Designing Applications that See
Lecture 2: Human Vision and Perception

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10 January 2008

Reminders

- Fill out the online course sign-up sheet
- Assignment #1 released next Tuesday, due one week later
- Remember to check the course calendar for the latest readings, and the course home page for announcements

Why Are People Taking CS377S?

- “I haven't taken any computer vision courses to date, so I'm interested in learning some basics.”
- “I've heard great things about it from previous students, and I've always wanted to take a computer vision course, but have been scared away by the theory.”
- “I want to build a dance interface! ”
- “It seems like a good application of my past Computer Vision and Graphics coursework, and I've always wanted to take an HCI-type course.”
- “Webcams are unlike any other input device, so I'm hoping that learning to make use of them will inspire new design opportunities.”
- “Because Monzy's gonna rap the lectures.”

Today's Goals

- Learn how human visual processing works
- Compare human vision to computer vision
- Understand the limits and constraints of human vision
- Discuss some relationships between vision, perception, and cognition

Outline

- Overview of visual system
- Constraints of human visual processing
- Shortcuts, “hacks,” and illusions
- Vision and cognition

A Bad Model of Human Vision

1. Eye captures scene

2. Images sent to brain for processing

3. Brain updates model of world

4. React and repeat loop

Problems with this Model

1. Eyes are not passive receptors; vision is an interactive process.

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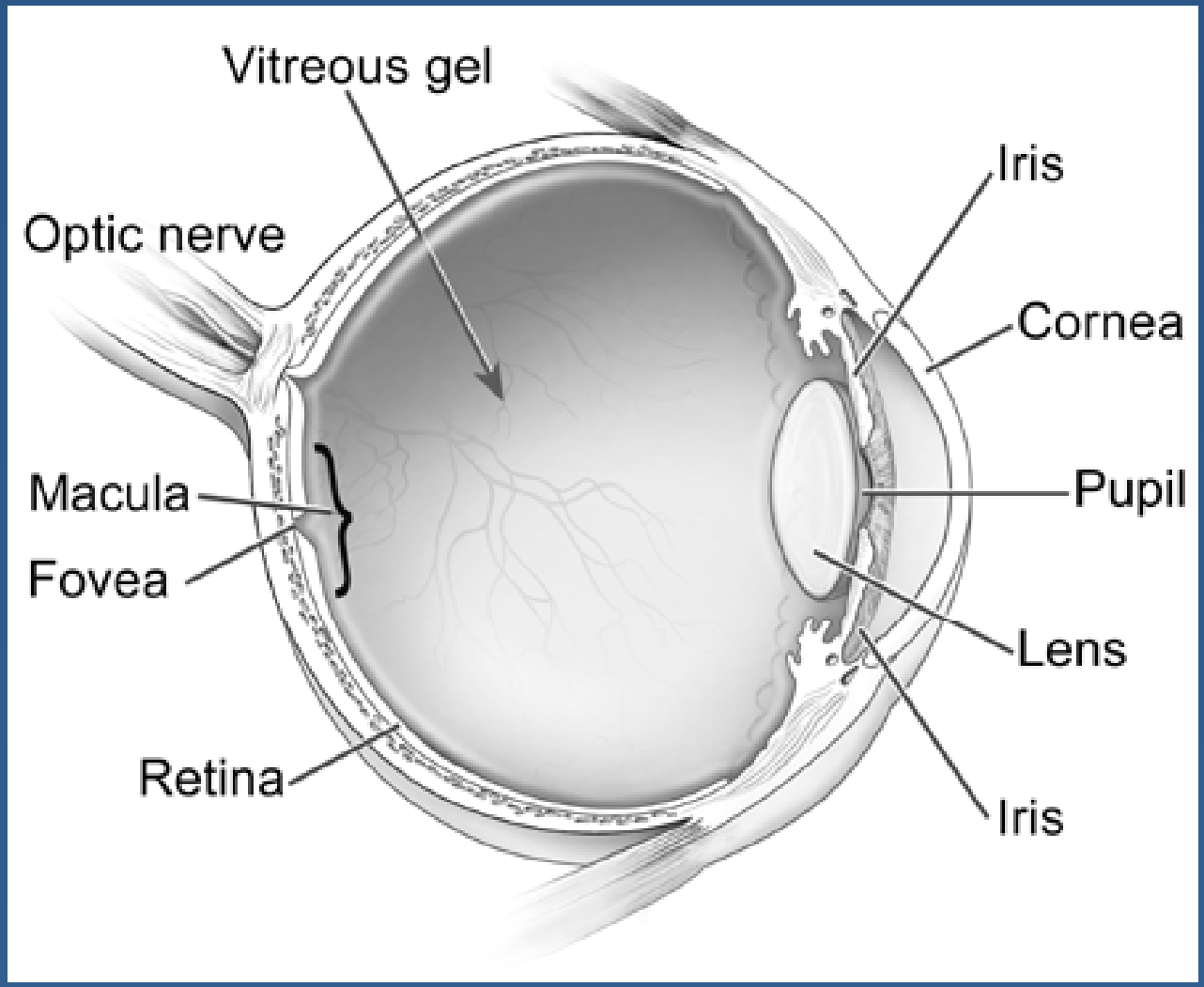
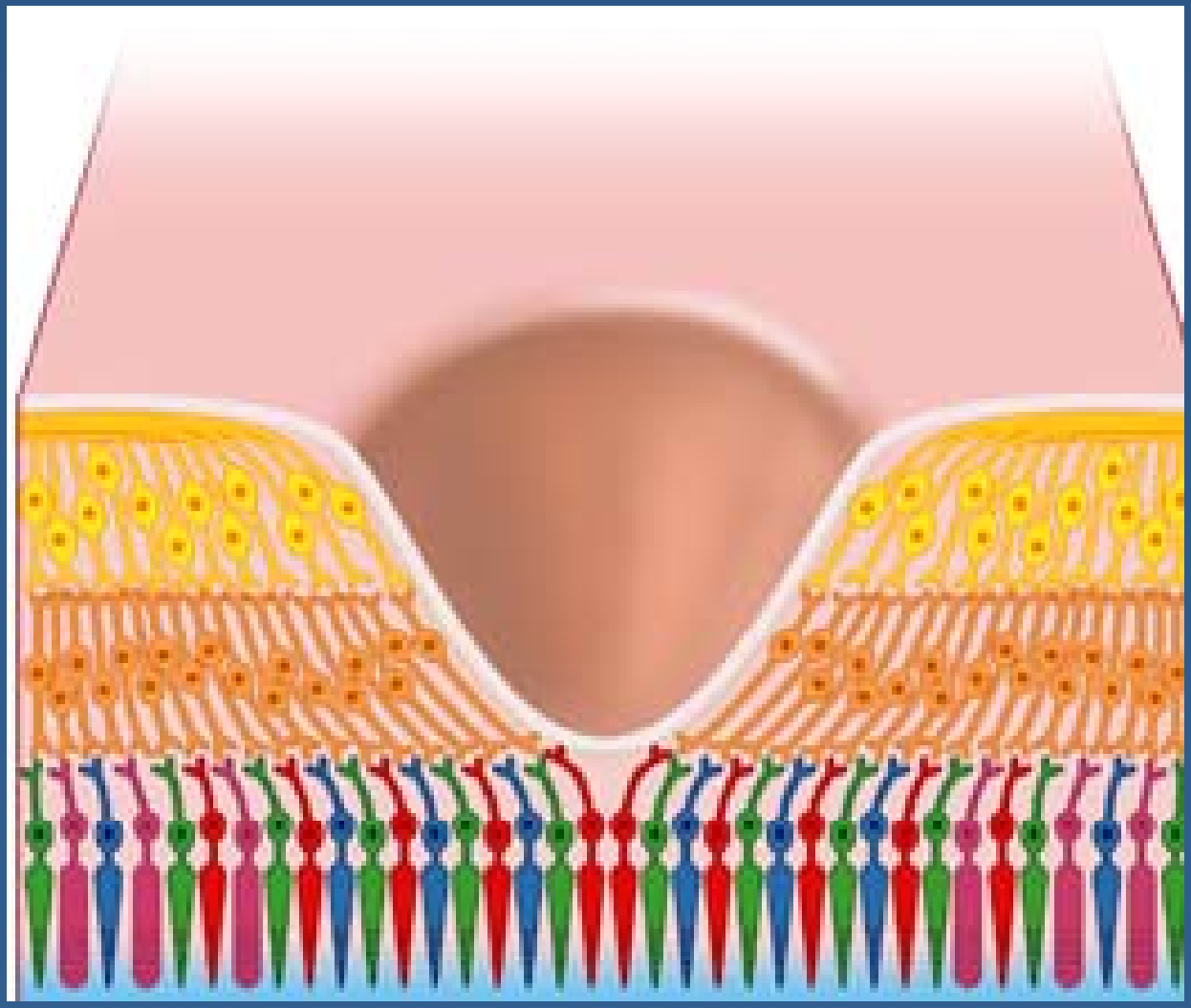
1. Eyes are not passive receptors; vision is an interactive process.
2. Processing is not serial, and reactions and decisions are made at different stages.
3. We see a complex world, not just colors, shapes, and motion.

The Retina



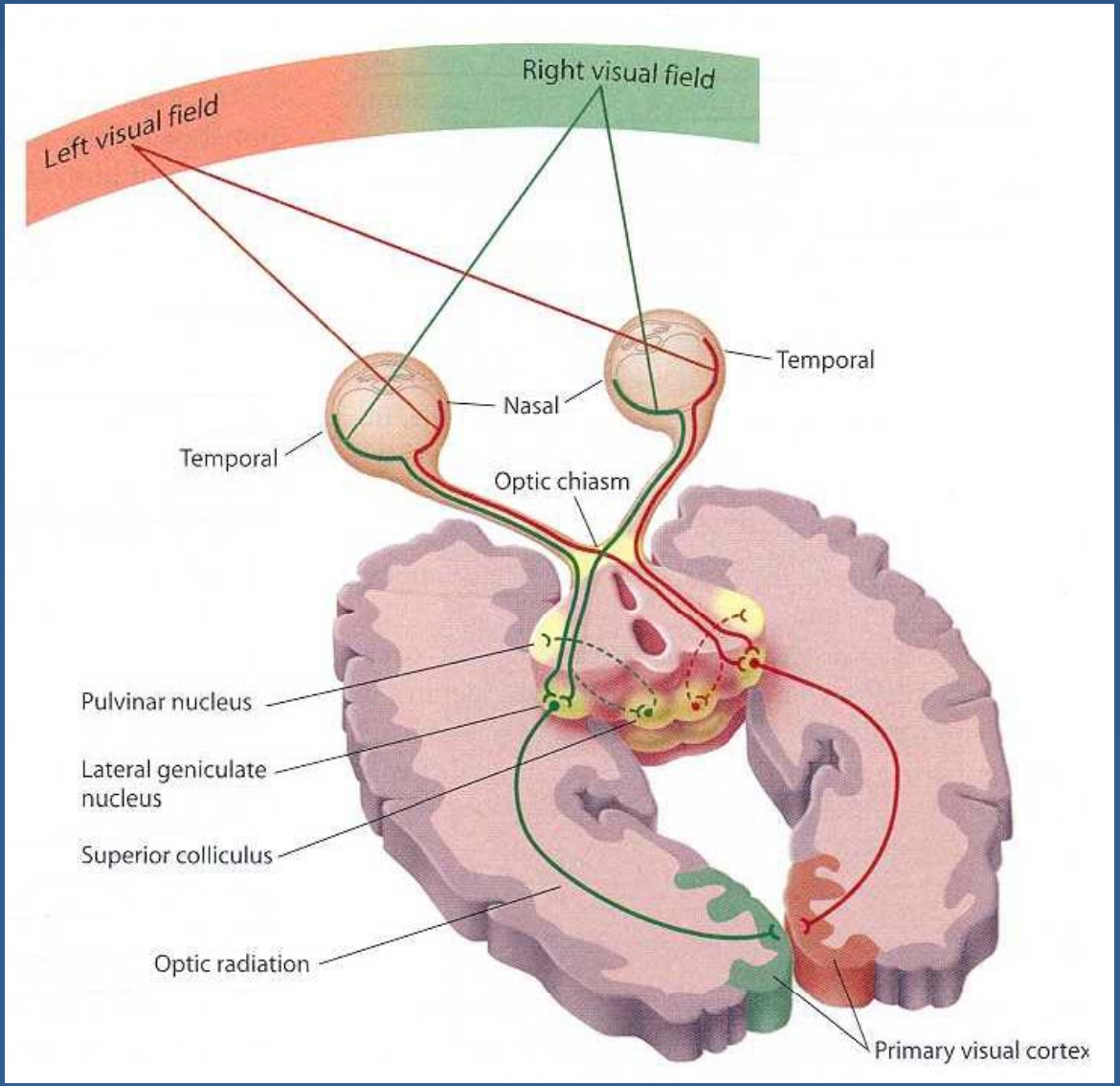
(courtesy of National Eye Institute)

The Fovea

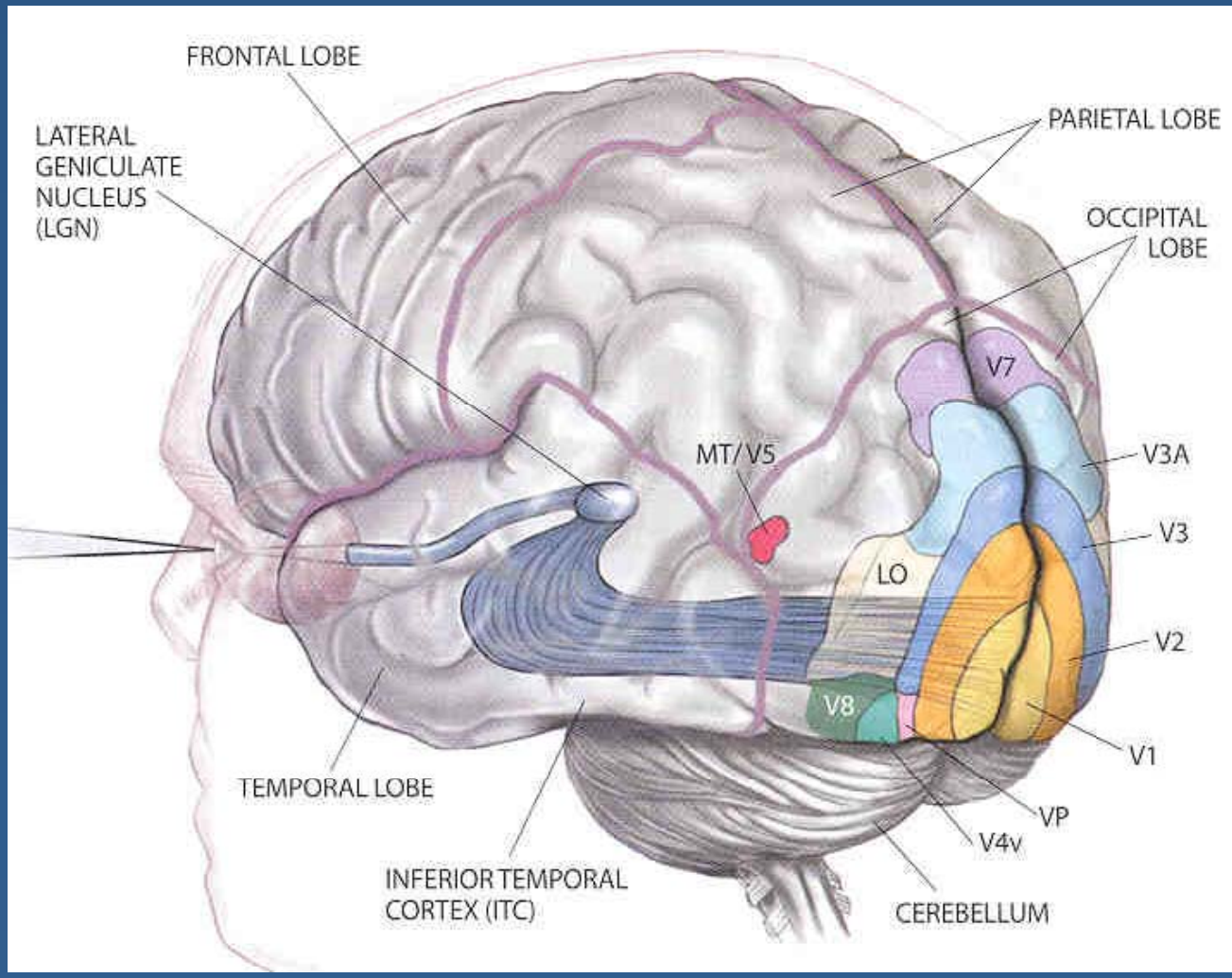


(courtesy of Brain Connection)

Behind the Eyes



In the Visual Cortex

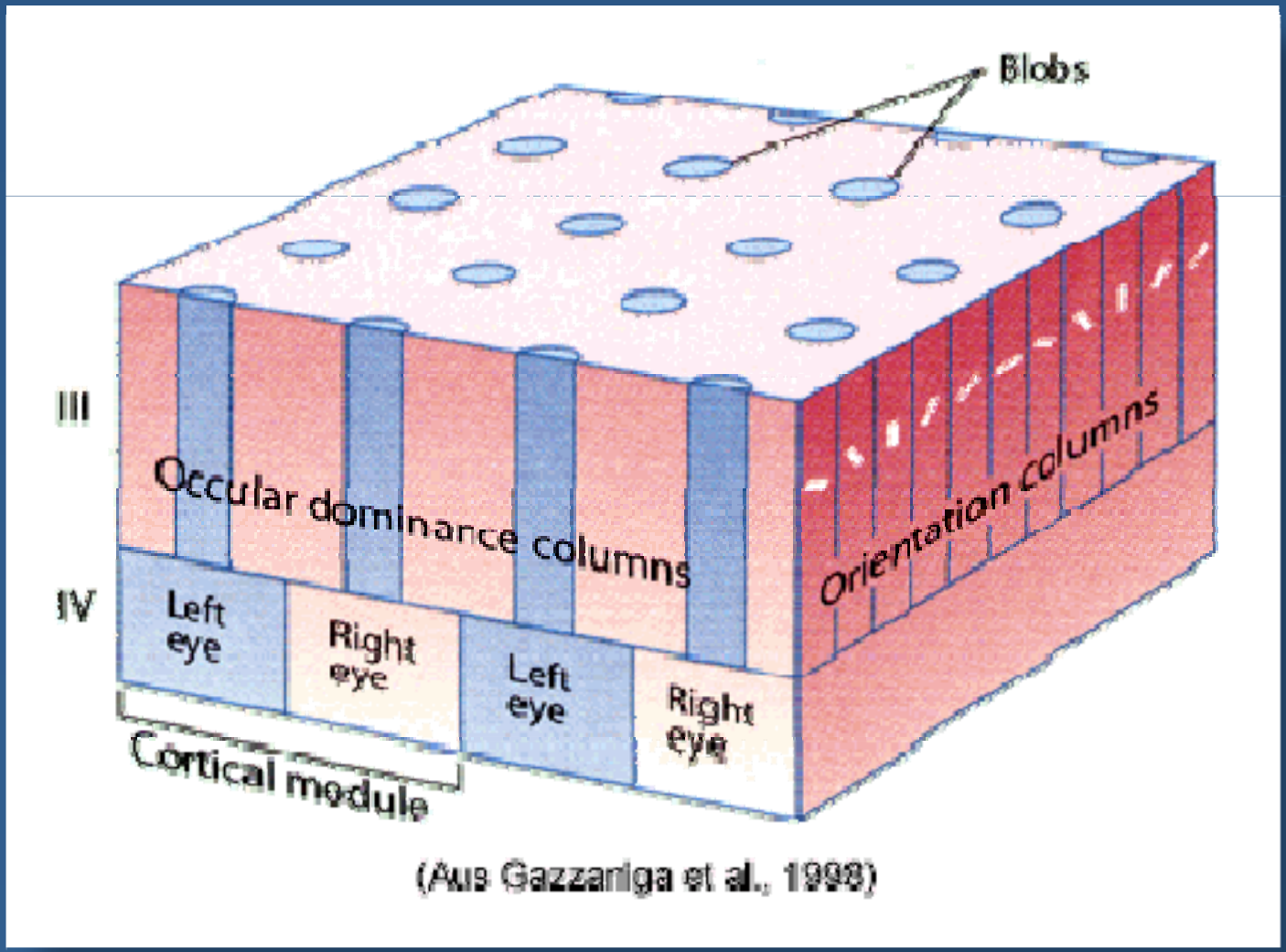


KEY TO FUNCTION

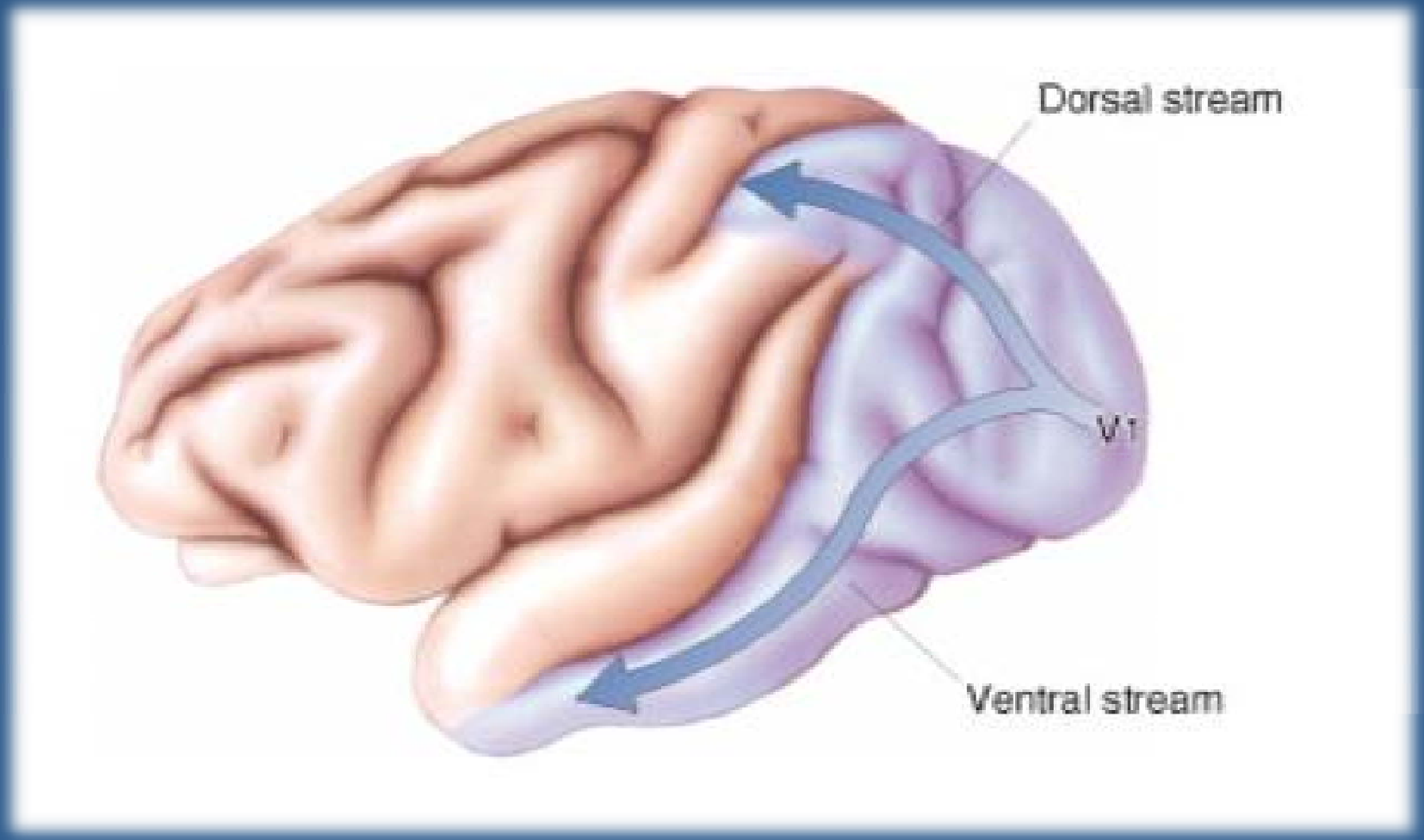
- **V1:** Primary visual cortex; receives all visual input. Begins processing of color, motion and shape. Cells in this area have the smallest receptive fields.
- **V2, V3** and **VP:** Continue processing; cells of each area have progressively larger receptive fields.
- **V3A:** Biased for perceiving motion.
- **V4v:** Function unknown.
- **MT/V5:** Detects motion.
- **V7:** Function unknown.
- **V8:** Processes color vision.
- **LO:** Plays a role in recognizing large-scale objects.

Note: A V6 region has been identified only in monkeys.

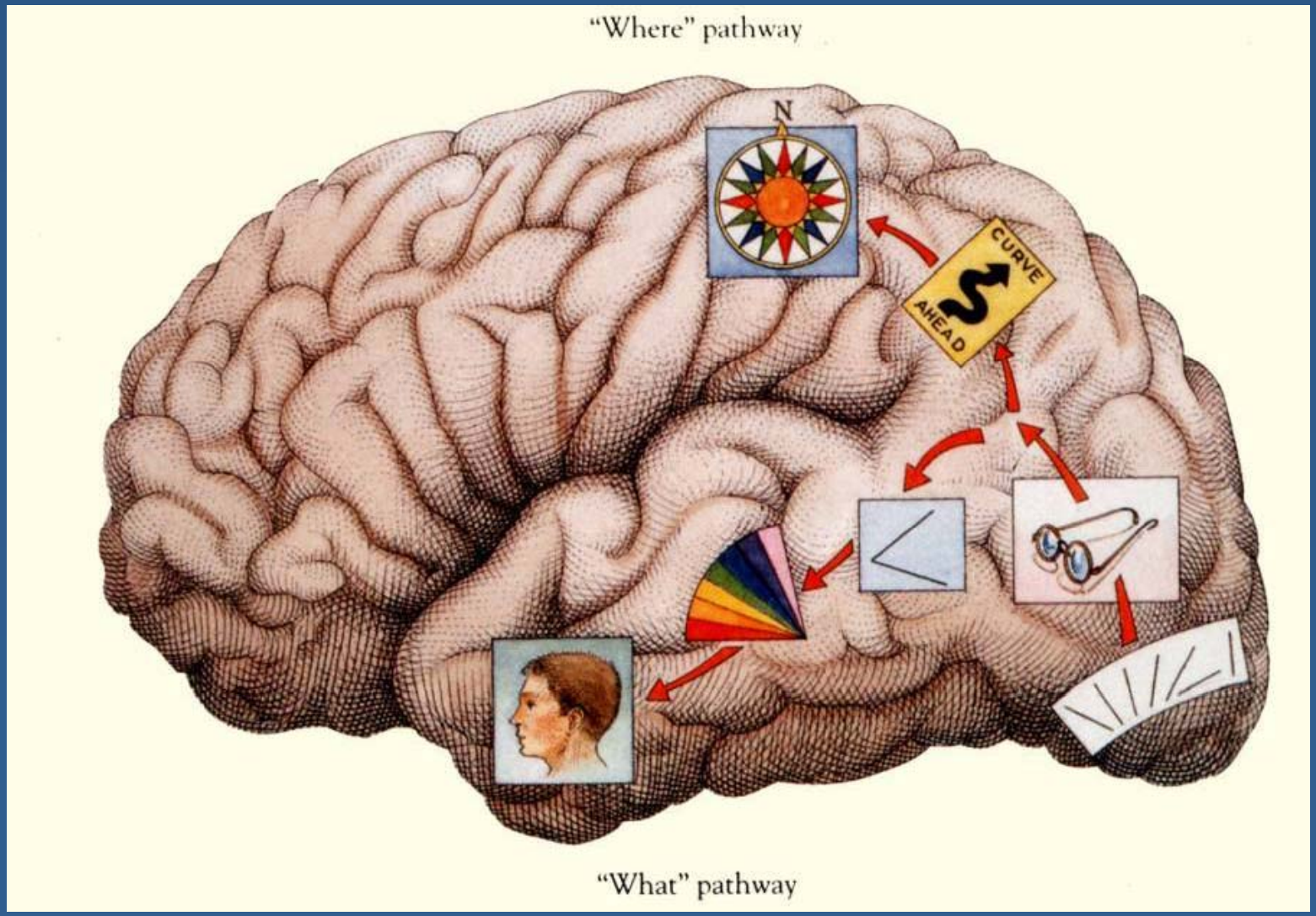
Hypercolumns



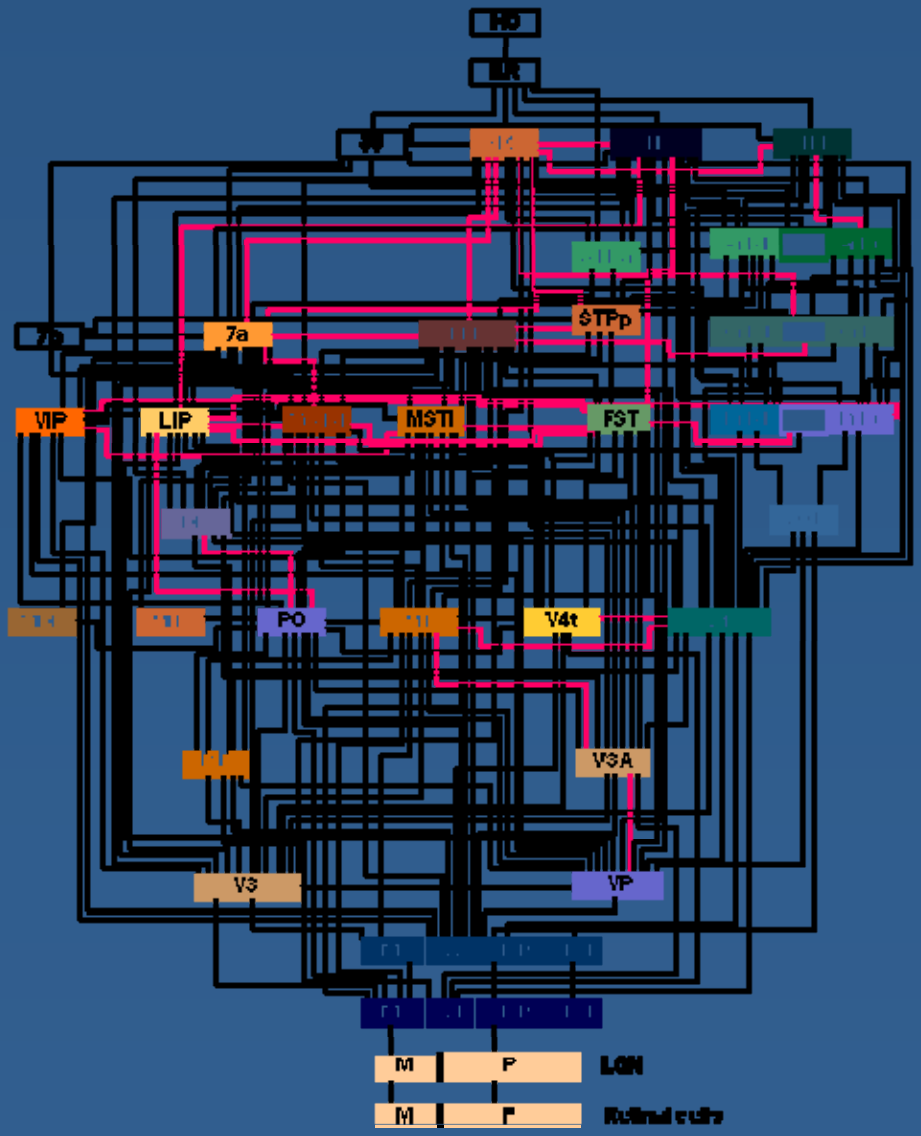
Processing Streams



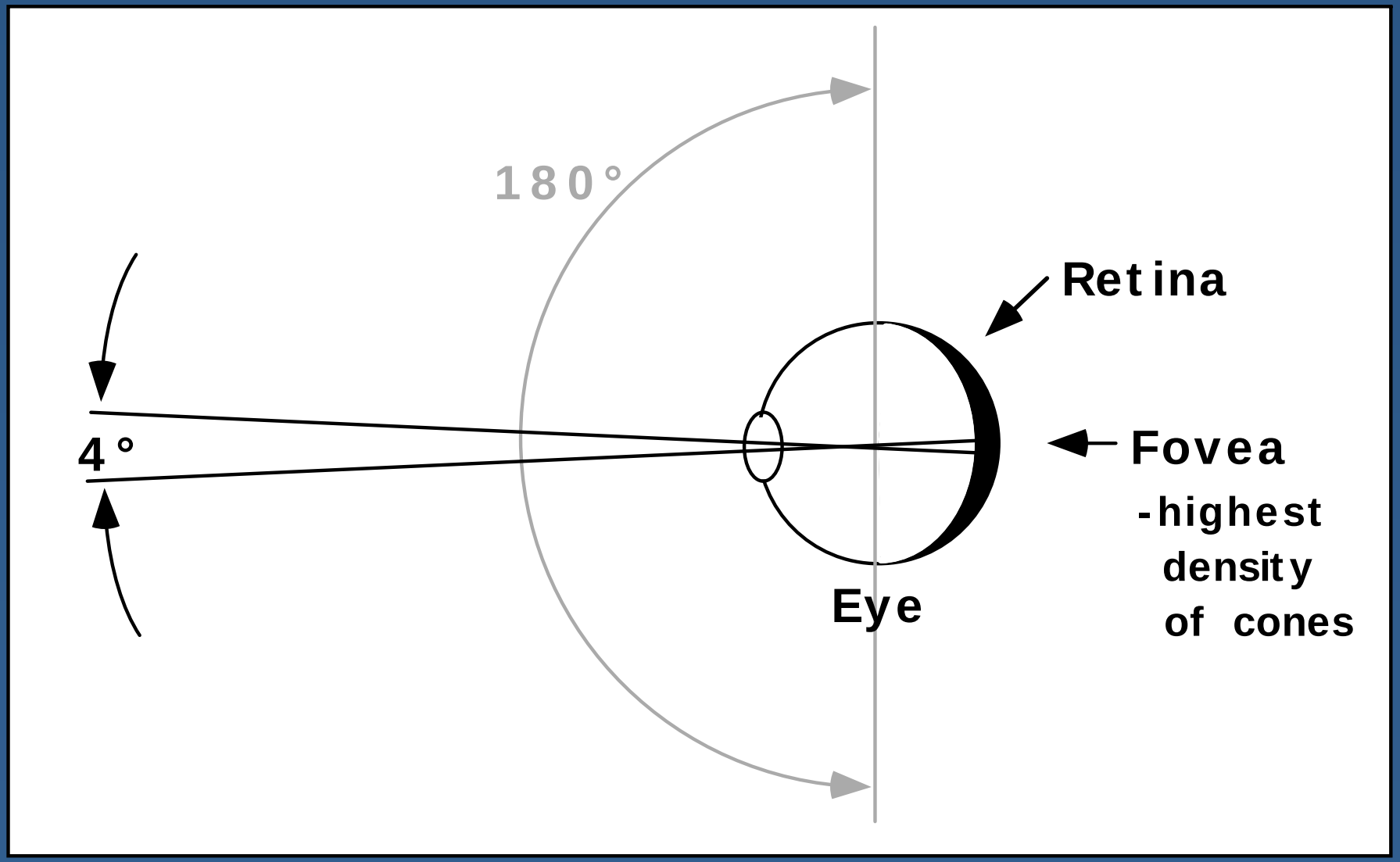
Processing Streams



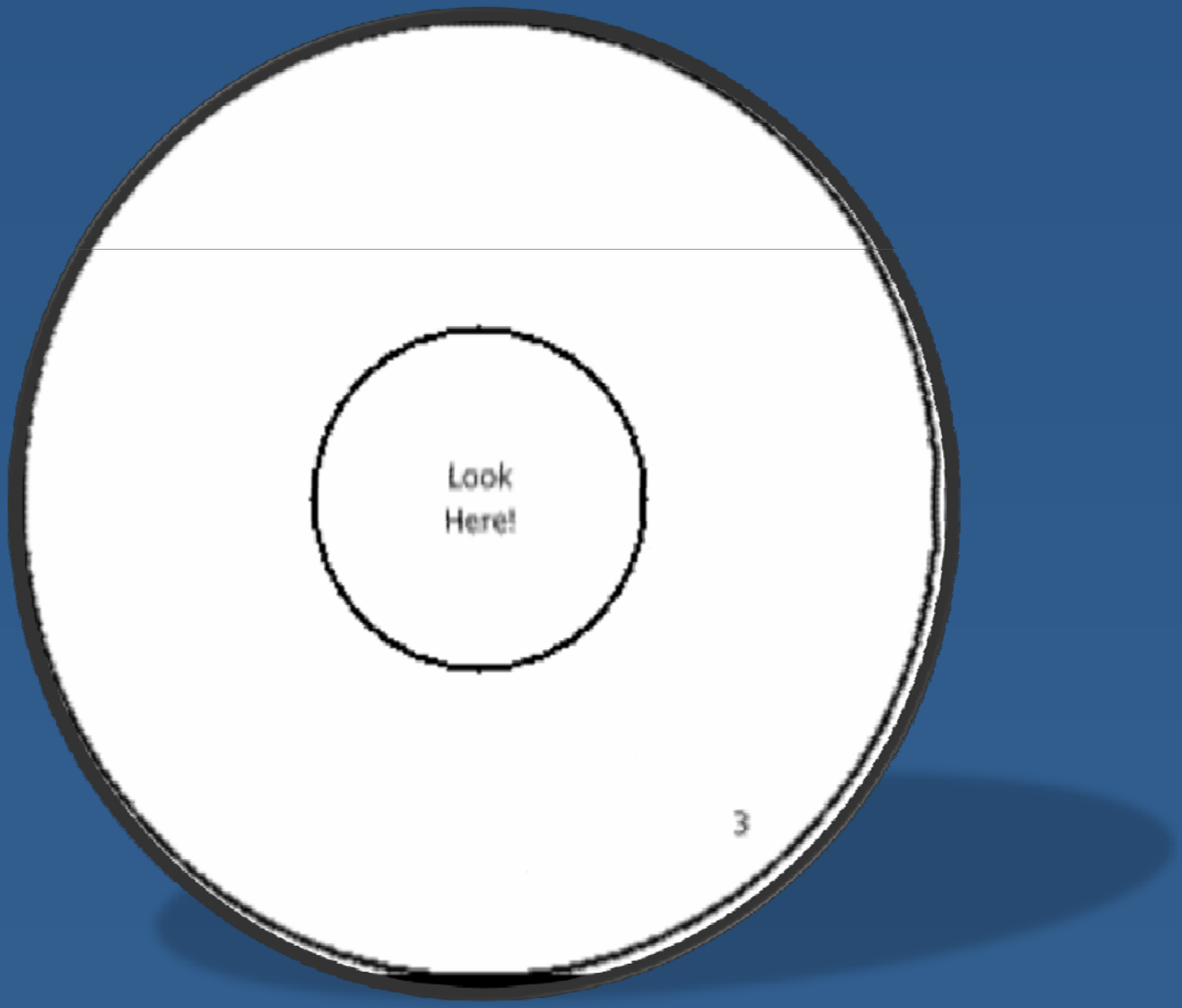
Higher-Order Functions



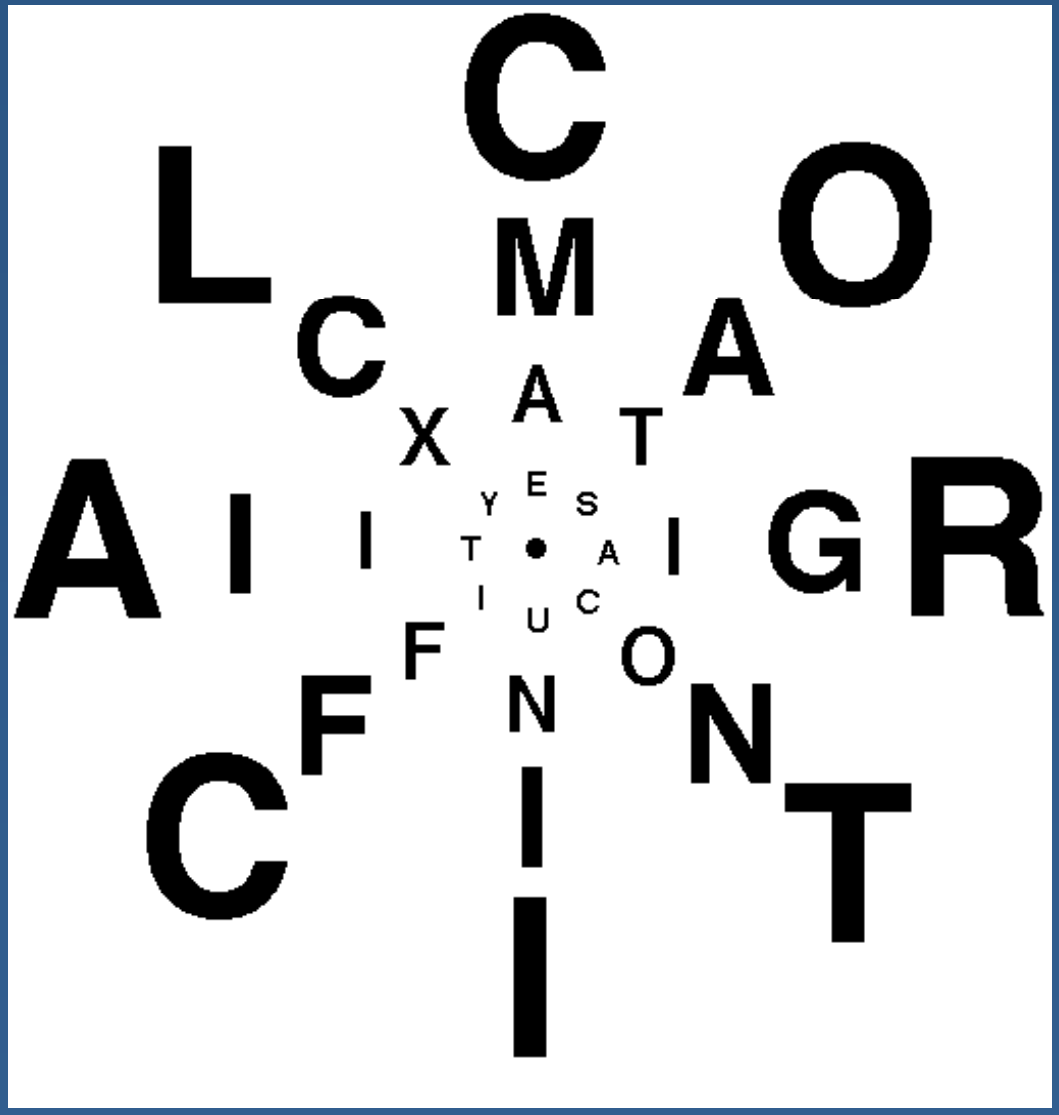
Resolution Limits



Fovea Demo

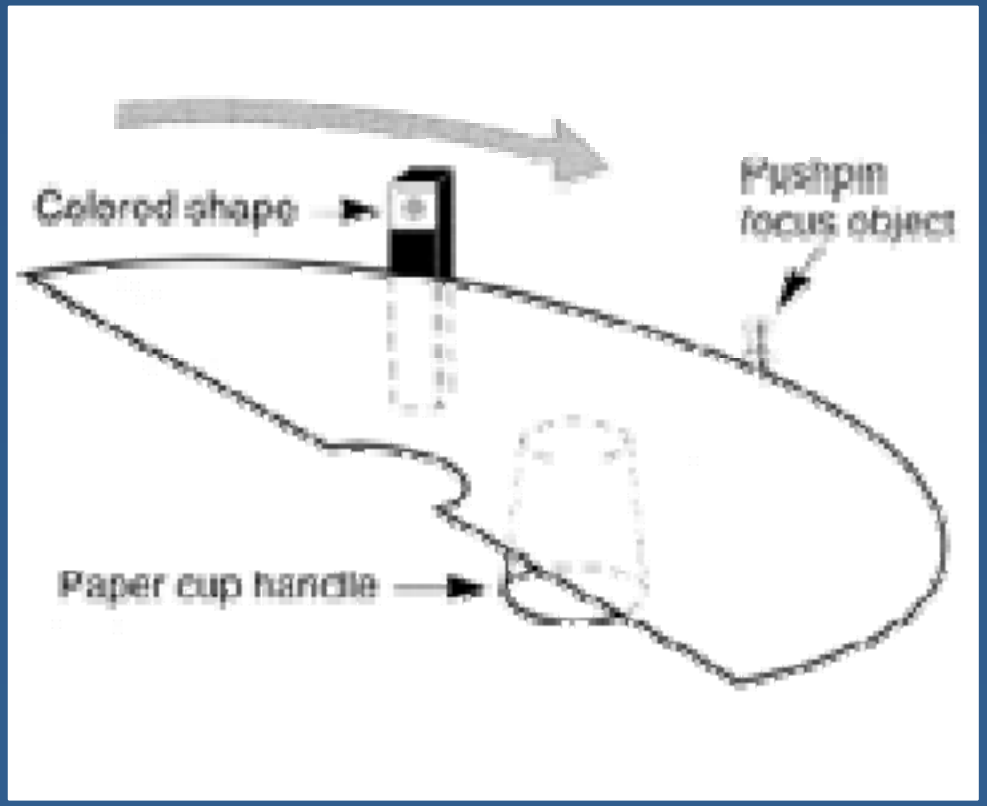


Foveal Eye Chart



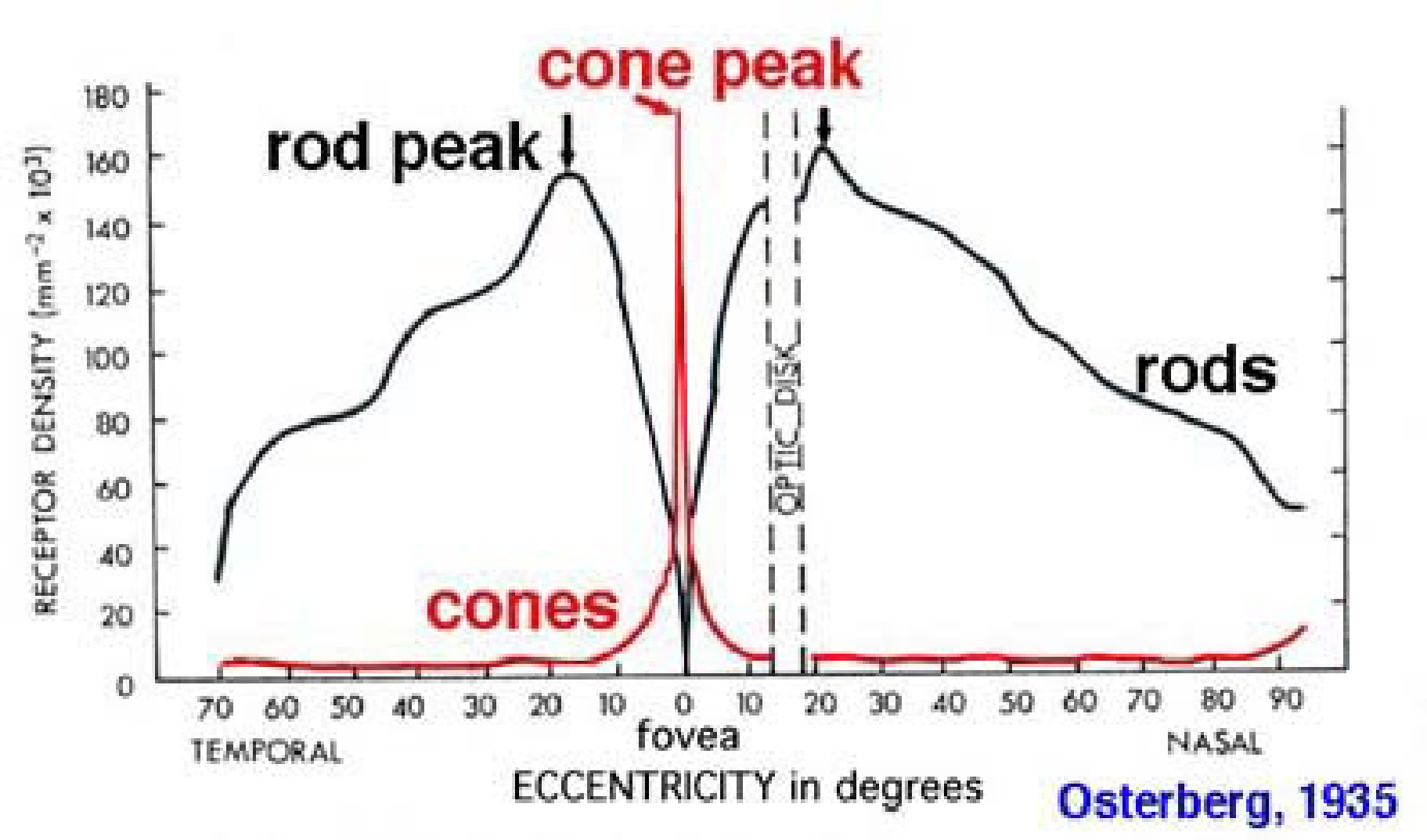
(courtesy of Stuart Anstis)

Color at the Periphery

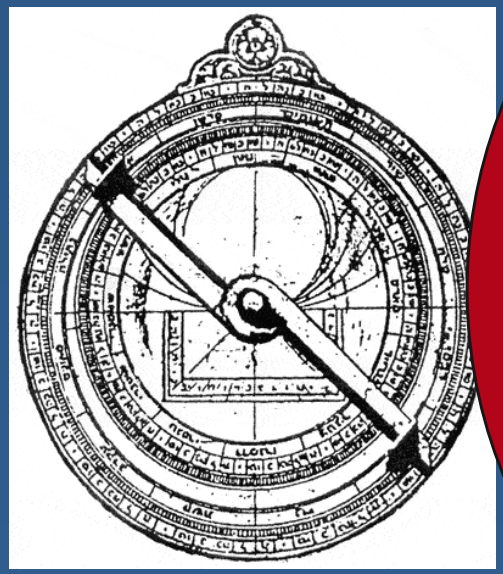


(courtesy of Exploratorium)

Photoreceptor Distribution



Aside: Why Do Pirates Wear Eyepatches?



(courtesy of Jason Harrison)

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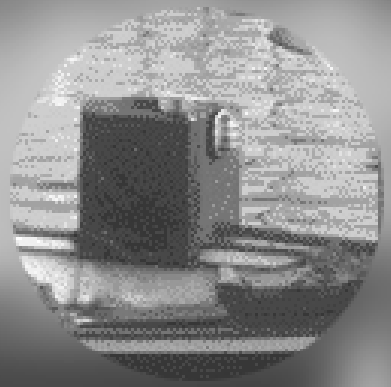

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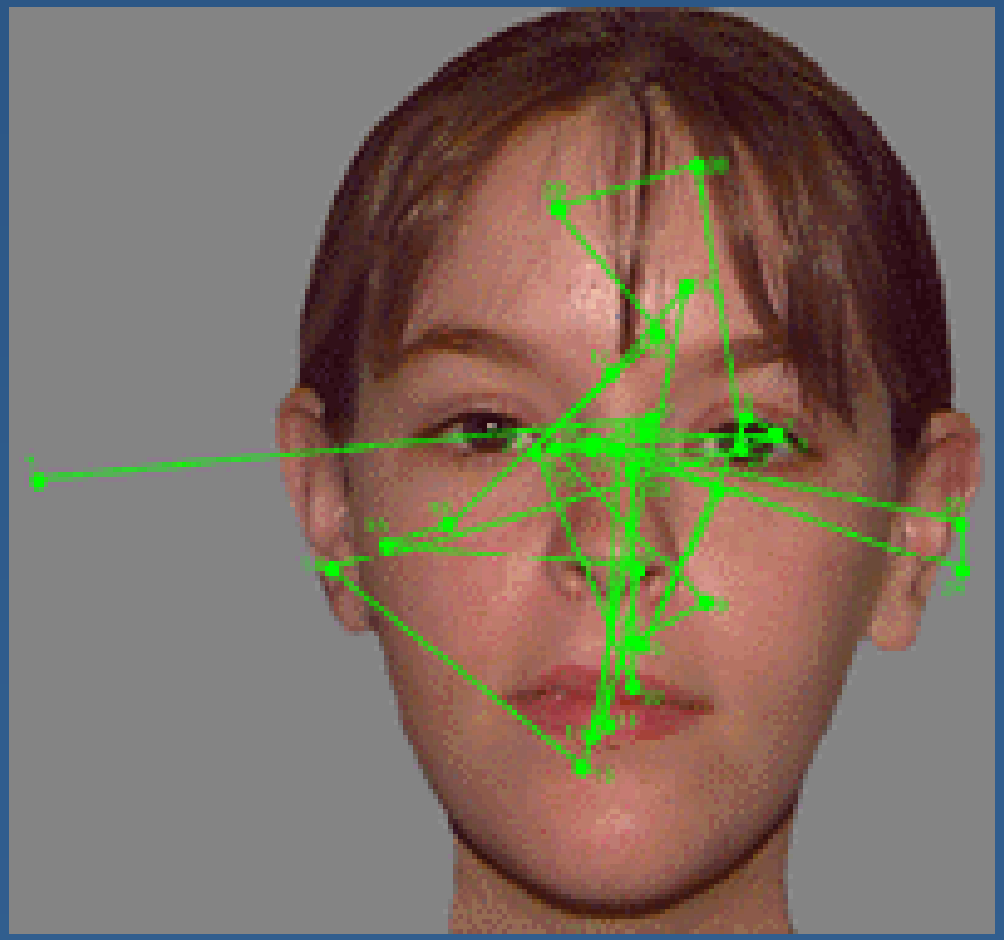
Constructing a Seamless Whole

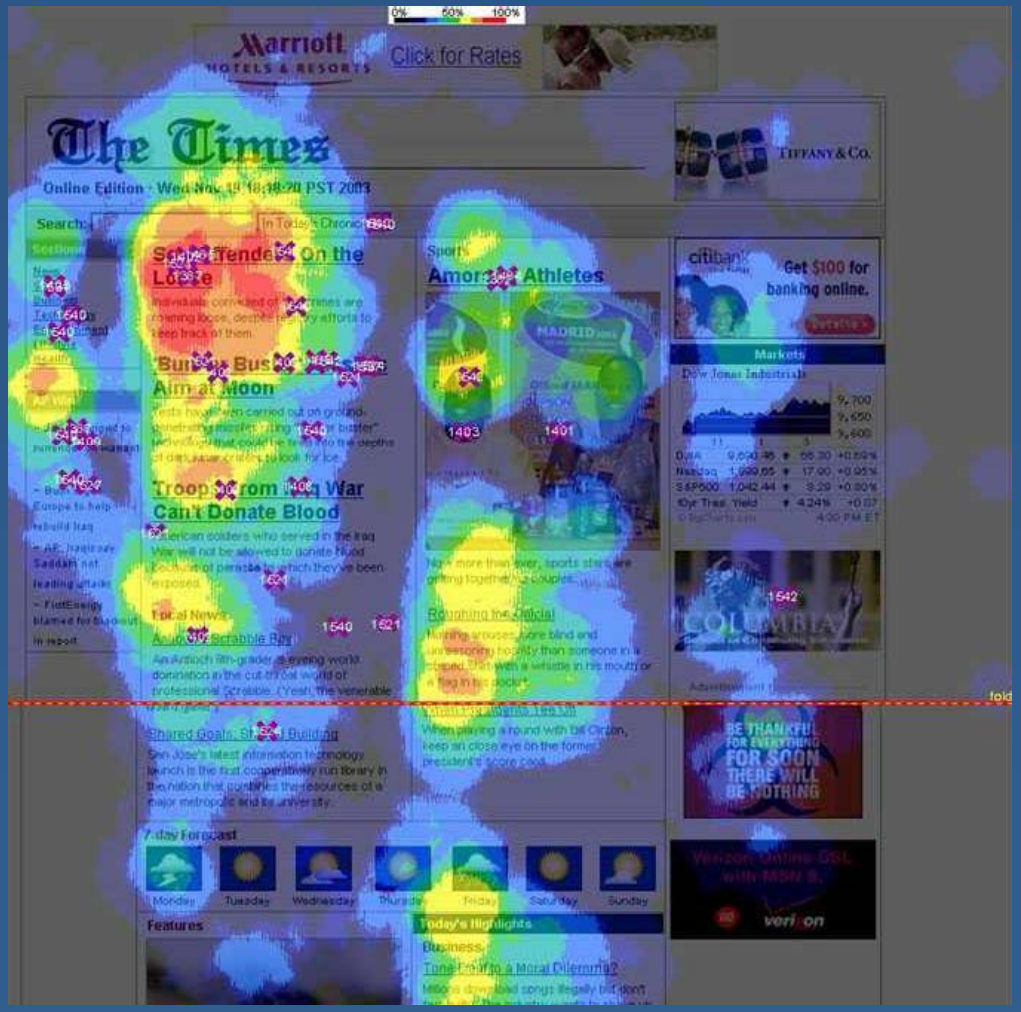
(courtesy of Stuart Anstis)

Saccades



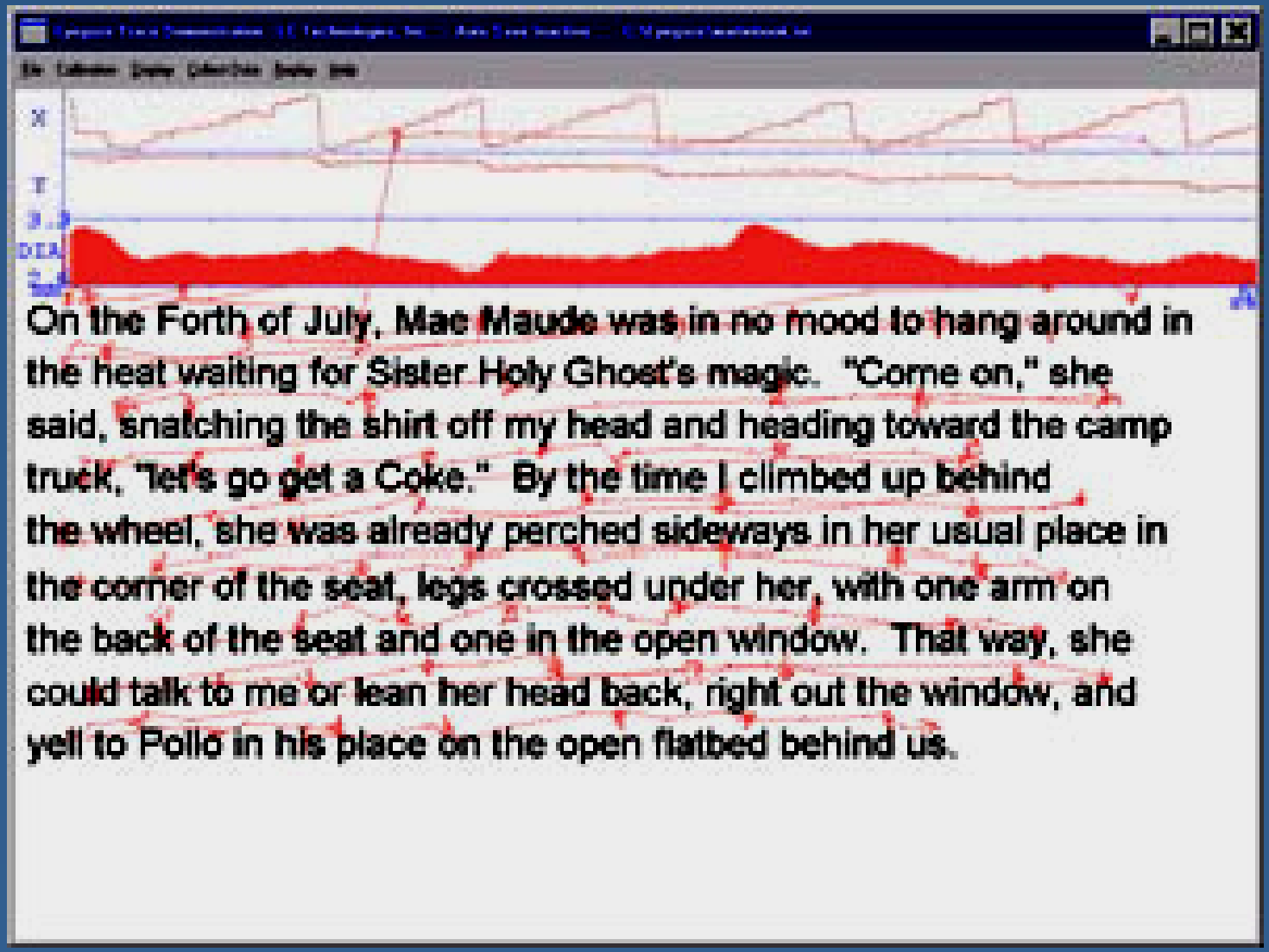
(courtesy of John M. Henderson)

Eye Tracking

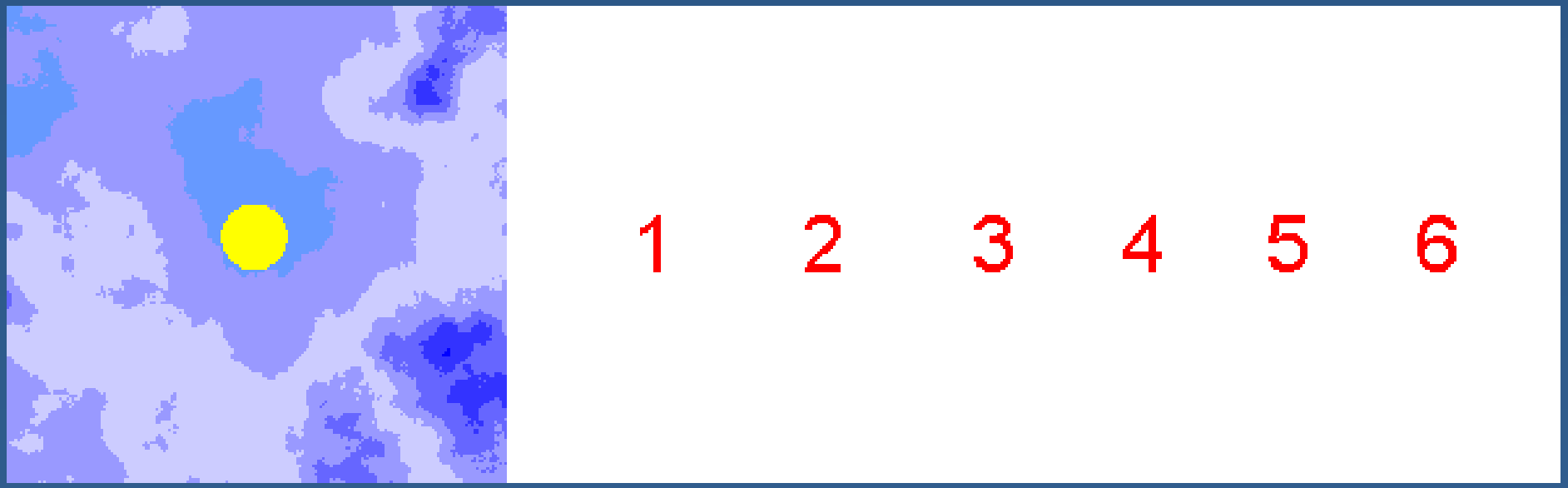


(courtesy of Poynter Institute)

Reading Saccades

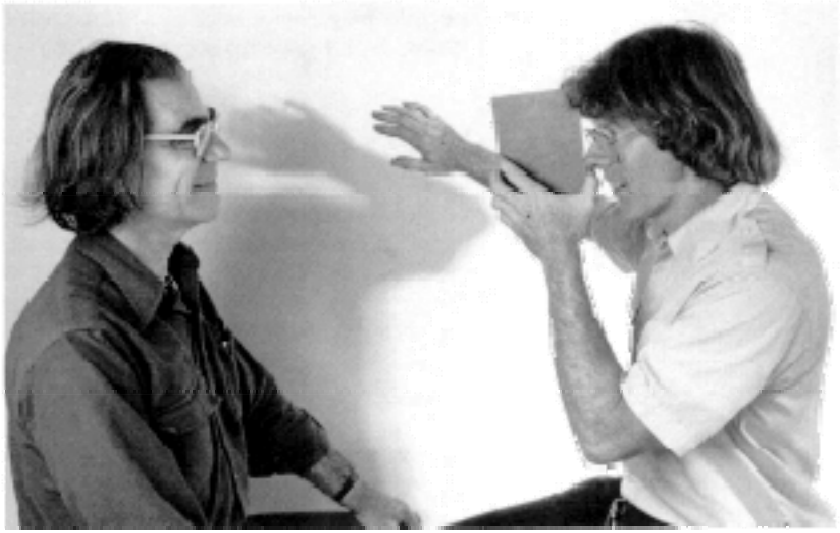


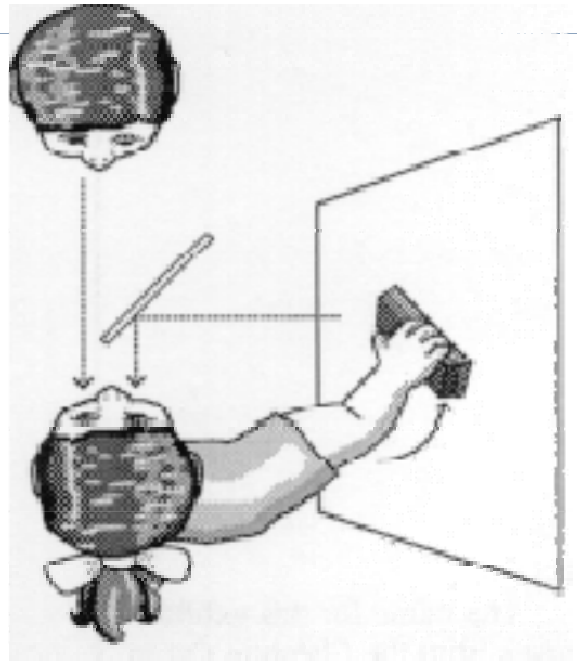
The Blind Spot



(courtesy of Peter Kaiser)

Cheshire Cat Illusion



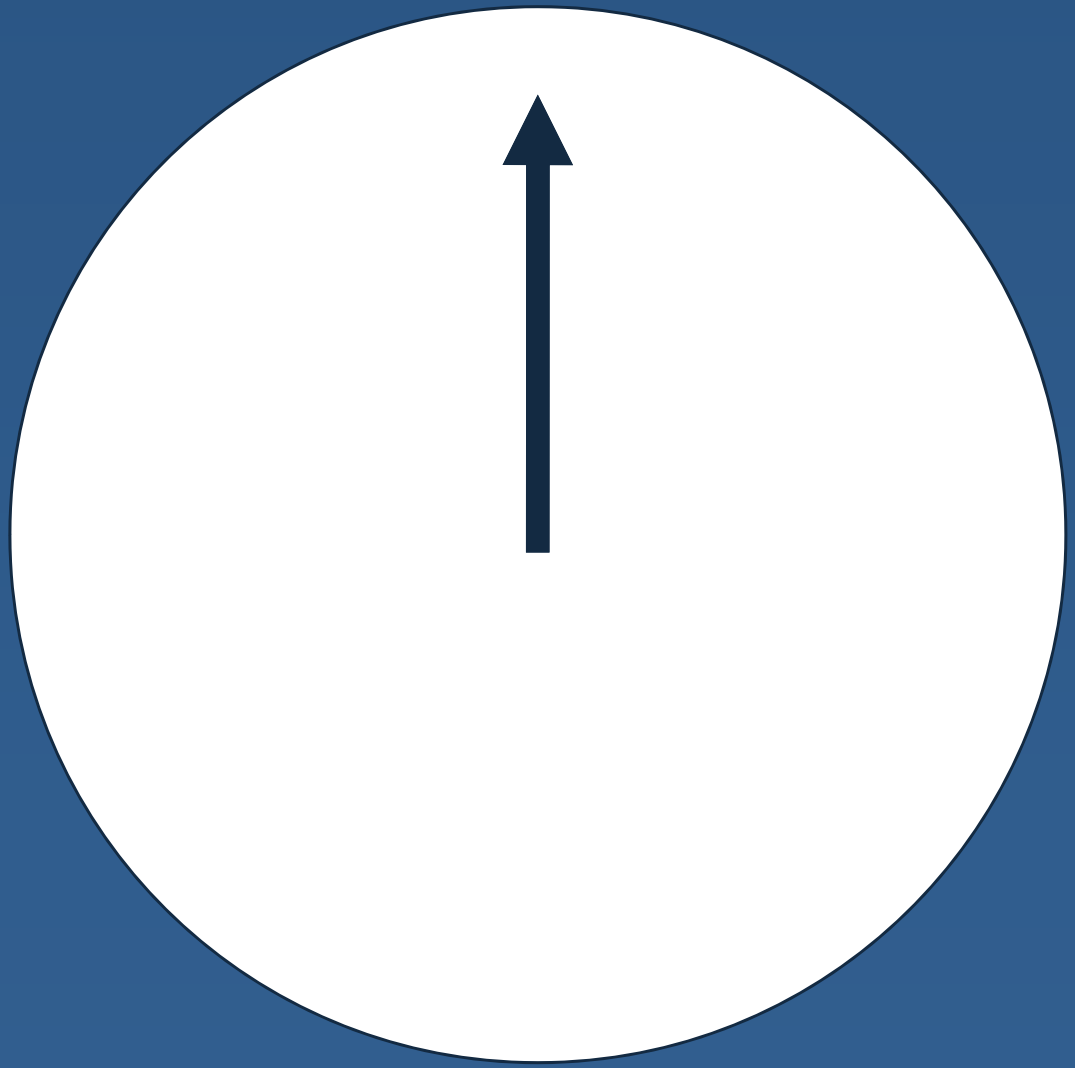


(courtesy of Exploratorium)

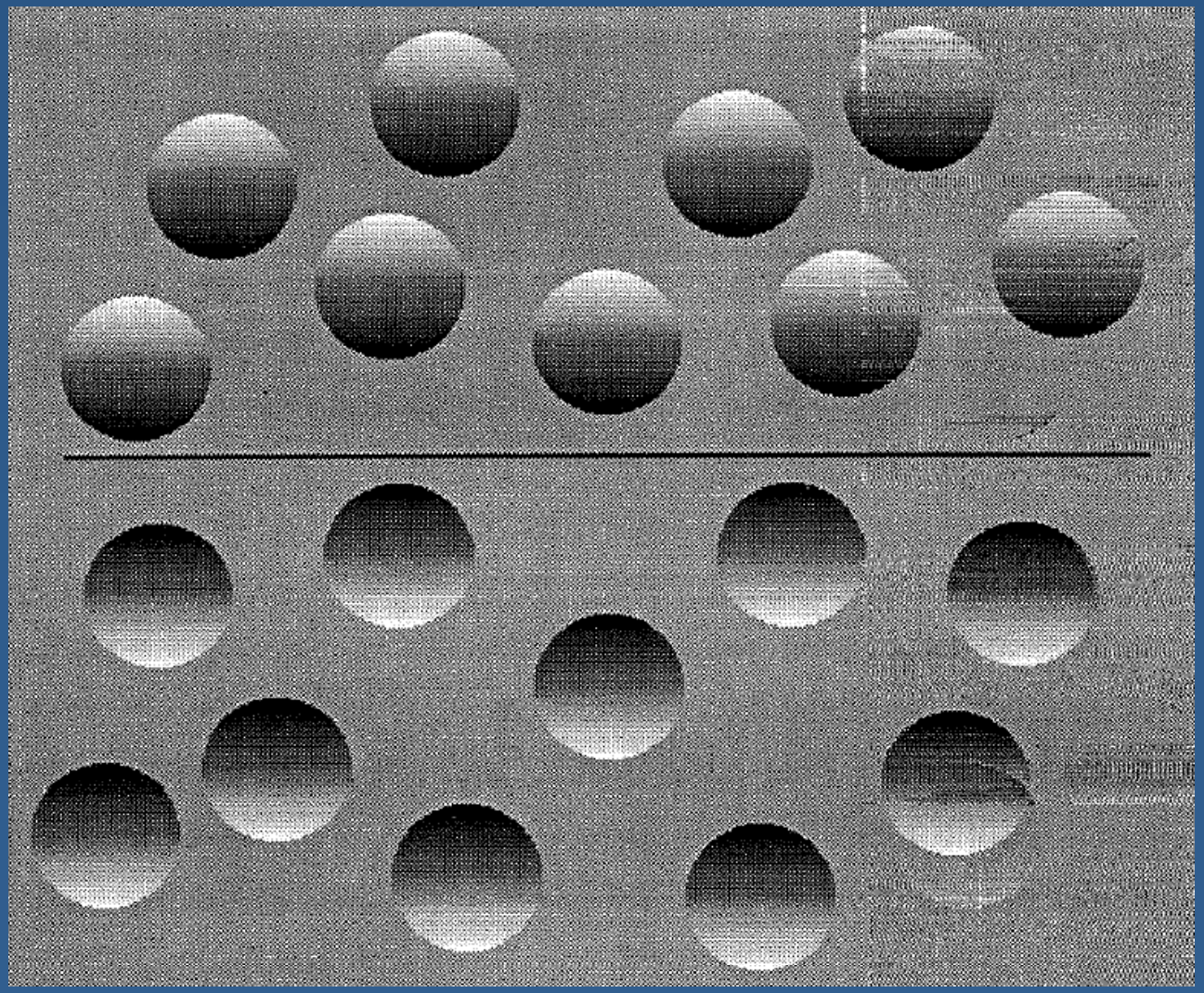
Saccadic Suppression

- You can see someone else's eyes shifting...
- But when you look in a mirror, you can't see your own eyes move!
- This may help some magic tricks work – a wave with one hand captures your gaze, and meanwhile you miss what the other hand is doing.

Stopped Clock Illusion



Shape from Shading



(courtesy of Dorothy Kleffner)

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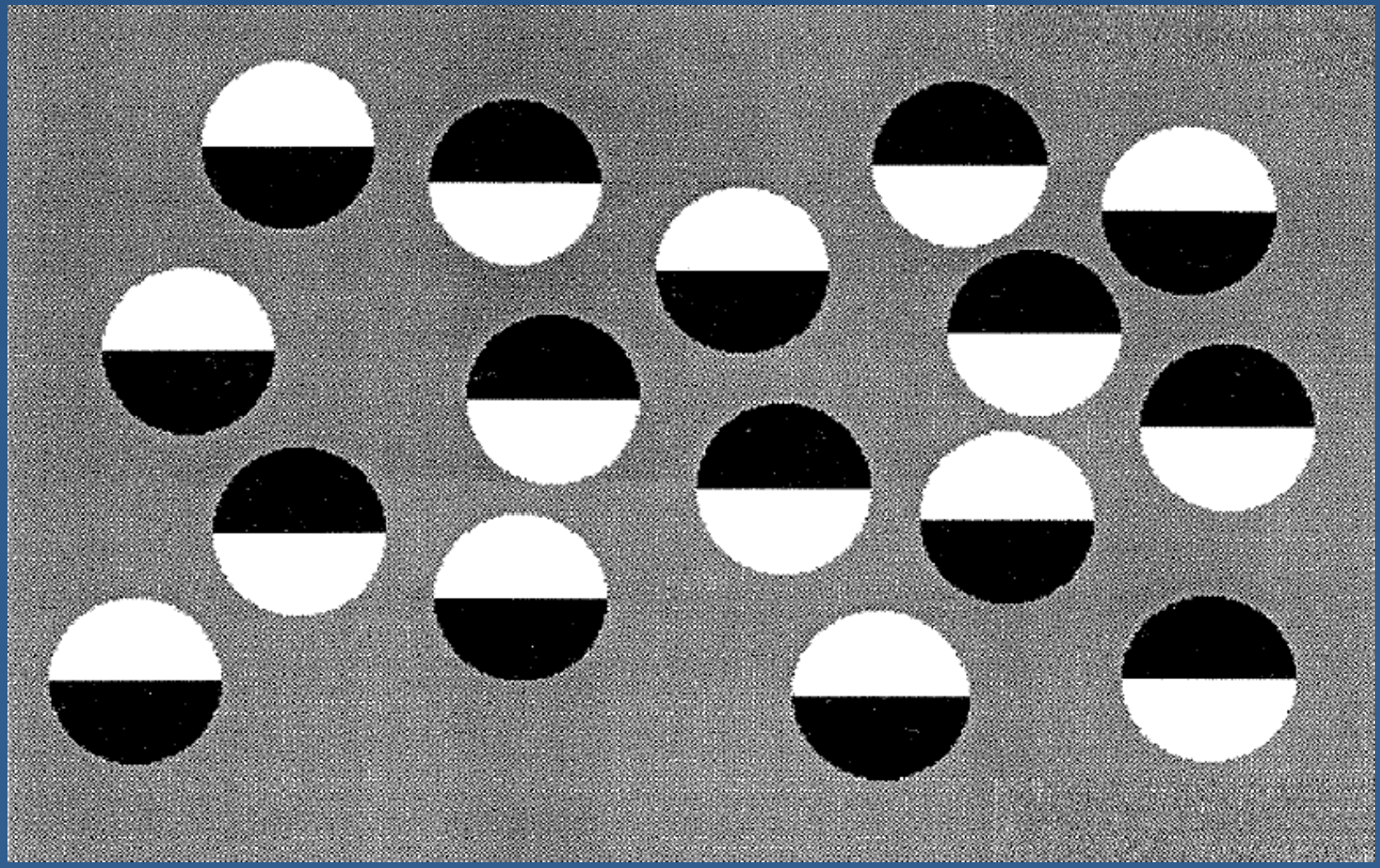

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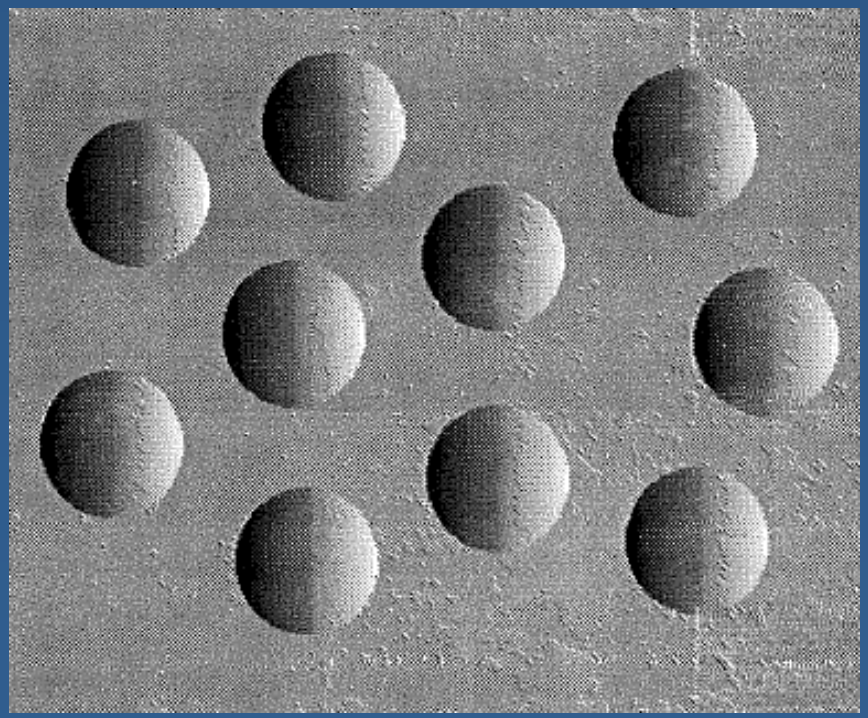
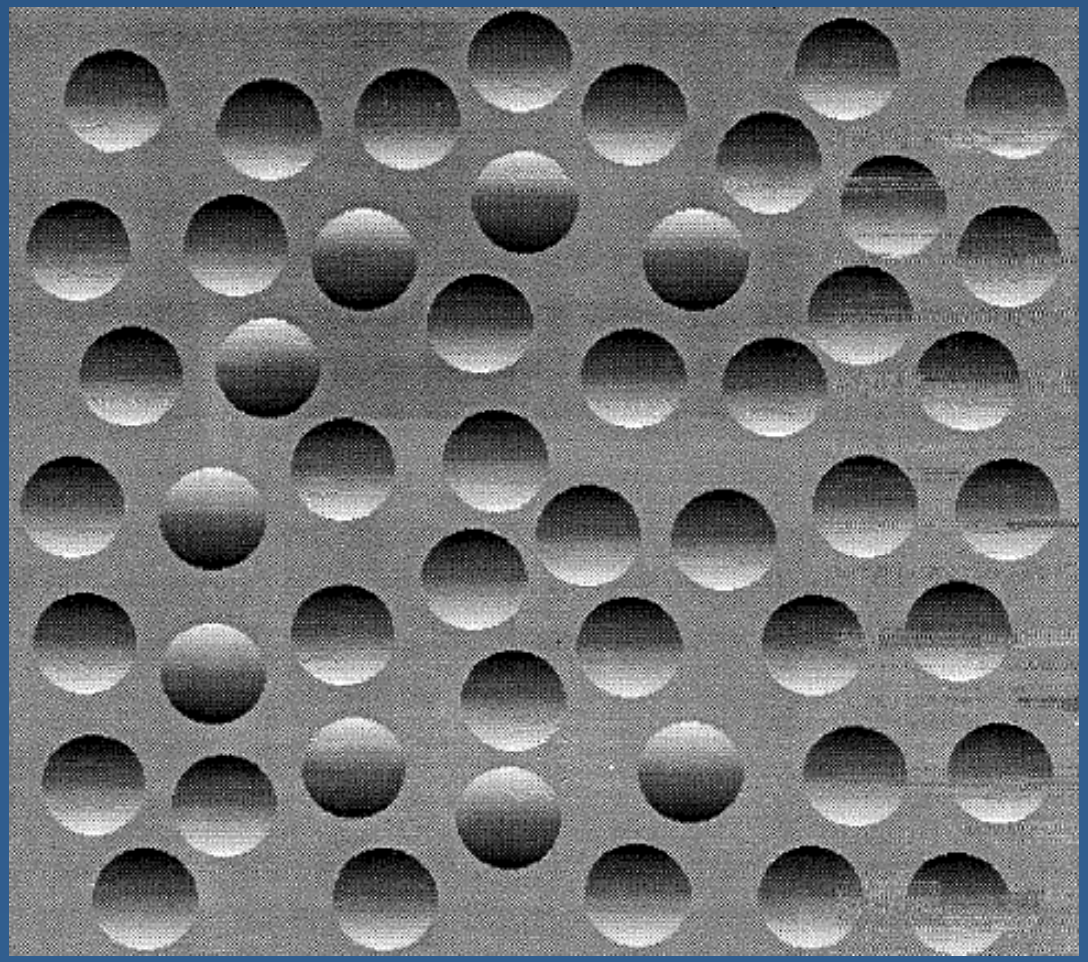


(courtesy of Dorothy Kleffner)

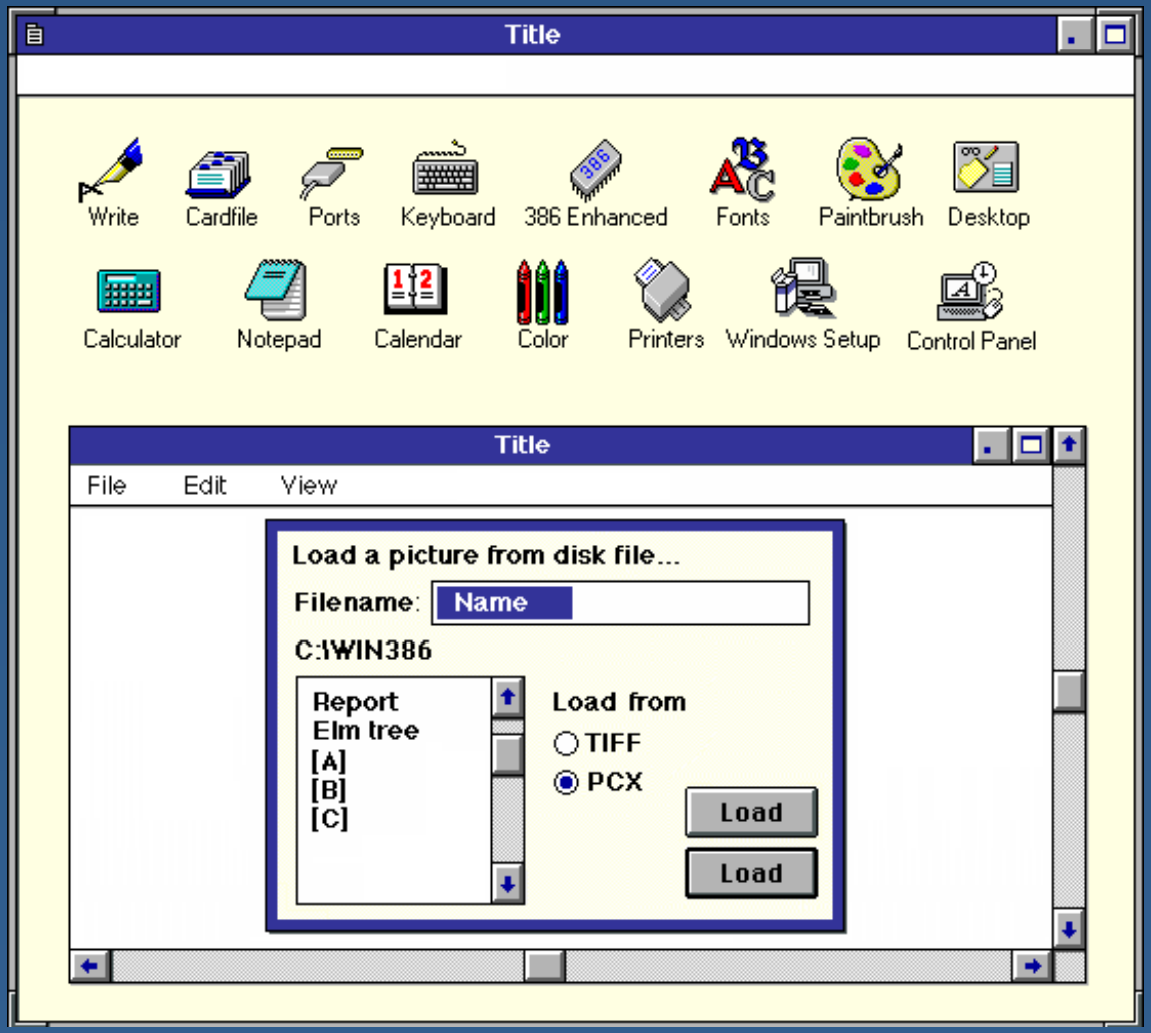
Pop-Out Effect



(courtesy of Dorothy Kleffner)

Real Life Example

Real-Life Example



(courtesy of Susan Kare)

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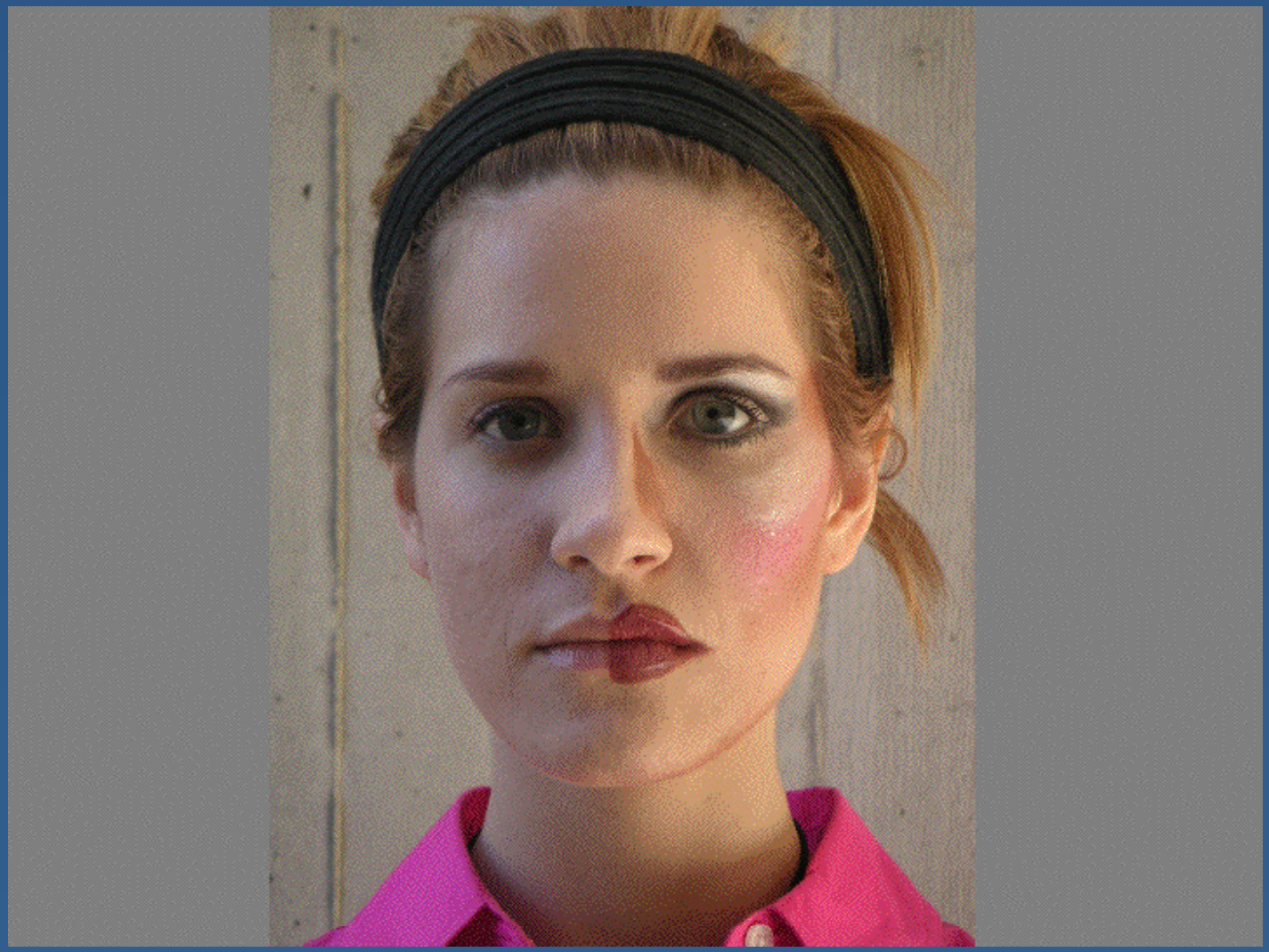
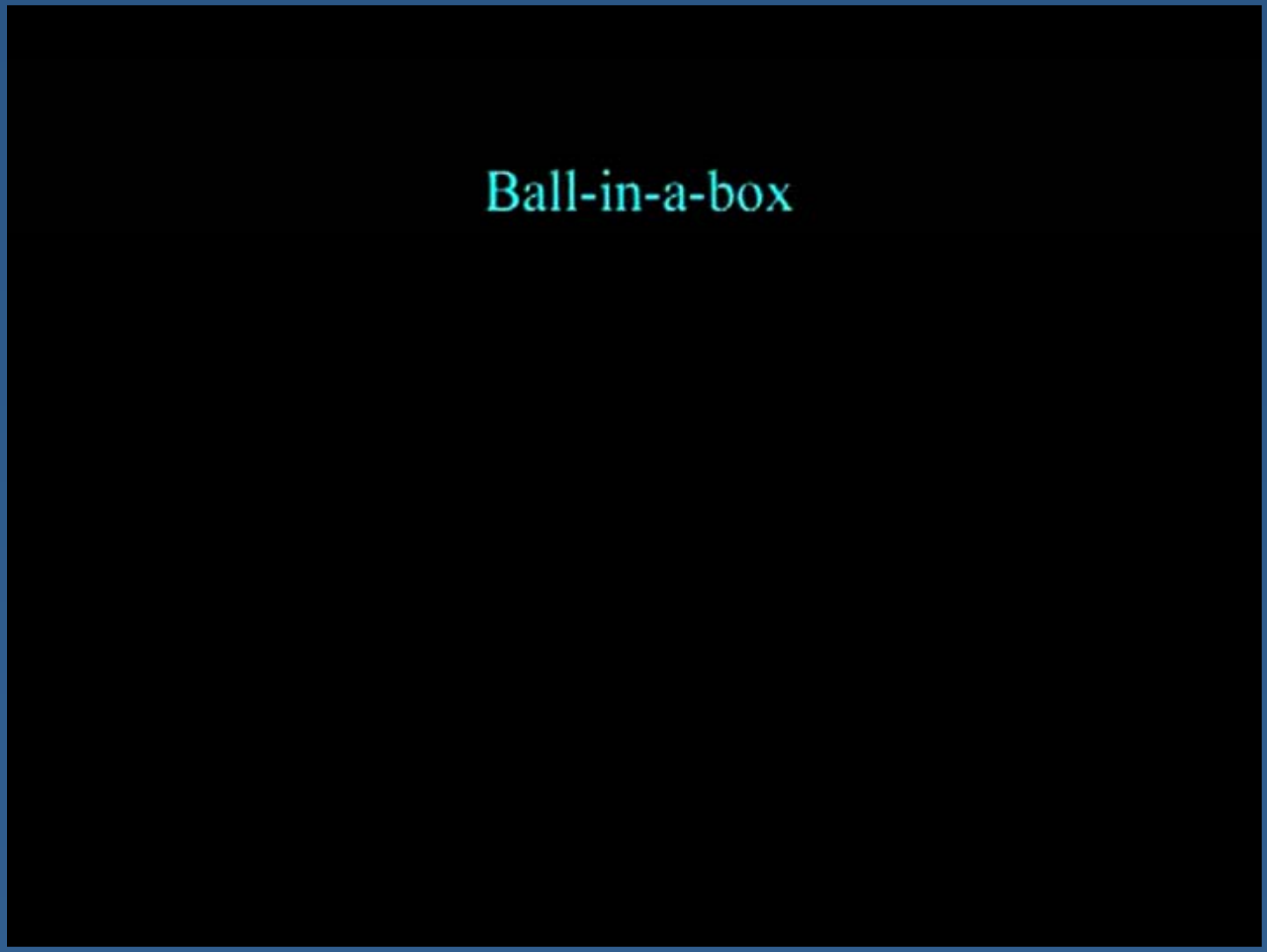


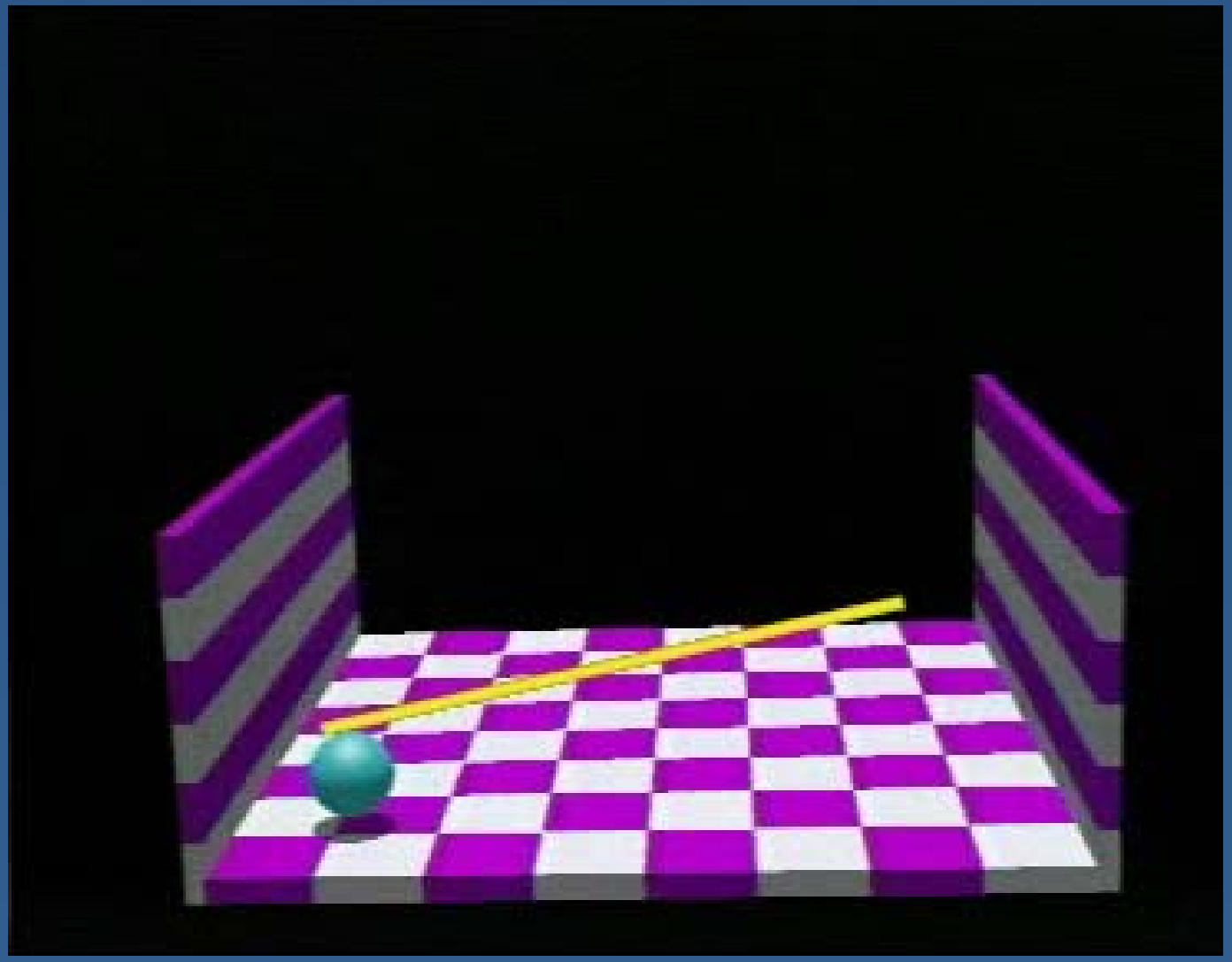
(courtesy of Stuart Anstis)

Moving Object or Changing Lighting?



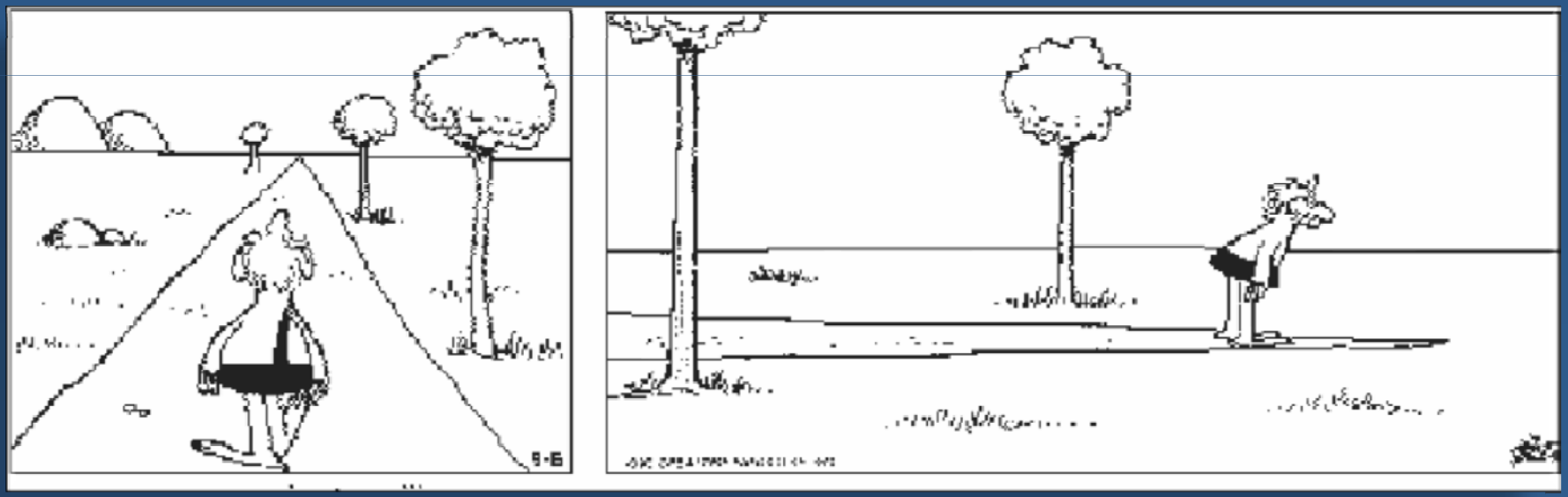
(courtesy of D. Kersten)

Moving Object or Changing Lighting?



(courtesy of D. Kersten)

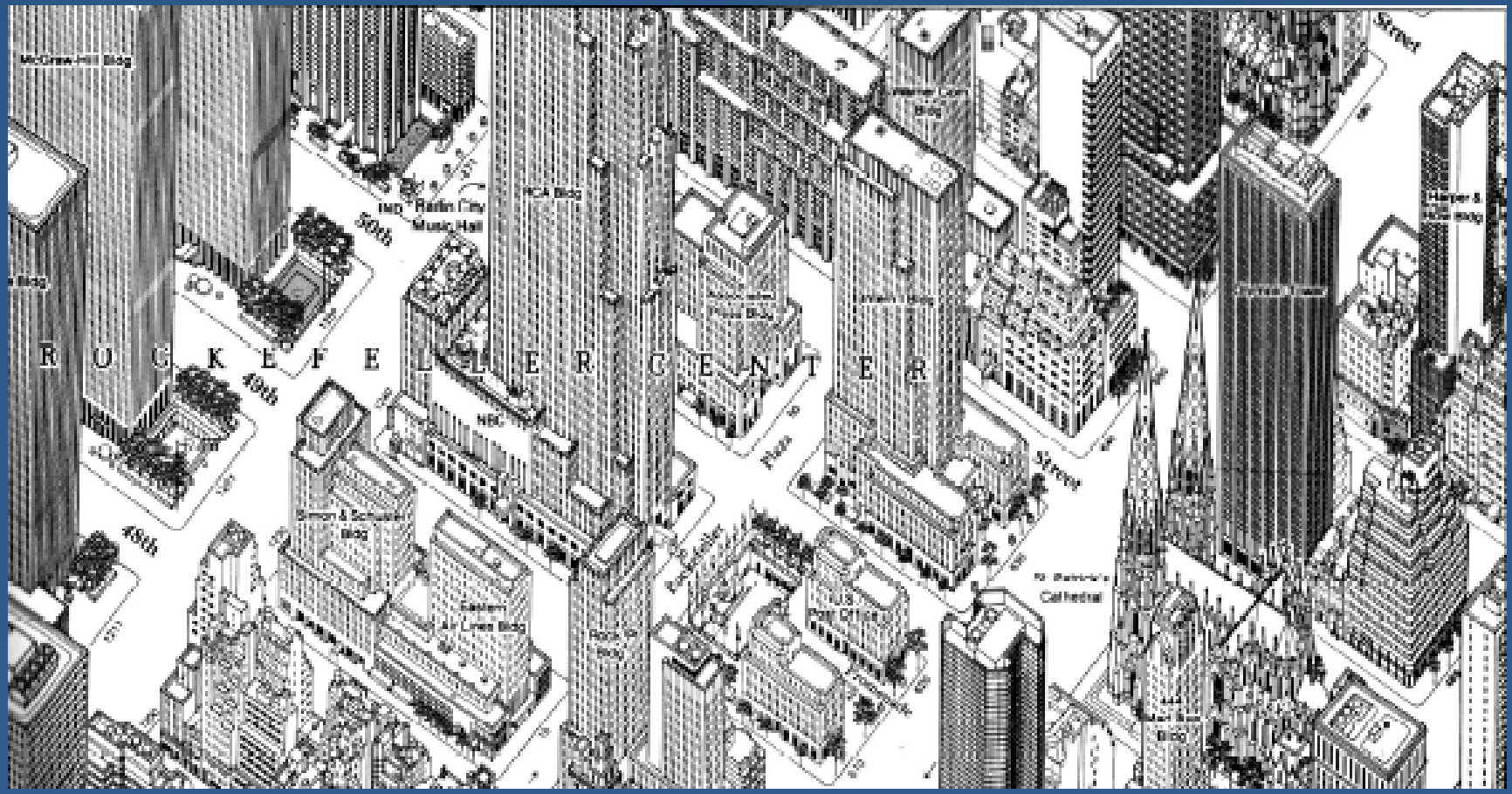
Depth Perception



Depth Cues

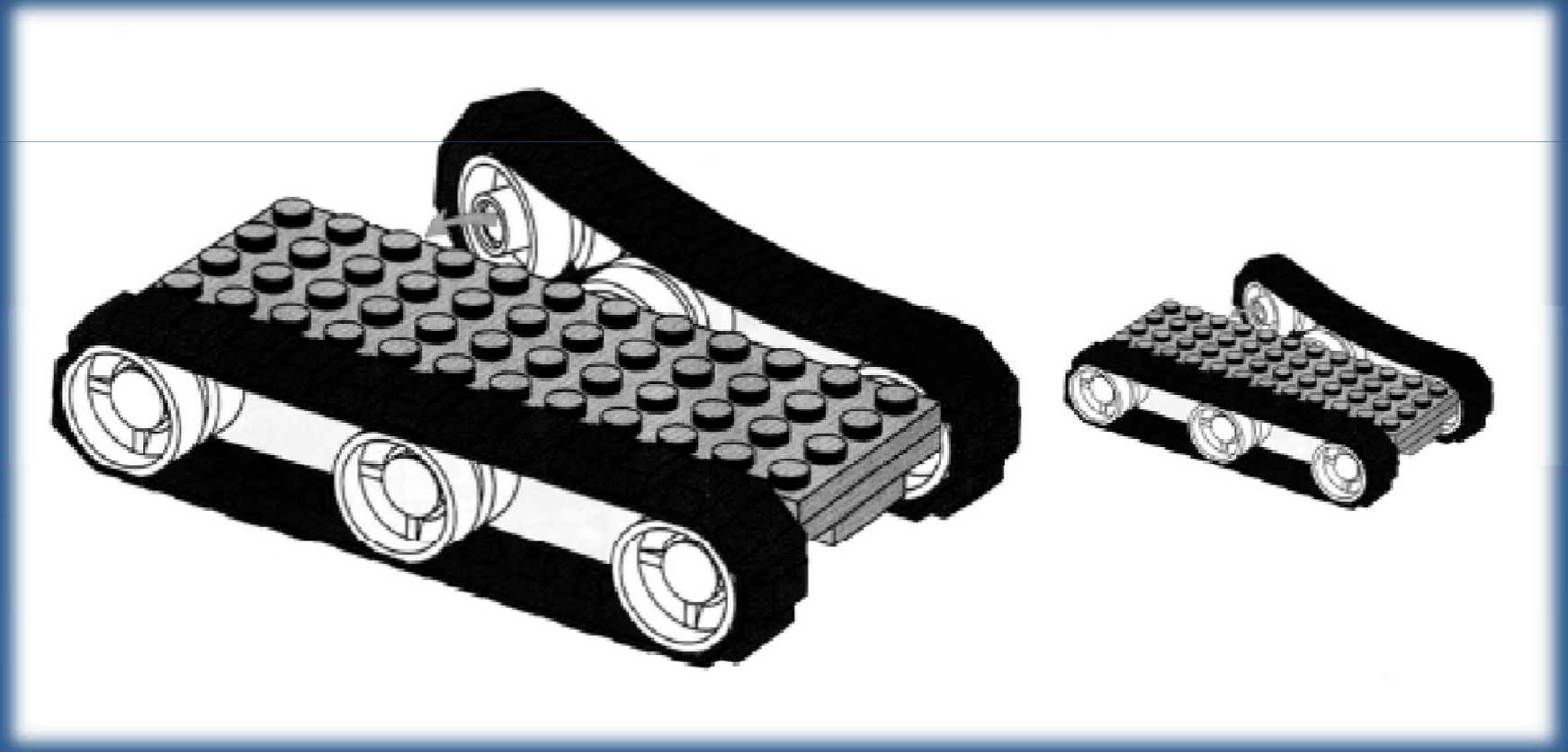
- Binocular cues
  - Stereoscopic depth
- Perspective-based cues
  - Size gradient, texture gradient
- Occlusion-based cues
  - Object overlap, cast shadows
- Focus-based cues
  - Atmospheric perspective, object intensity
- Motion-based cues
  - Parallax

Perspective Cue Example

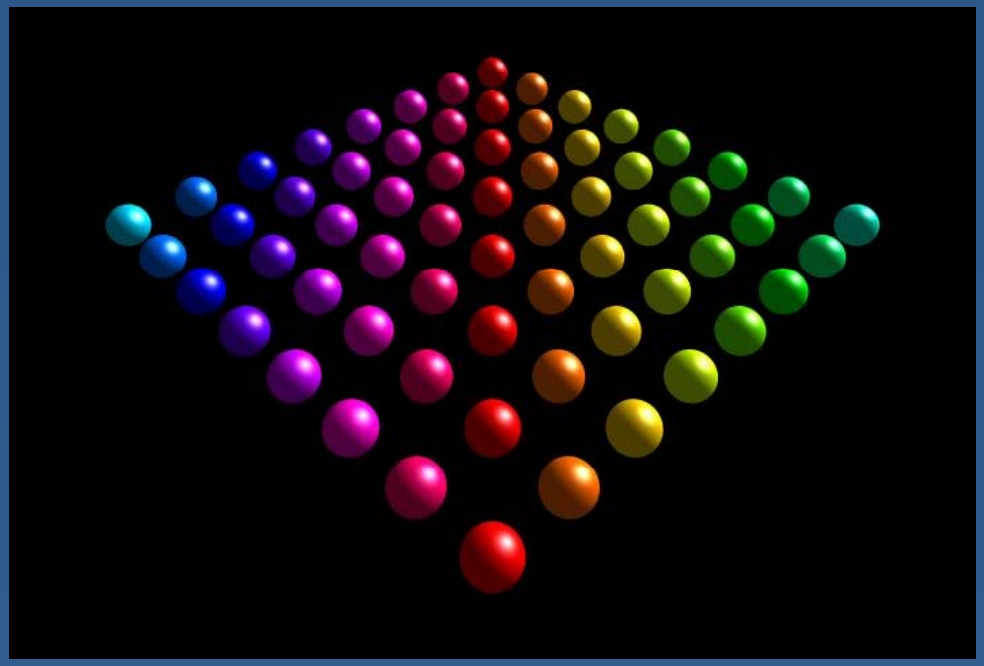


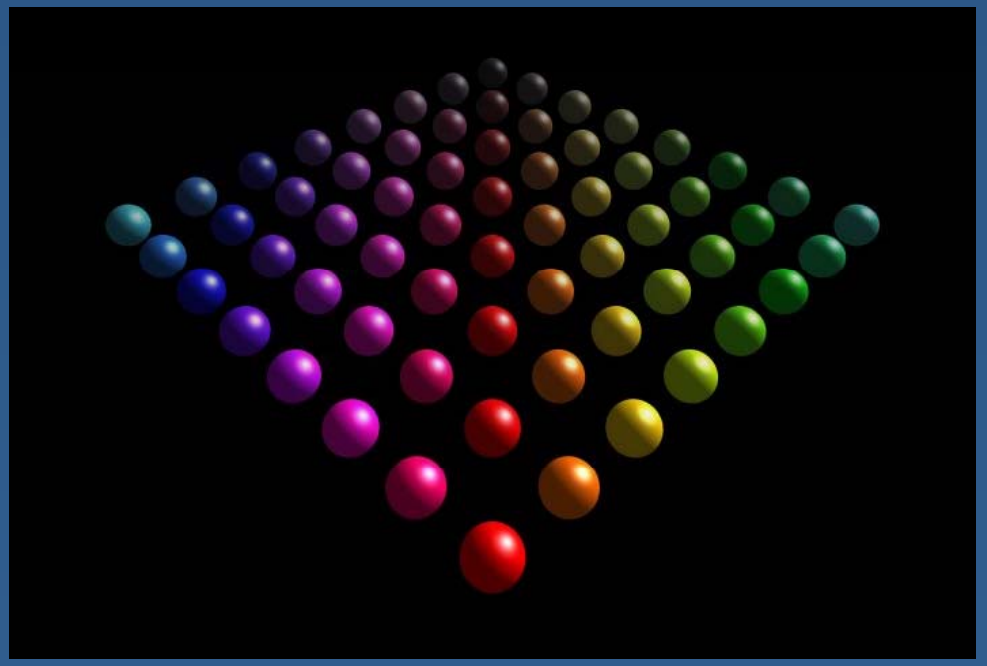
(courtesy of Herman Bollman)

Size Cue Example



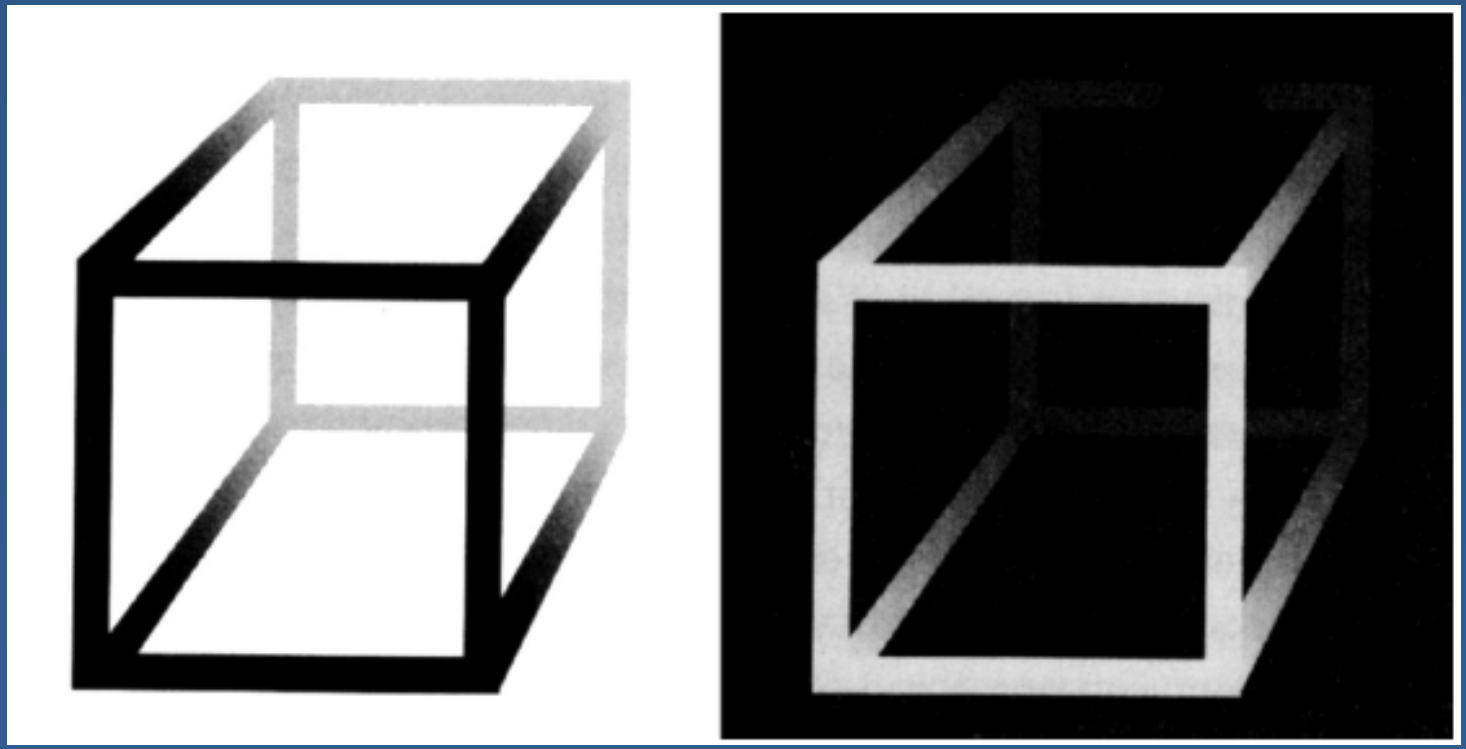
Atmospheric Cue Example





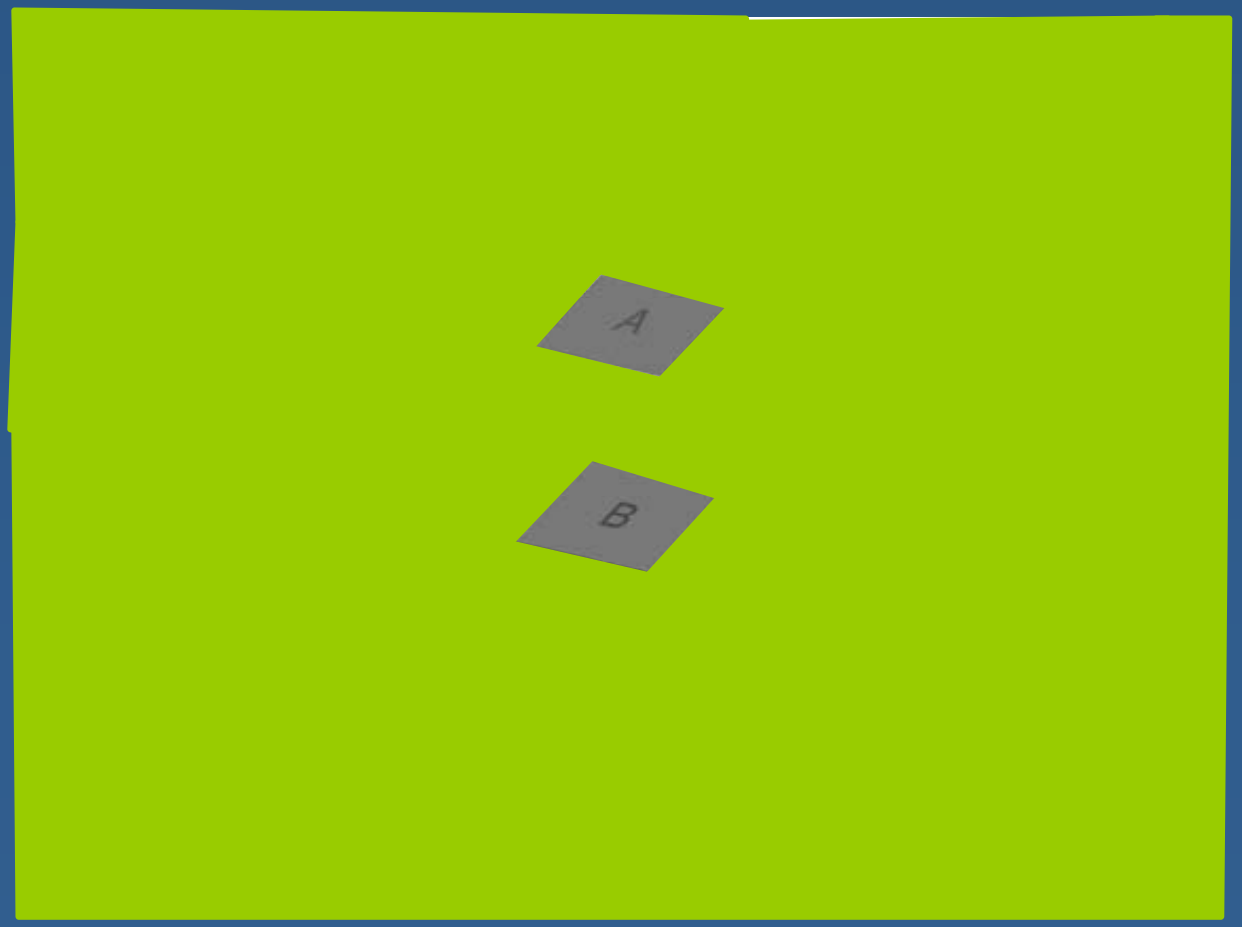
(courtesy of Daniel Weiskopf)

Intensity Cue Example



Brightness versus Luminance

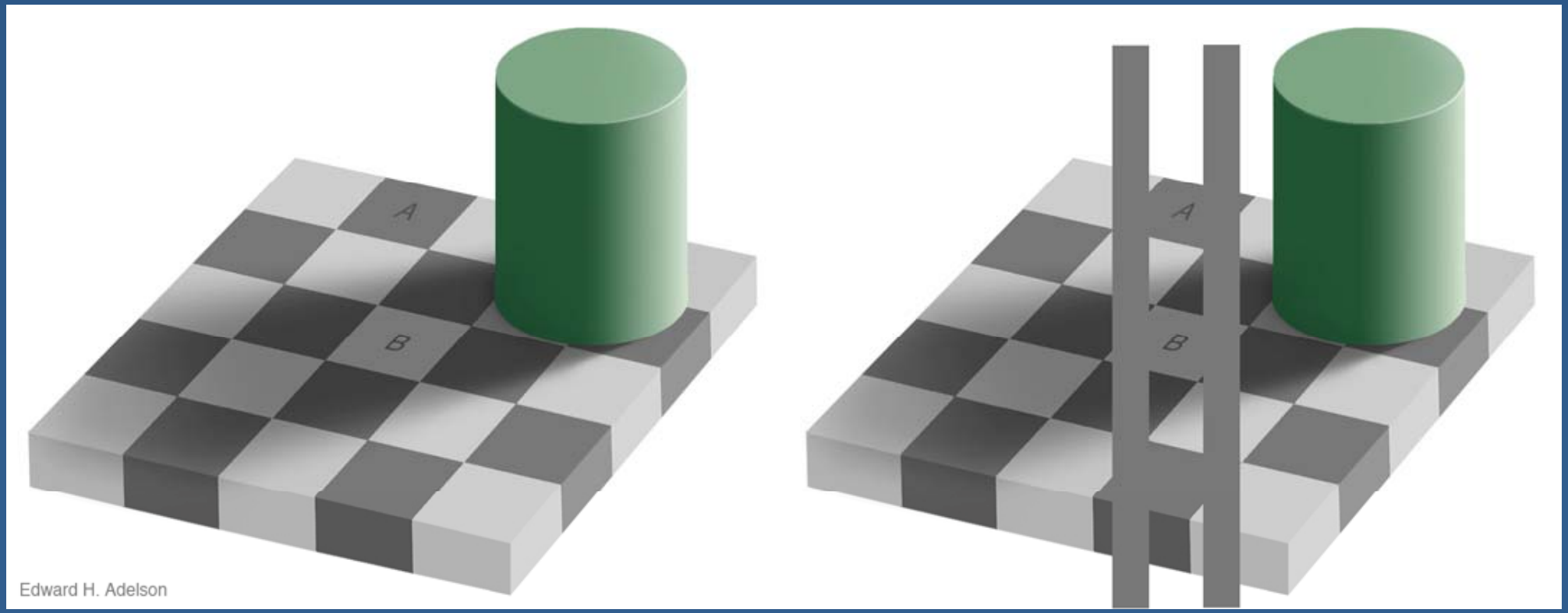
- Which square is brighter, A or B?



(courtesy of Edward Adelson)

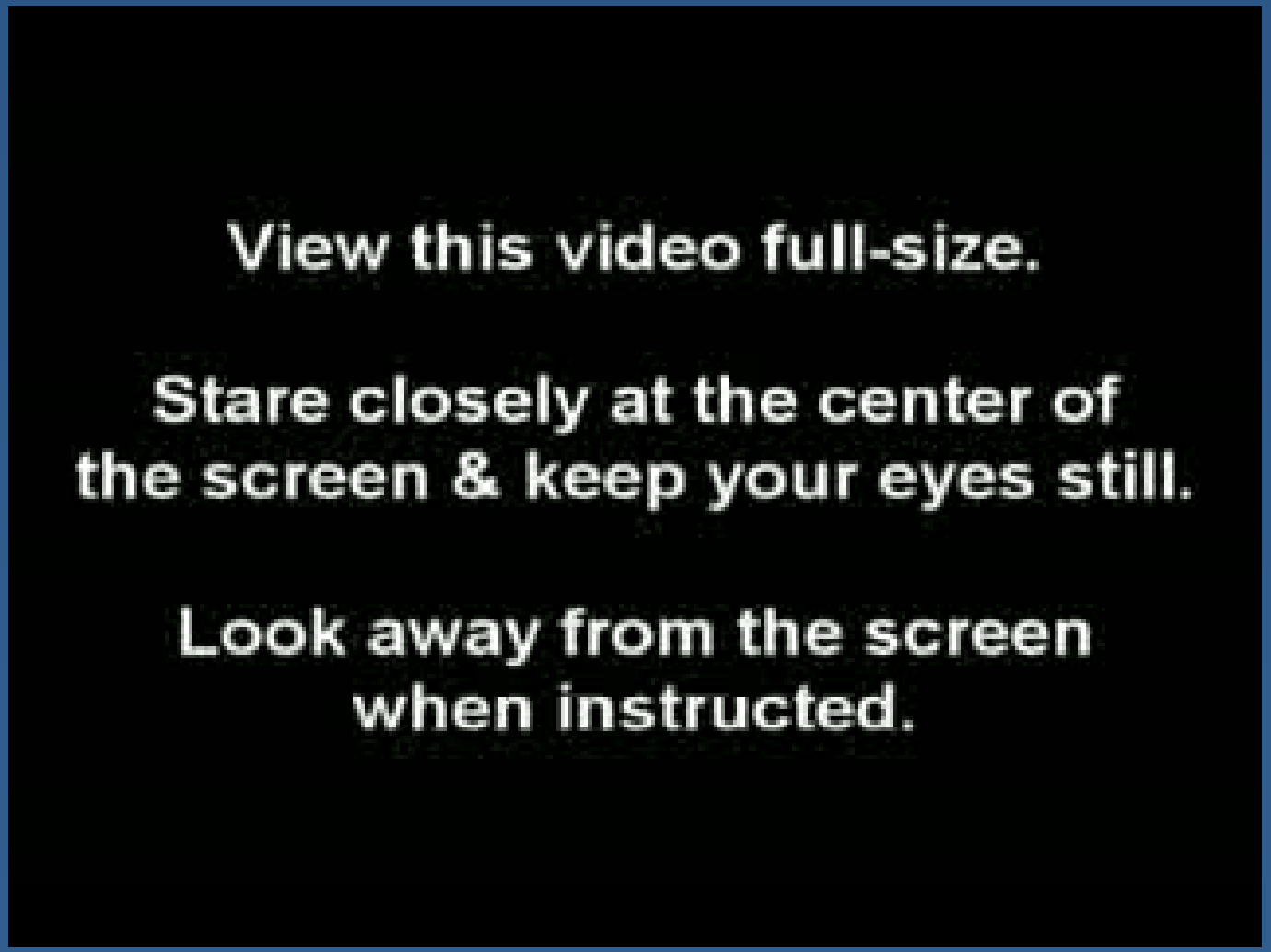
Brightness versus Luminance

- They are the same!

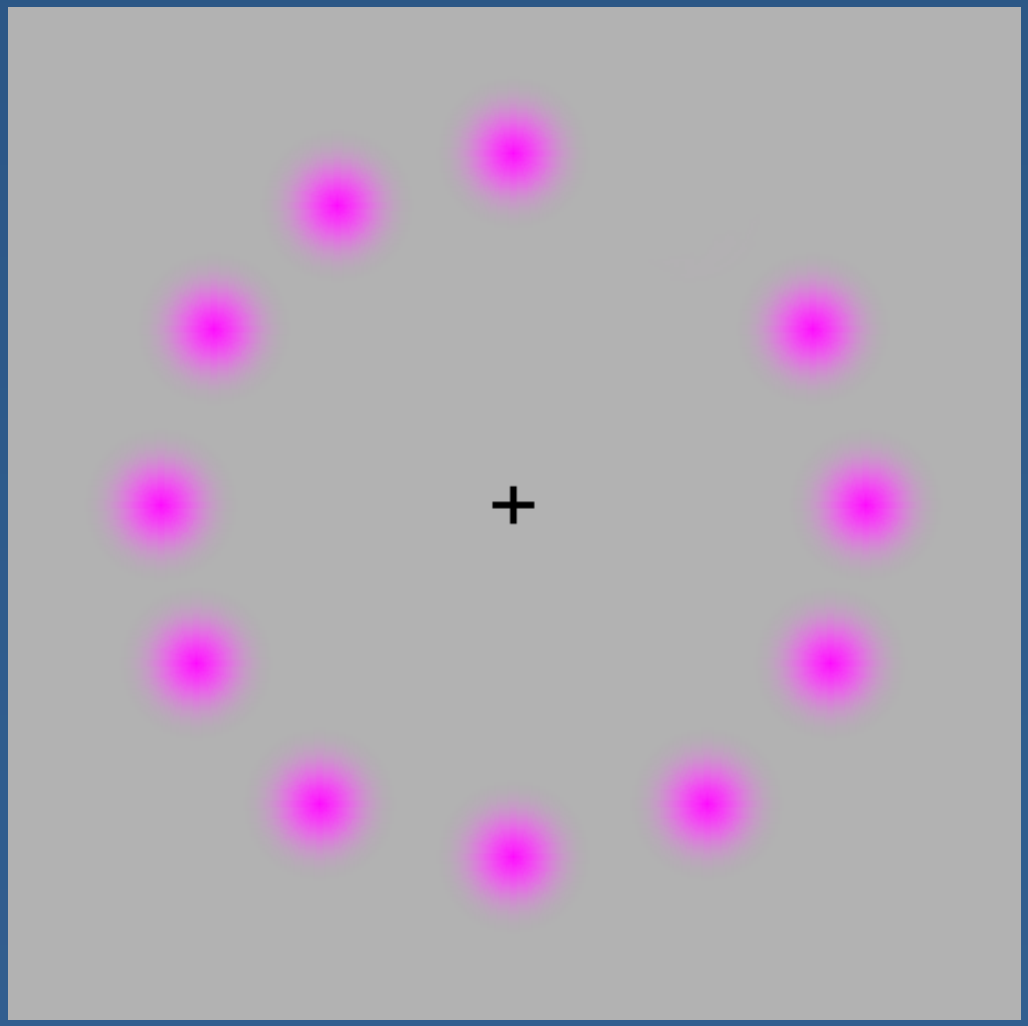


(courtesy of Edward Adelson)

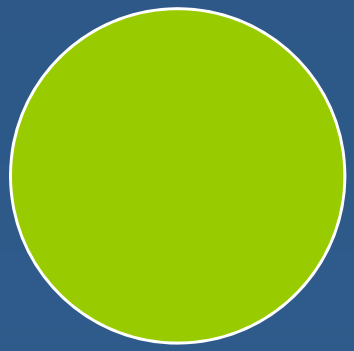
Aftereffect Illusions



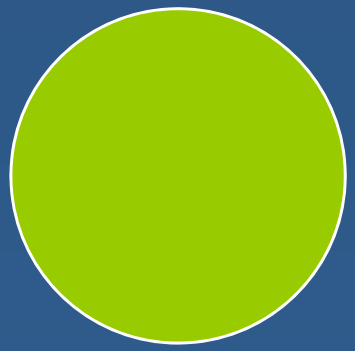
Aftereffect Illusions



Perception of Motion

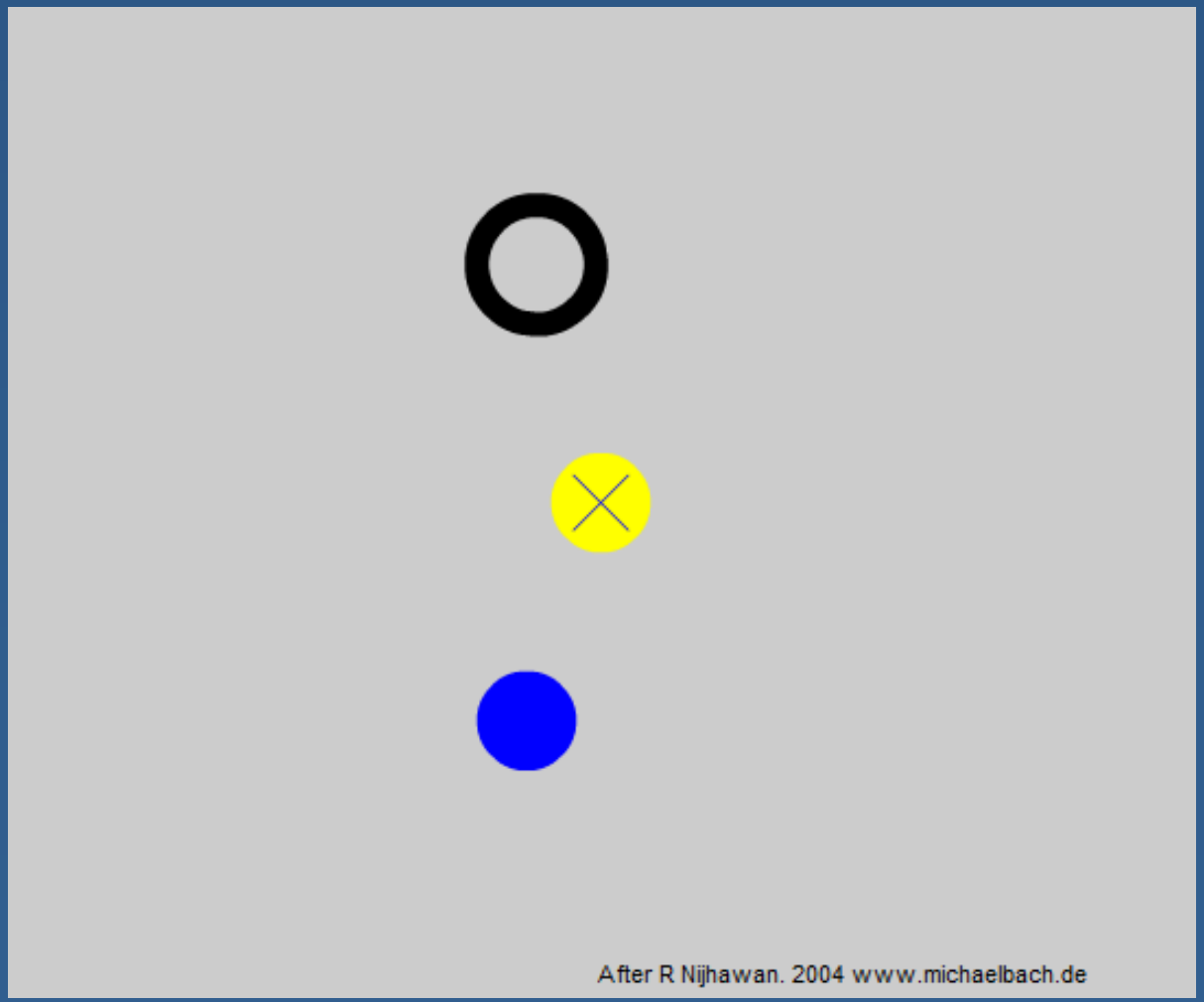


Perception of Motion



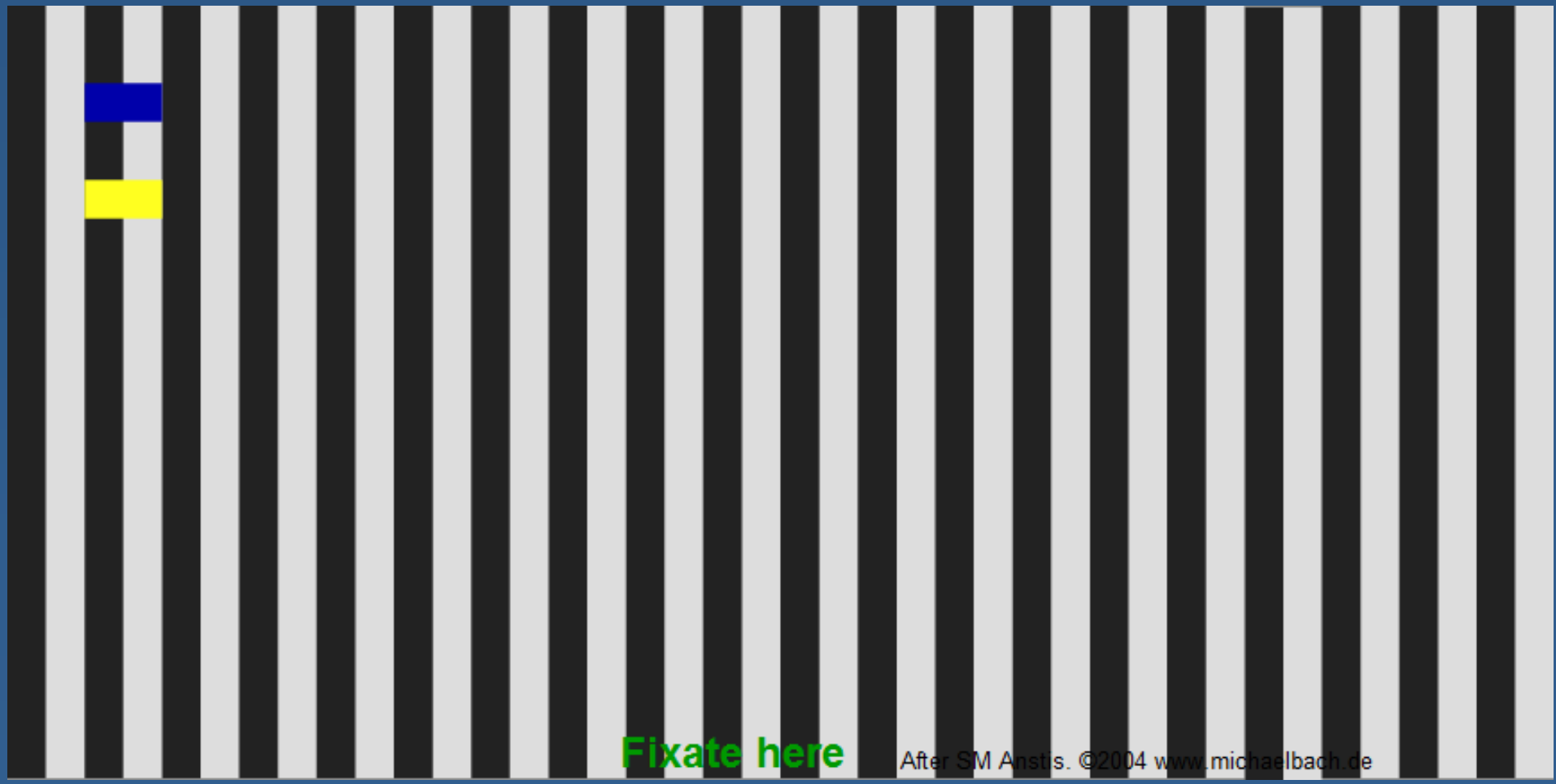
Motion Extrapolation

- The “Flash-Lag” Effect



Motion Detection

- "Stepping Feet" Illusion



Defense Hardware

Mark Leung's "Crazy Computer Bug"

A Human Frame Buffer?

- We know that we construct a seamless impression of the world from many small fixations.
- How do these pieces get put together?
- One possible answer: the information from each fixation is accumulated in a visual buffer somewhere in the brain.

A Human Frame Buffer?

(courtesy of Jason Harrison)

We Have No Frame Buffer

(courtesy of Jason Harrison)

Change Blindness (1)

Change Blindness (2)

Change Blindness (3)

More Examples

More Examples

Inattention Blindness

(courtesy of Daniel J. Simons)

Inattention Blindness

- Over half the observers did not see the person in the gorilla suit!
- If we are not looking for something, we often will not see it
- Instead of a complete, detailed world, we only see the part we are attending to
- This is how magicians make things disappear

Card Trick

- Pick a card...

Presto!

- I've removed your card

Stroop Effect

Name the COLOR of the word out loud (NOT what it spells)

RED	BLUE
GREEN	WHITE
BLUE	GREEN
YELLOW	YELLOW
PINK	ORANGE
ORANGE	BLUE
BLUE	WHITE

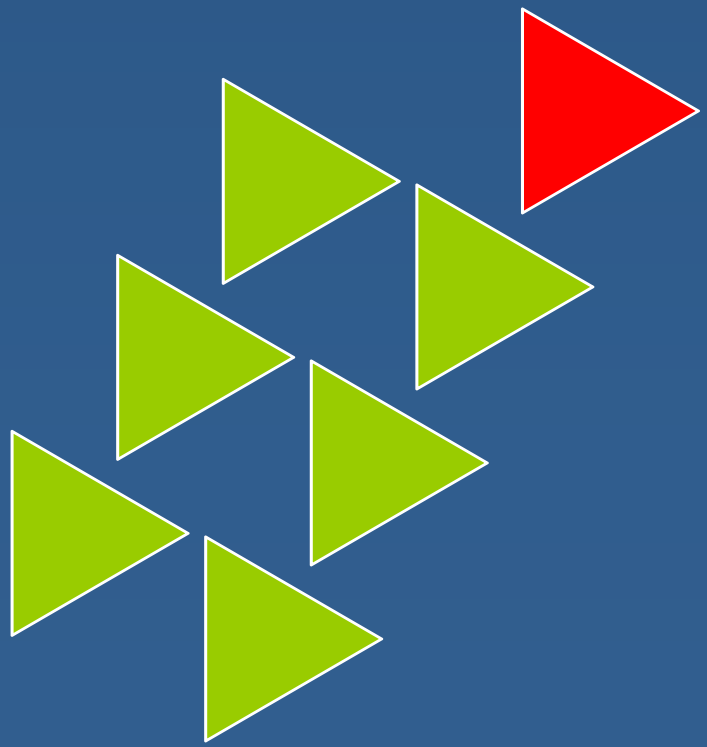
Stroop Effect

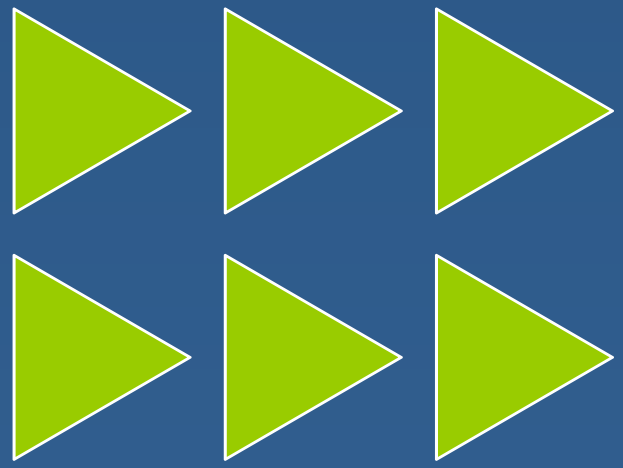
Name the COLOR of the word out loud (NOT what it spells)

YELLOW	RED
ORANGE	YELLOW
GREEN	BLUE
BROWN	GREEN
GREEN	CHAIR
BLUE	DONKEY
YELLOW	LAMP

Gestalt Principles

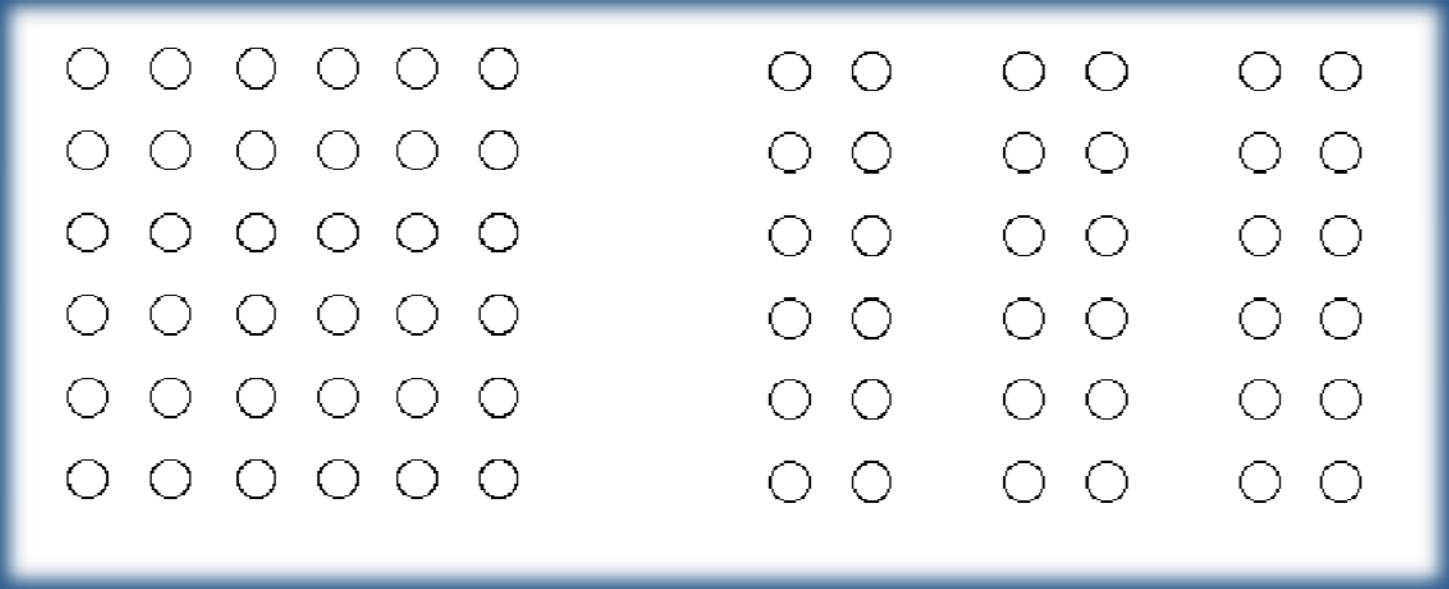
- We see the world as objects and groups, not as isolated parts
- Which way is the red triangle pointing?





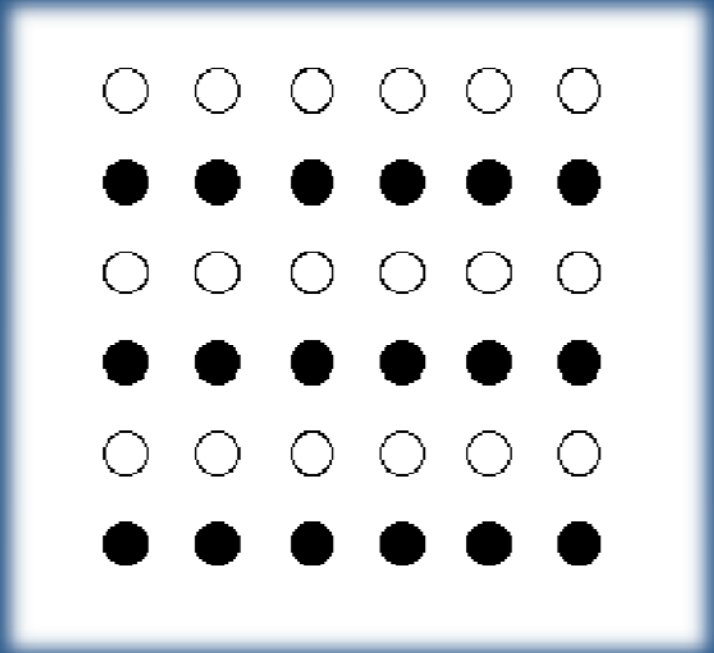
Proximity

- We group items that are close together.
- At right we see columns, not rows or a grid.



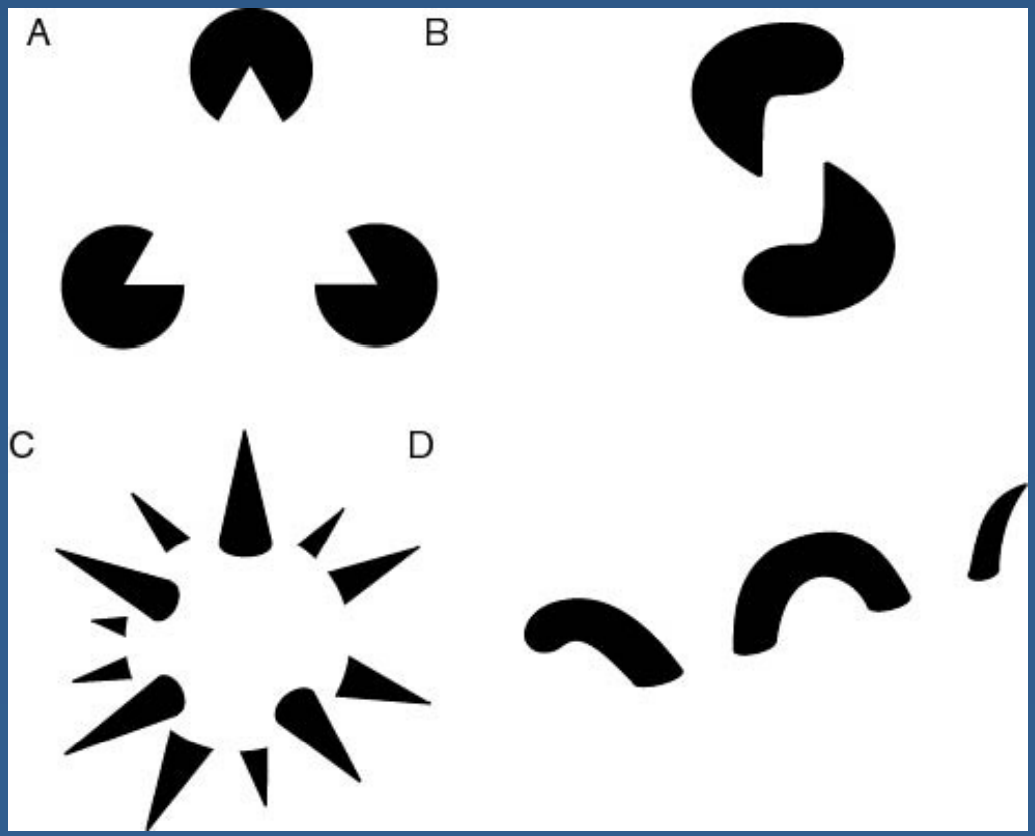
Similarity

- We prefer to group together objects of the same kind: here we see alternating rows of same-colored circles rather than columns of different-colored circles.



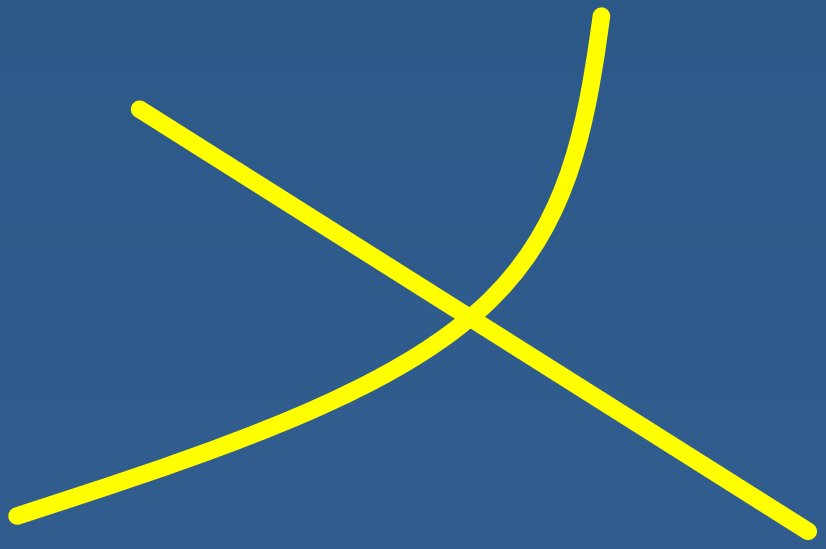
Closure

- We tend to complete patterns: in (A) we see a triangle where there is none.

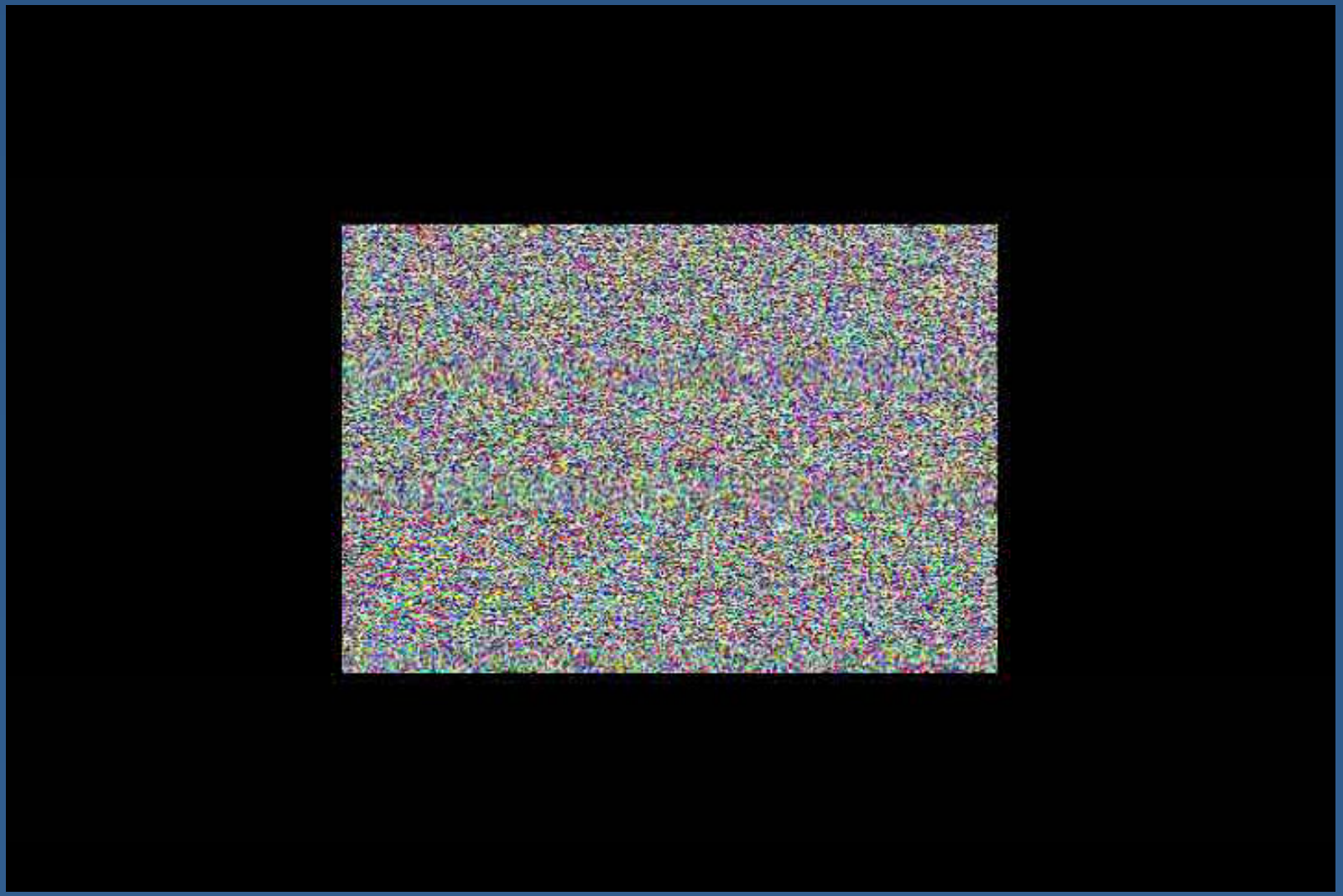


Continuation

- We like to see smooth continuations of shapes: here we see two lines crossing, rather than two arrowheads touching.



Common Fate



Common Fate

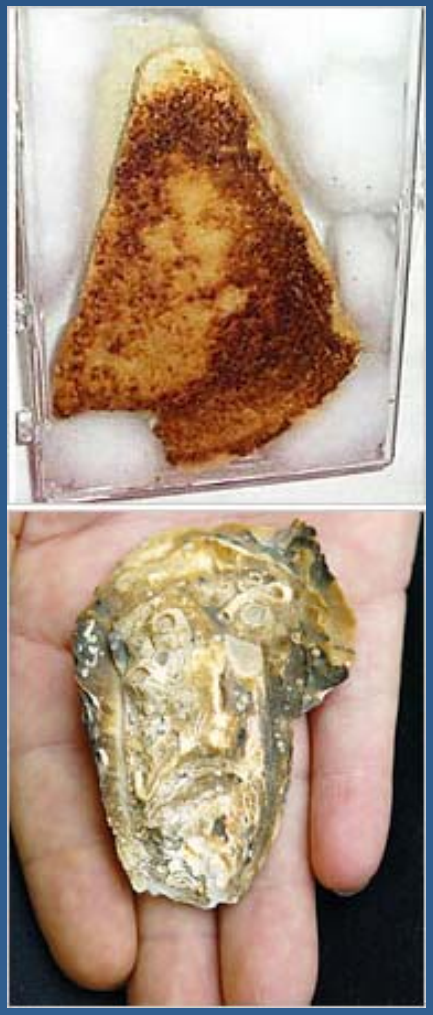
Biological Motion is Special

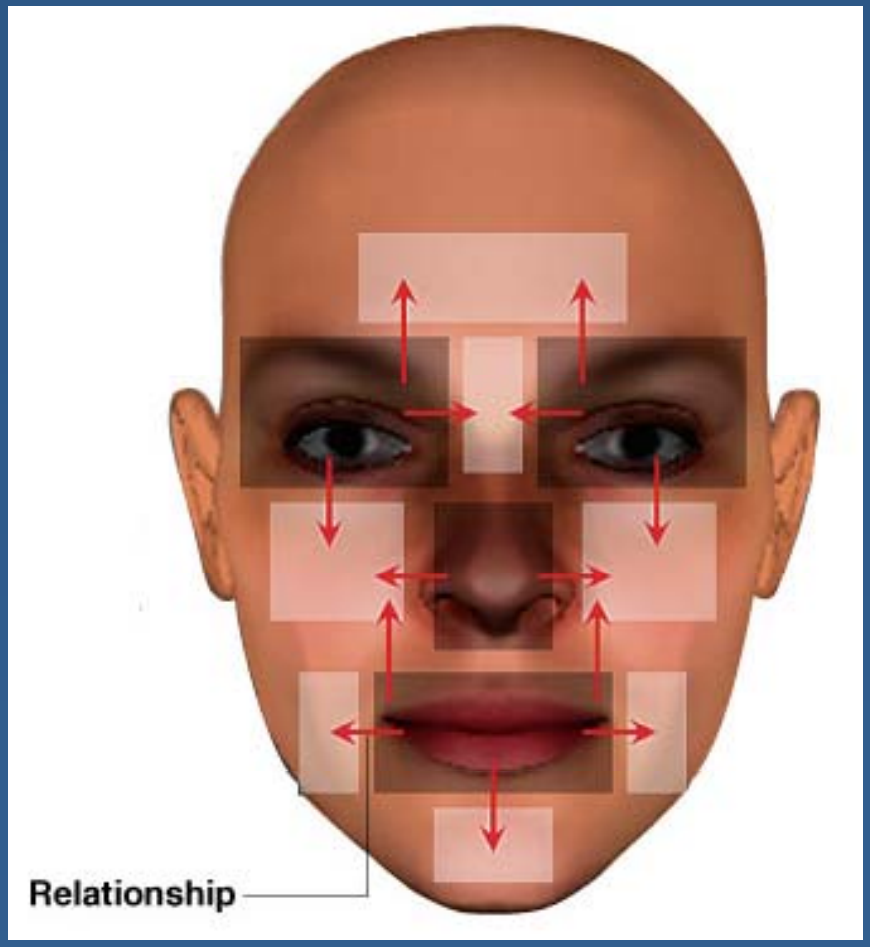
Faces are Special

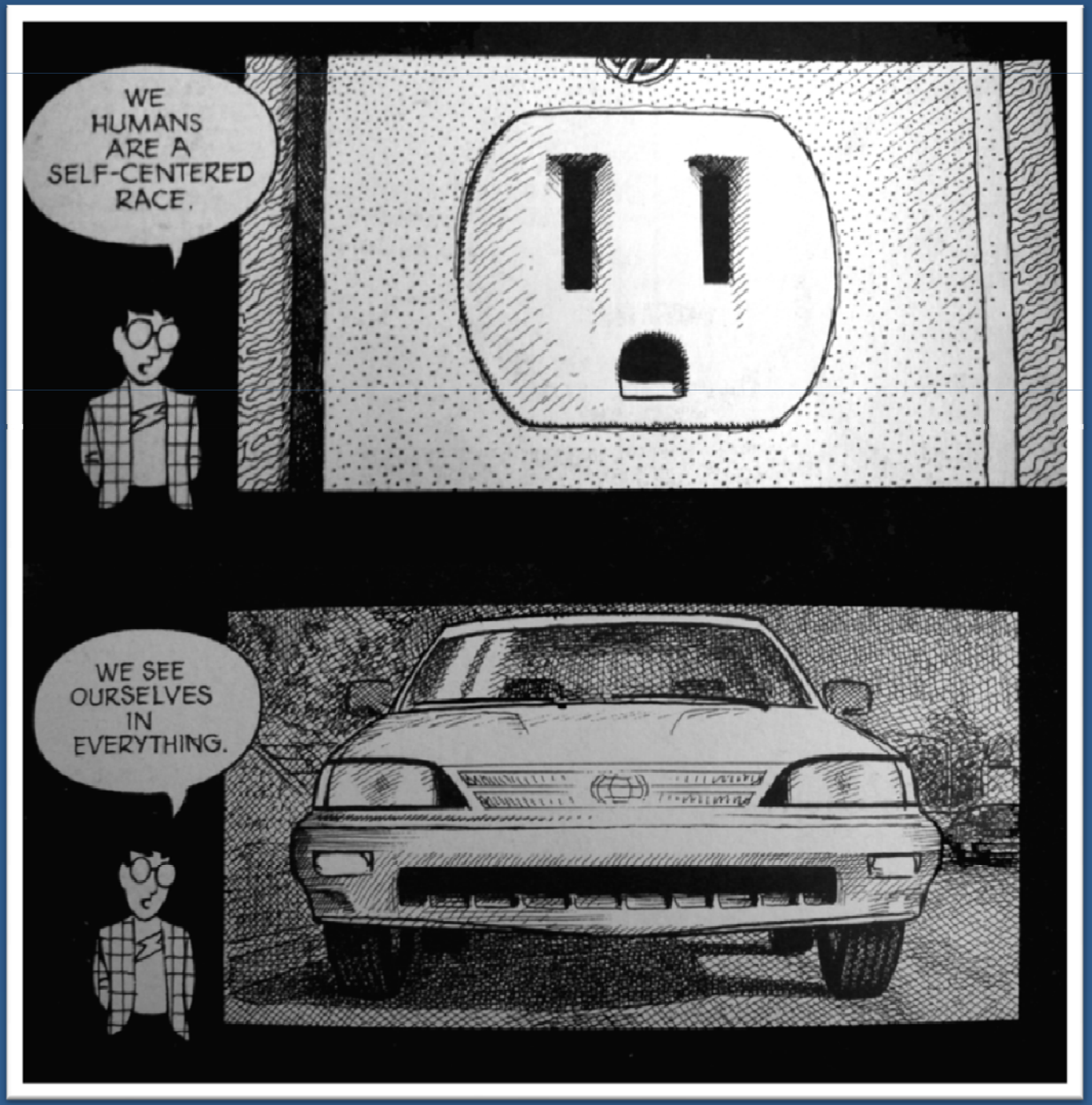
Faces are Special

Faces are Special

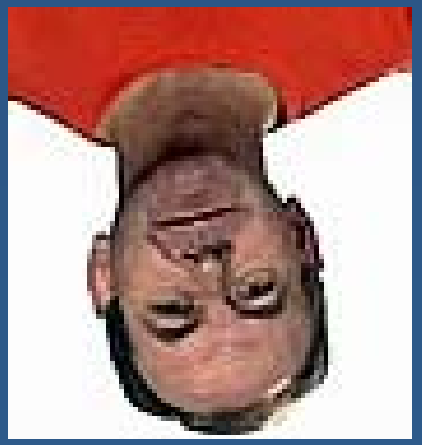
Faces, Faces Everywhere

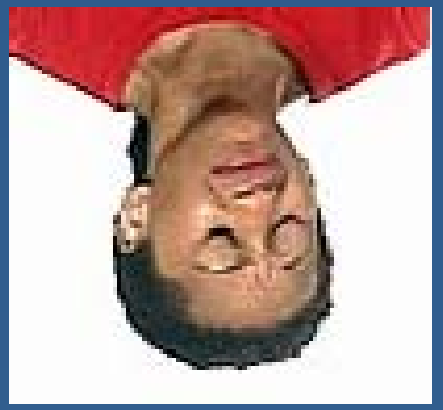




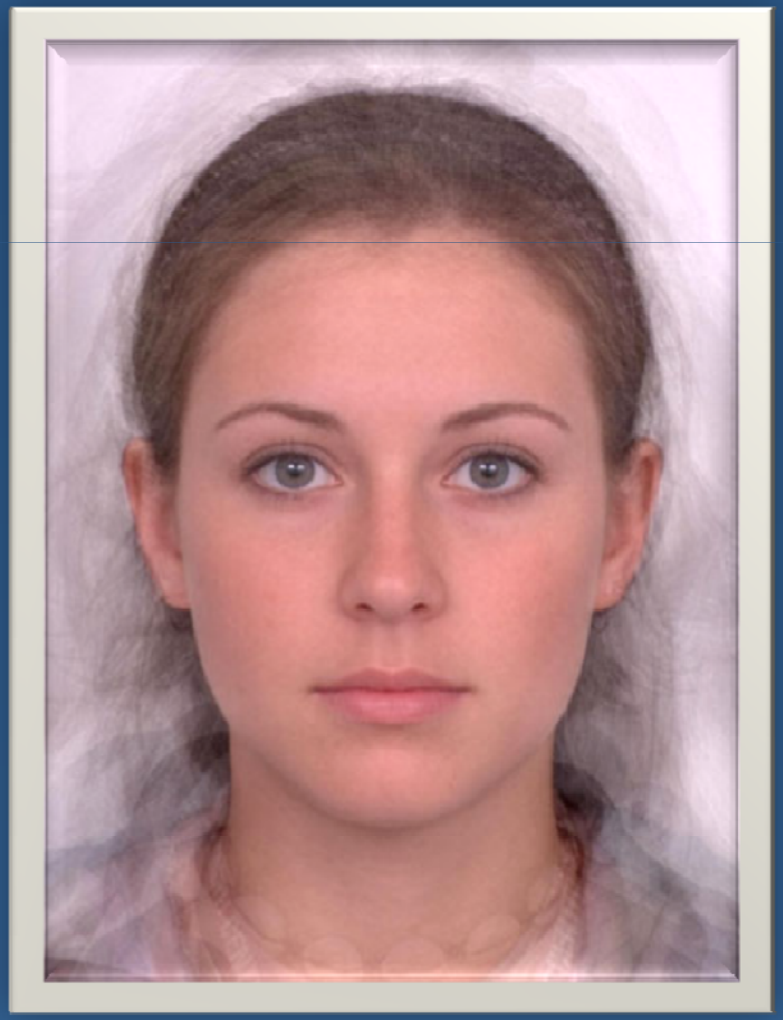

WE HUMANS ARE A SELF-CENTERED RACE.
WE SEE OURSELVES IN EVERYTHING.

Austism and Face Processing



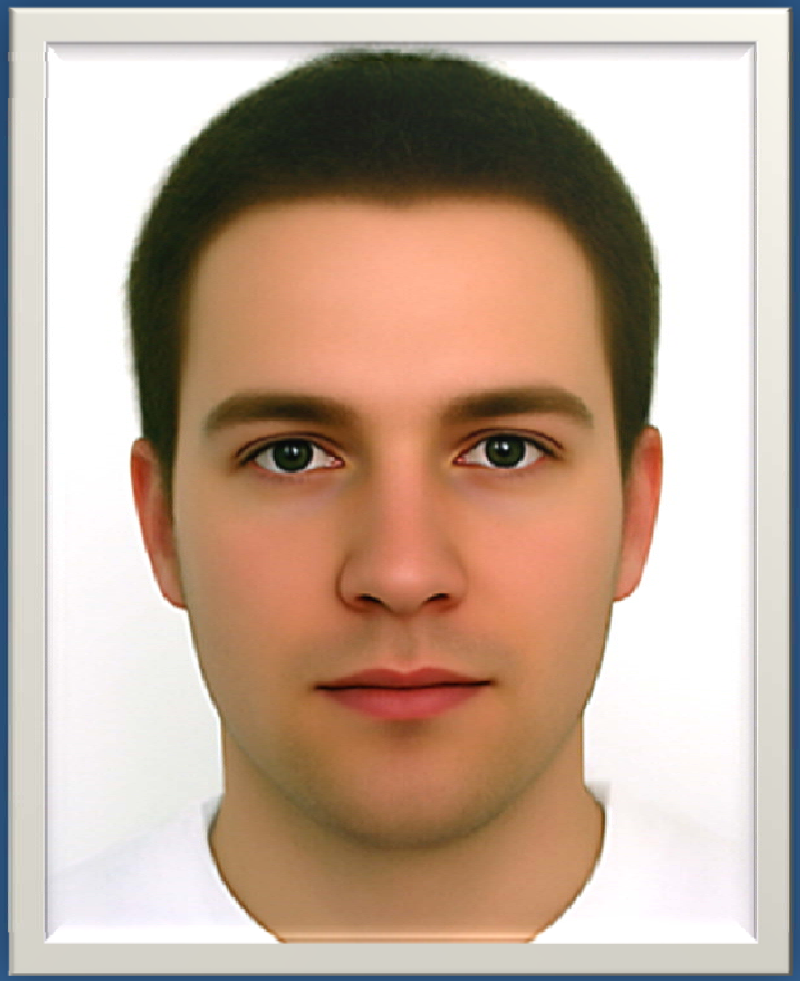


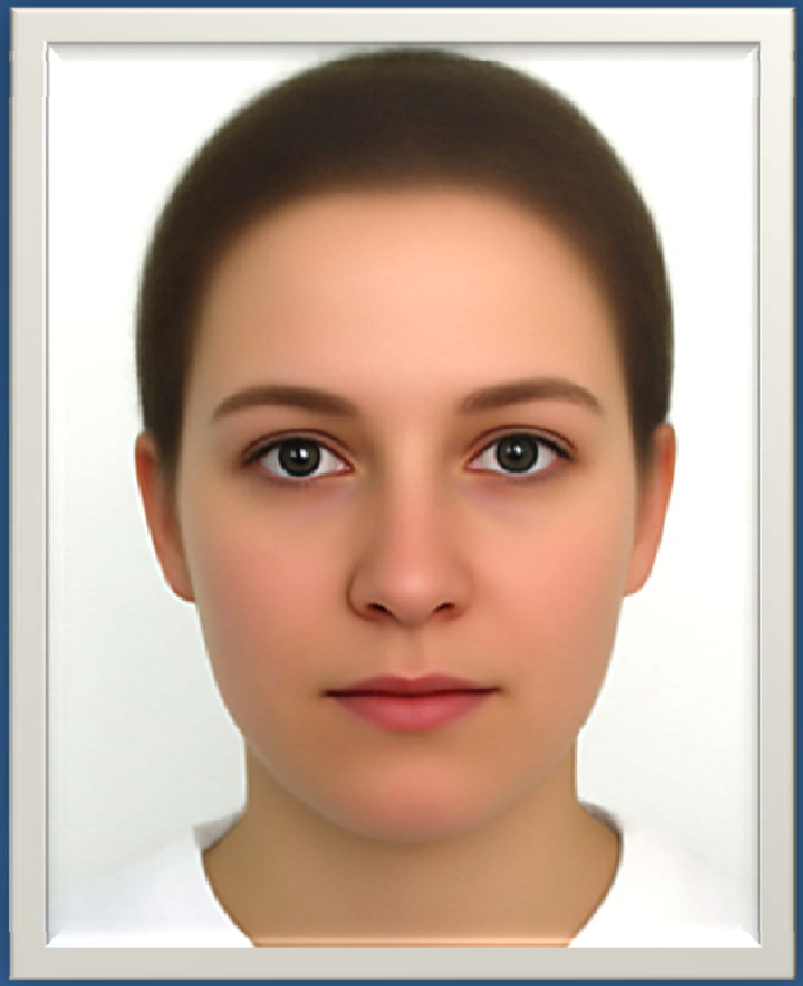
Average Girls are Hot



(courtesy of Seed Magazine)

Average Faces





(courtesy of University of Regensburg)

“2D” Painted Room

“2D” Painted Room

Summary

- Human visual perception is complex… more than just a picture on the retina
- Computer vision will take a long time to catch up!
- But we can apply some of the same kinds of "hacks" in computer vision to simplify particular problems

Reading for Next Lecture

- **Acquiring Images**
  John C. Russ, Chapter 1 of The Image Processing Handbook, CRC Press, 2002.