Cogs 160 (SP14):

Neural Coding in Sensory Systems

Prof. Angela Yu

Department of Cognitive Science, UCSD

https://thiscourse.com/ucsd/cogs180/sp14/
Action Potential

- A certain **threshold**-level input must be achieved in order to produce a spike. Below that, no spikes
- Spikes are **all-or-none**, discrete, stereotyped events
- **Refractory period**: after a neuron has fired an action potential, it cannot fire another until some time has passed
- The **firing rate** of the neuron (i.e., spikes per second) encodes information about stimulus/input intensity by each neuron
- Response **latency** (precise timing) may also encode information
The Eye and the Retina

Light is focused by the cornea and the lens onto the retina, a thin layer of neural tissue at the back of the eye which contains photoreceptors. Photoreceptors transduce light into neural signals and pass their signals on to the brain.
Circuit Diagram of the Retina
Classical View of Retinal Ganglion Cells (RGC)

ON-center/OFF-surround

OFF-center/ON-surround
Neurophysiology of On/Off Pathways

Light
Neurophysiology of On/Off Pathways
Classical View: Spatial Sharpening

Mach Band

- Edge detection
- Spatial sharpening
Modern View: Powerful Computations in Retina

Example functions

- Detecting dim light
- Detecting motion (object motion, self-motion)
- Adapting to changing visual environments
Detection of Dim Light

- Photoreceptors hyperpolarizes, releases inhibition on bipolar cells
- Rod bipolar pools over many rod photoreceptors (averaging out noise)
- Band-pass temporal filter minimizes chemical noise
- Thresholding (rectification) minimizes electrical & chemical noise
Band-Pass Filtering by Rod Bipolar Cells

- Rod bipolar cells only transmit intermediate frequency signals
- Noise dominates at frequencies > 4 Hz, so filtering out those higher frequencies helps to minimize noise transmission
- Y-type ganglion cells sensitive to motion (either direction)
- Each shift excites some bipolars and inhibits others
- Only active ones contribute, due to thresholding
- Biphasic dynamics $\Rightarrow$ transient response (why?)
- Motion prediction: RGC true center
- Continuation when stimulus turns
- RGC spatially extended, but no trailing edge (why?)
Differential (Object) Motion

- Object-motion-sensitive (OMS) ganglion cell is silent under global motion, active under local motion
- Y-type ganglion cell-like response in the periphery, inhibiting center response via amacrine cell
- OMS activates only when center & surround activities mismatch in time and/or response level
Approaching Motion

- A type of RGC responding to approaching motion, but not lateral motion
- Summing over many ON/OFF bipolar pairs, all thresholded
- Leading & trailing edge cancel out in lateral motion
- But only leading edge in approaching motion
- Only sensitive to expanding dark spot, why not bright spot?
Spike Latency Encoding

- Spike latency: dark: early, light: late, mixed: intermediate
- ON pathway is slower
- How does the brain know when to start timing the latency?
Switching Circuit

- OFF pathway normally dominant
- After saccadic eye movement, ON pathway dominant
- Mediated by amacrine cells
- Why is switching circuit useful?
- Decoding?
Synaptic Depression & Pattern Adaptation

- Synaptic depression due to vesicle depletion (seconds to recover)
- B1 & B2 have same RF; A1, A2 inhibit presynaptically
- Flickering vertical stripes: B1/A1 out-of-sync (asynchronous), strong response, depresses
- B2/A2 in-sync (synchronous), weak response, recovers from depression

Wed, 4/2/14
Linear Readout of Neural Computation

- What does a neuron “compute”?  
- Authors suggest readout should be “easy”  
- In particular, linear summation, e.g. summed by a dendritic tree  
- But dendritic response are known to be nonlinear
Discussion