

S. Rinzivillo – rinzivillo@isti.cnr.it

# **DATA VISUALIZATION AND VISUAL ANALYTICS**

# Who I Am?

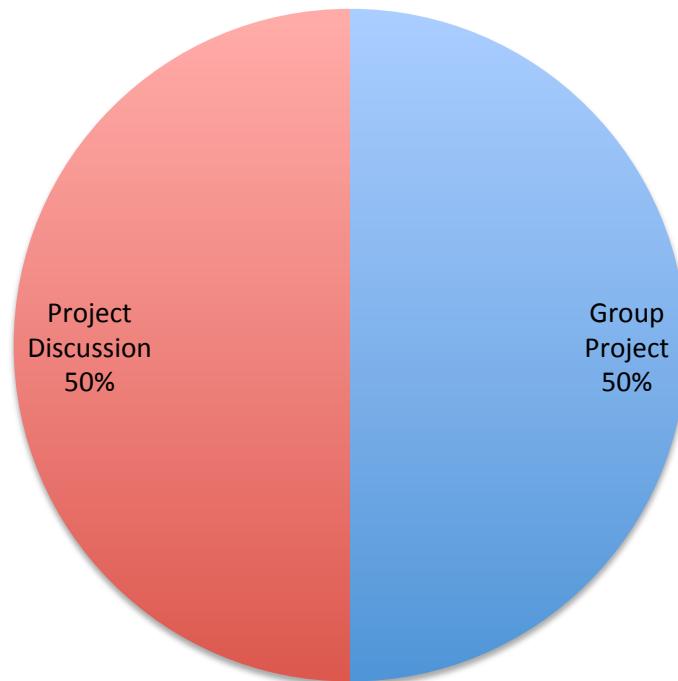
- Salvatore Rinzivillo
  - [rinzivillo@isti.cnr.it](mailto:rinzivillo@isti.cnr.it)
- Page course: <http://didawiki.cli.di.unipi.it/>
  - Visual Analytics

# Schedule

- On Monday
  - 14:00 to 16:00
  - Room: A1
- On Friday
  - 14:00 to 16:00
  - Room: A1

# Grading

- Project (50%)
  - Up to 2 persons per group (!)
- Project discussion (50%)
- Project topic
  - Multidimensional exploration of a dataset
  - One (or two) dataset(s) assigned for all
  - Specific proposal may be discussed

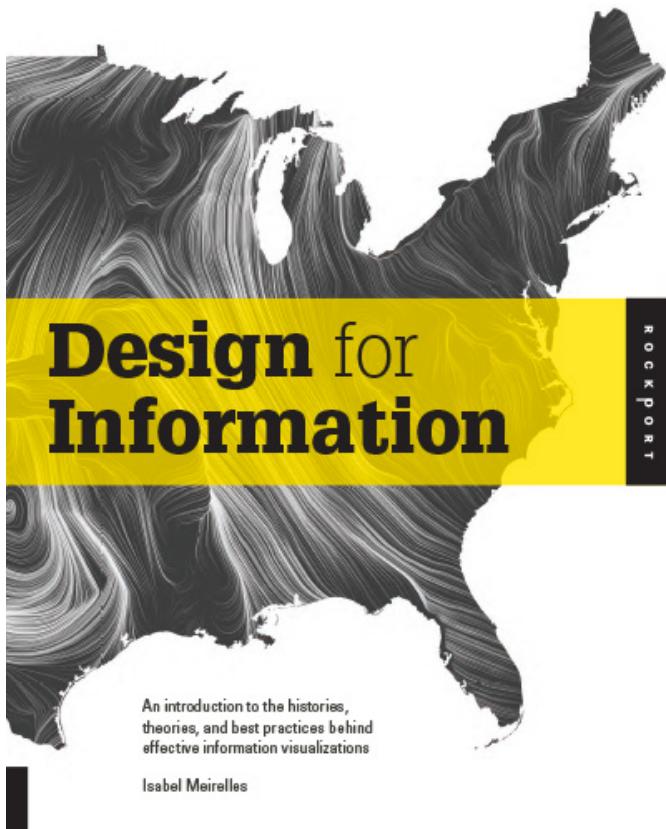




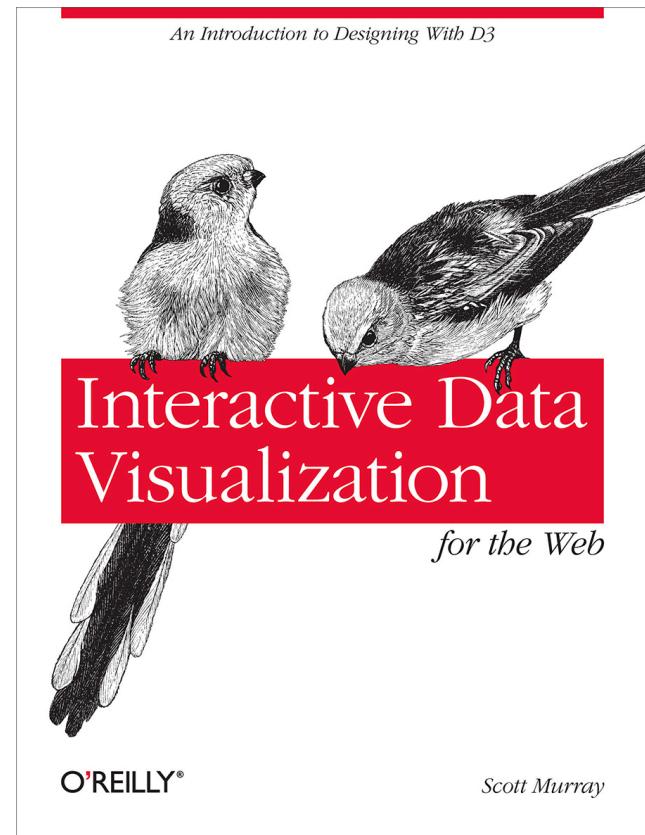
# **EXAMPLE SCHOOL DISTRICTS**

# Textbooks

**Design for Information**  
Isabel Meirelles



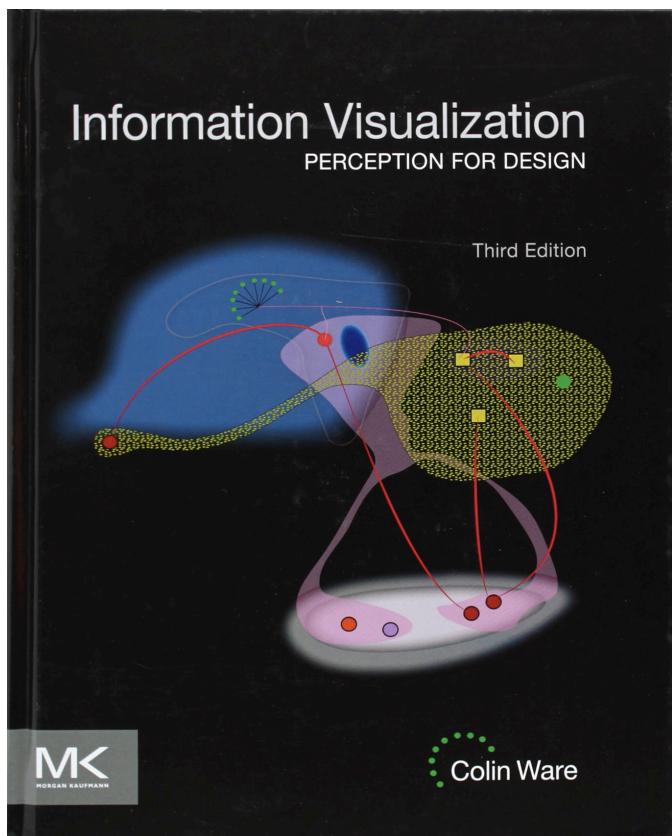
**Interactive Data Visualization**  
Scott Murray



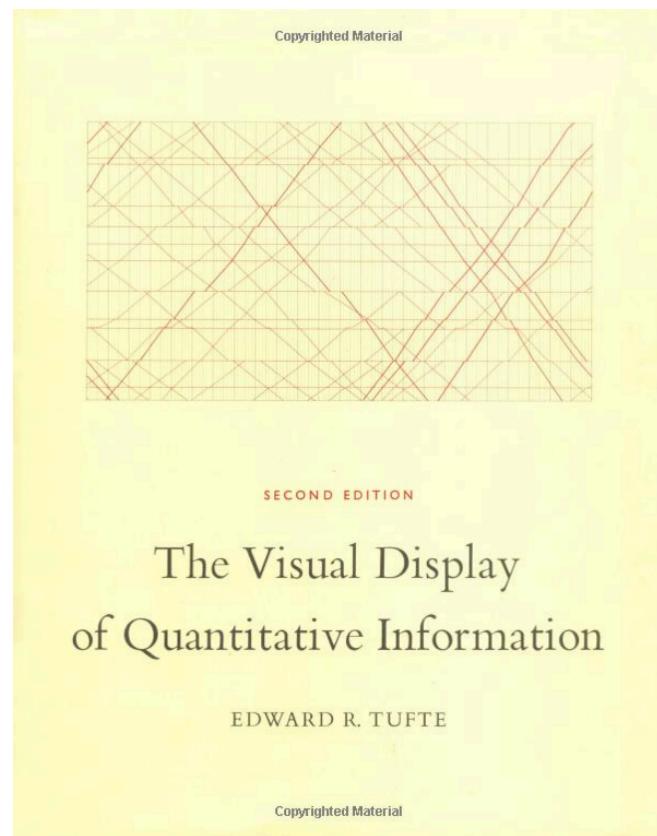
<http://alignedleft.com/tutorials>

# Interesting Readings

Information Visualization  
Colin Ware



The Visual Display of Visual Information  
Edward R. Tufte





# **DATA VISUALIZATION AND VISUAL ANALYTICS INTRODUCTION**

# VA - Crash course

- Effective Visual Representation
  - Vision System
  - Visual Variables
- Toolbox – Bootstrap, Node.js, Bower, REACT.js, crossfilter.js
- Toolbox – Base visualizations (NVD3, DC.js)
- Toolbox – D3.js
  - Basics
  - Charts
  - Advanced Visualization
- Scientific Visualization
  - Plotting
  - Geography
- Storytelling

# Data Visualization

Convey Information through  
graphical representation of data

# Motivations

- Data everywhere
- No value for raw data
  - Need to extract valuable information
- Information overload:
  - Irrelevant for current task
  - Processed in an inappropriate way
  - Presented in an inappropriate way

# Visualization Goal

- Record Information
  - Sketches, photographs, ECG,...
- Analyze data to support decisions (**exploration**)
  - Create and verify hypotheses
  - Identify Patterns
  - Identify Outliers
- Communicate (**explanation**)
  - Share or highlight insights on data
  - Persuade

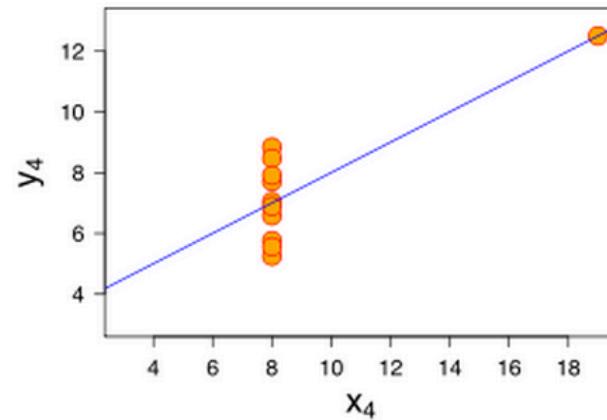
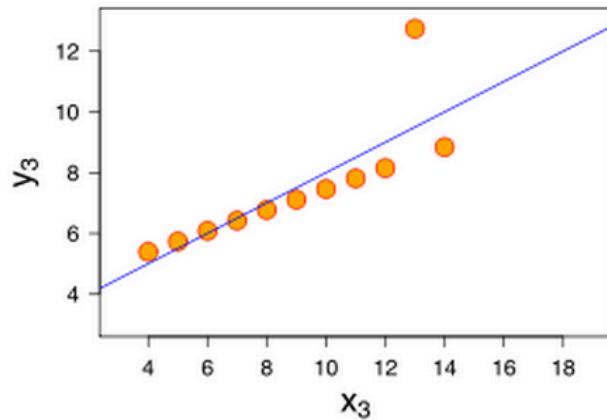
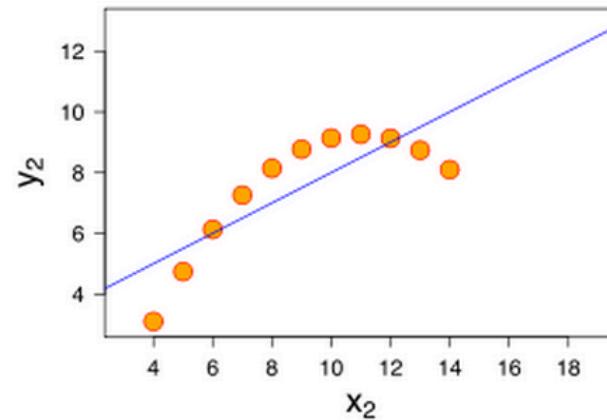
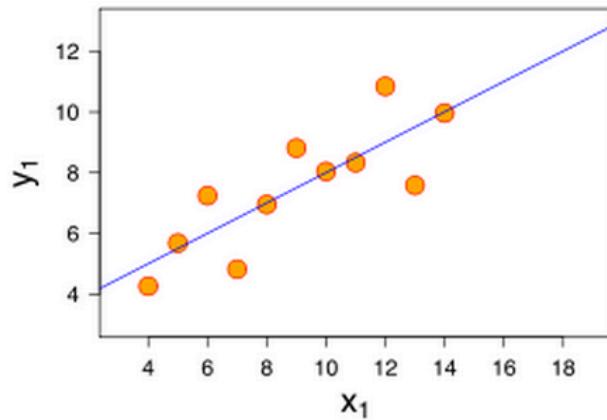
# Analyze: Anscombe's quartet - datasets

Data Set A		Data Set B		Data Set C		Data Set D	
X	Y	X	Y	X	Y	X	Y
10.0	8.04	10.0	9.14	10.0	7.46	8.0	6.58
8.0	6.95	8.0	8.14	8.0	6.77	8.0	5.76
13.0	7.58	13.0	8.74	13.0	12.74	8.0	7.71
9.0	8.81	9.0	8.77	9.0	7.11	8.0	8.84
11.0	8.33	11.0	9.26	11.0	7.81	8.0	8.47
14.0	9.96	14.0	8.10	14.0	8.84	8.0	7.04
6.0	7.24	6.0	6.13	6.0	6.08	8.0	5.25
4.0	4.26	4.0	3.10	4.0	5.39	19.0	12.50
12.0	10.84	12.0	9.13	12.0	8.15	8.0	5.56
7.0	4.82	7.0	7.26	7.0	6.42	8.0	7.91
5.0	5.68	5.0	4.74	5.0	5.73	8.0	6.89

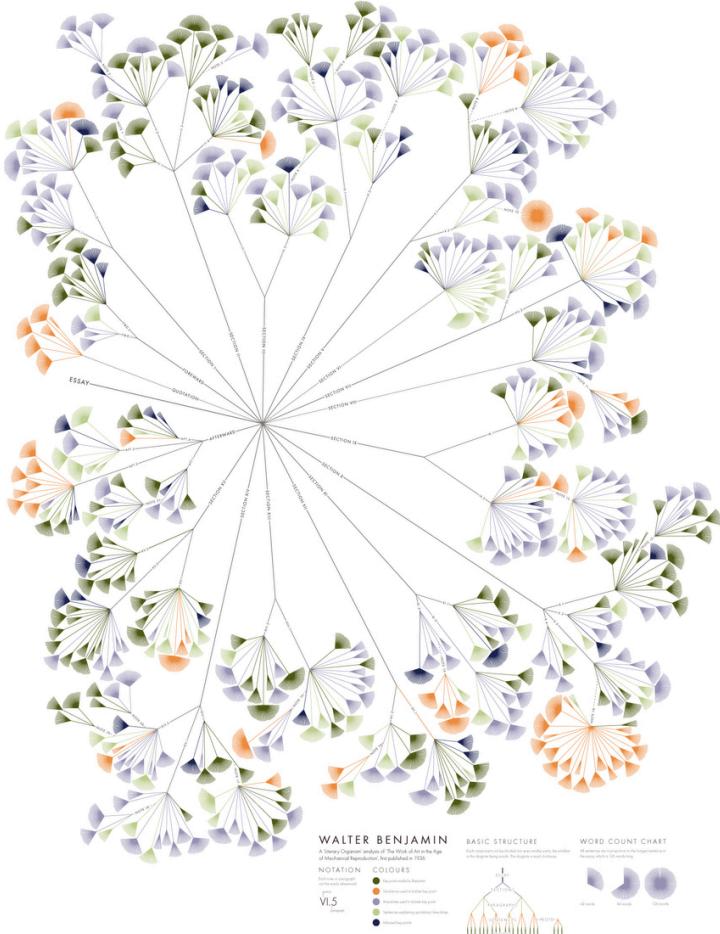
# Analyze: Anscombe's quartet - properties

Property	Value
Mean of $x$ in each case	9 (exact)
Sample variance of $x$ in each case	11 (exact)
Mean of $y$ in each case	7.50 (to 2 decimal places)
Sample variance of $y$ in each case	4.122 or 4.127 (to 3 decimal places)
Correlation between $x$ and $y$ in each case	0.816 (to 3 decimal places)
Linear regression line in each case	$y = 3.00 + 0.500x$ (to 2 and 3 decimal places, respectively)

# Analyze: Anscombe's quartet – graphics

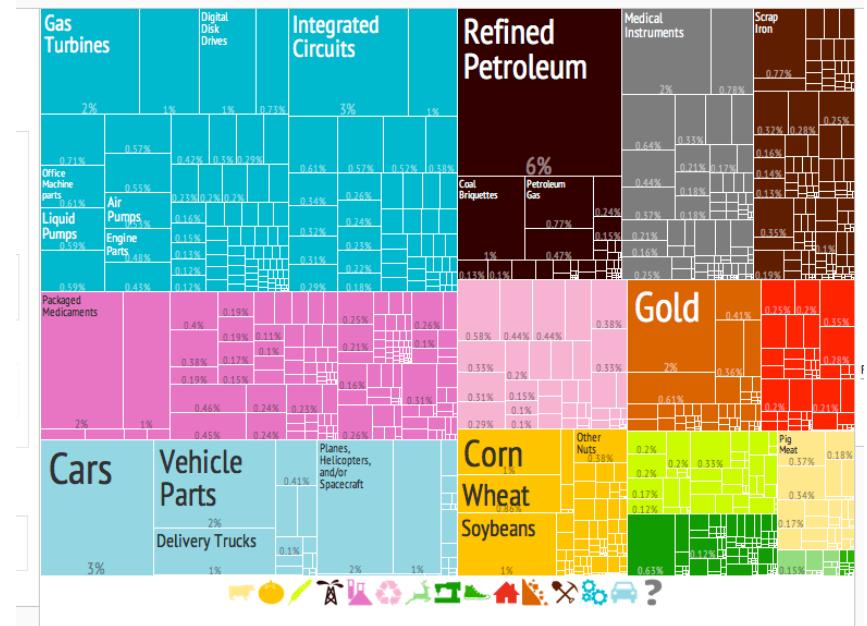


# Communicate: Hierarchical Structures



<http://www.stefanieposavec.co.uk/entangled-word-bank/>

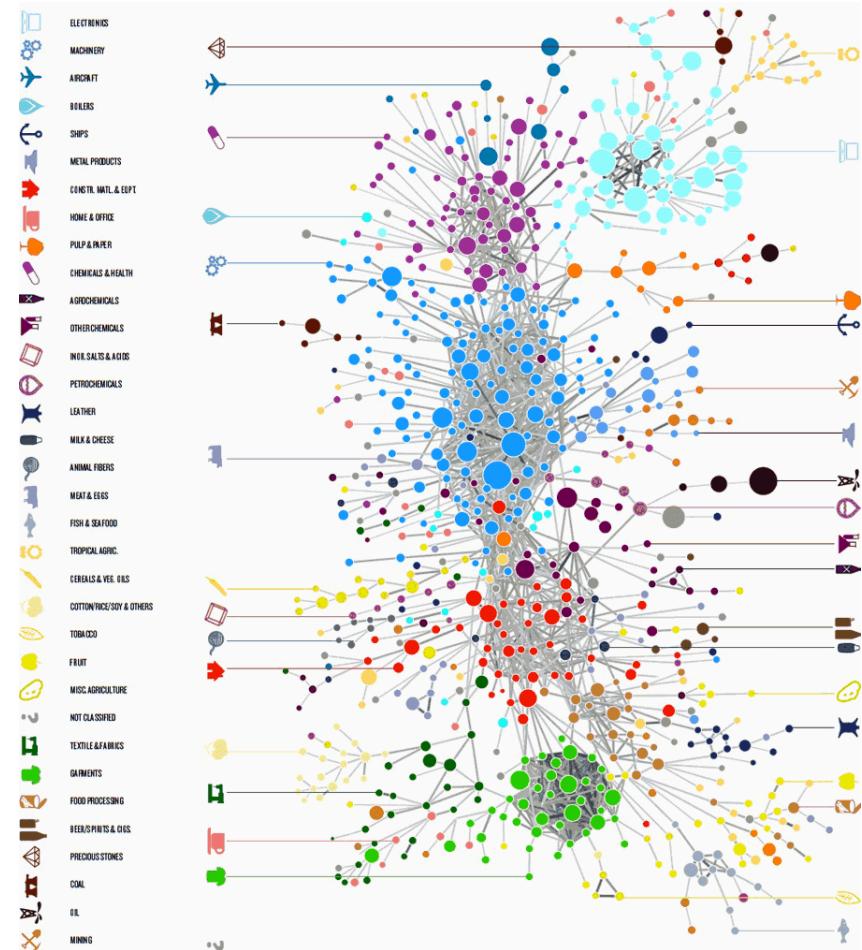
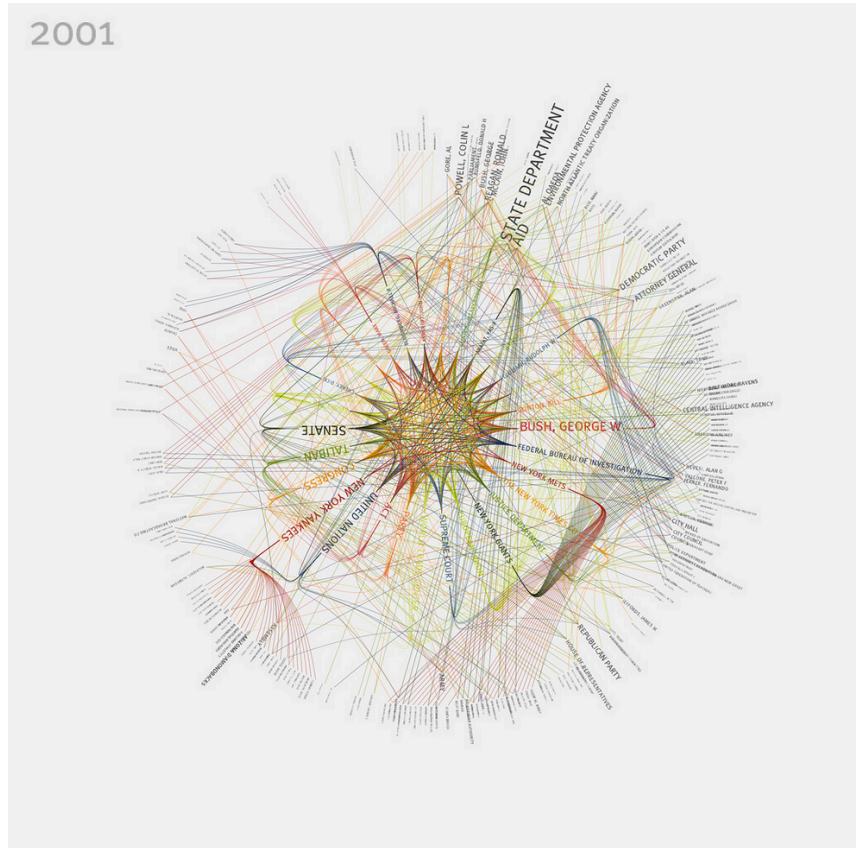
What did the United States export in 2011?



<http://atlas.media.mit.edu/>

# Communicate: Networks

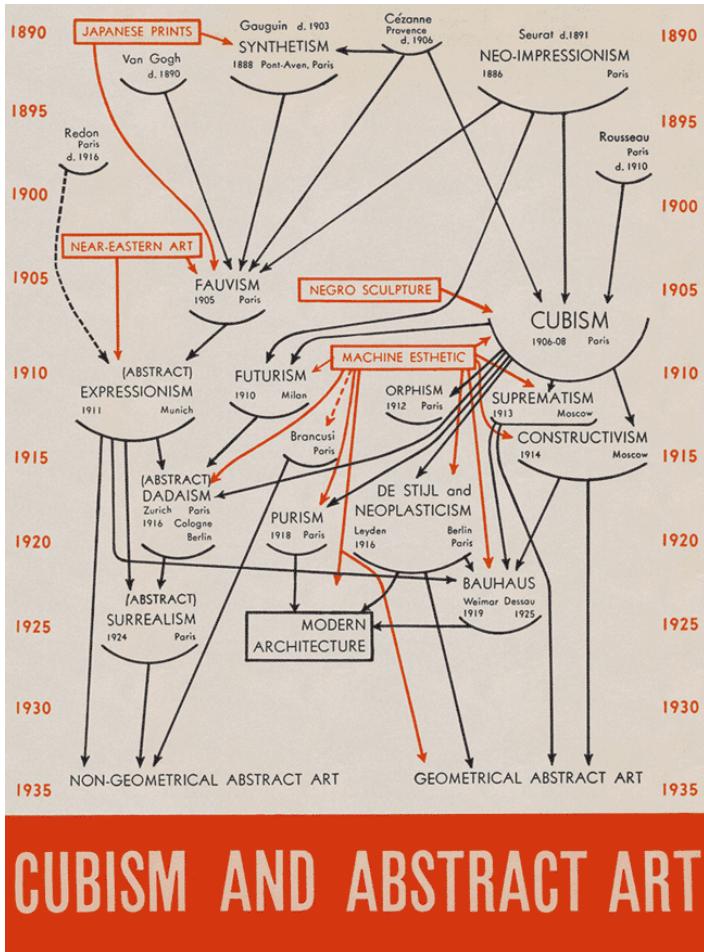
2001



<https://www.flickr.com/photos/blprnt/sets/72157614008027965/>

<http://atlas.media.mit.edu/>

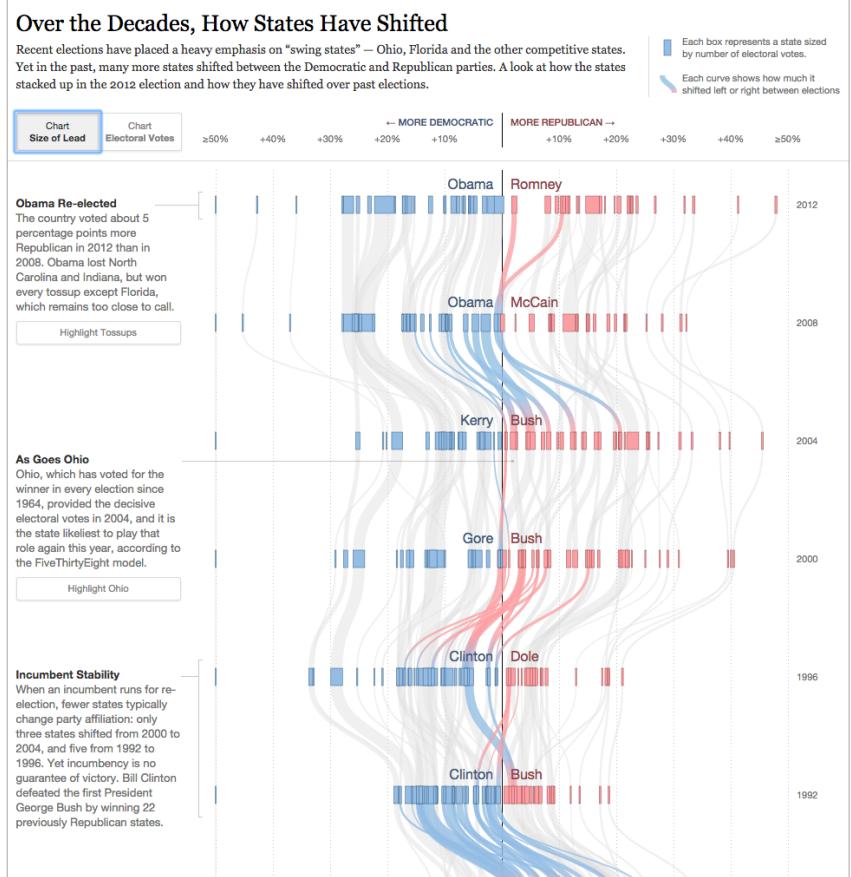
# Communicate: Temporal Structures



Cubism And Abstract Art (Alfred H. Barr 1936)

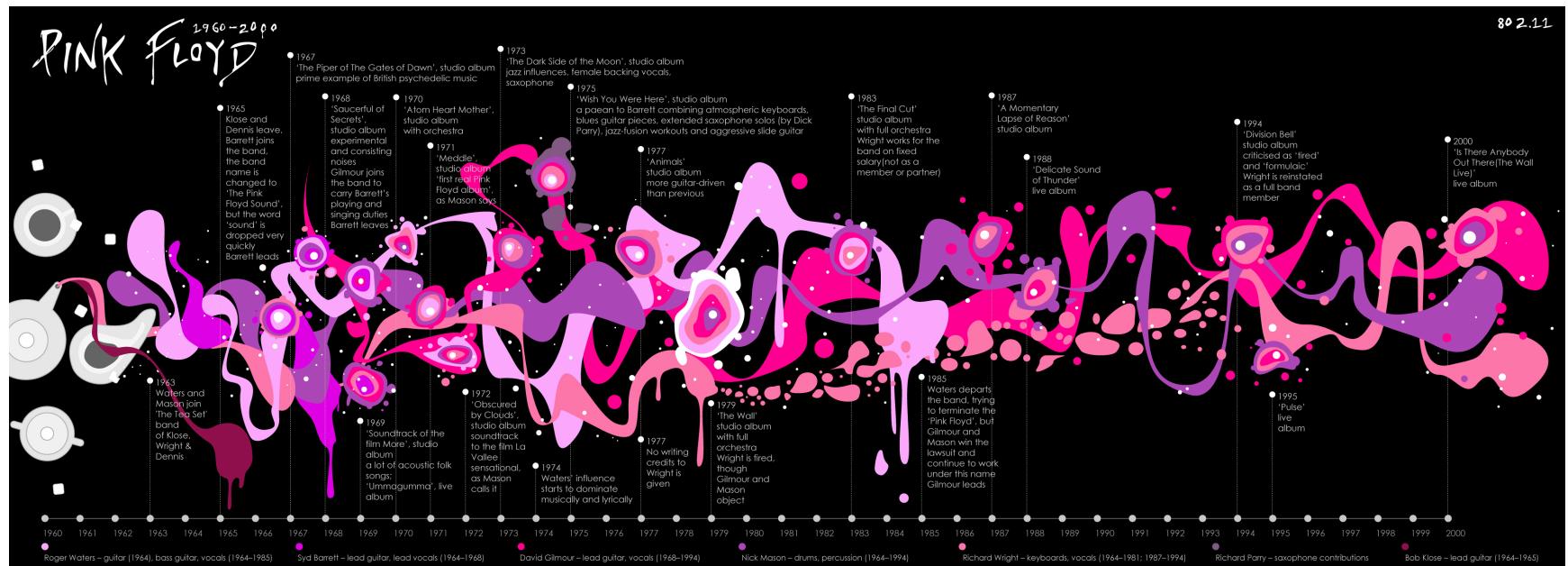
## Over the Decades, How States Have Shifted

Recent elections have placed a heavy emphasis on “swing states” — Ohio, Florida and the other competitive states. Yet in the past, many more states shifted between the Democratic and Republican parties. A look at how the states stacked up in the 2012 election and how they have shifted over past elections.



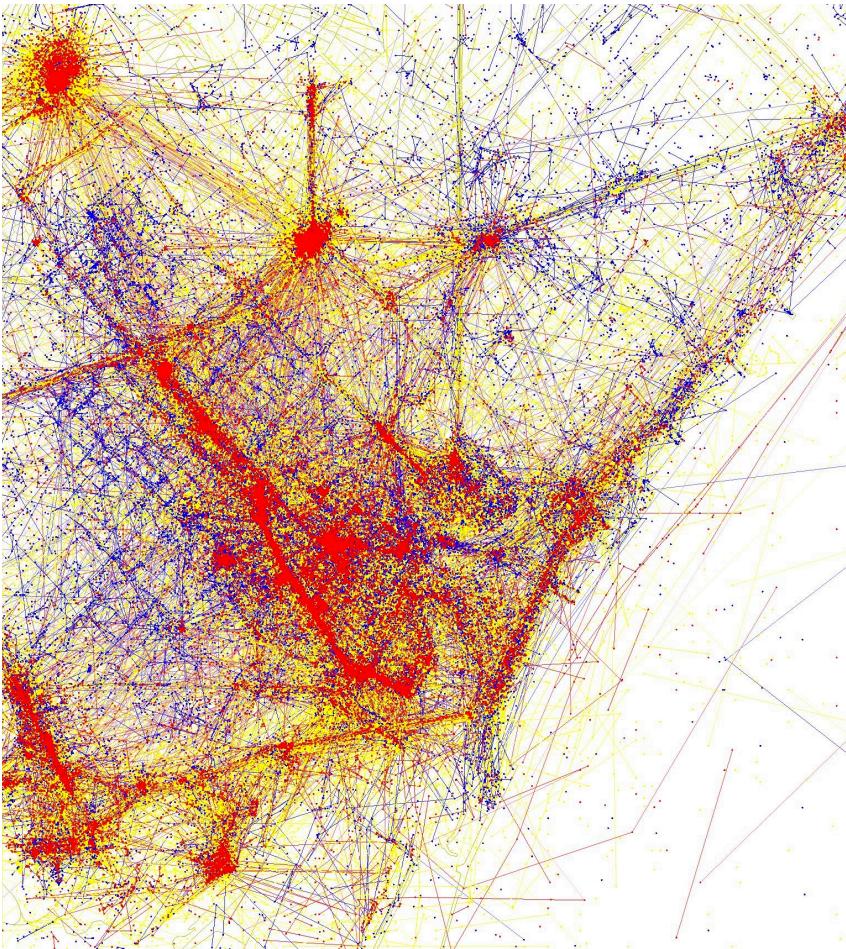
<http://www.nytimes.com/interactive/2012/10/15/us/politics/swing-history.html>

# Communicate: Temporal Structures

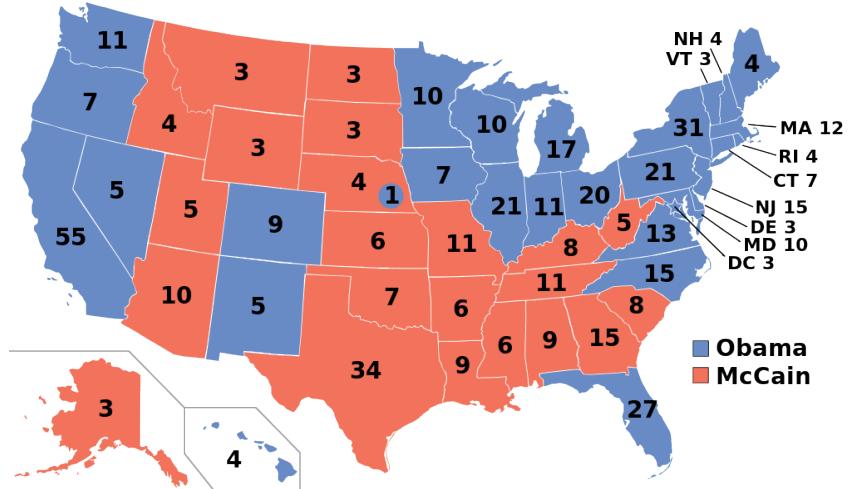


<http://www.80211.cc/>

# Communicate: Maps

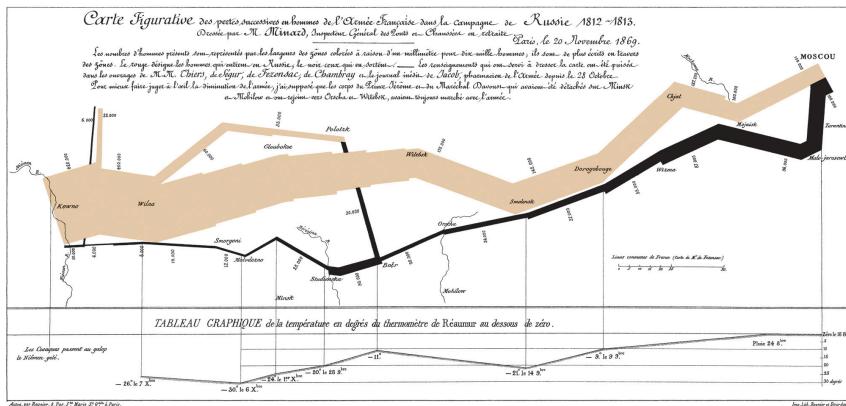


<https://www.flickr.com/photos/walkingsf/sets/72157624209158632/>

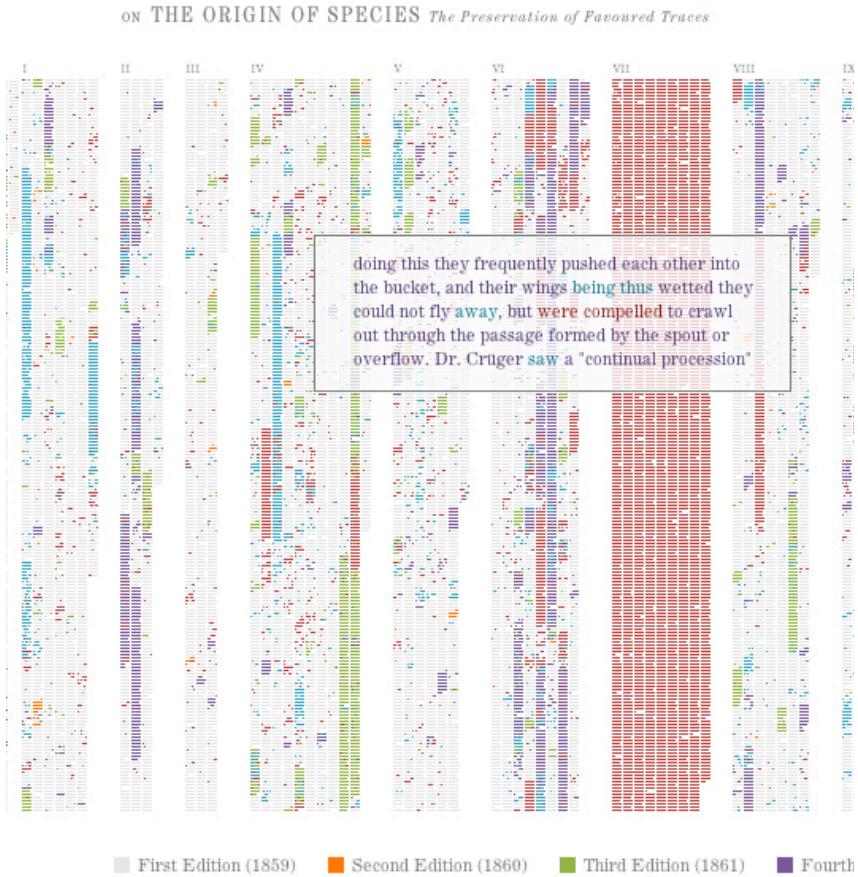


"ElectoralCollege2008" by Gage - Own work. Licensed under Public Domain via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:ElectoralCollege2008.svg#mediaviewer/File:ElectoralCollege2008.svg>

# Communicate: Spatio-Temporal data



# Communicate: Text



<http://benfry.com/writing/archives/529>

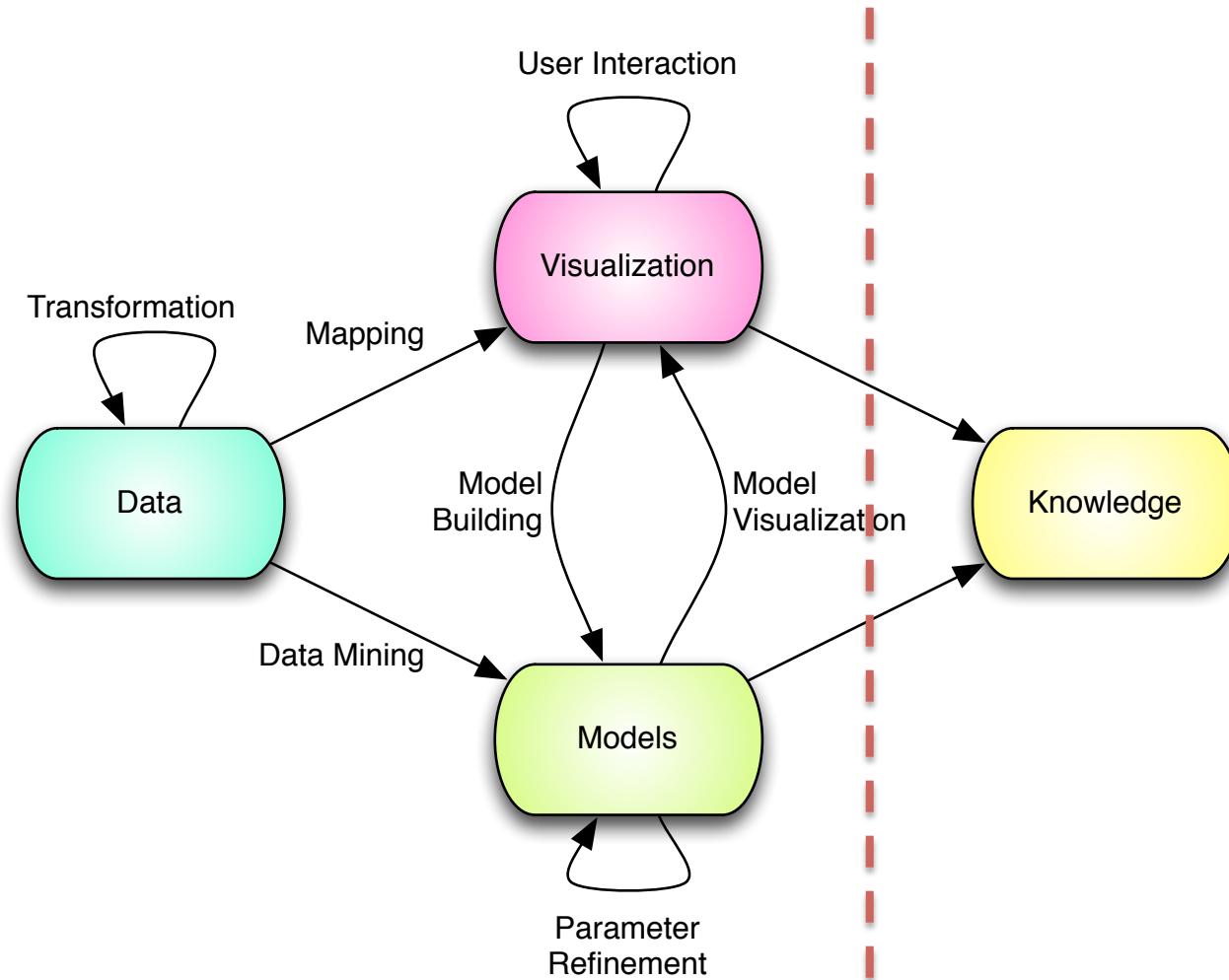
# Visualization and Visual Analytics

- Make data and information processing transparent
- Combine strengths of humans and computers

**Computers are  
incredibly fast,  
accurate,  
and stupid;  
humans are  
incredibly slow,  
inaccurate  
and brilliant;  
together  
they are powerful  
beyond  
imagination.**

Albert Einstein

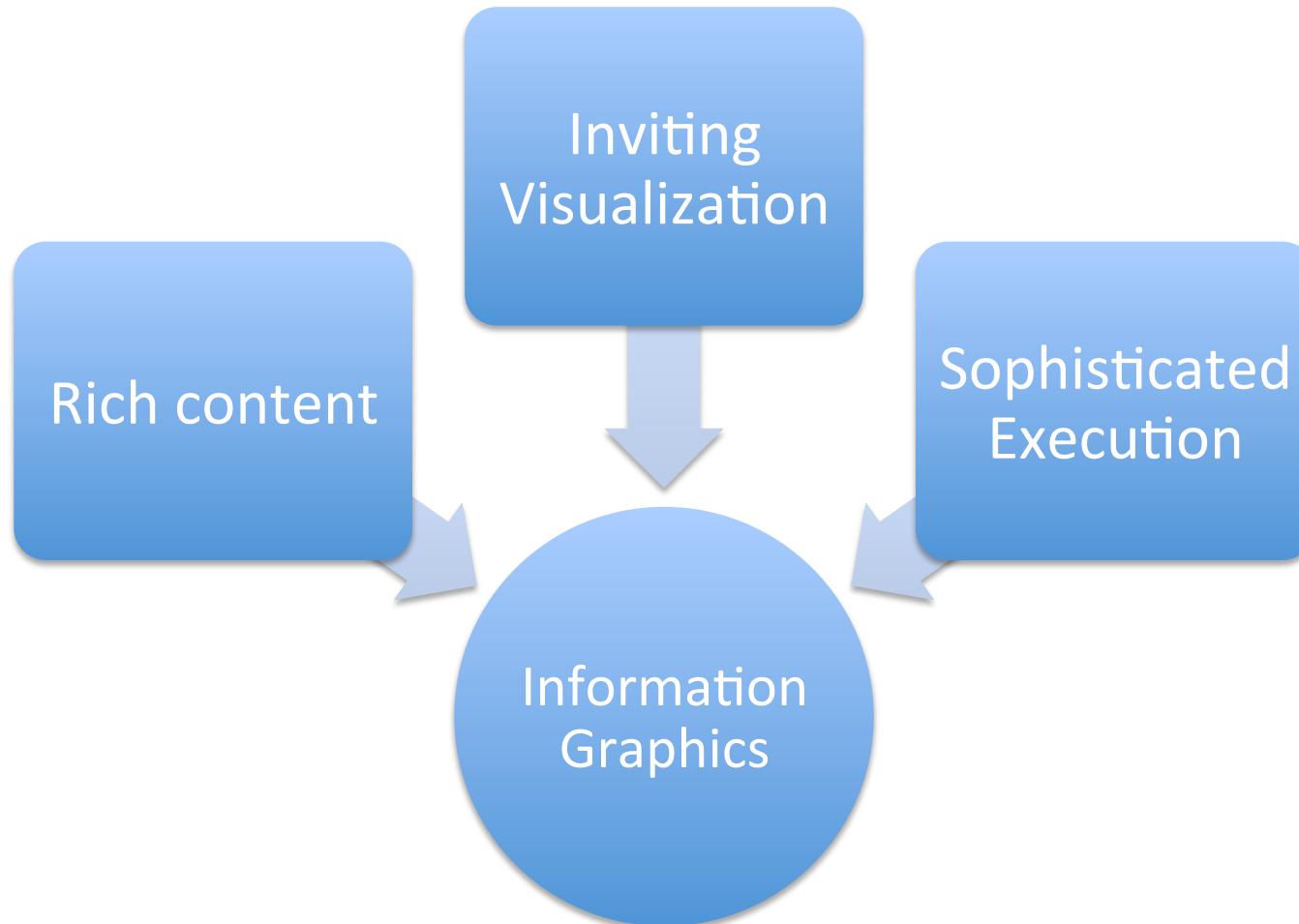
# Visual Analytical Process



Adapted from:  
Mastering the Information Age  
Keim, Kohlhammer, Ellis, Mansmann

Exploration ! Explanation <sub>24</sub>

# Elements of Good Visualization



# Importance of valid data



# Other Resources

## Observe how others resolved design problems

datavisualization.ch

The screenshot shows the homepage of datavisualization.ch. It features a main banner with a colorful bar chart titled "How We Created Color Scales". Below the banner are sections for "SPOTLIGHT", "SUBSCRIBE", "POPULAR", "SPONSOR", "ARTICLES", "ELSEWHERE", and "COMMENTERS". A sidebar on the left lists recent posts and a search bar at the bottom.

informationisbeautiful.net

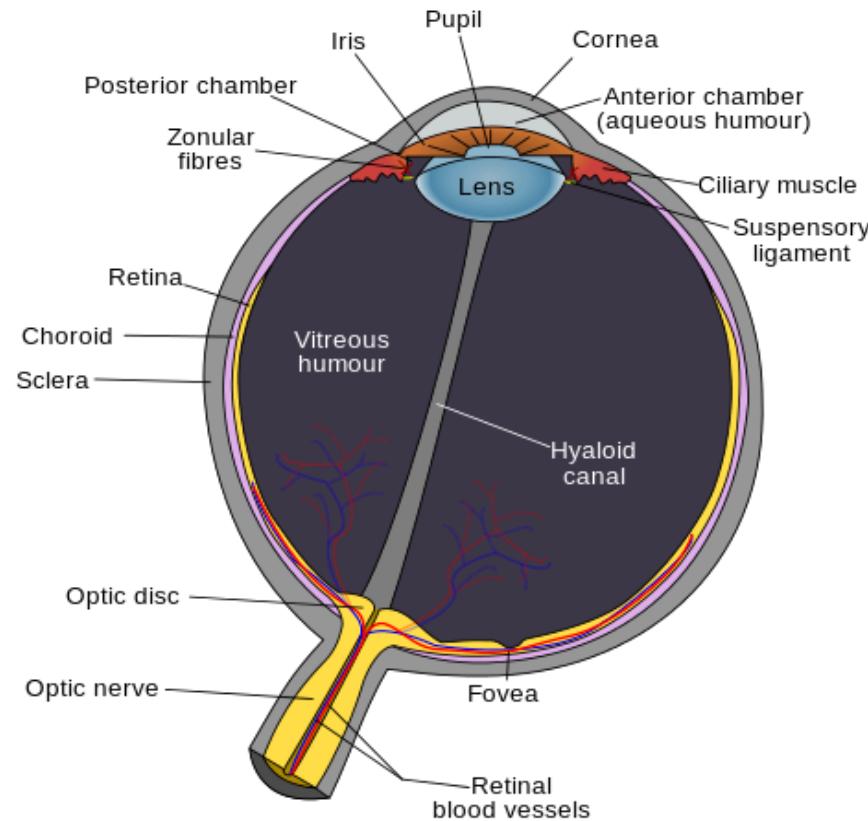
The screenshot shows the homepage of informationisbeautiful.net. It features a grid of various infographics, each with a unique visual style. The infographics include a large pink circle, a world map divided by a diagonal line, a tree with red arrows, a yellow sunburst, a black and red triangle, a blue pyramid, a red target, a green and blue circle, a green and blue bar chart, a green and blue scatter plot, and a grid of small human figures.

infosthetics.com

The screenshot shows the homepage of infosthetics.com. It features a grid of various infographics, each with a unique visual style. The infographics include a complex network diagram with purple lines and dots, a bar chart with red bars, a grid of small human figures, a bar chart with blue bars, a bar chart with orange bars, a bar chart with red bars, a bar chart with blue bars, a bar chart with orange bars, and a map of the Middle East with red lines and dots.

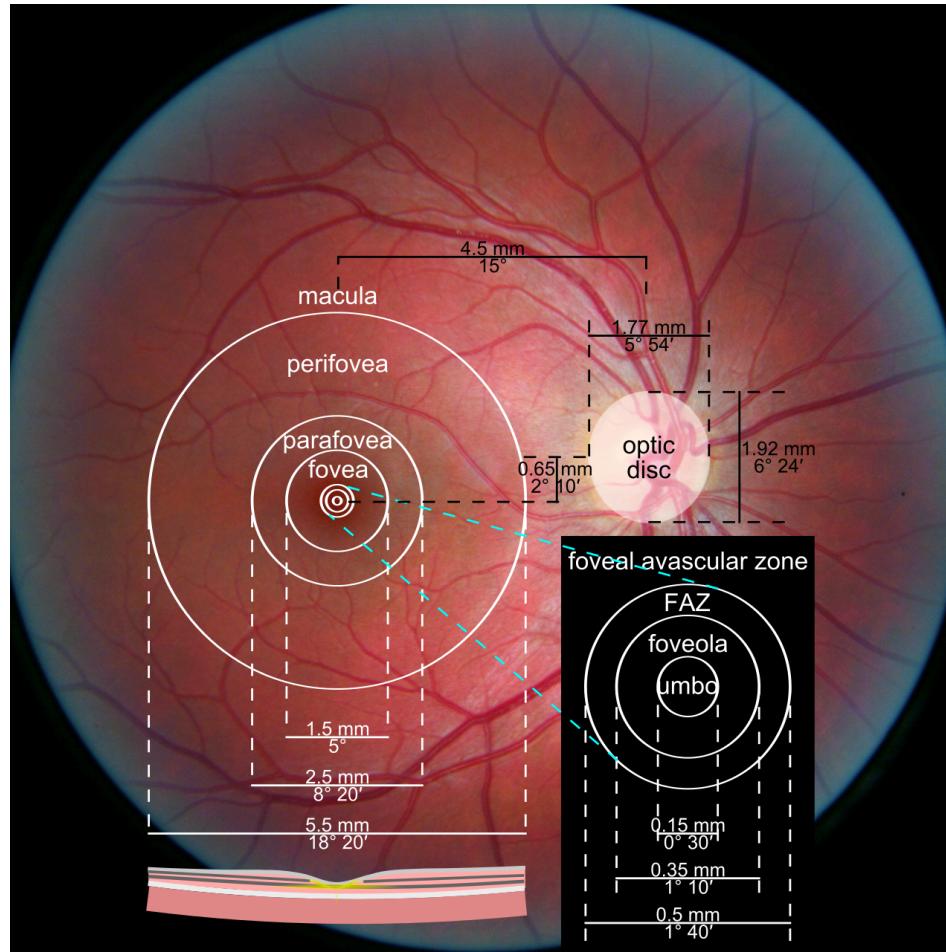
# **VISION AND PERCEPTION**

# Human Eye



"Schematic diagram of the human eye en" by Rhcastilhos - Schematic\_diagram\_of\_the\_human\_eye\_with\_English\_annotations.svg. Licensed under Public Domain via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Schematic\\_diagram\\_of\\_the\\_human\\_eye\\_en.svg#mediaviewer/File:Schematic\\_diagram\\_of\\_the\\_human\\_eye\\_en.svg](http://commons.wikimedia.org/wiki/File:Schematic_diagram_of_the_human_eye_en.svg#mediaviewer/File:Schematic_diagram_of_the_human_eye_en.svg)

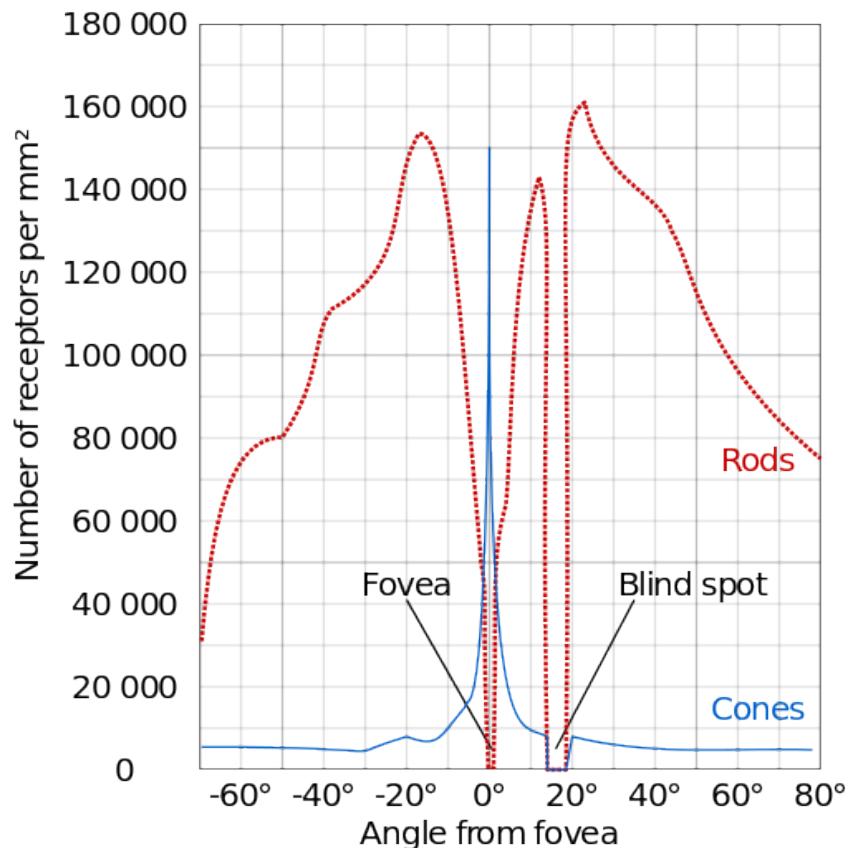
# Macula and Fovea



"Macula" by Photograph: Danny Hope from Brighton & Hove, UK -  
File:Righ\_eye\_retina.jpg (which come from My Right Eye). Licensed under CC BY  
2.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:Macula.svg#mediaviewer/File:Macula.svg>

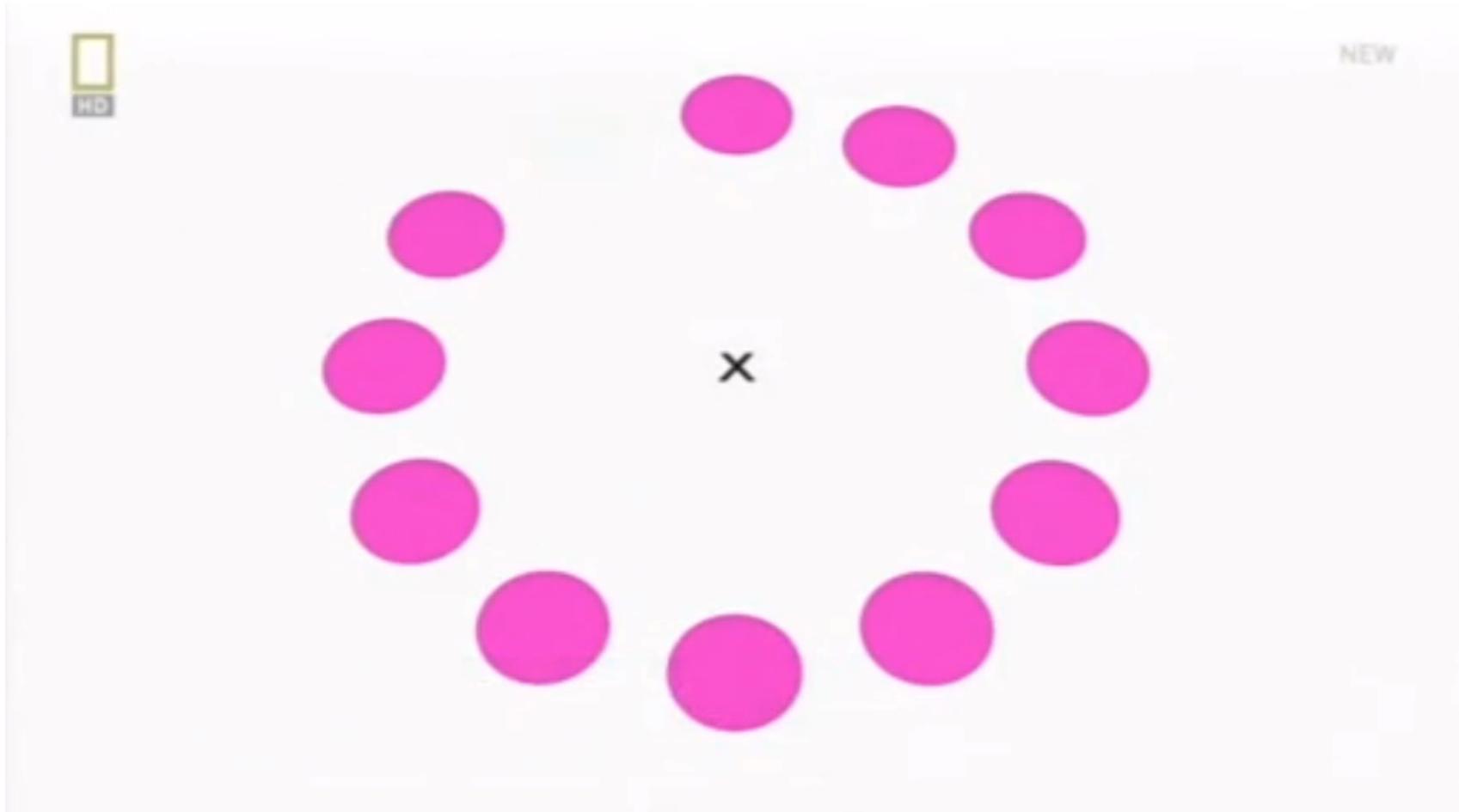
# Photo Receptor Cells

- Two types of light sensitive cells
  - Rod Cells (~120M)
    - Provide low-light vision
    - Peripheral vision
    - Almost no role in color vision
  - Cone cells (~6M)
    - Provide normal vision
    - Three sub-types of cells
      - Sensitivity to different light wavelengths
      - Used for colored vision

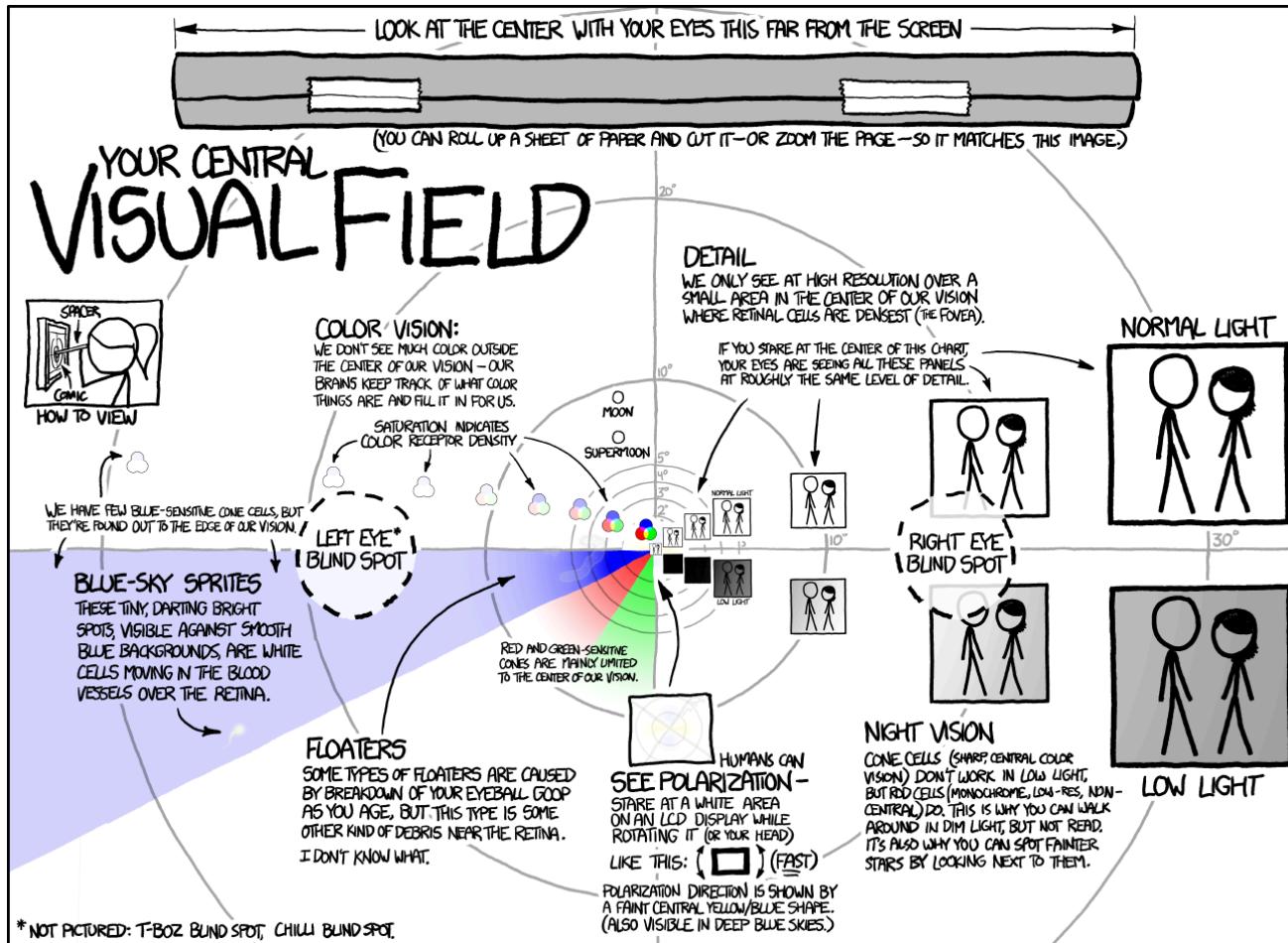


"Human photoreceptor distribution" by Cmglee - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Human\\_photoreceptor\\_distribution.svg#mediaviewer/File:Human\\_photoreceptor\\_distribution.svg](http://commons.wikimedia.org/wiki/File:Human_photoreceptor_distribution.svg#mediaviewer/File:Human_photoreceptor_distribution.svg)

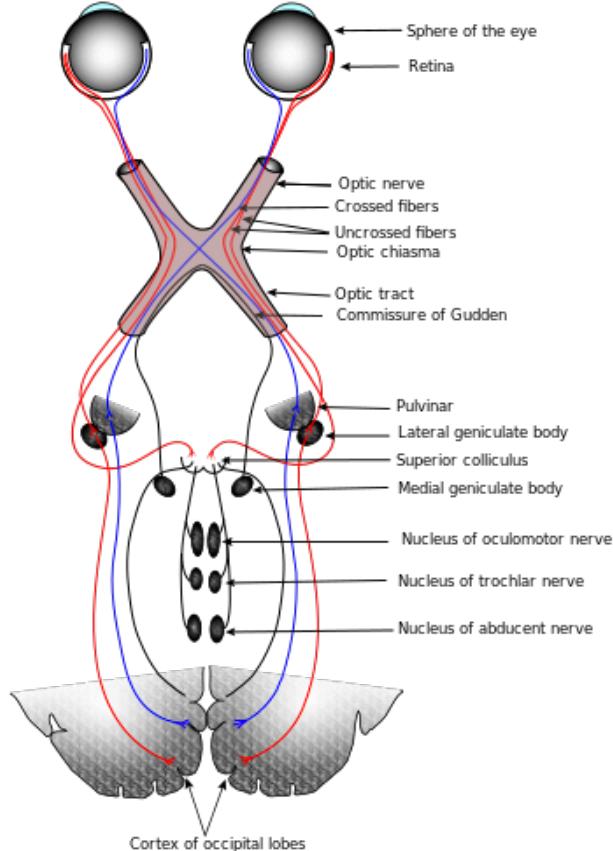
# Peripheral Vision Test – Game #1



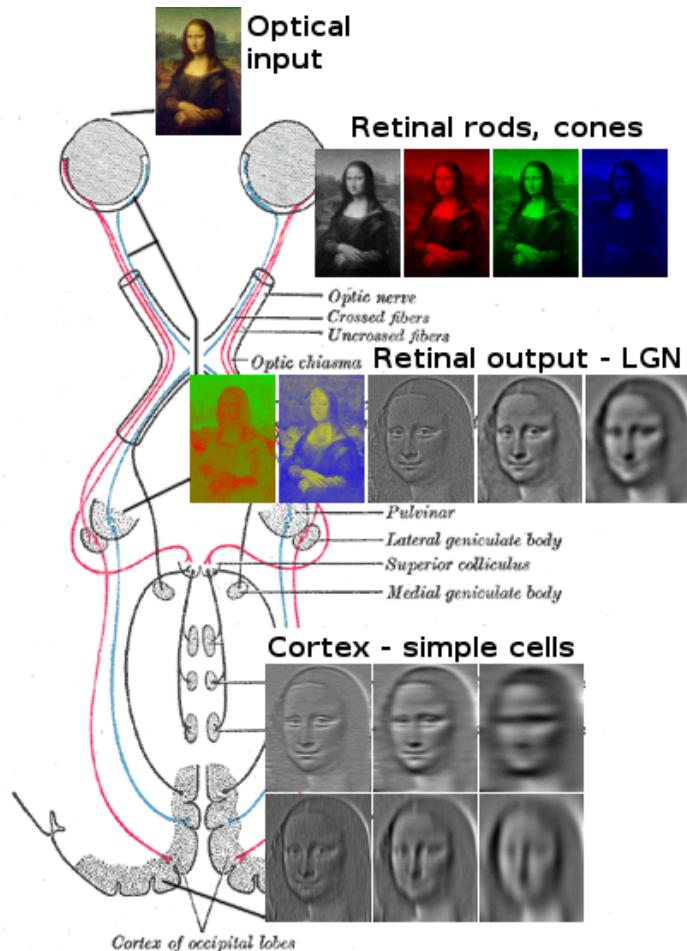
# Vision Resolution



# Visual System



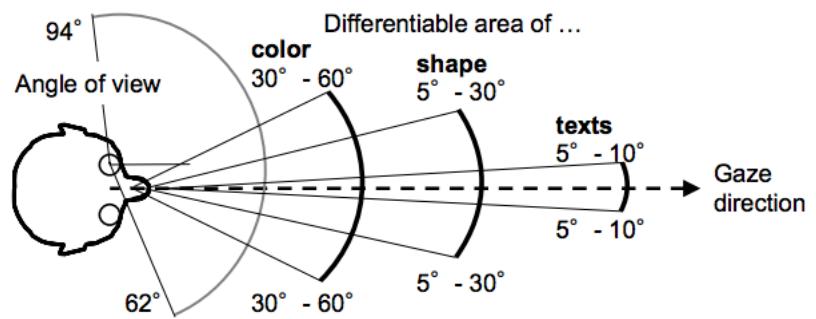
"Gray722-svg" by KDS444 - <https://commons.wikimedia.org/wiki/File:Gray722.png>. Licensed under Public Domain via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:Gray722-svg.svg#media/File:Gray722-svg.svg>



"Lisa analysis" by Clock - Own work. Licensed under CC BY-SA 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Lisa\\_analysis.png#/media/File:Lisa\\_analysis.png](http://commons.wikimedia.org/wiki/File:Lisa_analysis.png#/media/File:Lisa_analysis.png)

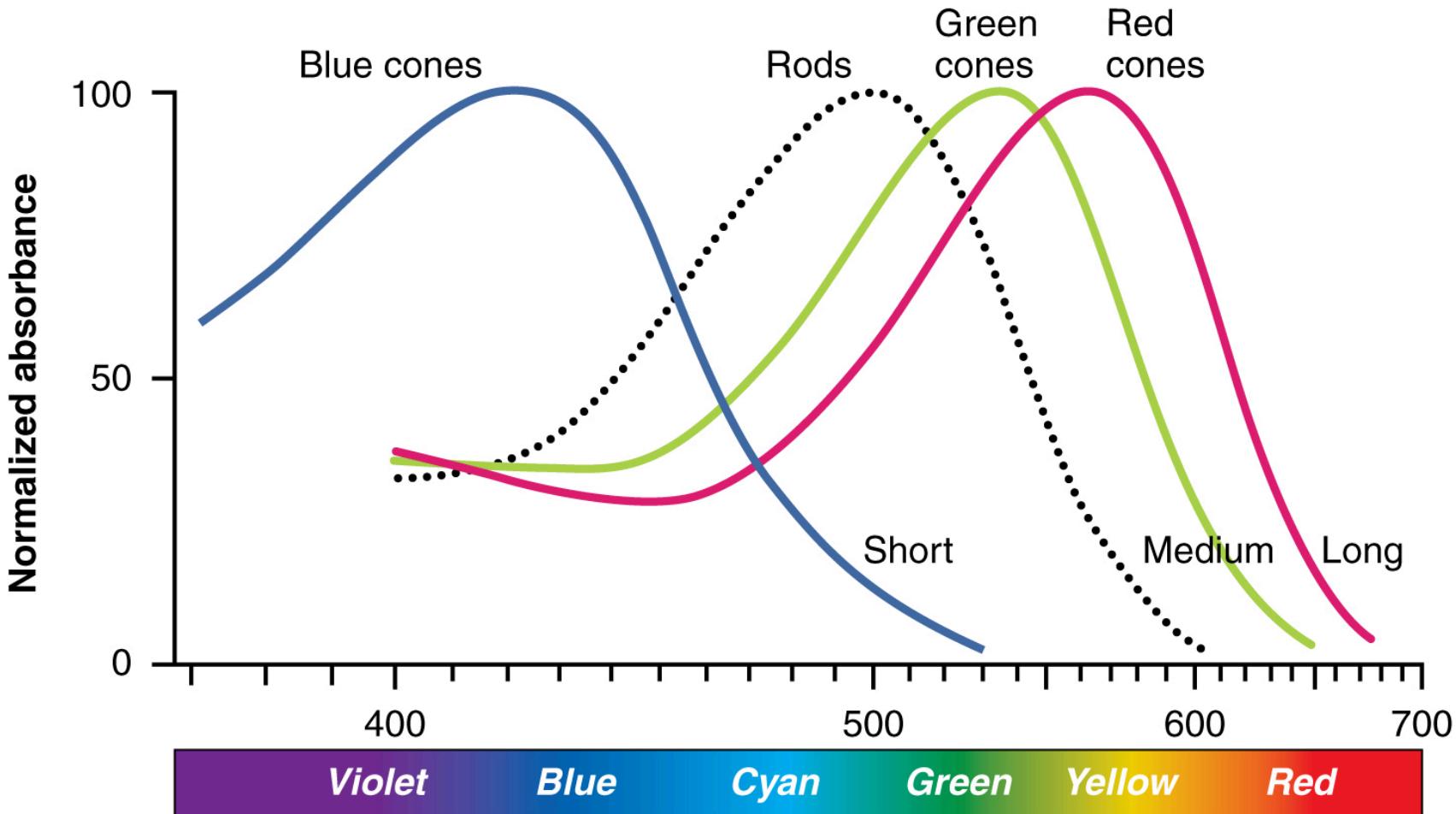
# Vision Resolution

- Fovea yields the highest resolution (normal light)
- Fovea occupies around  $15^\circ$  of visual field
- Highest resolution is provided by *fovea centralis* (around  $1^\circ$ )



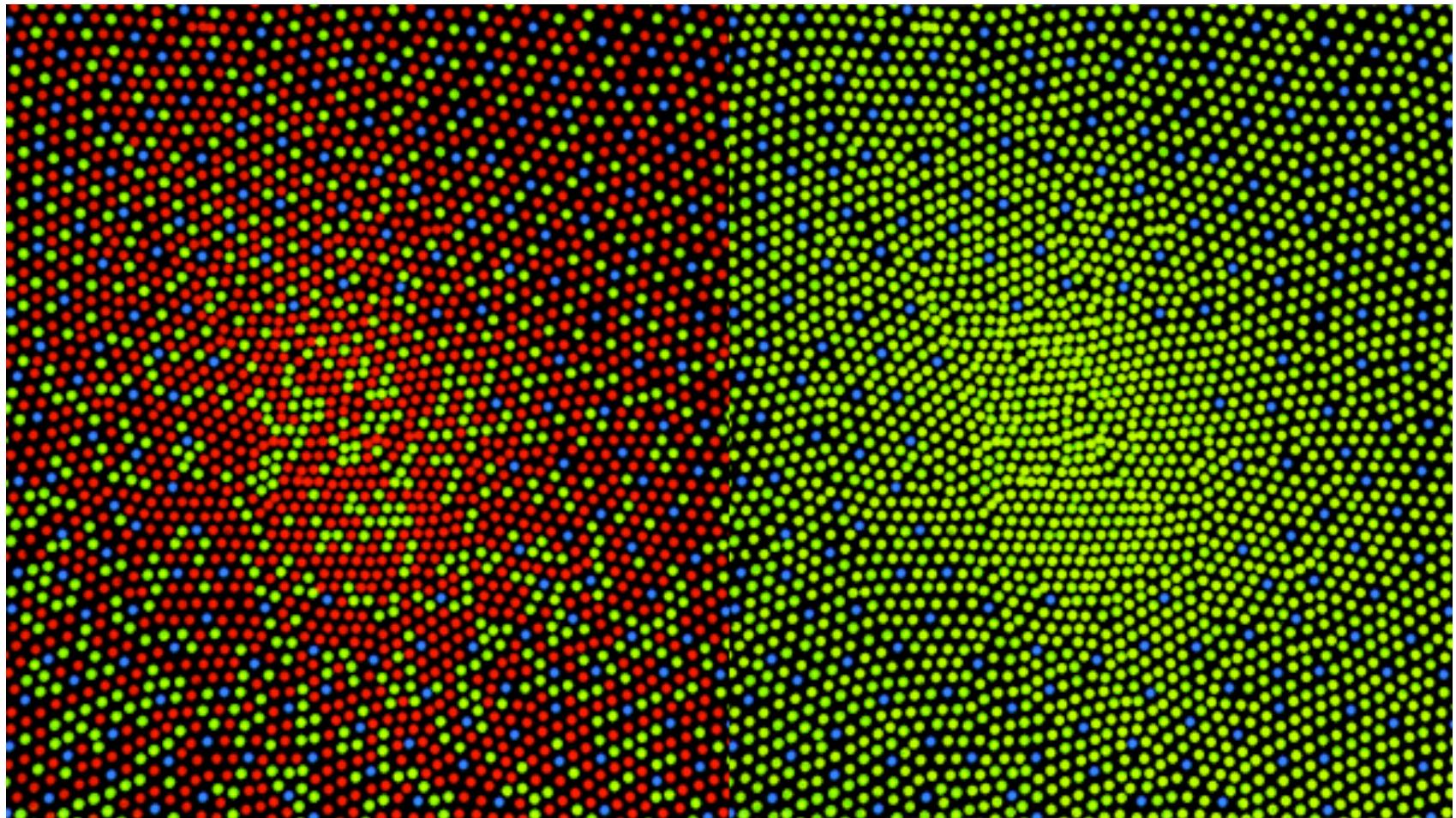
Komatsubara, A. Human error, Maruzen co. ltd. 2008. (In Japanese)

# Photo Receptor Cells



# Photo Receptor Cells

Distribution of cone cells in the fovea of an individual with normal color vision (left), and a color blind retina.



"ConeMosaics" by Mark Fairchild. Licensed under CC BY-SA 3.0 via Wikimedia Commons - <http://commons.wikimedia.org/wiki/File:ConeMosaics.jpg#mediaviewer/File:ConeMosaics.jpg>

## THE GOBBLING GLUTTONS

ONCE UPON A TIME, WALDO EMBARKED UPON A FANTASTIC JOURNEY. FIRST, AMONG A THRONG OF GOBBLING GLUTTONS. HE MET WIZARD WHITEBEARD, WHO COMMANDED HIM TO FIND A SCROLL AND THEN TO FIND ANOTHER AT EVERY STAGE OF HIS JOURNEY. FOR WHEN HE HAD FOUND 12 SCROLLS, HE WOULD UNDERSTAND THE TRUTH ABOUT HIMSELF.

IN EVERY PICTURE FIND WALDO, WOOF (BUT ALL YOU CAN SEE IS HIS TAIL), WENDA, WIZARD WHITEBEARD, ODLAW, AND THE SCROLL. THEN FIND WALDO'S KEY, WOOF'S BONE (IN THIS SCENE IT'S THE BONE THAT'S NEAREST TO HIS TAIL), WENDA'S CAMERA, AND ODLAW'S BINOCULARS.



THERE ARE ALSO 25 WALDO-WATCHERS, EACH OF WHOM APPEARS ONLY ONCE SOMEWHERE IN THE FOLLOWING 12 PICTURES. AND ONE MORE THING! CAN YOU FIND ANOTHER CHARACTER, NOT SHOWN BELOW, WHO APPEARS ONCE IN EVERY PICTURE EXCEPT THE LAST?



# Where is Waldo? – Game #2



# High Resolution Vision

- HiRes vision is limited to a narrow angle of field vision
- Eyes move to scan an object in order to expose the image on the fovea
- The movement of eyes is not regular or linear

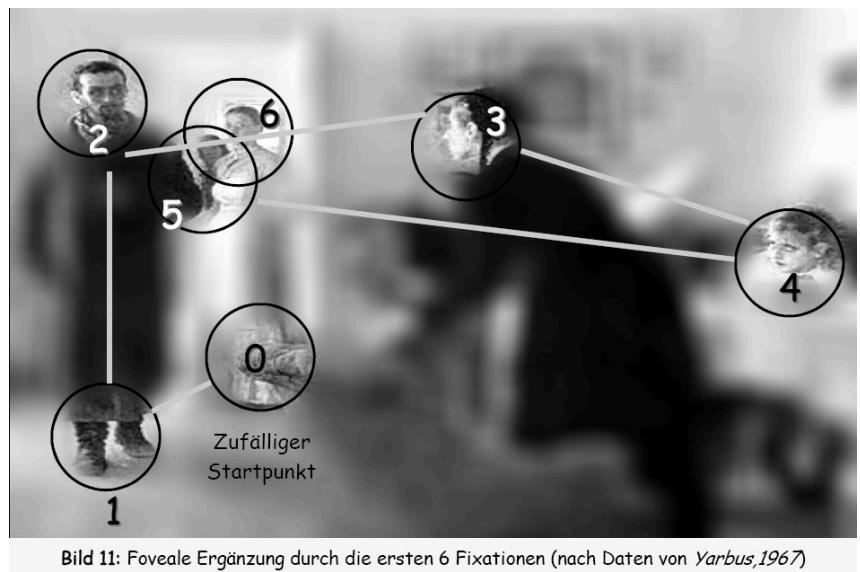


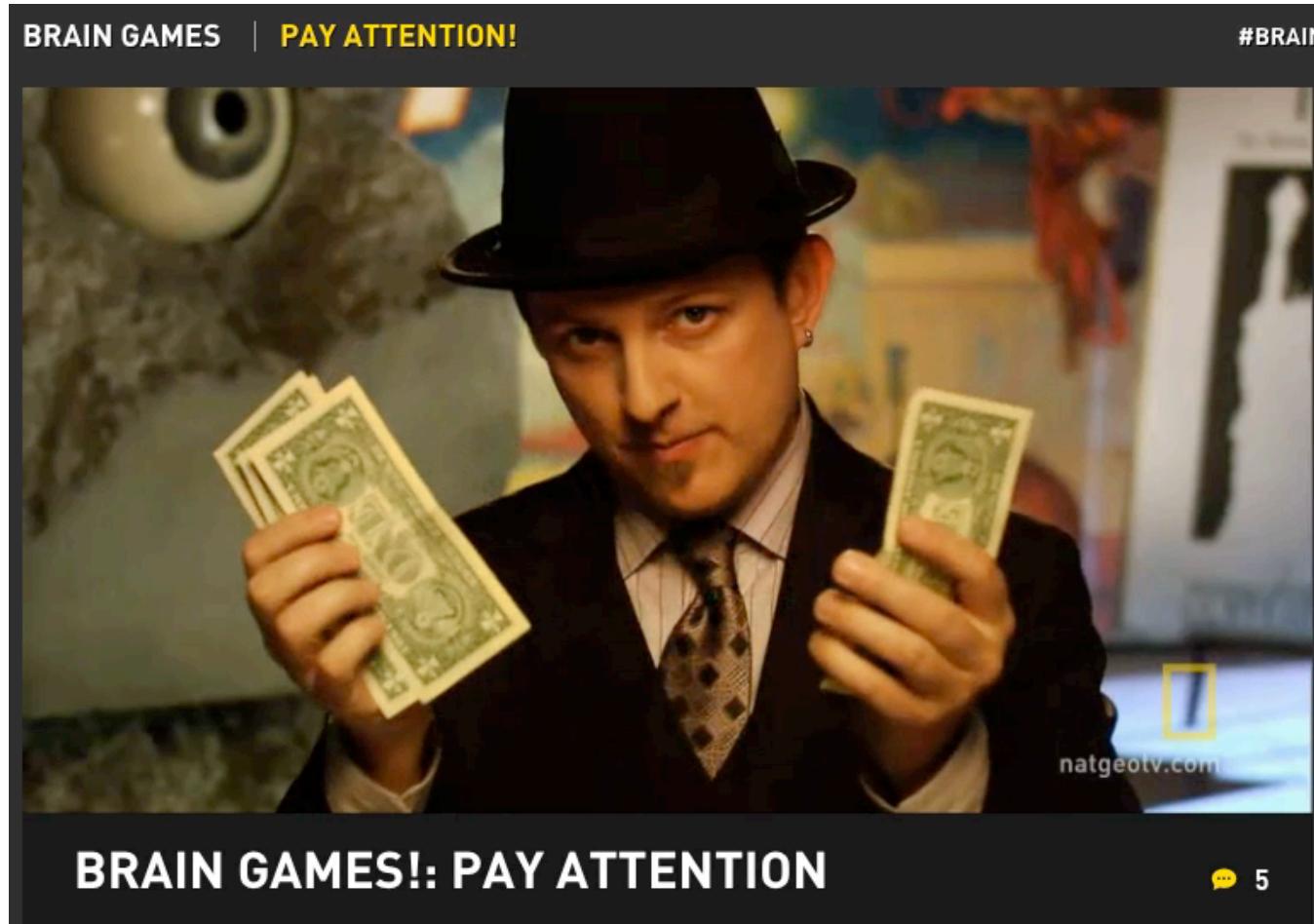
Bild 11: Foveale Ergänzung durch die ersten 6 Fixationen (nach Daten von Yarbus, 1967)

"Vision 2 secondes" by Hans-Werner Hunziker. Licensed under CC BY 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Vision\\_2\\_secondes.jpg#/media/File:Vision\\_2\\_secondes.jpg](http://commons.wikimedia.org/wiki/File:Vision_2_secondes.jpg#/media/File:Vision_2_secondes.jpg)

# Eye Tracking for Design



# Top-Down Attention



<http://channel.nationalgeographic.com/brain-games/videos/brain-games-pay-attention/>

# Perception and Cognition



VS



## Game #4 – How many 3s?

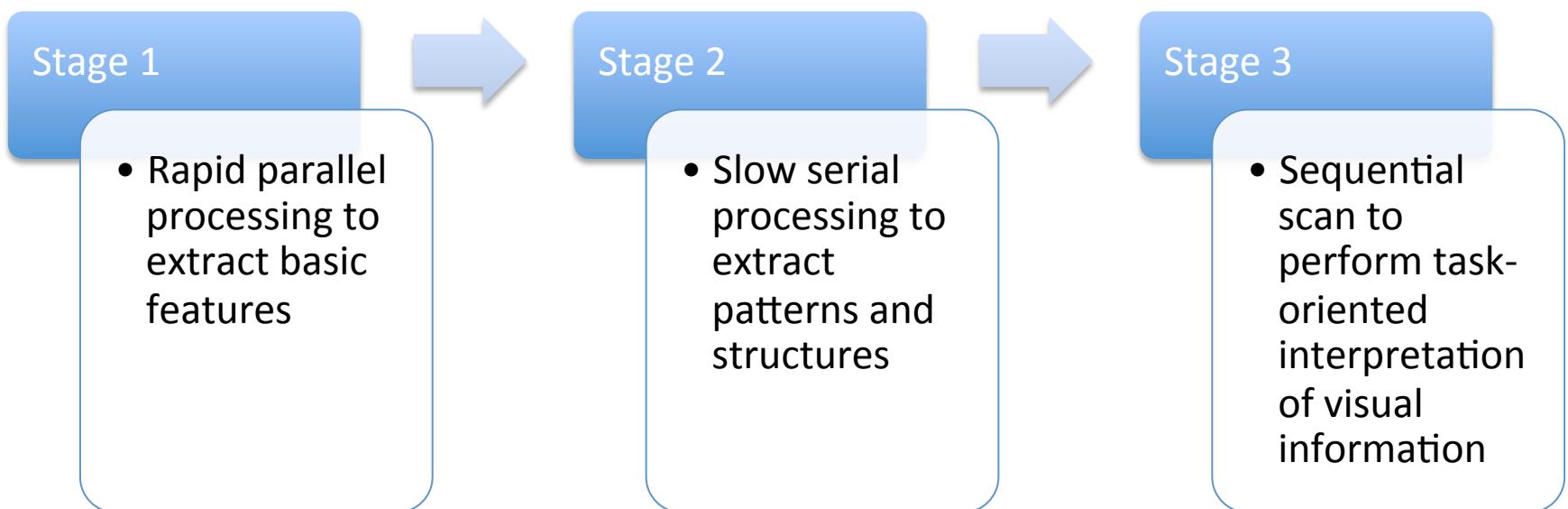
1258965168765132168943213  
5463479654321320354968413  
2068798417184529529287149  
2174953178195293926546831  
3546516509898554684982984

12589651687651**3**216894**3**213  
**5**46**3**479654**3**21**3**20**3**54968413  
2068798417184**5**205**5**29287149  
217495**3**178195**1**939**1**65468**3**1  
**3**546516509898**5**54**6**84982984

1258965168765132168943213  
5463479654321320354968413  
2068798417184**5**205**5**29287149  
217495**3**178195**1**939**1**65468**3**1  
**3**546516509898**5**54**6**84982984

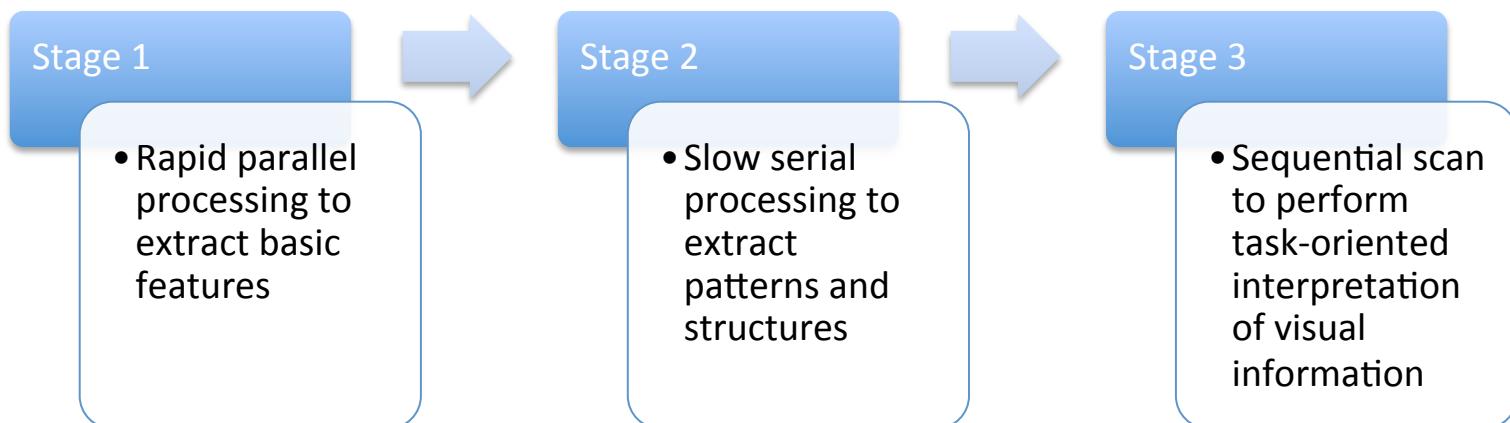
How many “3”?

# Perception and Cognition



# Visual Perception

- Early visual processing takes places without our conscious intervention
- Graphs that convey information at this level allow the observer to be more efficient in decoding



# Visual Cognition

- At second stage, the observer is required to consciously analyze the image/scene
- At this level, the observer can perform higher level reasoning
  - This object is larger than the other one
  - This street slope is lower than the previous

Timer

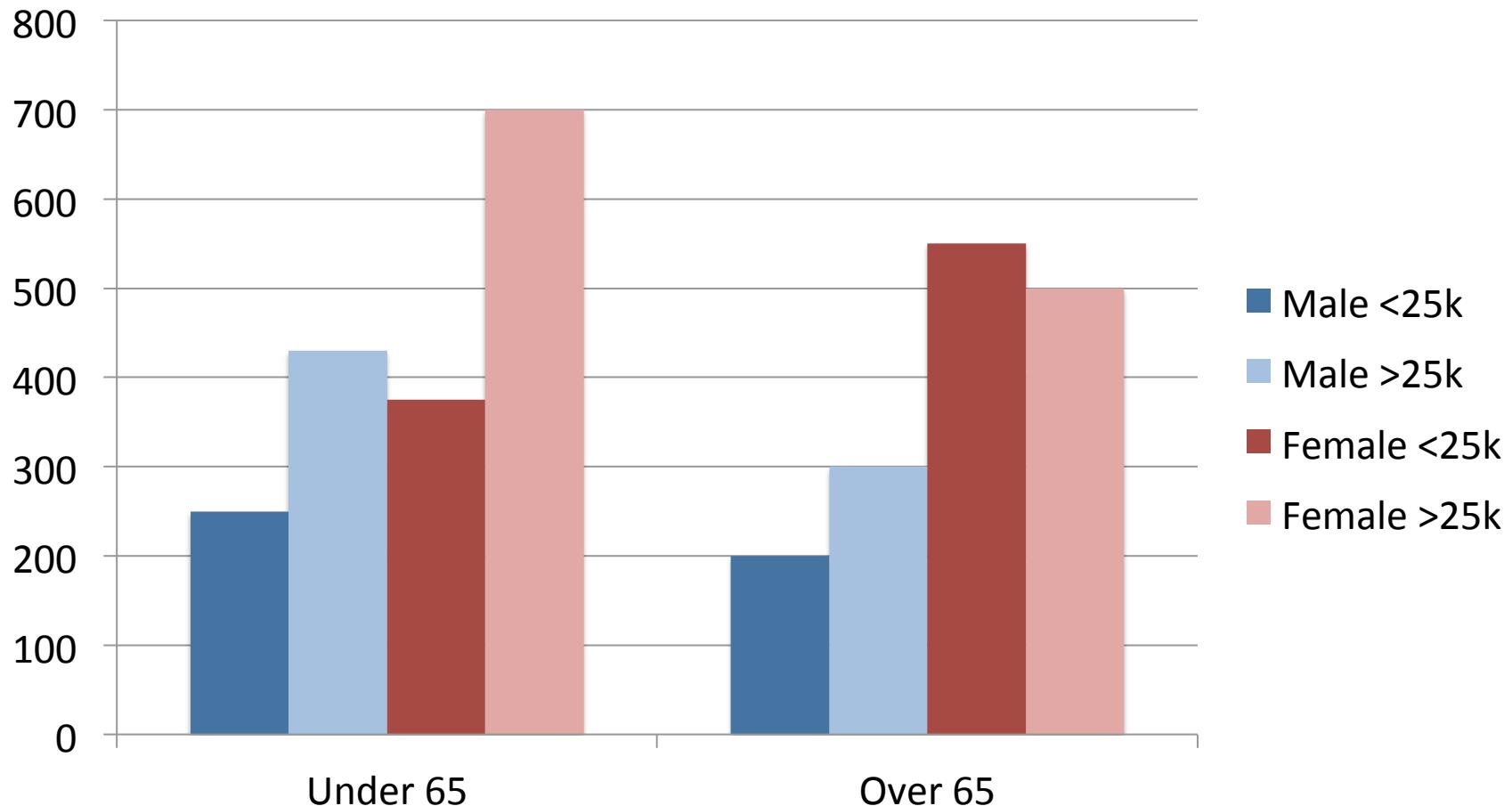
# **GAME #5 – CHOLESTEROL, AGE, AND GENDER**

# Game #5 – Cholesterol, Age, and Gender

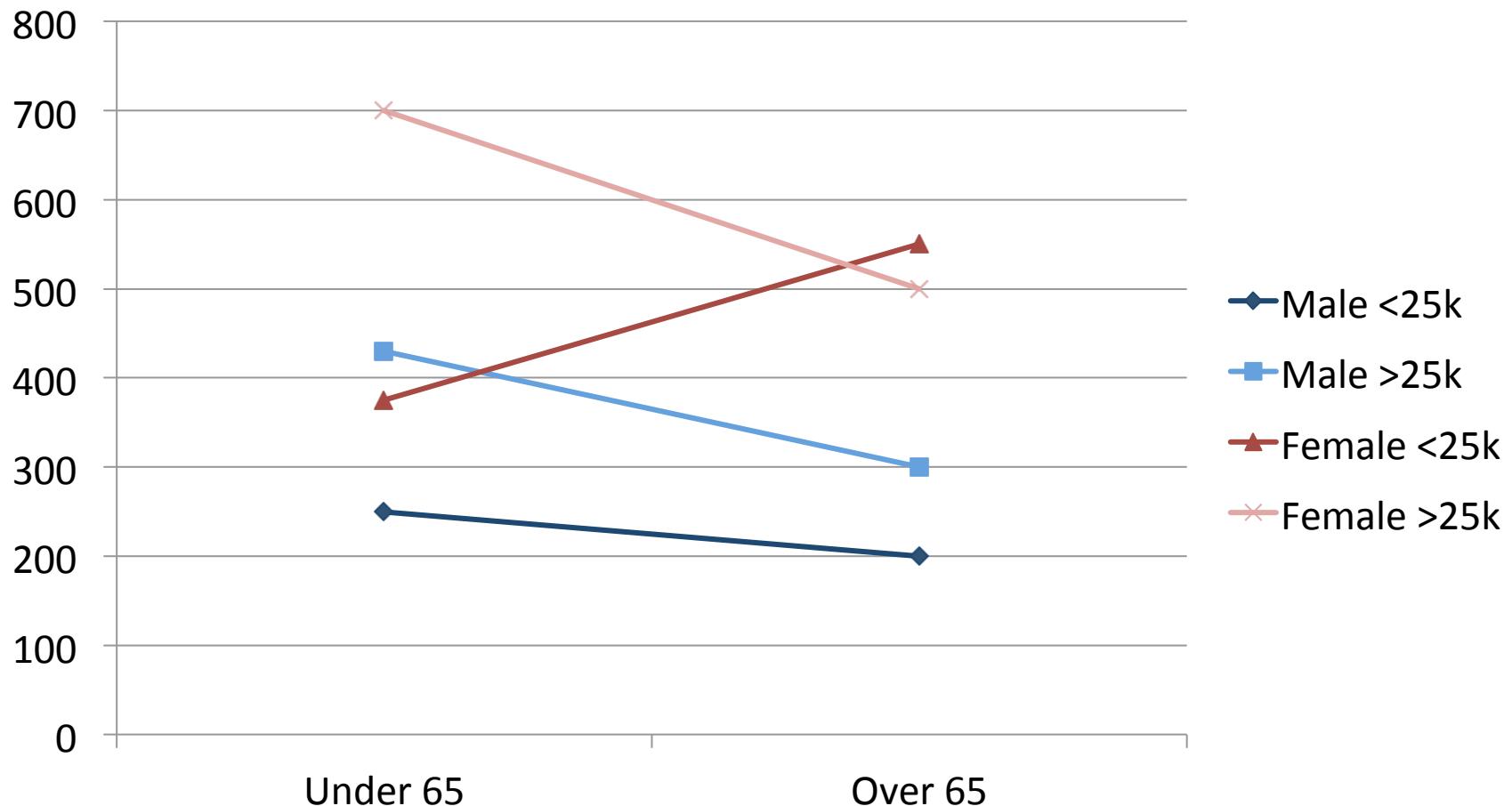
Which relation between gender or income level groups?

	Males		Females	
Income Group	Under 65	65 and Over	Under 65	65 and Over
0 – 24,999\$	250	200	375	550
25,000\$ +	430	300	700	500

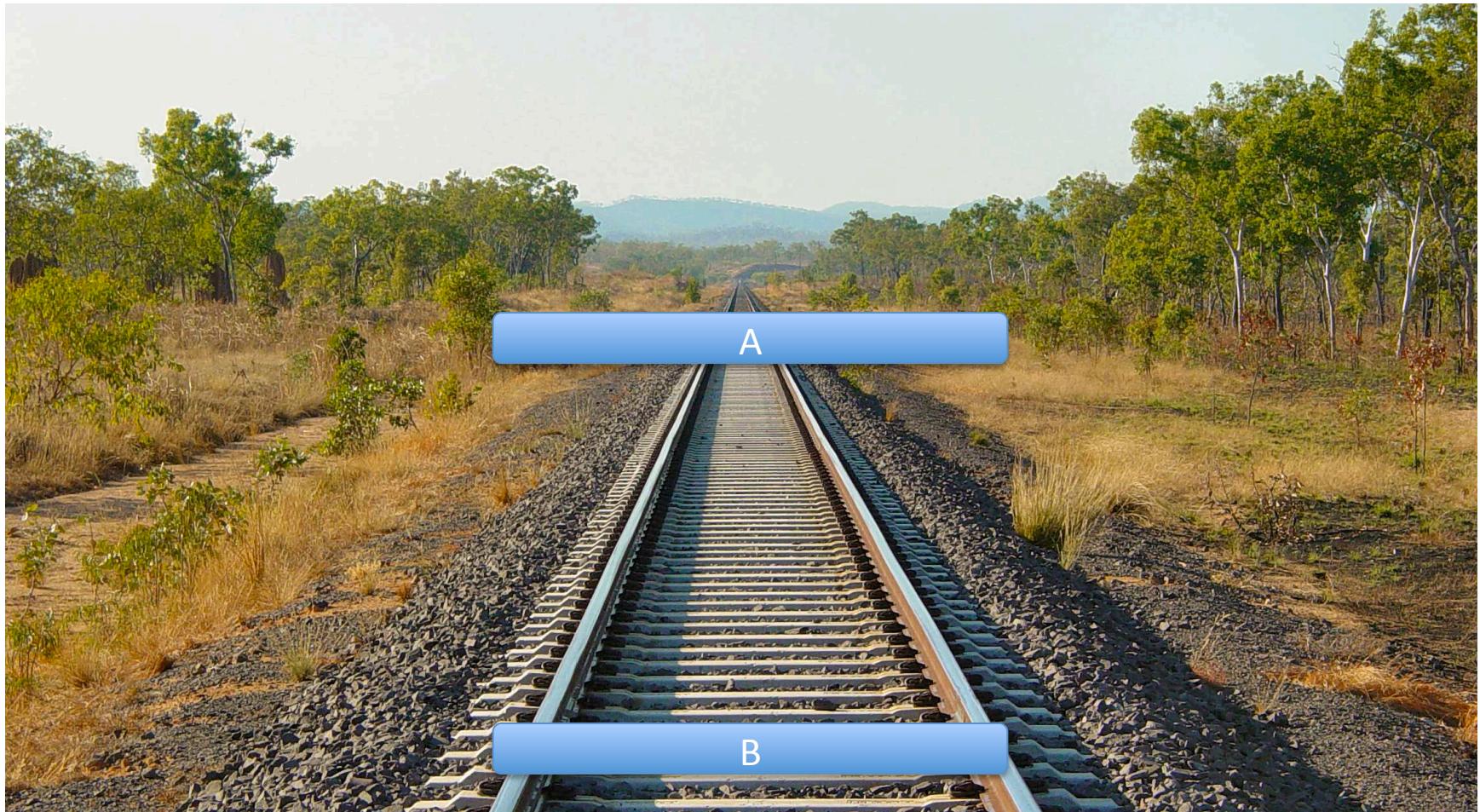
# Game #5 – Visual Solution (2)



# Game #5 – Visual Solution



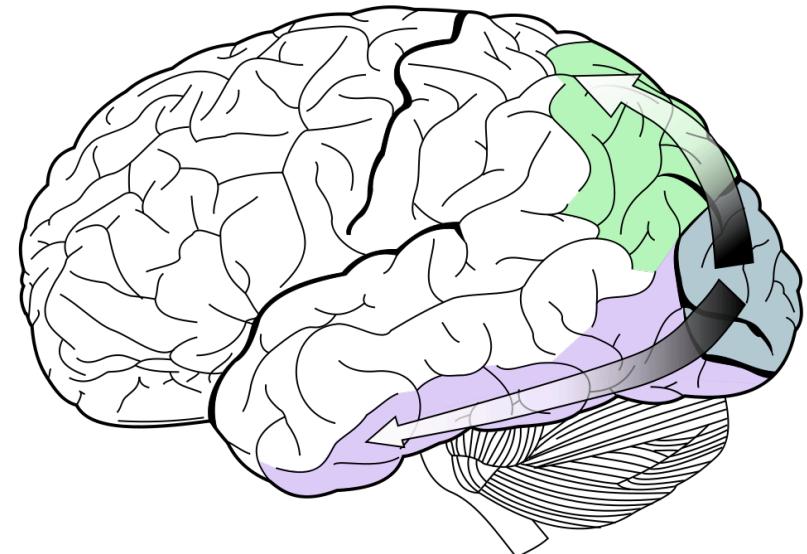
# Game #6 – Length comparison



# Perception

- Perception: the way in which something is regarded, understood, or interpreted (Oxford Dictionary)
- Electrical signals from vision system are interpreted and organized by the brain
- Two-stream hypothesis:
  - Ventral Stream
  - Dorsal Stream

The dorsal stream (green) and ventral stream (purple) are shown. They originate from a common source in the visual cortex

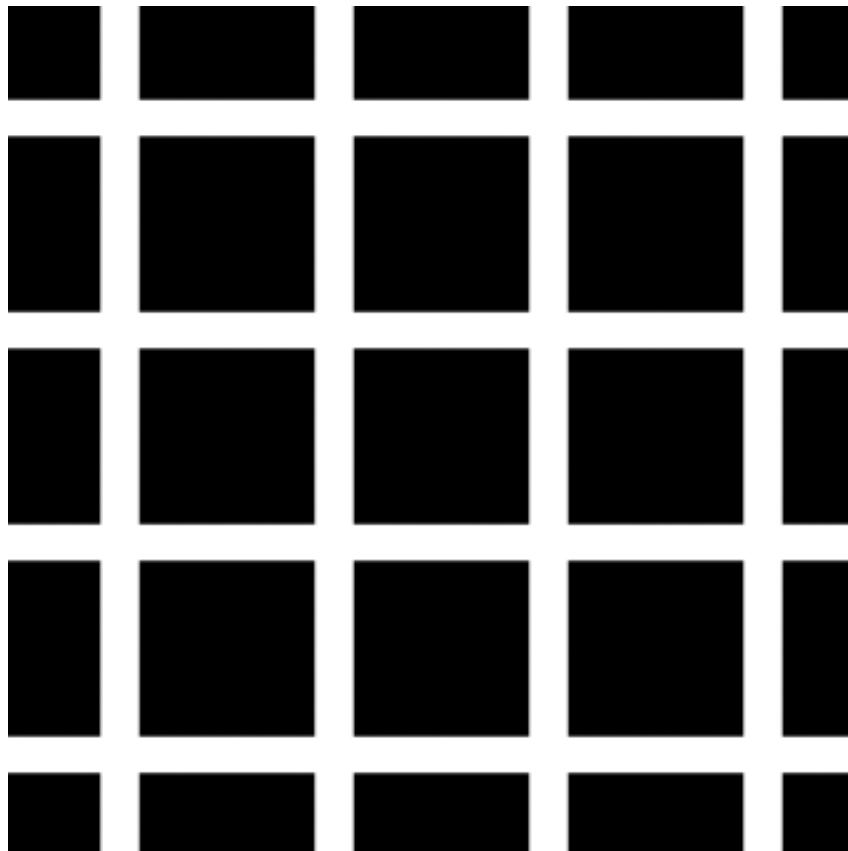


"Ventral-dorsal streams" by Selket - I (Selket) made this from Image:Gray728.svg. Licensed under CC BY-SA 3.0 via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Ventral-dorsal\\_streams.svg](http://commons.wikimedia.org/wiki/File:Ventral-dorsal_streams.svg#/media/File:Ventral-dorsal_streams.svg)

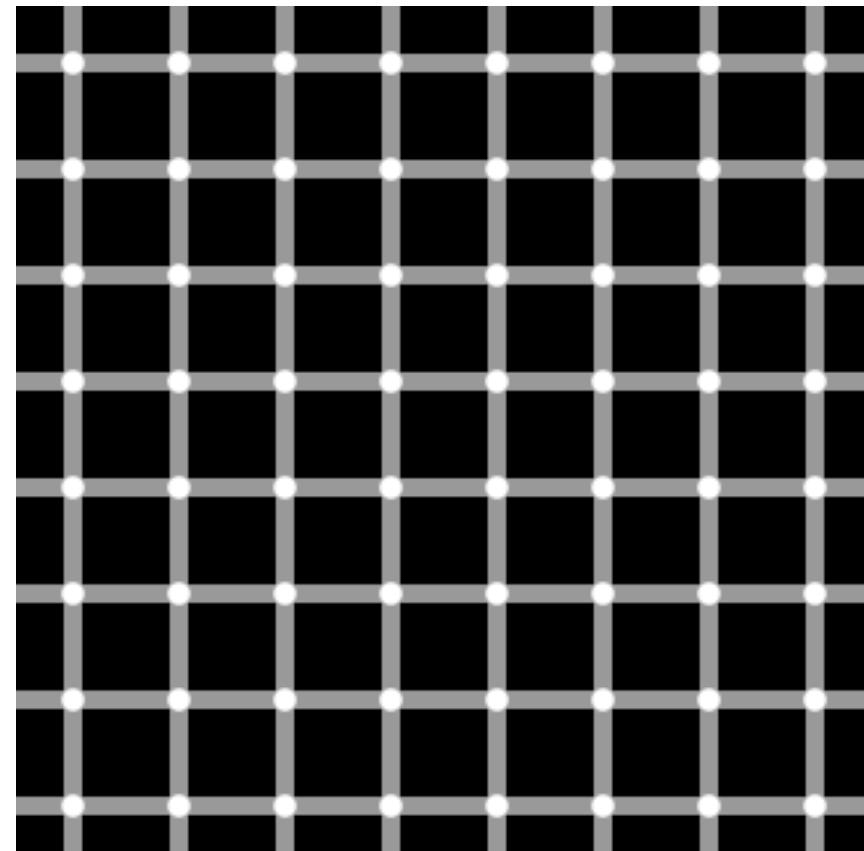
# Visual Illusions

- Perceived images differ from measurable reality
  - Optical Illusions
  - Physiological illusions (Mach Bands)
  - Cognitive illusions
    - Arise by unconscious inferences based on assumptions about real world

# Physiological Grid Illusion

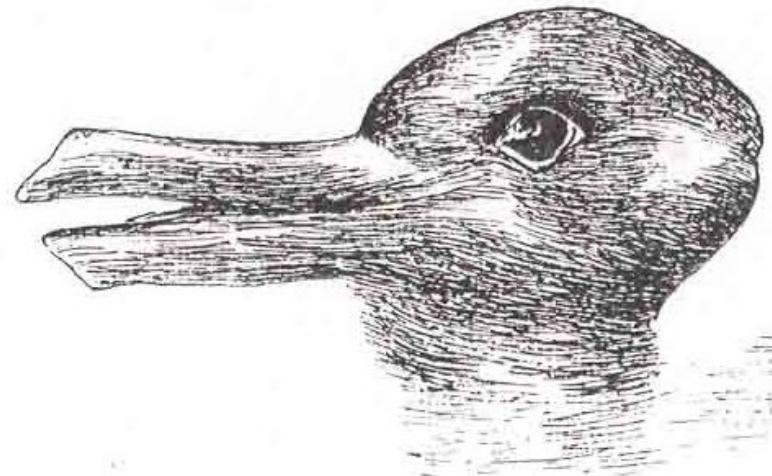
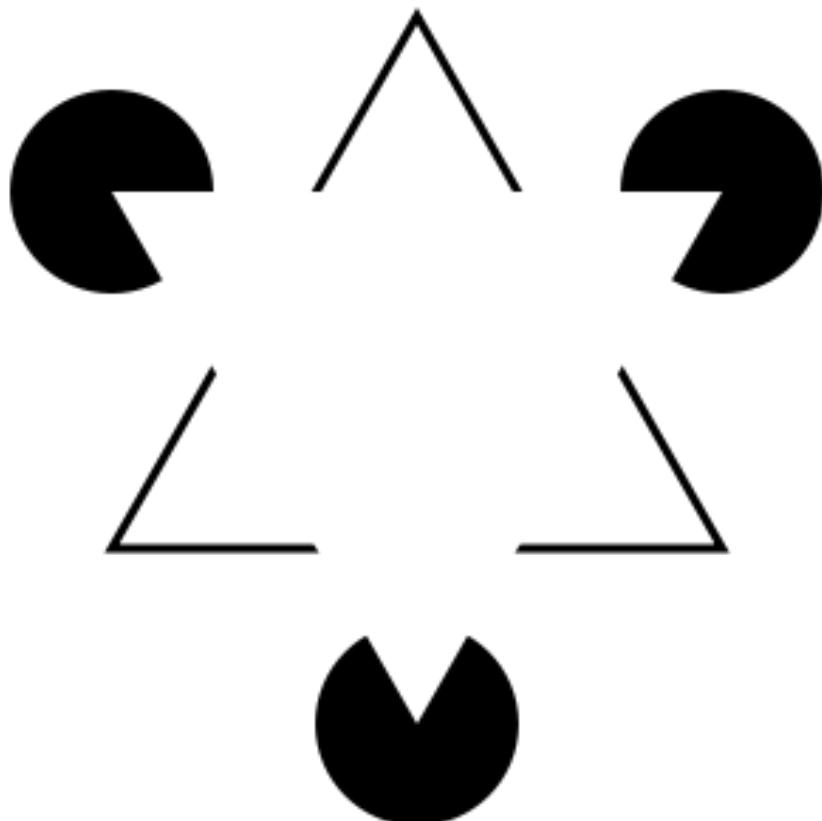


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# Paradox Ambiguos Illusions

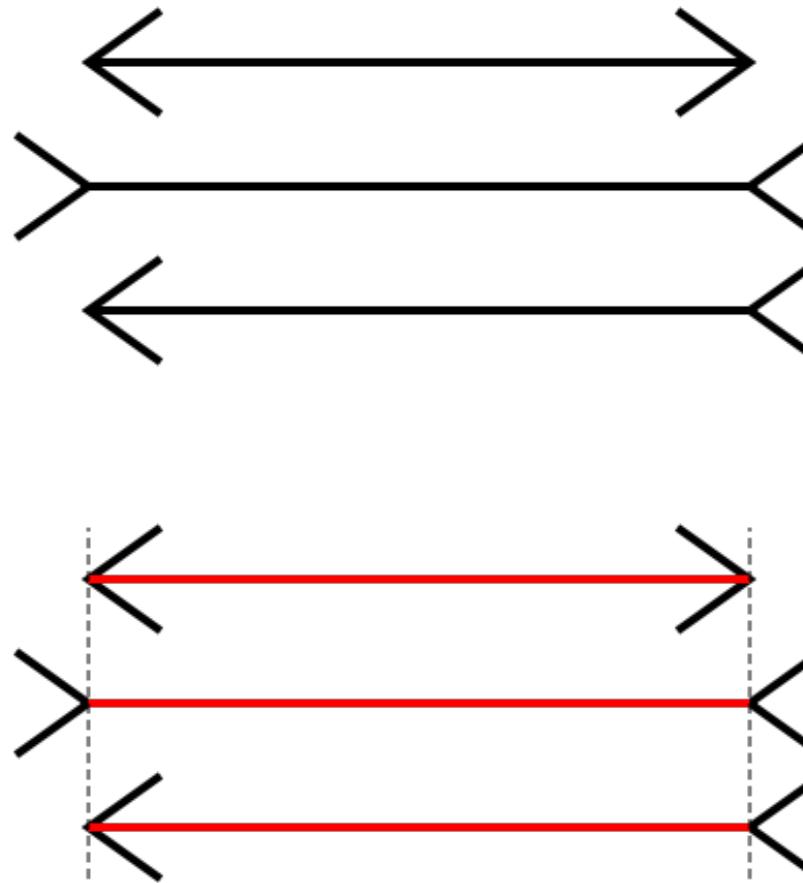


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# Lengths Distortion

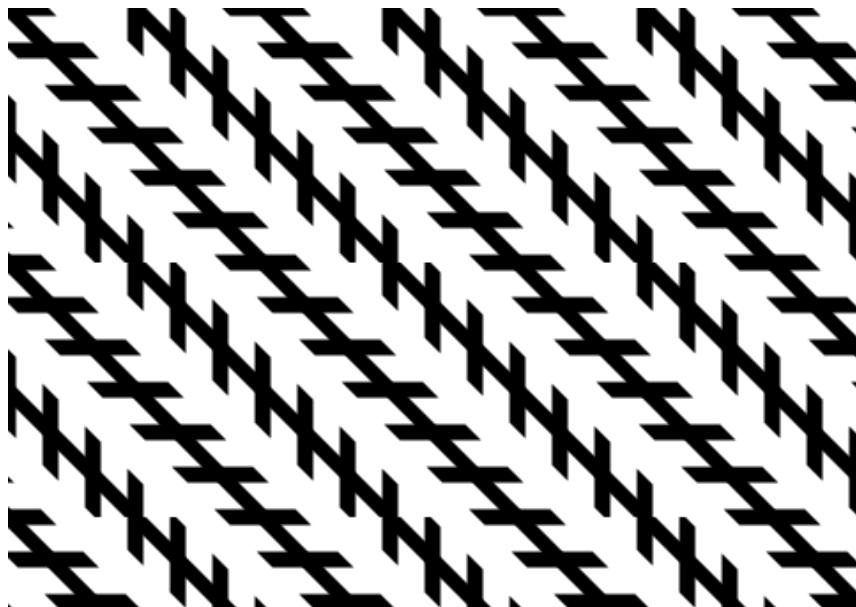
Müller-Lyer illusion



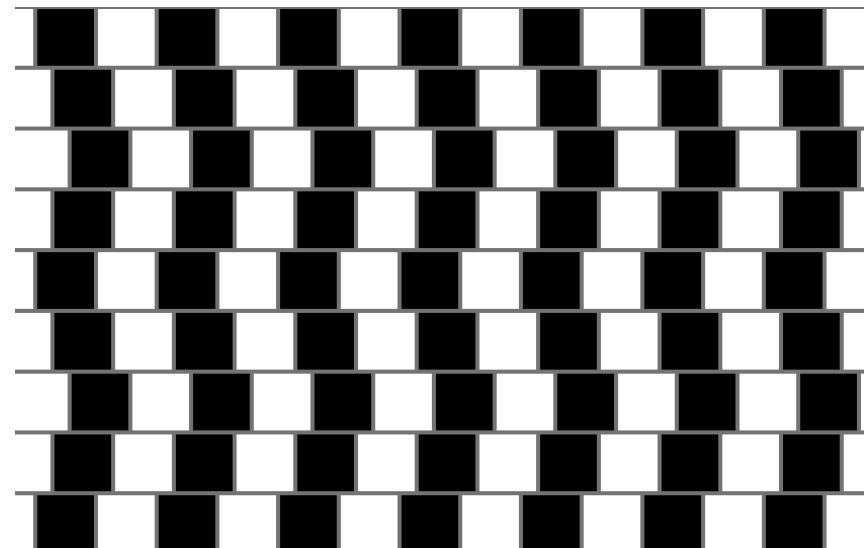
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# Orientation Illusion

## Zöllner illusion

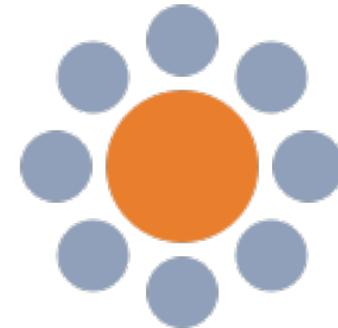
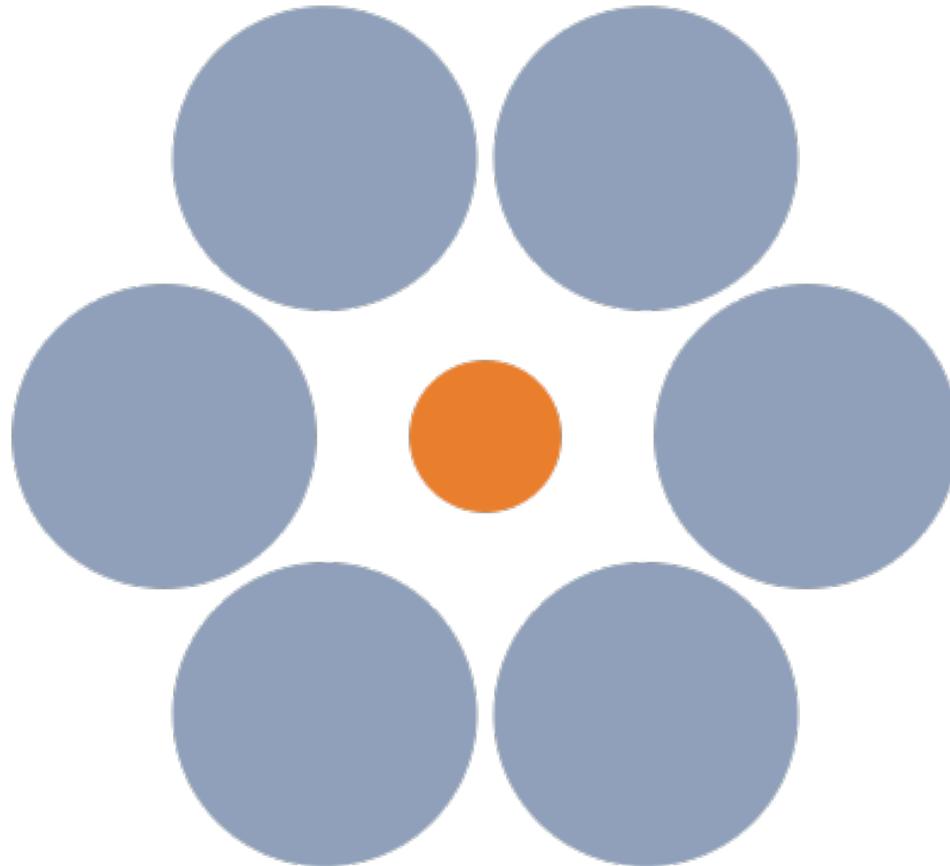


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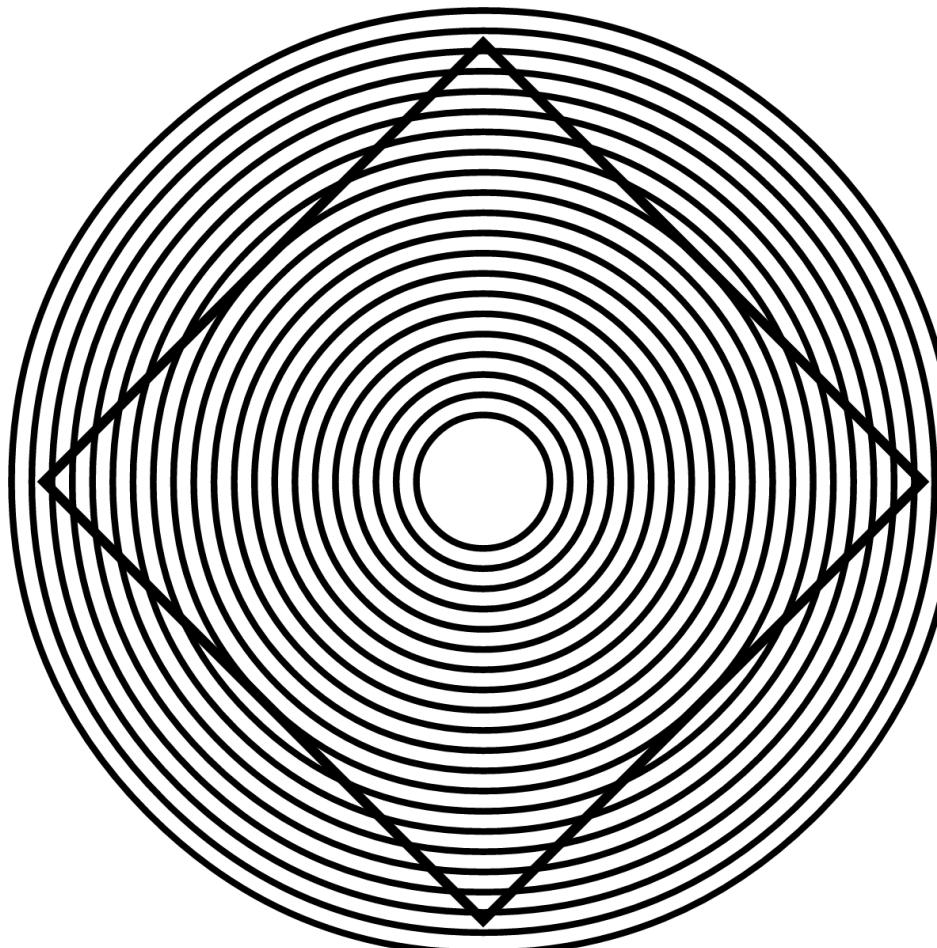
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# Ebbinghaus Illusion



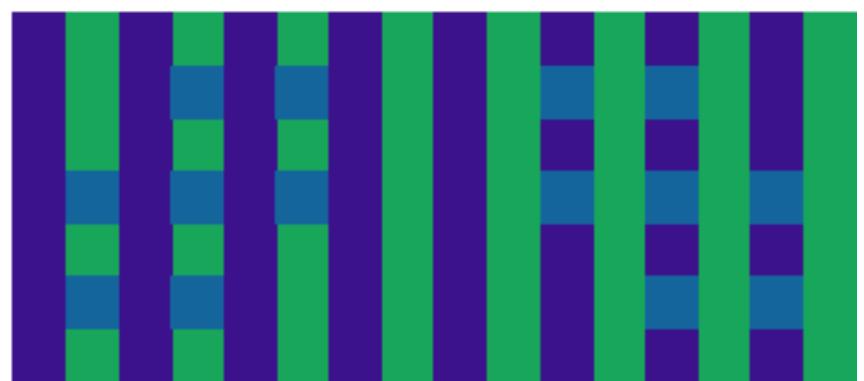
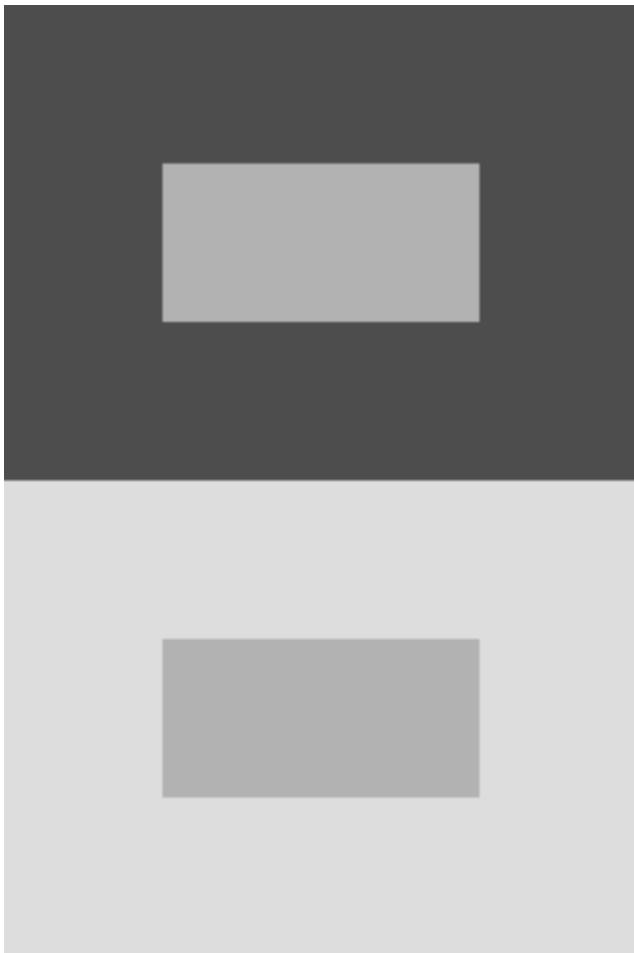
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# Ehrenstein Illusion



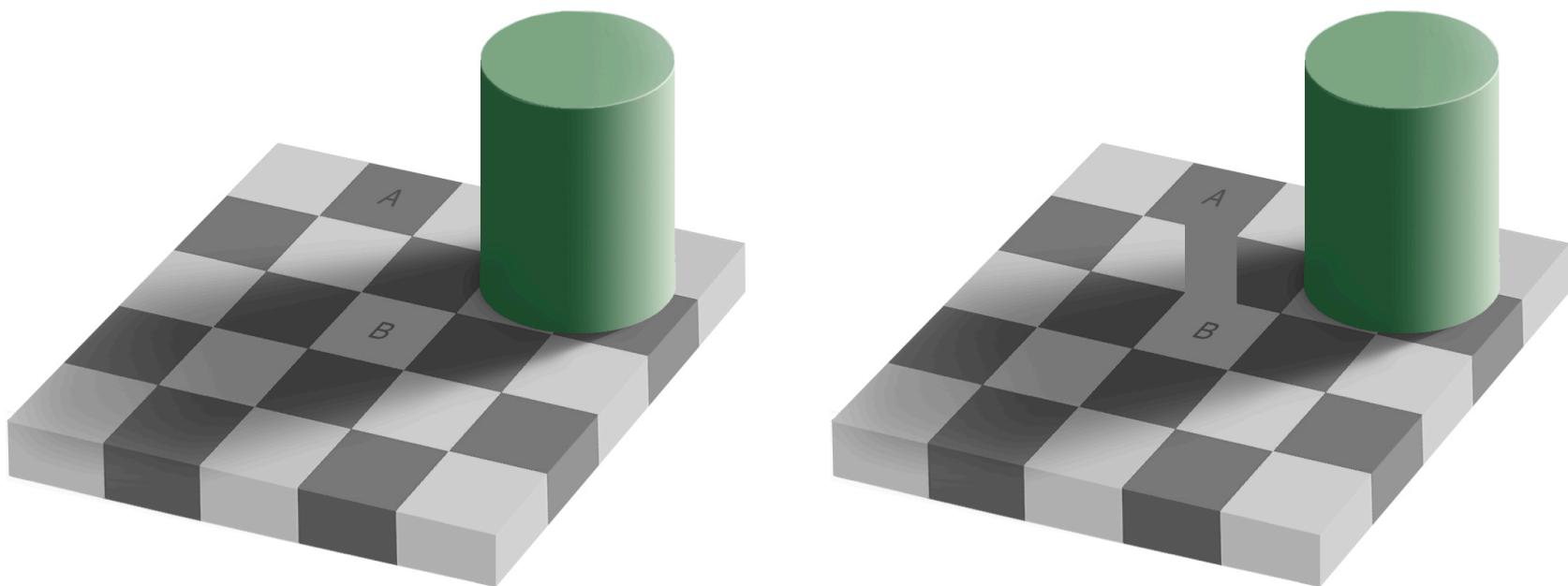
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# Simultaneous Contrast



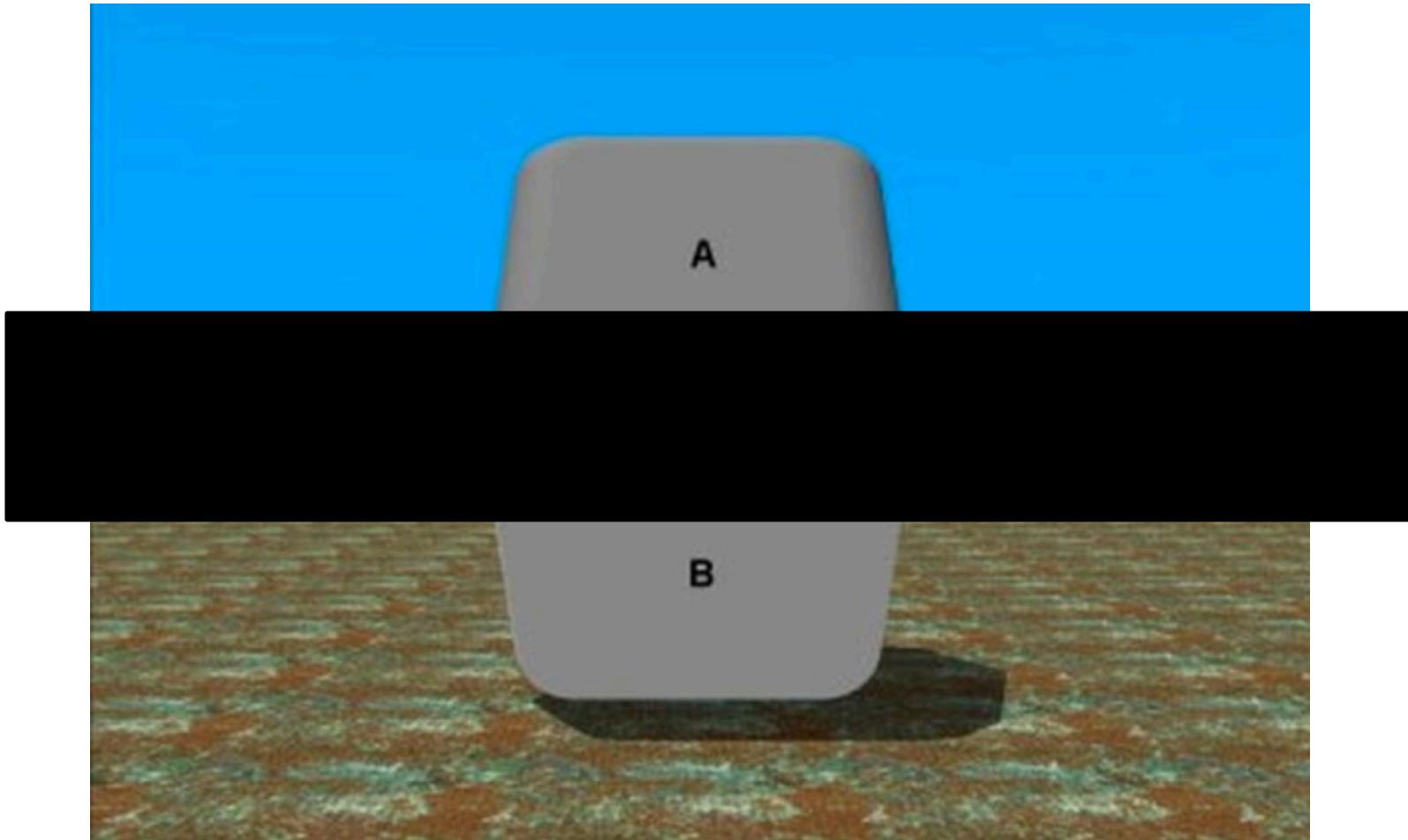
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# Adelson's Illusion

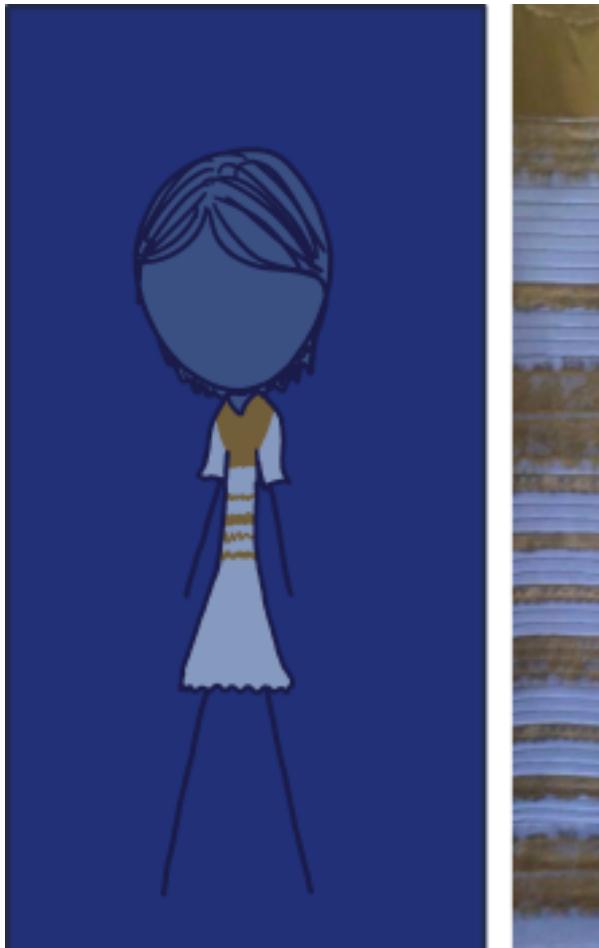


"Grey square optical illusion" by Original by Edward H. Adelson, this file by Gustavb - File created by Adrian Pingstone, based on the original created by Edward H. Adelson. Licensed under Copyrighted free use via Wikimedia Commons - [http://commons.wikimedia.org/wiki/File:Grey\\_square\\_optical\\_illusion.PNG#/media/File:Grey\\_square\\_optical\\_illusion.PNG](http://commons.wikimedia.org/wiki/File:Grey_square_optical_illusion.PNG#/media/File:Grey_square_optical_illusion.PNG)

# Context



# Dress Color



# Takeaway Messages

- Limitations of human vision system
- Exploits message broadcast at early stage of perception: preattentive perception
- Avoid possible causes of biases