



2019 ZJU International Summer School on Visual Analytics



Perception & Cognition

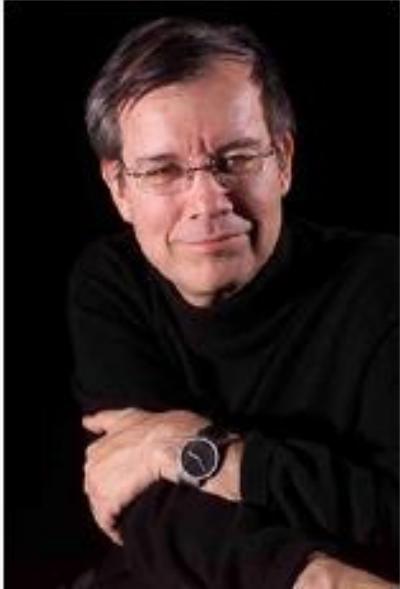
Guodao Sun

Associate Professor

Zhejiang University of Technology

Email: guodao@zjut.edu.cn

Homepage: <http://godoorsun.org>



“Visualization is really about external **cognition**, that is, how resources outside the mind can be used to **boost** the **cognitive capabilities** of the mind.”

Stuart Card

What is Visual ?



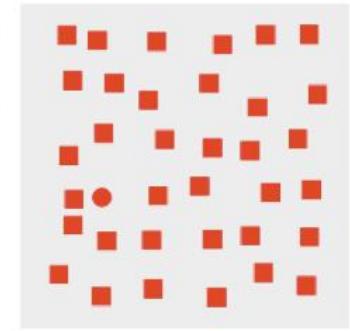
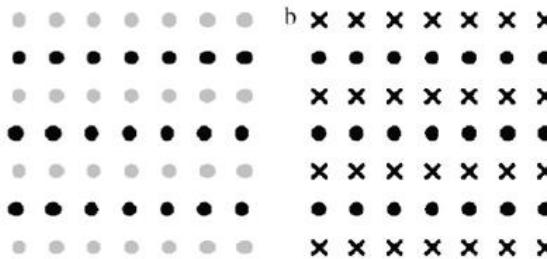
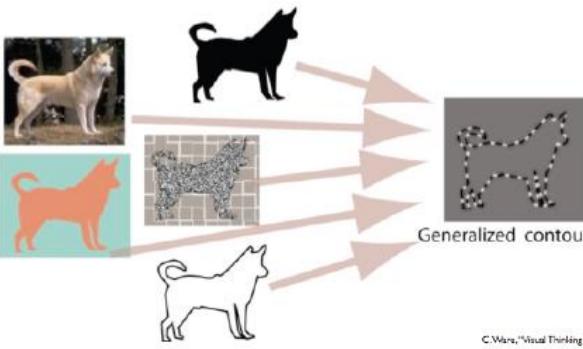
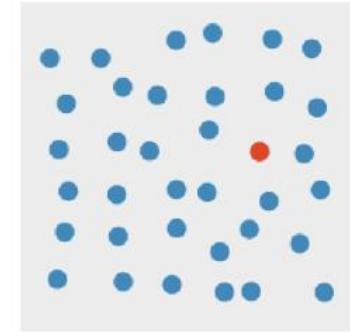
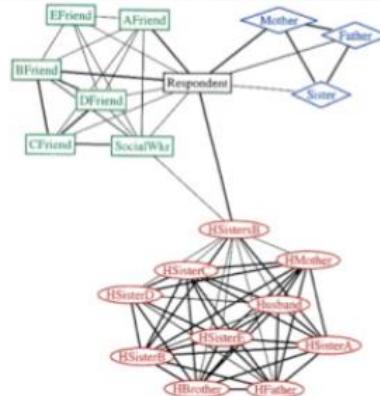
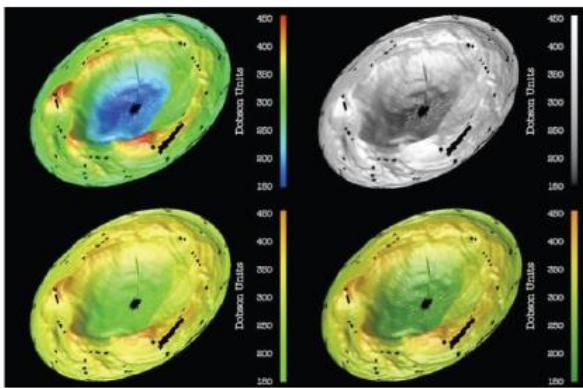
01 Perception:

about the nature of
the signals coming in;
what you see

02 Cognition:

about how you
understand and **interpret**
what you see

What is Visual Perception ?



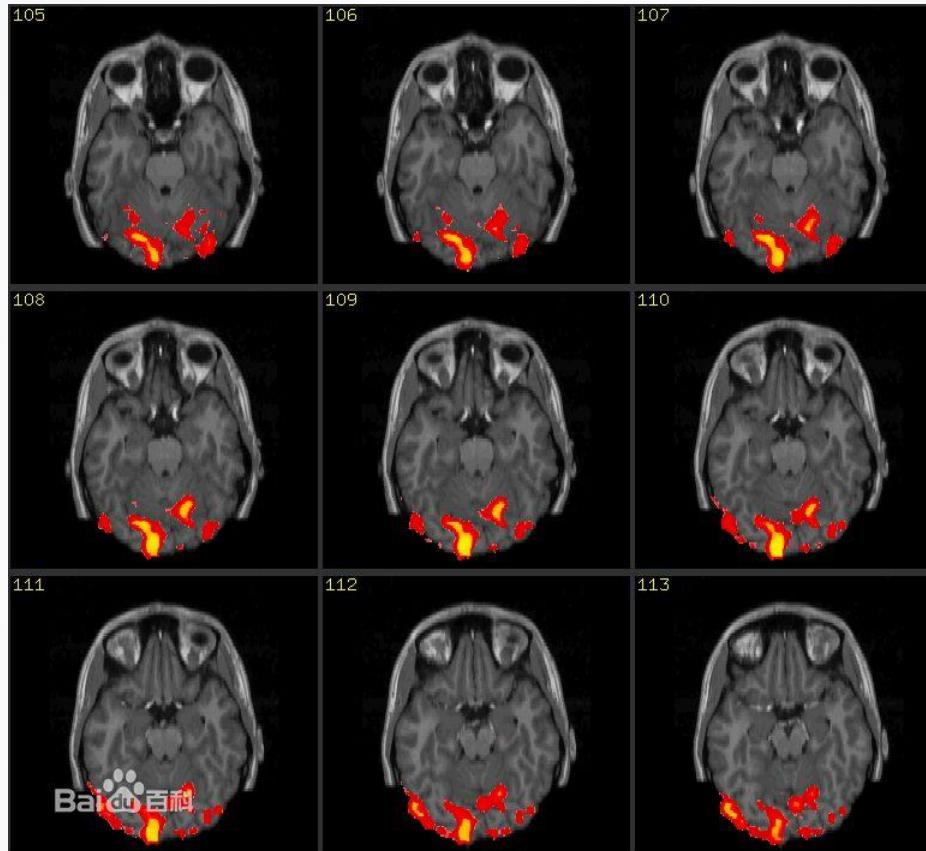
Perception is the organization, identification and interpretation of **sensory information** in order to represent and understand the environment.

Cognition

In science, cognition is a group of **mental processes** that includes:

- attention
- memory
- producing and understanding language
- solving problems
- making decisions

Recovering Visual Cognition using fMRI



fMRI, functional magnetic resonance imaging

Recovering Visual Cognition using fMRI

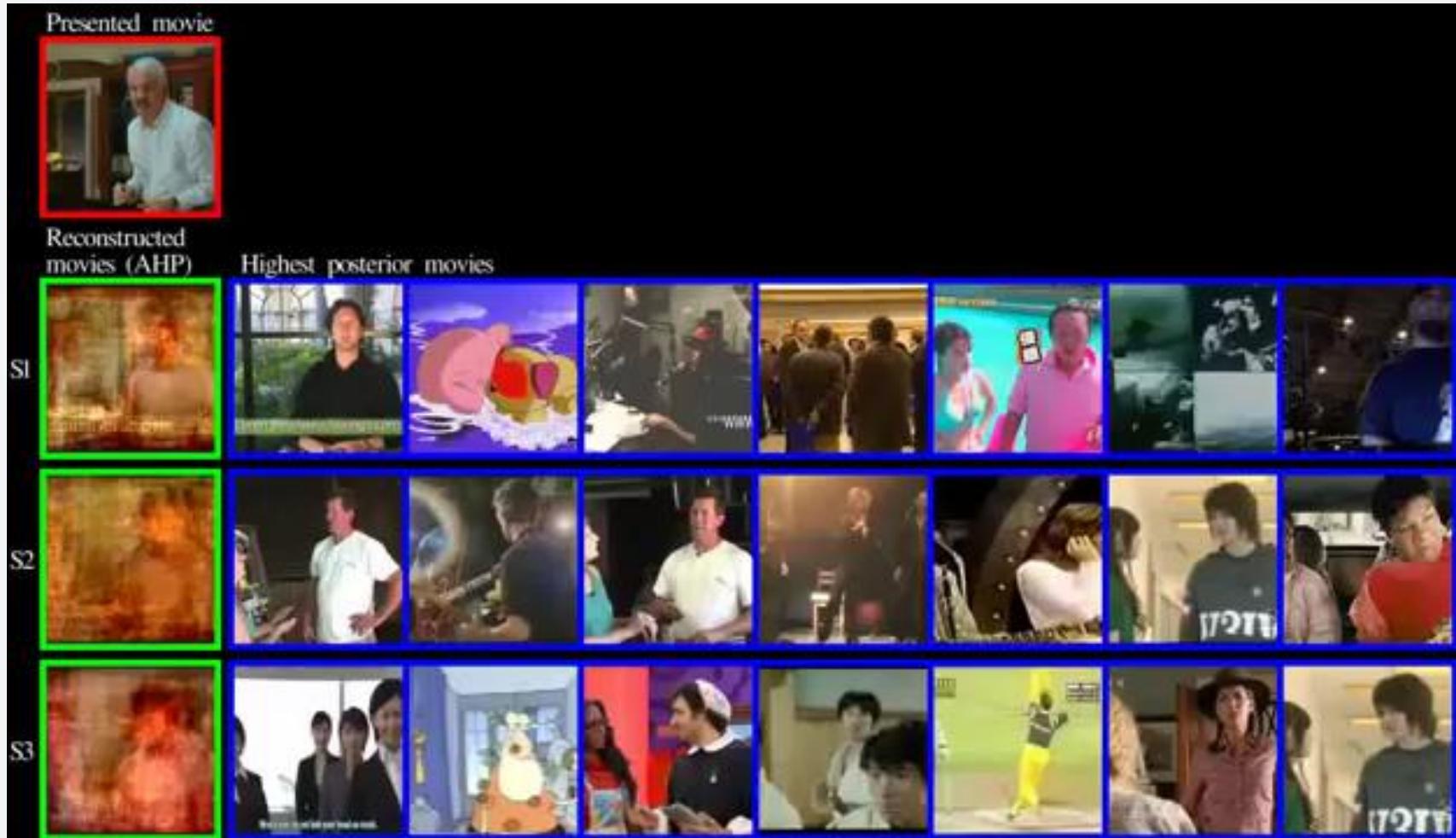
Presented clip



Clip reconstructed
from brain activity



Recovering Visual Cognition using fMRI



Outline

① Visual Perception

② Cognition

③ Shape

④ Color

⑤ Toolkits

Task1

01 This example requires sustained attention and concentration

02 3 players in white and 3 players in black passing a different basketball to each other

03 Count the total number of times people wearing white are passing the ball

04 Do not count passes by the players in black

selective attention test

Selective Attention Test

from Simons & Chabris (1999)





natgeotv.com

© National Geographic <https://www.youtube.com/watch?v=iiEzf3J4iFk>

Fact

Memory plays an important role in human cognition, but working memory is extremely limited.

Visualization must serve as an **external aid**
to augment working memory

Animated Transitions in Statistical Data Graphics



Task2

01

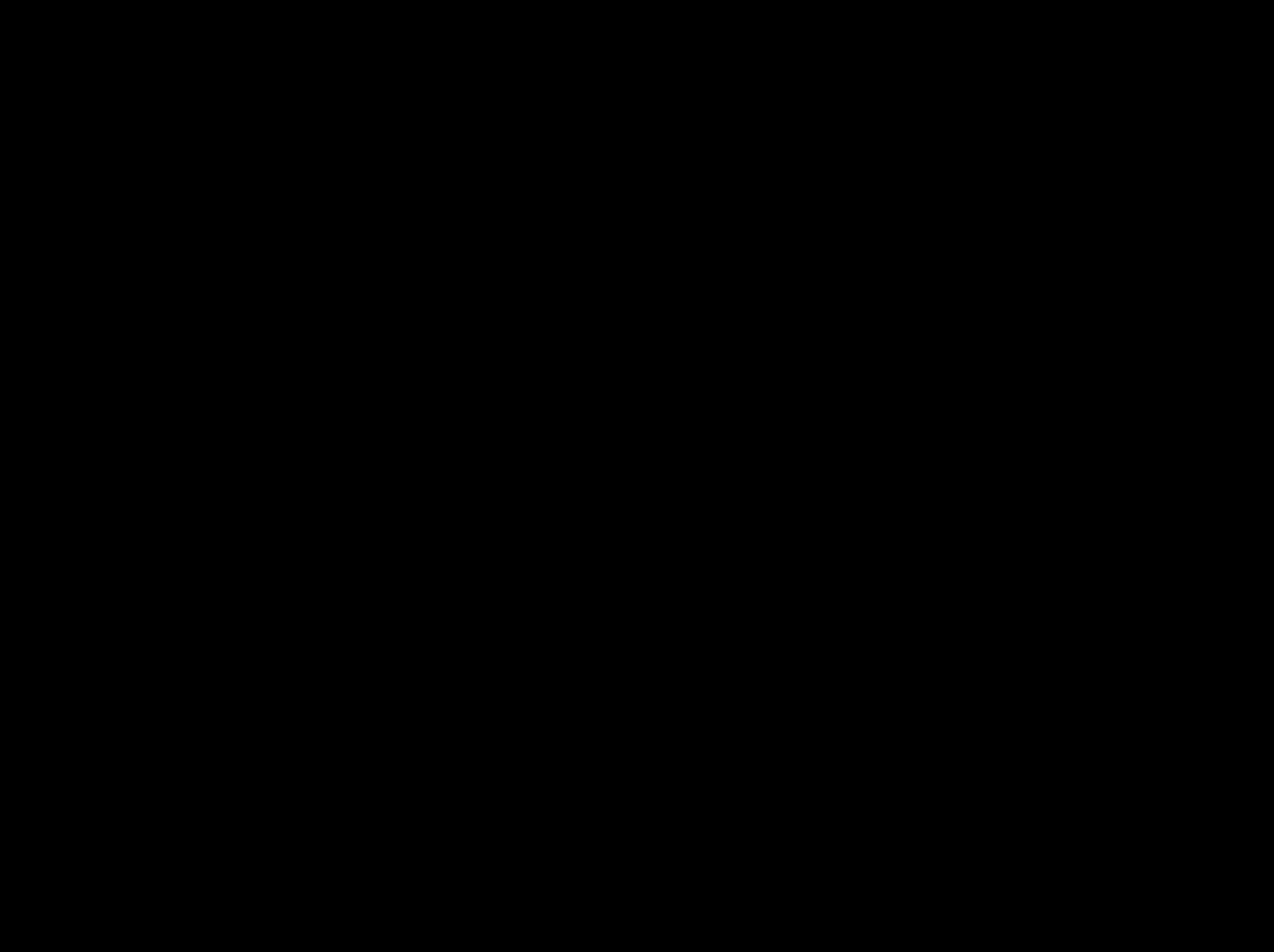
Find the one thing in the image that is changing

02

Raise your hand once you detect the change

03

Remain quiet while others continue to look



Visual Cognition Lab, UIUC

Change Blindness



Ron Rensink 2002

Fact

To see an object change, it is necessary to attend to it.

Make changes **visible** in visualizations
to reduce the cognitive load

Constancy



- Objects change in our eyes constantly as we or they move....but we are able to maintain content perception
- Shape Constancy
- Size Constancy
- Lightness Constancy
- Orientation constancy
- Distance constancy
- Location constancy

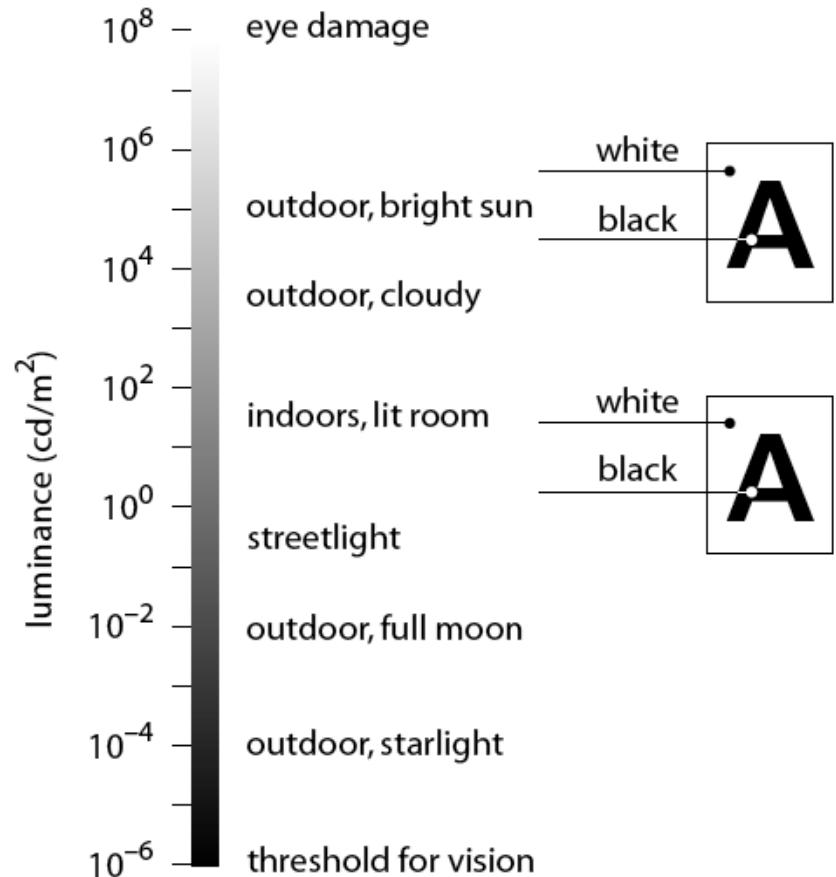
Lightness Constancy



Video Source: <https://www.youtube.com/watch?v=TVUrHf2kcUM>

Lightness Constancy

- Light levels can vary by six orders of magnitude.
- Our visual system deals with that by responding to relative differences.



Lightness Constancy



This is the same
gray as the center of
the **O** in **GLOVES**

This is the same gray
as the top part of the
S in **GLOVES**

Simultaneous Contrast

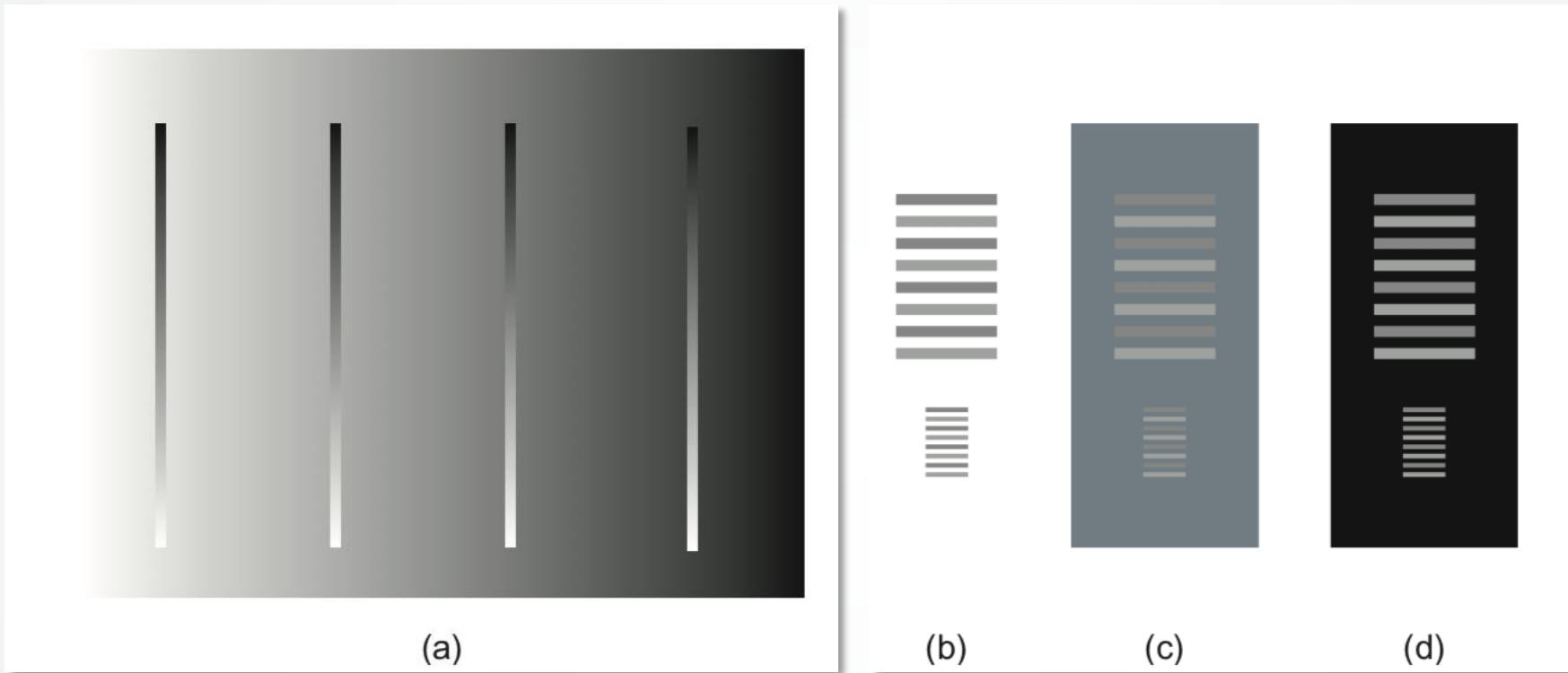
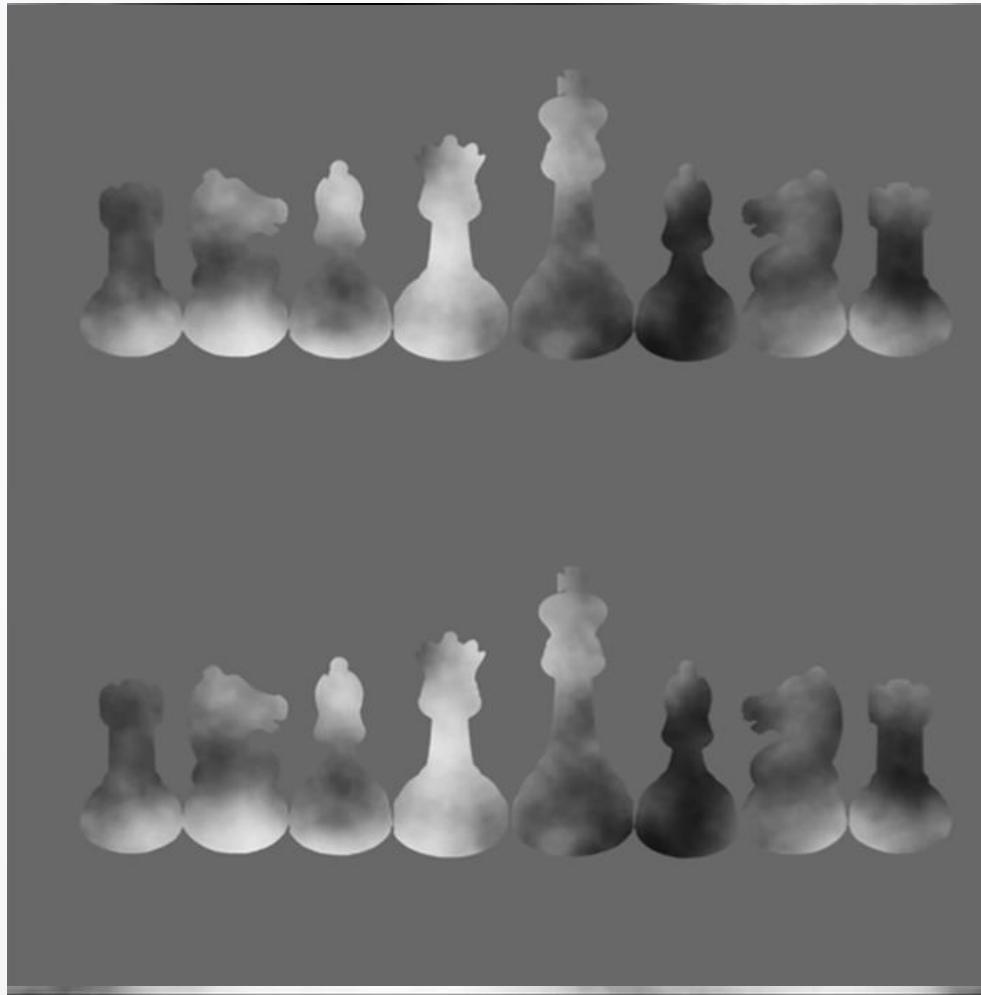


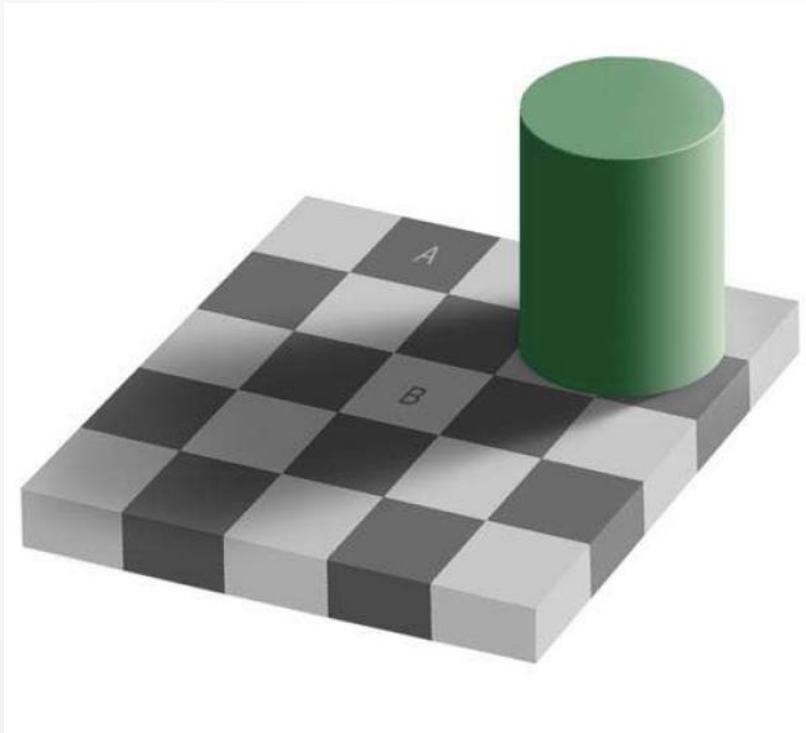
Figure 3.20 (a) All the gray strips are the same. Perceived differences between gray-scale values are enhanced where the values are close to the background gray value, an effect known as crispening. (b, c, d) The differences in the grays of the gray lattice are more evident (c) than with either the white (b) or the black (d) backgrounds, another example of crispening.

Simultaneous Contrast



相对性&绝对性

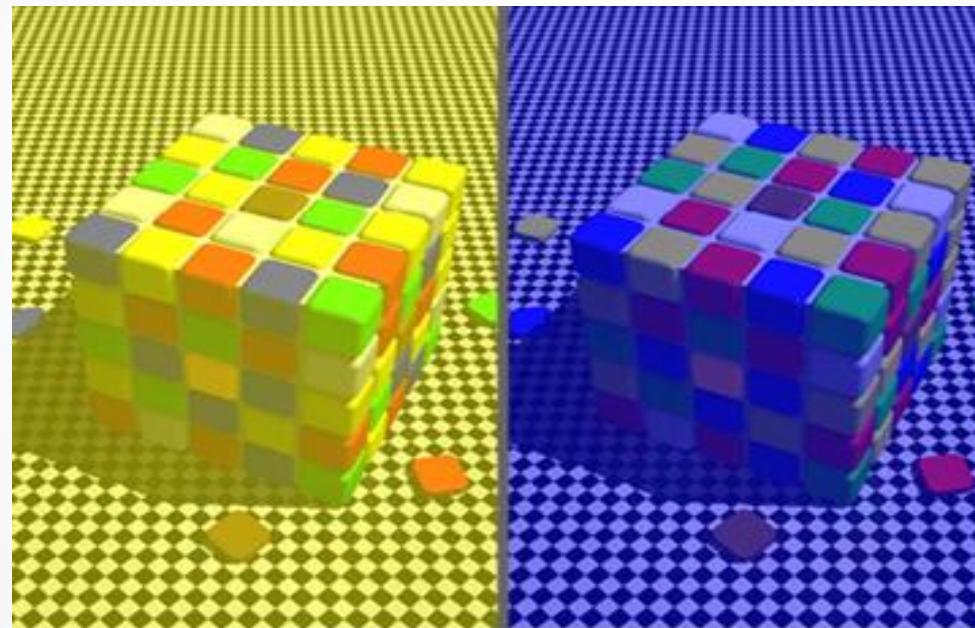
感知系统基于相对判断，而非绝对判断 (Weber's Law)



A和B哪一个更亮？

相对性&绝对性

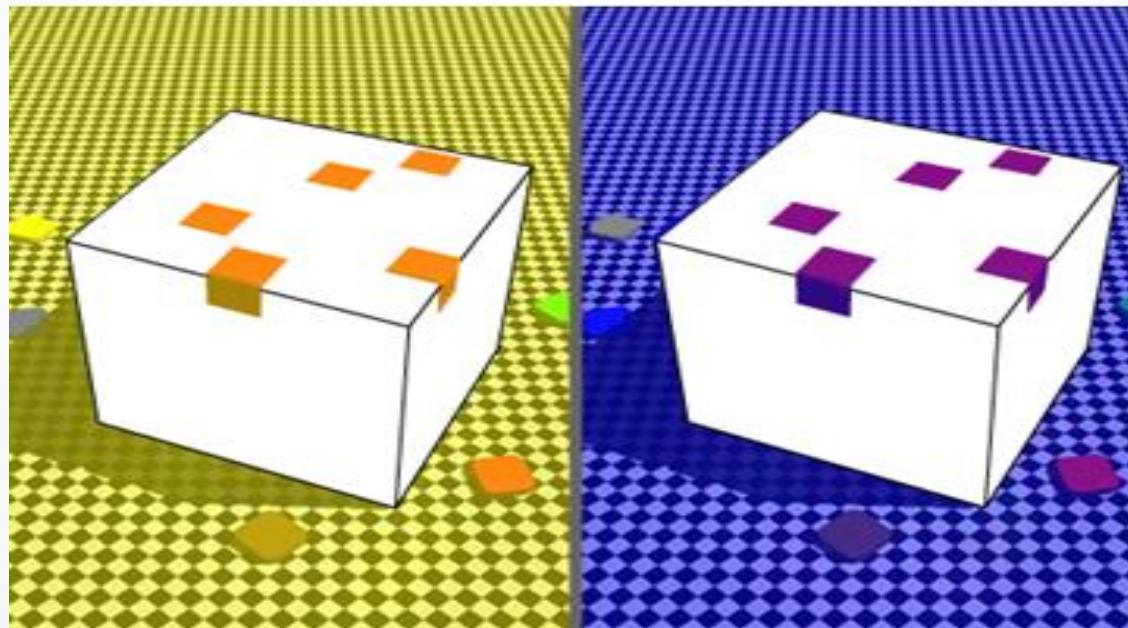
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颜色？

相对性&绝对性

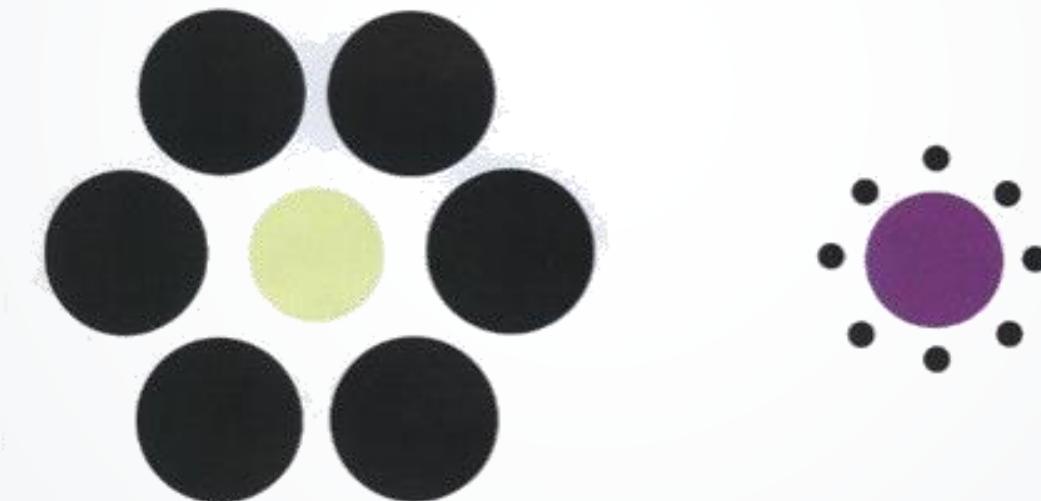
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颜色？

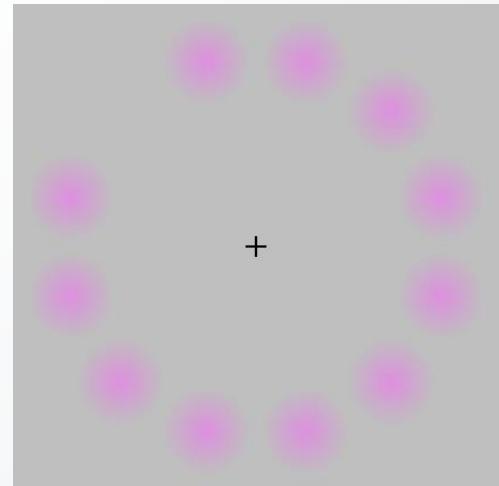
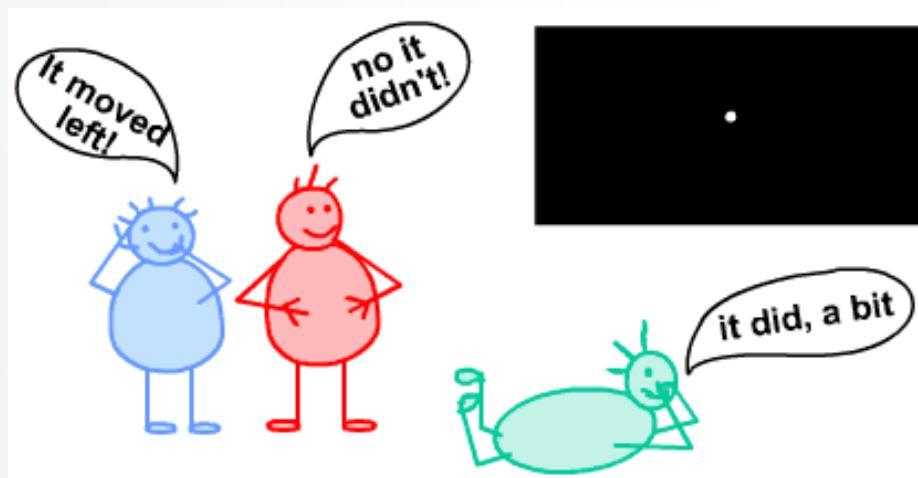
Perceived Shape

Are the two circles in the center of the same sizes?



Perceived Motion

- Stroboscopic Effect (flip book effect)
- Phi phenomenon
- Autokinetic Effect (if people stare at a white spotlight in a dark room, it appears to move.)



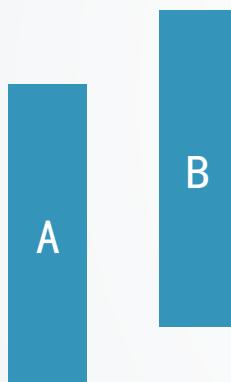
Fact

Our visual system sees differences, not absolute values, and is attracted to edges.

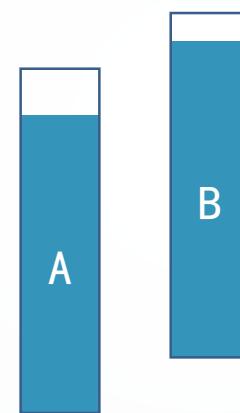
Use **high contrast** between objects that should be distinguishable

相对性&绝对性

感知系统基于相对判断，而非绝对判断 (Weber's Law)



无线框
未对齐



有线框
未对齐



无线框

A和B那一个更高？

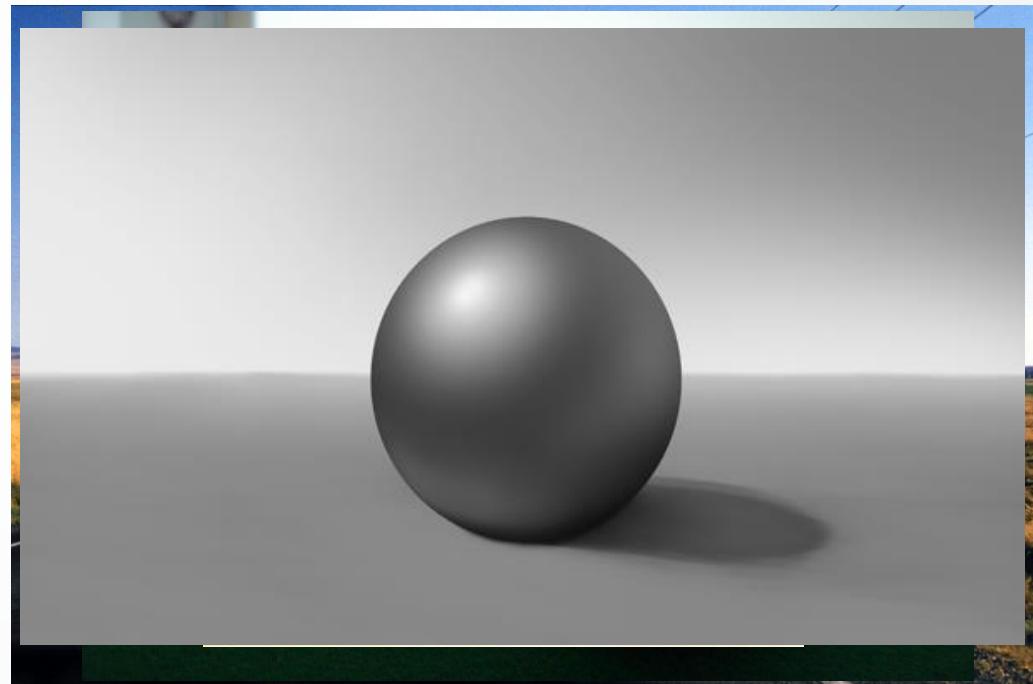
Depth Perception

Monocular depth cues – cues that provide depth information with one eye closed.

- pictorial cues (e.g., linear perspective)
- aerial perspective (differing contrast)
- texture gradients (decreased detail from front to back)
- interposition
- shading (production of shadows by 3-D objects)
- familiar size as anchor
- motion parallax

Monocular Cue

- You really only need one eye to use these (used in art classes to show depth).
- Linear Perspective
- Interposition
- Relative size
- Texture gradient
- Shadowing



Binocular Cues



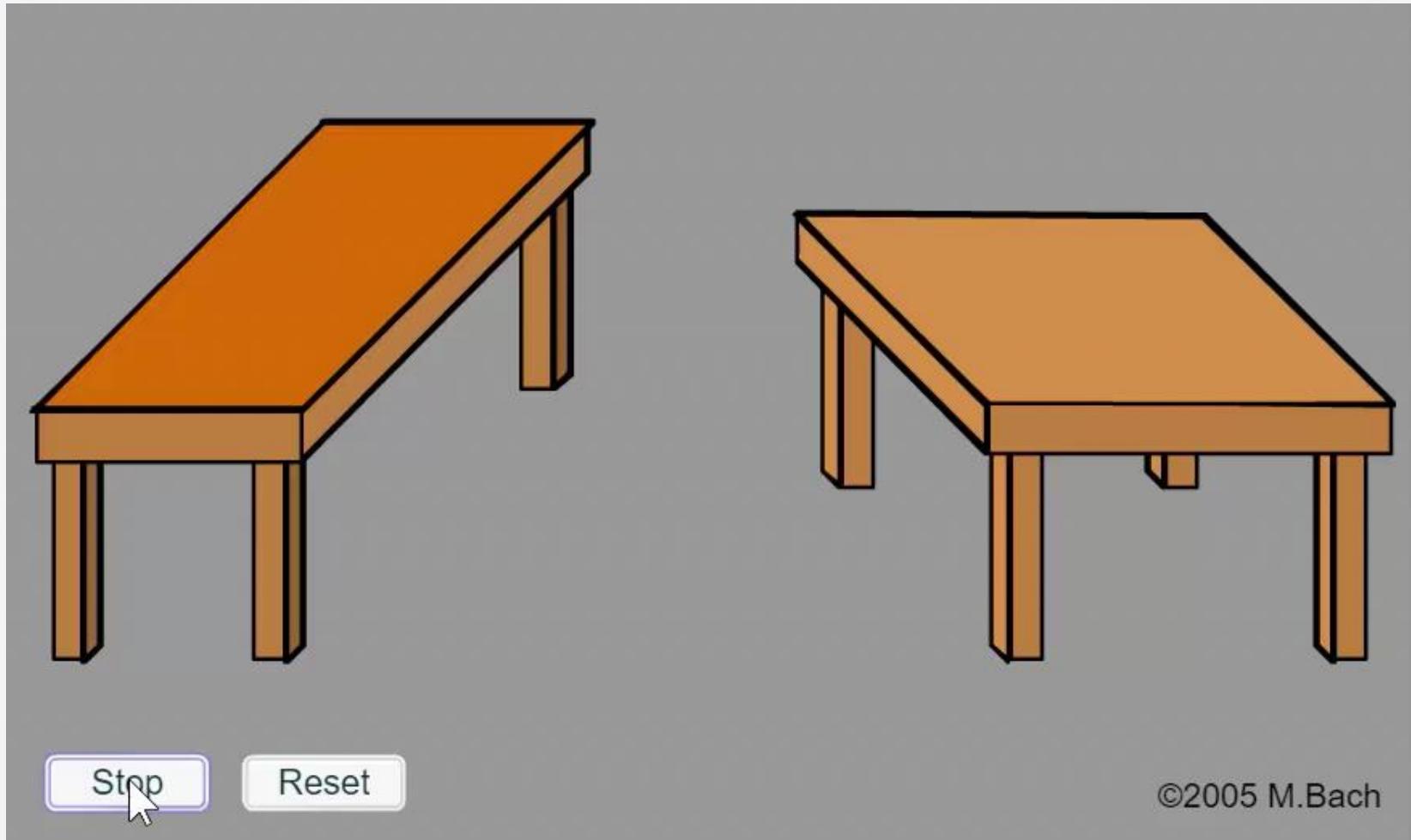
- We need both of our eyes to use these cues.
- **Retinal Disparity** (as an object comes closer to us, the differences in images between our eyes becomes greater).
- **Convergence** (as an object comes closer our eyes have to come together to keep focused on the object).

Seeing is Not Believing

Impossible Box



Shepard's Rotated Table

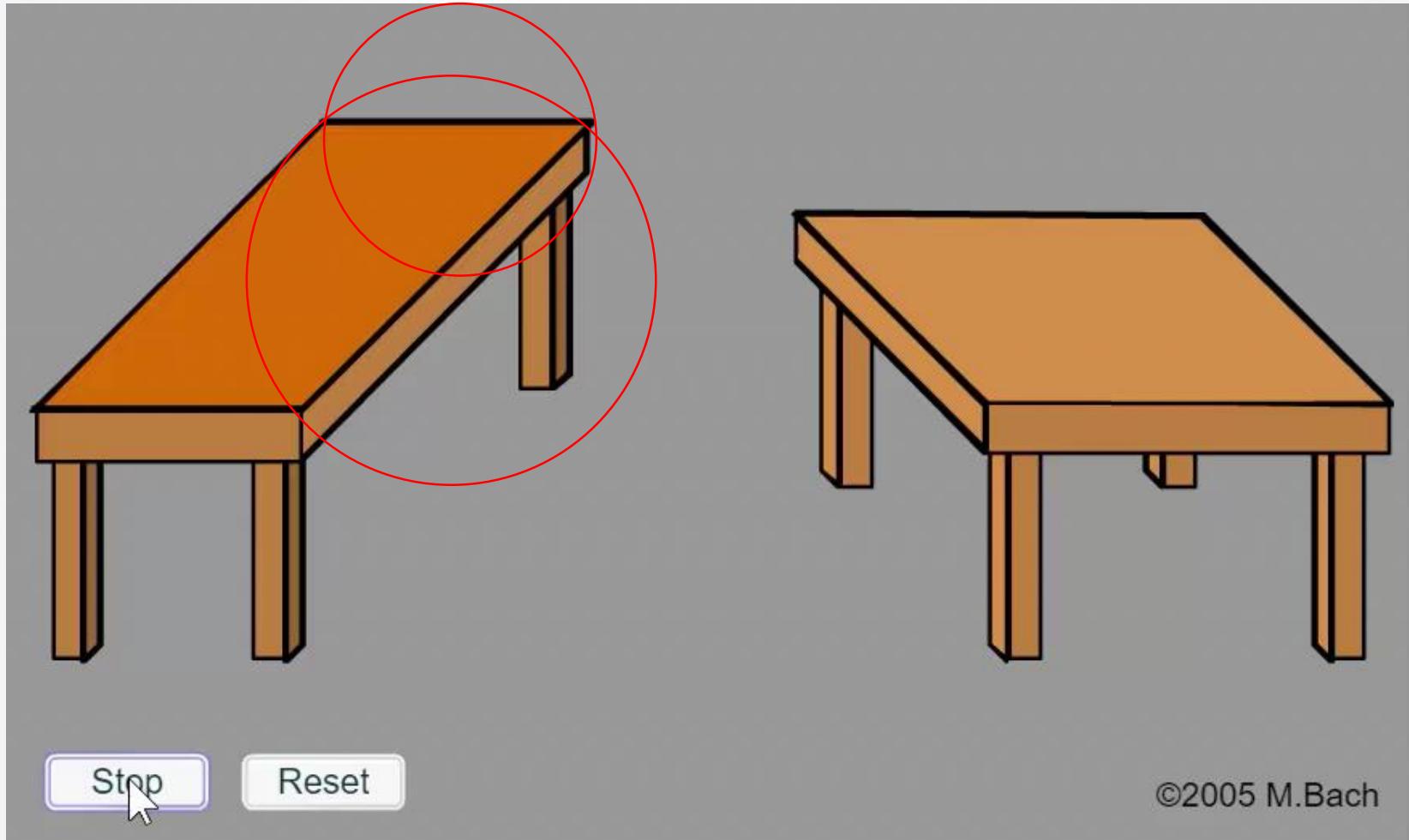


Stop

Reset

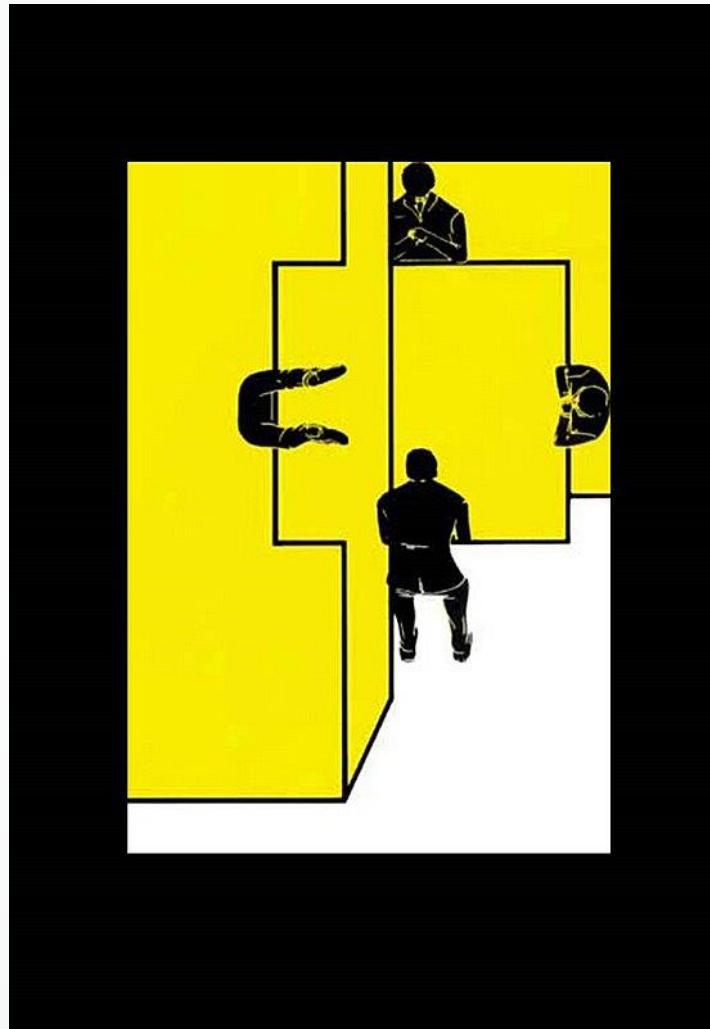
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Shepard's Rotated Table

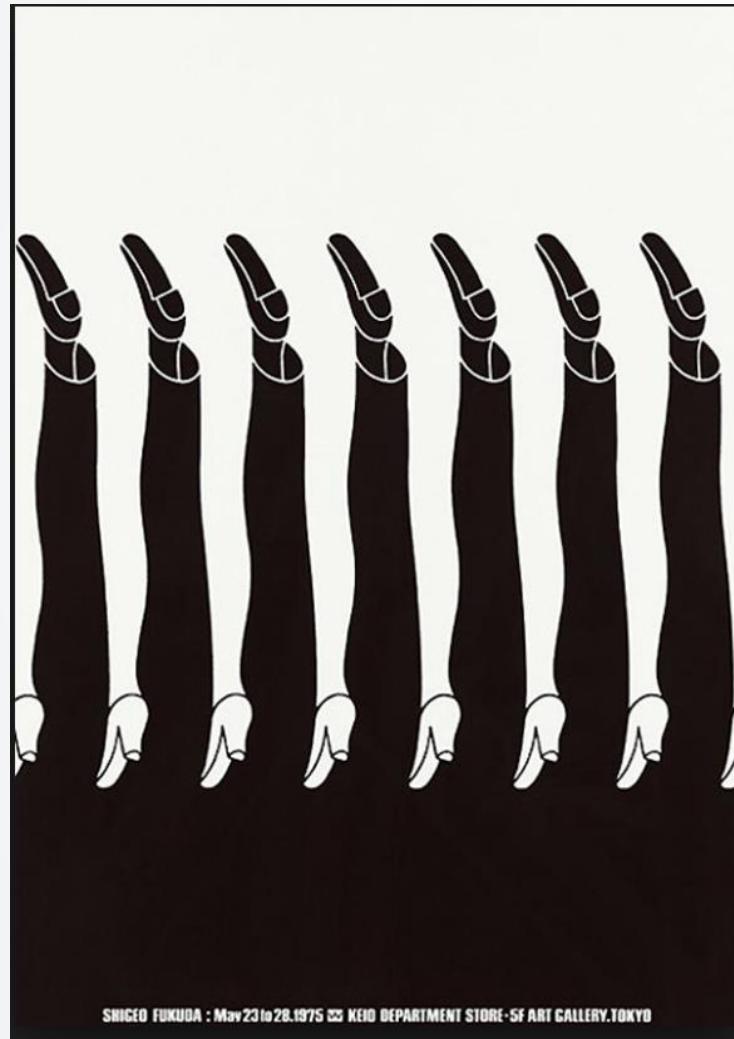


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Shigeo Fukuda



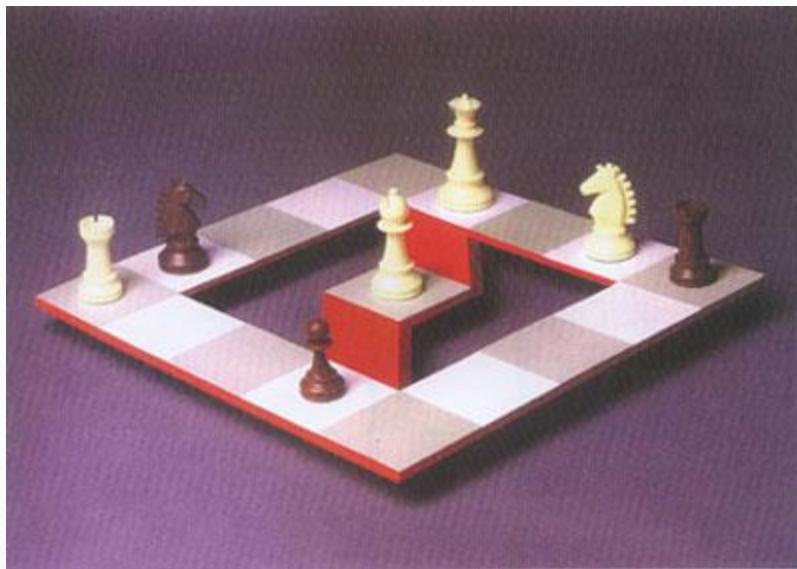
Shigeo Fukuda

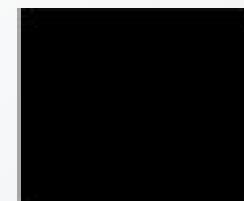
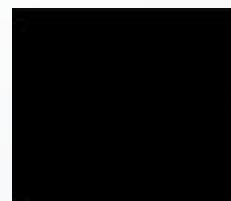
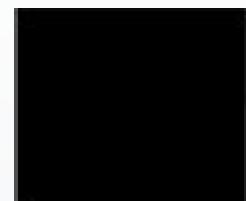
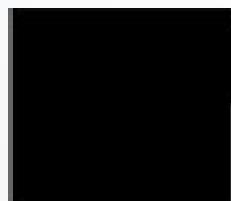
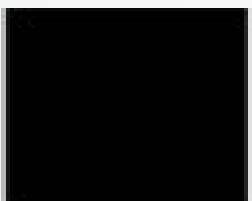
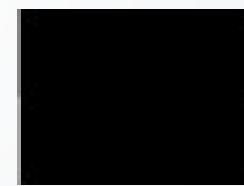
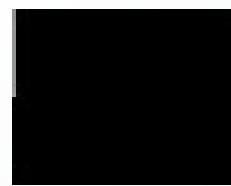
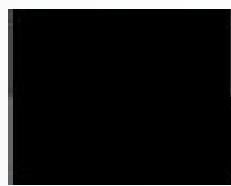
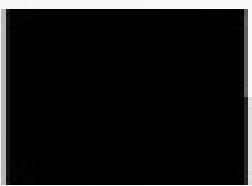
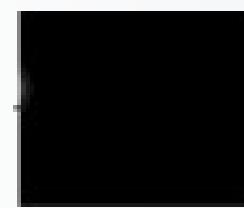
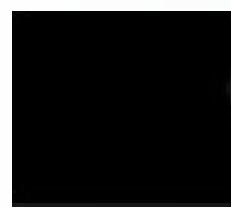
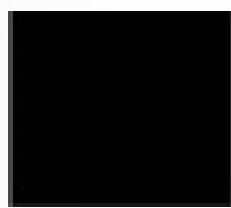
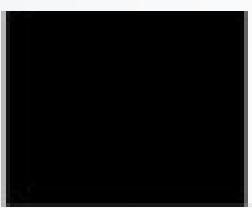
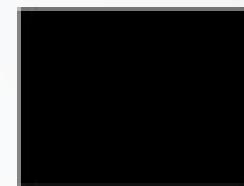
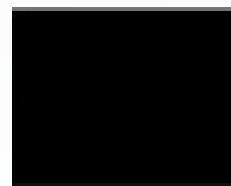
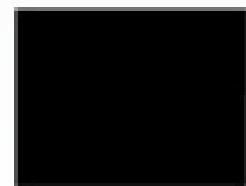
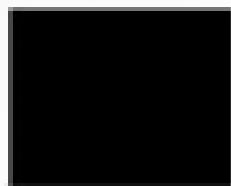
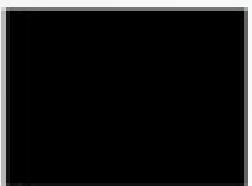
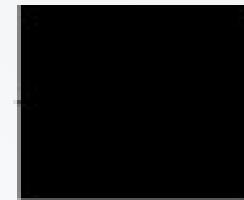
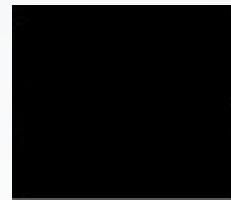
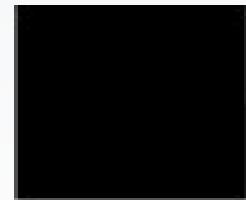
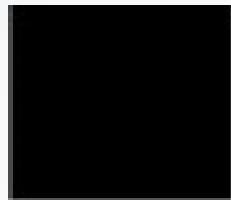
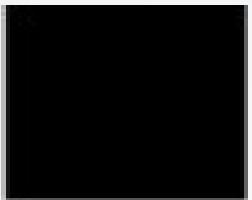


SHIGEO FUKUDA : May 23 to 28, 1975 KEIO DEPARTMENT STORE・SF ART GALLERY, TOKYO

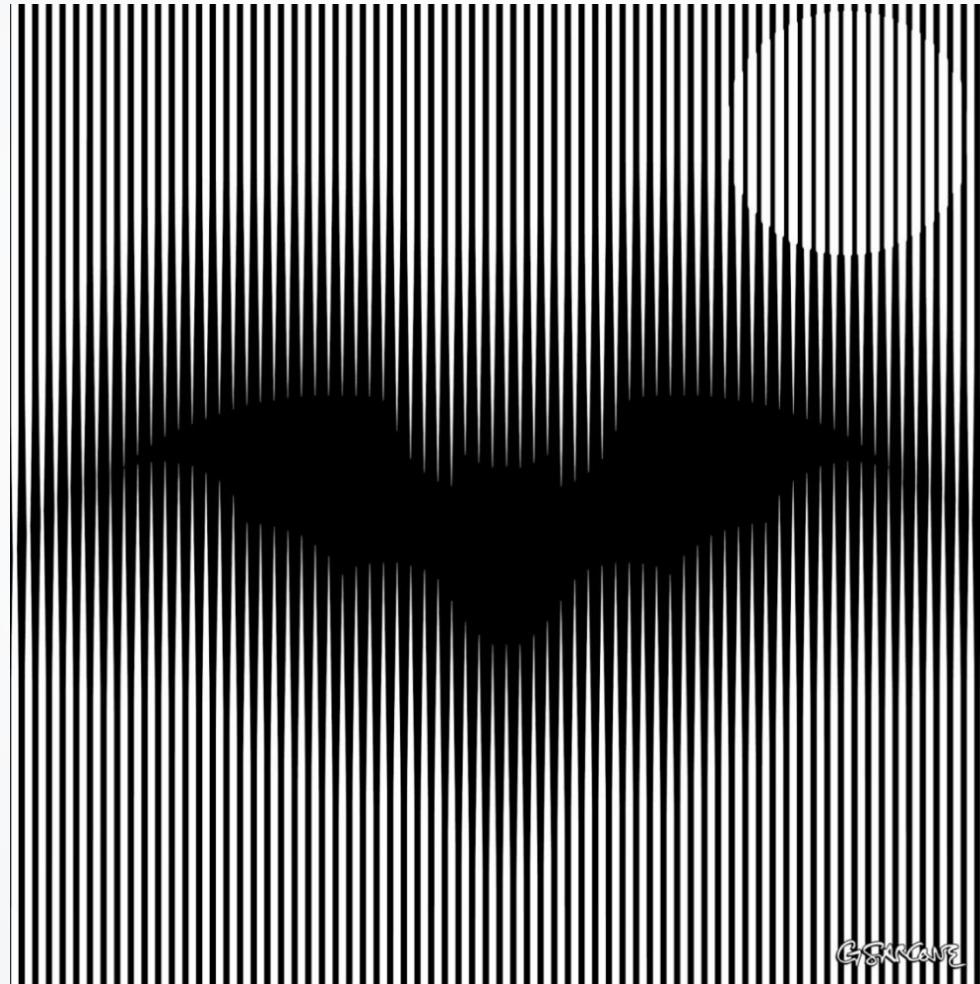


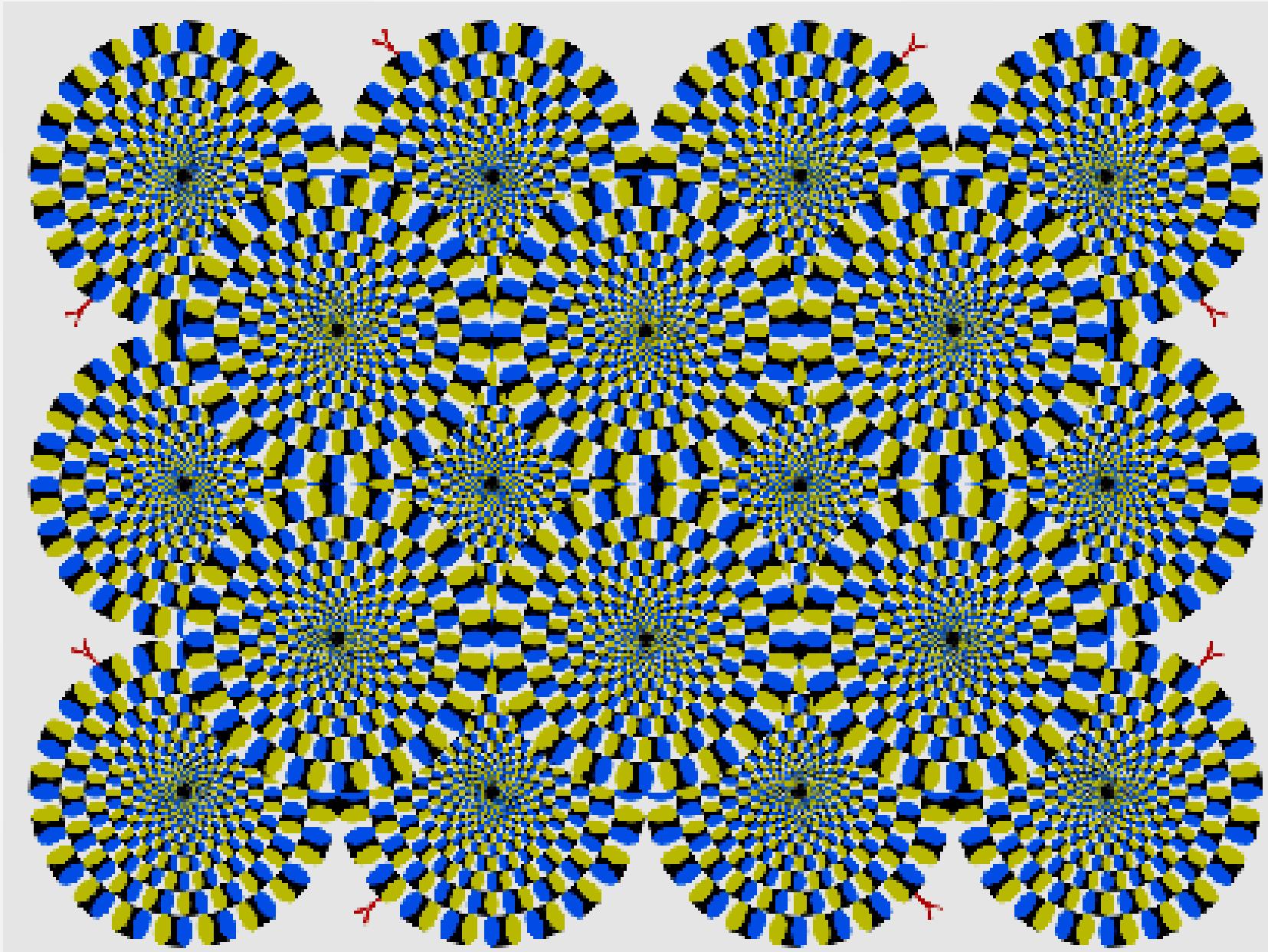
Impossible Chess

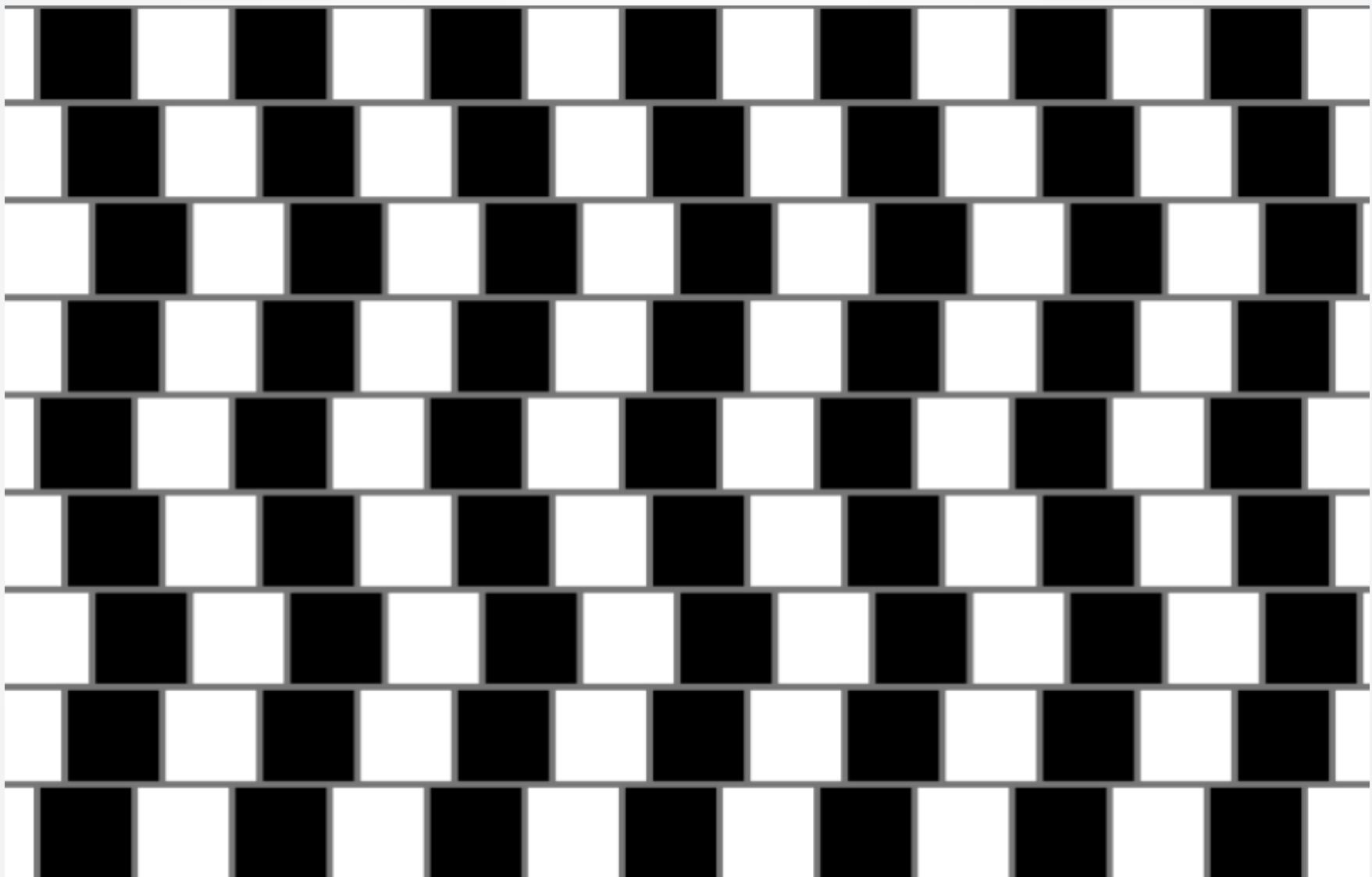




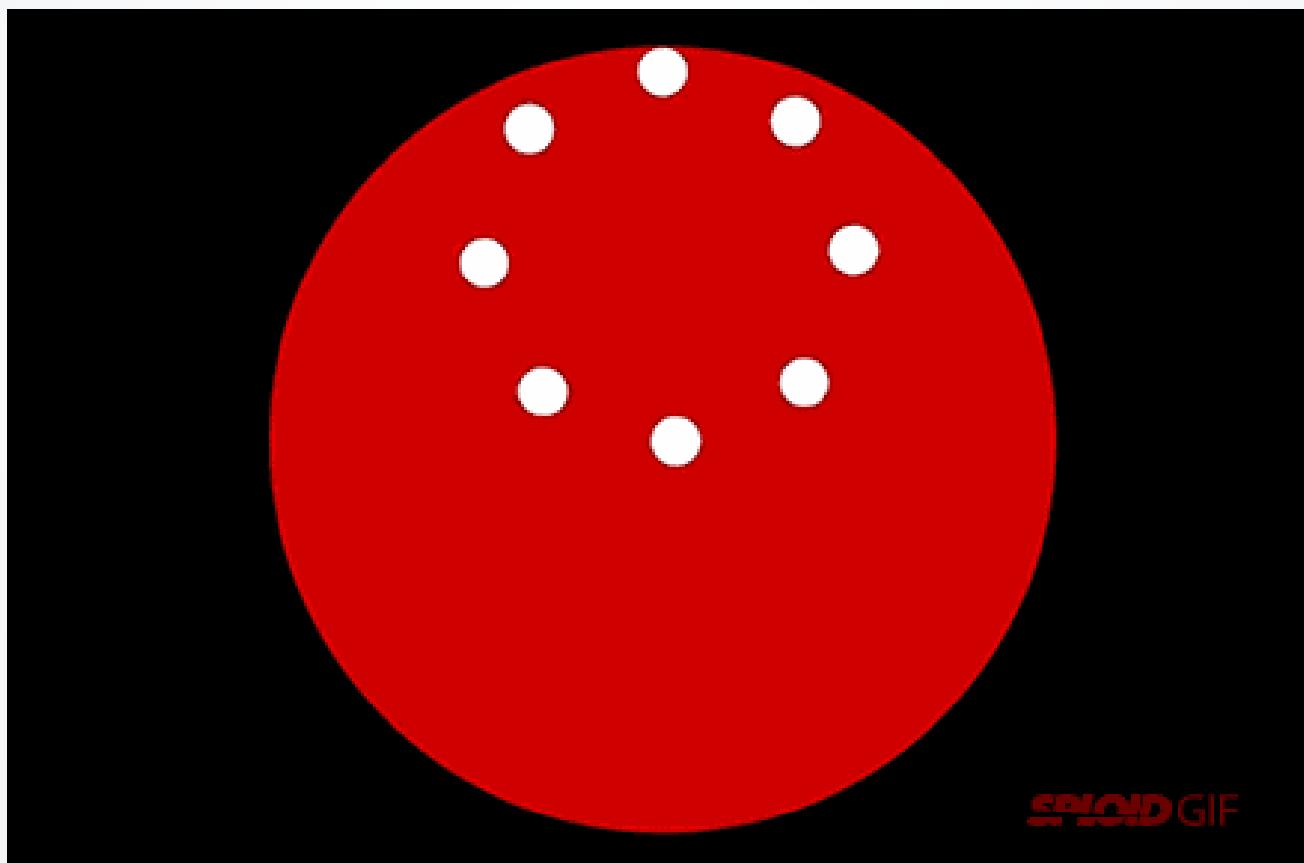
Flying Black Bat







Illusion



SPNOD.GIF

Outline

① Visual Perception

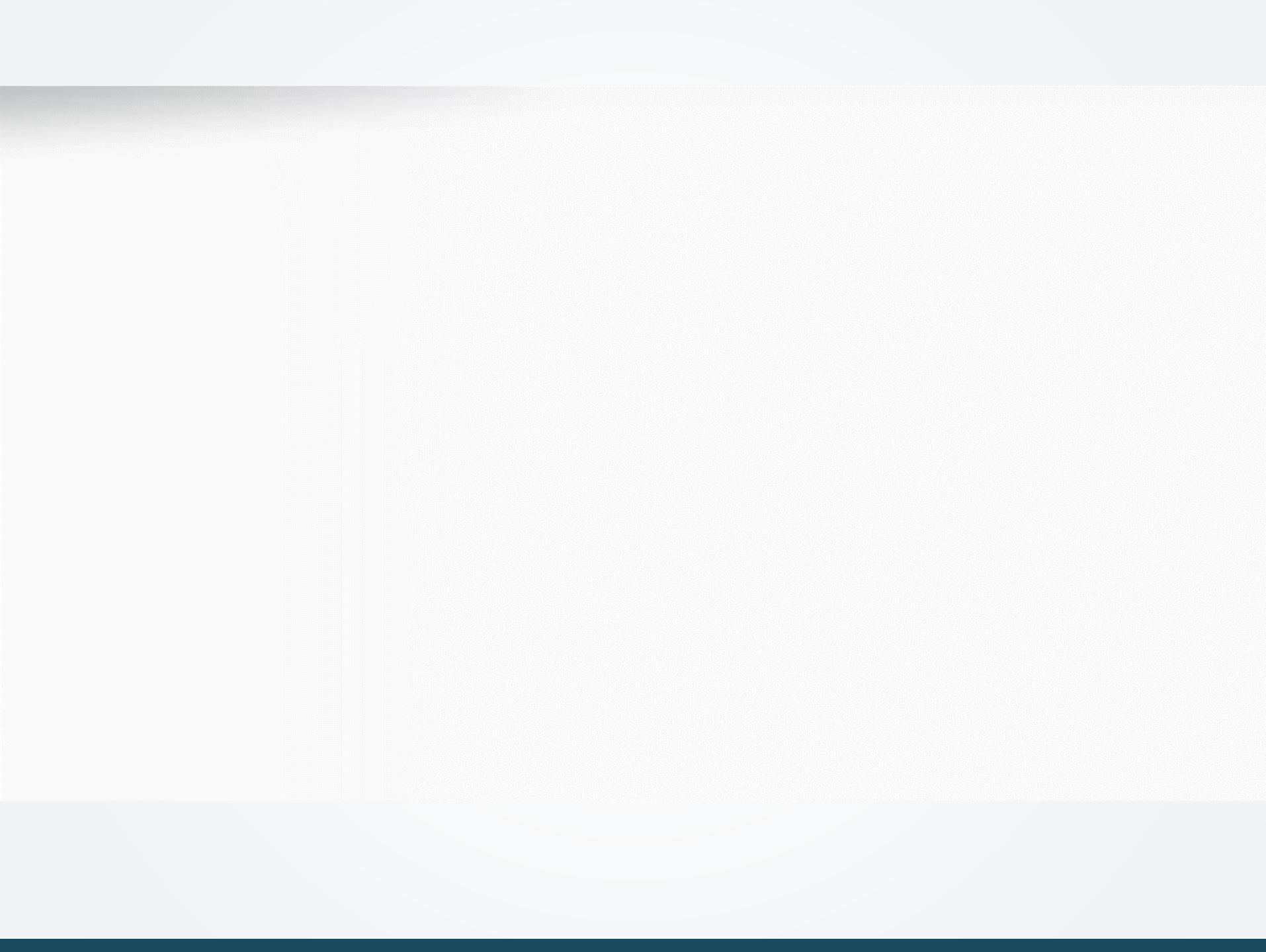
② Cognition

③ Shape

④ Color

⑤ Toolkits

There's more to seeing than just what's there

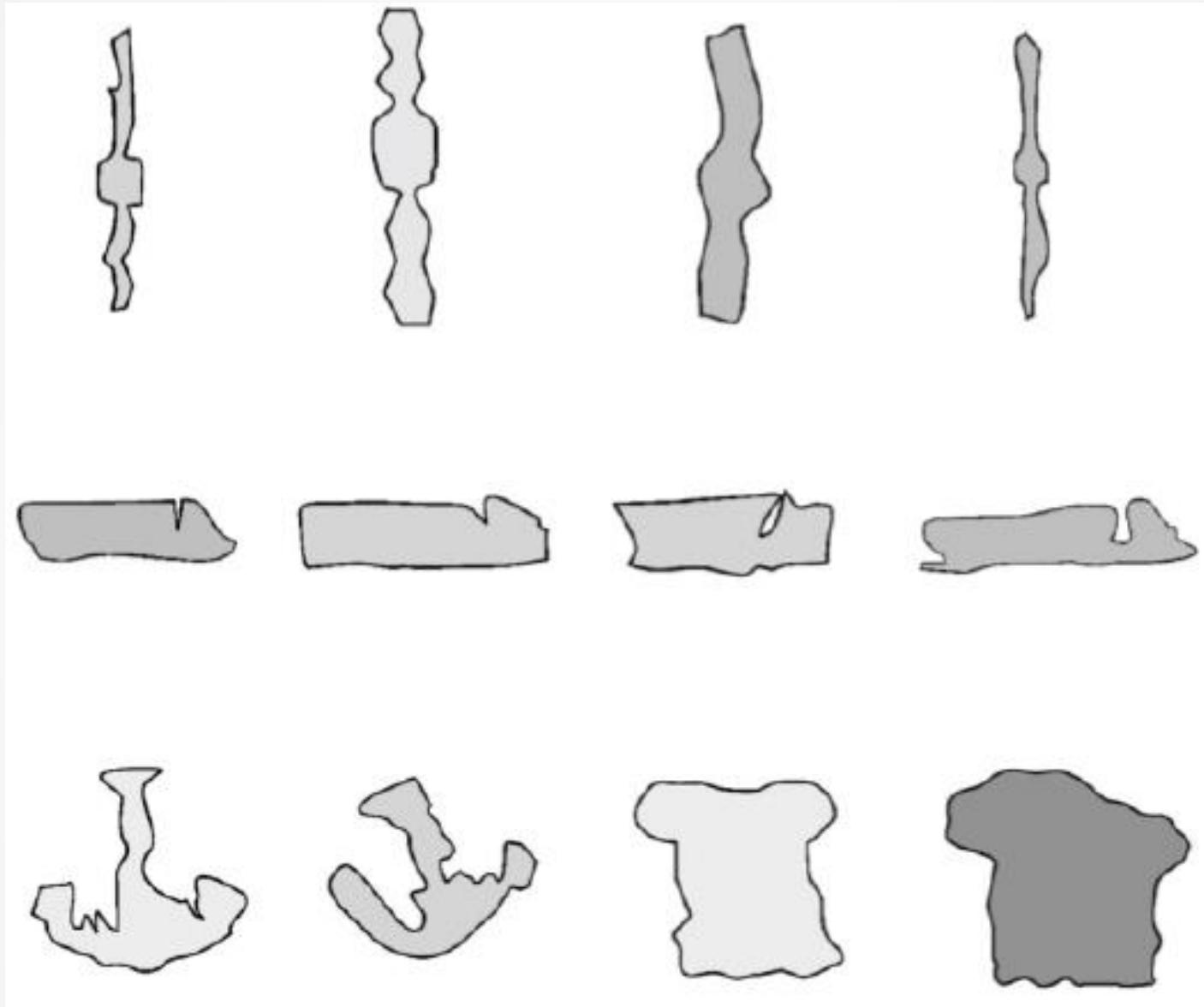








conceptual interpretation affects memory



conceptual interpretation affects memory





we rely on priors

Take Home Point

Vision is “constructed” from the input

“What you see when you see a thing depends on what the thing is. What you see the thing as depends on what you know about what you are seeing.”

Polyshyn

Outline

① Visual Perception

② Cognition

③ Shape

④ Color

⑤ Toolkits

Object Recognition: Key Question

- When does one object end and another begin?
(grouping/segmentation)
- Viewpoint independence (perception of objects as objects,
regardless of view)
- How do we know that two things belong together, and
how do we know that dogs are dogs and not cats?
(categorization)

More Key Issues

- The “binding problem”:

If perception of a given object is distributed throughout visual areas, how does the brain combine features to produce unitary percept?

- Conscious vs. unconscious perception:

Perception of some object or object qualities may proceed pre-consciously or without effort (a general principle).

- Example: Threat

Gestalt Theory



Wolfgang Köhler
1887-1967

为什么我们在观看
事物的时候会把一
部分当做前景，其
余部分当做背景？

Kurt Koffka
1886-1941

为什么我们能区分
形状？

Max Wertheimer
1880-1943

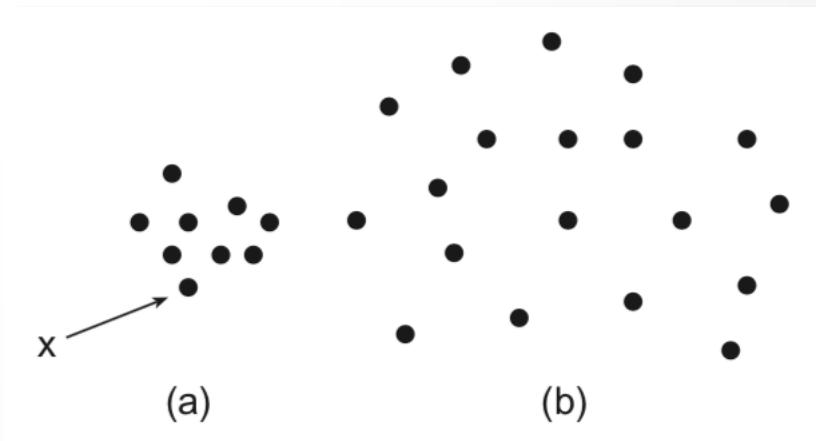
什么形状是好的？

格式塔 (Gestalt) 原则

- 结构比元素重要，视觉形象首先作为统一的整体被认知
- 原则(蕴涵律)
 - 接近性(proximity)
 - 相似性(similarity)
 - 连续性(continuity)
 - 闭合性(closure)
 - 简单性(simplicity)

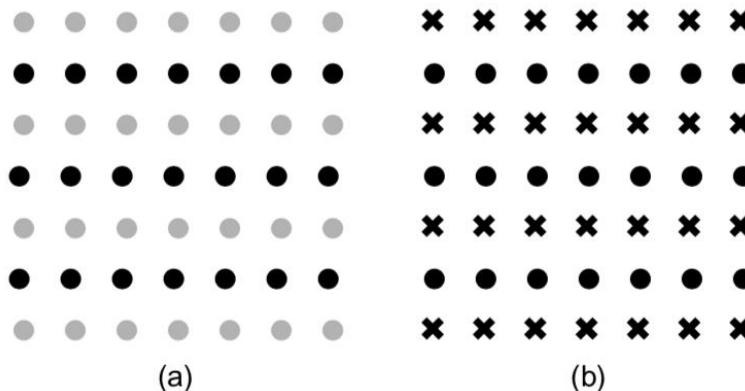
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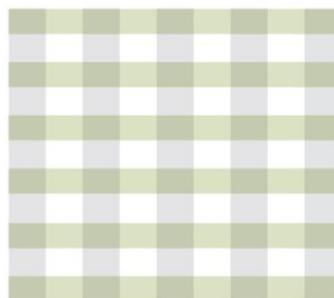
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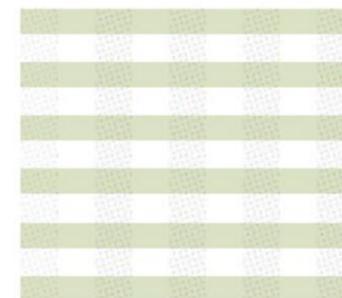


(a)

(b)



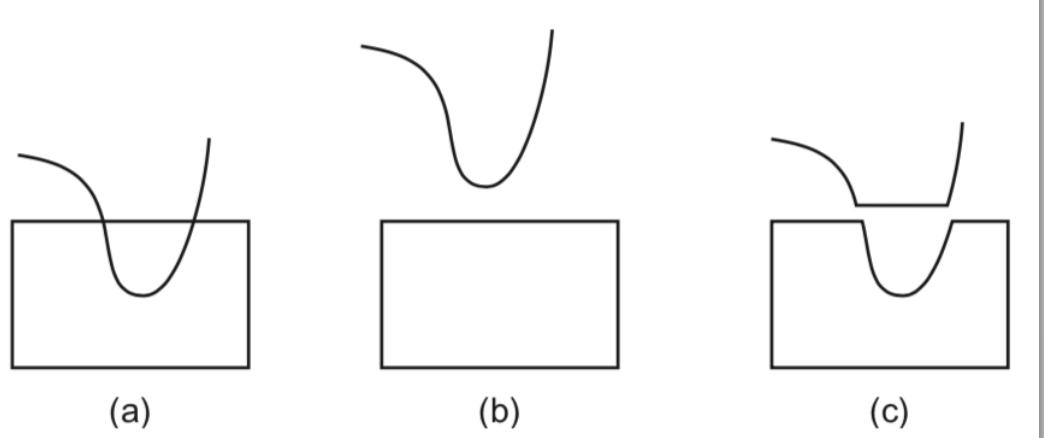
(c)



(d)

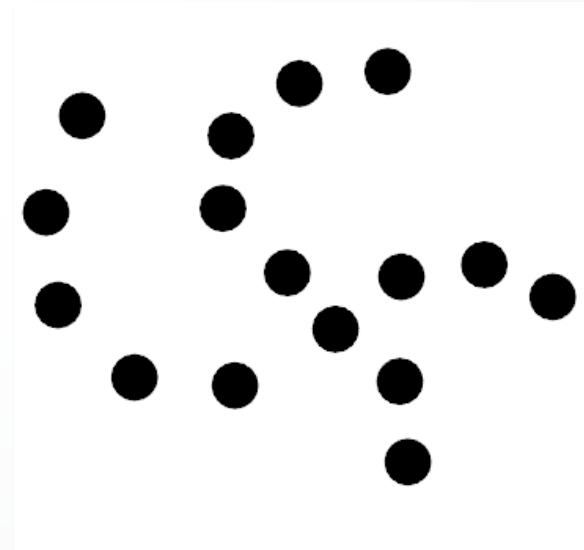
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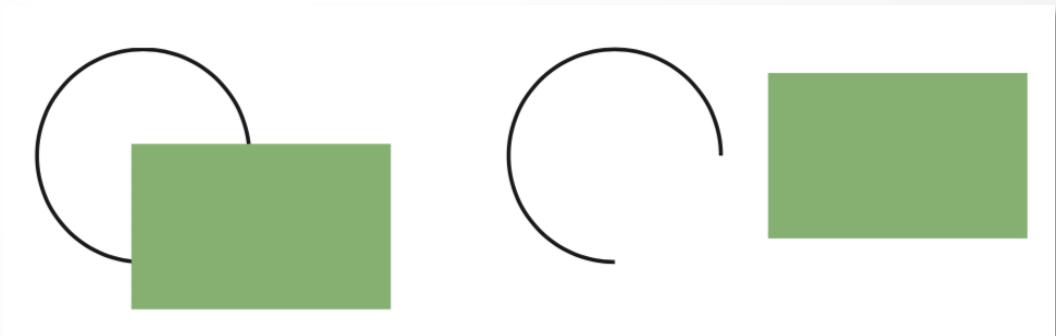
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 - 简单性(simplicity)



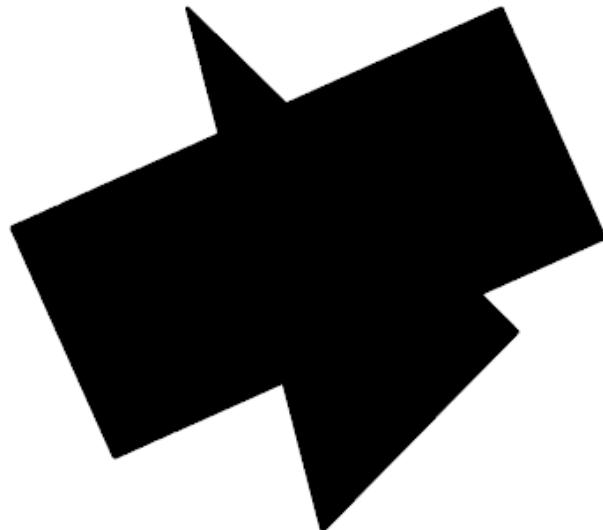
格式塔 (Gestalt) 原则

- 结构比元素重要，视觉形象首先作为统一的整体被认知
- 原则(蕴涵律)
 - 接近性(proximity)
 - 相似性(similarity)
 - 连续性(continuity)
 - 闭合性(closure)
 - 简单性(simplicity)



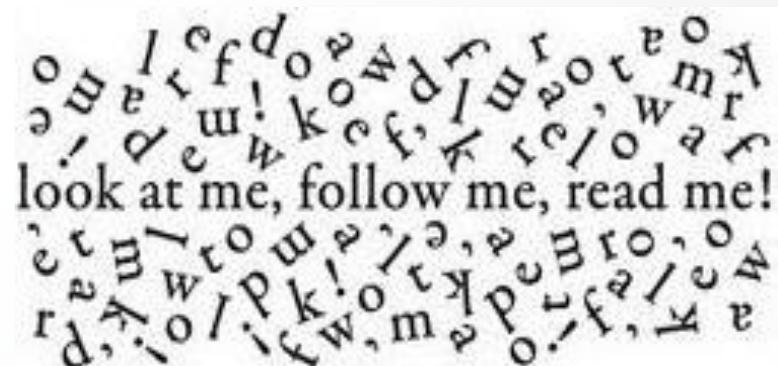
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 - 共势原则(common fate)
 - 好图原则(pragnanz)
 - 对称原则(symmetry)
 - 经验原则(past experience)



look at me, follow me, read me!

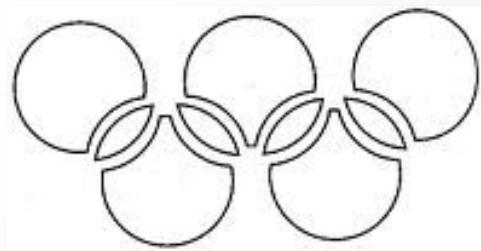
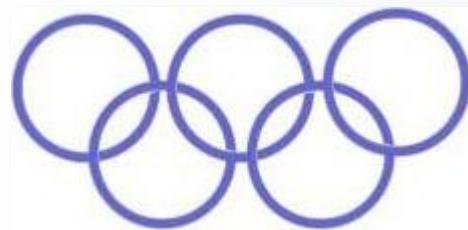
从一堆字符中认知语句

格式塔 (Gestalt) 原则

- 结构比元素重要，视觉形象首先作为统一的整体被认知

- 原则 (蕴涵律)

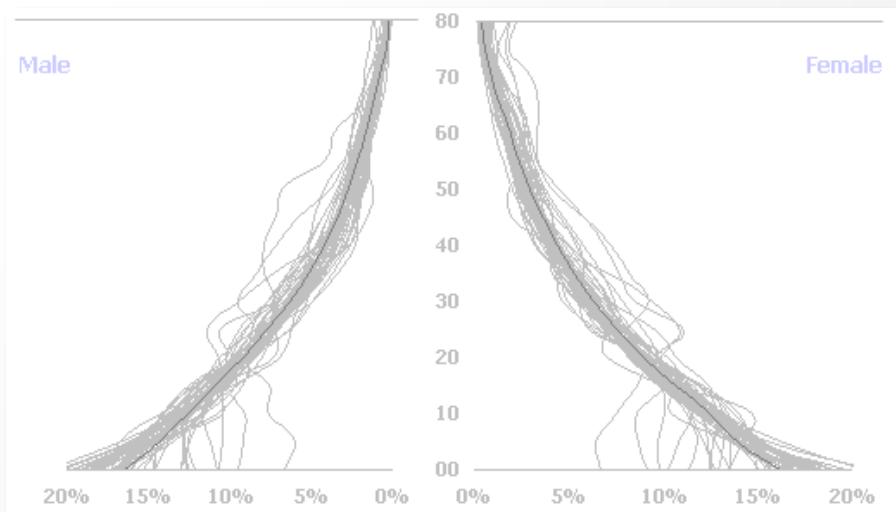
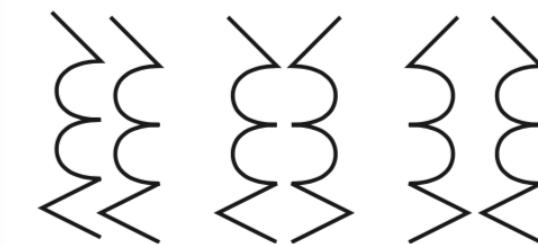
- 共势原则 (common fate)
- 好图原则 (pragnanz)
- 对称原则 (symmetry)
- 经验原则 (past experience)



对五环形状的两种识别
上：奥运环；下：割裂的圆环。

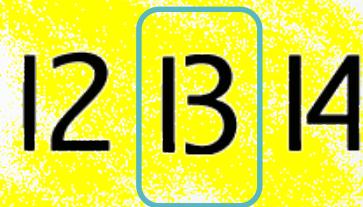
格式塔 (Gestalt) 原则

- 结构比元素重要，视觉形象首先作为统一的整体被认知
- 原则 (蕴涵律)
 - 共势原则(common fate)
 - 好图原则(pragnanz)
 - 对称原则(symmetry)
 - 经验原则(past experience)

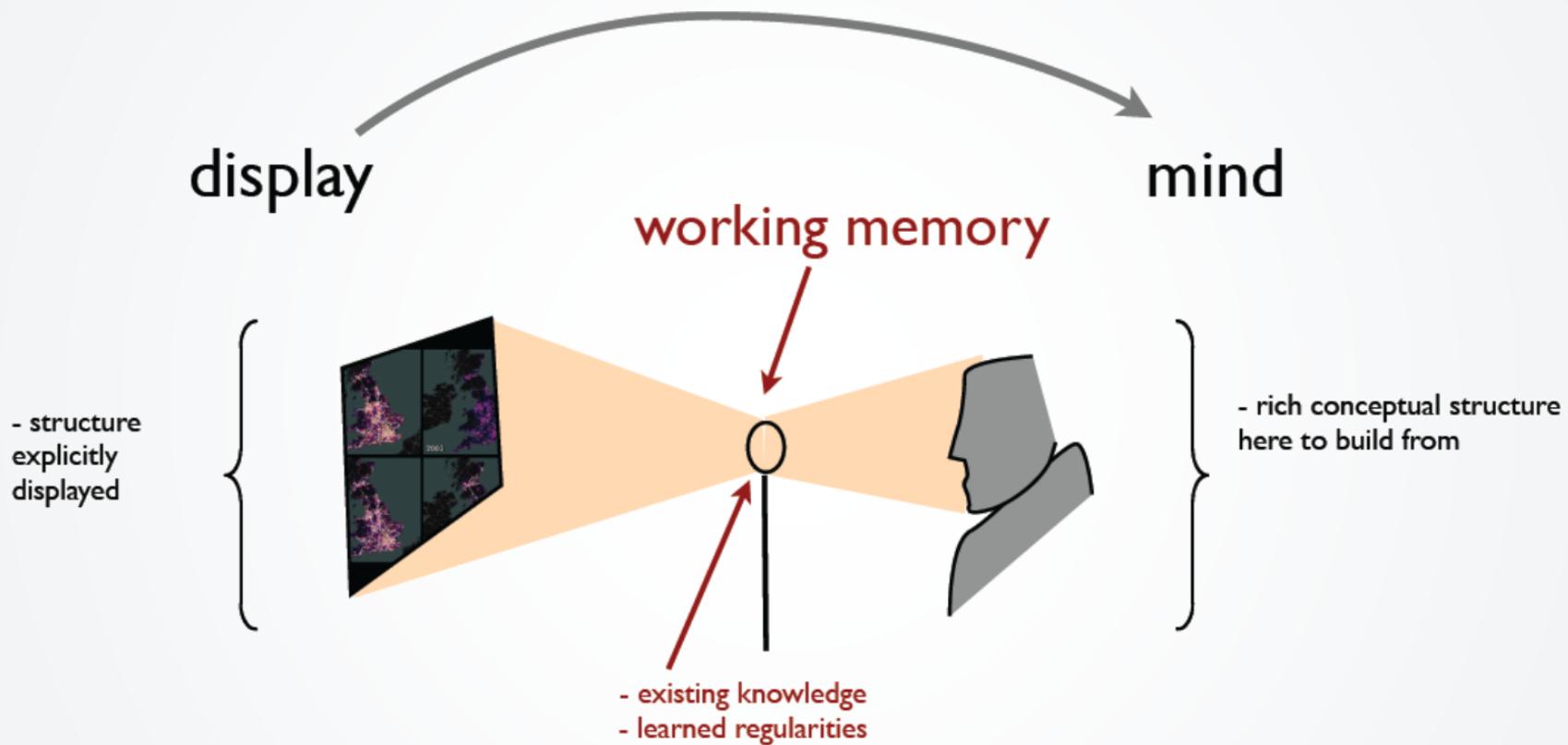


格式塔 (Gestalt) 原则

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 - 经验原则(past experience)



Take Home Picture



Active concepts in working memory can be synthesized

“The power of a visualization is that we can have a far more complex concept structure represented externally in a visual display than can be held in visual and verbal working memory.”

- Colin Ware

Outline

① Visual Perception

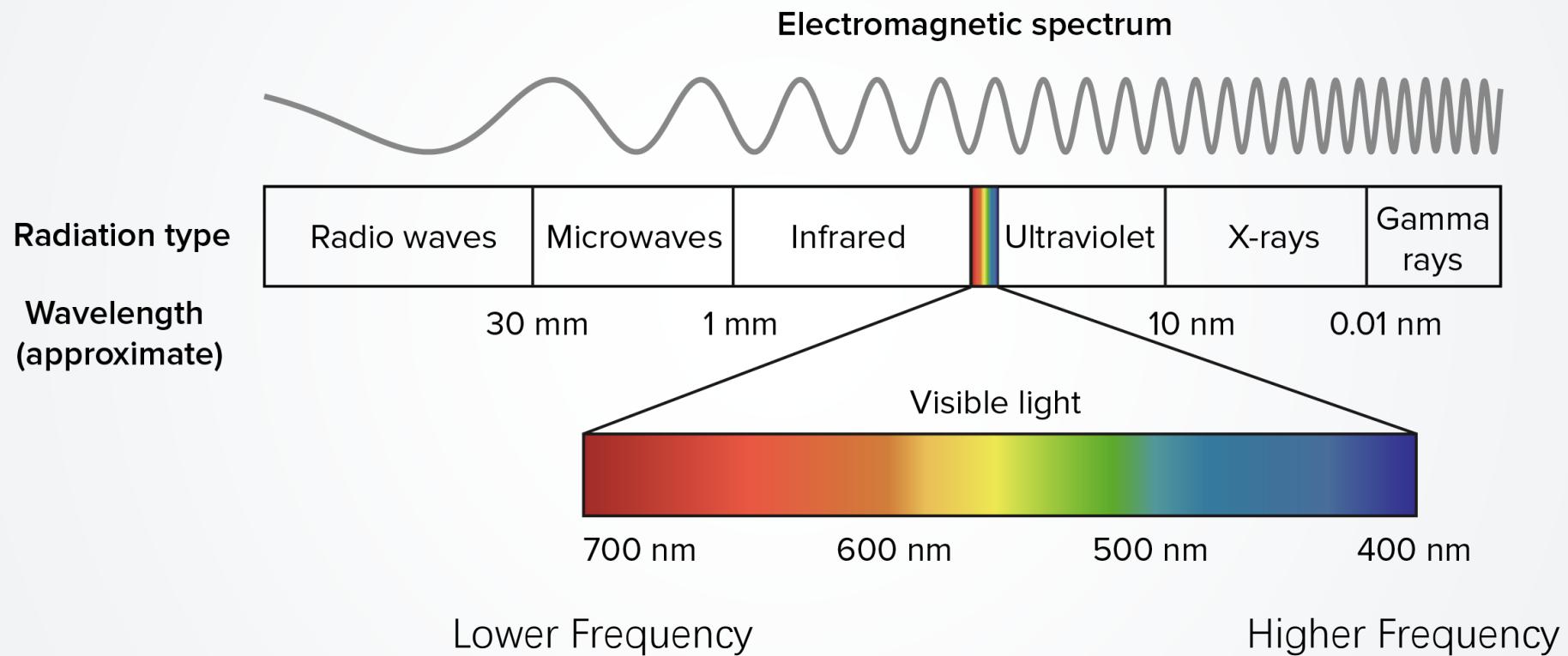
② Cognition

③ Shape

④ Color

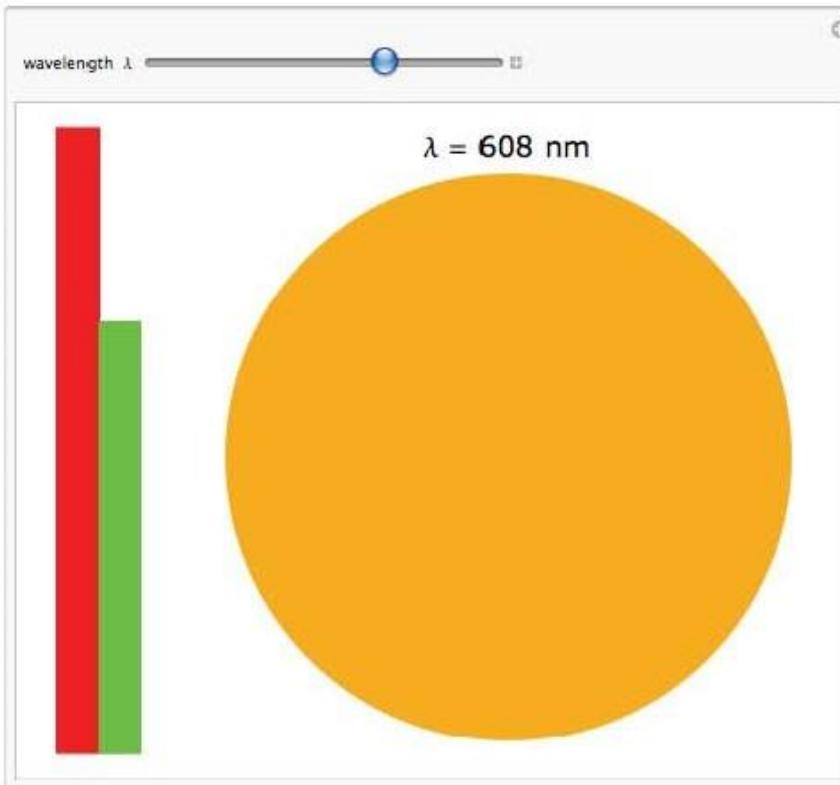
⑤ Toolkits

Spectrum of Light





Color versus Wavelength



The perceived color of light varies with wavelength, going from violet at the shortest wavelength to red at the longest.

Cone Response

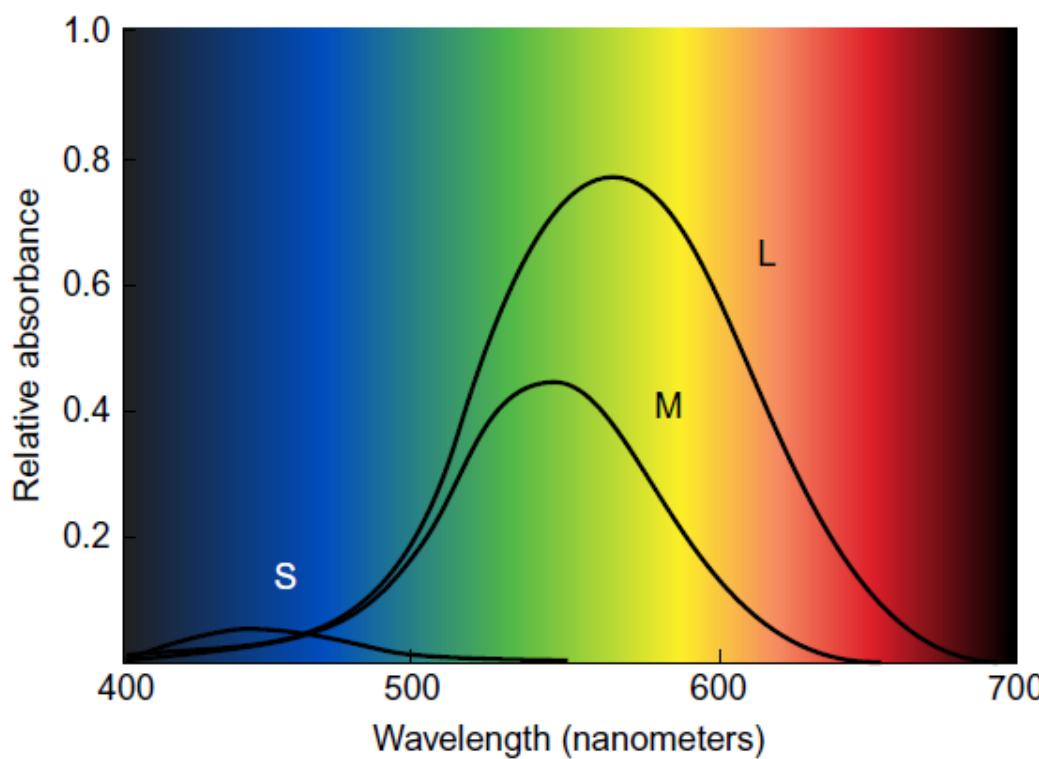


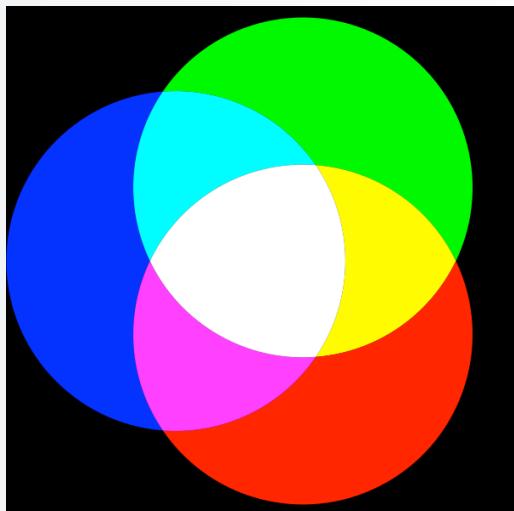
Figure 4.2 Cone sensitivity functions. The colors are only rough approximations to spectrum hues. Abbreviations: S, short-wavelength cone sensitivity; M, medium-wavelength cone sensitivity; L, long-wavelength cone sensitivity.

What are the primary colors?

- Red, Green, Blue
- Red, Yellow, Blue
- Orange, Green, Violet
- Cyan, Magenta, Yellow
- All of the above

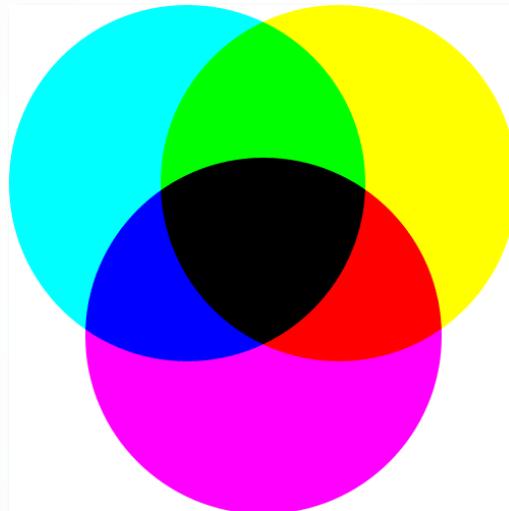
Color System

Additive System

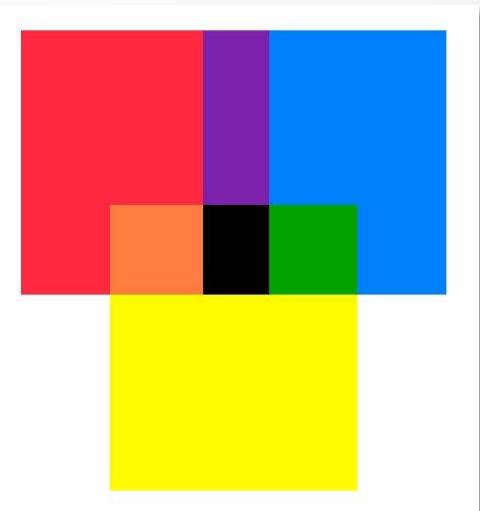


RGB

Subtractive System



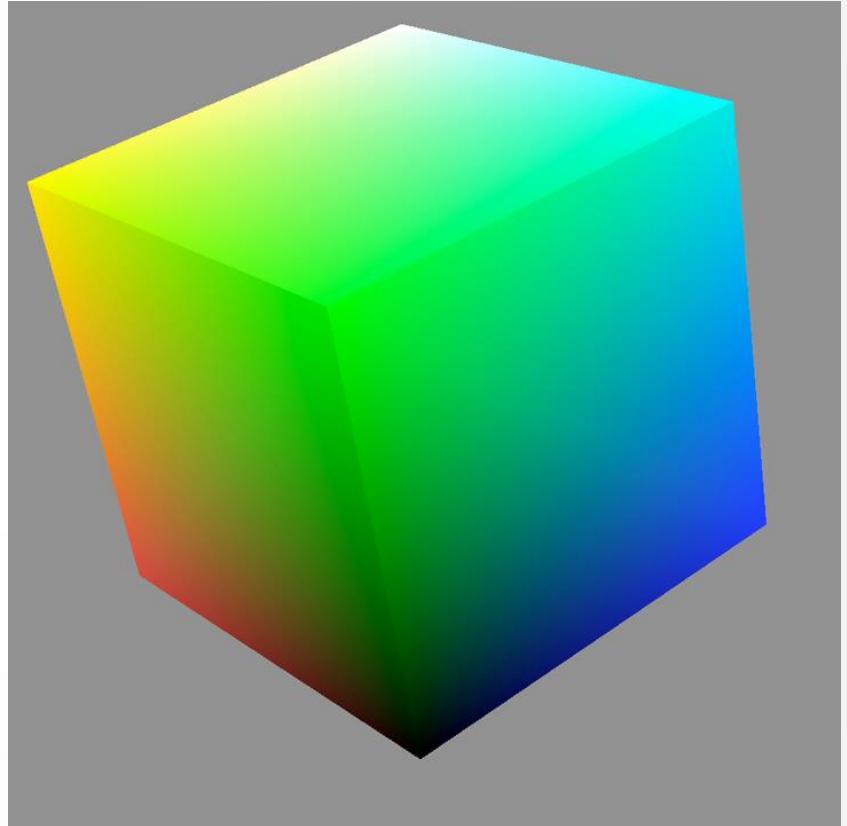
CMYK



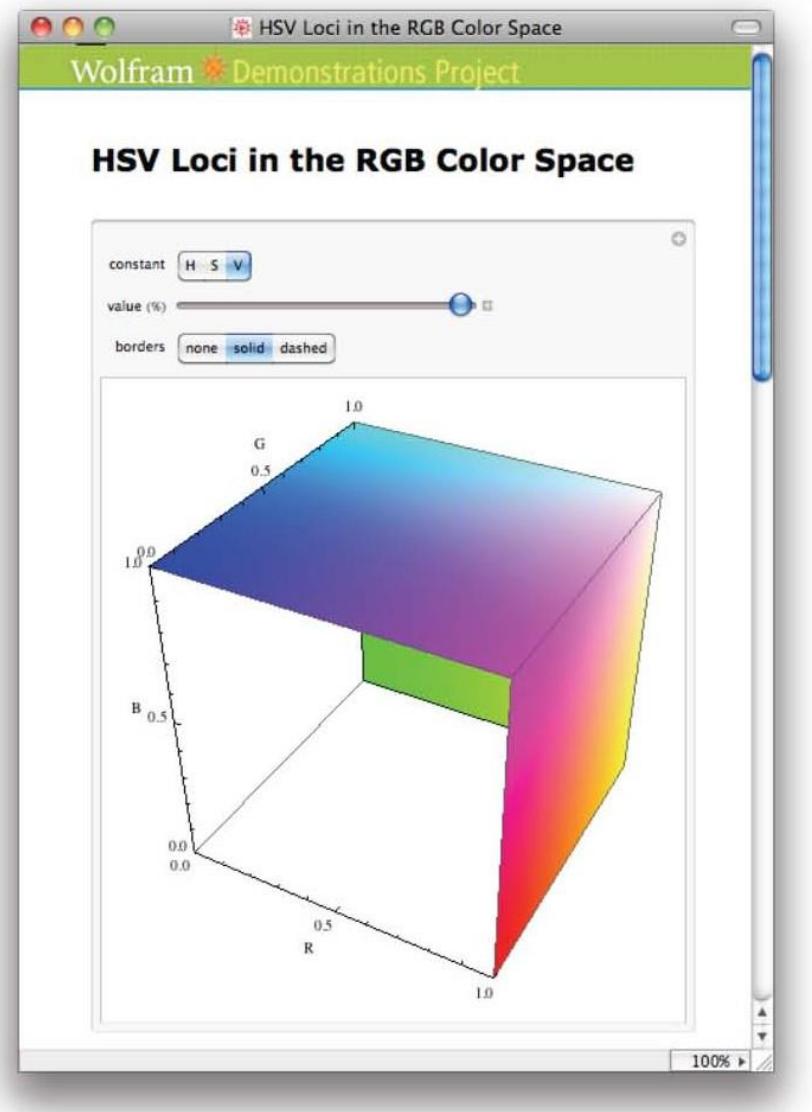
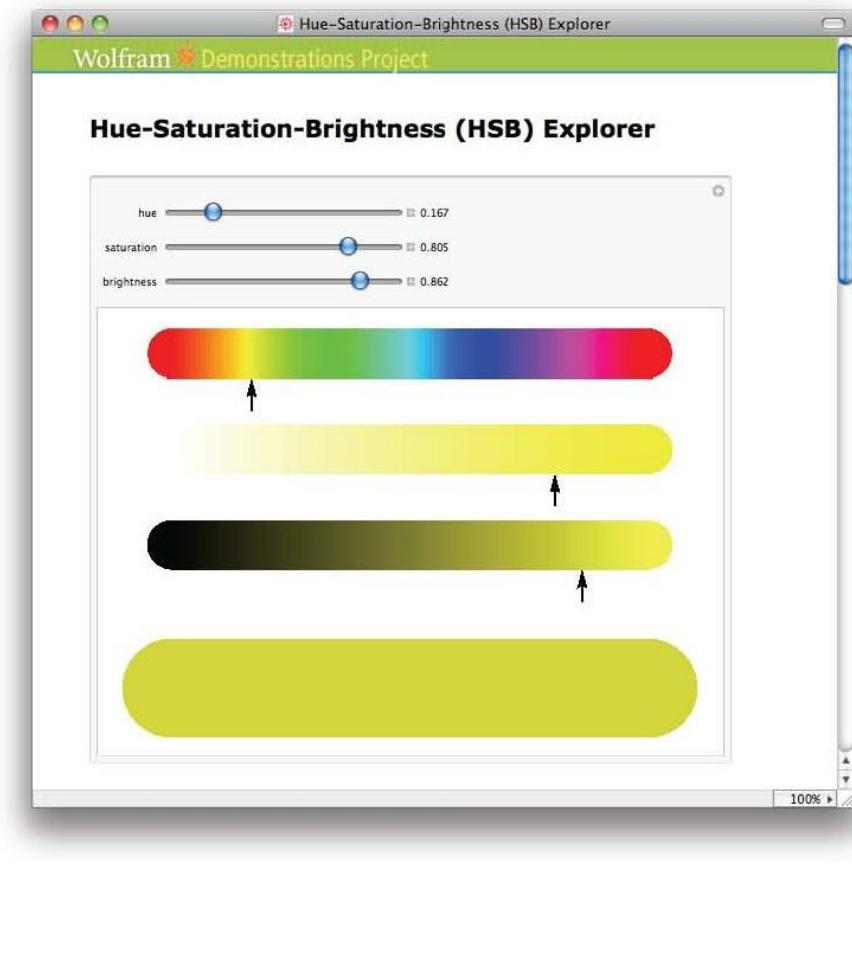
RYB

RGB Color Space

- Colors that can be represented by computer monitors
- Not perceptually uniform

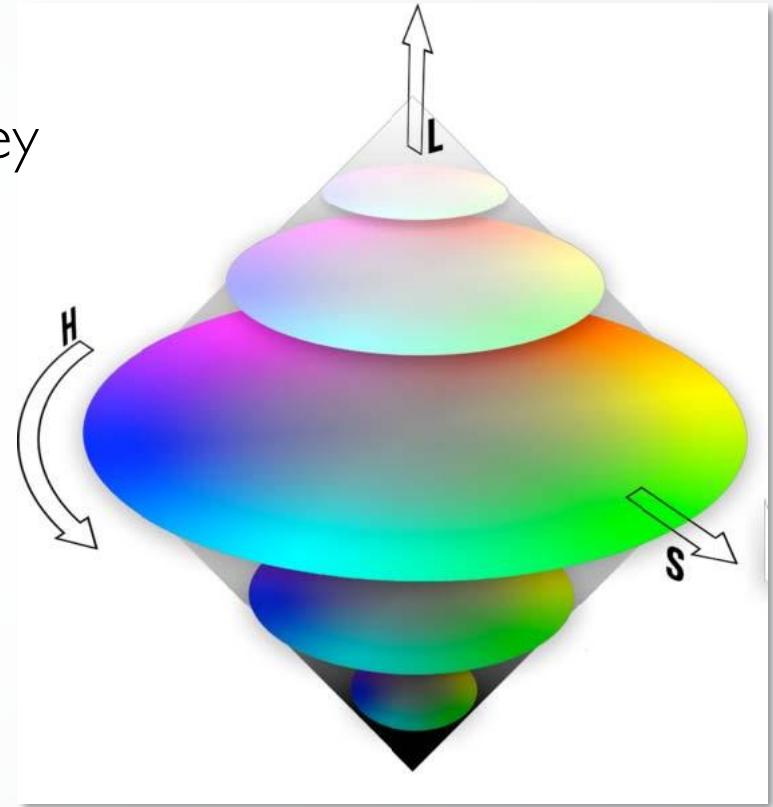


C. Ware, “Visual Thinking for Design”



HSL Color Space

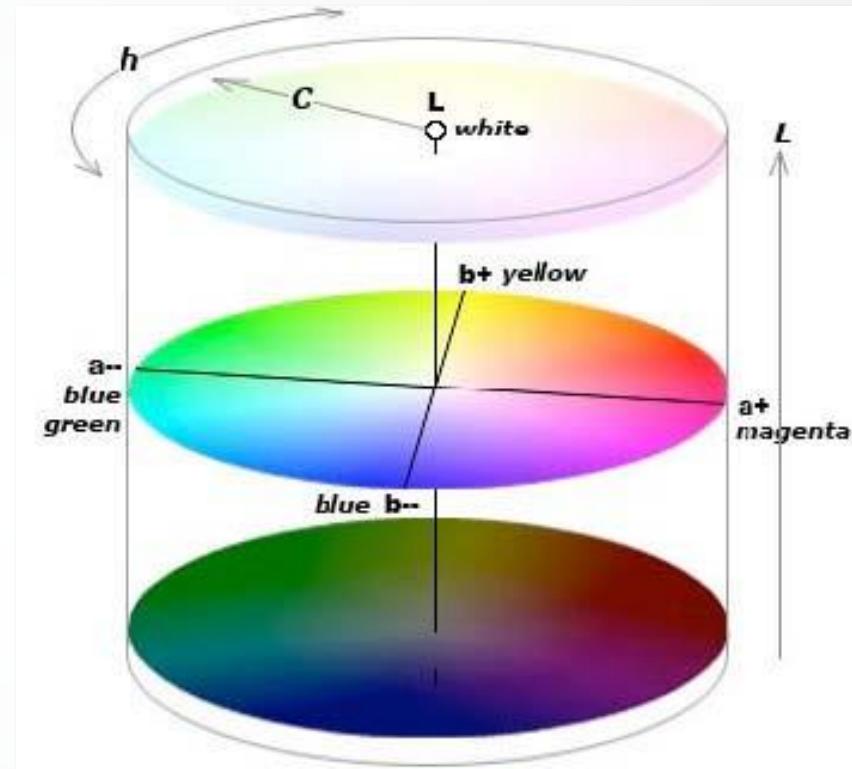
- Hue - what people think of color
- Saturation - purity, distance from grey
- Lightness - from dark to light
- Not perceptually uniform



wikipedia.org

Lab Color Space

- Perceptually uniform
- L approximates human perception of lightness
- a, b approximate R/G and Y/B channels



Lab Color Space



Lab



Luminance



a (red - green)



b (yellow - blue)

Based on slide from A. Oliva

Outline

① Visual Perception

② Cognition

③ Shape

④ Color

⑤ Toolkits

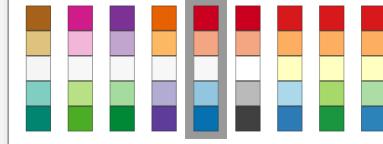
ColorBrewer

Number of data classes: 11 ▾ [i](#)

Nature of your data: [i](#)

sequential diverging qualitative

Pick a color scheme:



Only show: [i](#)

colorblind safe print friendly photocopy safe

Context: [i](#)

roads cities borders

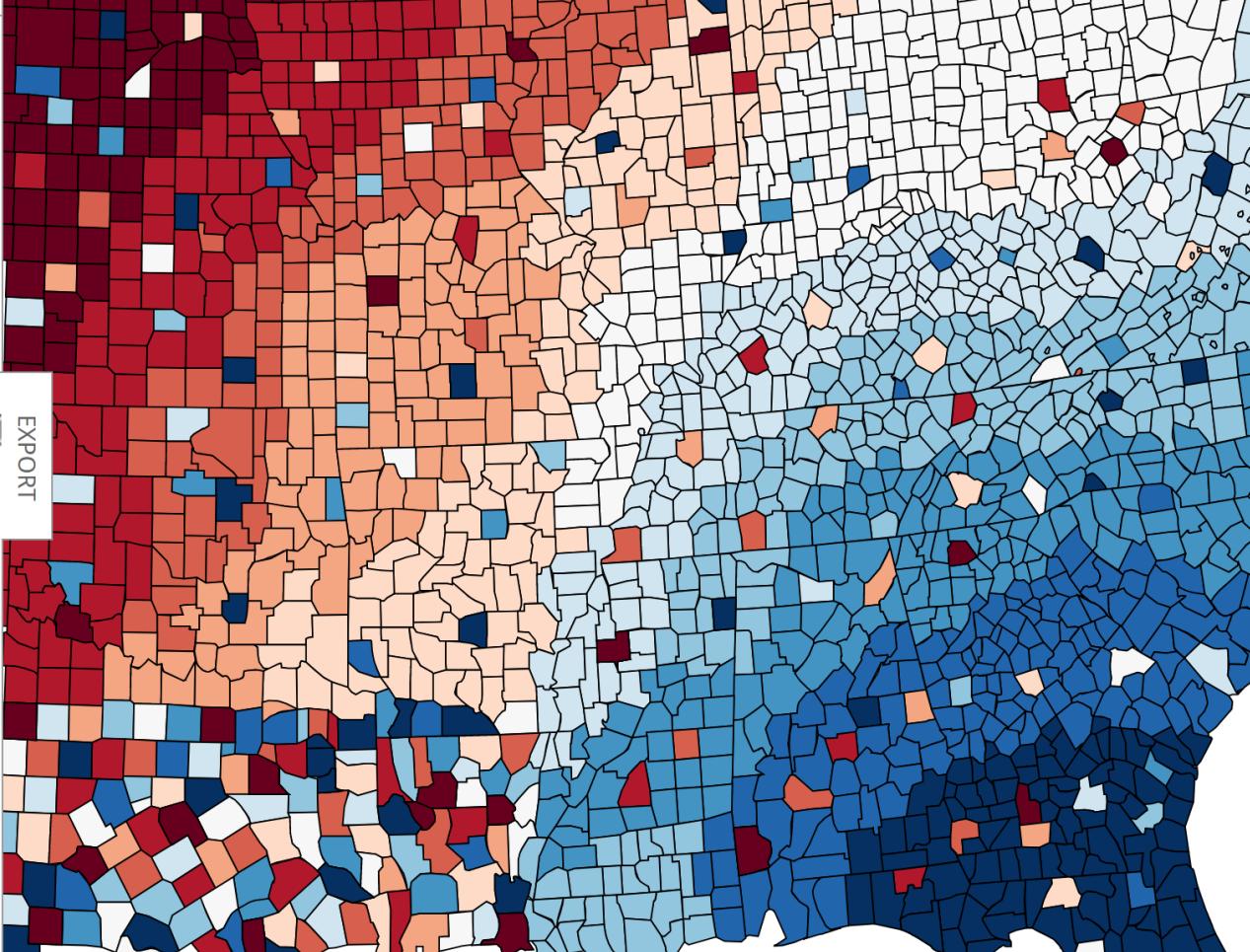
Background: [i](#)

solid color terrain

color transparency

how to use | updates | downloads | credits

COLORBREWER 2.0
color advice for cartography



11-class RdBu

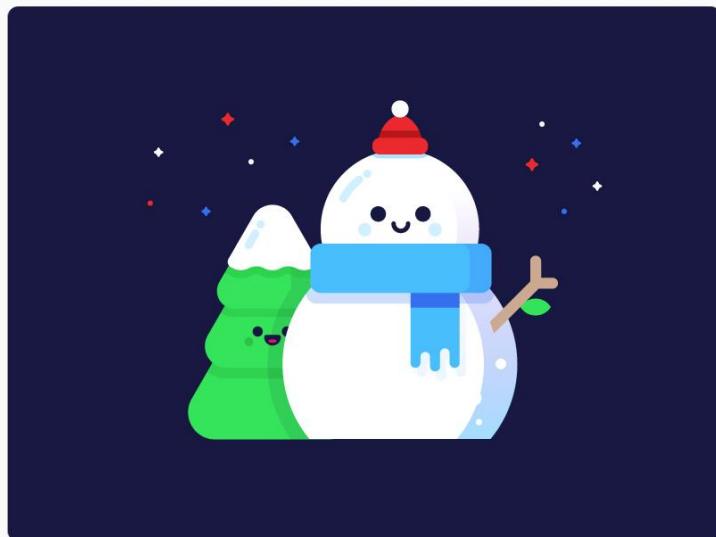
EXPORT [i](#)

HEX ▾

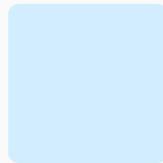
#67001f
#b2182b
#d6604d
#f4a582
#fd8d3c
#f7f7f7
#d1e5f0
#92c5de
#4393c3
#2166ac
#053061

<http://colorbrewer2.org>

Color Farm



Madebyelvis



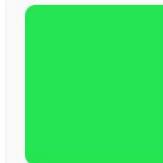
D1EDFF



38BBFF



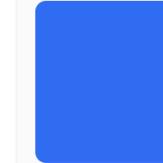
F22117



01E748



181544



2B67F5

Colorgorical

Colorgorical

Source

Generate

Number of colors: 8

Score importance: Perceptual Distance

Name Difference

Pair Preference

Name Uniqueness

Select hue filters: 90°, 180°, 270°

Drag wheel, or add angle: # to # +, -9° - 173°

Select lightness range: 25 to 85

Results: Color space, Hex, RGB, Lab, LCH, Array format, No quote, Charts, Clear all

Number of colors: 8

Score importance: Perceptual Distance

Name Difference

Pair Preference

Name Uniqueness

Select hue filters: 90°, 180°, 270°

Drag wheel, or add angle: # to # +, -9° - 173°

Select lightness range: 25 to 85

Instructions

To generate a palette with n colors, just enter the number of colors you want and click **Generate**. Bigger palettes will take longer than smaller palettes to make. Results will automatically appear when ready.

For greater detail, please consult our [paper](#) or the [source code](#).

Score Importance

Perceptual Distance

Increasing *Perceptual Distance* favors palette colors that are more easily discriminable to the human eye. To accurately model human color acuity, this is performed using [CIEDE2000](#) in CIE Lab color space.

Name Difference

Increasing *Name Difference* favors palette colors that share few common names. This is similar to perceptual distance, but can lead to different results in certain areas of color space. This happens when there are many different names for perceptually close colors (e.g., red and pink are perceptually close but named differently). Colorgorical calculates this using Heer and Stone's [Name](#)

About

Colorgorical was built by Connor Gramazio with advisement from David Laidlaw and Karen Schloss.

Documentation

If you'd like to read more about how Colorgorical works, please read our paper [here](#). If you're curious about the implementation, please see the Colorgorical GitHub repository located [here](#).

If you use Colorgorical, please use the following citation:

```
@article{gramazio-2017-ccd,
    author={Gramazio, Connor C. and Laidlaw, David H. and Schloss, Karen B.},
    journal={IEEE Transactions on Visualization and Computer Graphics},
    title={Colorgorical: creating discriminable and preferable color palettes for information visualization},
    year={2017}
}
```

<http://vrl.cs.brown.edu/color>

Gramazio C C et al., Creating discriminable and preferable color palettes for information visualization[J].
IEEE transactions on Visualization and Computer Graphics, 2017, 23(1): 521-530.

I want hue

I want hue

Tutorials

Examples

Theory

Experiment

Old version ▾

GitHub

Issues

+ Médialab Tools



i want hue

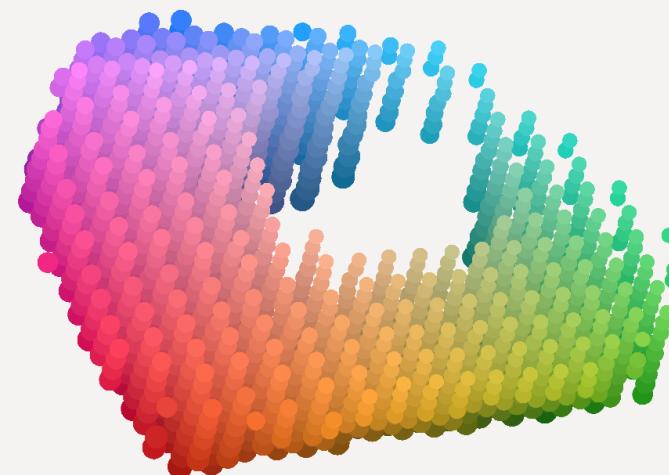
Color space

Default preset

H 0 ➤ 360
C 30 ➤ 80
L 35 ➤ 80

Improve for the colorblind (slow)

Dark background



Palette

5 colors soft (k-Means) ▾

↗ Make a palette



<http://tools.medialab.sciences-po.fr/iwanthue/>

Color Hunt

The screenshot shows the homepage of Color Hunt, a platform for color inspiration. The main area displays a 3x5 grid of color palettes, each consisting of five horizontal color swatches. Below each palette is a small card with a heart icon and a number (representing likes), and a timestamp indicating when the palette was created.

Row	Col 1	Col 2	Col 3	Col 4	Col 5
1	199 (5 days)	145 (6 days)	304 (1 week)	210 (1 week)	408 (1 week)
2	404 (1 week)	271 (1 week)	318 (1 week)	381 (1 week)	276 (2 weeks)
3	(empty)	(empty)	(empty)	(empty)	(empty)

On the right side of the page, there is a sidebar with the following content:

- Search Palettes** (with a search icon)
- Color Palettes for Designers and Artists**
- A brief description: "Color Hunt is a free and open platform for color inspiration with thousands of trendy hand-picked color palettes".
- A button to "Get our Chrome extension for color inspiration with every new tab".
- A "Add to Chrome" button with a Google icon.
- A note: "Made with ❤ by Gal Shir".

<https://colorhunt.co/>

Ambiance

Paint Flowers Only

by Halifax

#EED89C

#DEA286

#BD5749

#2C1211

#ED4731

rgb(238,216,156)
hsl(44,71%,77%)

rgb(222,162,134)
hsl(19,57%,70%)

rgb(189,87,73)
hsl(7,47%,51%)

rgb(44,18,17)
hsl(2,44%,12%)

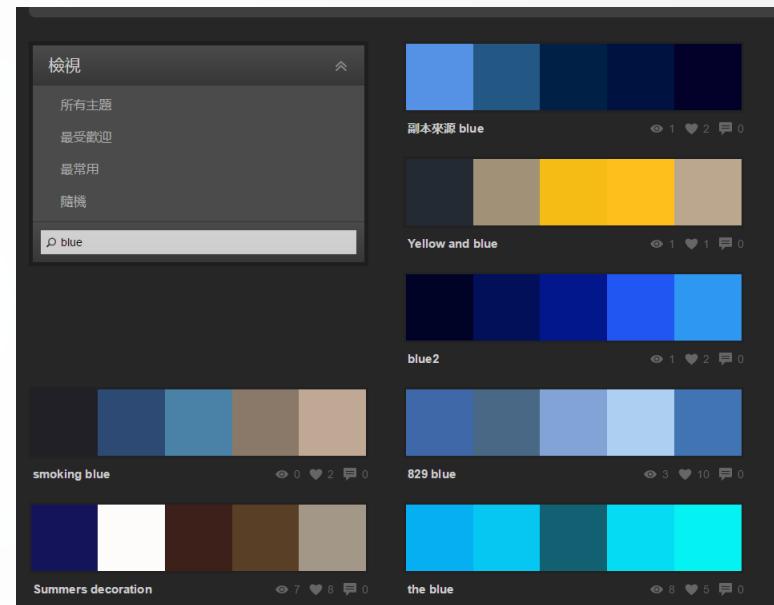
rgb(237,71,49)
hsl(7,84%,56%)



ambiance.

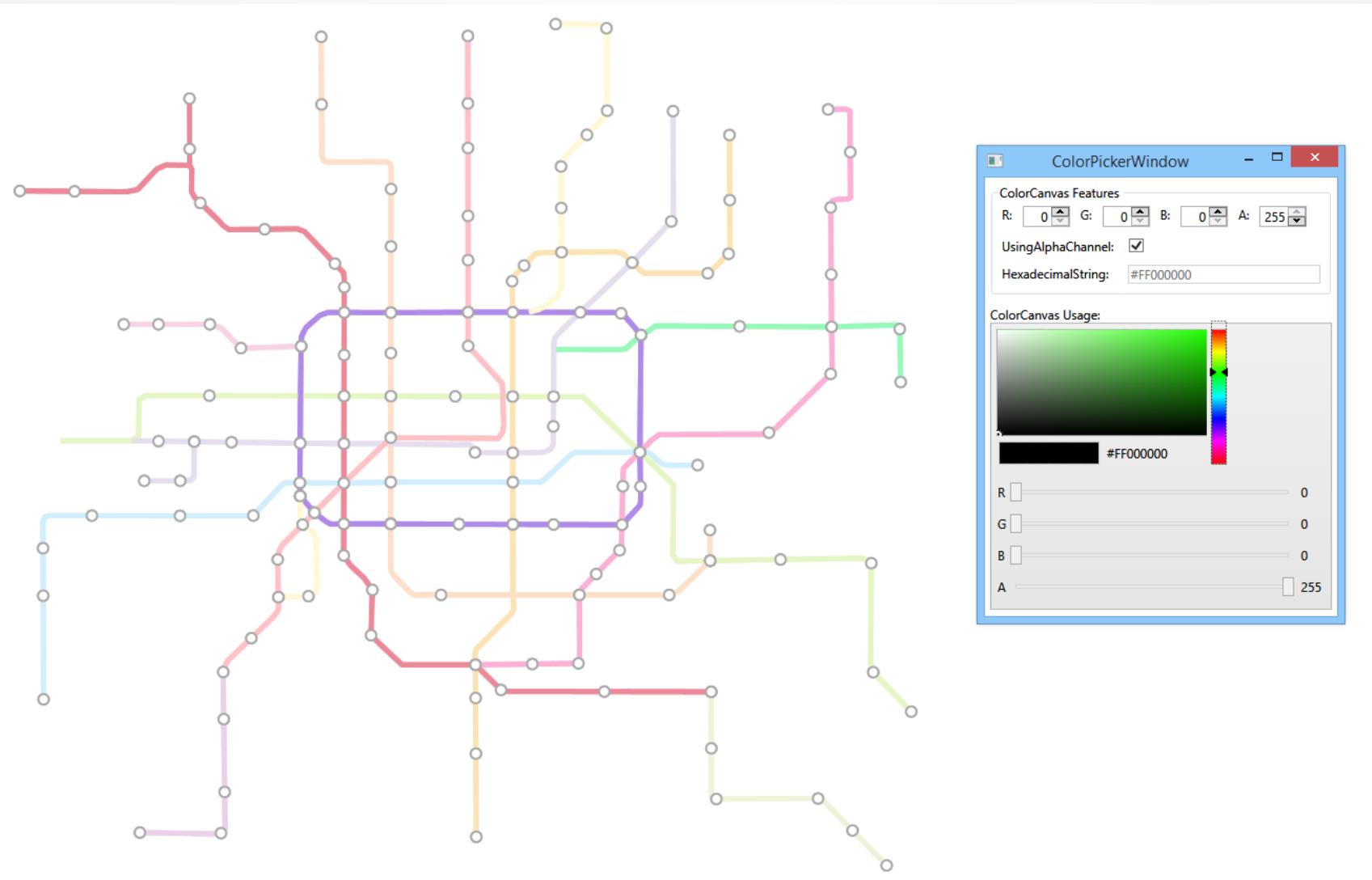


Color Wheel



<https://color.adobe.com/zh/create/color-wheel>

Build Tools Ourselves 😊



Classic and Going topic

InfoVis: Perception & Cognition 1

Session Chair: Danielle Szafrir

Mapping Color to Meaning in Colormap Data Visualizations (J)

Authors: Karen B. Schloss, Connor C. Gramazio, Allison T. Silverman, Madeline L. Parker, Audrey S. Wang

[Video Preview](#)

Optimizing Color Assignment for Perception of Class Separability in Multiclass Scatterplots (J)

Authors: Yunhai Wang, Xin Chen, Tong Ge, Chen Bao, Michael Sedlmair, Chi-Wing Fu, Oliver Deussen, Baoquan Chen

[Video Preview](#)

Looks Good To Me: Visualizations As Sanity Checks (J)

Authors: Michael Correll, Mingwei Li, Gordon L Kindlmann, Carlos Scheidegger

[Video Preview](#)

Is There a Robust Technique for Selecting Aspect Ratios in Line Charts? (T)

Authors: Yunhai Wang, Zeyu Wang, Lifeng Zhu, Jian Zhang, Chi-Wing Fu, Changhe Tu, Baoquan Chen, Zhanglin Cheng

[Video Preview](#)

Image-based Aspect Ratio Selection (J)

Authors: Yunhai Wang, Zeyu Wang, Chi-Wing Fu, Hansjörg Schmauder, Oliver Deussen, Daniel Weiskopf

[Video Preview](#)

InfoVis: Perception & Cognition 2

Session Chair: Karen Schloss

Mitigating the Attraction Effect with Visualizations (J)

Authors: Evangelia Dimara, Gilles Bailly, Anastasia Bezerianos, Steven Vidotto

[Video Preview](#)

Face to Face: Evaluating Visual Comparison (J)

Authors: Brian David Ondov, Nicole Jardine, Niklas Elmquist, Steven Vidotto

[Video Preview](#)

Task-Based Effectiveness of Basic Visualizations (T)

Authors: Bahador Saket, Alex Endert, Çagatay Demiralp

[Video Preview](#)

At a Glance: Approximate Entropy as a Measure of Line Chart Visualization Complexity (J)

Authors: Eugene Wu, Remco Chang, Abigail Mosca, Gabriel Ryan

[Video Preview](#)

Correlation Judgment and Visualization Features: A Comparative Study (T)

Authors: Fumeng Yang, Lane Harrison, Ronald A. Rensink, Steven Franks, Remco Chang

[Video Preview](#)

Classic and Going topic

SP #1: Design and evaluation (Room Porto)

Chair: Alexander Lex

= Label Placement for Outliers in Scatterplots

Haris Mumtaz, Mereke van Garderen, Fabian Beck, Daniel Weiskopf

= The Impact of Distribution and Chart Type on Part-to-Whole Comparisons

Robert Kosara

= Circular Part-to-Whole Charts Using the Area Visual Cue

Robert Kosara

= The Human User in Progressive Visual Analytics

Luana Micallef, Hans-Jörg Schulz, Marco Angelini, Michaël Aupetit, Remco Chang, Jörn Kohlhammer, Adam Perer

= Visualizing Transportation Flows with Mode Split using Glyphs

Ignacio Pérez-Messina, Eduardo Graells-Garrido

= Color Names Across Languages: Salient Colors and Term Translation in Multilingual

Color Naming Models

Younghoon Kim, Kyle Thayer, Gabriella Gorsky, Jeffrey Heer

Thanks