1. Encoding

readings: encoding D&A ch.1

If you're talking about what you can feel, what you can smell, what you can taste and see, then ‘real’ is simply electrical signals interpreted by your brain. This is the world that you know."

Morpheus, in the Matrix.

What is real? How do you define ‘real’?

• Neurons and Glial cells (insulating, supporting, nourishing neurons).
• 10^11 neurons in human brain, each link to up to 10,000 other neurons.

The Brain

Neurons

• neuron = cell, diverse morphologies
• Dendrites: receive inputs from other cells, mediated via synapses.
• Soma (cell body): integrates signals from dendrites. 4-100 micrometers.
• Action potential: All-or-nothing event generated if signals in soma exceed threshold.
• Axon: transfers signal to other neurons.
• Synapse: contact between pre- and postsynaptic cell.
  - Efficacy of transmission can vary over time.
  - Excitatory or inhibitory.
  - Chemical or electrical.
10^16 synapses in young children (decreasing with age — 1-5x10^15)
Membrane potential and action potential

- Ions channels across the membrane, allowing ions to move in and out, with selective permeability (mainly Na+, K+, Ca2+, Cl-)
- \(V_m\): difference in potential between interior and exterior of the neuron.
- At rest, \(V_m\)~ -70 mV (more Na+ outside, more K+ inside, due to Na+/K+ pump)
- Following activation of (Glutamatergic) synapses, depolarization occurs.
- If depolarization > threshold, neuron generates an action potential (spike) (fast 100 mv depolarization that propagates along the axon, over long distances).

Synapses

- Axon terminate at synapse.
  - AP-> opens ion channels, influx of Ca2+, release of neurotransmitter in the synaptic cleft, which bind at the post-synaptic receptors, causing ion-conducting channels to open.
- Glutamate: main excitatory neurotransmitter -- bind to AMPA, NMDA, mGlu receptor, induces depolarization.
- GABA: main inhibitory neurotransmitter -- GABA receptor, induces hyperpolarization.

Electrophysiological Recordings

- Intracellular recordings (commonly in vitro, sometimes in vivo (anesthesized, paralyzed))
  - Sharp electrode placed inside the neuron patch electrode, sealed to the membrane. view \(V_m\).
- Extracellular (often in vivo, possibly awake behaving animal)
  - Electrode is placed near a neuron. view action potentials.
- Commonly, one neuron at a time, now use of arrays of electrodes is beginning.
Intracellular and Extracellular electrophysiology

1. Intracellular and Extracellular electrophysiology

2. Excitatory and Inhibitory synapses -- EPSP and IPSP

3. Describing neurons' activity

- One aim of experimental neuroscience: describing the activity of neurons: what are they responding to?
- Sensory neuroscience: activity as a function of sensory stimulus (e.g., visual image, skin stimulation, sound, odor etc.).
- 2 alternatives: describe spike sequence, or number of spikes, or rate r in time window (somewhat arbitrarily defined) -- depending on assumptions about the code (spike times or rate?).

\[ \rho(t) = \sum_{i=1}^{N} \delta(t - t_i). \]

\[ \text{number of spikes}/T = r \]
Describing neurons' activity

- Variability is very large --> statistical measures.
  Average over many trial: trial average rate \(< r \>\).

![Image of tuning curves](image)

Neurons in the visual cortex

In retina, LGN and visual cortex, the activity of neurons (spike count) is correlated with some aspects of the visual image (contrast, orientation, color, spatial frequency, ... in early visual cortex ... towards more complicated features such as faces and object shapes in 'higher' areas).

![Image of visual cortex](image)

Neurons in the visual cortex

- Tuning curves: modify an aspect \( s \) of the stimulus, and measure the trial-average spike rate, \( r(s) \).
- V1 neurons are highly selective to the orientation of the stimulus (e.g. bar) flashed in their receptive field.
- Such bell-shaped (Gaussian-like) tuning curves are very common in the cortex.

![Image of tuning curve model](image)

Tuning Curve Model 1: Gaussian

\[
f(s) = r_{\text{max}} \exp \left( -\frac{1}{2} \frac{(s - s_{\text{max}})^2}{\sigma_f^2} \right)
\]

- \( s_{\text{max}} \): preferred orientation of the cell
- \( r_{\text{max}} \): maximal response of the cell
- \( \sigma_f \): tuning curve width (selectivity)