Chapter 3  Perception

"The real voyage of discovery consists not in seeking new landscapes, but in having new eyes."

Marcel Proust
Five Sensory Organs

Transform energy (air waves and pressure, chemicals in the air and food, light waves, temperature and pressure in the skin) into neural inputs that are the basis of perception.
Areas of the cortex are specialized for processing sensory input.
Systems that receive and process sensations allowing us to understand and interpret the sensations we receive from the sense organs.
Primary role of a sensory system is to receive energy from the environment (distal stimulus) into a representation in the brain. The representation of information from sensory receptors is referred to as the proximal stimuli.

A percept is information that is processed for meaning.
Perception involves reducing and categorizing, interpreting and sometimes misinterpreting information.
Assume a real world exists out there!!!

Distal Stimuli

How do we get information about it into our cognitive systems?
Information about Distal Stimuli is carried by Energy

• Vision - Light Waves
• Hearing - Sound Waves
• Taste & Smell - Chemicals
• Touch & Pain - Direct Pressure
Visual Perception

Qualities of Light that make it ideal for carrying information

- fast
- constant speed
- travels in straight lines
- abundant
- Predictably interacts with object surfaces
  - absorbed (by pigments)
  - reflected
Retina has three layers of neurons
1) is a single layer of photo sensitive cells (rods & cones)
2) Bipolar cells
3) Ganglion cells
Photoreceptors – Rods and Cones

Transduce light into neural messages.
Cone system has 3 types of Photoreceptors each with a different type of photopigment that respond to a specific range of light waves which produces Color vision.

The Rod system has 1 type of photoreceptor with a photopigment called **rhodopsin**. Rod vision responds to the full range of light wavelengths.
Visual Information is carried by the optic nerve which crosses hemispheres at the optic chiasm.

The optic tract then carries the neural messages to the visual receiving area in the occipital lobe.
Information from both eyes is carried to each the occipital lobe of both hemispheres of the brain.
127 million photoreceptors per eye.
1 million ganglion neurons leave each eye.

Conclusion: A lot of processing of visual information goes on in the nerve cells of the eye.

Compression
Photoreceptors pass information to collector cells which pass it on to ganglion cells.
Compression occurs through synapses made between receptors and connector cells (horizontal cells, Bipolar cells and amacrine cells) and the ganglion cells
**Compression** - reduction in neural messages between photoreceptors and Ganglion cells.

<table>
<thead>
<tr>
<th>Rods</th>
<th>Cones</th>
</tr>
</thead>
<tbody>
<tr>
<td>120 million</td>
<td>7 million</td>
</tr>
</tbody>
</table>

Ganglion

1 Million
Approx 120 **rods** compress onto a single ganglion.

Approx 6 **cones** compress onto a single ganglion.

**Effects of Convergence.**
When a large number of photoreceptors are converged on a single Ganglion cell, **acuity** (detail) is lost, but **sensitivity** is gained.
Cones have less convergence → greater acuity.  
Rods have more convergence → greater sensitivity.
Fovea

- mostly cones
- densely packed
- provides most accurate precise vision
Fovial vision has color perception, high acuity but lower sensitivity.

Peripheral vision has less color and low acuity but high sensitivity.

Demonstration of low acuity of peripheral vision
Strengths of Peripheral Vision

Because they are more sensitive, rods operate better than cones in low light. This makes peripheral vision useful for detecting faint light sources at night (e.g., pilots are taught to use peripheral vision to scan for aircraft at night) and for detecting motion in the peripheral field.
Fun Fact

Peripheral vision can be practiced and improved; for example, jugglers that regularly locate and catch objects in their peripheral vision have improved abilities. Jugglers focus on a defined point in mid-air, so almost all of the information necessary for successful catches is perceived in the near-peripheral region.
In the retina there is also cross talk (amacrine and horizontal cells) among neurons so that the firing of one neuron can effect the message sent by its neighbors.
Lateral Inhibition

The firing of one neuron triggers inhibition of the firing of its neighbors. So the fewer neighboring neurons stimulated, the more strongly a neuron responds. This process greatly increases the visual system's ability to respond to edges of a surface.
Lateral Inhibition

This happens because neurons responding to the edge of a stimulus respond more strongly than do neurons responding to the middle. The "edge" neurons receive inhibition only from neighbors on one side -- the side away from the edge. Neurons stimulated from the middle of a surface get inhibition from all sides.
Lateral Inhibition
Mach Band Illusion

When there is a change in intensity of light information carried by adjacent neurons, crosstalk (lateral inhibition) produces an illusion that exaggerates the contrast between edges. These are called Mach Bands.
Lateral Inhibition
Color Contrast Effects
Processes (neural cross-talk) that occur in the eye, detects and emphasize edges which are the important information about the visual stimuli, while removing redundant information.
Processing in the eye greatly reduces the amount of information that needs to be further processed. Your visual system detects edges and assumes that the information remains the same until another edge is detected.
Blind Spot

The ganglion neurons form the optic nerve which exits the eye at the optic disk (see slide 22). At the optic disk there are no detectors. Everyone has a blind spot in the visual field of each eye. We do not perceive this blind spot because the visual system assumes that if there are no edges, the missing area is the same as the surrounding area.
Demonstration

Cover your left eye and stare at the cross. Slowly move the paper closer and further away. When the star falls within your blind spot it will disappear. (You can also do this demonstration on your computer using the next slide: cover you left eye, stare at the cross and move closer and further from the screen. You should get the same effect.)
Sensation vs. Perception

Sensation is the registration of sensory input at the sensory receptor cells (proximal).

Perception is the process of interpreting and understanding sensory information (precept).
Approaches to the Study of Perception

- Computational Approach
- Gestalt Approach
- Perception/Action Approach
Computational Approach

Studies how we use features of objects and scenes to interpret and understand them.
**Bottom-Up Processing**

In the bottom-up processing approach, perception starts at the sensory input of the stimulus. Thus, perception can be described as **data-driven**. Perception is conducted starting with the most basic features of a stimulus and adding the parts together to be able to understand the whole.
Feature Analysis or Detection: break objects down into features and match against stored object features.

<table>
<thead>
<tr>
<th>Features of Stimuli</th>
<th>Letter A</th>
<th>Letter H</th>
<th>Letter T</th>
</tr>
</thead>
<tbody>
<tr>
<td>Two vertical lines</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>One horizontal line</td>
<td>Yes</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>Diagonal converge at top</td>
<td>Yes</td>
<td>No</td>
<td>No</td>
</tr>
<tr>
<td>Horizontal joins vertical</td>
<td>Yes</td>
<td>Yes</td>
<td>No</td>
</tr>
</tbody>
</table>
Do Feature Recognition Models Make Sense?? Evidence:

**Neurological:** feature detectors in visual cortex
Hubel & Wiesel (1965).
- located feature neurons that respond best to specific feature “line orientations, curves, corners ends”.
Video
Feature detectors are neurons that respond to specific features of the environment, such as lines, orientation, edges (end-stops), and movement.

Figure 23. The ice-cube model of the cortex. It illustrates how the cortex is divided, at the same time, into two kinds of slabs, one set of ocular dominance (left and right) and one set for orientation. The model should not be taken literally. Neither set is as regular as this, and the orientation slabs especially are far from parallel or straight.
Visual Object Recognition

Feature approaches may work for simple two dimensional objects, but what about more complex stimuli?
Template Theories

Comparing the 2-D shape of the object with stored shapes in Memory (template).

Problems

1) Too many templates would be needed.

2) Inflexible
Same object at different viewing angles has very different shapes.

Rotational Invariance: People are capable of recognizing objects from many different vantage points, even views that have never before been seen (Biederman & Gerhardstein, 1993).
Many things we can readily distinguish have very similar shapes.
Recognition-By-Components Theory

• Biederman (1987)
  – Describes how 3D images are identified
  – Breaks objects down into geons
  – Objects are identified by geons and relationship between them
View Invariant:

• Look the same from most angles
• Spatial arrangement of geons is the same.
Discriminable
• Difficult to confuse one for another

Noise Resistant
• Can be identified under less-than-ideal conditions
• Parsimonious

36 Geons can define 150 million 3-geon objects.

• Allows novel stimuli to be identified by comparing Geon structures to similar stored stimuli.
Environmental Cues

E.g., Depth Perception

While the world is 3D, the image detected in the single layer of photo receptors of the retina cannot directly sense depth and distance. It is much like an image on a screen. So how do we know how far objects are from us or from each other in depth.
1. Linear Perspective

Parallel lines appear to converge at some point in the distance. Objects size and distance are interpreted according to their relationship to the vanishing point.
One way computational perception researchers study environmental cues is by looking at illusions.
Ponzo Illusion
Which Line appears Longer?
Möller-Lyer Illusion
Why? Linear Perspective.

Our brain makes assumptions about the relative depths of the two lines based on environmental cues.
2. Retinal Image Size

The size of the object represented on the retina.

Did the balloon get bigger or did it move closer?
Retinal image size gives ambiguous clues to both size and distance.
Top Down Processes

Using our knowledge about the world to disambiguate ambiguous environmental cues. i.e., we know the man is smaller than the cars, therefore he must be closer to us and the cars must be in a distance.
Fun Fact

Artists may have difficulties with binocular (two eye) depth cues and may rely more on monocular (picture cues). “Because they rely so strongly on these cues, they may be better able to exploit them to make drawings and paintings that convey depth than people who also use the two-eyed cues well.”
Bottom–up processes are not enough to explain perception. We tend to perceive the global before the features. We recognize the schoolroom before noticing it is made up of crayons and pencils.
Theory of Unconscious Inference (Helmholtz)

Theory that we make unconscious, top-down inferences about the world when we perceive it.
Gestalt Approach

Gestalt is a psychology term which means "unified whole". It refers to theories of visual perception developed by German psychologists in the 1920s. These theories attempt to describe how people tend to organize visual elements into groups or unified wholes when certain principles are applied.
Because of Top-down processes, “the whole is more than the sum of its parts.
Organizational Principles

The Gestalts studied and defined several organizational principles. These principles follow physical processes in the natural world. We use them to infer meaning when perceiving visual stimuli.
Figure-Ground
Tendency to separate a visual display into figure and ground.
OW! That must hurt!
Law of Pragnanz (good form or simplicity)
Objects with similar properties (e.g. shape, color)

Nearby objects

Objects that define smooth lines or curves

Objects that form symmetrical patterns

Objects that form periodic patterns
Similarity occurs when objects look similar to one another. People often perceive them as a group or pattern.

The example above (containing 11 distinct objects) appears as single unit because all of the shapes have similarity.
Good Continuation:
Group together items that follow in a straight or smooth line.
Closure

*Closure* occurs when an object is *incomplete* or a space is not *completely enclosed*. If enough of the shape is indicated, people perceive the whole by filling in the missing information.

Although the panda above is not complete, enough is present for the eye to complete the shape. When the *viewer's perception completes a shape*, *closure* occurs.
Witness the Ontario launch of the "Flick Off" campaign, and Environment Minister Laurel Broten's desperate attempt to maintain her dignity in front of its official logo.

Campaign is aimed at getting young people to cut energy use. http://www.cbc.ca/canada/toronto/story/2007/04/26/flick-off-campaign.html#ixzz0fnapnrAP
Gestalt – Motion Perception

**Phi Phenomenon** is an illusion in which people see motion that is produced by a succession of immobile images. Illusion of smooth movement is created when our brain fills in the missing information that does not exist between successive images.
Law of Common Fate

Mental grouping of objects that share a common motion or have a common destination.
Configural Superiority Effect

Arrays of stimuli containing basic feature elements are easier to perceive when they form a complex organized whole than when the features are depicted individually.
Perception/Action Approach
Ecological View

Focus on **Affordances** (What is the object for?)

View perception and action as intricately linked. Focus on how we perceive in a world where we engage in goal-directed behaviors. A chair may be perceived as “climb-able” or “sit-able” depending on our current needs.
Optic Flow

Optic flow is the pattern of apparent motion of objects, surfaces, and edges in a visual scene caused by the relative motion between an observer and the scene.

e.g., When in motion there are patterns generated by objects at Different distances as you pass them.
Optical flow allows is to infer action even without identifying the object.

Biological Motion
Example

Objects that are closer to you seem to by faster than objects that are further away.

According to this view we perceive objects distance based on optic flow not from first representing the object in our minds based on retina size.
Studies have asked participants to carry out real-life tasks and measured the amount of time it take them to consider their options.
Rosenbaum, 2012

Asked participants to pick up a child’s beach bucket on a table and carry it to either of two sites beyond the table. Asked to choose the route with the least effort involved.
Rules: If you walked along the left side of the table, need to pick up the bucket with the right hand and carry it to a stool beyond the table’s left end. If you walked along the right side need to pick up the bucket with the left hand and carry it to a different stool beyond the tables right end.
Conditions

In different trials, the left and right target sites (stools) were different distances from the end of the table.

Crossed with this variable, the bucket was close to the left edge of the table, in the middle of the table, or close to the right edge of the table.
When planning route two variables to consider.

1. Distance to target site (stool).
2. Reaching distance to bucket.
Measured reaction time (RT) to choose a path in different scenarios.

**Hypothesis:**

If processing is **Sequential** in that we mentally simulate all options one after another, then time should in increase with overall distance of the total options.

If processing is **Parallel** in that we consider all options simultaneously, time should not increase with overall distance of the total options.
Results

RT did not increase with increased distance.

- Parallel processing
Perception can affect Action
The Ebbinghaus Illusion

Which orange circle looks bigger?
Compared putting performance in relation to hole size. Performance was related to perception.
Are the same brain areas used to recognize objects and to locate them?

Different pathways for recognition of an object (WHAT-Ventral System) and location of an object (WHERE/HOW – Dorsal system).
Two Visual Systems:

The ventral stream, projecting from the primary visual cortex to temporal lobe, processes information relevant for object recognition, while the dorsal stream, projecting from the primary visual cortex to the parietal lobe, processes information for action. (Goodale & Milner)
Systems are Partially Independent.

“Where” or “How” dorsal stream

“What” or ventral stream

When we ask people which line is longer, they rely on the “What” system and they show evidence of the Illusion.

When you ask people to interact, (e.g. point) they use the “Where” system and the illusion is greatly reduced?
Ames Window Illusion

Although people perceive the illusion action, if you ask them to interact with the object (pointing at or grasping the pen) the illusion is reduced.
Example from Neurocognitive Case study: Patient DF

D.F. has a profound inability to recognize objects, places and people, in large part because of her inability to make perceptual discriminations of size, shape or orientation (agnosia), despite having good visual acuity.
When asked to copy (draw) a line at the same angle as one that is displayed to her, she is much worse than control subjects.

(a) Perceptual orientation matching
When DF is asked to reach for an object (post a letter), she can do well and she shows appropriate pre-shaping of her hand which scales correctly with the size of the object. This suggests she has an intact "Where/How" pathway but a damaged "What" pathway.

Figure 4.29 Performance of D.F. and a person without brain damage for two tasks: (a) judging the orientation of a slot; and (b) placing a card through the slot. See text for details. (From Milner & Goodale, 1995.)
Further strong evidence for the two pathways comes from a rare disorder called Blindsight.
Perception improves with practice as long as practice has feedback! Practice increases Top-down factors.