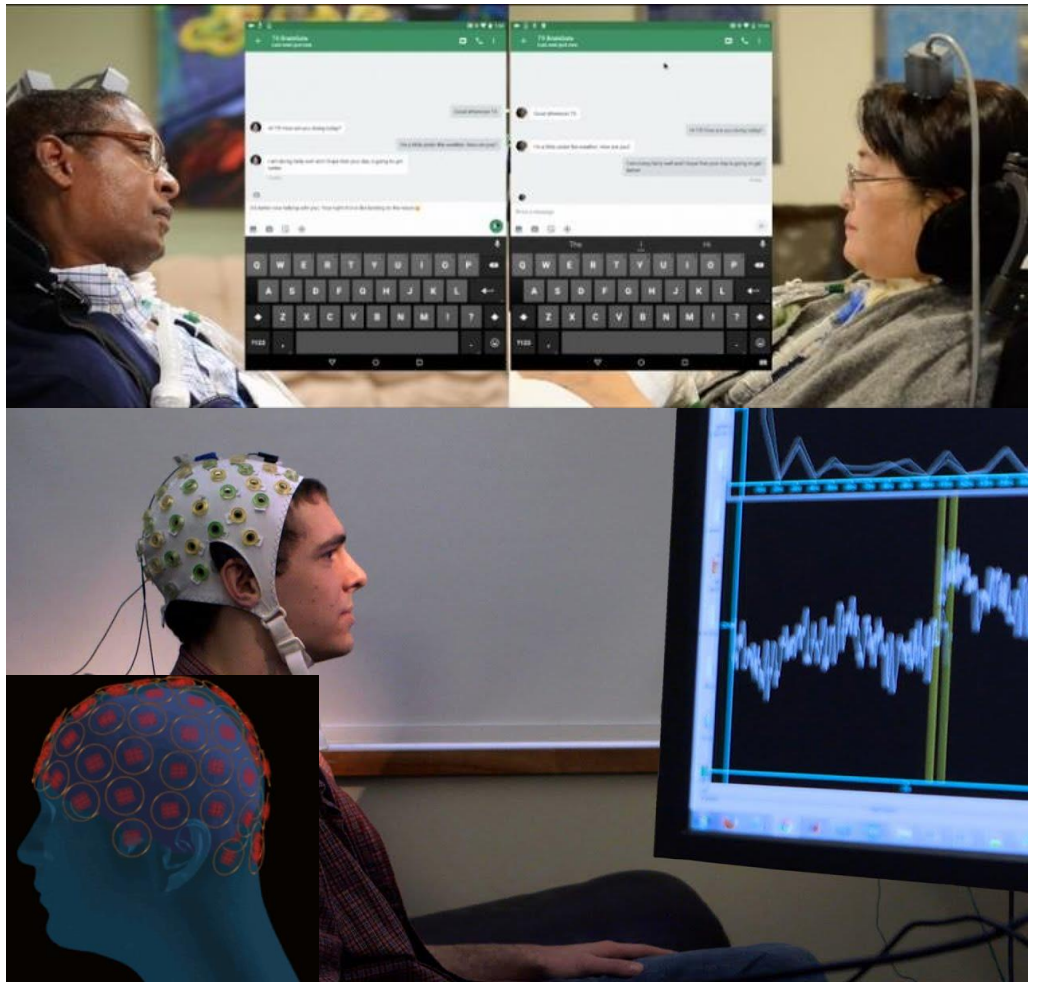


Image from stanleysuen.com

- Human evolution
- Evolutionary optimization
- Guided optimization of humanity
- BMI is the next step

Brain-machine interfaces

- Communicating directly to machines via neural activity
  - Reading from and stimulating neurons in the brain
- Bypassing natural effectors
- Invasive, non-invasive
- Companies and organisations
  - Neuralink, Kernel, BrainGate and many more…



Images from BrainGate Collaboration, 2018, National Science Foundation, Psychology Today, Kernel

Brain-machine interfaces

Record neural activity (brain)

Brain imaging:

- Multi/single-unit recording
- fMRI
- M/EEG
- OP-MEG
- fNIRS
- TD-NIRS

Brain-machine interfaces

Record neural activity (brain)

Computer with decoding algorithms (interface)

Brain imaging:

- **Multi/single-unit recording**
- fMRI
- M/EEG
- **OP-MEG**
- fNIRS
- **TD-NIRS**

Decoding:

- Supervised ML
- **Neuron encoding**
- Unsupervised ML
- GLM
- **Population vectors**

Brain-machine interfaces

Record neural activity (brain)

Computer with decoding algorithms (interface)

Prosthetic effector (machine)

Brain imaging:

- **Multi/single-unit recording**
- fMRI
- M/EEG
- **OP-MEG**
- fNIRS
- **TD-NIRS**

Decoding:

- Supervised ML
- **Neuron encoding**
- Unsupervised ML
- GLM
- **Population vectors**

Effector:

- **Robot arm**
- **Smartphone**
- **Keyboard**
- **The internet (!)**
- **Etc.**

Terminology

Brain-computer interface (BCI)

Brain-machine interface (BMI)

Neural prosthetics

Neural interfacing

Neural engineering

Neuromodulation

Neurofeedback

(ScienceDirect, 2020)

Terminology

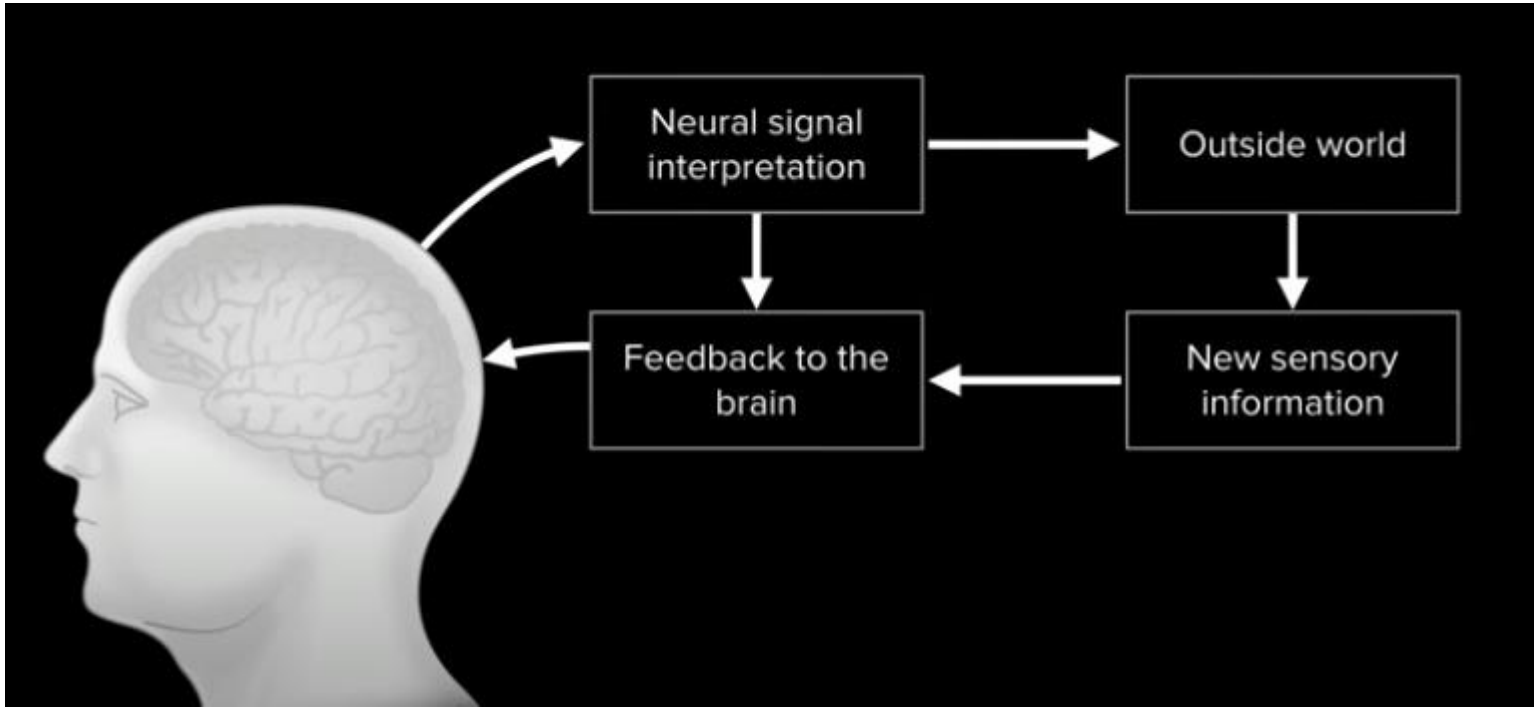


Image from Neuralink

The Past

- Early proof of concepts
- 1999, Chapin et al.
- Rat lever experiment
  - Lever controls robot arm by pressure
  - Recording neuronal activity during lever interaction
  - Rat stops using the lever (!!)
- Human motor neurons
  - 300 ms effector delay
- Cochlear implant, 1953

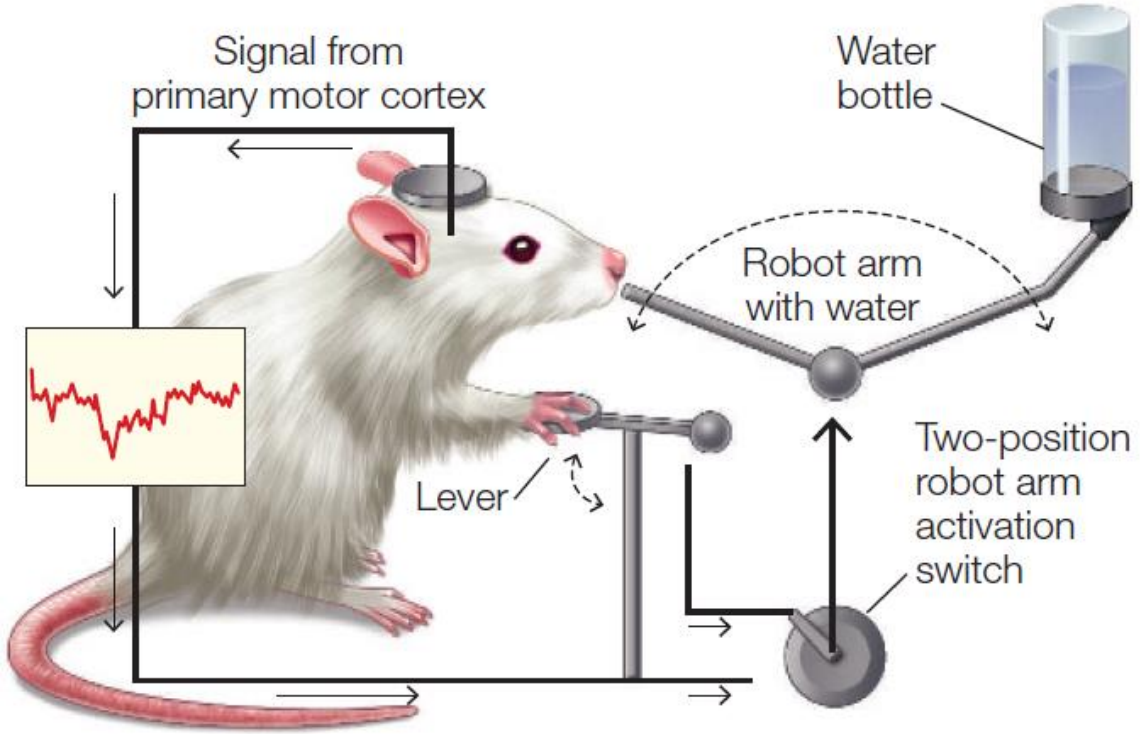
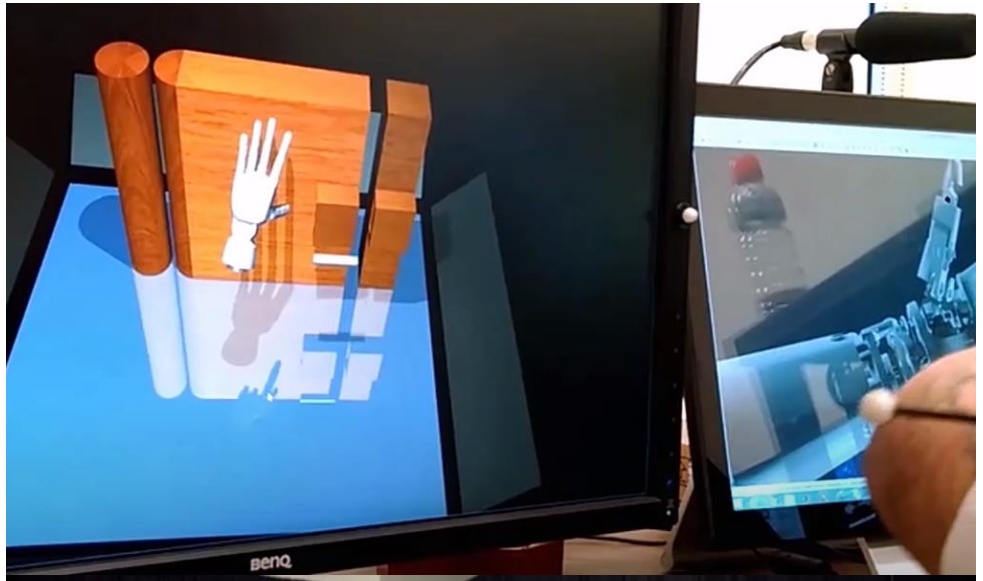


Image from Gazzaniga et al., 2019

(Chapin et al., 1999)

Prosthetics

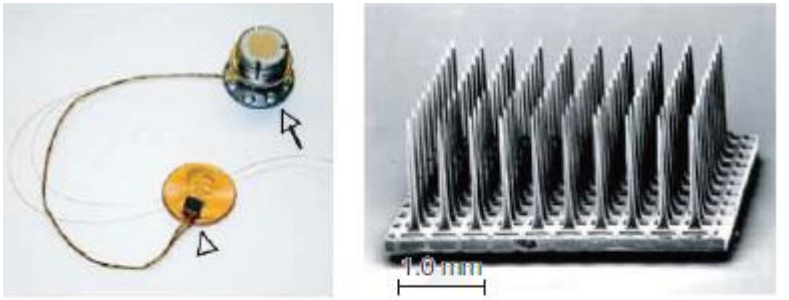
- Premotor and motor neuron interfacing
- Somatosensory feedback
- External effectors for paralyzed people
- Circumvent spinal cord
- DARPA and many others

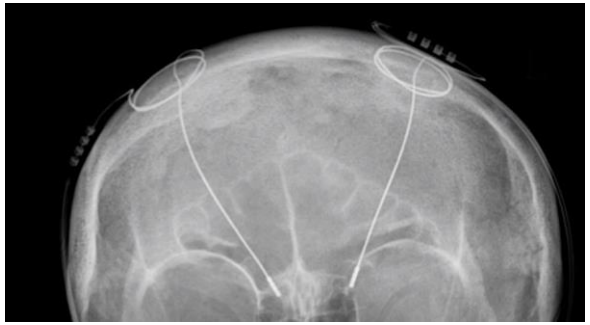


(DARPA, J. Sanchez, 2017, Rajesh PN Rao et al., 2006-2020)

Neurological disease mitigation

- Parkinson’s
  - Reactive deep brain stimulation
- Utah arrays
  - BrainGate
  - Paralysis patients
  - Control cursor





(P. Anikeeva, 2015)

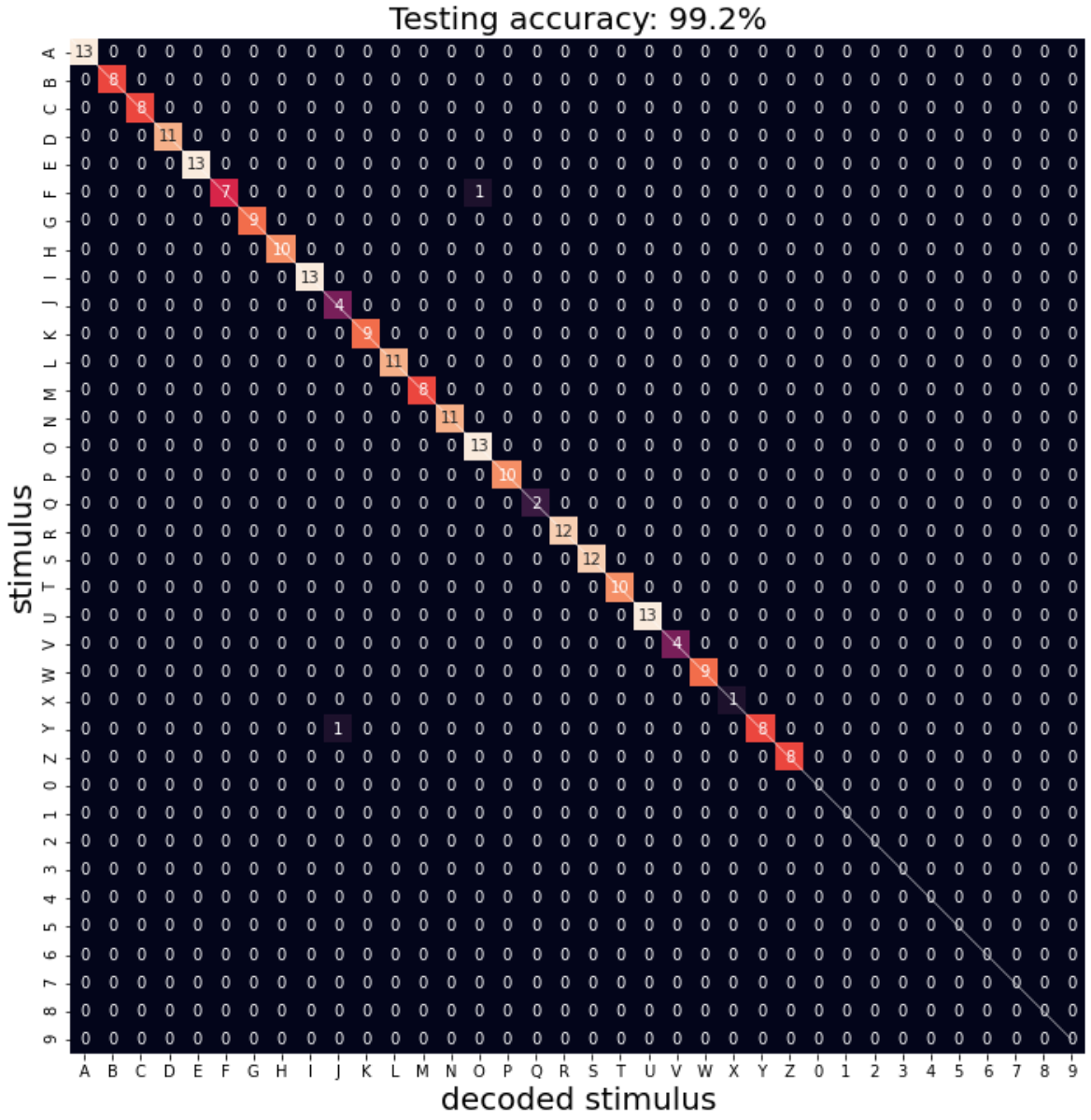
Neuromodulation

- Memory recall
- Neural stimulation
- Activity modulation inside the brain to enhance current abilities

(DARPA, J. Sanchez, 2017)

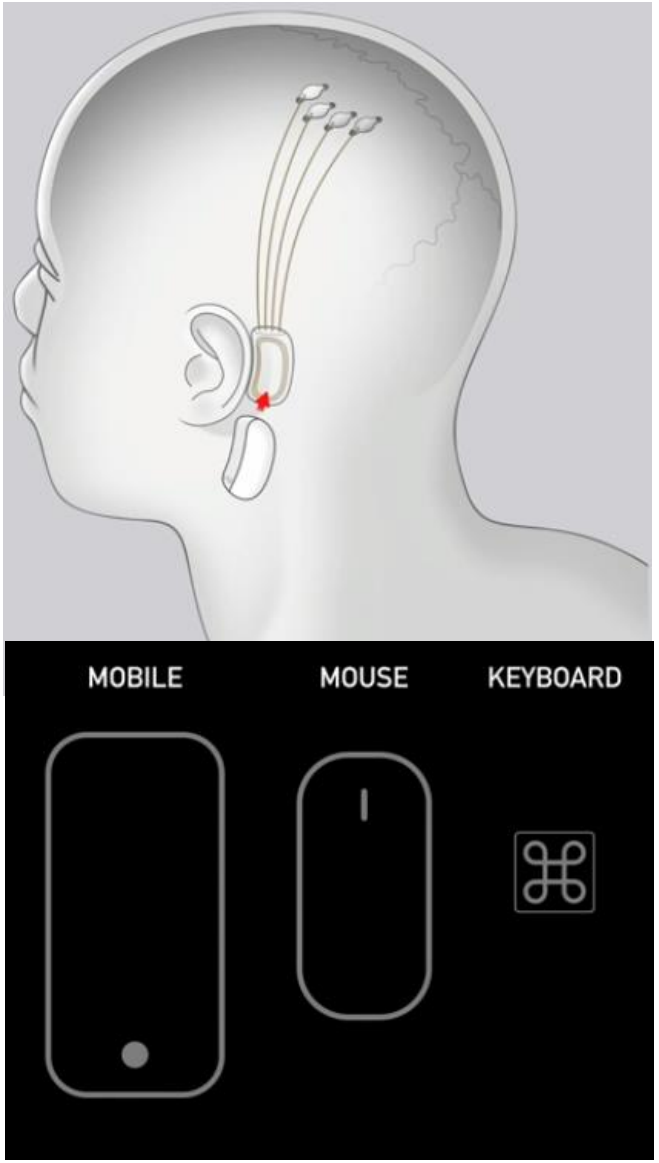
The Present

- Going a bit deeper
- Innovation is *mostly* about imaging capability
- Invasive
  - Neuralink
  - Multi-unit recording electrode recording
- Non-invasive
  - Kernel
  - OP-MEG and TD-NIRS



Neuralink

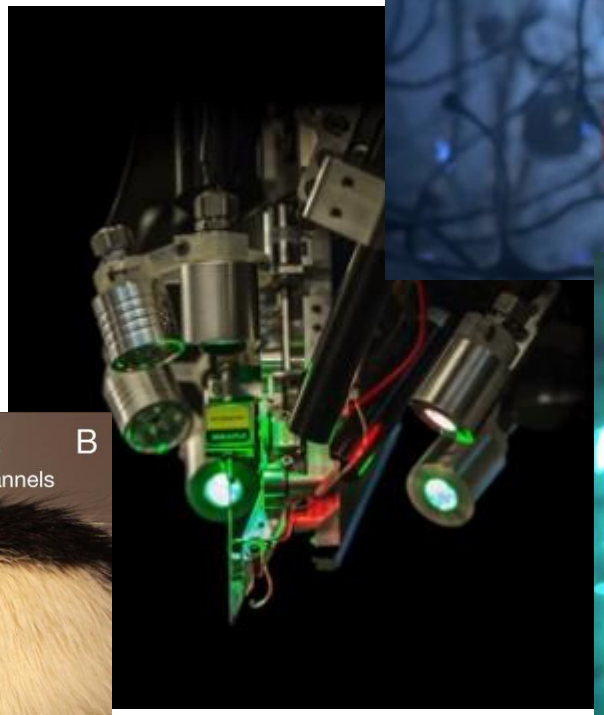
- Conceptual introduction
- Electrodes into brain areas
  - Motor cortex
  - Premotor cortex
  - Somatosensory cortex
- Increase electrode amount by several magnitudes
  - Utah arrays: <256 electrodes
  - Neuralink: 3,072< electrodes
- Safety in usage and implementation
- App-based interactivity through bluetooth

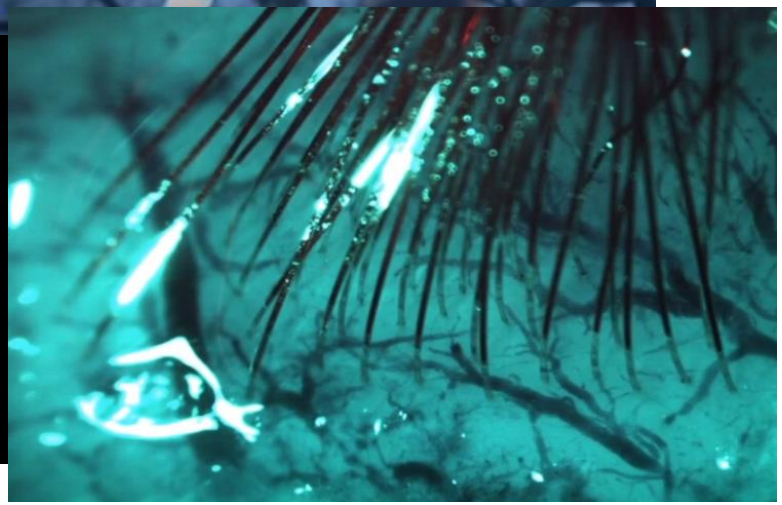


(Neuralink, 2019)

Recording

- Implanted electrodes with high-tech “sewing machine”
- 3072 ch. Electrode arrays
- Spike detection
- Output through interface

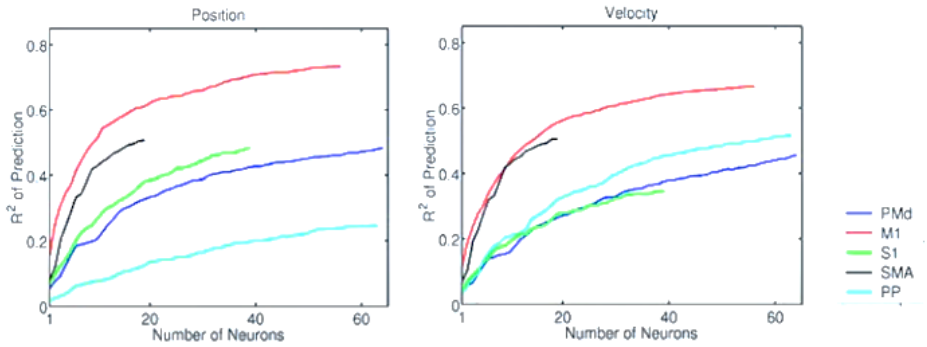


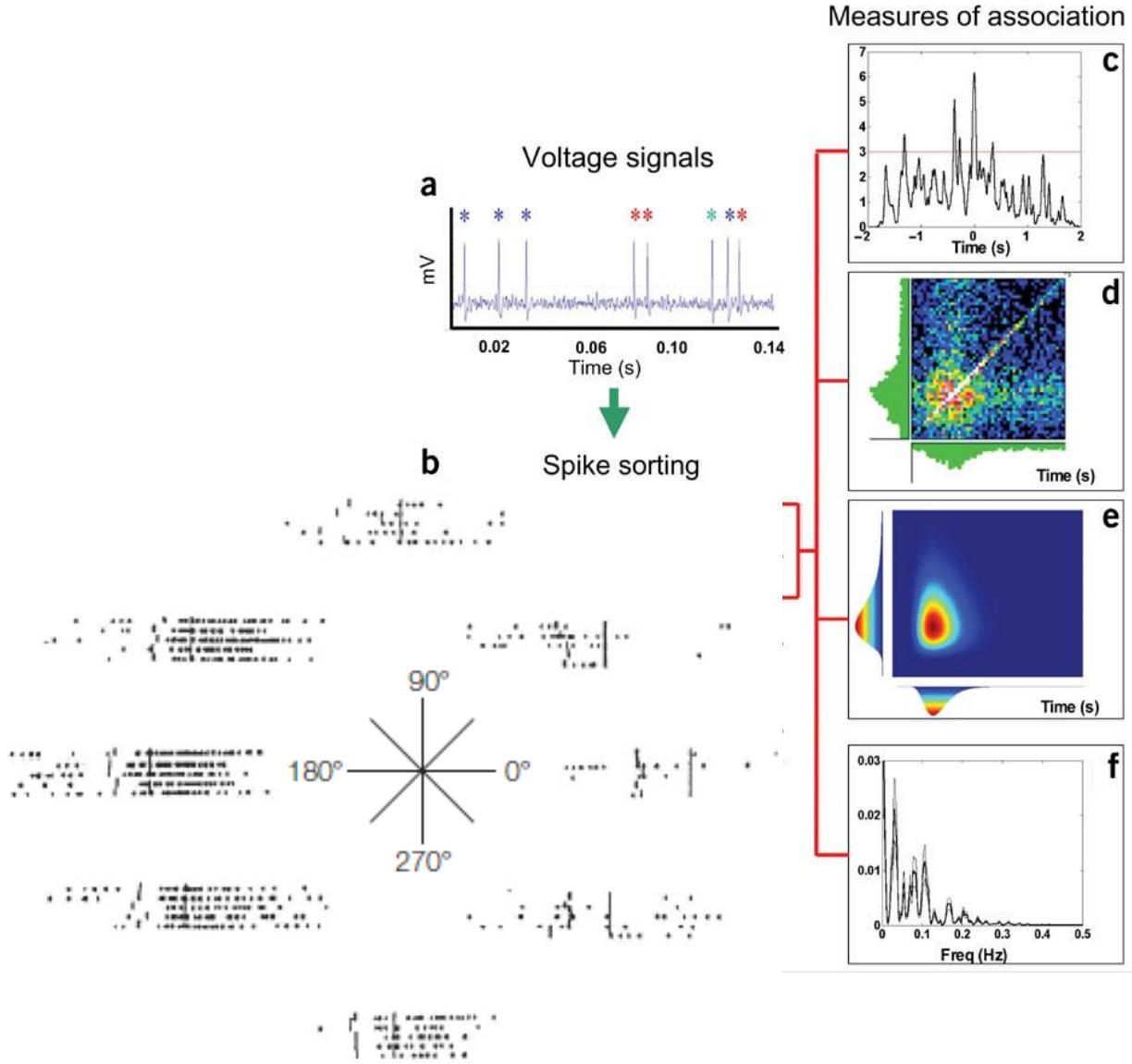


(Neuralink, 2019, Musk & Neuralink, 2019)

Decoding

- Neuronal population vectors
- Algorithms
- Reading signals
- Extracting meaning
- Neural encoding

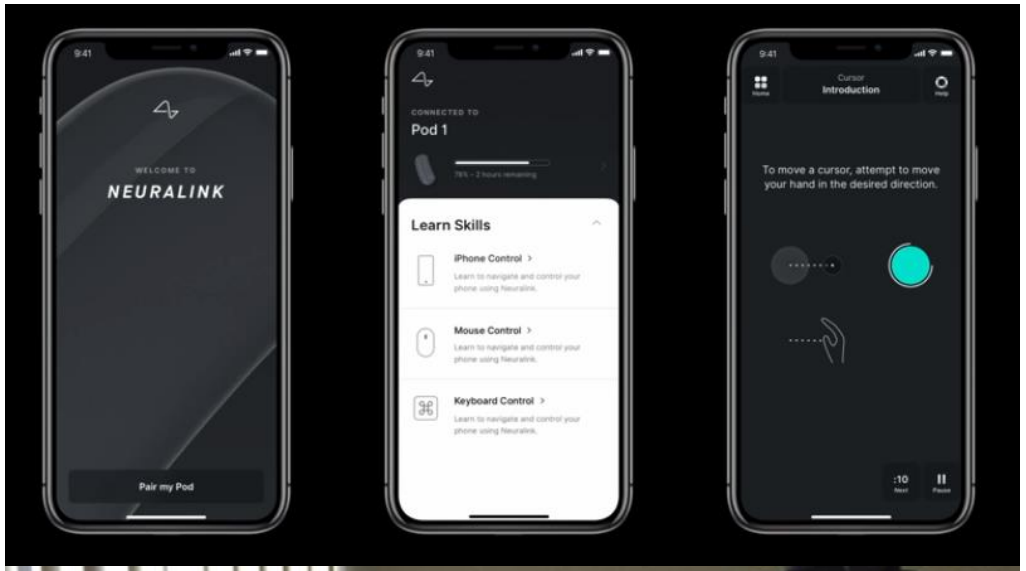


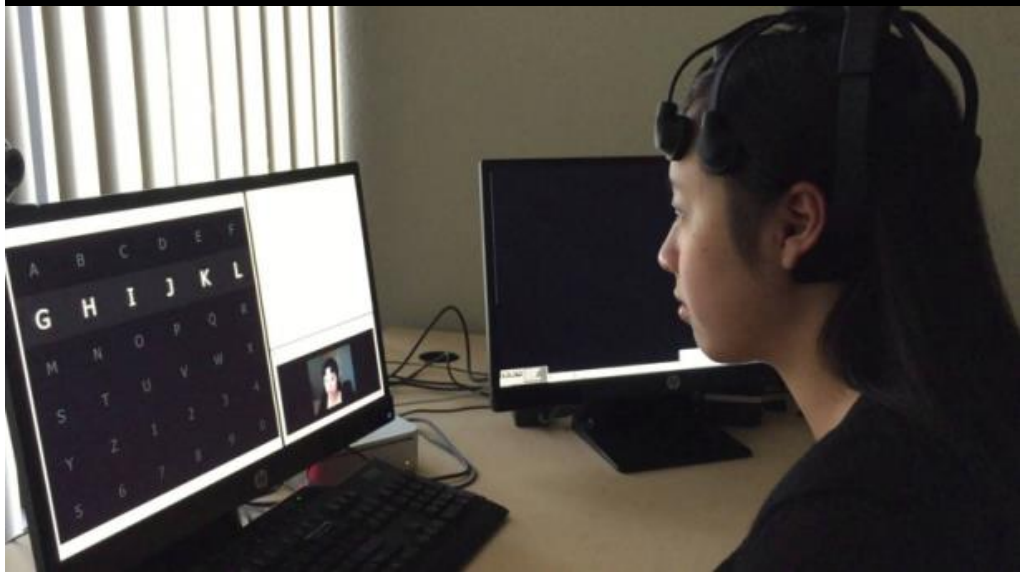


(E. Brown et al., 2004, Neuralink, 2019)

Interacting and learning

- Use signals
- External effectors
  - Basically anything
  - Mouse, keyboard, smartphone
- Connect signal to interpreting machine – app through Bluetooth
- Learning to use through feedback systems
  - Somatosensory
  - Audiovisual

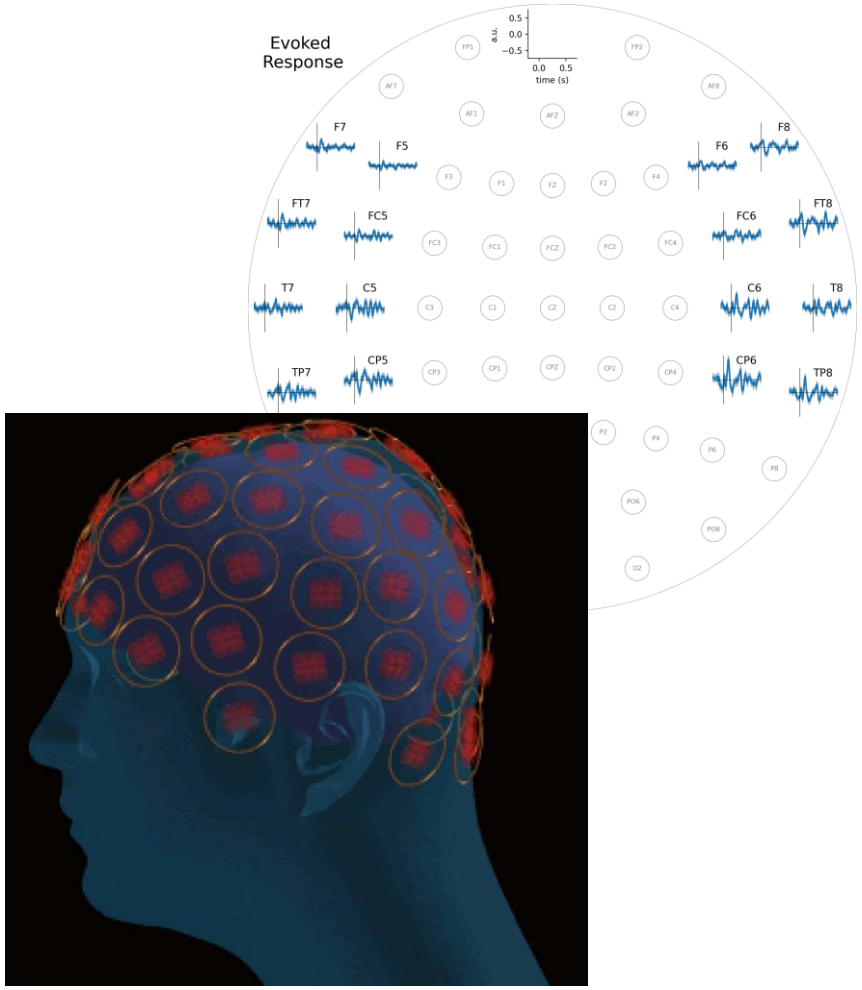




(Neuralink, 2019, bootstrapping.dk, 2019)

Kernel Flux

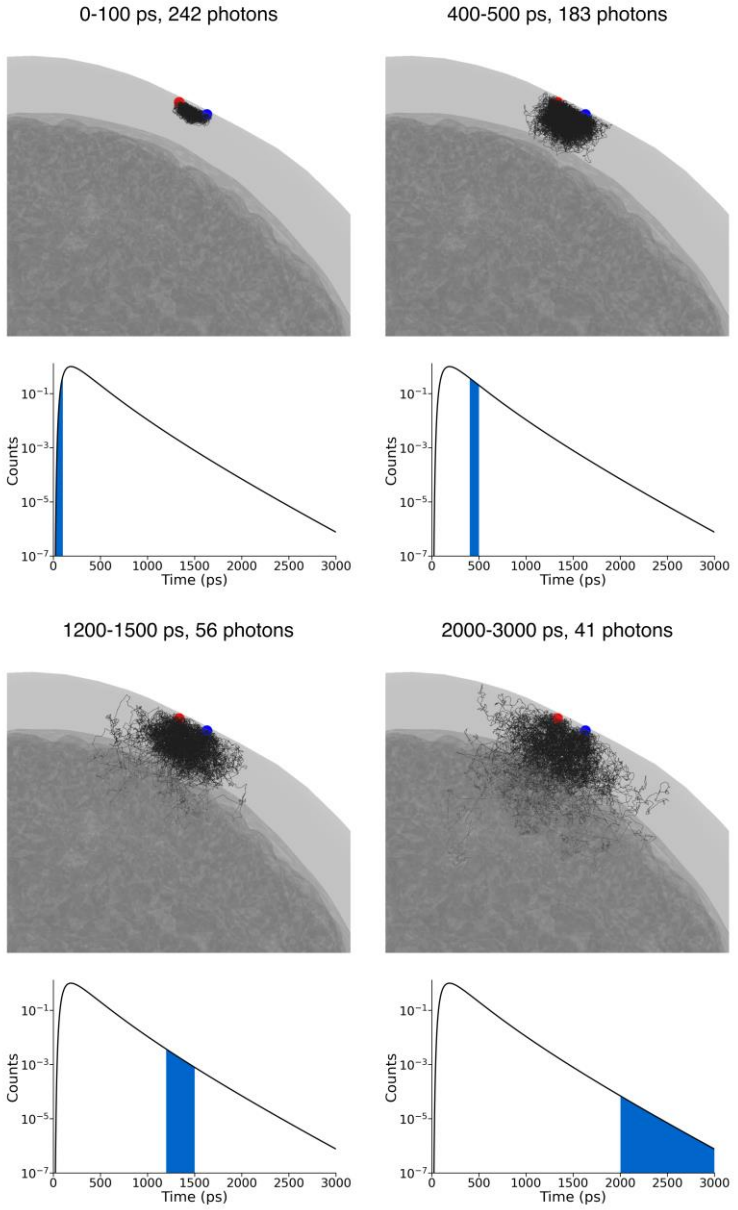
- Optically pumped magnetometers for magnetoencephalography (OP-MEG)
- 720 channels
- <1.6 kg
- 1-200 Hz
- 3x3, 15 magnetic field vectors, 720 channels with 48 modules



(Kernel, 2020)

Kernel Flow

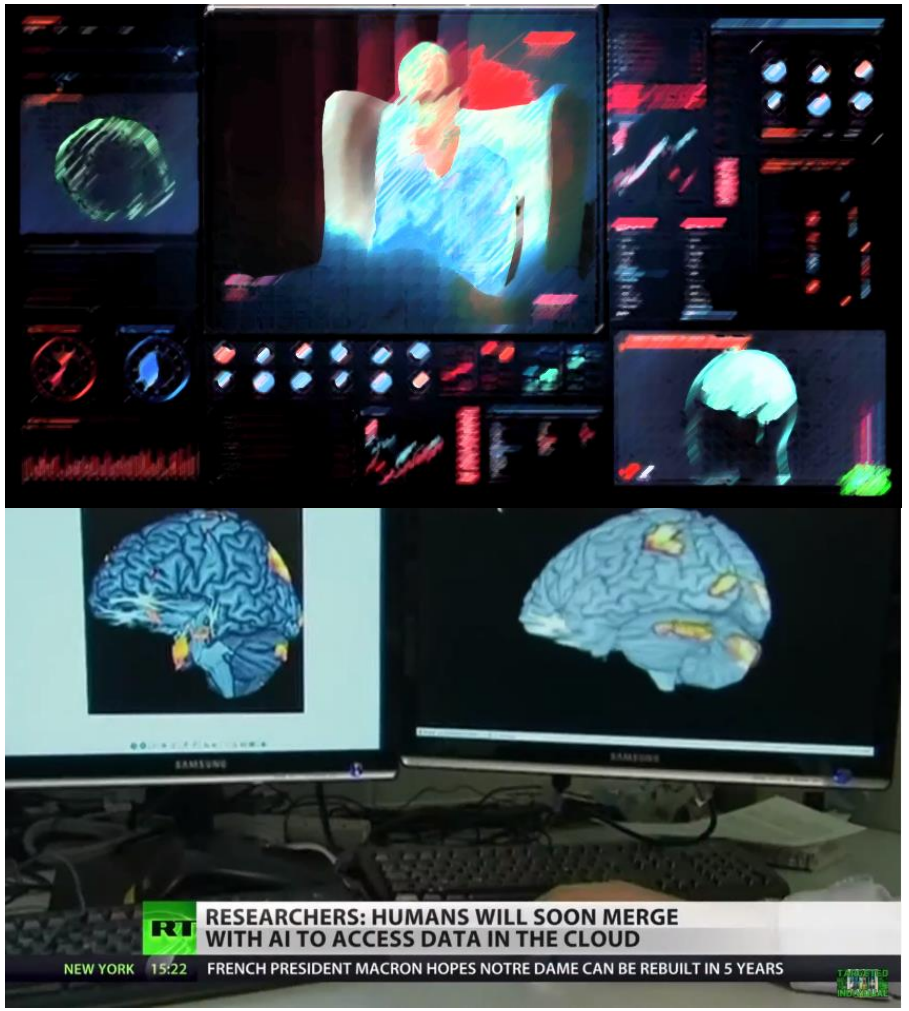
- Time-domain near-infrared spectroscopy (TD-NIRS)
  - Light pulses with delay detection
- Optical tissue information: Oxy, deoxy, total, coefficients
- Complementary EEG
- <1.5 kg
- 1kHz EEG, 500 Hz optical
- 1344< source-detector pairs



(Kernel, 2020)

Ethics

- Before entering the magnificent future
- Data ethics
- Access
  - Facebook???
  - The state?
  - Yourself.
- Reading thoughts? Giving thoughts??
  - Hacking???
- Some of the same questions as modern smartphone use



Images from shady YouTube video and RT (just as shady)

The Future

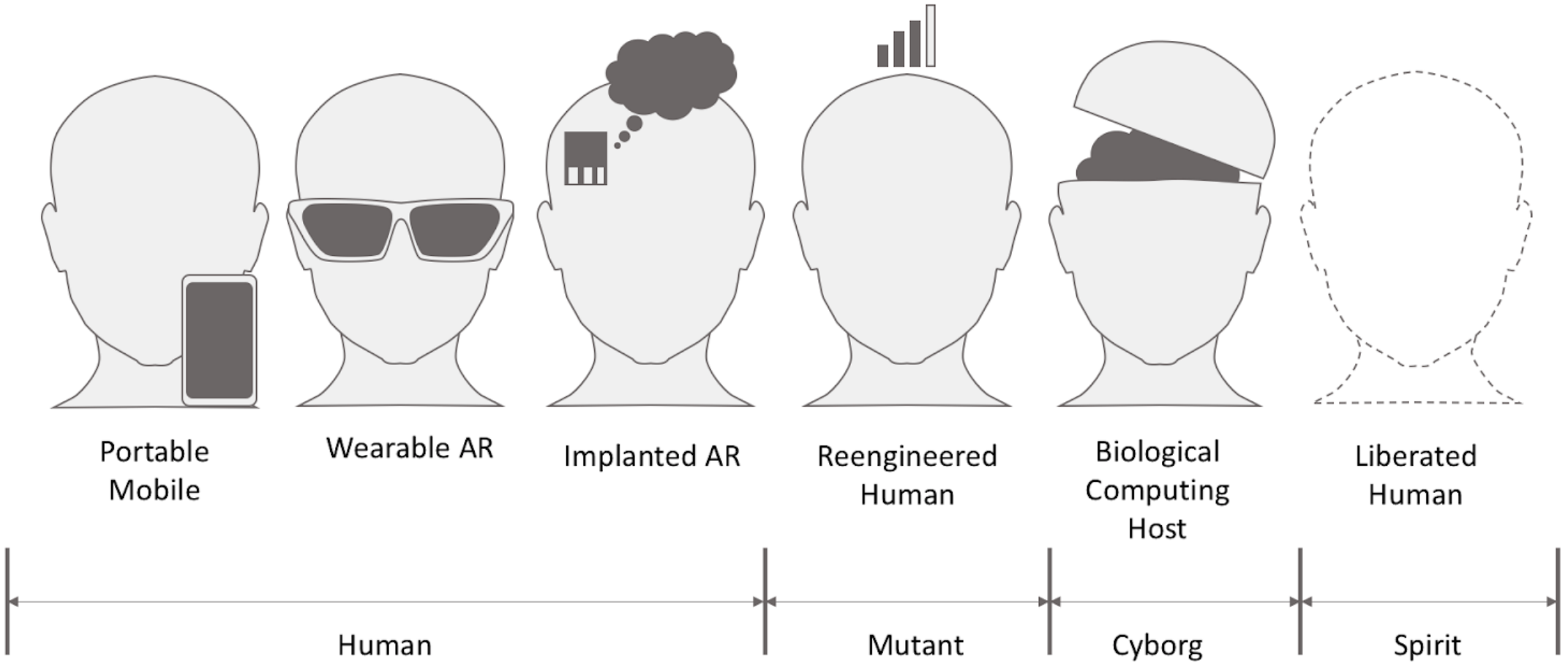


Image from stanleysuen.com

Connection

- Mind to mind communication
  - Bandwidth question
- Rats connected
  - Problem solving
- Transfer memories
- Brain to internet
- In general, low speed information transfer

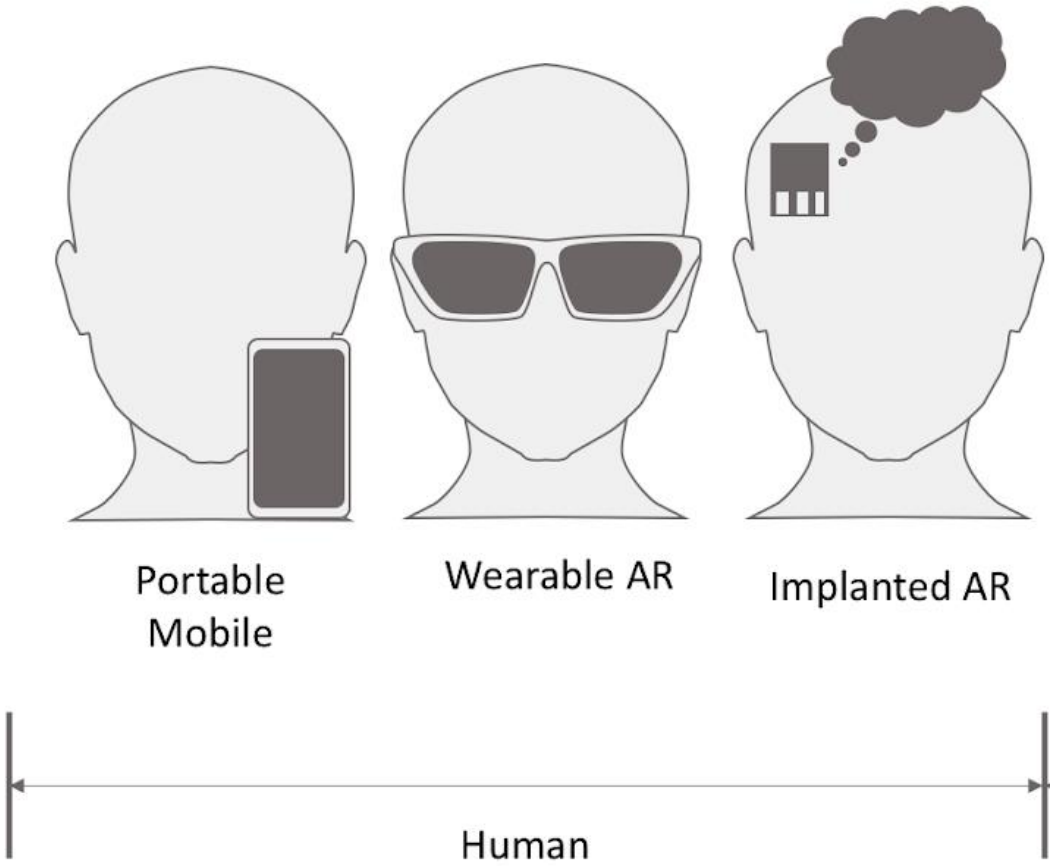
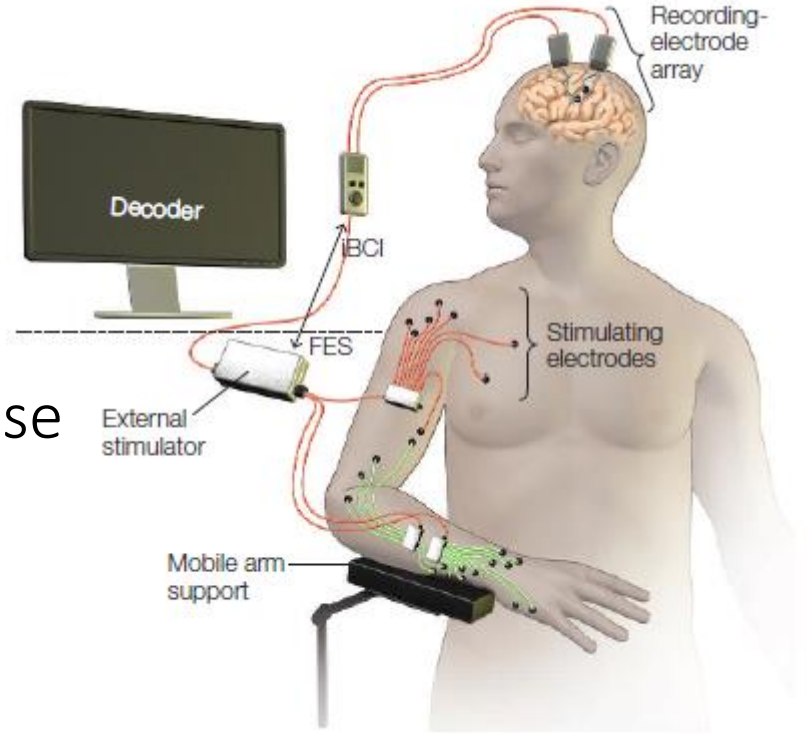
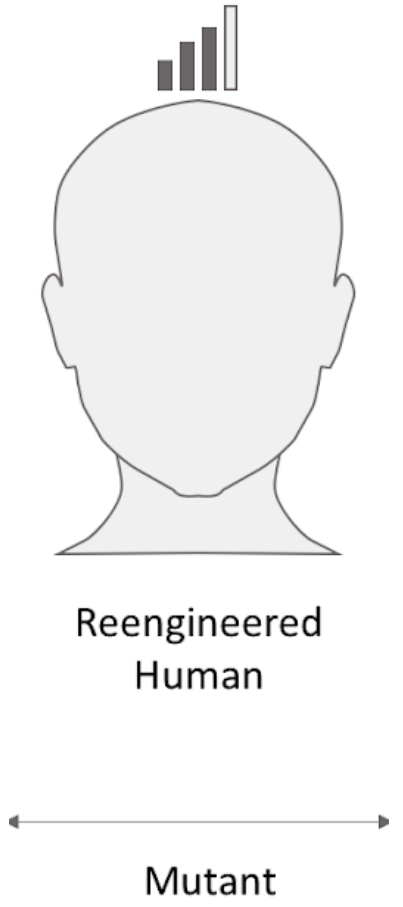


Image from stanleysuen.com

Neurological ailments

- Removing or limiting
- Depression, 6.7% US
- Bipolar, 2.8%
- Parkinson's, 0.3% 2020
- Alzheimer's, 6th leading cause of death in US
- Paralysis, 1.7%
  - Stroke, spinal cord injury, multiple sclerosis…
- Epilepsy, OCD, dystonia, etc.

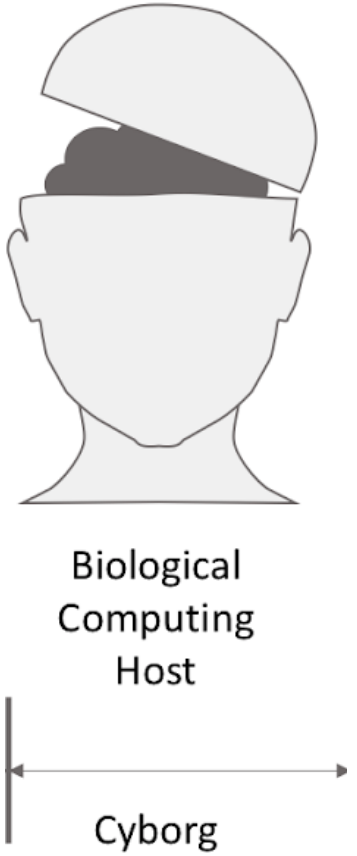




Images from stanleysuen.com, Gazzaniga et al., 2019

Neural enhancement

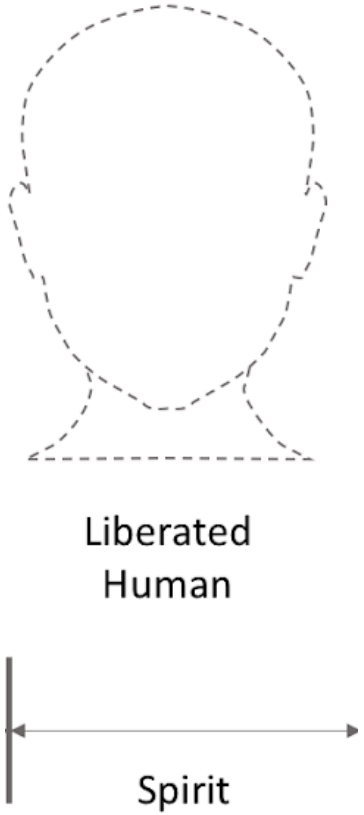
- Knowledge
  - Transfer knowledge
  - Download knowledge
  - Memory enhancement
- Personal optimization
- Neuromodulation
- Expand computing power
  - Cyborg humanity
  - Artificial Intelligence



Images from stanleysuen.com, Linus Tech Tips

Immersion

- Complete immersion
- Virtual reality
  - Education
  - Existence
  - Climate change
  - Entertainment
- Avatars
- Cryosleep
- The final question
- *Exo-human experience*
  - Mind uploading



Images from stanleysuen.com, Ready Player One

Summarization

- BMI:
  - Brain imaging
  - Signal interpretation
  - Execution
- Technology:
  - Invasive
  - Non-invasive
  - Potential
- Future
  - Extreme possibilities
  - Both positive and negative

Plan sheet

Abstract

Brain-machine interfaces will have immeasurable consequences on the future of humanity. In this talk, we will highlight some of the reasons why, from controlling robot arms with your mind to being our frontline in the battle against artificial intelligence. We will also touch upon the state-of-the-art technologies and the ethical concerns that apply when computers become part of our cognition!

Jonathan's list

- hvad er den grundlæggende idé?
- hvad er state of the art?
- hvorfor er det en fed teknologi?
- hvordan kan man bruge teknologien (cases)?
- hvilke etiske overvejelser er der?

Notes

Slide concepts

- Timeline of the future
- 3D views of the brain and systems
- Cases before theory

Companies

- CTRL-labs (Facebook)
  - Neuromuscular control
- Kernel
- Neuralink