Informatics 1 Cognitive Science

Lecture 11: Measuring Brain Activity

Matthias Hennig

School of Informatics
University of Edinburgh
mhennig@inf.ed.ac.uk

Overview

Overview of Measurement Methods

Electrical Recordings

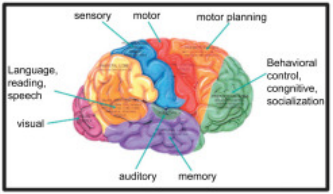
Field Recordings

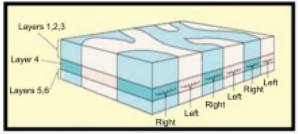
Magnetic Recordings

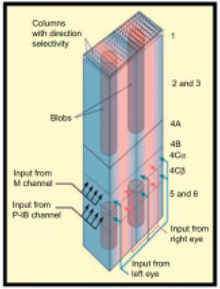
Optical Recordings

Overview of Measurement Methods

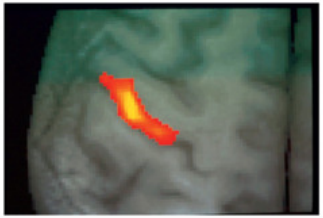
Observing the brain at different scales

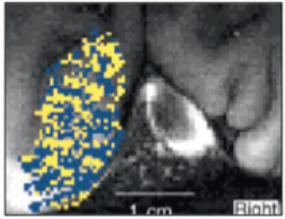


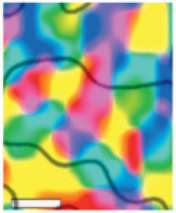




Regions **Columns**



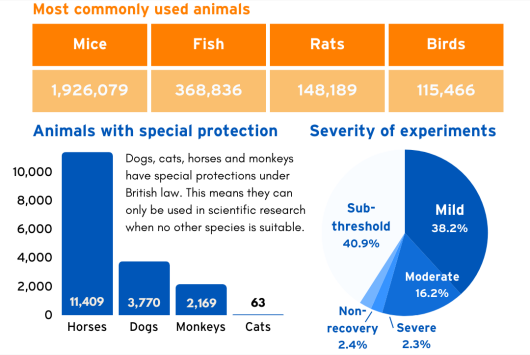




Summary of Methods

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

Animals in Research



In the UK, around 2.7 mio animals are used in research per year: 52% in basic research, 25% in translational and applied research, and 21% in regulatory testing.

https://www.gov.uk/government/statistics/statistics-of-scientific-procedures-on-living-animals-great-britain-2023/annual-statistics-of-scientific-procedures-on-living-animals-great-britain-2023/

Animals in Research

Regulatory & ethical requirements

- Comply with Home Office legislation
- Demonstrate no alternative to using animals
- Justify the number of animals used
- Requires approval from local Ethics Committee

The 3Rs

Replacement Develop/use models and tools to address important scientific questions without animals.

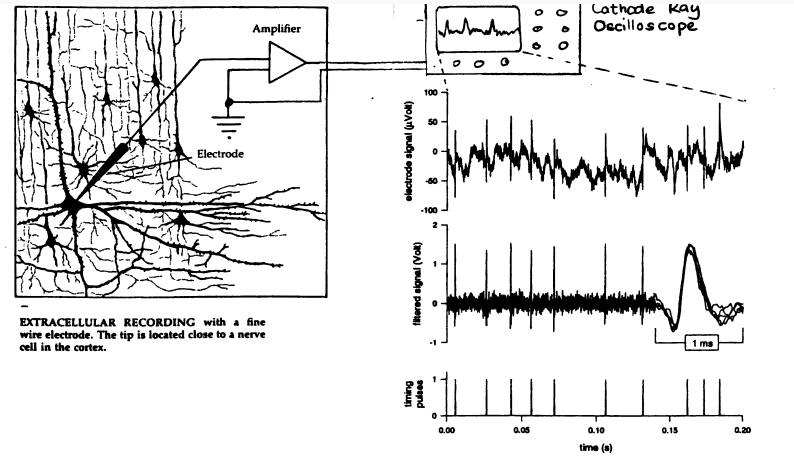
Reduction Careful experimental design; experiments that add to the knowledge base.

Refinement Technology focused on improved animal welfare.

https://www.understandinganimalresearch.org.uk/

Electrical Recordings

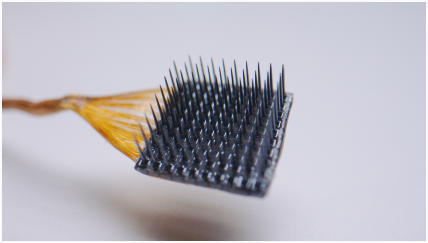
Extracellular electrodes



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

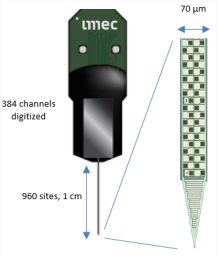
One or few neurons at a time. High precision in time, sub-millisecond resolution.

Implantable Arrays

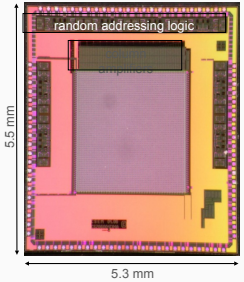


Arrays with multiple recording channels, these can be implanted chronically (prosthetics, see e.g. BrainGate Consortium), Utah array is the most widely used design.

Example Recordings from Neuropixels Probes



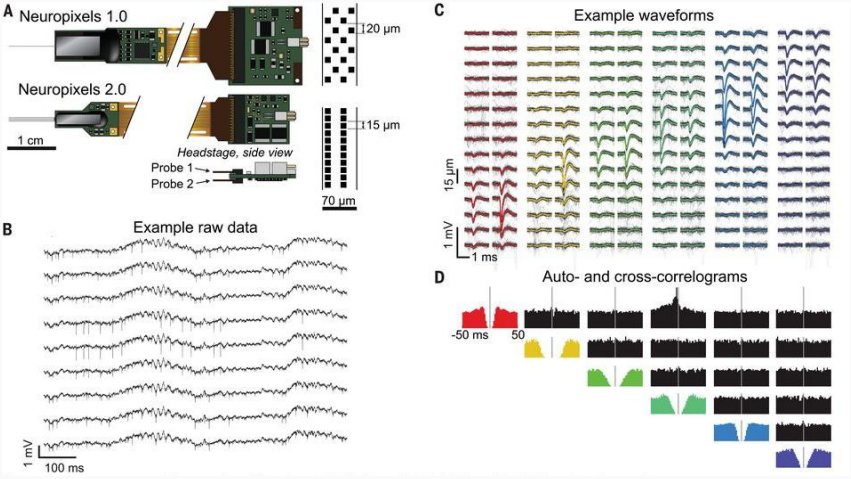
Neuropixel Probe
384 channels at 30kHz
22 MB/s



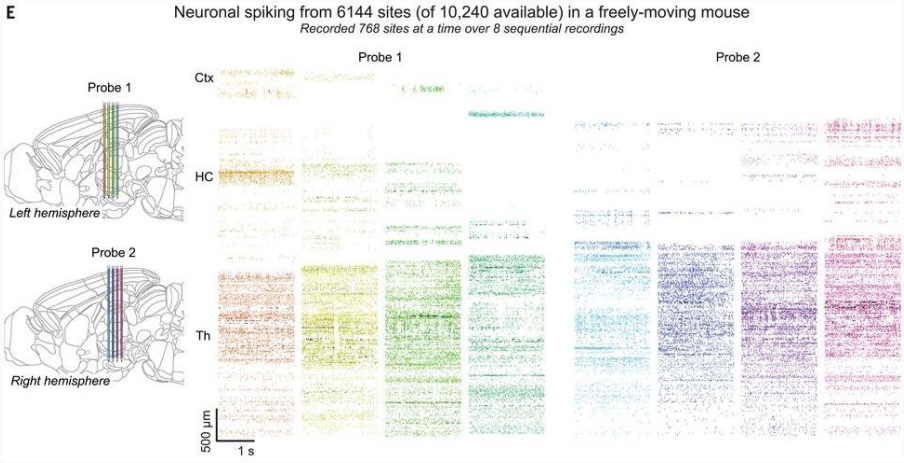
Biocam Array
4,096 channels at 18kHz
142 MB/s

In vivo or in vitro recordings from 100+++ neurons simultaneously.

Recordings from multiple brain areas



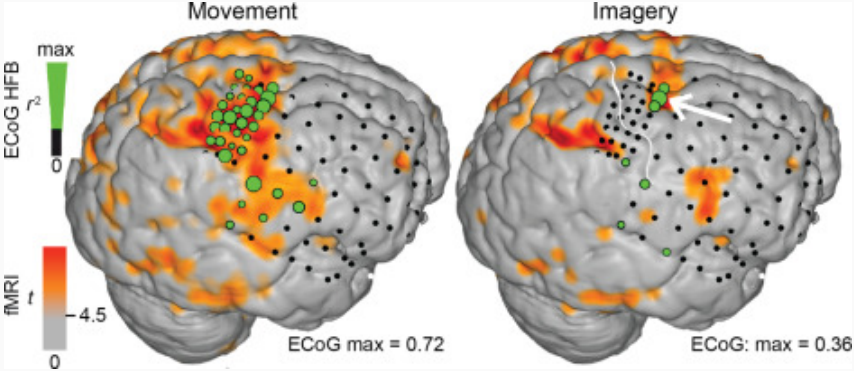
Dense arrays



Multiple shanks to record from different areas simultaneously.

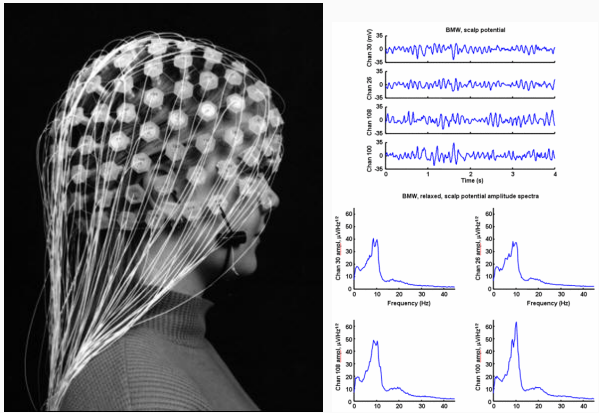
Field Recordings

Electrocorticography (ECoG)



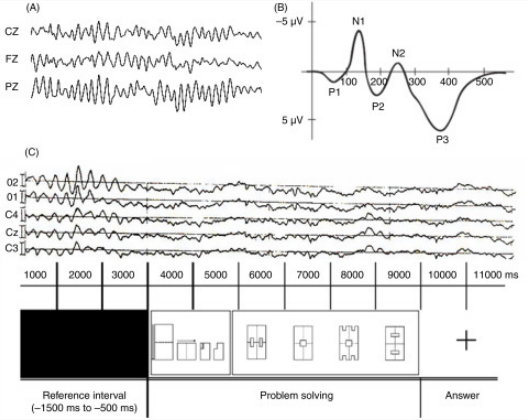
Electrodes placed directly on the surface of the cortex. Can record from large areas, and is used in clinical settings for epilepsy surgery planning.

Electroencephalography (EEG)



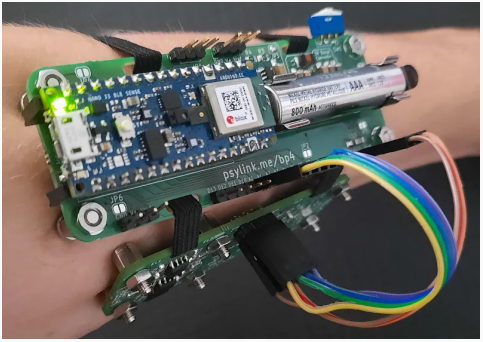
Scalp electrodes (a few to several 100). Records mostly synaptic activity from thousands of neurons in the volume around electrodes. Cannot resolve single neurons, but high time resolution (sub-millisecond).

Electroencephalogram: Event Related Potentials (ERPs)



ERPs are computed over many stimulus repetitions to cancel out noise. They reflect the average activity of the brain during stimulation and cognitive processes.

Electromyography: recording motor neurons

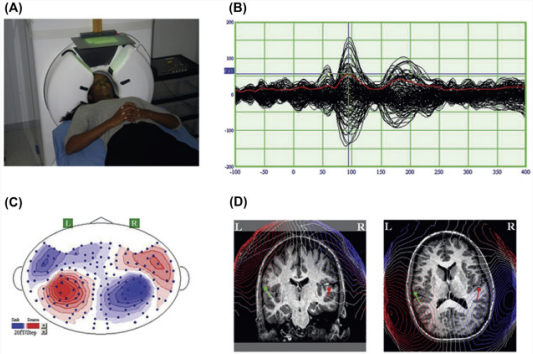


EMG records the electrical activity of motor neurons. There is a current effort to use EMG to control prosthetic limbs, and there may even be consumer devices in the future.

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

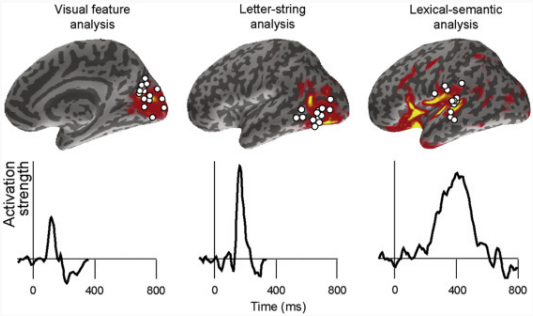
Magnetic Recordings

Magnetoencephalography (MEG)



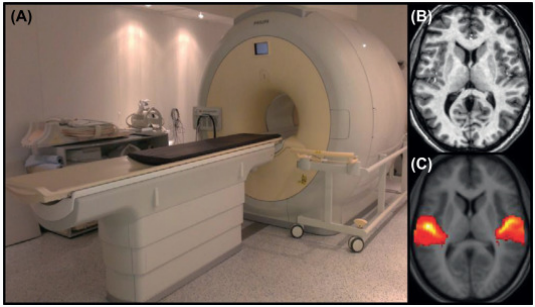
MEG records the magnetic field generated by neural activity. It has a similar spatial resolution to EEG, but is less sensitive to distortions by the skull and scalp.

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.

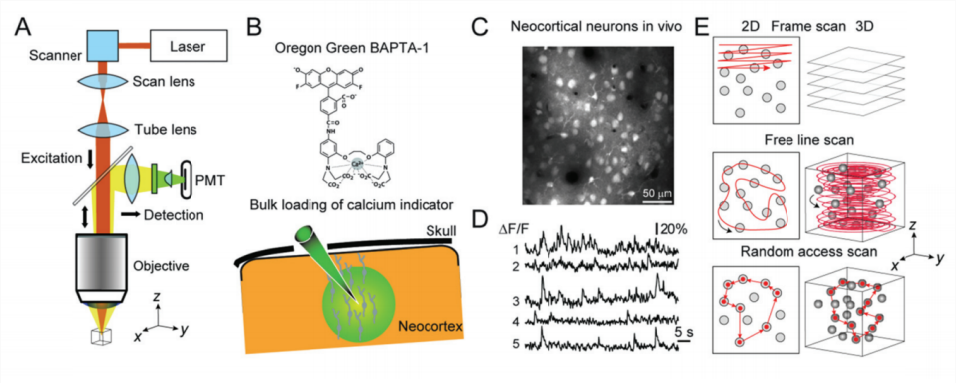
Functional Magnetic Resonance Imaging (fMRI)



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.

Optical Recordings

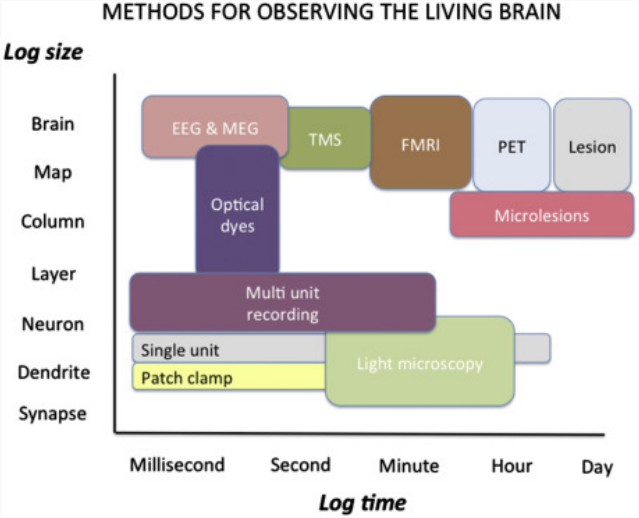
Fluorescence Imaging



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).

Videos

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