Human Perception CS 101A Fall 2004

Lecture 6: Contrast and Spatial Frequency

(See Chapter 3 and Appendix B)

SPATIAL FREQUENCY = # cycles / degree of visual angle

VISUAL ANGLE= arc, in degrees, of the retina that is subtended by a given stimulus
= arc, in degrees, of the visual field (in the world) that is filled by that stimulus

Note: "Thumb Method" - at arms length, thumbnail subtends about 2 degrees of visual angle.

For a given visual angle, objects farther away will be larger (and if closer, will be smaller)

- e.g. Moon and sun: same visual angle (~2^o) but since sun farther away, it must be (and is) bigger.

For a given size object, objects farther away will have a smaller visual angle (and if closer, greater)

- e.g. A nearby object looms (fills visual field) then seems to grow "smaller" as it recedes into distance

CYCLE = One dark/light sequence in a **Contrast Gradient**

- Wave measured peak to peak (OR trough to trough, OR any point to same point in next cycle)
- Typical Contrast Gradients used as lab stimuli:
  - Sine Wave Gradient (dark gradually changes to light and gradually back to dark)
  - Square Wave Gradient (dark abruptly changes to light and then abruptly back)

SPATIAL FREQUENCY is a measure of "how rapidly the stimulus changes across space" (p. 90)

High Spatial Frequency = many cycles / degree of visual angle (many changes across space - detailed info)

Low Spatial Frequency = few cycles / degree of visual angle (few changes across space - gross info)

CONTRAST SENSITIVITY FUNCTION (or "CSF")

Graph of "(log of) Contrast Sensitivity" versus "(log of) Spatial Frequency" (See Textbook - Figs 3.22 & 3.23)

- To generate a CSF, expose Subjects (Ss) to a uniform field of grey, then gradually increase the contrast to create a "Contrast Gradient" (dark/light/dark/light pattern) until that gradient can be detected by the Ss.
- Shows how Contrast Sensitivity (i.e. threshold for detection) varies as a function of Spatial Frequency

i.e. High Spatial Frequency	requires	Very High contrast	
Medium Spatial Frequency	requires	Very Low contrast	
Low Spatial Frequency	requires	Medium contrast	…for gradient to be detected.

So, we are most sensitive to contrast at medium Spatial Freqs, and least at high Spatial Freqs

SPATIAL FREQUENCY DETECTORS

Some cells in visual cortex (V1 and V2) respond best to different Spatial Frequencies

- Each cell responds best to narrow range of freqs, and increasingly less well to neighboring freqs
- Effect often most pronounced when contrast gratings are moved across cell's receptive field

These, and other, data (see more on this below) suggest that there are multiple, (semi) independent **Spatial Frequency Channels** that together make up the CSF curve.

i.e. CSF reflects activity of Detector Cells, each most sensitive to contrast at **particular range** of Spatial Freqs that **overlaps**, to some extent, with the ranges of other such detectors

Selective Adaptation of Spatial Frequency (Try demo in book - Page 93)

As described above, CSF curve can be subdivided into overlapping component curves for each SF channel

For simplicity's sake, suppose there are only 3 Spatial Frequency channels

- One for Low Spatial Freqs, one for Medium Spatial Freqs, and one for High Spatial Freqs
- There are actually MANY such semi-independent channels

According to "Across Fiber Coding"/ "Population Coding" each stimulus is encoded by the

relative proportion of activity across all the relevant detectors

For example, given 3 Spatial Freq detectors contributing to the CSF, consider the normal "codes" for a Medium Spatial Freq stimulus compared to a Medium-High Spatial Freq stimulus:

Contributing Detector	Normal Code for Medium SF Stimulus	Normal Code for Medium-High SF Stimulus
Low SF Detector	Some Response	Least Response
Medium SF Detector	Most Response	Most Response
High SF Detector	Some Response	Some Response

In order to Selectively Adapt a subject to, for example, a Low Spatial Frequency, we would require:

- Subject must fixate on a Low Spatial Freq stimulus until he/she "adapts" to it
    - i.e. Until subject loses ability to detect contrast and stimulus appears to fades to overall grey
        - (Effect is presumably a result of fatigue in, especially, the Low Spatial Freq detectors)
- In TEST: Subject is then exposed to Medium stimulus, but reports it **appears** to be a Medium-High stimulus

- **WHY?** Since the fatigued, Low SF Detectors cannot make their normal contribution (i.e. "Some" Response) to the code for a Medium stimulus ("Some + Most + Some"), the system instead ends up generating the pattern of activity that normally encodes for a Medium-High Stimulus (i.e. "Least + Most + Some"),

    - i.e. The stimulus is **misinterpreted** as Medium-High.

- So, adapt Low SF detector, other stim appear higher in Freq from reduced contribution of Low SF Detector
- Or, if adapt High SF detector, other stim appear lower in Freq from reduced contribution of High SF Detector

NOTE: If adapt only one eye, effect will still be visible in other eye, suggesting that relevant detectors are in Cortex

- Compare this with Selective Adaptation of COLOR effects, which do not transfer to other eye... (More later)

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Lecture 7: COLOR

We can discuss color in terms of three separable aspects:
- Hue - equivalent to the common use of the term "color"   e.g. Red vs. Green
- Saturation - Amount of whiteness, more saturated = less white   e.g. true Blue vs. light Blue
- Brightness - Amount of light reflected from object (or intensity of light source)
  e.g. bright pink vs. dull pink

Reflectance: Percentage of light reflected; **Achromatic Colors**: When light reflectance is flat across the spectrum (black, white, gray) **Chromatic Colors**: Some wavelengths are reflected more so than others
Desaturation: add more white

We can also describe the characteristics of "visible light"
- i.e. Apectra of visible (to primates) EM radiation -
  - The **wavelengths** (or **λs**) range from ~350nm to ~700nm (1nm=.000000001m)
- (Note wavelength relationship to frequency: Long λs = low freqs, short λs = high freqs
  - Prism refracts different λs = rainbow: ROYGBV (Red, Orange, Yellow, Green, Blue, Violet)
  - Short λs seen as Violet & Blue, med as Green, med-long as Yellow, long as Orange & Red

<u>Subtractive</u> color mixing - <u>Combining pigments</u> (e.g. paints)
- The color of an object depends on which λs are absorbed & which reflected, <u>only see reflected</u>
  - e.g. A bluish object tends to reflect medium and short λs (GBV), absorbs long λs (ROY)
    - A Yellow object tends to reflect med to med-high (OYG), absorbs highs & lows (RBV)
    - If combine <u>Blue and Yellow</u> (pigment) get <u>Green</u> since <u>subtract</u> what is absorbed by both
      - i.e. Subtract ROY for Blue and RBV for Yellow, leaves only G (Green) to be reflected

<u>Additive</u> color mixing - <u>Combining lights</u>
- The color of light depends only on the λs present
  - e.g. Unlike above, if combine <u>Blue and Yellow</u> (light) get <u>white</u> since <u>add</u> all λs involved
    - i.e. Blue light tends to be made of short λs, Yellow light of medium and long
      - Added together, equal full spectrum of light, so seen as white

In BOTH cases, it is only the wavelengths that enter eye that determine perceived color

<u>The Young (1807) - Helmholtz (1852) "Color Matching" experiment</u>
Using colored filters over lamplight, these researchers found that subjects could <u>match</u> any single test λ to a set of <u>at most 3</u> other λs (Note: sometimes 2 is enough)
- e.g. 500nm λ test color looks the "same" as the combo of 420nm, 560nm, & 640nm
  - Lights with different λ components that are nonetheless perceived as the same are called "**metamers**". So 500nm "is a metamer with" 420+560+640nm

In fact, ANY three λs (at various intensities) can be used to match ANY single test λ
- As long as the 3 are "unique" (i.e. no 2 of the 3 λs can be combined to match the third)
  - The 3 will tend to be unique if they are selected from the short, medium and long λ ranges
- So, pick 3 unique λs, shine them on same spot, adjust their brightness (intensity) => create ANY other color

This result led Young & Helmholtz to propose The **TRICHROMATIC** Theory of Color Vision
- i.e. They concluded there must be 3 types of color receptors, for short, medium & long λs

Contemporary research supports this conclusion - i.e. There are 3 Cone Types
- Photopigment is made of a Retinal molecule and an Opsin molecule
  - All Retinals are the same, but the Opsins vary between Cones (and from Rod Opsin)
  - Tho Retinal actually absorbs photon, Opsin influences range of λs Retinal will react to
  - Each Cone has only one type of Opsin, a long protein (amino acid) chain
    - Medium λ Cones and Long λ Cones have ~96% of their amino acids in common
      - So they respond to very similar ranges of light
        - i.e. Their response curves show considerable overlap

- Short □ Cones have only ~45% of their amino acids in common with Medium & Long □ Cones
    - So they respond to very different ranges of light
        - i.e. The response curve of a Short □ Cone overlaps little with Medium and Long
- See graph of Receptor Response vs. Visible Spectra: <u>**3 overlapping curves**</u> for 3 Cone types

- Short □ Cones give best response to ~ 420nm, Med □: ~ 530nm, Long □: ~ 560nm
    but note, <u>each Cone type responds to a RANGE of □ s</u>

<u>Four Different Types of Color Blindness</u>:

1. Monochromat has only one kind of cone or just rods. Can match any wavelength by adjusting the intensity of any other
2. Dichromat has two kinds of cones. Can match any wavelength by adjusting the intensity of two others
    a) Protanopia: Missing L pigment (1% of males, 0.02% of females)
    b) Deuteranopia: Missing M pigment (1% of males, 0.01% of females)
    c) Triptonoia: Probably missing S pigment (0.002% males, 0.001% of females)
3. Anamolous trichromat has three cones but the M and L spectra are shifted closer together. Can match any wavelength by adjusting the intensity of three others but uses different proportions than people with "normal" color vision.
4. Achromatopsia: Damage to V4: Inability to see color though cones are intact.

V4 Color Constancy: Colors seen as same color though colored object is in very different lighting (a white wall at dusk looks "white" just as a white wall in the middle of the day looks "white" though it reflects different wavelengths at different times in the day).

Even tho Trichromatic Theory <u>seems</u> to suggest that each color can be encoded by activity in <u>one</u> of the three Cone types, in fact, the absolute firing level of <u>one</u> Cone type CANNOT unambiguously code for a color...

- e.g. Short □ Cone may respond at 50% of its max to a <u>bright 400nm</u> (violet) light *AND* at that same 50% to a <u>dim 440nm</u> (bluish) light *AND* at that same 50% to a <u>bright 480nm</u> (Blue-Green) light - *Ambiguous*!

<u>**Selective Adaptation**</u>

i.e. "Adapt" to a color through prolonged, focused exposure to a particular □ (see upcoming Lab)

- If stare at brightly lit <u>Blue</u> stimulus until color fades to (nearly) grey
    then, when you look at a white surface, you will see a <u>Yellow afterimage</u> - WHY?

Consider the normal "code" for white and Yellow

- White light has all □s, so it stimulates all 3 Cone types equally.
    So, <u>code for white</u>: Short □ Cones = Med □ Cones = Long □ Cones
- Yellow light has □s that stimulates Medium & Long □ s Cones, but not Short (see graph)
    So <u>code for Yellow</u>: Short □ Cones <<< Med □ Cones = Long □ Cones
- When Short □ Cones are adapted (fatigued) by prolonged exposure to Blue, they cannot respond,
    so now <u>white light produces pattern that normally codes for Yellow</u>
- So when you look at white surface, you now interpret (perceive) it as Yellow.

While evidence for Trichromatic Theory is strong, it cannot be whole story - Other evidence suggests that **OPPONENT PROCESSES** are also involved. Consider the following psychophysical evidence...

<u>Hurvich & Jameson (1957) "Color **Cancellation**" experiment</u>

Show subjects one □ of light, they can always find one other □ that will, when added to the first, cancel the colors (i.e. See Additive Mixing, above)

(NOTE: Like the Young-Helmholtz experiments, these involve combing <u>lights not pigments</u>.)

- A pattern emerges from these experiments, such that

Blue-ish colors tend to cancel (and be canceled by) Yellow-ish colors (leaving white)
Red-ish colors tend to cancel (and be canceled by) Green-ish colors (leaving yelow)

Other psychophysical support for Red/Green and Blue/Yellow Opponency:
- Afterimages (after adapting to one color) will feature opponent color
  - Adapt to Red, see Green afterimage - Adapt to Blue, see Yellow afterimage
- Colorblindness (which occurs most often in males) always occurs in opponent sets
  - If colorblind to Red, will be colorblind to Green, but not to Blue or Yellow.
  - If colorblind to Blue, will be colorblind to Yellow, but not to Red or Green.
- The Color Wheel: Cross-culturally, Subjects asked to create a continuous circle of color, organize the colors such that Red is opposite Green on the wheel, and Blue is opposite Yellow.
  - This organization also appears in art around the world.
- Cross-cultural linguistic data indicate that if only 4 chromatic (hue) terms appear in lexicon, they will be the equivalent of the English "primaries": "Red" "Green" "Blue" & "Yellow"

All of the above suggest there are physiological (neurological) mechanisms for "Opponency"...

Neurological Support for Opponency:

In the Parvocellular pathway of Rhesus monkeys...

Some Ganglion and LGN cells are "Opponent Cells" for color
- Have Receptive Fields (RFs) that are (R+ G-)
  - i.e. Red light to entire RF will *increase* the response of the target cell
    and Green light to entire RF will *decrease* the response of the target cell.

Some LGN and V1 (Striate Cortex) cells are "Type I Opponent Cells"
- Have, for example, R+ center / G- surround RFs
  - i.e. Red light to the center of the RF will *increase* response of the target
    and Green light to the surround of the RF will *decrease* response of the target.
- Note that other combinations (e.g. R-center / G+ surround) also occur, but rarer

The "Blobs" that exist in each Hypercolumn of V1 exist in Opponent Pairs
- Cells that respond best to Red and Green (in a given RF) are found in one set of "Blobs" and cells that respond best to Blue and Yellow (in same RF) are found in other set of "Blobs"

Neurological Support for Opponency (Continued)

Some V1 and V2 cells are "Double Opponent" cells: R+G- center and a G+R- surround RFs
- i.e. Red light to the center *increases* the target's response
  and Green light to the surround *increases* the target's response and
  and Red light to the surround *decreases* the target's response and
  and Green light to the surround *increases* the target's response
- Above is most common type of Double Opponent cell = The "ripe fruit" ("cherry") detector
  - i.e. Reddish fruit against Green leafy background is adaptively salient to this system

So, how do the existence of such opponency cells help explain the above "Color Cancellation" results?
- e.g. Why does Red + Green (light) = Yellow?
  - If you start with Red light and gradually add Green (i.e. increase Green's intensity, brighter & brighter), subject will say that Red gets "Yellower" (i.e. "looks Orange") until it appears "true Yellow" (all Red gone), after which it would begin to look "Yellowish-Green".
  - So, at the point there is no trace of either Red or Green, the remaining stimulus looks Yellow.

This result should already make sense based on Trichromatic Theory
- i.e. Per the Overlapping Response Curves of the three Cone types.
  - The curve for the Cones that respond best to LONG (Reddish) wavelengths overlaps with the curve for the Cones that respond best to MEDIUM (Greenish) wavelengths such that, when both types are stimulated equally, this corresponds to MEDIUM-LONG (Yellow) wavelengths.

It also make sense in terms of Opponent Processes.
- e.g. R+G- and R-G+ cells respond according to the **difference*** between how much Red vs. how much Green there is in a given stimulus.
- So in Red light, the R+G- cells are strongly activated & the G+R- cells are inhibited => light appears "Red". - As more Green light impinges on the system, the R+G- cells are less and less likely to fire while the G+R- cells are increasingly likely to fire => Light appears Orange (moves away from Red)
- When these two cell types are firing at equal rates we see neither Red nor Green, but Yellow.

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Lecture 8: Depth and Size

First, consider once more, in detail, how incoming image impacts on retina

When 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 your right visual field) will fall on the left side of both retinas

Any stimulus to the left of that point (i.e. left visual field) will fall on the right side of both retinas

Any stimulus above that point falls below the fovea on both retinas, any stimulus below falls above both foveas

-As a result, the images that fall on the retina are **inverted and mirror-reversed**.

STOP - How is it we don't see world upsidedown? Is the image re-inverted/reversed in our brain?

NO! There is no image "in our brain"! All there is is patterns of neural firing…

- Through experience with the world during infant development, we come to learn that when cells in the lower part of our retinas are stimulated, then there is something of interest (i.e. something we can touch, hear, watch move, etc) in our upper visual field.
- And, similarly, for upper, right, or left parts of retina => in lower, left, right visual fields, respectively
- In experiments in which Ss wear special glasses that invert/reverse the image that enters the eye, after several days the Ss can function fairly normally and even report that world looks right-side up.

PLUS since most pts in visual field fall on slightly different places in the 2 eyes, we use this for depth perception

Binocular Disparity - (or "Retinal Disparity") One important source of Depth Perception: Stereopsis

"HOROPTOR" - a curved plane through visual space, its central point determined by where the eyes are focused

- i.e. Central point of Horoptor falls on foveas of both retinas
  - AND all other points on Horoptor also fall on corresponding points of the two retinas
  - AND all points not on Horoptor fall on **non**-corresponding points of the two retinas
    i.e. Same point in environment lands on points that are different distances from the two foveas

- This disparity between the location of non-Horoptor points on the 2 retinas = "**BINOCULAR DISPARITY**"
  - The farther from the Horoptor a point is (whether closer or farther from you), the greater it's Binoc Disparity
    - If point is closer than the Horoptor, its image falls to the outside of both foveas = "Crossed Disparity"
    - If point is farther than Horoptor, its image falls to the inside of both foveas = "Uncrossed Disparity"

Stereo-gram/-scope - 2 "flat" views presented from slightly different perspectives to 2 eyes => 3D effect (see LAB)

- Stereoblindness = unable to detect depth via Binocular Disparity, must use other cues (see "Sausage" Demo)

NEUROLOGICAL EVIDENCE - Mostly from research on Magnocellular ("Where") Pathway in primates

- In V2, some cells differentially respond to different ranges of disparity (0^o, 15^o, 30^o etc) in a given RF
  - Plus, recall that Ocular Dominance in V1 columns preserves info on which eye is source of which info
- In MT (end of Magno path), some respond to diff ranges of disparity, <u>regardless</u> of RF (anywhere on retina)
- Recent MRI work on Humans shows activity in MT during stereopsis (e.g. while viewing 3D images)

SIRDs: Single image random dot stereograms (magic eye)

<u>Constancy Scaling Mechanism</u> (Perception of Size depends on Depth)

EMMERT'S LAW: Sp = K(Sr X Dp) See LAB

- Perceived Size (Sp) is a function of Retinal Size (Sr = Visual Angle) and Perceived Distance (Dp)
- Adapt to stimulus of a given size, then look at surface same distance away, afterimage same size as stimulus
- But, look at surface farther away, afterimage appears <u>larger</u>
  - Visual Angle fixed (since area of affected retina is fixed) so as Distance increased, Perc'd Size increased

HOLWAY & BORING (1941) - Eliminate distance cues, Size Constancy fades

- Subject sits at intersection of two hallways
- Comparison Circle of given (but adjustable) size, 10 feet away down one hallway
- Test Circles in other hall, each subtend same visual angle as Comparison Circle, but size & distance vary
- RESULTS: Subject can <u>easily adjust size of Comparison Circle to match actual size of each Test Circle</u>
  - Must be using depth cues to determine size, since visual angle is initially the same
- BUT when <u>eliminate depth cues</u>, by making subjects view circles through peephole (so can't see hallways)
  Ss <u>lose ability to correctly adjust Comparison Circle</u>

BUT, FAMILIARITY can also influence Size Constancy judgments

- Knowledge about size of an object enables judgment of distance even in absence of other cues
- Dime & Quarter, lit in darkened room (no depth cues), subtend same visual angle, dime looks (& is) closer

<u>Other Cues to Size & Depth</u>

Size in field of view - All other things being equal, larger object is closer

- e.g. Lit balloon in darkened room (no depth cues) - slowly inflate (i.e. increase size), it appears to approach

Linear Perspective - Parallel lines appear to converge as they approach horizon

Atmospheric Perspective - Dust in air has cumulative effect making far objects look fuzzy

Oculomotor Cues - You <u>feel</u> "Accommodation" by ciliary muscles & convergence of eyes by extraocular muscles

- The more accommodation and convergence, the closer the object you are focused on

Note, above even work with <u>one eye only</u>

Pictorial Cues: Occlusion, relative height (objects below the horizon seem farther if they are higher, objects above the horizon seem farther when they are lower), cast shadows, relative size, familiar size (fairly weak compared to other cues) atmospheric perspective (farther things look fuzzier), linear perspective (convergence of parallel lines into the distance), texture gradient

PLUS - Many more we will discuss later. . .

<u>Motion Parallax</u> - Depth cues based on <u>movement</u>

(Passengers only: Try this in a moving car…)

When perceiver moves, stationary objects at different distances will show systematic differences in their **apparent** <u>velocity</u> and <u>direction of movement</u> that provide information on their relative location.

- Based on velocity and direction of movement of images across retina
- AND on perceiver's focus point (point in environment aligned with fovea)

Note: This is a **monocular** effect: one eye is sufficient, altho additional depth info is available when 2 are used

DEMONSTRATION: Close 1 eye, line up 3 fingers with that eye, focus on middle finger, move head

When you focus on middle stimulus:

* Stimulus <u>closer</u> than focus point <u>appears</u> to move in <u>**opposite**</u> direction that you do
* Stimulus <u>farther</u> than focus point <u>appears</u> to move in <u>**same**</u> direction that you do

This is strikingly evident when change focus to closest finger - both far fingers move same direction you do

- Or if you change focus to farthest finger - both close fingers will move opposite direction you do

Furthermore, if move 1 finger very far from others and focus on closest (or much closer & focus on farthest)…

* The <u>farther</u> a stimulus is from <u>focus point</u> (either closer to you <u>or</u> farther from you), the <u>**farther & faster**</u> it will appear to move when you move.

<u>**Why**</u>**?** Given that, as mentioned above, images that fall on the retina are <u>inverted and mirror-reversed</u>, an image that <u>sweeps from **left to right** across the retina</u> will <u>code</u> for <u>stimulus motion from **right to left**</u>

(& from right to left codes for motion left to right, up to down for down to up, down to up for up to down)

Thus, if the perceiver moves left to right, and keeps its eye(s) fixed on a single focus point, then ANY point closer than focus point will sweep from left to right across retina, and thus be perceived as motion from right to left (opposite the perceiver's direction of movement)

<u>and</u> ANY point farther than focus point will sweep from right to left across retina, and thus be perceived as motion from left to right (same as the perceiver's direction of movement)

<u>plus</u> for motion of a given duration, the farther a point is from the focus point, the farther it will sweep across the retina in that same period of time and thus the faster it will appear to move.

Lightness Perception: If something appears to be in shadow, it's lightness can be discounted and appear the same color as darker parts outside the shadow.

NOTE: Text pp: 221-223 oversimplifies the above and wrongly implies that all points closer to the observer will move faster than all points farther from the observer. This is only true if the observer's focus is at the most distant point.

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Cognitive Science 101A Midterm 2 Study Guide

MOVEMENT
- Motion parallax
- Apparent motion, its three determining factors
- Inter-Stimulus interval
- Paths apparent motion can take
- Causes of motion aftereffects
- Corollary discharge theory, four experiments to test theory
- Motion aperture problem
- Direction detectors in V1
- Role of MT in motion processing
- Optic flow, MST sensitivity to optic flow patterns
- Induced movement
- Motion capture
- Plaid motion
- Biological motion
- How motion affects depth perception

BOTTOM-UP MODELS OF PERCEPTION
- Bottom-up vs. top-down models of perception
- David Marr's computational model
  - Primal Sketch, primitives, 2 _ D Sketch, 3 D Sketch
- Treisman's Feature Integration Theory
  - Primitives (different from Marr's primitives)
  - Pop-out effects, texture segregation
- Biederman's Recognition by Components
  - Geons
- Pre-attentive vs. attentive stages
- Illusory conjunction
- Feature vs. conjunction search
- Serial vs. pop-out search

TOP-DOWN MODELS OF PERCEPTION
- Gestalt psychology
- Learned top-down effects
- Context effects, contextual priming
- Gestalt principles of perceptual organization
  - Pragnanz, similarity, proximity, good continuation, common fate, meaningfulness/familiarity
- Psychophysical evidence of Gestalt principles
- Figure/ground assessment, factors that affect it
- Palmer and Rocks' principles of common region, element connectedness, synchrony
- Occlusion heuristic

ECOLOGICAL MODEL OF PERCEPTION
- Optic flow, how it affects movement and balance
- Focus of Expansion
- Rate of expansion, rate of contraction
- MST role in optic flow
- Collision detection, □= (image size)/rate of expansion
- Linear optical trajectory
- Intraparietal areas – LIP, MIP, AIP, VIP
- Mirror neurons
- High level adaptation