Large-scale patterns of neural activity

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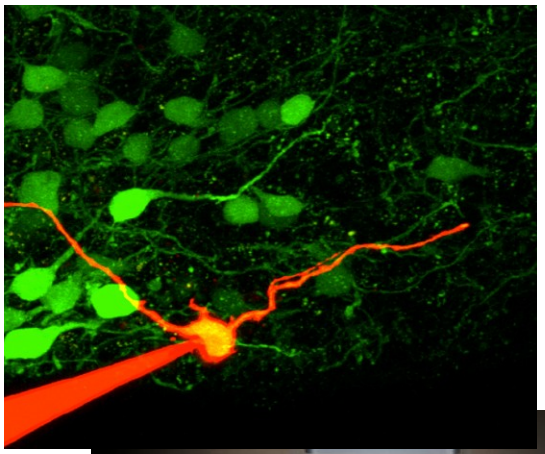
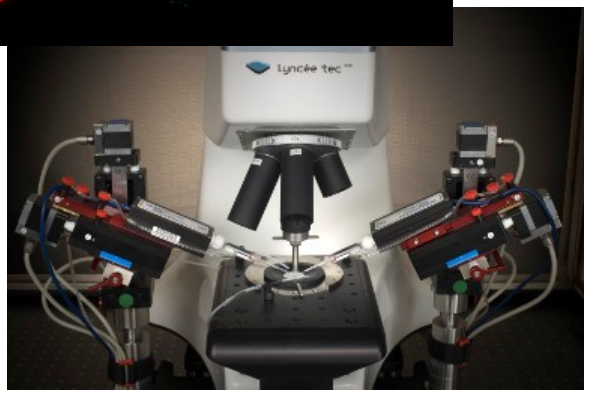
Scales of measurement

Neural activity can be measured at multiple scales.

What is the best scale for relating neural activity to behavior?





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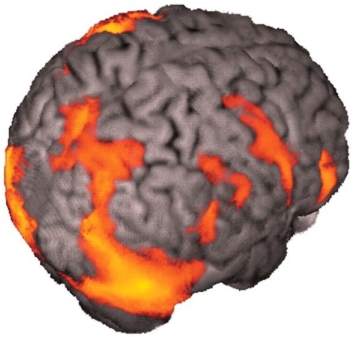
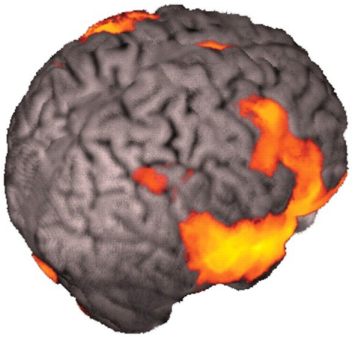


Pictures



Voices

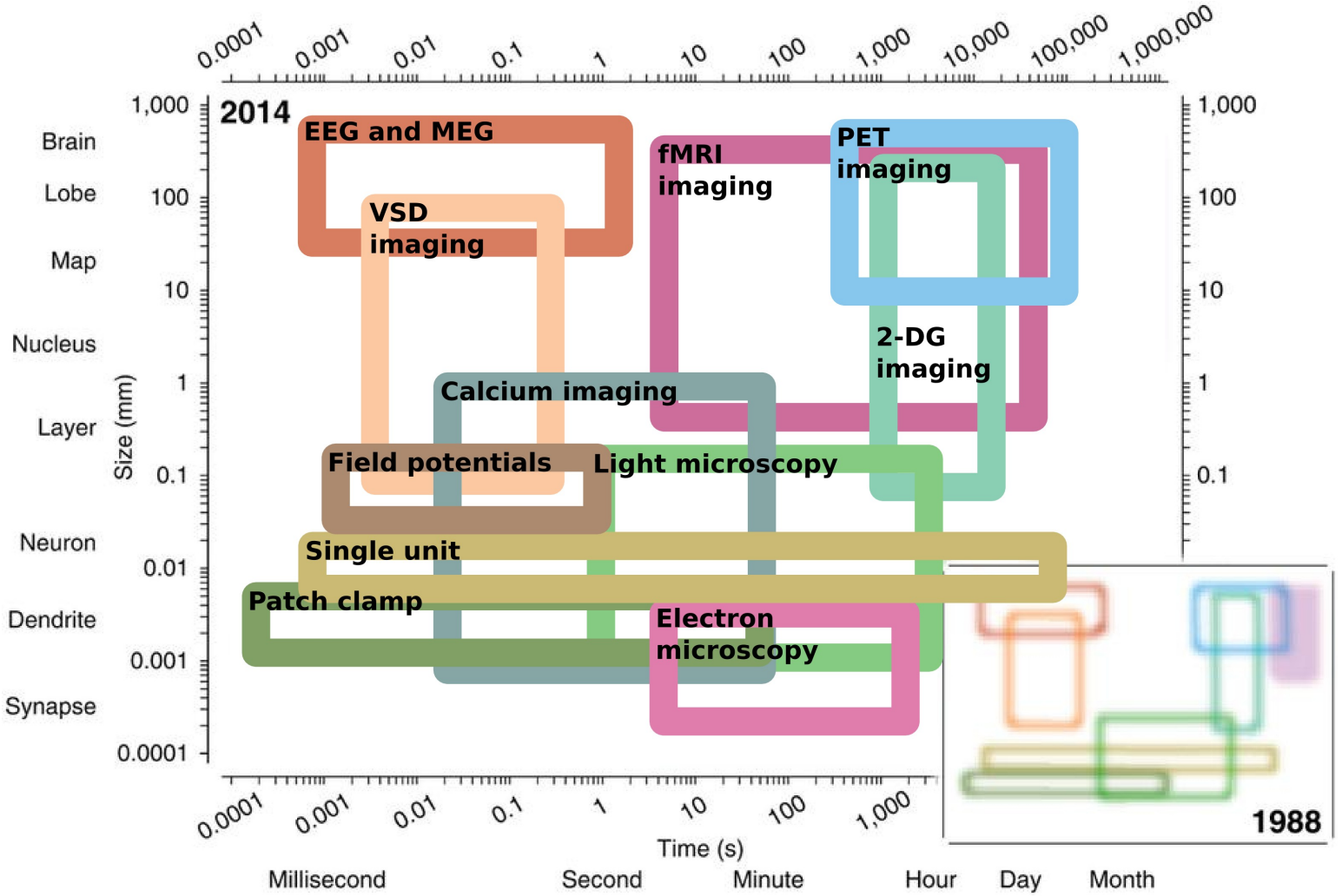
Goal:
characterize large scale patterns

- Historically, large pattern patterns has often been postulated:
  - Cortical fields (Lashely, 1931)
  - Cell assemblies (Hebb, 1949)
  - Units of selection (Edelman, 1987)
  - Synfire chains (Abeles, 1991)
  - Coalitions of neurons (Crick & Koch, 2003)
  - Cortical songs (Ikegaya, 2004)
- Identify appropriate the spatial and temporal scale of measurement
  - The pattern that best predicts behavior on individual trials, given available models for analysis.
- Characterize basic features
- Make inferences of size, distribution and temporal dynamics of the neural population

Requirements on the method

- Global & regularly spaced sampling (as fMRI)
- Temporal & spatial resolution in the range relevant to neural events (as single unit and VSD recordings)
- Neurophysiologically interpretable
  - i.e. possible to relate the measures to more fine grained measures (single unit, patch clamp, …)
- Signal-to-noise good enough for prediction of single occurrences of behavior
- Rich & natural behavior
  - Don't assume reducibility

Methods available I

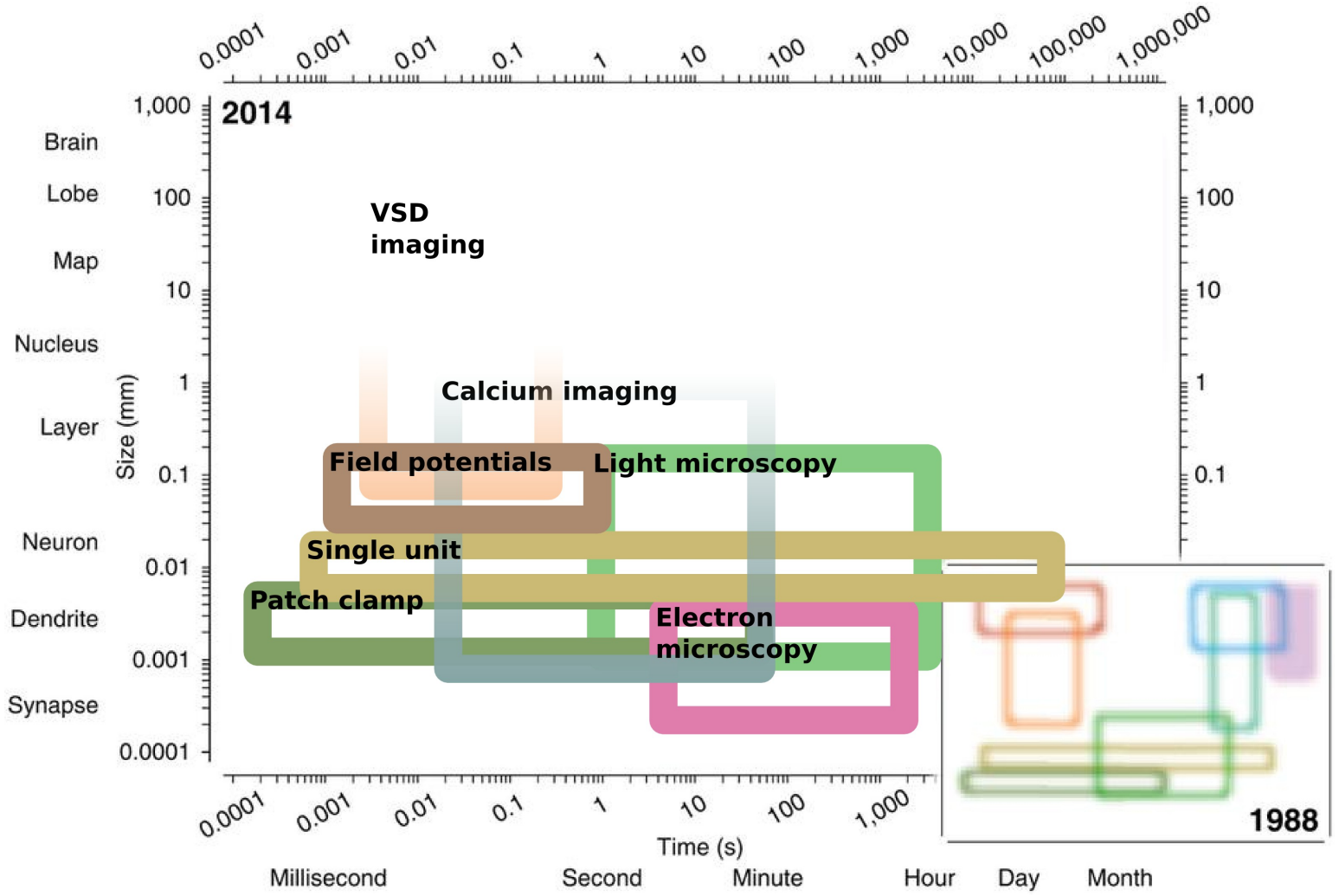


Adapted from Sejnowski, Churchland and Movshon (2014)

Pruning the methods

- EEG, MEG, fMRI and PET are neurophysiologically ambiguous
  - EEG & MEG: large population synchrony, cell type and orientation, skull and scalp distortions (EEG only)
  - fMRI: Too low temporal (1-3 s) & spatial (5 million neurons in a voxel) resolution; measures blood flow and oxygenation level which do not have to be linked to changes in synaptic or spiking activity.
  - PET: Too low temporal (30-40 s) & spatial (> 5 million neurons in a voxel)
- Optical imaging (VSD & Ca^{+2})
  - To achieve a big field of view the entire region to image needs to be exposed and connected to a microscope; low SNR (requires averaging)

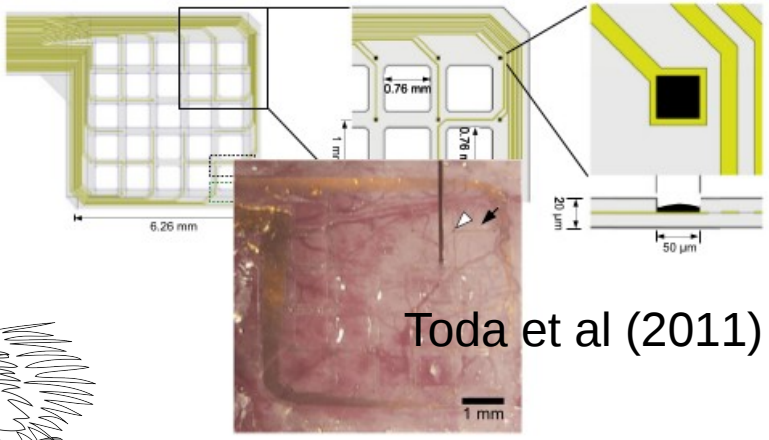
Methods available II



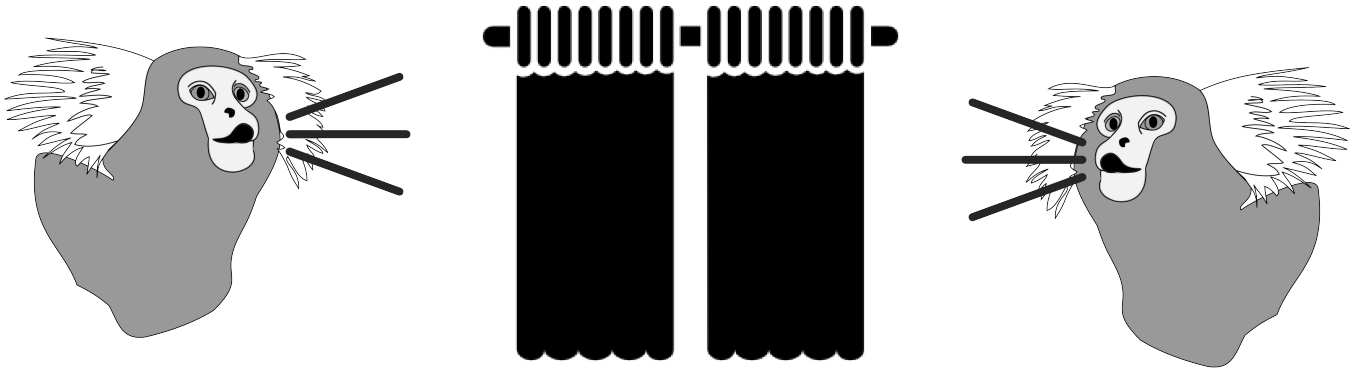
Adapted from Sejnowski, Churchland and Movshon (2014)

Proposal:
μECoG recordings in behaving marmosets

- **Electrophysiology: subdural** micro electro-corticography (μECoG) over the cortex
- **Species**: Common marmoset (*Callithrix jacchus*)
- **Behavior**: Anti-phonal calling

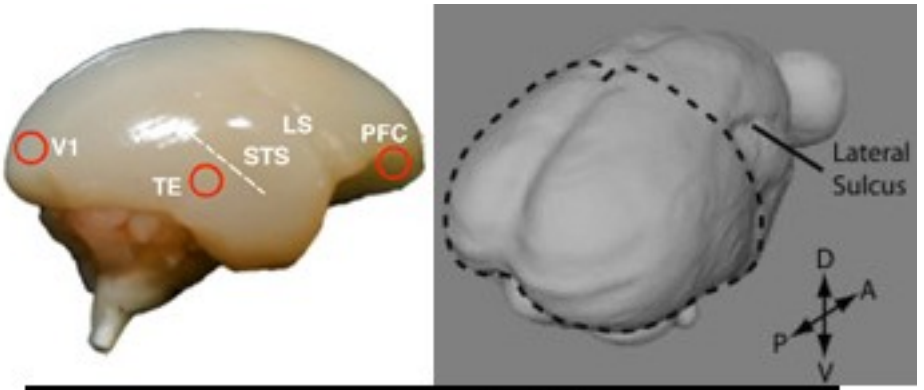


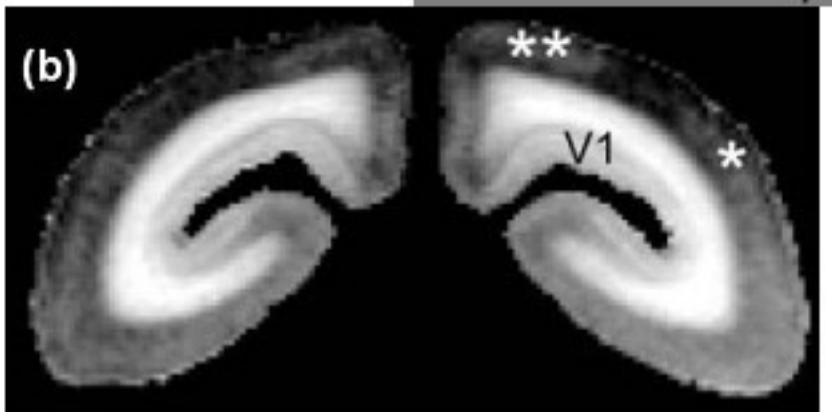
Toda et al (2011)

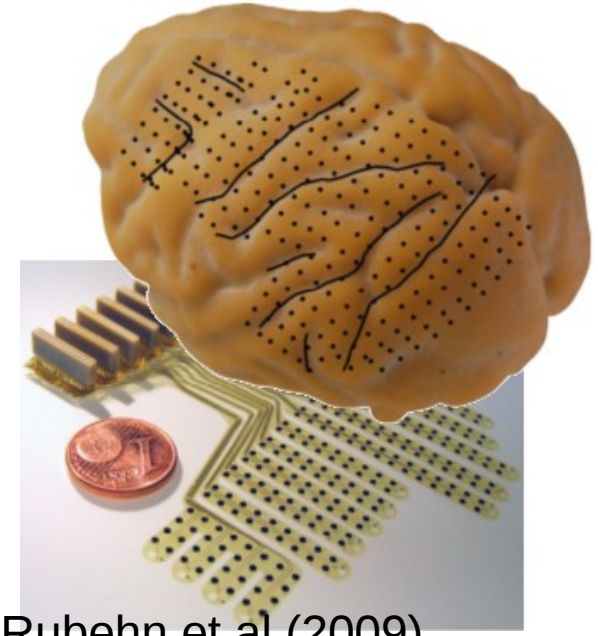


Physiology:
spatio-temporal extent

- Cortex is smooth and thus good for µECoG
- µECoG could cover most of a hemisphere







Rubehn et al (2009)

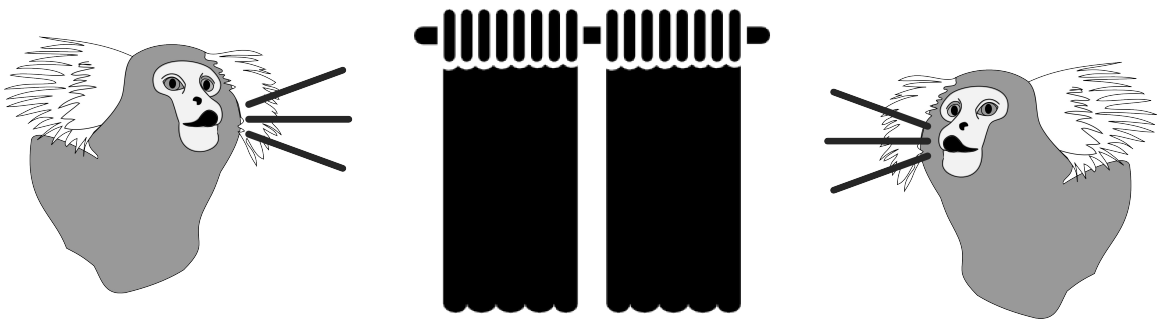
Physiology:
interpreting the signal

- Mainly a summation of EPSPs (excitatory post-synaptic potentials) of many cortical pyramidal cells.
  - Requires coherent activity and orientation of neurons
- Possible to combine with single unit recordings
- Spatial resolution around 0.5 mm
  - Probably corresponds to the spatial scale of the electrical field on the cortical surface
- However, higher resolution is possible, Khodagholy et al (2014) showed single unit recordings
- Surface area of a cortical hemisphere is around 500 mm^2, thus requiring 2 000 electrodes for perfect coverage

Behavior:

antiphonal calling (spontaneous replying to calls from other individuals)

- The brain has evolved and developed to support a certain behavioral repertoire.
- Sensori-motor behavior → cross-regional interactions → large scale patterns
- Spontaneous behavior don't require preparatory training → increased experimental turnover.
- Marmosets still call and reply reliably while physically constrained.



Data set

- Electrophysiological data
  - 250 – 1 000 channels
  - 1 – 5 kHz sample rate
  - 15 – 30 min per session
  - 50 – 100 sessions

    187.5 – 15 000 million data points (0.75 – 60 GB)

- Behavioral data

  Video from two cameras
  - 480 x 640 pixels per frame
  - 30 & 200 fps
  - 15 – 30 min per session
  - 50 – 100 sessions

    110 – 430 GB compressed video

  Sound from two microphones
  - 44.1 & 192 kHz sampling rates
  - 15 – 30 min per session
  - 50 – 100 sessions

    24 – 96 GB raw sound

Data analysis

- Identify patterns of neural activity that are predictive of behavior without averaging over multiple repetitions.
- Characterize those patterns.
- Make inferences about the population of neurons giving rise to the observed patterns.

Thanks