Recording Neural Activity

Informatics 1 Cognitive Science

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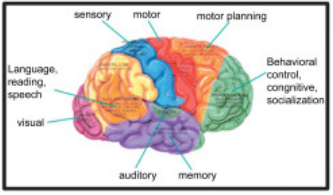
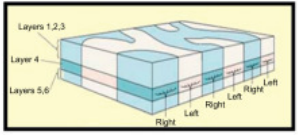
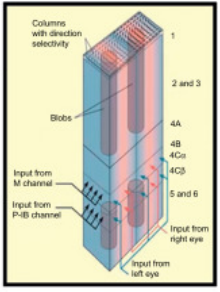
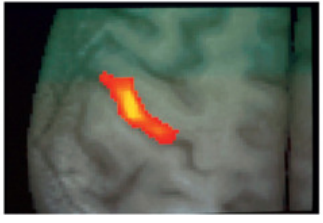
Observing the brain at different scales



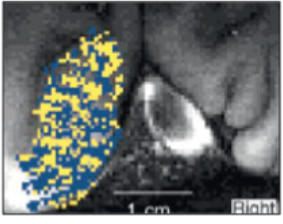


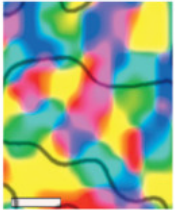


Regions

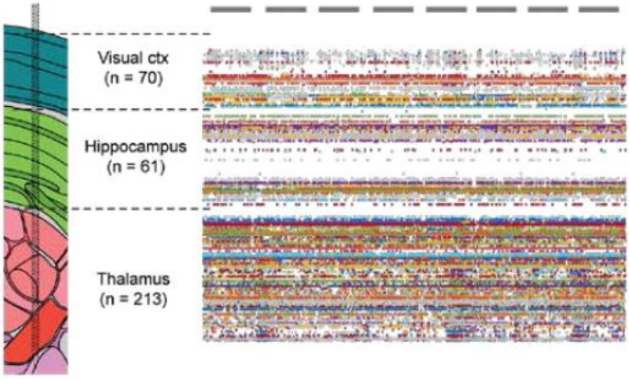


Columns





Listening to the brain in action



- Approaches: Non-invasive or invasive
- Spatial resolution: Single neuron or pooled activity
- Temporal precision: Single spikes or averaged signals

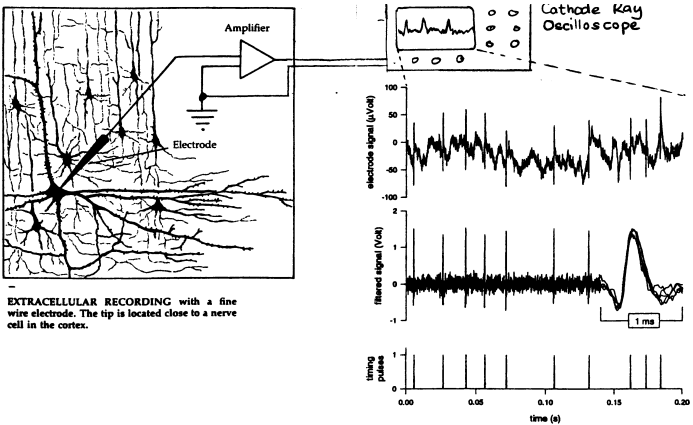
Summary of Methods

- Electrodes:
  - Extracellular electrodes report spiking activity
  - Intracellular electrodes to measure membrane voltage
  - Single neuron resolution: singe or multiple electrodes, multi-electrode arrays
  - Population response: field electrodes, EEG, MEG
- Optical measurements:
  - Fluorescence signals emitted from neural activity indicators
- fMRI (functional Magnetic Resonance Imaging):
  - Reports blood oxygenation level

Recording Methods

1. Invasive methods

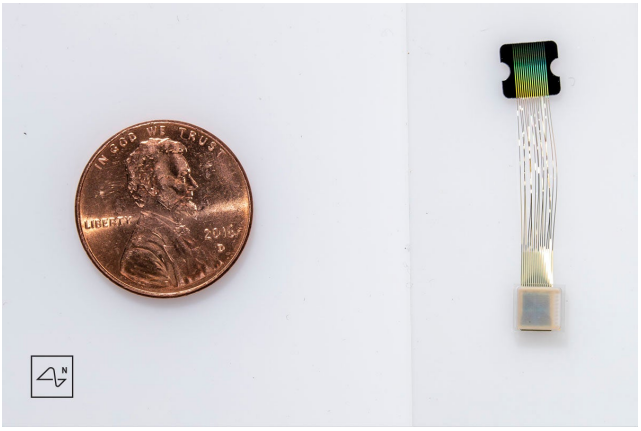
Extracellular electrodes



EXTRACELLULAR RECORDING with a fine wire electrode. The tip is located close to a nerve cell in the cortex.

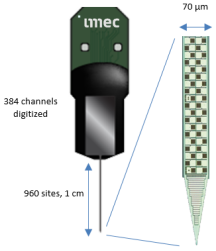
One or few neurons at a time. High precision in time, sub-millisecond resolution.

Implantable Arrays

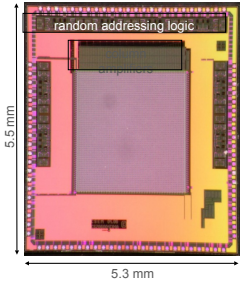


Arrays with multiple recording channels, these can be implanted chronically (prosthetics).

Dense arrays



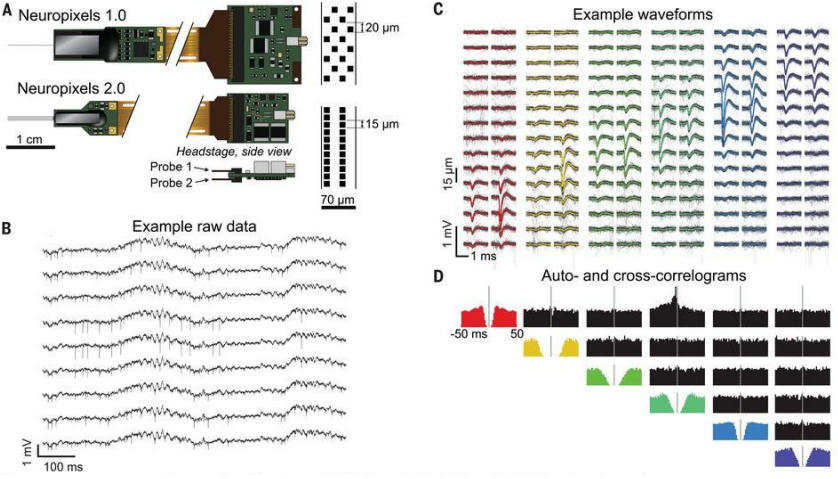
Neuropixel Probe
384 channels at 30kHz
22 MB/s



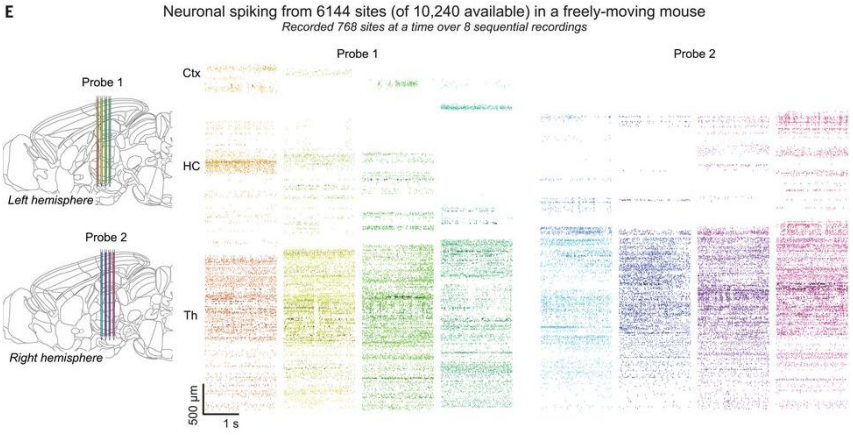
Biocam Array
4,096 channels at 18kHz
142 MB/s

100+++ neurons close to the array simultaneously.

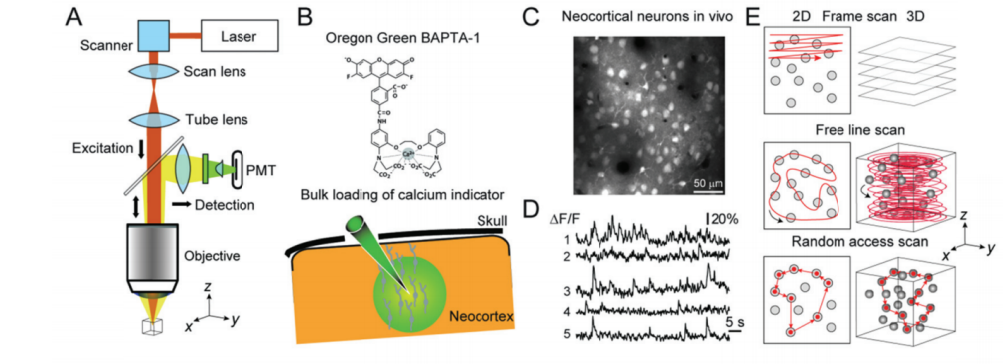
Dense arrays



Dense arrays



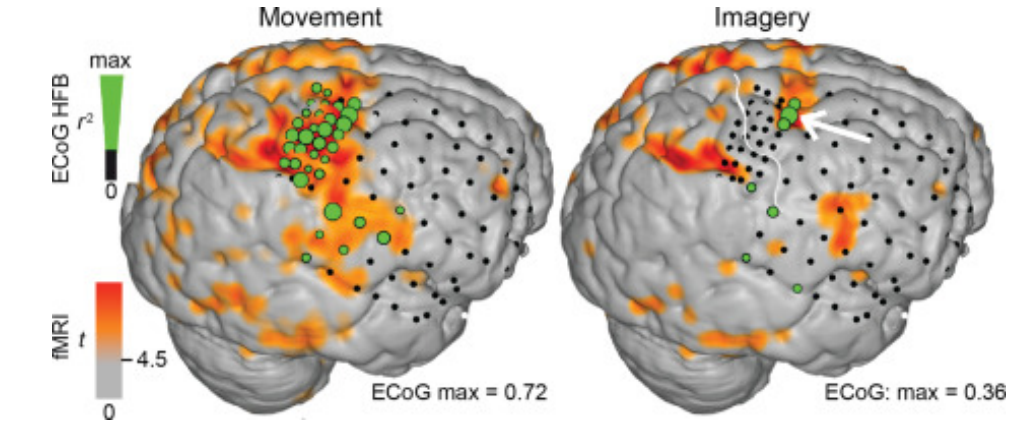
Fluorescence Imaging



100-10,000 neurons at a time, using a fluorescent calcium indicator to measure neural activity. Low time resolution (30 frames/second or less), fluorescent dyes react slowly (decay in seconds). Single neurons are easy to identify. Can record all neurons in a large volume (unlike electrodes).

Video

Electrocorticography (ECOG)

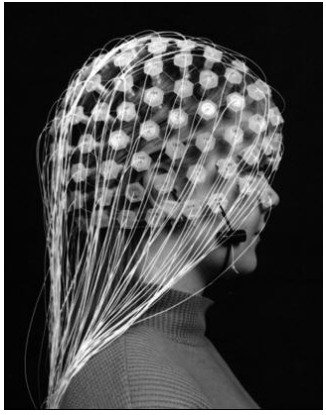


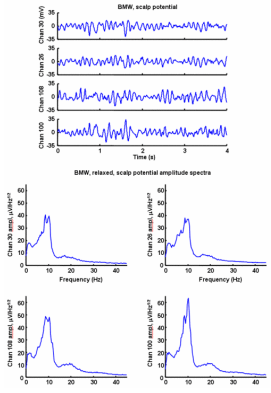
Electrodes placed directly on the surface of the cortex. Can record from large areas, and is used in clinical settings for epilepsy surgery planning.

Recording Methods

2. Non-Invasive methods

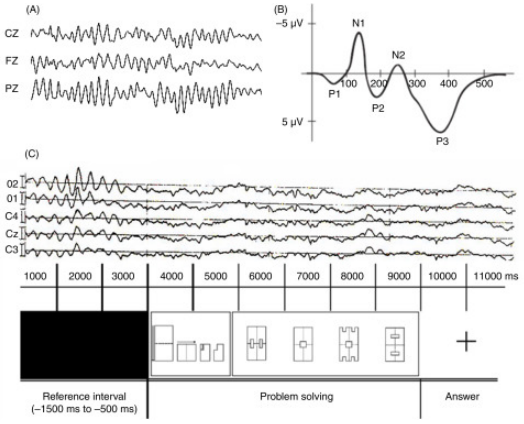
Electroencephalogram





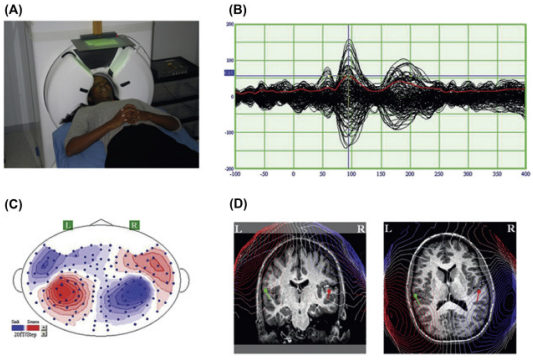
Scalp electrodes (a few to several 100). Records mostly synaptic activity from thousands of neurons in the volume around electrodes. Cannot resolve single neurons, but high time resolution (sub-millisecond).

Electroencephalogram: Event Related Potentials (ERPs)



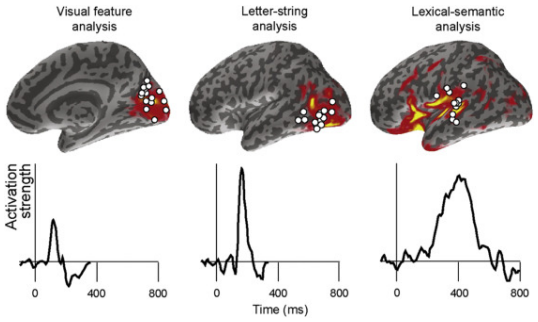
ERPs are computed over many stimulus repetitions to cancel out noise. They reflect the average response of the brain to a stimulus.

Magnetoencephalography (MEG)



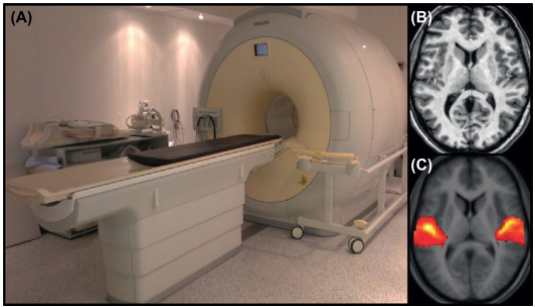
MEG records the magnetic field generated by neural activity. It has a similar spatial resolution to EEG, but is less sensitive to distortions by the skull and scalp.

Magnetoencephalography: localising function



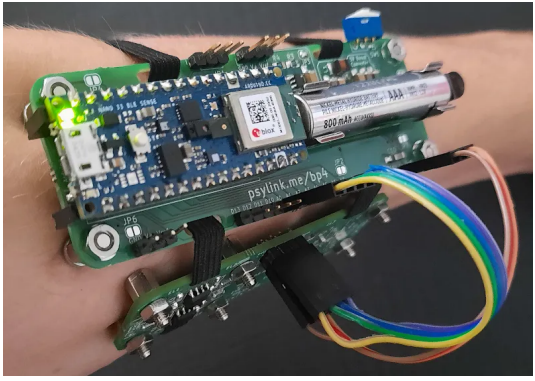
MEG allows breaking signals down in time, here an example of localising the source of a signal in time and space during reading.

Functional Magnetic Resonance Imaging (fMRI)



Measures blood-oxygen-level dependent (BOLD) contrast, a proxy for increased metabolic activity due to neural (synaptic) activity, in voxels (3D volumes). Low spatial resolution: a single voxel contains up to millions of neurons. Low time resolution: 1 sample per 1 or 2 seconds.

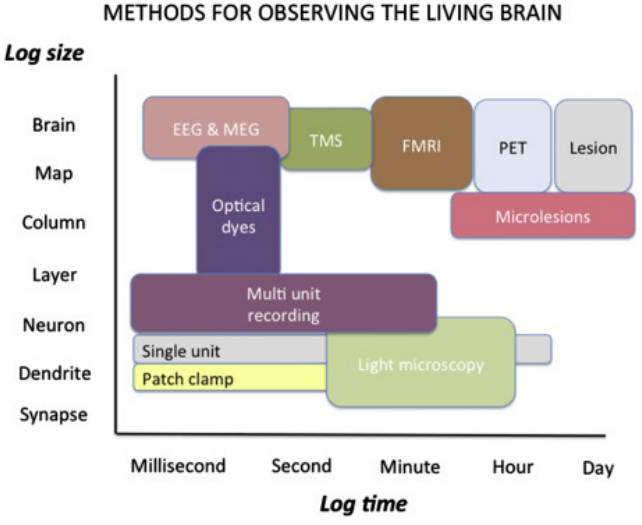
Electromyography: recording motor neurons



EMG records the electrical activity of motor neurons. There is a current effort to use EMG to control prosthetic limbs, and there may even be consumer devices in the future.

Source: https://hackaday.com/2022/01/07/psylink-an-open-source-neural-interface-for-non-invasive-emg/

Summary


METHODS FOR OBSERVING THE LIVING BRAIN
Log size
Brain
Map
Column
Layer
Neuron
Dendrite
Synapse
EEG & MEG
TMS
FMRI
PET
Lesion
Optical dyes
Microlesions
Multi unit recording
Single unit
Patch clamp
Light microscopy
Millisecond
Second
Minute
Hour
Day
Log time