LISC-322 Neuroscience

THE VISUAL SYSTEM
Visual Perception

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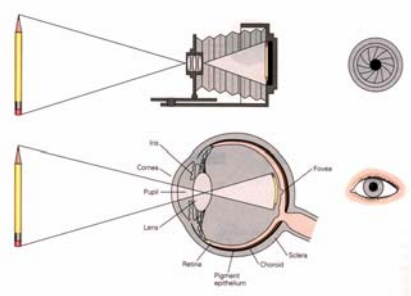
What is involved in seeing?

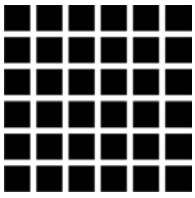
The Problem of Perception

The eyes are much more than a camera.



The Problem of Perception

The visual system ***actively transforms*** its stimulus inputs, emphasizing areas of difference (or contrast) within the input and minimizing areas of uniformity.



The Problem of Perception

The problem of perception consists of determining:

Where is the object?
Where it is going?
What it is? How do we recognize an object?

The Perception of 3-D space
Where is it?

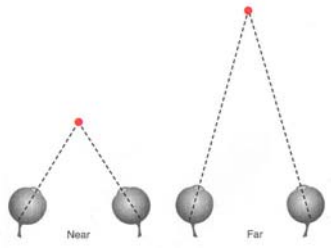
The Perception of 3-D space

Perceiving 2-D objects is fairly simple because 2-D visual images are already constructed at the level of the retina. Furthermore, our visual system is composed of numerous areas containing ***Topographical Maps*** of visual space.

The non-trivial 3-D perception that we experience everyday results from our visual system's use of ***Depth Cues***.

Oculomotor Cues: *Convergence*

Convergence can serve as a cue for depth because the convergence of the eyes depends on the distance of the objects we fixate.



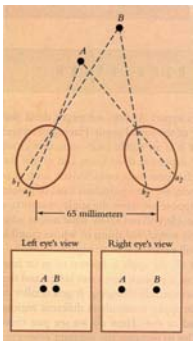
Oculomotor Cues: *Accommodation*

Accommodation also serve as a depth cue because the shape of the lens depends on the distance of the objects we focus on.

Binocular Cues: *Retinal Disparity*

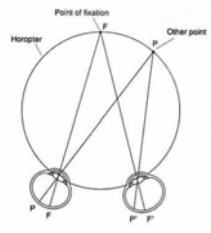
As binocular creatures, our two eyes look onto the world from slightly different position, providing slightly different views of the world. This ***Binocular Disparity*** grants us important information about depth relationships between objects.

Some neurons in the visual cortex are able to detect retinal disparity and act as ***depth detectors***.



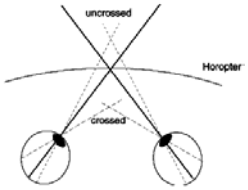
Binocular Cues: *Retinal Disparity*

Objects falling on the ***Horopter*** (an imaginary surface that passes through the point of fixation) result in images that fall on corresponding points on the two retinas.



Binocular Cues: *Retinal Disparity*

Objects in front of the horopter produce ***crossed disparity***.
Objects beyond the horopter produce ***uncrossed disparity***.
The farther an object is from the horopter,
the greater is the ***angle of disparity.***



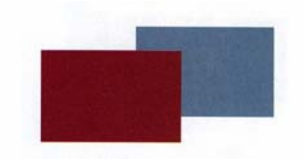
Monocular Cues for Depth

Binocular disparity is a powerful (and probably innate) cue for depth perception. Yet we can perceive depth beyond our binocular field of vision and even with one eye closed.

Clearly, there are cues for depth perception that come from the image obtained from one single eye. These are ***Monocular Depth Cues***, most of them being *pictorial cues* that we use to create an impression of depth on a flat canvas.

Monocular Cues: *Interposition*

When the boundary of an object is interrupted by the presence of another object, we use this pattern of blocking as a cue to determine the object as more distant from us. The near object is perceived as ***interposed*** between the far object and us.

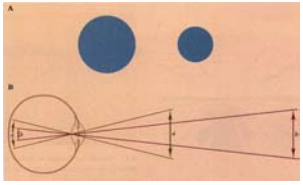


Monocular Cues: *Linear Perspective*

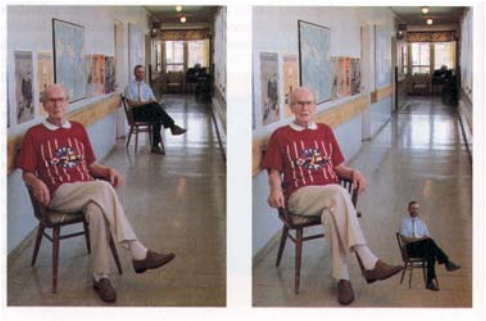
Distant objects necessarily produce a smaller retinal image than nearby objects of the same size. This provides the basis for the cue of ***Linear Perspective***.

Monocular Cues: *Relative Size*

That distant objects produce a smaller retinal image than nearby objects of the same size also provides the basis for the cue of ***Relative Size***: the larger of two identical objects tends to be perceived as closer that the smaller one.



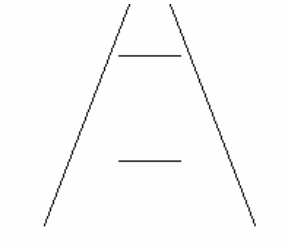
Size Consistency



Size Consistency

Framing Effect and Size Illusion

An object that seems to fill a bounding outline looks larger than the same object within a larger outline.



Monocular Cues: *Texture Gradients*

Uniformly textured surfaces produce ***Texture Gradients*** that provide depth information: as the surface recedes, the texture elements' size decreases and their density increases.

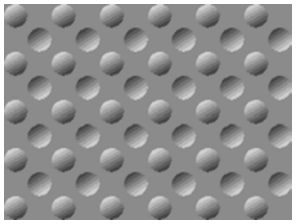
Monocular Cues: *Texture Gradients*

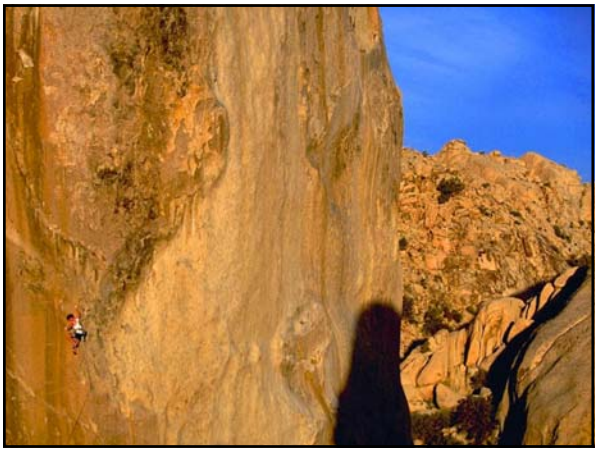
Discontinuity in texture gradients produces further information about the layout of the surfaces.

an upward tilt *a sudden drop*

Monocular Cues: *Light and Shadow*

The distribution of ***light*** and ***shadow*** on a objects is also a powerful monocular cue for depth provided by the biologically correct assumption that light comes from above.

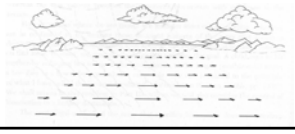




Perception of Depth through Motion

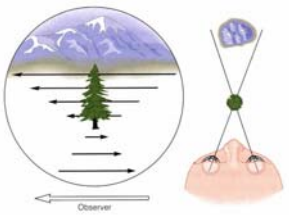
In real life, we are constantly moving through space and this motion provides an additional source of visual information about the spatial arrangement of objects around us.

Whenever we move, the images projected by objects located at different distances move across our retina with different speed and create patterns of motion in the retinal images that provide highly informative depth cues.



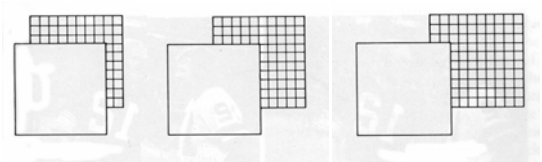
Motion Parallax

The direction of motion across the retina depends on where we point our eyes. Objects closer than our fixation point appear to move in a direction opposite to our own. Those farther away appear to move in the same direction.



Motion Parallax

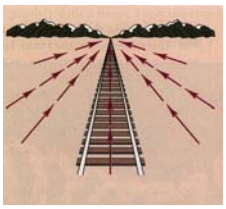
Deletion and ***Accretion*** occur when an observer moves in a direction not perpendicular to two surfaces that are at different depths.



The far surface becomes covered ← → The far surface becomes uncovered

Optic Flow

As we move *forward* or *backward* into space, the pattern of stimulation across the entire visual field changes, producing a pattern of *expanding* or *contracting* ***Optic Flow***.



The Perception of Movement

Where is it going?

Retinal Motion

Our perception of movement arises from the motion of images across the retina as detected by visual neurons that either simply sensitive to motion or specifically selective to the direction of motion of visual stimuli.

These neurons are well-suited to act as ***motion detectors***.

Apparent Movement

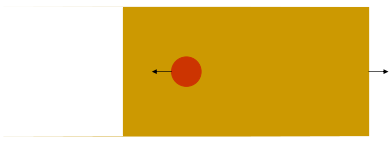
Motion can be perceived even when there is no motion of an image across the retina. Appropriately timed change in position is sufficient for the visual system to make something appear as moving.

Illusion of Motion

We not only detect motion, we also interpret it. Specifically, the perceptual system must solve the ***Correspondence Problem***: determining which elements of the current view corresponds with which elements in the previous view.

Induced Motion

The physical movement of a frame enclosing an object can induce the perceived movement of the enclosed shape.

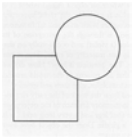


The Perception of Form

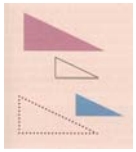
What is it?

The Perception of Form

Form is our major avenue for identifying what we see. The question is how? How do we recognize the various forms and patterns taken by different objects, and how do we recognize a form even if its components parts are altered?



It this a square?



Are these all triangles?

The Perception of Form

One solution to these issues was advanced by ***Gestalt psychology***, a school of psychology whose adherents believed that organization is an essential feature of visual perception.

They argued that a form is not perceived by somehow summing up all its individual components, but by considering is as a coherent, intact *Gestalt*[1], a whole that is different from the sum of its parts.

[1] "*entire figure*"

The Elements of Form

Perceiving a visual scene involves:

1) The detection of its features
2) The parsing of the scene so that figures can be identified from the background
3) The grouping of the figures' parts into single objects
4) The recognition of the pattern, i.e., answering the question: What is it?

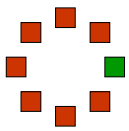
The Elements of Form (1)

The perception of form begins with the detection of ***Primitive Features***, the building blocks of visual perception.

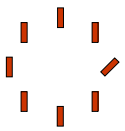
Various visual neurons in the brain act as feature detectors, responding selectively to certain elements of visual form. Evidence suggests that these simple features (color, orientation, curvature, ends of lines) form the basic units in our perception of form.

Primitives revealed in Visual Search

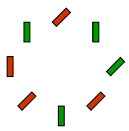
Feature (color) Search



Feature (orientation) Search

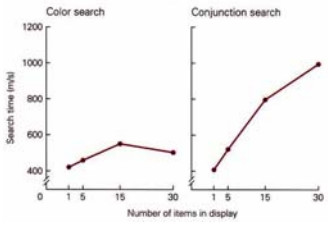


Conjunction Search



Primitives revealed in Visual Search

The search time in *feature search* is independent of the display size, as if the items were processed in ***parallel***. In contrast, the search time in *conjunction search* does depend on the display size, as if the processing was in ***series***.



The Elements of Form (2)

Once the we identified which features are present, the next step is to organize the overall visual scene, a process called ***Perceptual Segregation***.

To make sense of a visual scene, the perceptual system must somehow group the elements of the scene appropriately.

The major questions are:
What goes with what? What is focal?

Perceptual Segregation: What is it?

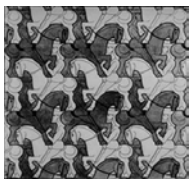
Perceptual Segregation: What is focal?

A crucial step in visual segregation is the separation of the object from its setting, so that a the object is seen as a coherent whole, separate from its background.

This separation of ***Figure*** and ***Ground*** allows us to recognize as focal both objects that we are familiar with and objects without particular meaning.

Figure and Ground

The differentiation of ***Figure*** and ***Ground***, like all aspect of perceptual segregation, is contributed by the perceiver.
It is not a property of the stimulus itself.
There can be more than one way to parse a stimulus!



Element of Form (3)

The ***Perceptual Organization*** of the elements within a visual scene is guided by some factors that were described by *Gestalt* psychology and regarded as principles.

These principles demonstrate that "*the whole is different than the sum of its parts"*.

Once again, ***perceptual grouping*** is an achievement of the perceiver and not a property of the stimulus.

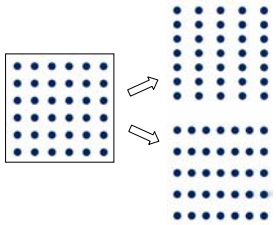
Gestalt Principles: *Prägnanz*[2]

Every stimulus pattern is seen in such a way that the resulting structure is as simple as possible; the simplest and most stable interpretations are favored .

[2] "*goodness of form*"

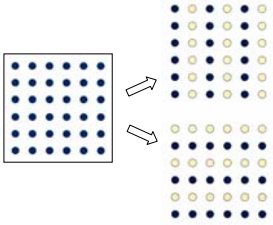
Gestalt Principles: *Proximity*

Objects that are near to each other appear to be grouped together.

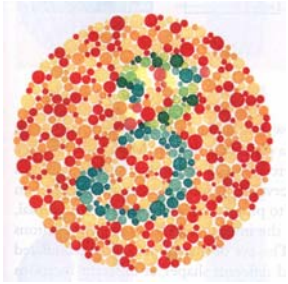


Gestalt Principles: *Similarity*

Visual features that look similar appear to be grouped together.

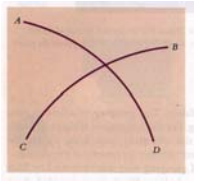


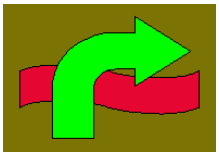
Grouping by similarity is used in color vision tests:



Gestalt Principles: *Continuity*

Points that form smooth, straight, or curving lines appear to belong together. Contours based on ***smooth continuity*** are preferred to abrupt changes of direction.



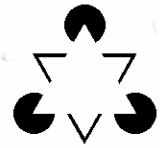


Good Continuation is the basis of camouflage.

Gestalt Principles: *Closure*

The principle of closure applies when we tend to see complete figures even when some information is missing.

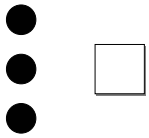
Figures can even be created by completely subjective contours!



What other processes is at work here?

Gestalt Principles: *Common fate*

Objects that are moving in the same direction appears to be grouped together.



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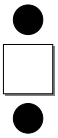
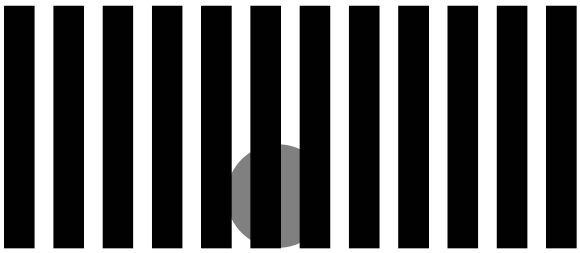


Gestalt Principles: *Common fate*



Gestalt Principles: *Familiarity*

Objects that are more likely to form groups if the groups appear familiar or meaningful.

Gestalt Principles: *Familiarity*

The Maximum-likelihood Principle

The Gestalt principles emphasize fact that we tend to perceive objects in the world according to rules that we have learned from observing the regularities of our environment.

These perceptual grouping principles can all be united under a single general rule: ***the principle of maximum likelihood***.

The knowledge about which configurations are likely and which are not guides us whenever we seek to determine what is the relationship between neighboring stimuli.

The Elements of Form (4)

Once the features of a visual scene are detected, that the figures have been segregated from each others and from the scene background, that the parts of the figures has been grouped into single objects, the next step consists of ***recognizing the pattern***, i.e., answering the question: what is the object?

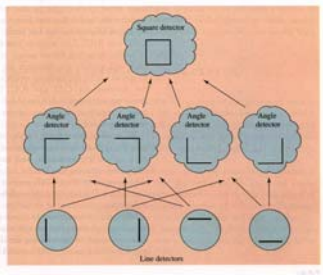
Bottom Up Processes

Some simple pattern recognition can be fully accomplished by an ensemble of detectors whose responses are determined almost entirely by the incoming stimulus information.

These ***data-driven*** networks can be built with a series of detectors organized in hierarchical order, with feature detectors at the bottom level. The specific combinations of low-level detectors activate mid-level detectors that, in turn, trigger the activation of higher level detectors.

Bottom Up Processes

A ***feature network*** capable of identifying a square pattern.



Top Down Processes

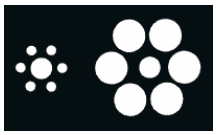
Bottom-Up processes can accomplish a great deal, but there are evidence indicating that pattern recognition also involves processes that are ***knowledge-driven***, or ***Top-Down***, in which pattern recognition is influenced by one's expectations and beliefs, as well as by the incoming stimulus information.

Prior knowledge about a visual scene and the current context thus shape the recognition of objects.

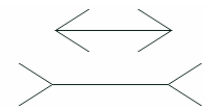
Top Down Processes

Context Effects

Titchener circles



Müller-Lyer bars



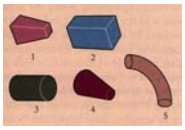
Top Down Processes

Priming Effects (Change Blindness)

Recognition by Components

Although ***feature networks*** can recognize simple objects, the process underlying the recognition of the vast variety of 3-D objects that surround us must be more complex.
Some ***geometric primitives*** (*Geons*) may substitute the feature primitives and this more complex recognition process may involve some analysis levels concerned with objects parts.

Geons



Objects

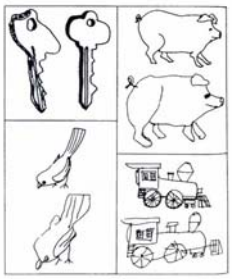
Meaningful Perception

Although *Geons* and their relationships can give us a complete ***structural description*** of an object, a representation of the object's geometry in 3-D, this is not enough for our visual system to attach a meaning to that object.

Some patients, known to suffer from ***visual agnosia***, possess accurate structural descriptions but fail to endow perceived objects with meaning.

Meaningful Perception

Some patients with *visual agnosia* can copy models well enough to reproduce them fairly accurately, but they are unable to recognize the objects in them.



Hypothesis Testing in Perception

Just like patients with visual agnosia can have a structural description for an object without accessing its meaning, we can be confronted with visual forms whose identifications temporarily escape us.

These perceptual problems can be solved by involving a process of ***hypothesis testing*** similar to the *principle of maximum likelihood*, i.e., we will perceive the object that is most likely to occur in that particular situation.

Perceptual Problem Solving

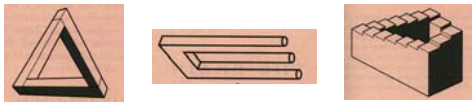
The Logic of Perception

Everyday perception and overt perceptual problem solving seem to be governed by a series of logical principles:

1) The solution must provide a coherent explanation for all the information contained within the visual scene.
2) It must avoid contradiction.
3) It must avoid interpretations of the world that are unlikely.

The Logic of Perception

When logic fails, impossible figures can be perceived…



These figures are 2-D drawings, but we perceived them as solid, 3-D shapes despite their impossibility.

Visual System: Visual Perception

Reference for this Lecture:

- Psychology, 5th edition (1998) by Gleitman et al., Chapter 6 (on reserve at Braken Library).

Reference for next Lecture:

- Neuroscience, 2nd edition (2001) by Purves et al., Chapter 11.

Lectures are posted:

- http://brain.phgy.queensu.ca/pare

Office Time:

- Tuesday & Thursday (15:00-17:00)
  Botterell Hall, Room 438