Introduction to Neuroscience:
Systems Neuroscience - Concepts and Methods

Seeing: Central visual processes

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Is Vision a result of information processing of the incoming optical signals?
Our visual images combine incoming information with prior knowledge.
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Prior knowledge often dominates over incoming optical signals
The triangle we see is a result of an internal reconstructive process.
Illusory motion
Illusory motion
Unconscious priors in image generations
Unconscious priors in image generations
Image generation is highly non-linear
Heuristic aspects in image processing
Vision is a process by which pre-existing information is integrated with optic information to build an adaptive visual interpretation.

How is this process implemented by neuronal circuits?
The Human Visual System
Definitions:

retinotopy, visual field, contra-ipsi, fixation point, vertical meridian, horizontal meridian
Flow of information form the eye to the brain

Optic nerve, chiasm, tract and radiation
Many light related functions - not only vision
LGN- Relay and gating station

Magno (~ motion) and Parvo (~shape) pathways
Atlas of human visual areas

Large scale organization principles
Center-Periphery organization
Foveal magnification in V1

Log Topographical representations in the human visual system

Magnification factor: how many mm cortex correspond to a mm on the retina
Meridians define borders of visual areas

- Vertical Meridian: Upper
- Horizontal Meridian
- Vertical Meridian: Lower
The properties of single neurons in area V1
Text-fig. 2. Responses of a complex cell in right striate cortex (layer IV A) to various orientations of a moving black bar. Receptive field in the left eye indicated by the interrupted rectangles; it was approximately 1/8 x 3/8° in size, and was situated 4° below and to the left of the point of fixation. Ocular-dominance group 4. Duration of each record, 2 sec. Background intensity 1·3 log_{10} cd/m², dark bars 0·0 log cd/m².
The Concept of a Receptive Field

Firing Rate

Visual Stimuli
“Tuning curve”

Sharply or narrowly tuned, selective retinotopic

Firing Rate

Visual Parameter
(e.g. retinal position)

Example: “Simple cells”- Tuned to orientation and position
Stimulus selectivity of receptive fields

Receptive field of a “Simple” cell in area V1

Text-fig. 2. Common arrangements of lateral geniculate and cortical receptive fields. **A.** ‘On’-centre geniculate receptive field. **B.** ‘Off’-centre geniculate receptive field. **C–G.** Various arrangements of simple cortical receptive fields. ×, areas giving excitatory responses (‘on’ responses); △, areas giving inhibitory responses (‘off’ responses). Receptive-field axes are shown by continuous lines through field centres; in the figure these are all oblique, but each arrangement occurs in all orientations.
The simple cell model

Convergence, threshold, synchrony
An “and” function
Invariance: a group of stimuli that equally activate a neuron

Visual Parameter
(e.g. retinal position)

Example: position invariance
(Large retinotopic receptive field)
Text-fig. 20. Possible scheme for explaining the organization of complex receptive fields. A number of cells with simple fields, of which three are shown schematically, are imagined to project to a single cortical cell of higher order. Each projecting neurone has a receptive field arranged as shown to the left: an excitatory region to the left and an inhibitory region to the right of a vertical straight-line boundary. The boundaries of the fields are staggered within an area outlined by the interrupted lines. Any vertical-edge stimulus falling across this rectangle, regardless of its position, will excite some simple-field cells, leading to excitation of the higher-order cell.

Complex cells: the first step towards position invariance
An "or" function
The Hierarchy principle
The cortex is organized in layers.
The flow of hierarchical information is directed to specific layers.
Simple, complex… “grand-mother” cells
Complex properties of neurons at the top of the hierarchy

“Hand” neurons
Complex properties of neurons at the top of the hierarchy

“Face” neurons
Complex element representation at the top of the hierarchy
"Stream" specialization in the human brain

Two streams: dorsal- action, where, Ventral- what
Computation and neuronal properties

Action Pathway: Eye-hand coordination
Necessary computation - topographic map transformation
The problem of eye movements
Efferent copy
Dorsal stream- “action”- neurons
Invariant to identity
Sensitive to position
Selective to “action items”
Linked to the motor system
Dorsal stream- “action”- neurons
Invariant to identity
Sensitive to position
Selective to “action items”
Linked to the motor system
Ventral stream- “Recognition”- neurons

Sensitive to identity
Increased invariance to position
Tight link to memory systems
Medial Temporal Lobe as the highest stage in the recognition hierarchy
Complex properties of neurons at the top of the hierarchy

**Viewing Session**
- 5-10 sec clips
- each clip = an episode
- famous people / landmarks
- 6-10 repeats for each clip
- interleaving blanks
- pseudo-random order
- 10-16 different clips

**Intervening Task**
- digit task
- short conversation

**Free Recall Session**
- “what do you remember seeing?”
- No cue!
- 91.1% recalled

Time
- 10 min
- 1-5 min
- 3-8 min
Visual responses

What the patient saw

Neuronal activity

entorhinal cortex

beeps are spikes of a single human neuron
Recollection in the absence of visual stimulation

What the patient said

Neuronal activity

entorhinal cortex

beeps are spikes of a single human neuron
Large scale principles: Category organization
Fusiform “Face” Area
Fusiform "Face" Area
LOC "object" Area

3D Obj vs Textures

Unrelated to familiarity

Noise degradation
Parahippocampal “Place” Area
Face “Patches” are built of “face-neurons”
Columns: Within area subdivisions
Orientation and ocular columns- the “hyper–column”
The true organization, “pinwheels”
Top down information flow
Two main kinds of visual attention:

a. Spatial attention
Two main kinds of visual attention:
b. Feature-based attention