COMS30017
Computational Neuroscience

Week 1 / Video 5 / Recording from the brain

Dr. Cian O'Donnell
cian.odonnell@bristol.ac.uk

Intended learning outcomes

- Gain an overview of the modern neuroscience techniques for recording from the brain — and appreciate the difficulties.
- Have a basic understanding of the types of data arising from these experiments.

Key factors in brain recording.

- Ideal case: we would like to record the voltage of every neuron in the human brain simultaneously, with great signal-to-noise, at ~kilohertz sampling rate. “Leave no spike behind”.

- But this is not possible — not now, and maybe not this century, if ever. As a result, we have to compromise.

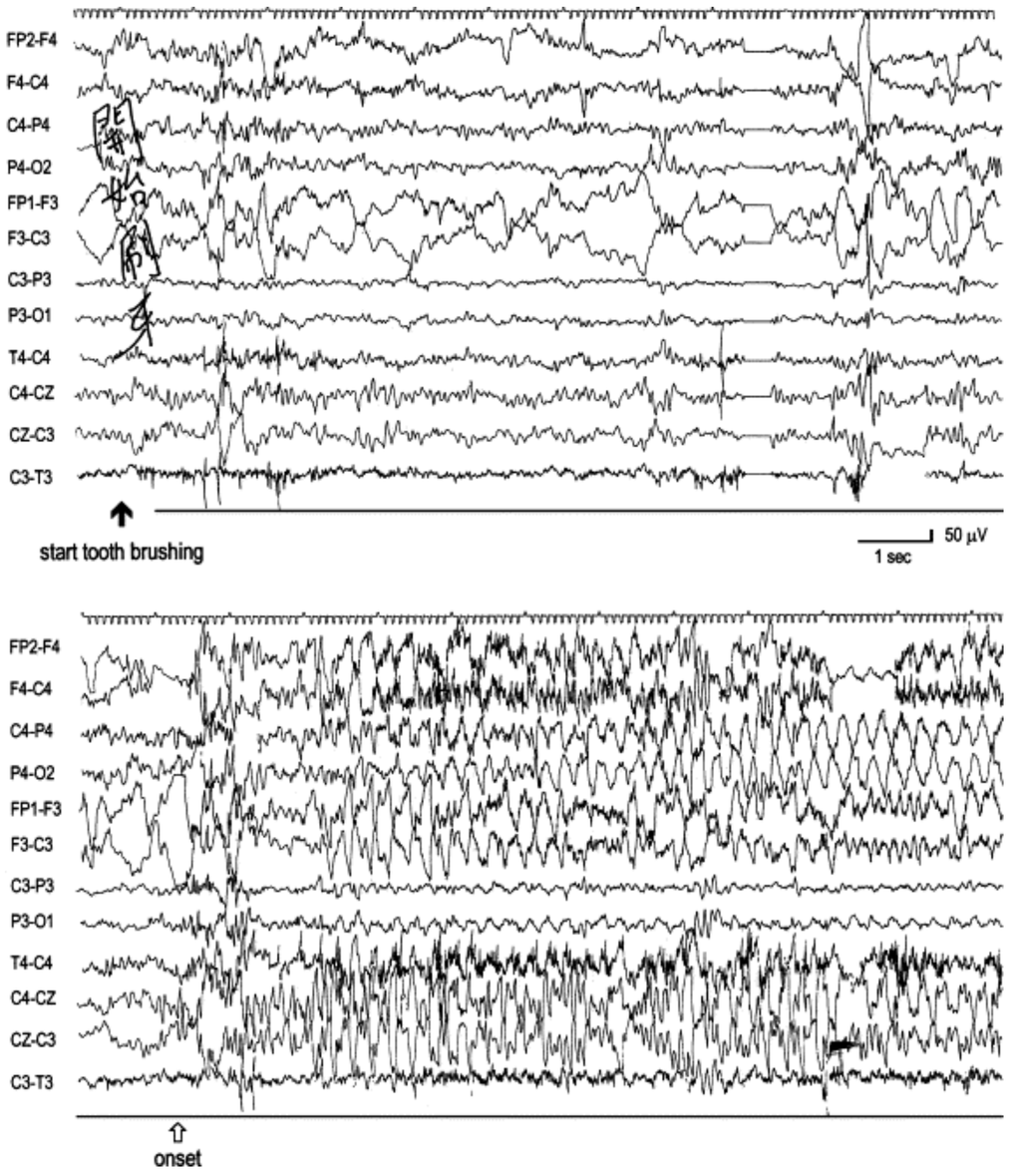
- Different techniques have different strengths and weaknesses. Key dimensions on which they differ:
  - Spatial scale. Can it resolve individual neurons? Or just brain regions?
  - Temporal scale. How fast can it record?
  - Electrophysiology vs imaging. Some methods measure voltages directly, others record proxy variables via imaging.
  - Invasive vs non-invasive. “Do we have to open up the skull?” (an important factor in human studies 😬)
  - *In vivo* vs *in vitro*. “Can we do this in an intact animal? Yes = *in vivo*; No = *in vitro*.

Methods we will cover

- EEG (electroencephalography).
- fMRI (functional magnetic resonance imaging)
- Intracranial electrophysiology
- In vitro electrophysiology: patch clamp
- Calcium imaging

EEG

- Oldest brain recording method, around since late 1800s.
- Simply involves putting electrodes directly on the scalp and recording voltage changes.
- Good temporal resolution (<1ms) but poor spatial resolution (~10cm).
- Often used in humans as cheap and non-invasive.
- Data are voltage time series, typically from 8–64 electrodes.



Chuang et al. 2004. Tooth-brushing and epilepsy

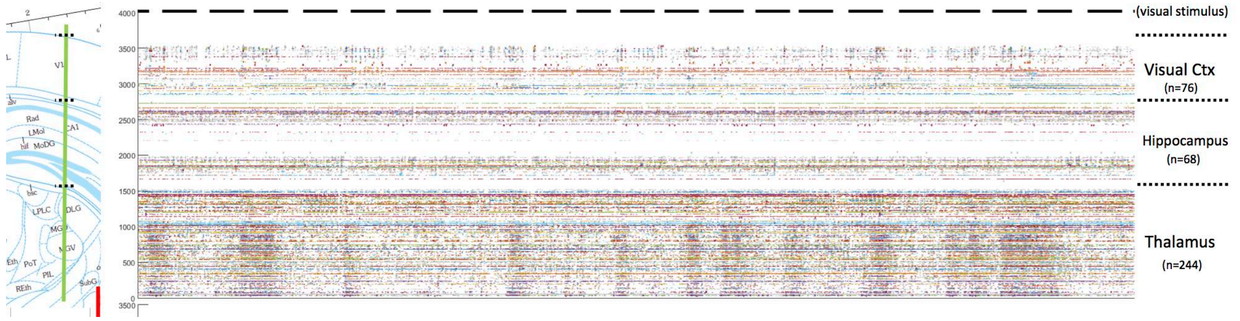
functional-MRI

- Basically a sensitive MRI scan, that detects changes in blood-oxygen levels (BOLD signal).
- Blood supply is thought to correlate with neural activity so it can indirectly measure brain activity.
- Decent spatial resolution (~1mm) but poor temporal resolution (~3 seconds).
- Often used in humans as can get whole-brain scans non-invasively.
- Data is in the form of time series from each “voxel” in the image - a 3D movie.

From wikipedia

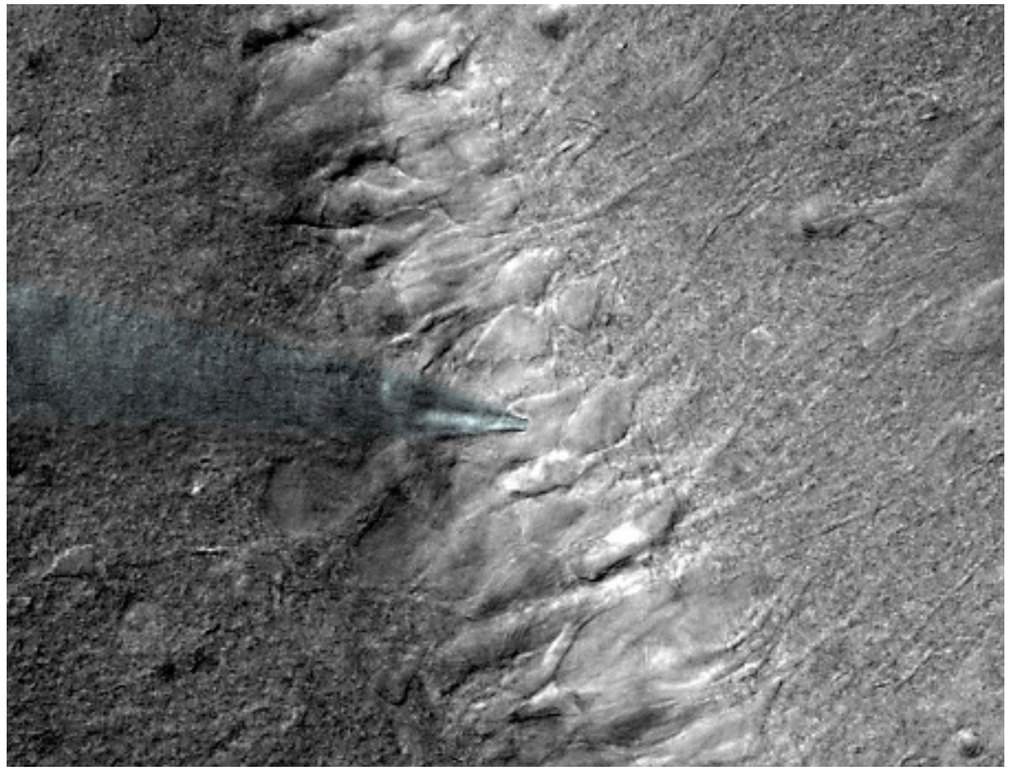
Intracranial electrophysiology

- Electrodes inserted directly into the brain to record field potentials/voltages “extracellularly”.
- Invasive, so only used in humans in medical cases. But routinely used in rodents and some non-human primates.
- Excellent temporal resolution (<1ms) and good spatial resolution: with care can resolve single neurons.
- Data in the form of voltage time series but usually processed to extract spike times.
- Recently with “Neuropixels” probes thousands of neurons can be recorded in rodents.



In vitro electrophysiology: patch clamp

- Extracellular electrophysiology can detect action potentials. But it cannot see 'subthreshold' voltage signals like PSPs.
- To record intracellular voltage researcher use a method called the patch clamp.
- Basically involves sealing a cylindrical glass pipette (with an electrode inside) onto the neuron's membrane and bursting a small hole through to allow the electrode to measure the intracellular voltage.
- If the seal is not physically stable it will break. So the method is difficult to do in vivo.
- Most often done in *in vitro* brain slices or in neurons grown in a petri dish.



From: https://en.wikipedia.org/wiki/Patch_clamp

Calcium imaging

- When neurons are active, calcium floods in to the cell body.
- Some synthetic dyes and genetically engineered proteins are sensitive to calcium and emit photons when bound.
- These photons can be imaged with camera and used to see the activity in single neurons.
- OK temporal resolution (~100 ms) but excellent spatial resolution (~1 micron).
- Some researchers can record all ~5000 neurons in small invertebrates, or up to 50,000 neurons in a mouse.
- Raw data are movies but usually processed into activity time series for each neuron.

https://www.youtube.com/watch?v=xr-flH2Ow2Y

Test yourself questions

- What temporal resolution would we need to record at to resolve individual spikes?
- Name two variables that are commonly recorded as proxy measures of electrical activity in the brain.

Summary

- Modern neuroscience has a range of techniques to record brain activity that vary in invasiveness, temporal and spatial resolution.
- Some are good for recording single neurons (intracranial electrophysiology, calcium imaging), others are good for whole-brain measurements (EEG, fMRI).