Chapter 3
Visual Perception and Cognition

3.1 Motivation

n Representing data by images allows quick grasp of important information.

   ·· "A picture says more than one thousand words"

n Visual pattern perception is a "natural" function of the human brain .

n In order to convey information correctly and efficiency we must understand the processes of visual perception and cognition.
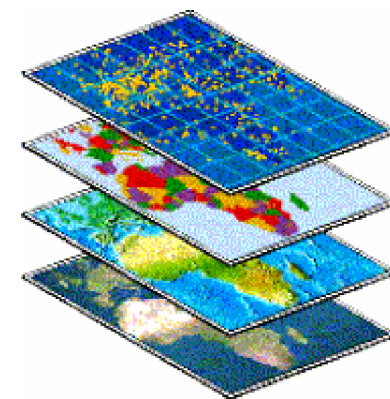
Motivation (cont'd)

- Difficulty of visualizing data compounded by
  - Must visualize 3D information on 2D screen
  - Have limited screen resolution
- Important to understand human vision
  - Spatial and temporal limitations of human vision
  - Depth perception in human vision
  - Colour perception
  - Preattentive processing

Motivation (cont'd)

Also important …

n How humans store and process information and solve problems

·· Tools for data exploration and manipulation

n How humans physically manipulate objects

·· User interaction with the data/visualizatio

3.2 The Visual System

- n *Cornea, lens* focus light onto *Retina*
- n *Photoreceptors*
  - *rods* - brightness
  - *cones* - color (red, green and blue)
- n *Ganglions* – nerve cells
  - (*X-cells*) - detect pattern
  - (*Y-cells*) - detect movement
- n *Fovea* – center of vision

The Visual System (cont'd)
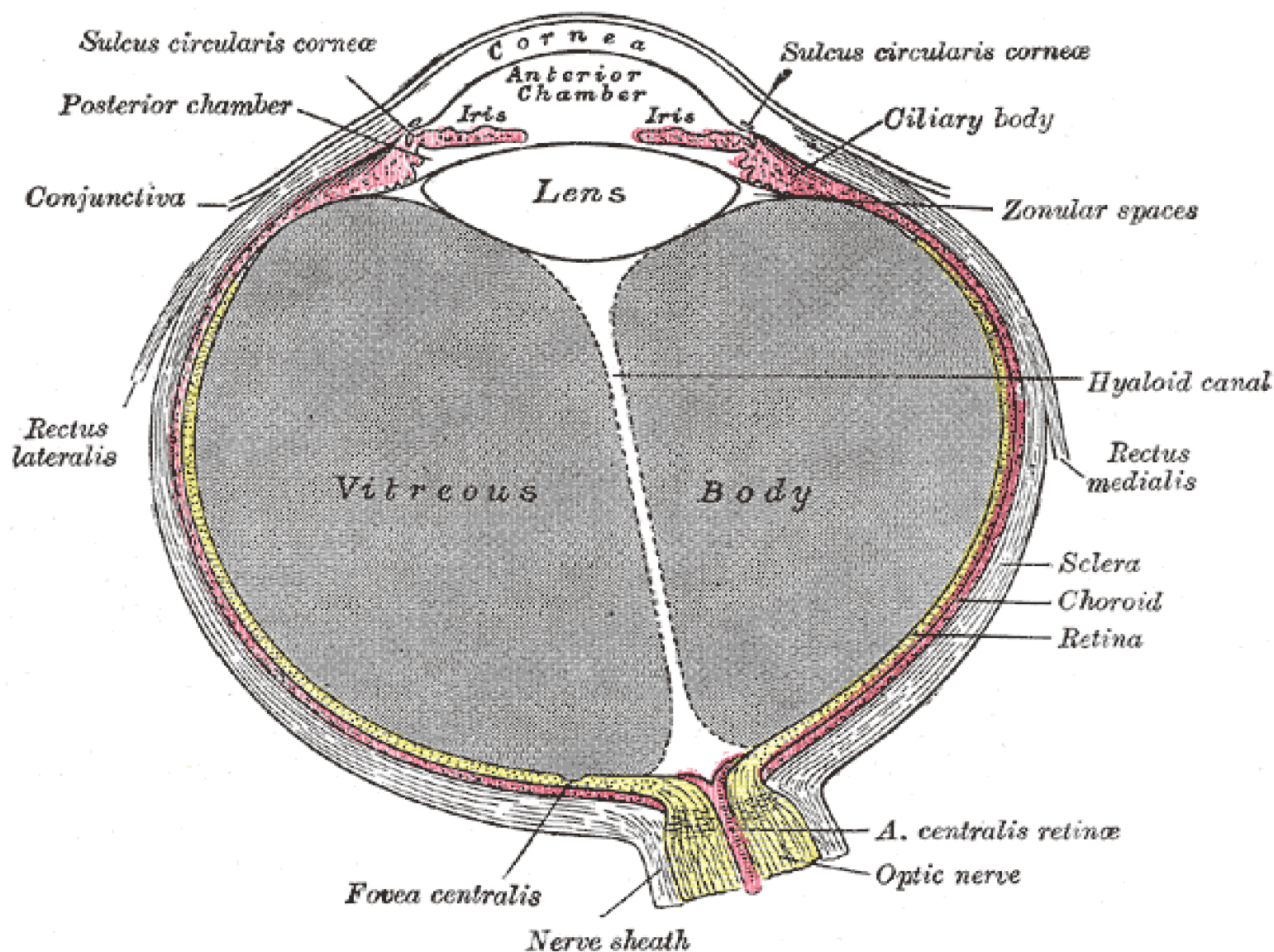
Photoreceptors

- Rods
  - More sensitive, but only perceive intensities
  - 120 million rods
- Cones
  - Concentrated around the "fovea centralis"
  - 6-7 million cones
  - Divided into 3 types according to measured response curves: 64% "red", 32% "green", 2% "blue"
  - 150 hues
- Combined
  - 7 million shades

Spatial and Temporal Resolution

n Spatial Resolution

   ·· minimum separation between the centers of adjacent dark and light bars is under optimal conditions about 0.5 minute of arc.

n Temporal resolution

   ·· 20 Frames/sec are usually perceived as a continuous motion.
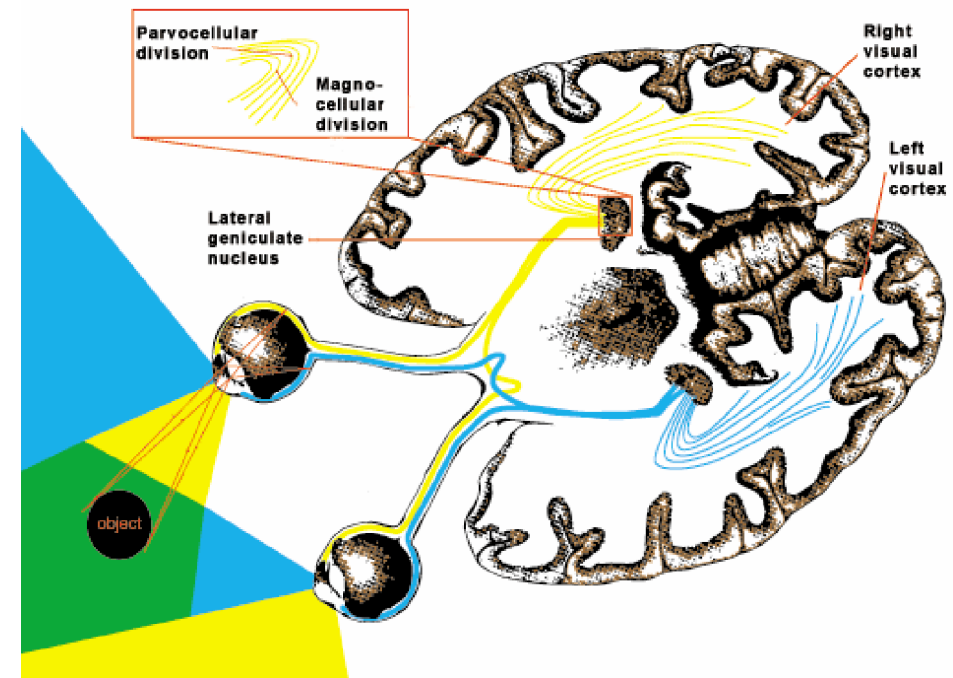
   ·· Sensitive to flicker up to 75 Hz.

3.3 Visual Processing

n **Preattentive processing**

- Perception of simple features without conscious attention.

n **Focused attention stage**

- Conscious examination of a scene.

- Rapid mental calculations and quantitative reasoning.

Parvocellular division

Magno-cellular division

Right visual cortex

Left visual cortex

Lateral geniculate nucleus

object

Preattentive processing

n Brain performs simple tasks on some features at a glance (<200ms).

  ¨ **Features:** line orientation, size, curvature, color (hue), intensity, flicker, motion, 3-D depth cues, texture.

   n importance varies (intensity>hue>boundary)

  ¨ **Tasks:** target detection, boundary detection and counting and estimation.

n often fails if features mixed

n Examples: http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

Preattentive processing (cont'd): Target Search
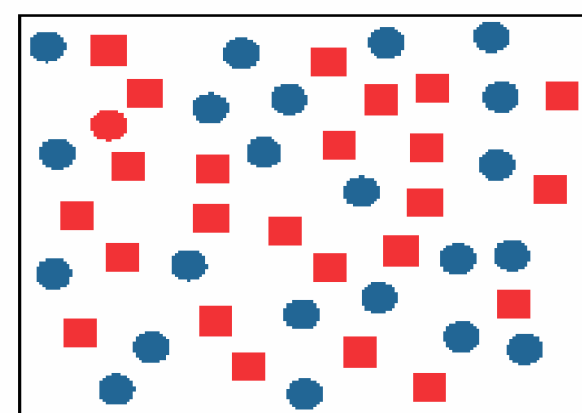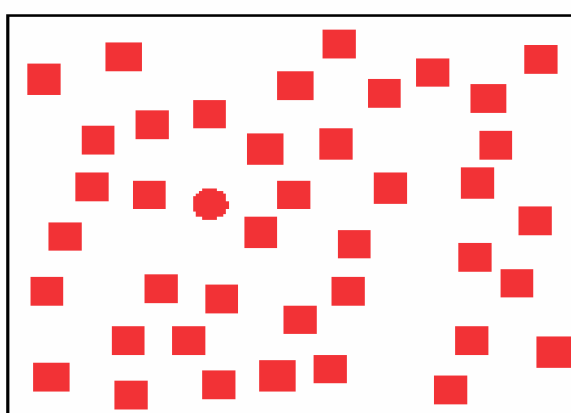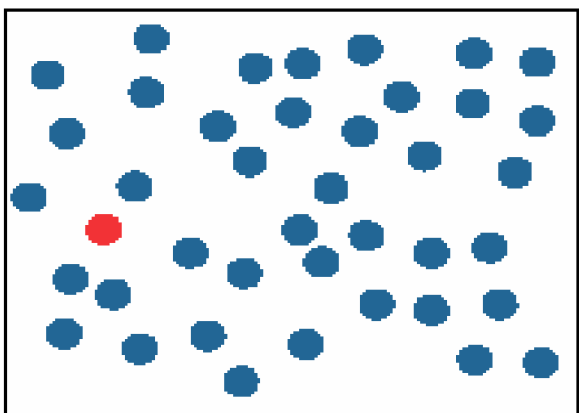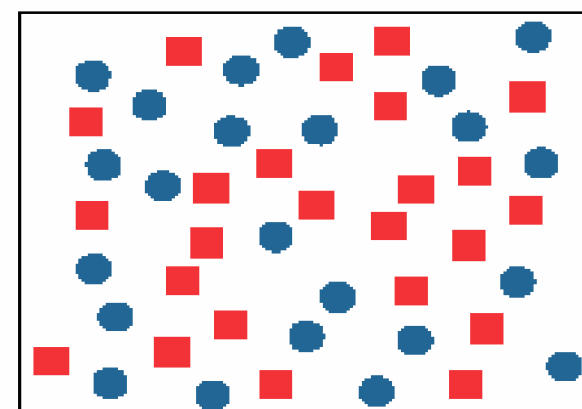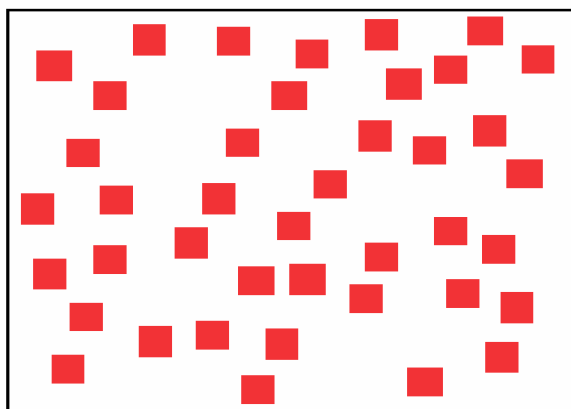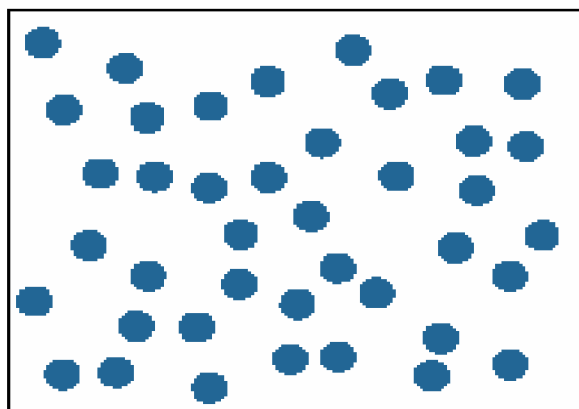
© Christopher Healey, Victoria Interrante and Penny Rheingans, Fundamental Issues of Visual Perception for Effective Image Generation, SIGGRAPH 1999, Course Note # 6

3.4 Visual Attributes

n Perception of complex forms achieved by

·· processing visual stimuli into integrated units

·· several layers of perceptual mechanisms

n Most basic integrated units

·· Colour, line orientation, contrast, transparency, position size

n Complex tasks

·· Spatial vision: shape, Gestalt, depth
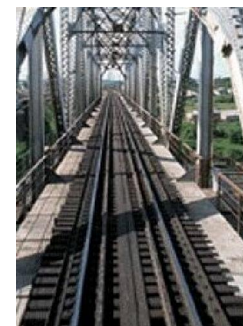
·· Figure-ground perception, texture perception
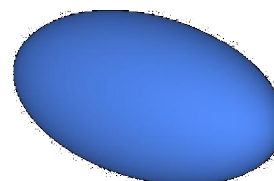
Visual Attributes (cont'd)
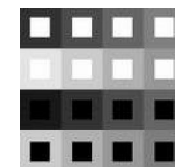
High level
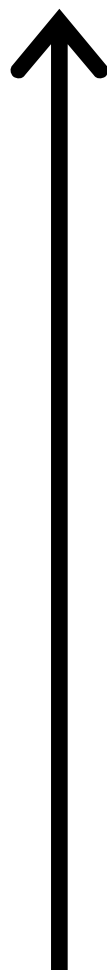
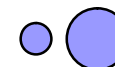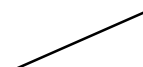Gestalt, figure-ground perception
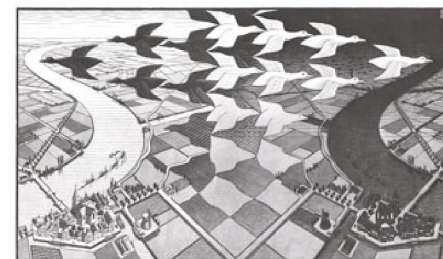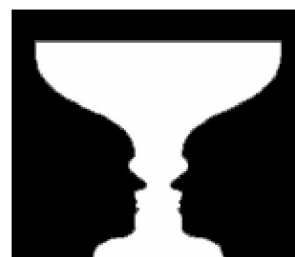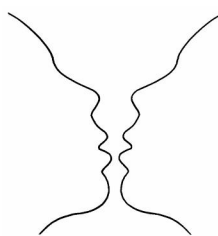
Texture, shape, depth

Low level

Colour, line orientation, contrast, transparency, position, size

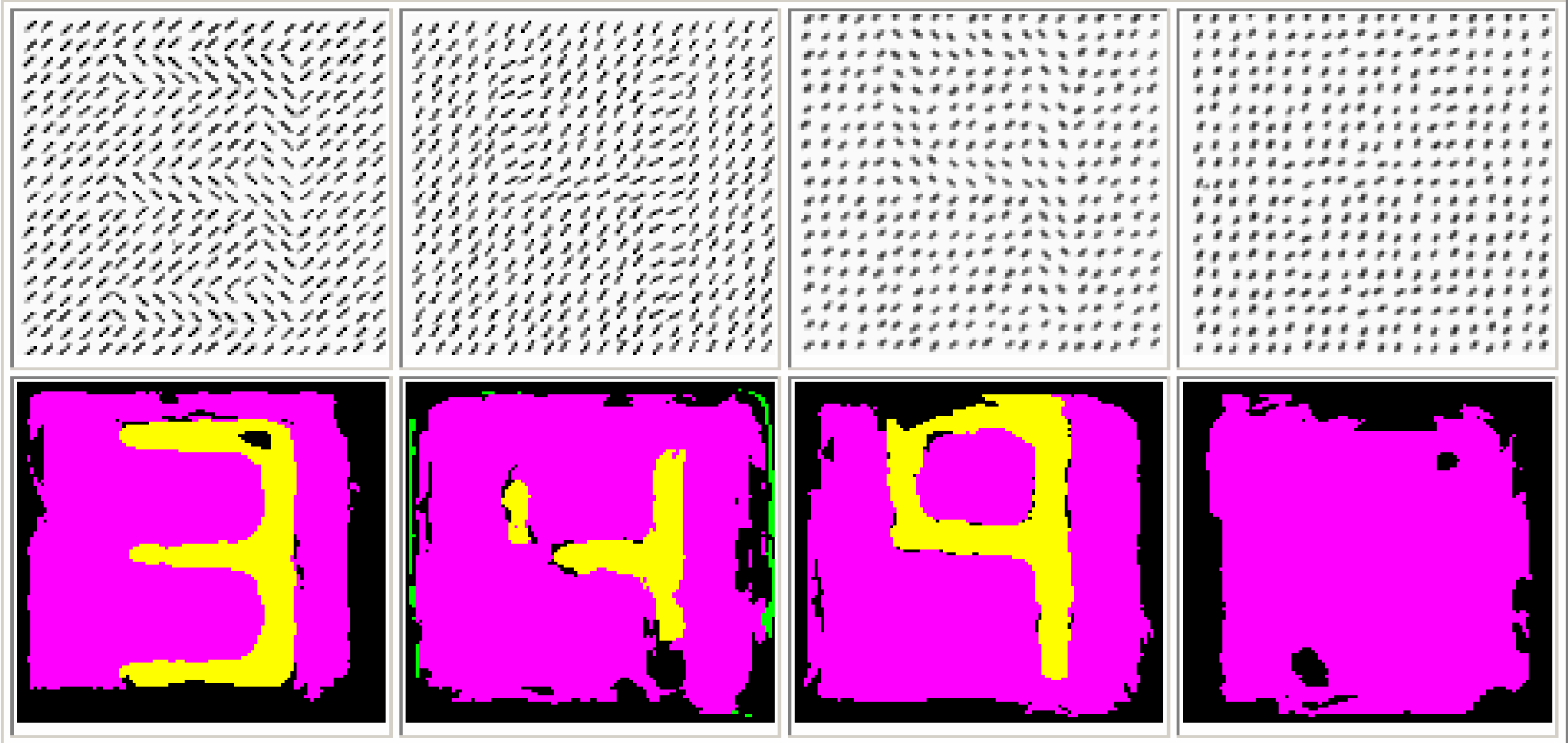# Texture perception

n Perceptually characterized by

- Spatial frequency
- Contrast
- Orientation

n Recognition of feature patterns accomplished using primitive textural features (textons)

- E.g. length, width and orientation of line segments
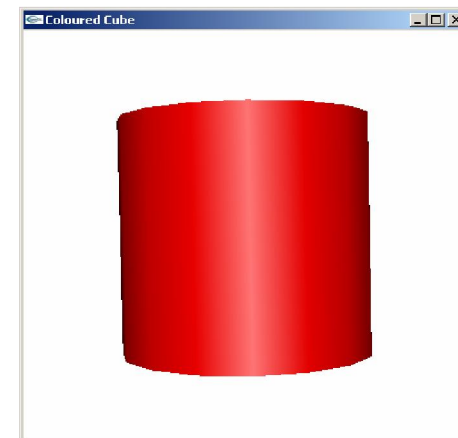
Texture perception (cont'd)

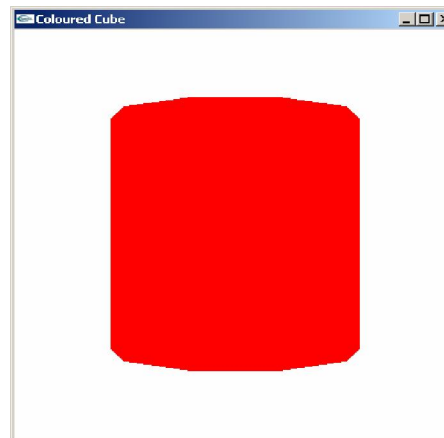© H.C. Nothdurft, "Sensitivity for Structure Gradient in Texture Discrimination Tasks", Vision Research, Vol. 25, No. 12, 1985, pp. 1957-1958.

Shape perception

n **Derived from**

    ·· Luminance gradient

        $\rightarrow$ silhouette contour

        $\rightarrow$ 3D surface shading

    ·· Motion

    ·· Binocular disparity

    ·· Colour

    ·· Texture
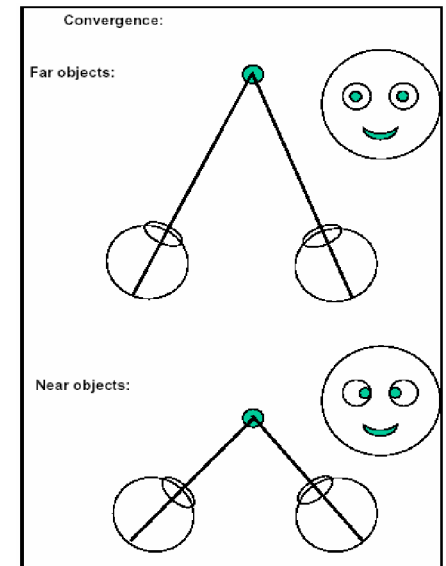
n **Shape perception is orientation dependent**

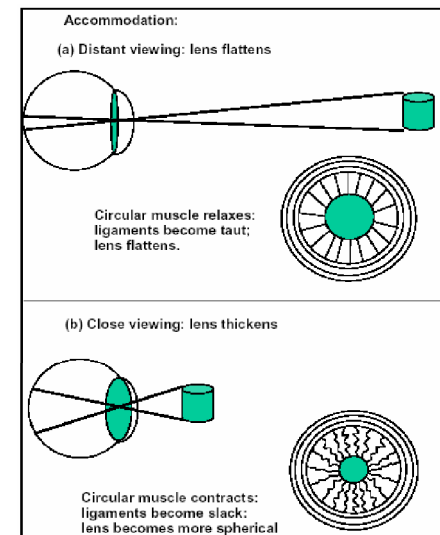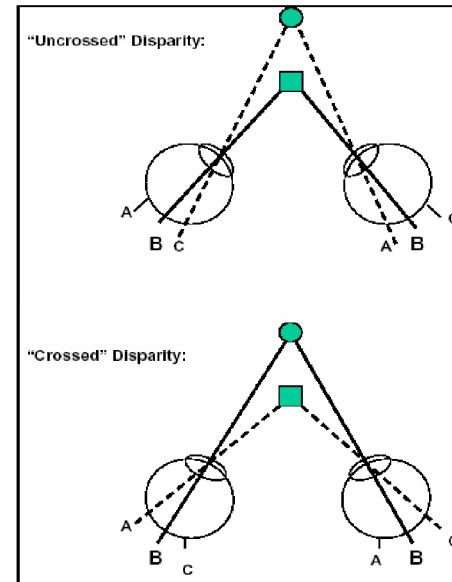# Depth perception

Physiological

n Disparity (stereopsis)

n Convergence

n Accomodation

© 2003, Ronald W. Mayer, Psychology Department, San Francisco State University, http://online.sfsu.edu/~psych200/

Depth perception

Psychological

n Motion Parallax

n Overlay (Interposition)

n Shadows

n Relative Size/Height

n Linear Perspective

n Texture Gradient
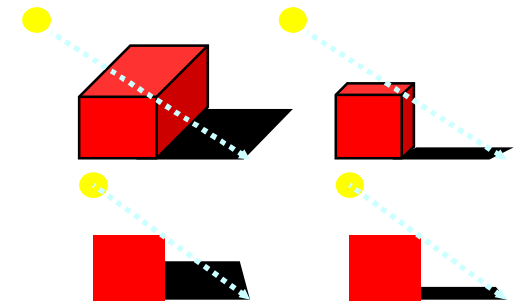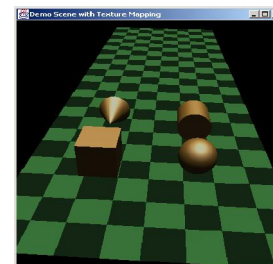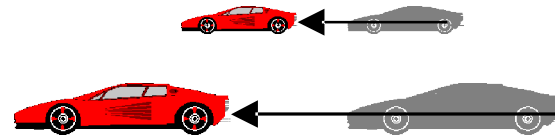
Gestalt perception

n Concept of gestalt originates from the fine arts

"The whole contains more information than the parts"

n Perception influenced by

Proximity, similarity, continuation

closure, area, symmetry
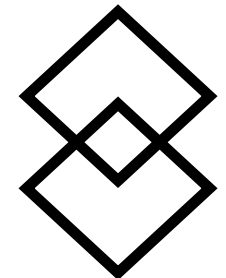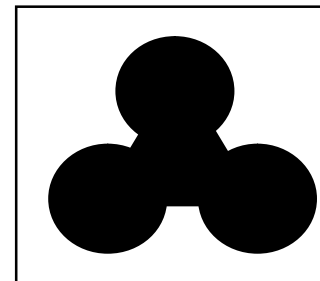
Law of Prägnanz

n the eye tends to see the most stable figure

Colour Perception

n **Colour Resolution**

- human eye can distinguish tens of 1000s of different colors but only 20-30 gray tones.

n **Target identification by colours**

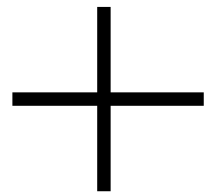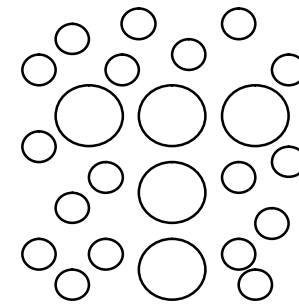- Hot colors (yellow, orange, red, magenta (long wavelength)) catch attention

  → Used to emphasize small regions or features (use high saturation) Hot colors (yellow, orange, red, magenta (long wavelength)) perceived easier.

- Cool colours (violet, blue, cyan, green (short wavelength))

  → Used for large regions or features without special emphasis (use low saturation)

- Linear separation

Colour Perception (cont'd)

Linear Separation
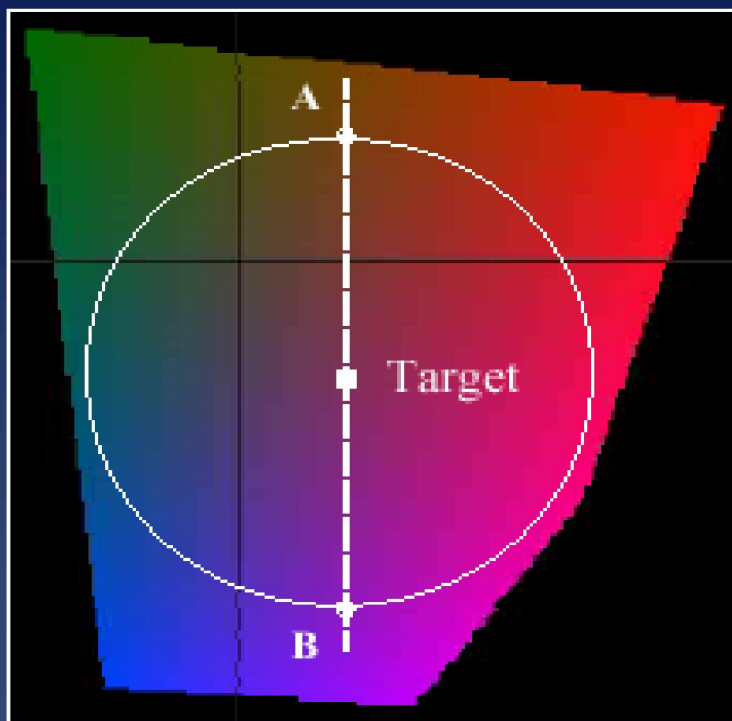
Without Linear Separation: Harder
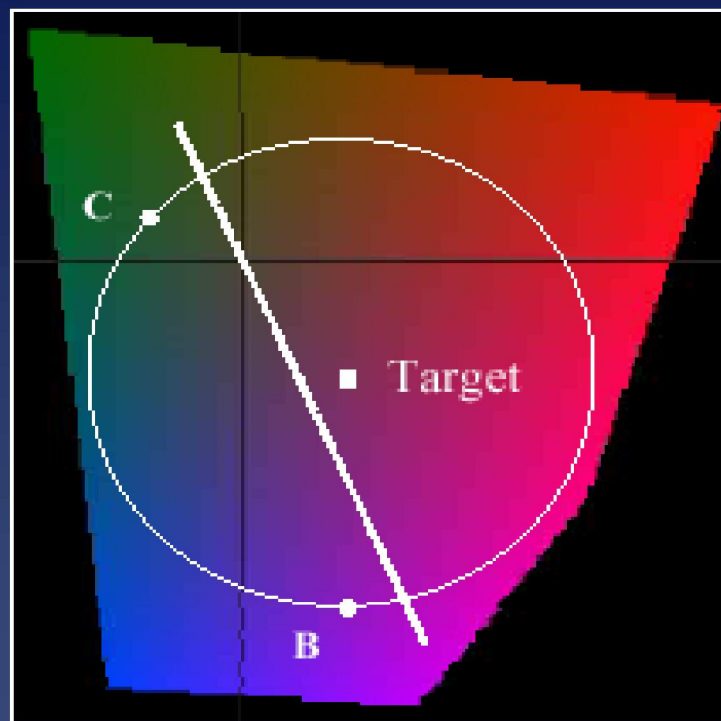
With Linear Separation: Easier

Colour Perception (cont'd)

n **Colour Interpolation**

- RGB colour space is not perceptually uniform

- CIE LUV space is perceptually uniform
  - n Colour with same L value are isoluminant
  - n Perceived colour differences vary linear
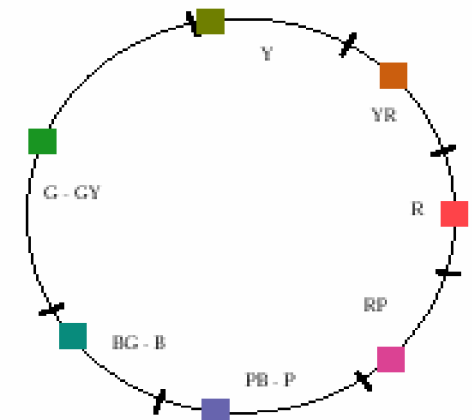
3.5 Optical Illusions

Most optical illusions are the result of

1) Incongruent design elements at opposite ends of parallel lines

2) Influence of background patterns on the overall design

3) Adjustment of our perception at the boundaries of areas of high contrast

4) Afterimages resulting from eye movements or from kinetic displays

5) Inability to interpret the spatial structure of an object from the context provided by the picture.

Simultaneous Contrast

n **Due to Lateral Inhibition**
- Nerves accentuate and exaggerate differences
- Eye's internal real-time edge detector
- Used to detect predators like tigers in the bushes

© 1996-2003 Alexander Bogomolny, http://www.cut-the-knot.org/Curriculum/index.shtml

Simultaneous Contrast (cont'd)
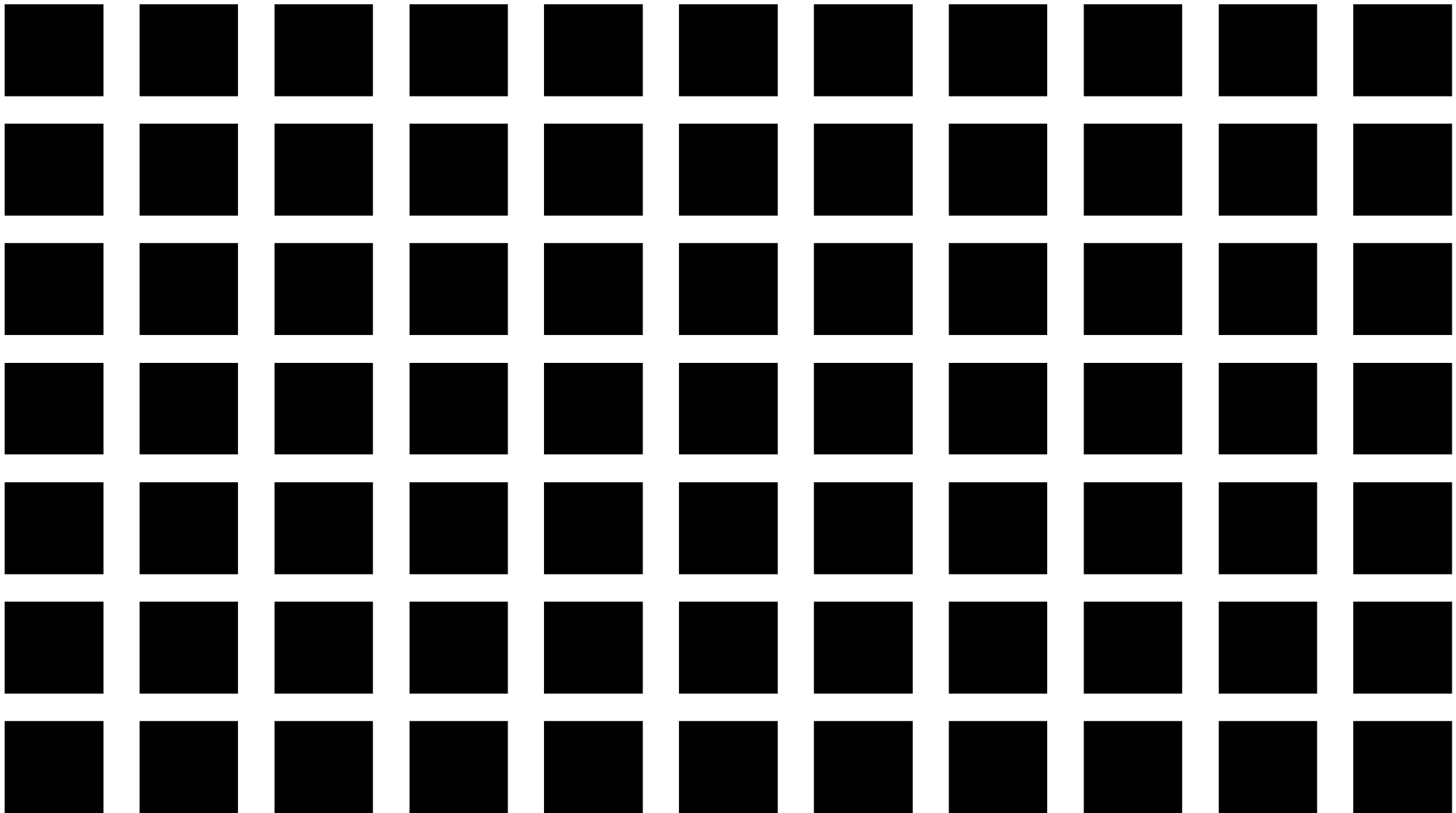
Ponzo Illusion

n Due to Size Constancy

.. size perception depends on the eye's interpretation of depth clues

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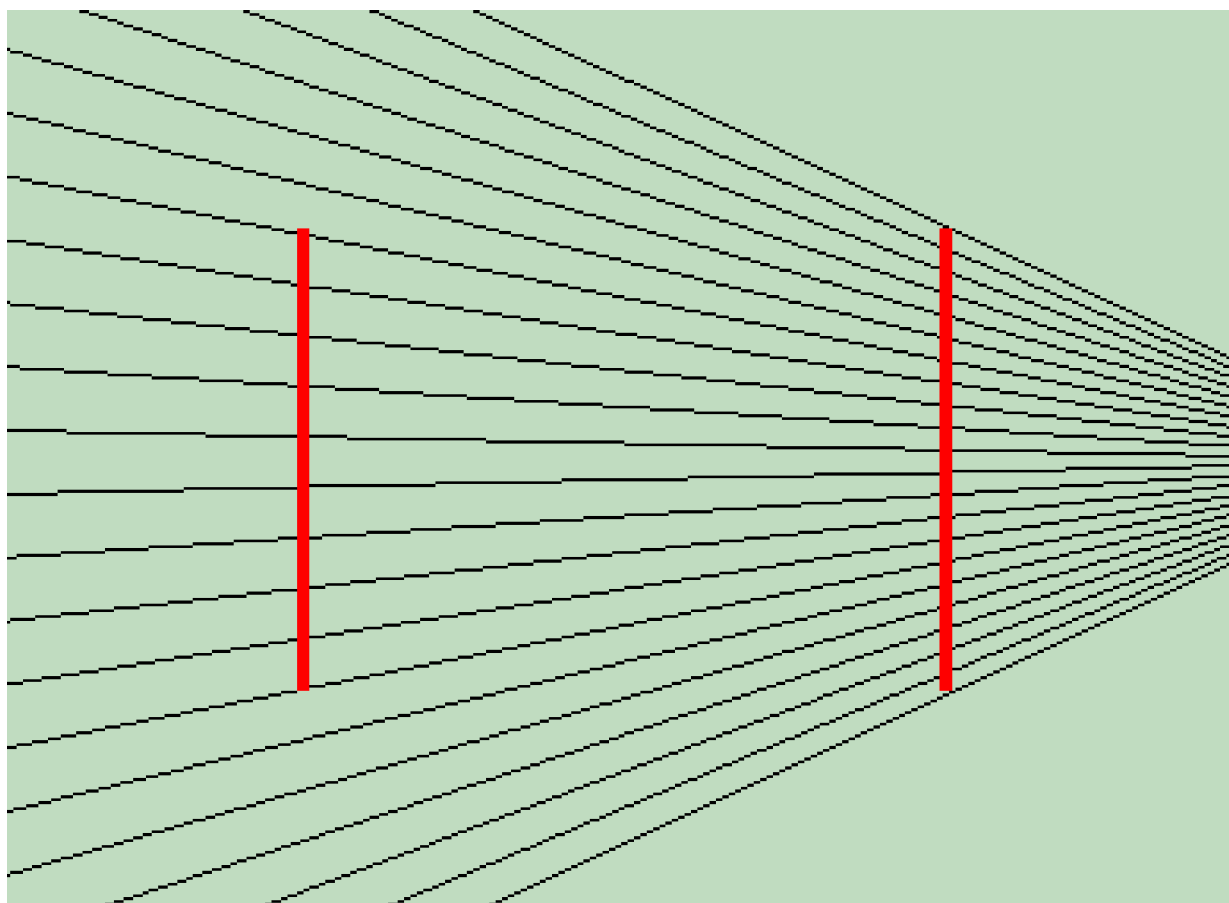
Hering Illusion

n Due to Size Constancy

.. Lines appear to be distorted due to the eye's interpretation of depth clues

© 1996-2003 Alexander Bogomolny, http://www.cut-the-knot.org/Curriculum/index.shtml
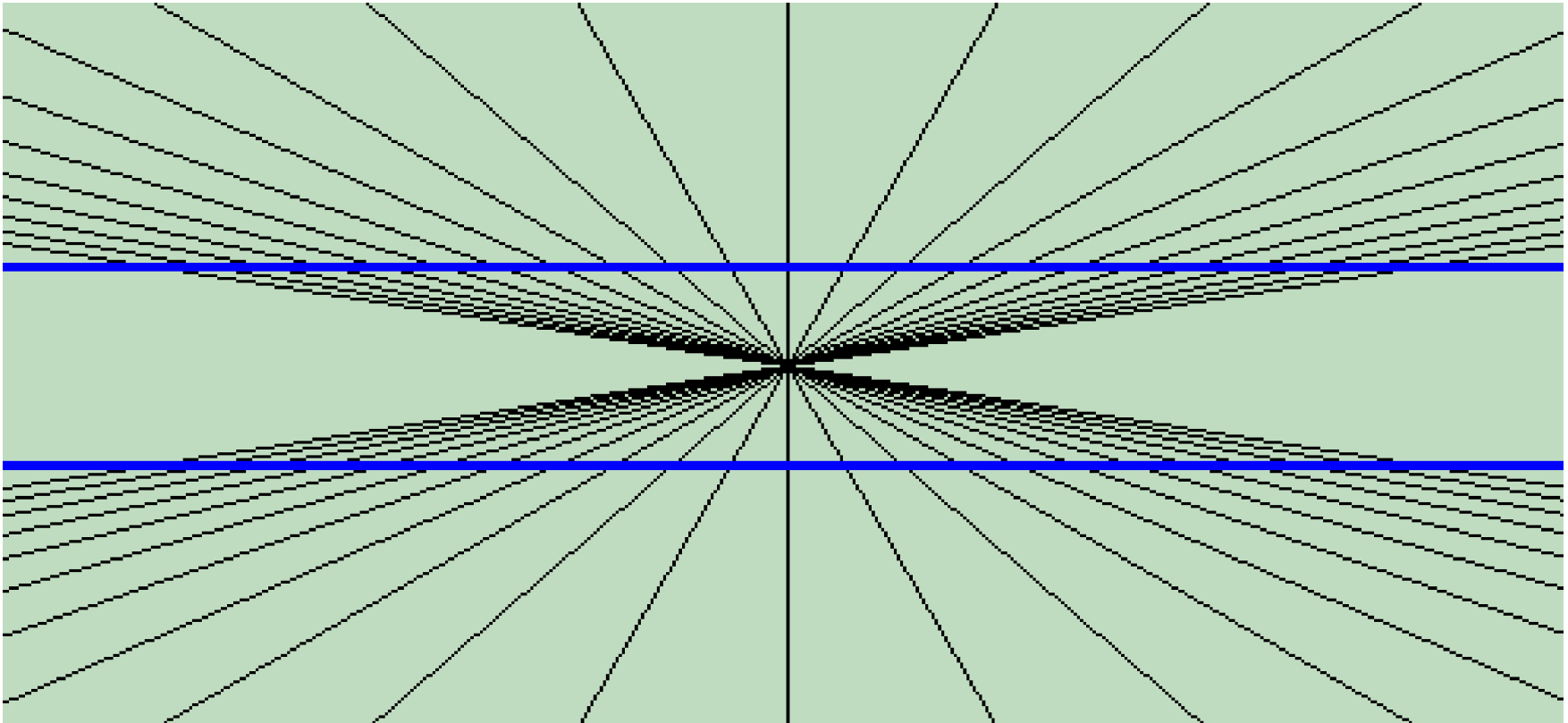
Rubin Vase

n Due to figure-ground perception ambiguities

.. Depending on the perceived background we see either a vase or two faces.
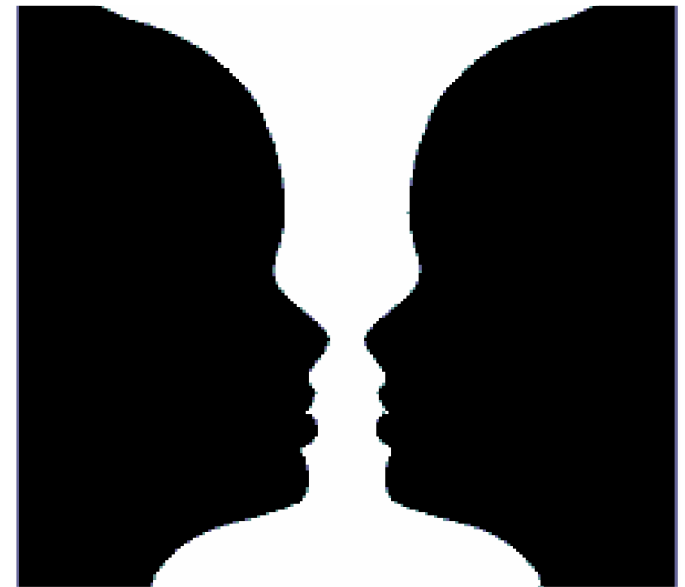
© 2003 McGraw-Hill Books, Terry F. Pettijohn Psychology: A ConnecText, Fourth Edition, http://www.dushkin.com/connectext/psy/

Penrose beams

n Due to continuation, closure, similarity and size constancy

- Beams appear connected since they have equal size and no boundary visible between them.
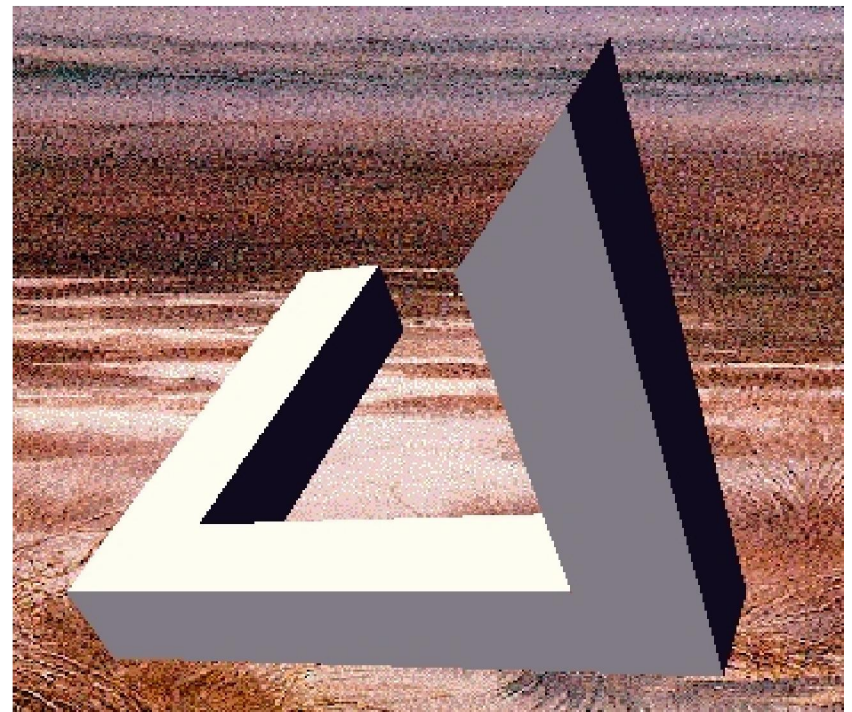
© 2003 Patrick Duverger , http://www.rez-gif.supelec.fr/home_pages/kfra/parad_3d.htm

Afterimages of complementary colors create apparent movement in our peripheral vision as our eyes shift across the page
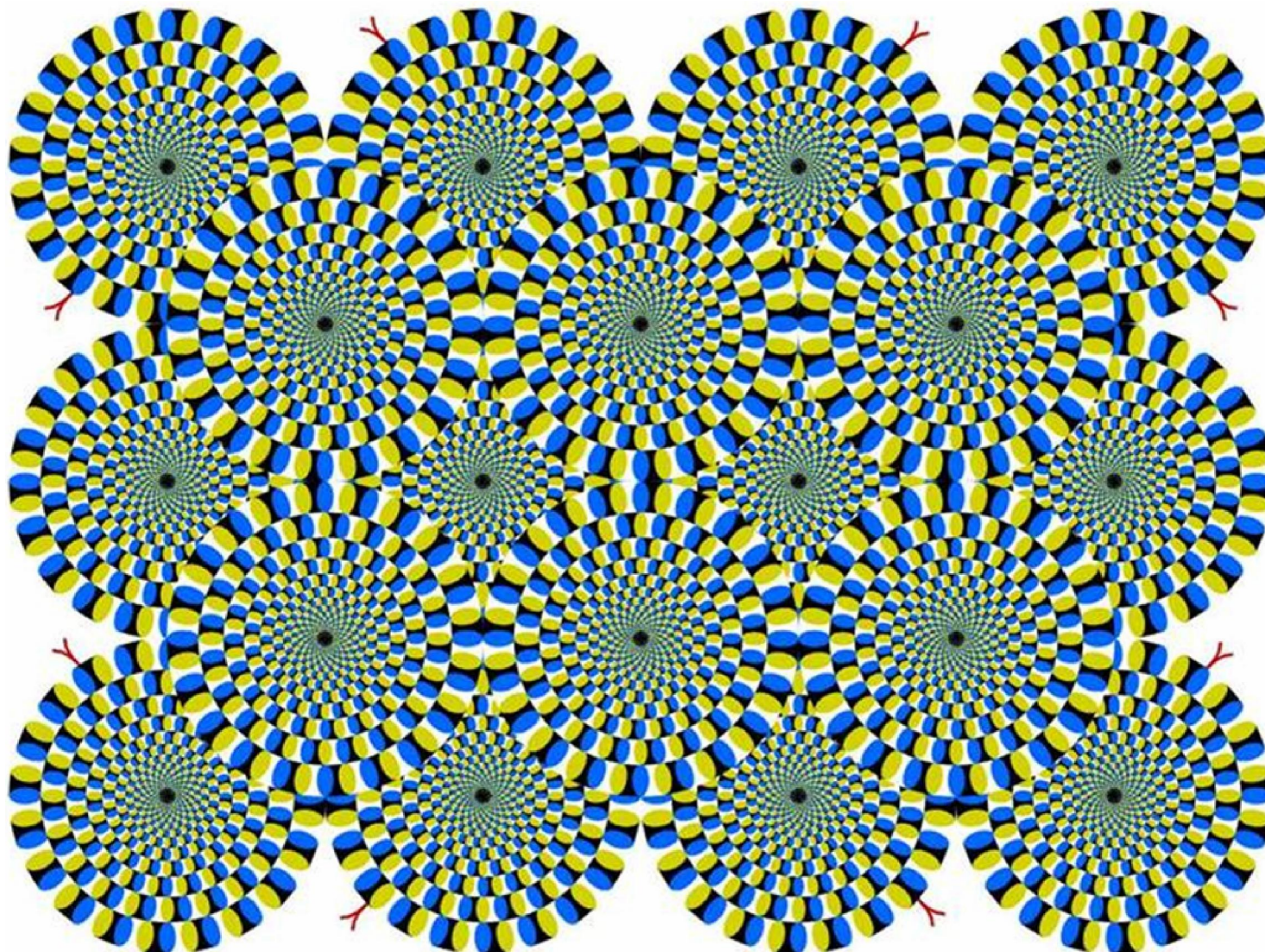
… it really doesn't move! :p
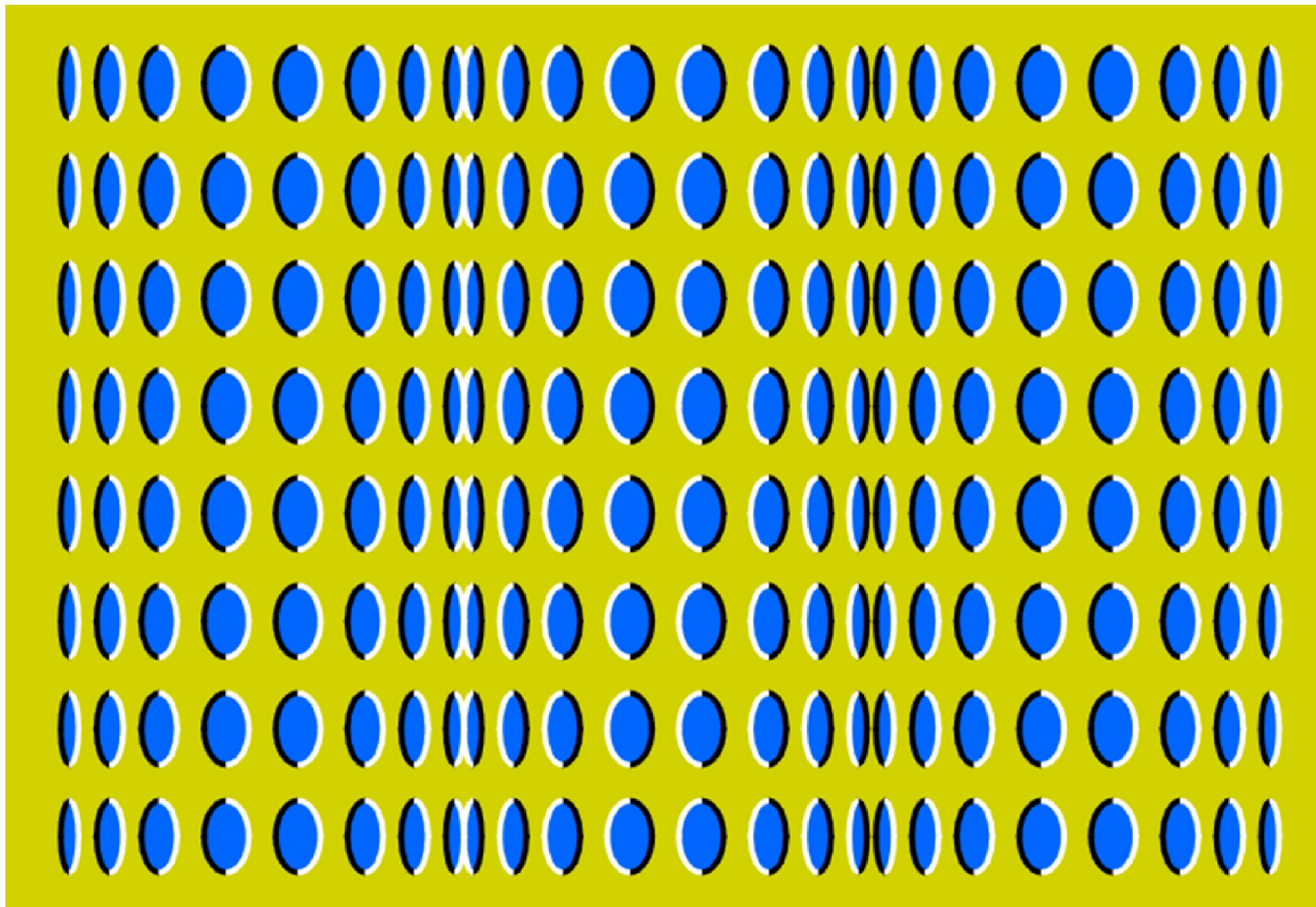
Perception depends on
prior memories!
What do you see?

- An intimate couple

- Or nine dolphins?
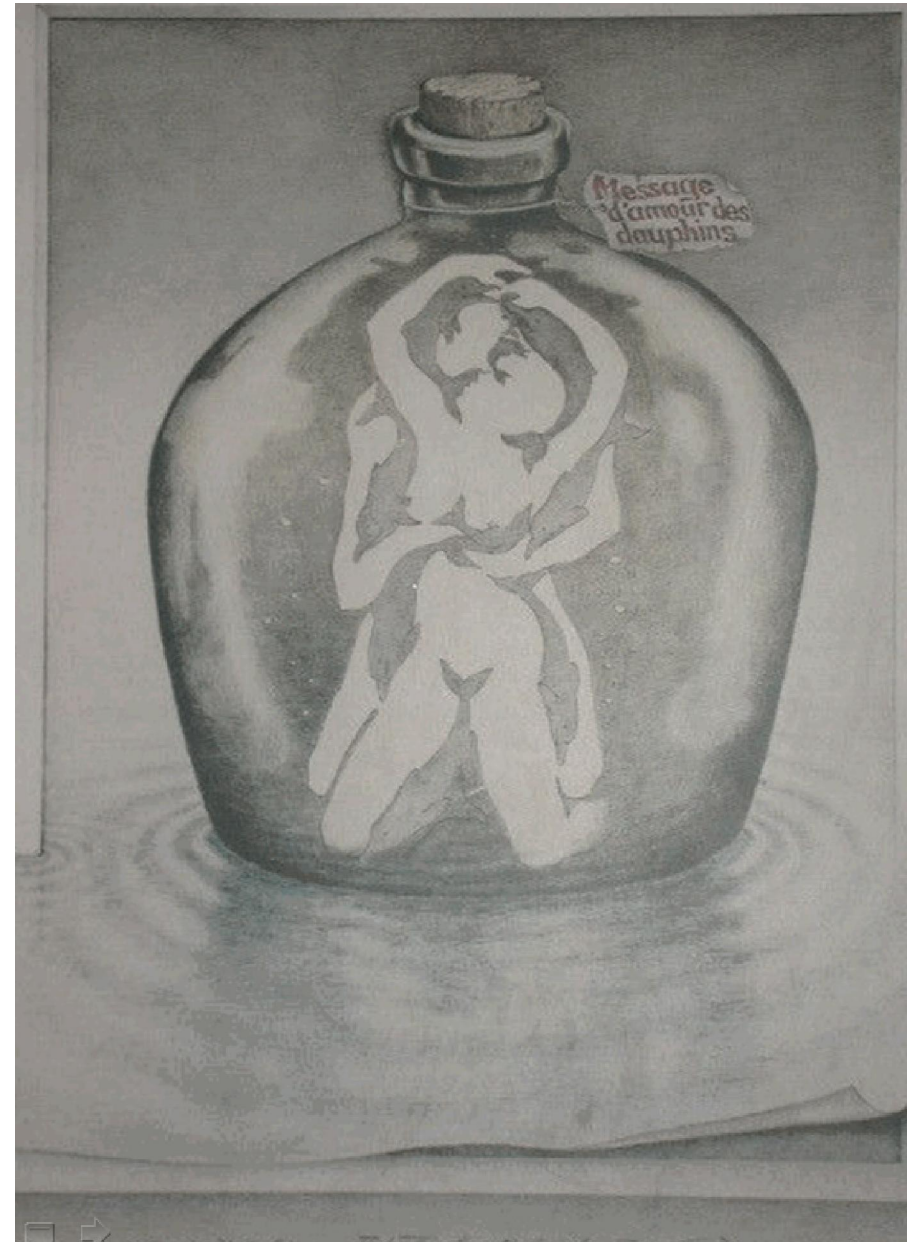
Afterimage

An afterimage is a visual impression that remains in the retina after the initial stimulus is removed. The afterimage always has colors that are complementary to those of the original image.

Look steadily at the cross in the center of the picture to see an afterimage.
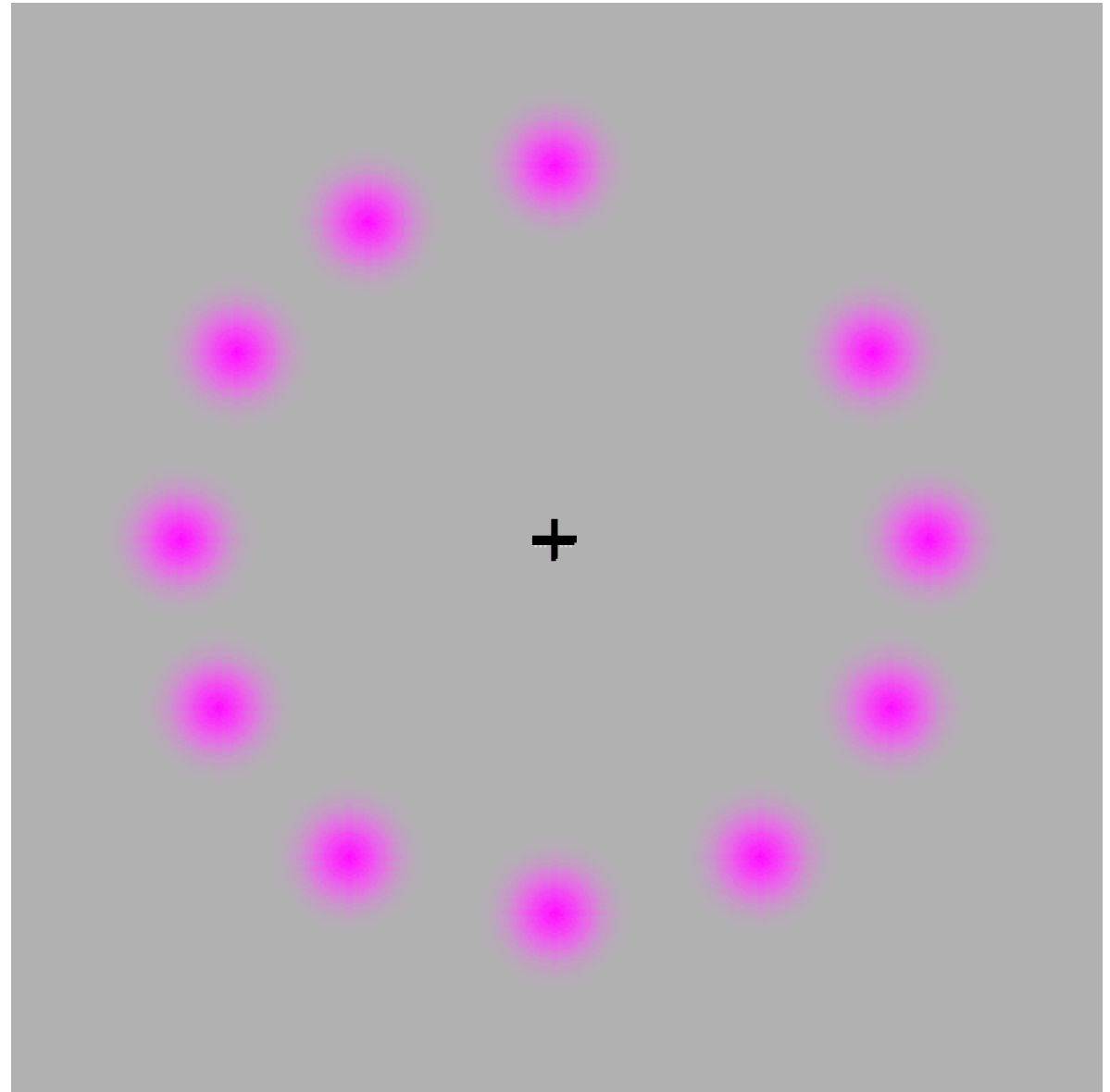
Retinal Fatigue

Hold your head steady and fix your eyes on the dot in the center of the picture. The colored dots will seem to disappear in a few seconds.

The effect is due to *retinal fatigue* which occurs when the afterimage of an object cancels the stimulus of the object on the retina.
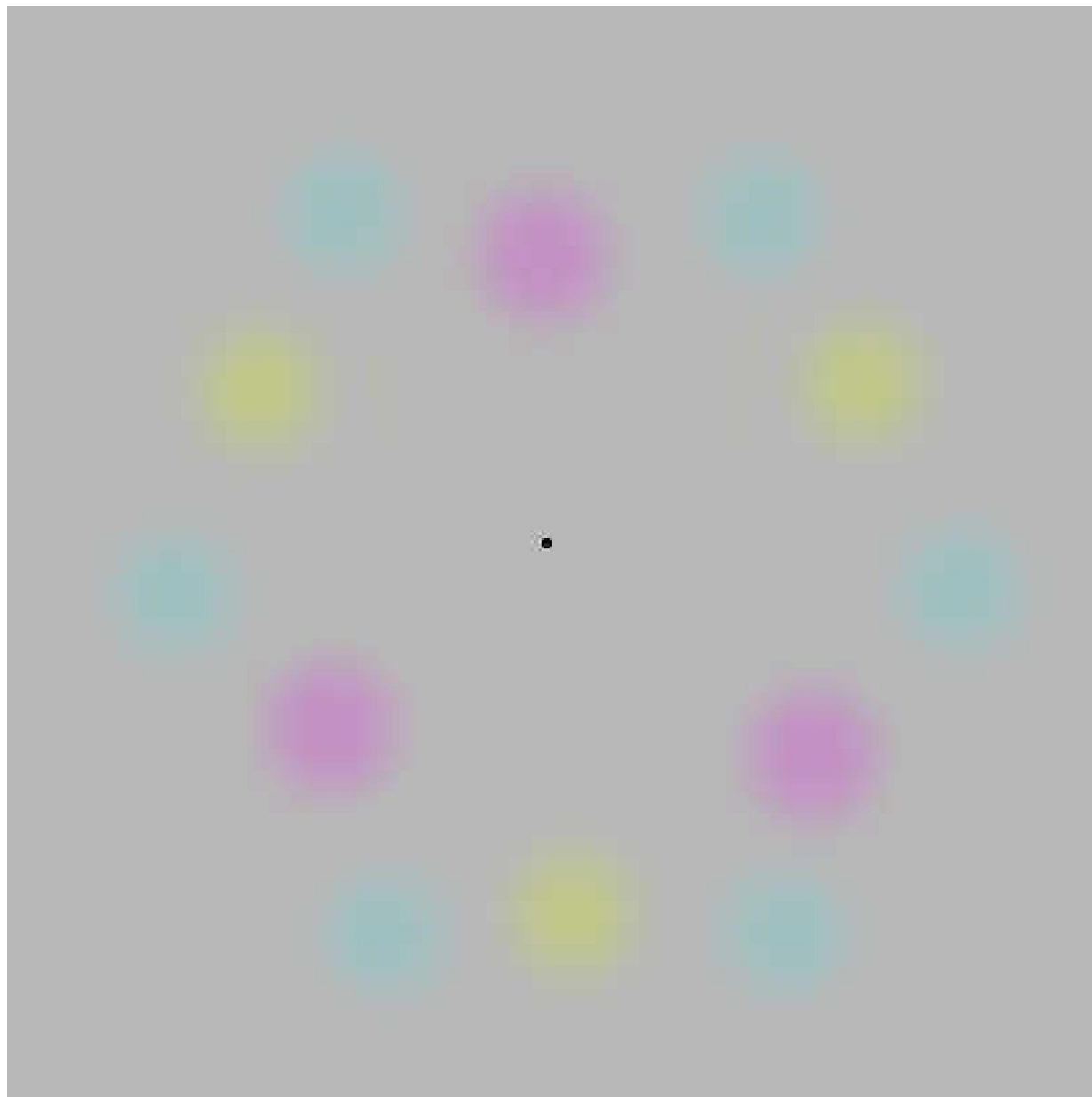
3.6 Human Intelligence

n Humans use information to
- Reason & solve problems
- Even if the info is partially missing or completely absent!

n Human thought is
- conscious & self-aware
- capable of imagination

Reasoning

Inferring missing information

- **Deductive – conclusions**
  - The phone rings when I'm in the shower

    (*If* I'm in the shower, *then* the phone rings)

- **Inductive – generalizations**
  - Specific A has property B then all A is B

    (Birds can fly, Geeks are rich,...)

- **Abductive – suppositions**
  - From fact to the action that caused it

    (Wet streets, Broken window and soccer ball inside the room, Black eye, …)

Problem Solving

Using knowledge to find a solution

- **Gestalt theory**
  - *Reproductive* problem solving (Learned behavior, trial and error, …)
  - *Productive* problem solving (Invention, innovation, insight)
- **Problem space theory**
  - Mapping out a solution step by step (Problem states, goal state, current state, Legal state transition operators, …)
- **Analogy**
  - Applying one solution to a different problem (Purely productive reasoning is hard (10%), Drawing analogies is easier (80%))

Human intelligence and the visualization process

Memorised information, reasoning skills and problem solving skills are used in the visualization process for:

- Cognition of the visualization

- Interpretation and understanding of the visualization

] A visualization should always be designed with the user in mind!

3.7 References

- Christopher Healey, Victoria Interrante and Penny Rheingans, *Fundamental Issues of Visual Perception for Effective Image Generation*, SIGGRAPH 1999, Course Note # 6
- Harvey Richard Schiffman, *Sensation and Perception: An Integrated Approach*, John Wiley & Sonds, 4th Ed, 1996
- James A. Ferweda, *Fundamentals of Spatial Vision*, in *Application of visual Perception in Computer Graphics*, SIGGRAPH 1998, Course Note # 32
- Eugene Hecht, *Optics*, 2nd Ed, Addison Wesley, 1987
- S. J. Williamson, H. Z. Cummins, Light and Color in Nature and Art, Wiley 1983.
- A. Seckel, *The Art of Optical Illusions*, Carlton Books, 2002
- … and numerous web pages!