Cogs17 Neurobiology of Cognition

Lecture 4.2 Vision - Continued

Cross-Over Each **Optic Nerve**, from each eye, divides and goes to both sides of the brain
- Consider: When you fixate on single point in environment, you have aligned your centrally-located Foveas with that point
  - Any stimulus to the right of that point (i.e. in the Right Visual Field=RVF) will fall on the left side of *both* retinas
  - Any stimulus to the left of that point (i.e. in the Left Visual Field=LVF) will fall on the right side of *both* retinas
- Info from Right & Left Visual Fields follows different paths through bilateral brain such that **LVF>R Brain** & **RVF>L Brain**
  - e.g. Info from Left Visual Field => Retina on right side of **RIGHT eye** => right LGN => right Striate Cortex
    - But info from Left Visual Field => Retina on right side of **LEFT eye** **crosses over** at the **Optic Chiasm**
      => right LGN => right Striate Cortex (And vice versa for Info from Right Visual Field)
- Then, info from right & left Striate Cortex (i.e. from both left & right Visual Fields) is exchanged across **Corpus Callosum**

Visual Cortex

- **Columnal Organization** – Like all of Cerebral Cortex, Visual Cortex has six layers of cells; Layer 4 receives input from LGN
  - All cells within a given **Column** of perceptual cortex show same "preferred stimulus" (i.e. react best to same stimulus)
    - e.g. Cells each column respond to lines oriented in one particular Orientation (e.g. ||||| vs. ///// vs. = vs. \\\\\ etc)
  - All cells within a given **Hypercolumn** (set of columns) have same Receptive Field
    - One Hypercolumn includes cols for 1 full set of **Orientations**, plus "**Blobs**" for color processing, from same area of retina
- **Retinotopic Map** reproduces retinal layout such that adjacent columns of Cortical cells have adjacent RFs in Retina
  - This **topological map** preserves spatial relationships (area A next to B next to C etc. in both the Retina and the Cortex)
    altho *not* necessarily absolute distances (e.g. distance from A to C in Retina may be greater/less than A to C in Cortex)
  - **"Magnification Factor"** = Cortical cells with small RFs fill a disproportionally large area of the visual projection areas
    - e.g. The Fovea takes up only .01% of the Retina, but 8% of V1
- **Imagery** (in absence of actual visual input) activates many of the same areas of Visual Cortex as actual input
  - e.g. Visualize distant mouse, macular (fovea and nearby) map active; Visualize close-up elephant, peripheral map also active

Information Pathways

NOTE: While paths have stops in common (e.g. LGN, V1, V2) information sub-pathways remain largely independent

Ventral Stream ("Parvocellular Pathway", "Temporal Pathway", "**Who/What** Pathway") For **identifying** stimuli
- Specialized for **color & detail** (shape, texture); Integrated with Language centers for naming identified objects
- Begins at Cones in and near Fovea
  => Mostly **Parvocellular** (small) Ganglions (called "X Ganglions"), w/small RFs, give sustained response
  => Basic pathway (with sub-paths): Top 4 layers of **LGN** (**Lateral Geniculate Nucleus**) of Thalamus
  =>**V1**("**Striate** Cortex") =>**V2**=>**V3**=>**V4** all in Occipital lobe =>**IT** (in Inferior Temporal Cortex)

Dorsal Stream ("Magnocellular Pathway", "Parietal Pathway", "**Where/How** Pathway") For **visio-spatial** mapping
- For detecting **motion, locating objects, navigating & manipulating** environment including **gross outline**
  Integrated w/ Somatosensory info from antero-dorsal Parietal and with Premotor & Motor Cortex from Frontal
- Begins at Rods & Cones in periphery of Retina
  => Mostly **Magnocellular** (large) Ganglions (called "Y Ganglions"), large RFs, transient response
  => Some of these to **Superior Colliculus** of Midbrain (e.g. for "Blindsight"), then on to LGN
  => Most Y Ganglions go directly to (bottom 2 layers of) **LGN;** All=>**V1**=>**V2**=>**MT** (Medial Temporal Cortex)
  =>**MST** (Medial Superior Temporal Cortex) => <= Posterior **Parietal** Cortex

The **WHO/WHAT** (Ventral Stream / **Parvocellular**) Pathway

DETAIL: To determine shape and texture, Visual Cortex begins by analyzing scene per Orientations & Spatial Frequencies
- In V1, each **Simple Cell** gives its best response to lines of particular Orientation, less well to similar orientations
- In V2, **Complex Cells** give best response to Moving lines of particular Orientation - In **V3**, to Combinations e.g. < L →
- Above often respond best to **Sine Wave Gradients** - gradually changing bands of dark & light - at diff **Spatial Frequencies**
  - Spatial Frequency = # dark-light changes / degree of visual angle: High SFs for detail, Low SFs for Gross outline
- Visual scene coded as simul activity along multiple, (semi)-independent **Spatial Frequency Channels** for diff Orientations
  - Combinations of these, at multiple orientations = image, for identifying objects, faces, etc.
  - Spatial Freq changes across a whole scene also involved in depth perception (processed along other pathway - see below)
- **IT** (Inferior Temporal Lobe; end of "What/Who" path) active in recognition of complex stimuli (hand, geom. shape, gaze, etc)
  - e.g. Some cells in **Fusiform Gyrus** (on medial ventral surface of Temporal cortex) give best response to Faces
    - e.g. Damage certain parts of Fusiform Gyrus can lead to **Prosopagnosia** = inability to recognize familiar faces
  - Other cells in IT react to objects (dog breeds, cars, etc) of which you are an expert (highly practiced) discriminator

COLOR: Spectra of "visible light" include **wavelengths** (or **λs**) ranging from ~350nm to ~700nm
- e.g. Prism refracts different λs = rainbow: ROYGBV (red, orange, yellow, green, blue, violet)
  - Short λs seen as violet & blue, Med λs as green, Med-long λs as yellow, Long λs as orange & red

Trichromatic Color Vision – Young-Helmholtz Theory
- **3 Cone types** (Short, Medium, Long); Each w/diff type of Opsin that determine which λs that Cone responds to
- Each responds *best* to Short, Medium or Long λs and *less well* to adjacent λs. So Note: response ranges overlap!
  - e.g. Orange (~630nm) = high response from Long λ Cones, less from Medium λ Cones, and none from Short λ Cones
  - So color is, in part, coded by the **RATIO of activity** across multiple receptor types = **Across Fiber Coding**

Color Opponency - Trichromatic System is then *recoded* into a Red/Green & Blue/Yellow (& Black/White) Opponent System
- e.g. If adapt to red, see green afterimage & if adapt to blue, see yellow afterimage (& vice/versa)
- e.g. If colorblind to red, will be colorblind to green, but not to blue or yellow (or if to B&Y not to R&G)
- e.g. In **V1**, each Hypercolumn has one set of Red/Green & another of Blue/Yellow "**Blobs**" for color processing
- Arises via Lateral Inhibition (e.g. via Horizontal Cells in Retina & inter-neurons in LGN & V1)
  - e.g. Some Ganglion & LGN cells are "**Opponent Cells**" = have Receptive Fields that are R+G-, G+R-, B+Y- or Y+B-
    - i.e. R+G- = Red light on RF increases Ganglion's response, while green light on same RF dec's that cell's response
  - These converge in complex ways, to cancel out/ enhance one another, or form more complex "detectors"
    e.g. Double Opponent Cells (with R+G- Center / G+R- Surround Receptive Fields for detecting ripe fruit

Color Constancy - Humans can recognize colors even under changing light conditions (where actual λs change)
- e.g. If whole scene tinted green, can still ID white, red, blue etc. as long as can compare across scene (*not* if only see one object)
- **Retinex Theory** (Retina + Cortex) = Visual cortex (probably **V4**) compares color & light levels across scene, and somehow (? probably via feedback circuits) "subtracts out" shared tint, enables comparative analysis/identification of colors

The **WHERE/HOW** (Dorsal Stream / **Magnocellular**) Pathway

MOTION: Many cells in pathway leading to **MT** & **MST** are direction-sensitive (respond to stimulus moving in certain direction)
- Probably depends on **Uni-Directional Lateral Inhibition** (See schematic of circuit on *Supplement to Vision Lecture*)
  - These cells' RFs consist primarily of Rods, which are sensitive to movement because of their convergence and clustering
    - i.e. Image sweeping across multiple Rods clustered in peripheral Retina is more likely to trigger Ganglion response than if sweeps across individual, non-convergent Cones that are dispersed through periphery
  - In **MST**, some cells respond best to ("**Optic Flow**")
    - .i.e Whole environment streaming toward/from observer as when observer moves forward/backward
- Motion is also represented elsewhere in cortex (sometime called a third visual pathway, for Kinesis)
  - **i.e.** In **STS (Superior Temporal Sulcus** in lateral Temporal lobes) active during observing **Biological Motion**
    - Includes observed motion of walking, head movements, facial expressions, gestures, etc.

DEPTH via **Binocular Disparity** - (or "Retinal Disparity")
- When both eyes focus on one environmental pt (i.e. both Foveas aligned w/"Focal Point") the farther any other pt is from that pt, the greater the disparity (in degrees of visual angle) between where that non-focal pt will fall on the 2 Retinas
  - DEMO: Line up 2 fingers with your nose, keep focus on closer one. Look with one eye, then the other, and notice how finger not-focused-on seems to shift position. Repeat w/non-focused-on finger farther away. Repeat focusing on far finger.
  - Point not far from focal point will fall on nearly corresponding positions on 2 Retinas (= just a few degrees of disparity) while a point very far from focal point will fall on very diff locations (= many degrees of disparity) on the 2 Retinas
  - Such disparities are used by visual system to help judge relative distance in depth of such points
    - In V2, **Disparity Detectors** differentially respond to different ranges of disparity (0°, 15°, 30° etc) in a given RF
    - In MT, **Disparity Detectors** respond to different ranges of disparity, regardless of RF (i.e. anywhere on retina)
- Higher Parietal Cortex includes integration of visual & somatosensory (w/connections to Motor Cortex in Frontal Lobe)
  - AIP, **Canonical Cells** that respond to affordances (e.g. per its size, shape, does object afford grasping, sitting on, etc.)
  - **Mirror Cells** (also in Frontal Lobe) that respond to seeing self, or other, performing a familiar task

Modularity and The Binding Problem

A **Module** can be defined as brain structure specialized for processing a specific type of information
- e.g. MT cells respond to movement, IT cells do not; - e.g. V4 cells sensitive to color, MST cells are not

But, if, indeed, color, detail, movement, etc. are processed along INDEPENDENT pathways, with different destinations in brain, how is it we perceive WHOLES (i.e. a blue Frisbee flying at us)??? = the "**Binding Problem**"

Answer...???? Perhaps a TEMPORAL SOLUTION to this spatial problem…?
- Preliminary data suggest that when we perceive wholes, relevant cell assemblies **synchronize** their oscillation of activity …