上海科技大学
ShanghaiTech University

ARTS1422 Data Visualization

Lecture 3

Perception and Cognition

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Spring 2024
2024. 03.05

Stuart Card

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

What is Visual ?

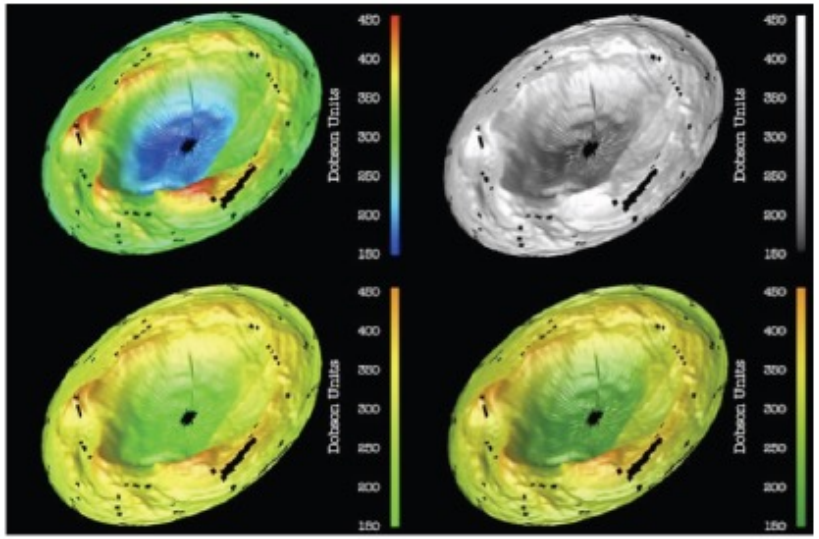
01 Perception:

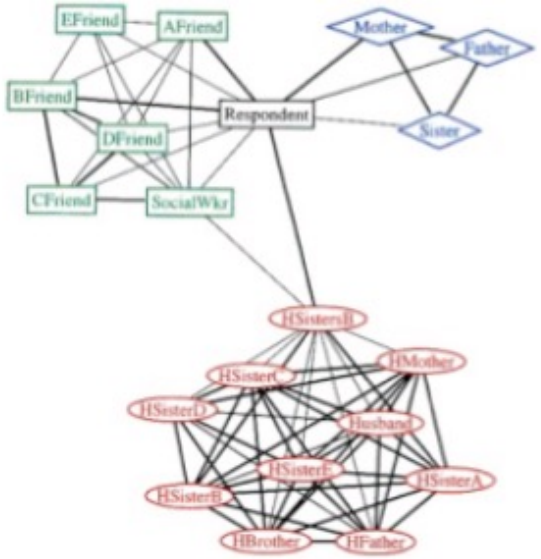
about the nature of the signals coming in; what you see

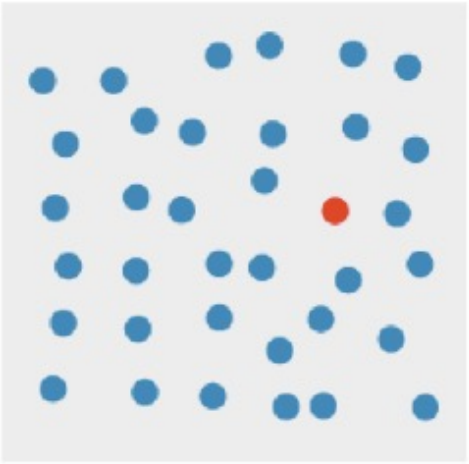
02 Cognition:

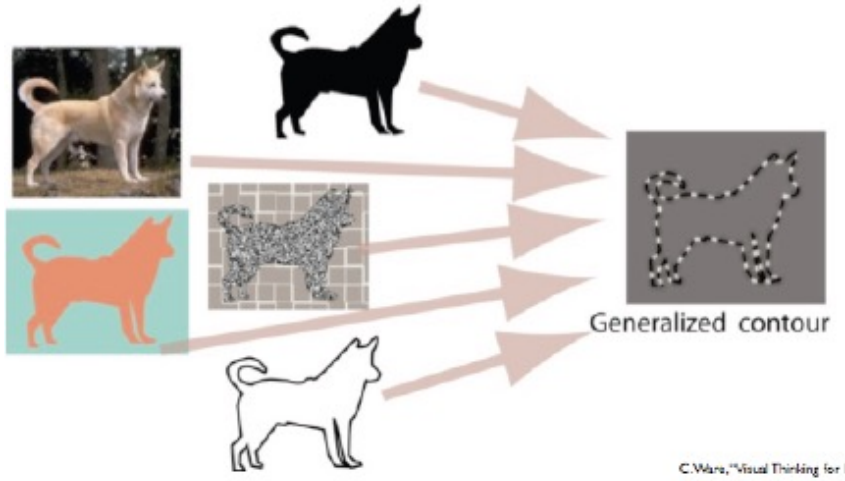
about how you understand and interpret what you see

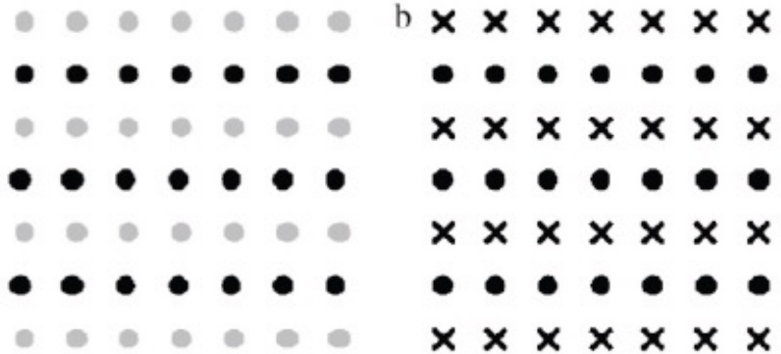
What is Visual Perception?

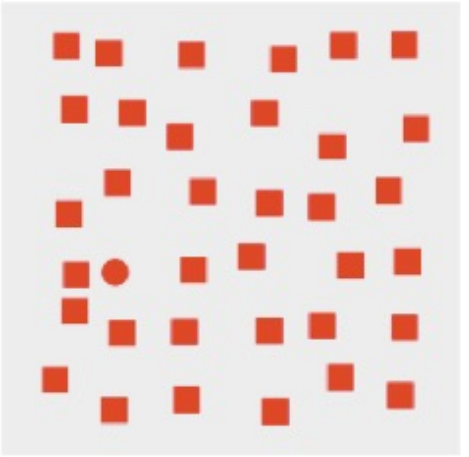












Visual Perception

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, and making decisions.

OUTLINE

1. Visual Perception
2. Cognition
3. Shape
4. Color
5. Toolkits

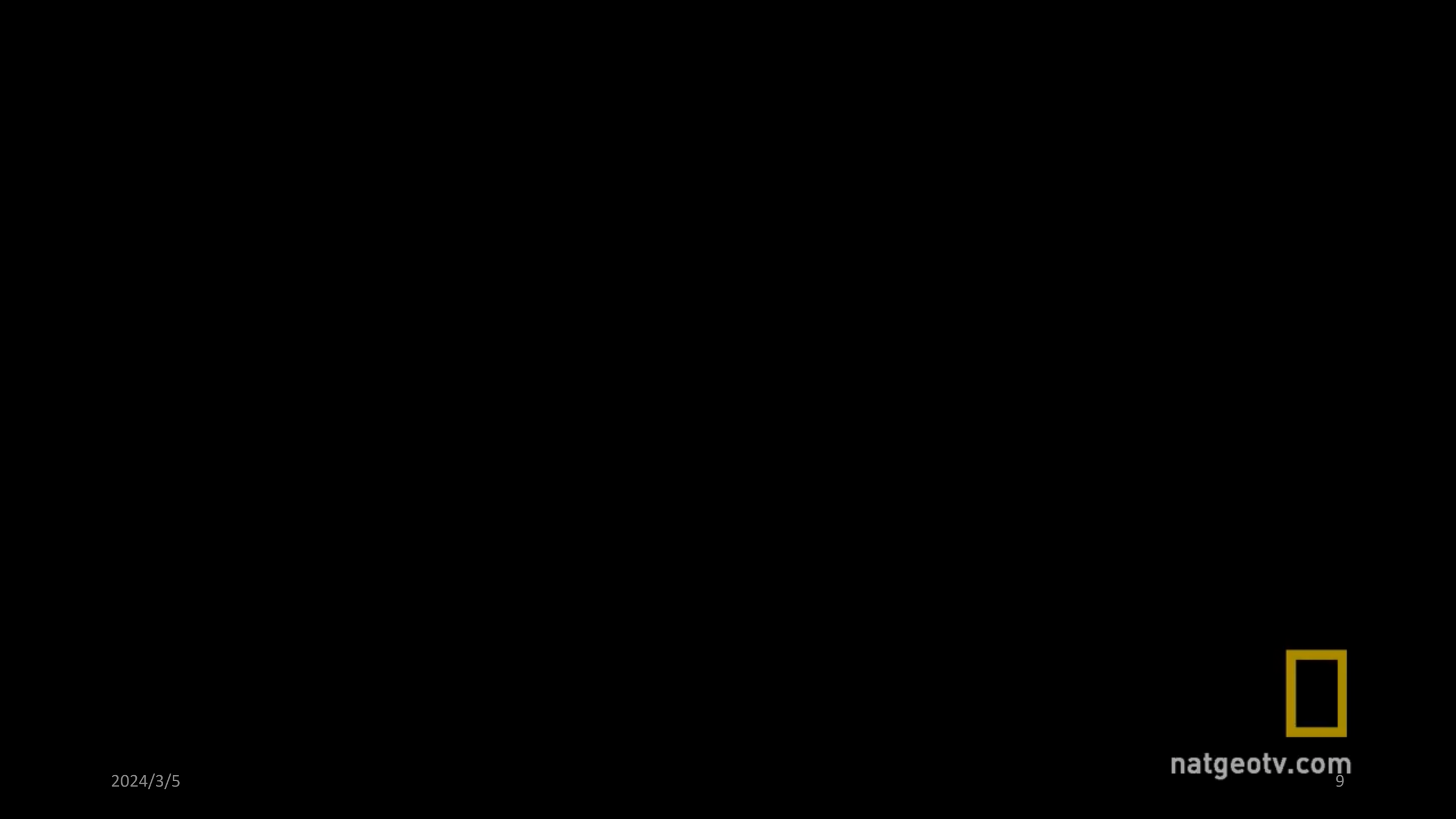
Task1

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

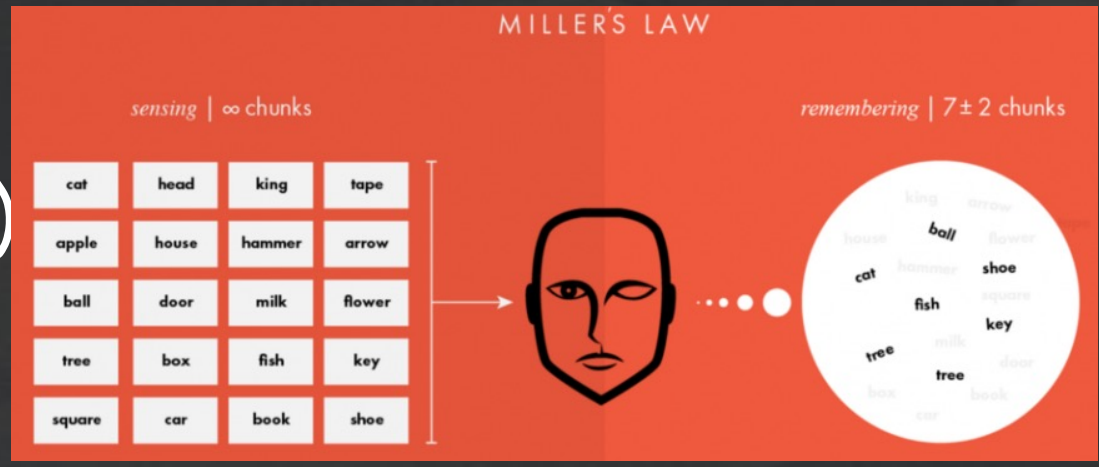
03 Count the total number of times people wearing white are passing the ball

04 Do not count passes by the players in black



Memory

- Working memory (short term)
  - small capacity (7 ± 2 "chunks")
    - 6174591765 vs. (617) 459-1765
    - NBCIBMGMC vs. NBC IBM GMC
  - rapid access (~70ms) & decay (~200 ms)
    - pass to LTM after a few seconds of continued storage



- Long-term memory
  - huge (if not "unlimited")
  - slower access time (~100 ms) w/ little decay

Simple Experiment

- Volunteer
- Start saying ***colors*** you see in list of words
  - when slide comes up
  - as fast as you can
- Say "done" when finished
- Everyone else time it…

Paper

Home

Back

Schedule

Page

Change

Simple Experiment

- Do it again
- Say “done” when finished

Bandana

Forward

Home

Test

Basket

Paper

Simple Experiment

- Do it again
- Say “done” when finished

Yellow

White

Black

Blue

Red

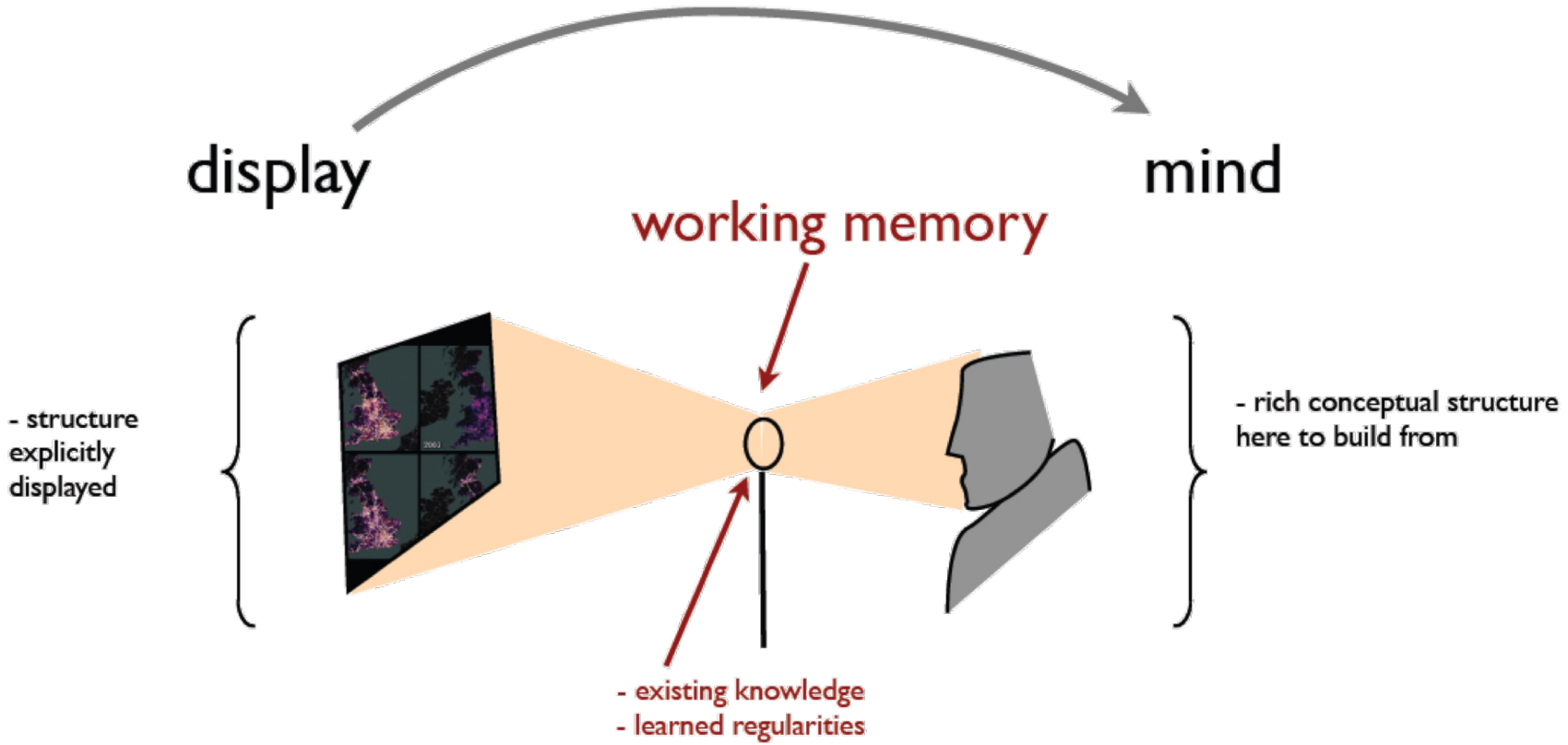
Green

Memory

- Interference
  - two strong cues in working memory
  - link to different chunks in long term memory

- Why learn about memory?
  - know what's behind many HCI techniques
  - helps you understand what users will "get"
  - aging population of users

Take home picture



active concepts in working memory can be synthesized

Fact

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

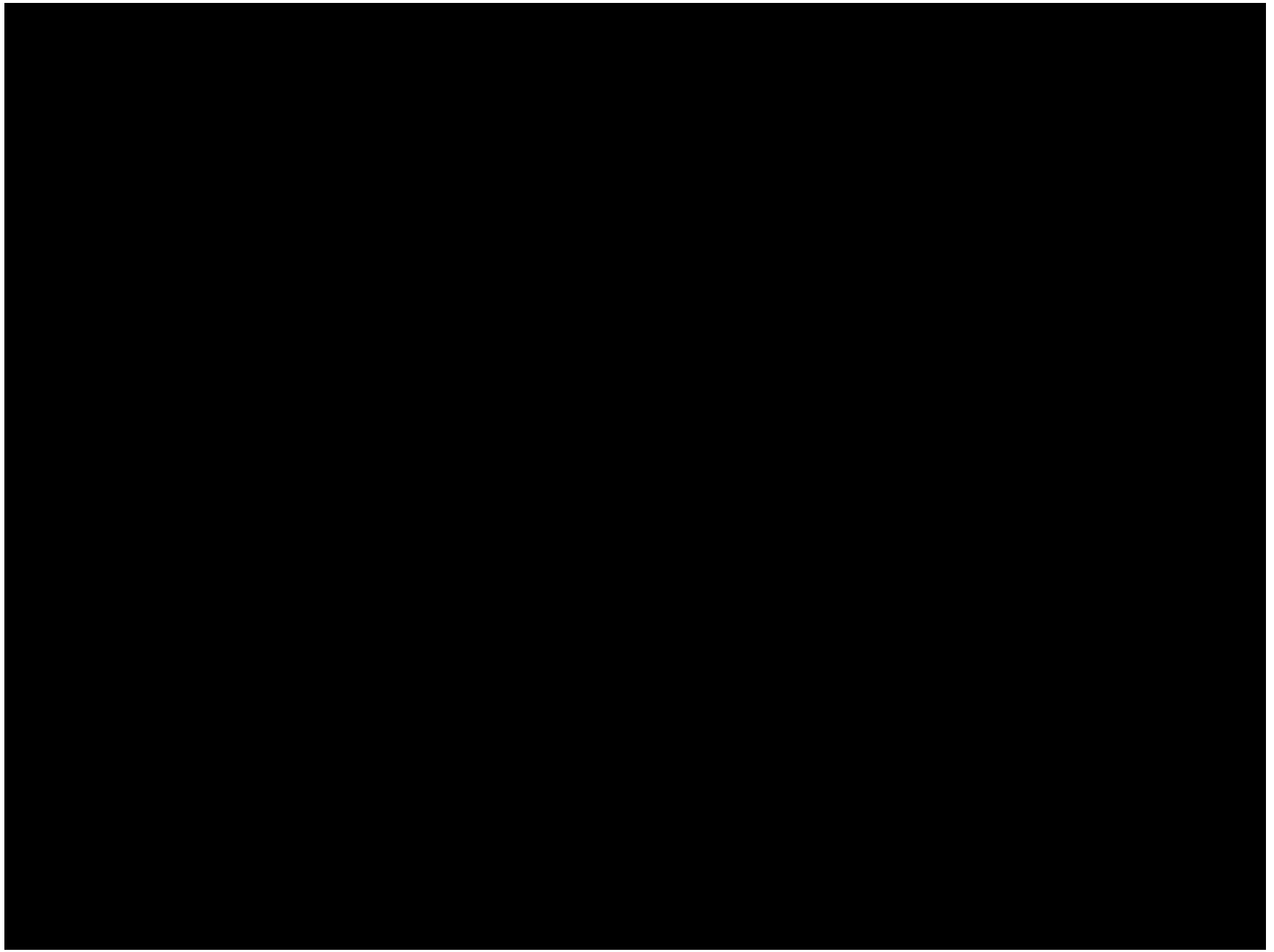
Visualization must serve as an external aid to augment working memory

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



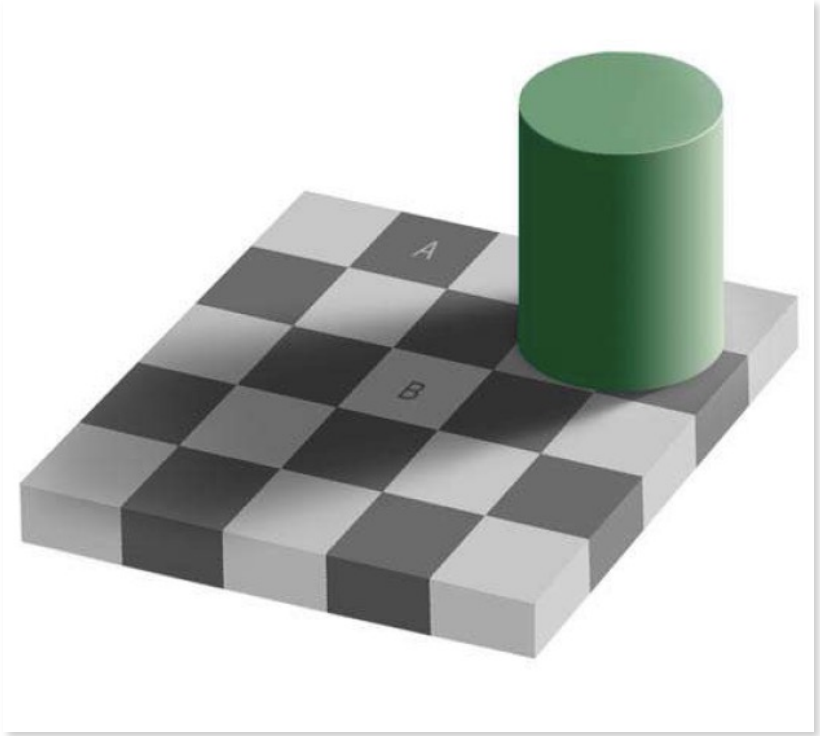
Fact

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

Make changes visible in visualizations to reduce the cognitive load

Relativity & Absoluteness

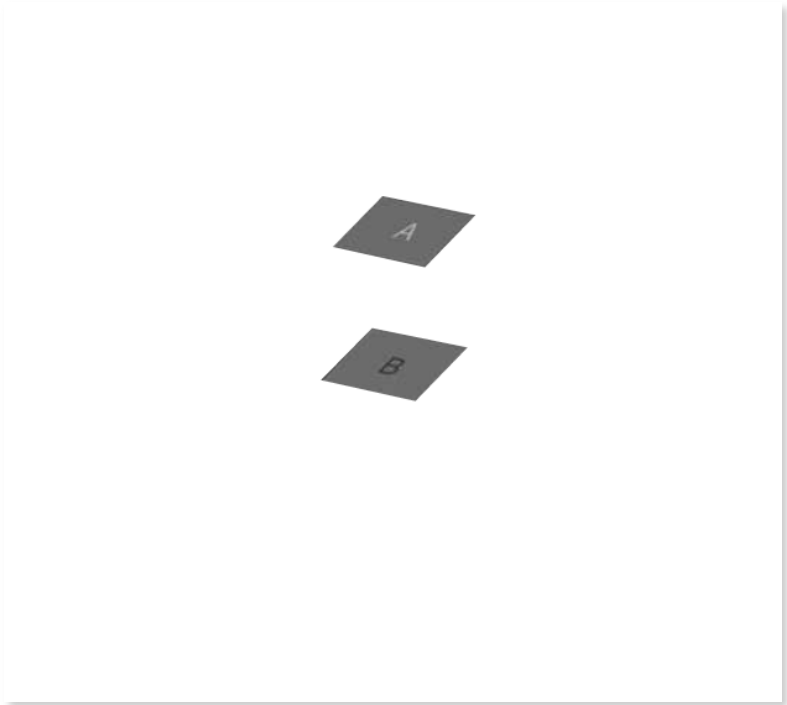
The perceptual system is based on relative judgment rather than absolute judgment (Weber's Law)



Which is brighter, An or B?

Relativity & Absoluteness

The perceptual system is based on relative judgment rather than absolute judgment (Weber's Law)



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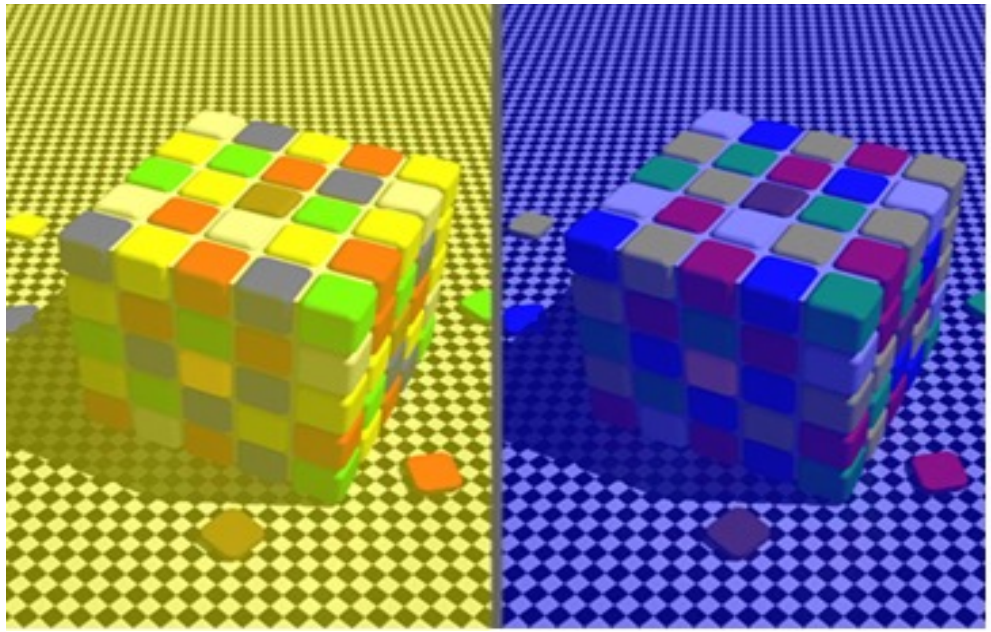

Color?

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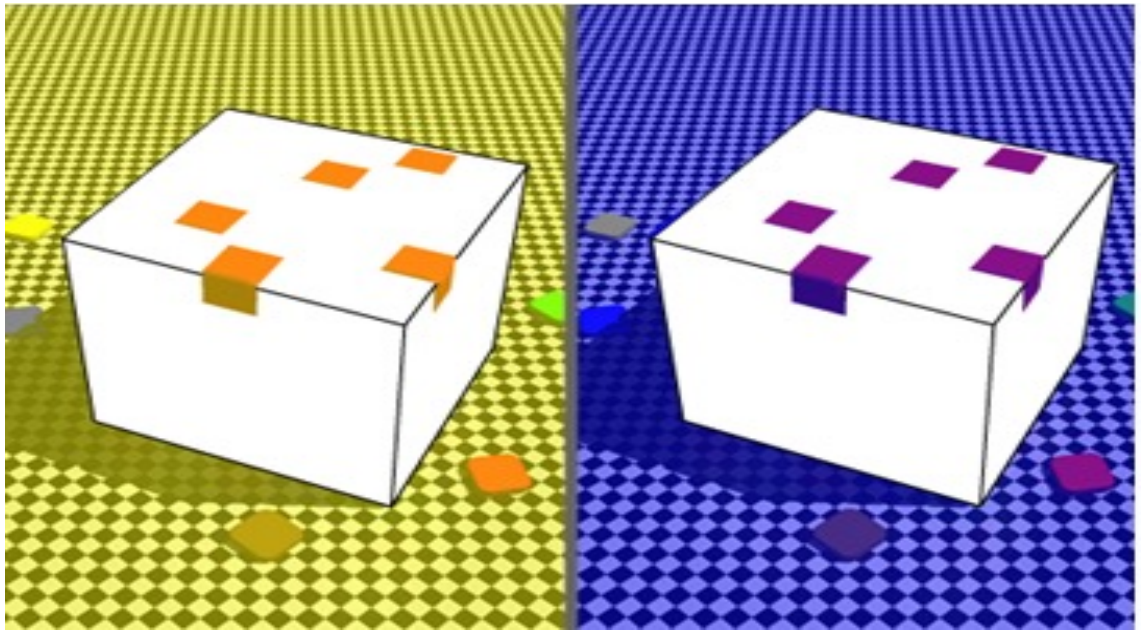
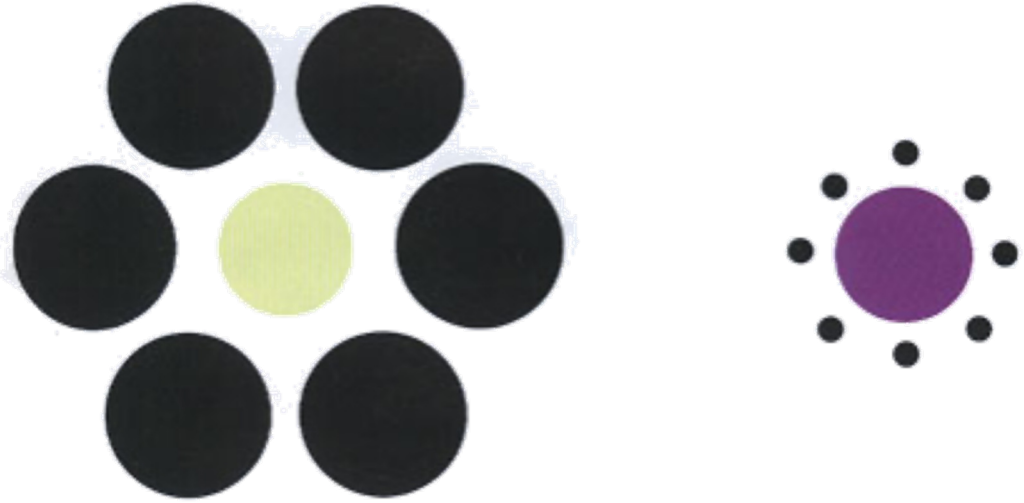


Color?

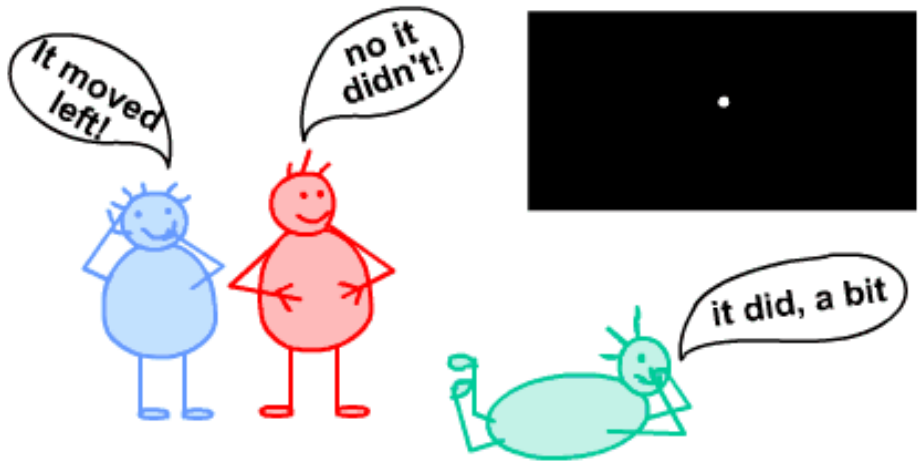
Perceived Shape

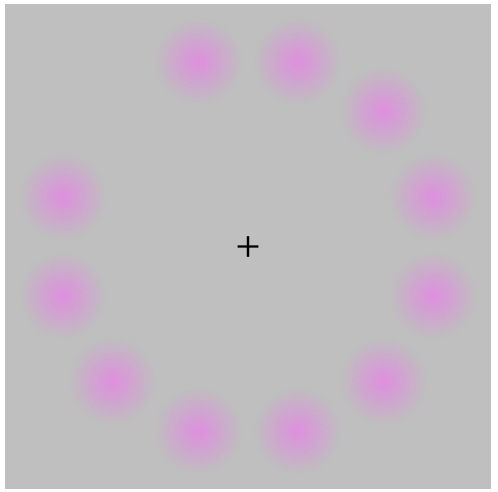
Are the two circles in the center of the same sizes?



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

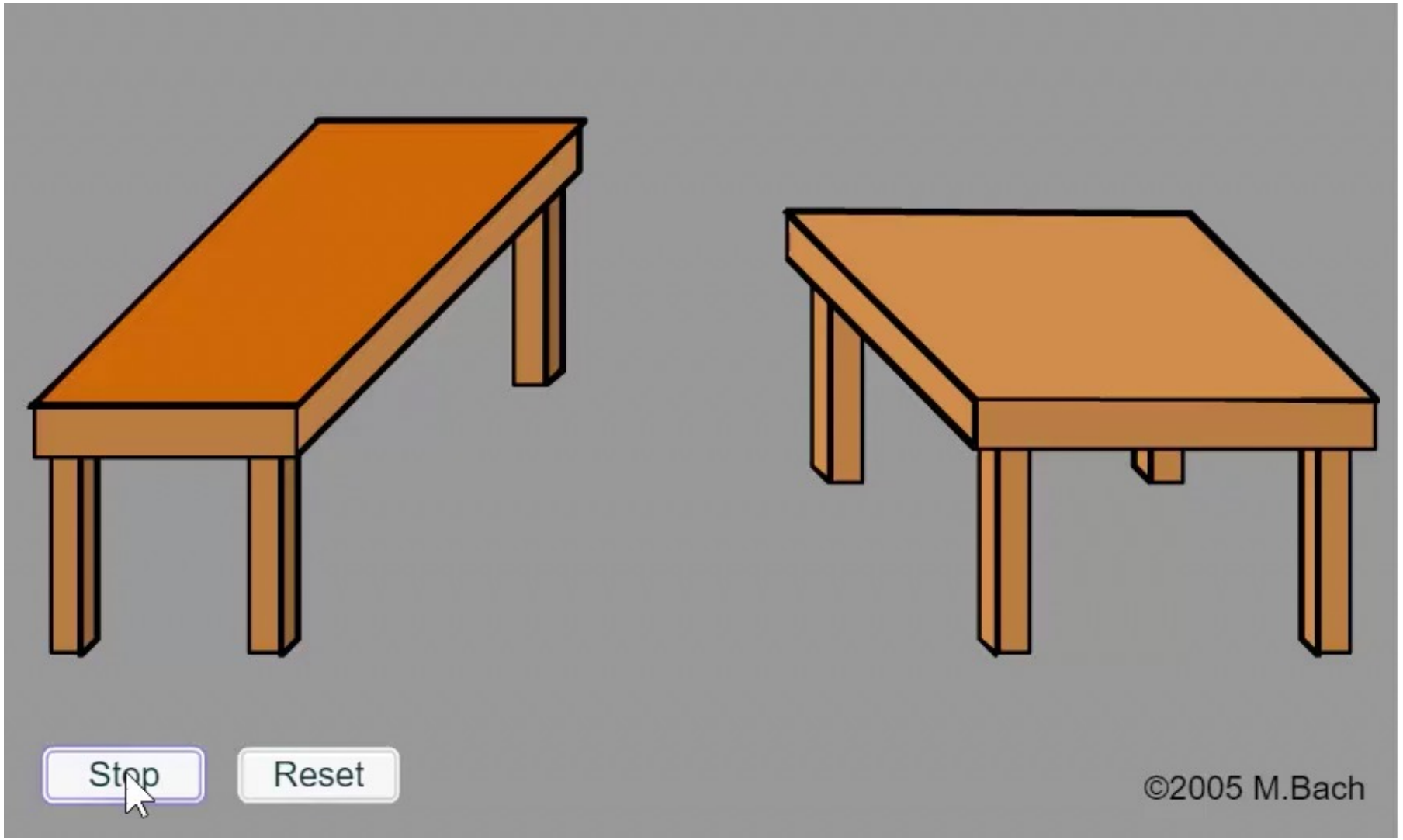
Our visual system sees differences, not absolute values, and is attracted to edges.

Use high contrast between objects that should be distinguishable

Seeing is Not Believing

Impossible Box

Shepard's Rotated Table



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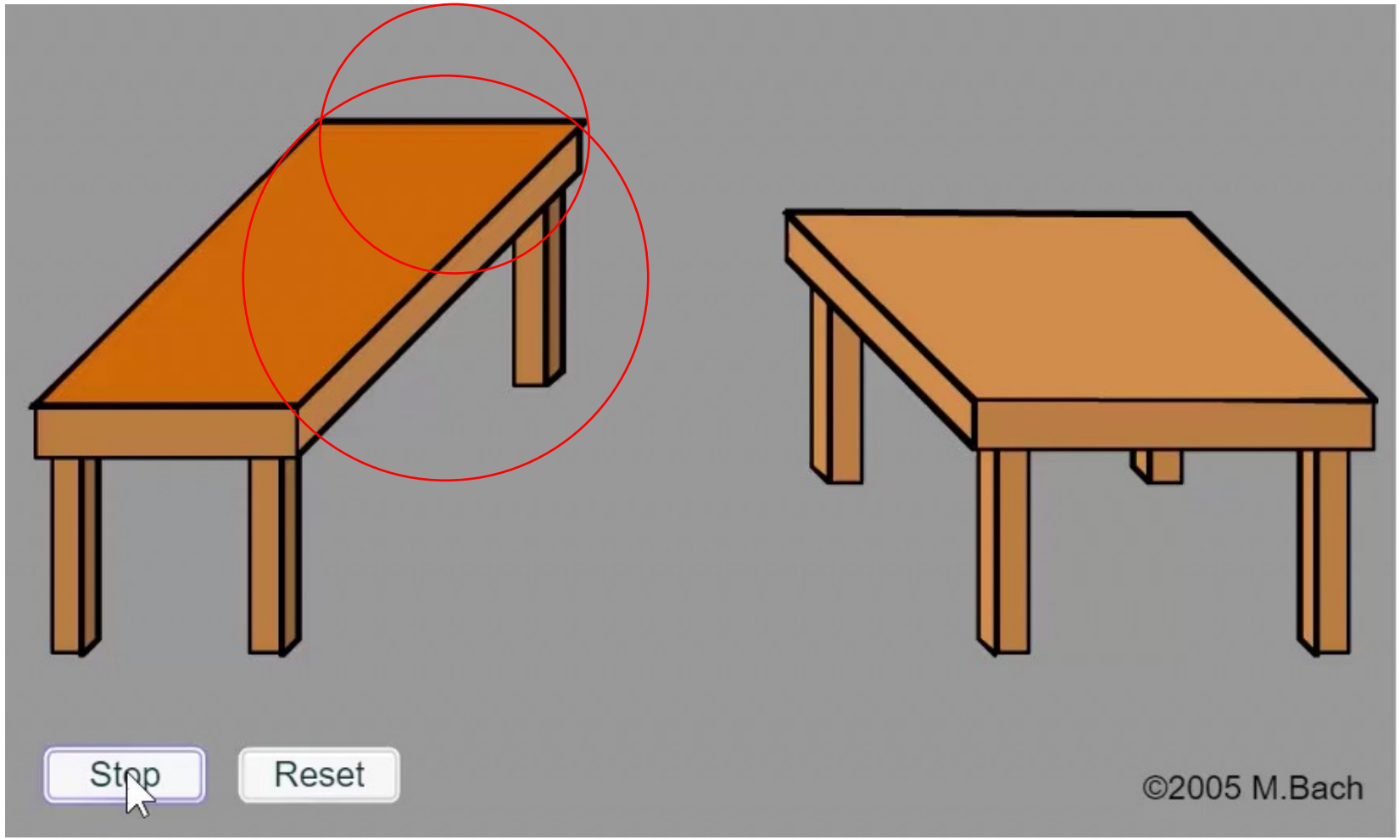
Shepard's Rotated Table



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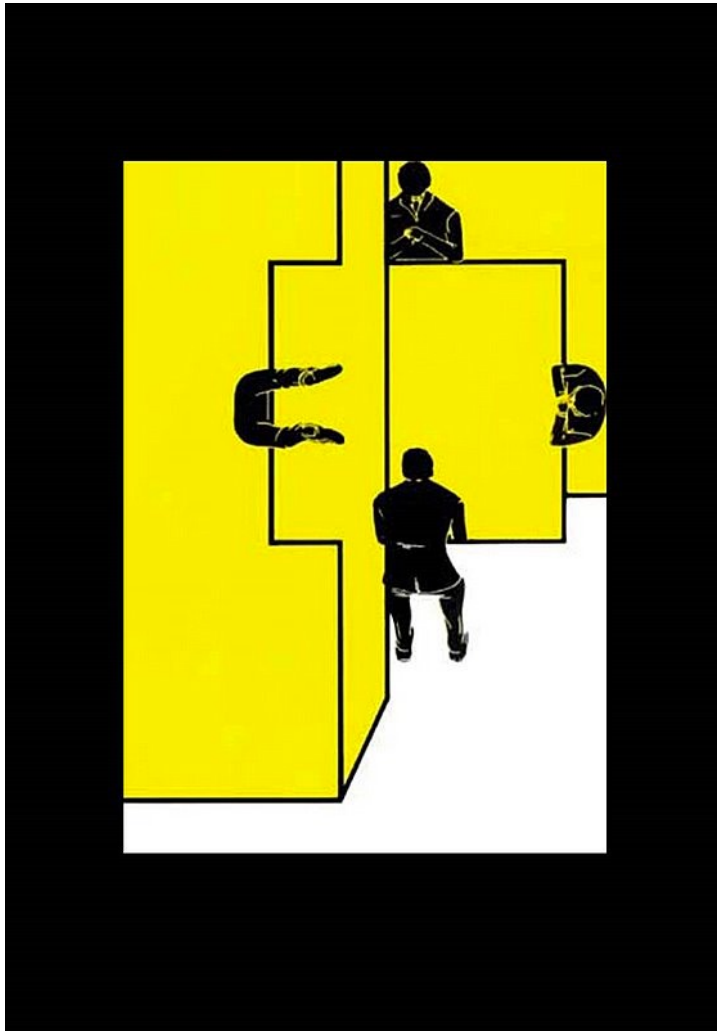
Shigeo Fukuda



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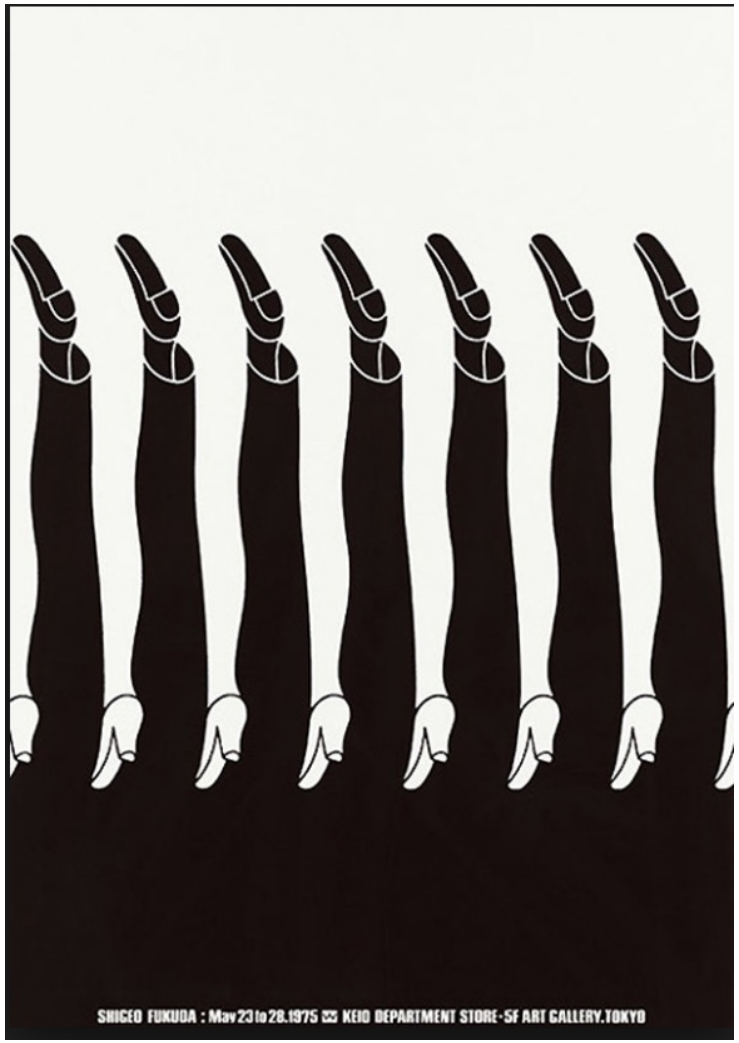
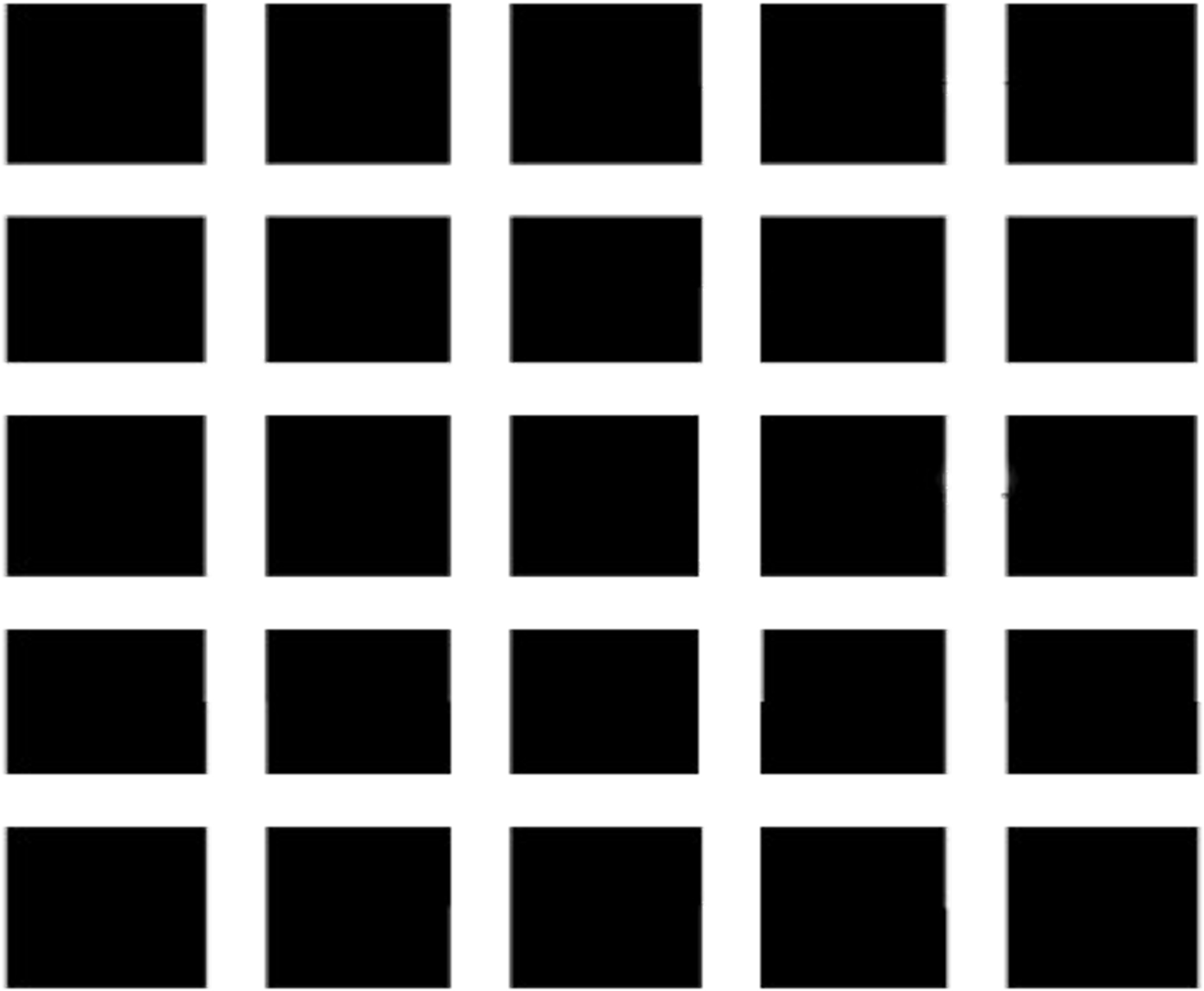
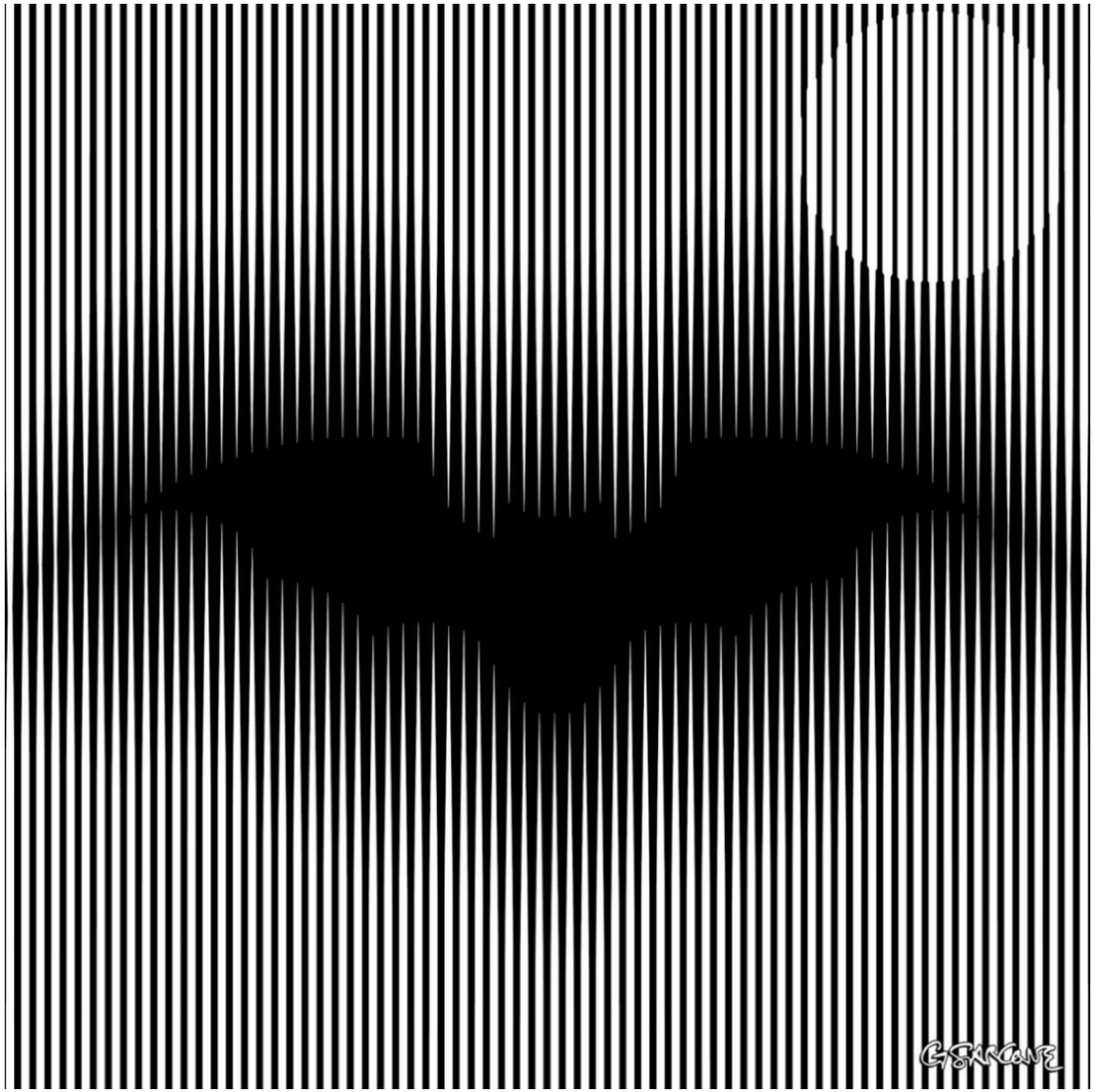
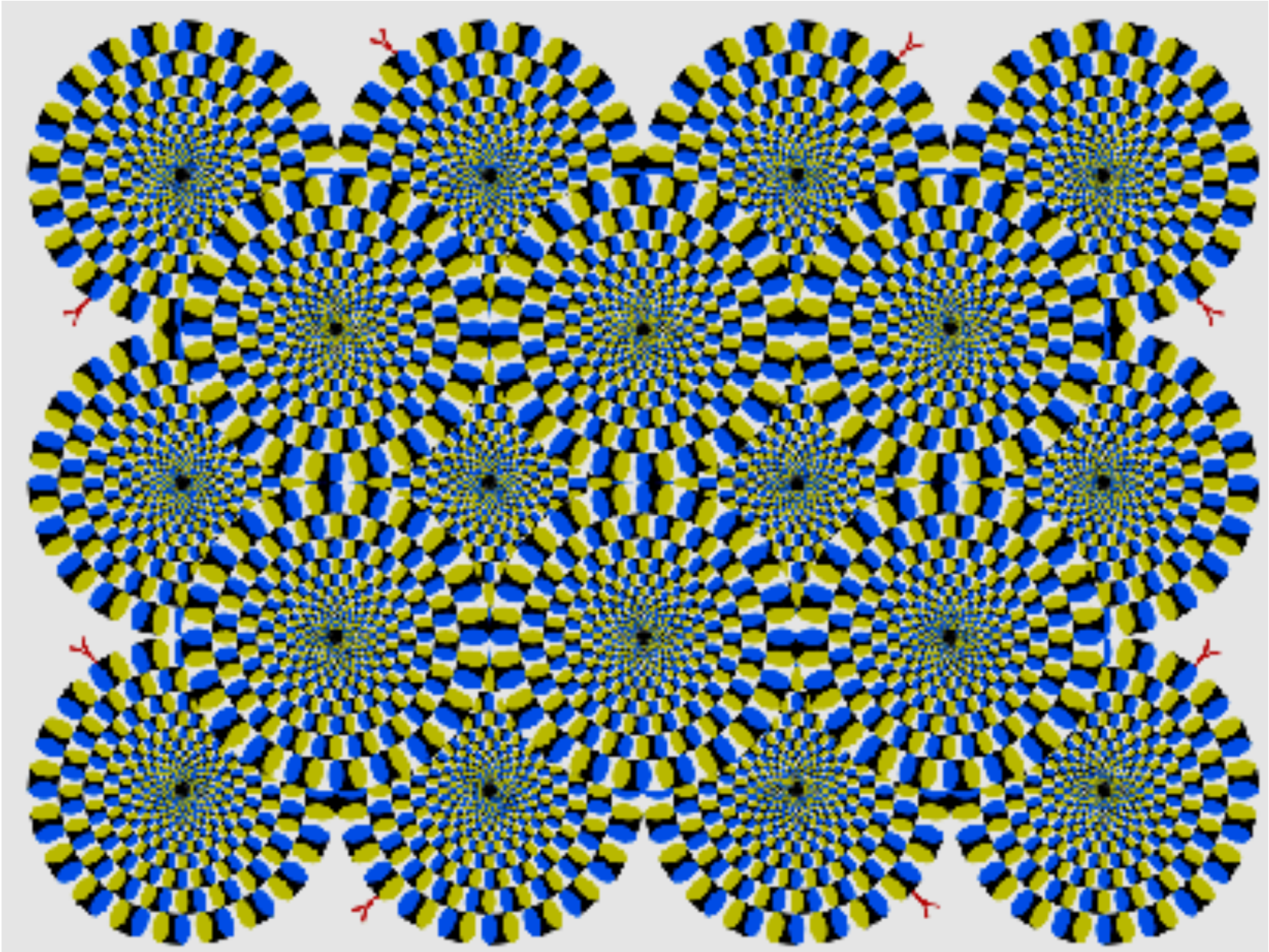


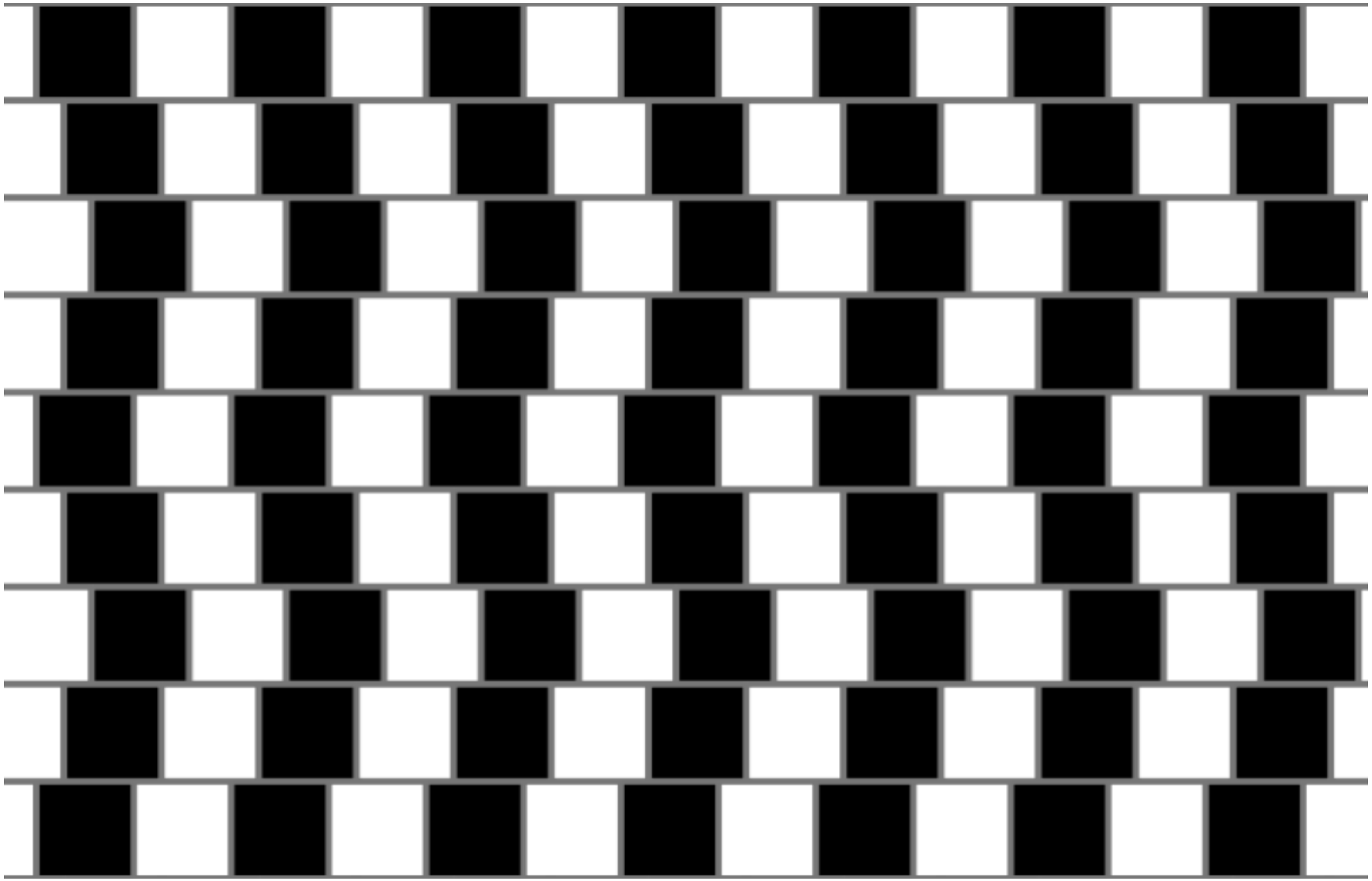
Impossible Chess



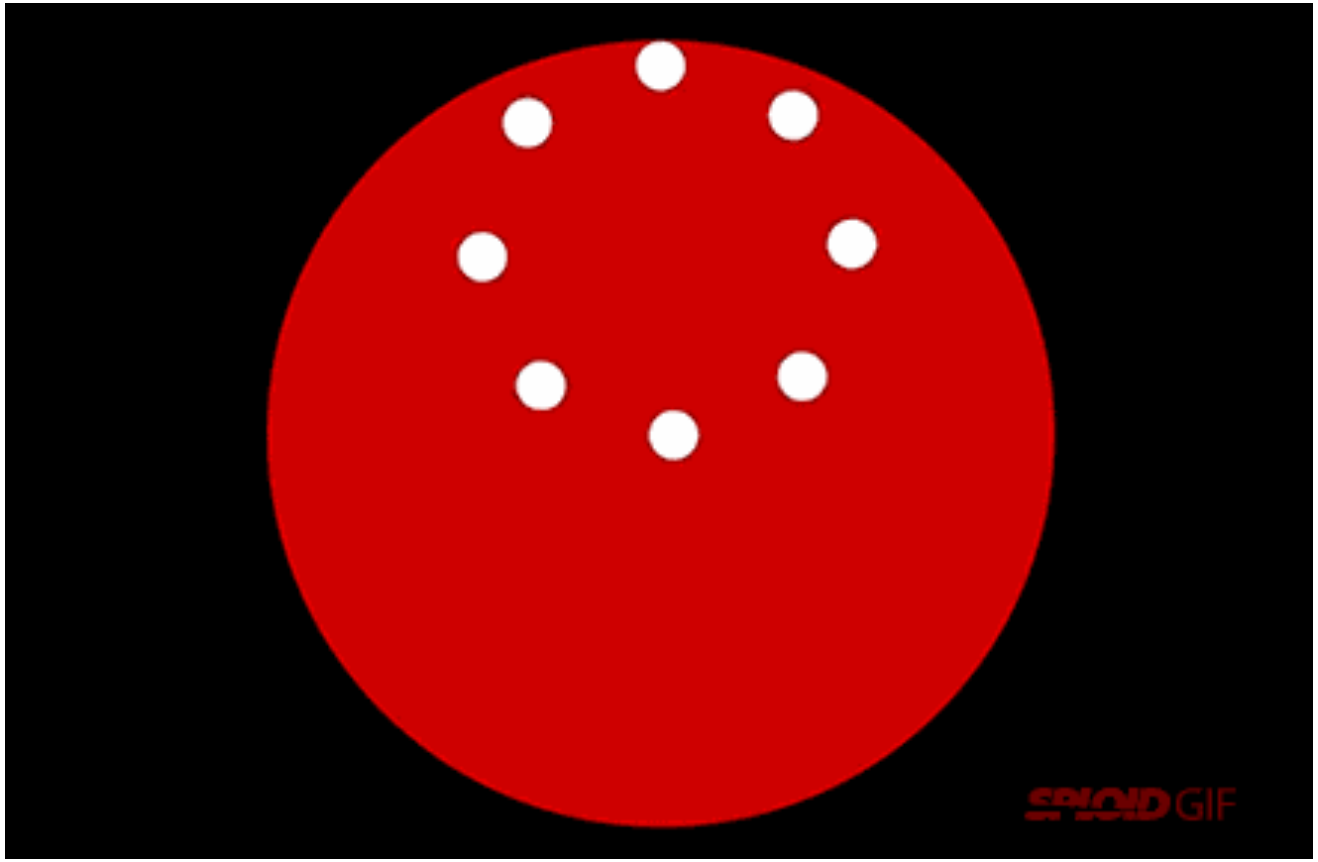
Flying Black Bat







Illusion



OUTLINE

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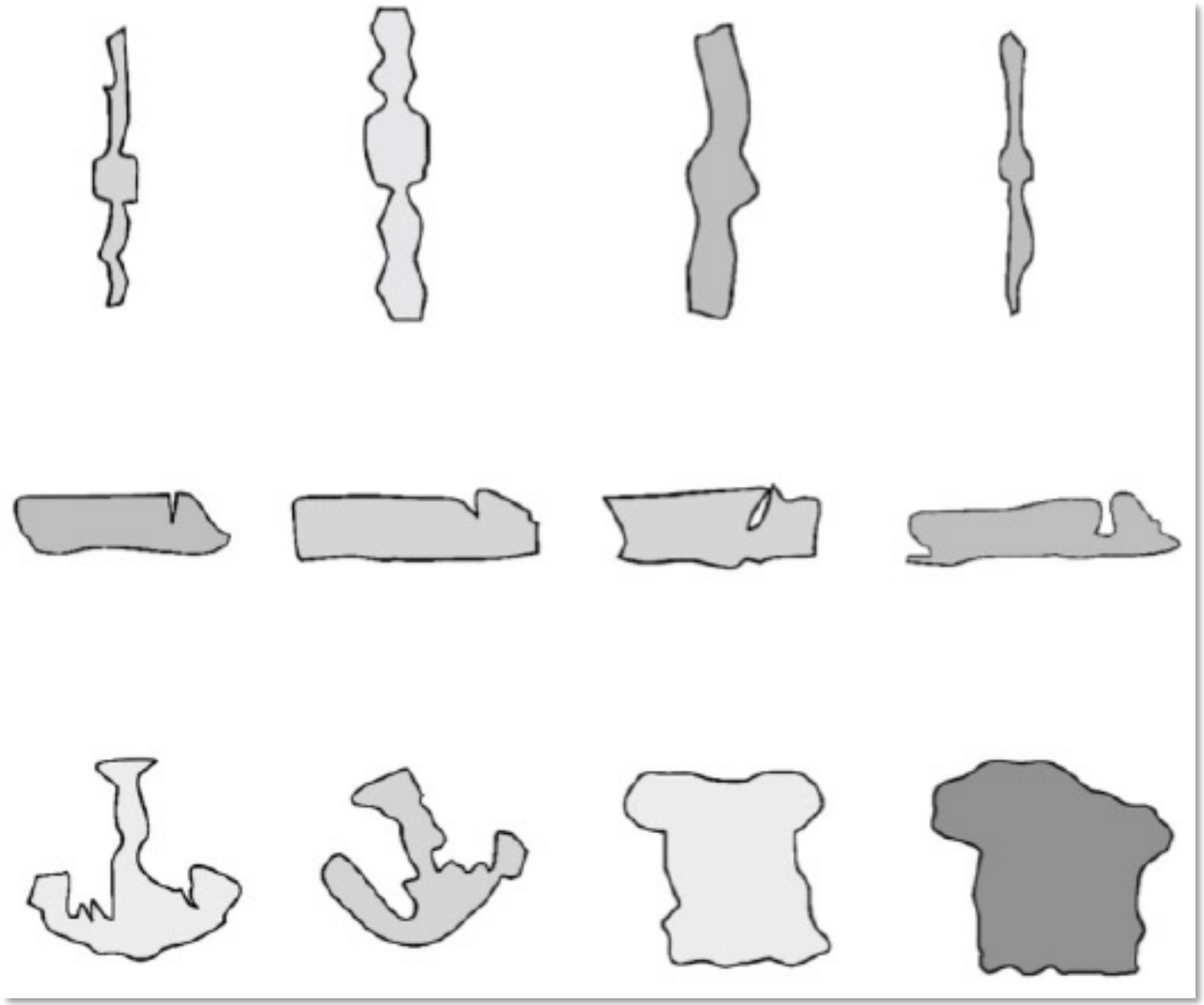
There's more to seeing than just what's there

conceptual interpretation affects memory



conceptual interpretation affects memory

we rely on priors

OUTLINE

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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)

Gestalt Theory

I.I Heuristics: Mental Shortcuts

- Gestalt Theory
  - Figure and Ground
  - Closure
  - Similarity
  - Continuity
  - Proximity

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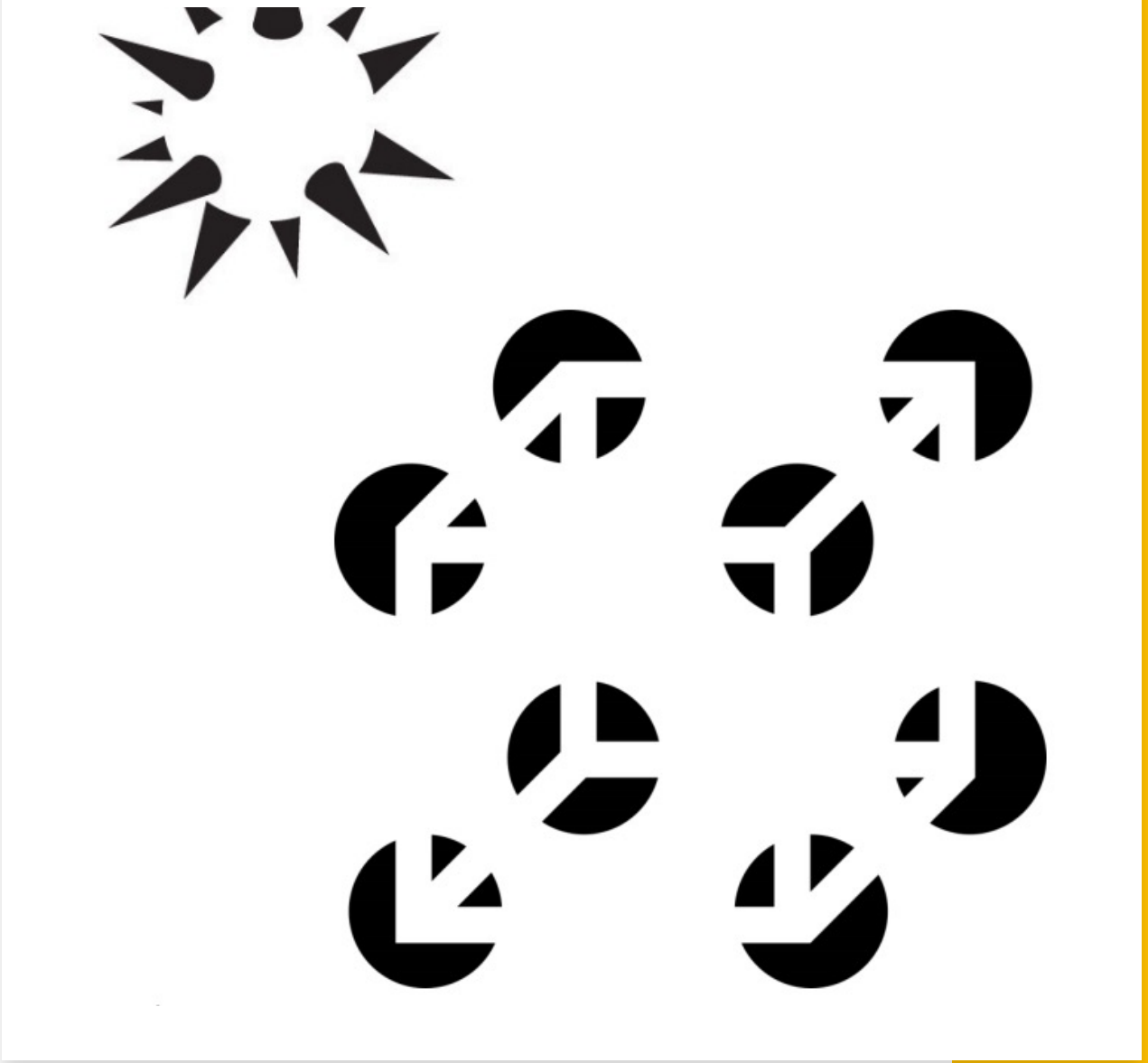

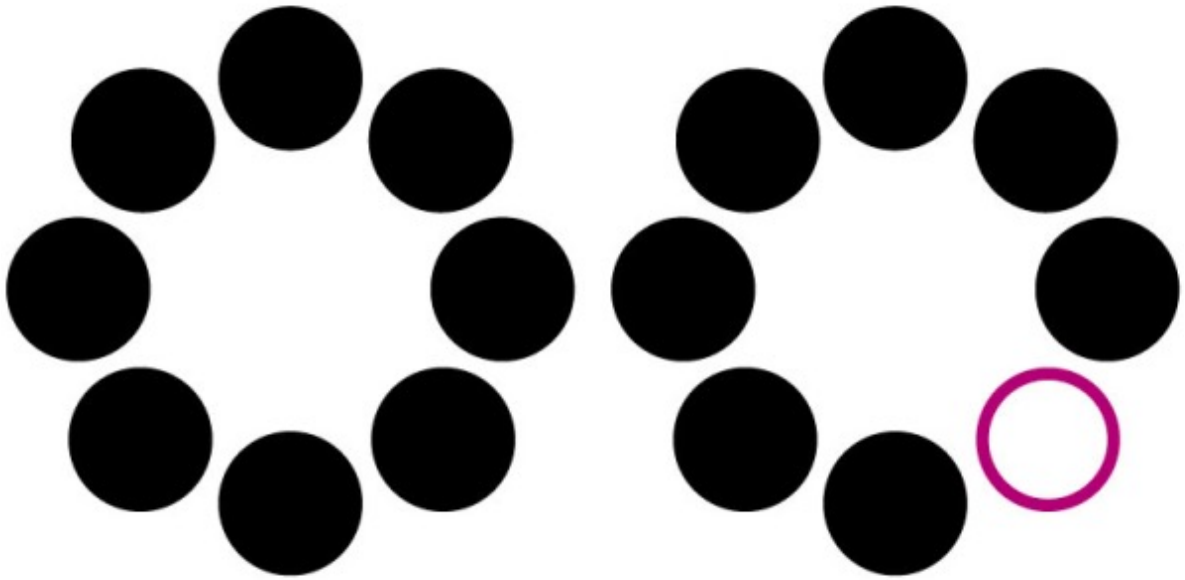

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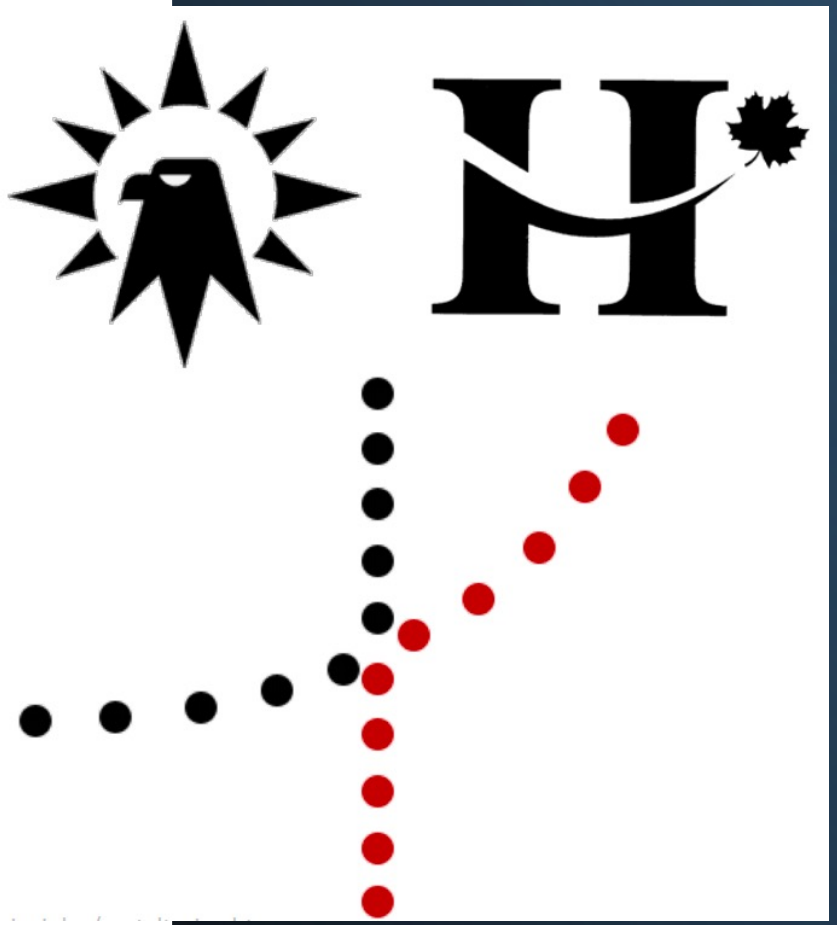

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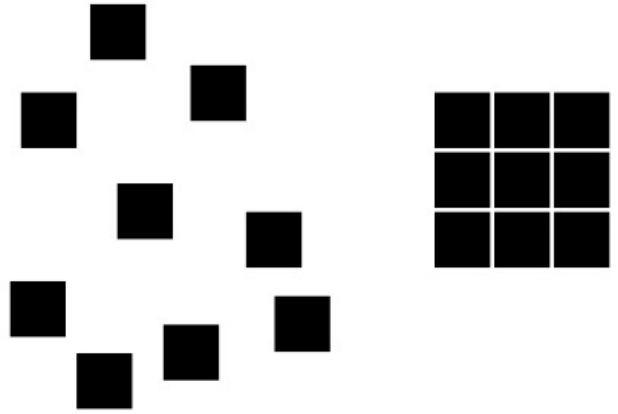

OUTLINE

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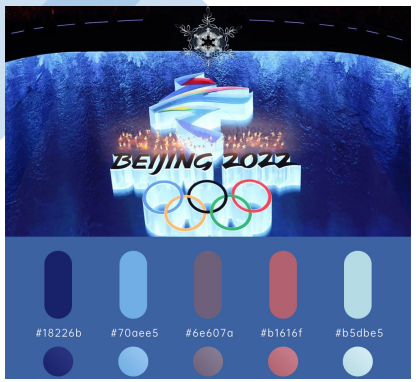
Why Study Color?

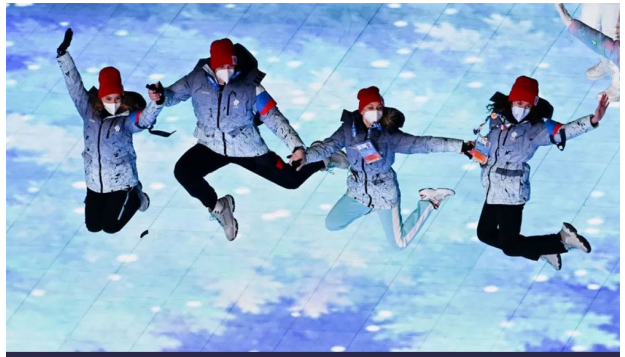
Color can be a powerful tool to improve user interfaces by communicating key information

Inappropriate use of color can severely reduce the performance of systems we build

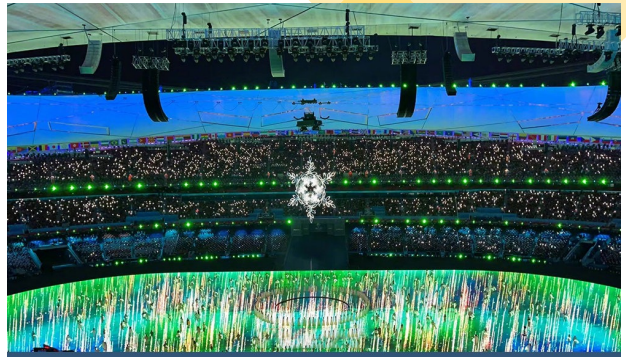


#18226b #70aee5 #6e607a #b1616f #b5dbe5

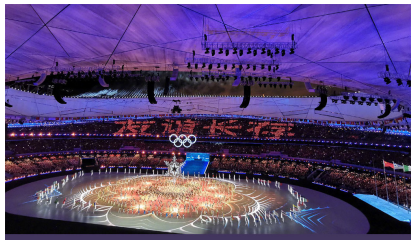
#182a74 #2c66cb #6068b1 #dea85d #a4648c



#aed6ec #a33839 #6e9be0 #555bdf #6db2d1

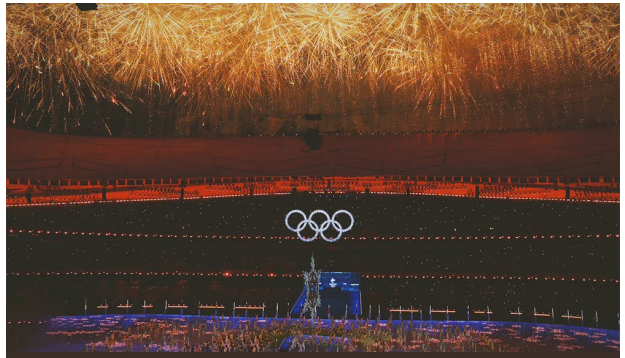


#142726 #568d74 #2380dd #cfdec4 #979783

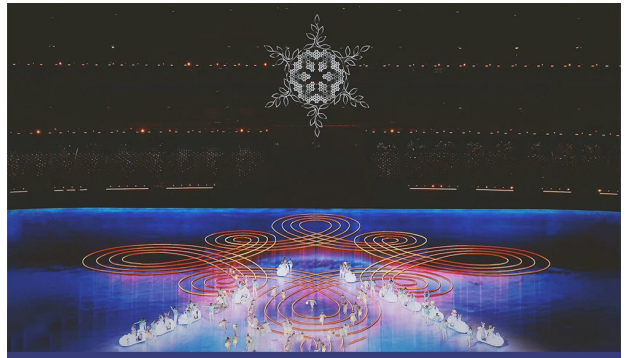


#6648c5 #cfaa96 #815b5d #85a4b7 #4d2c38

#307aed #7ebefa #05248f #6ca1f1 #e2a097



#653b2b #c08a4a #4d456c #b6371f #3653b4



#34364a #424473 #b6bec8 #76443d #ae7073

#484572 #6467b2 #bdbed6 #7ea0d4 #d7a5d2


22
春分
Spring Equinox


24
雨水
Rain Water


16
夏至
Summer
Solstice


12
处暑
End of Heat

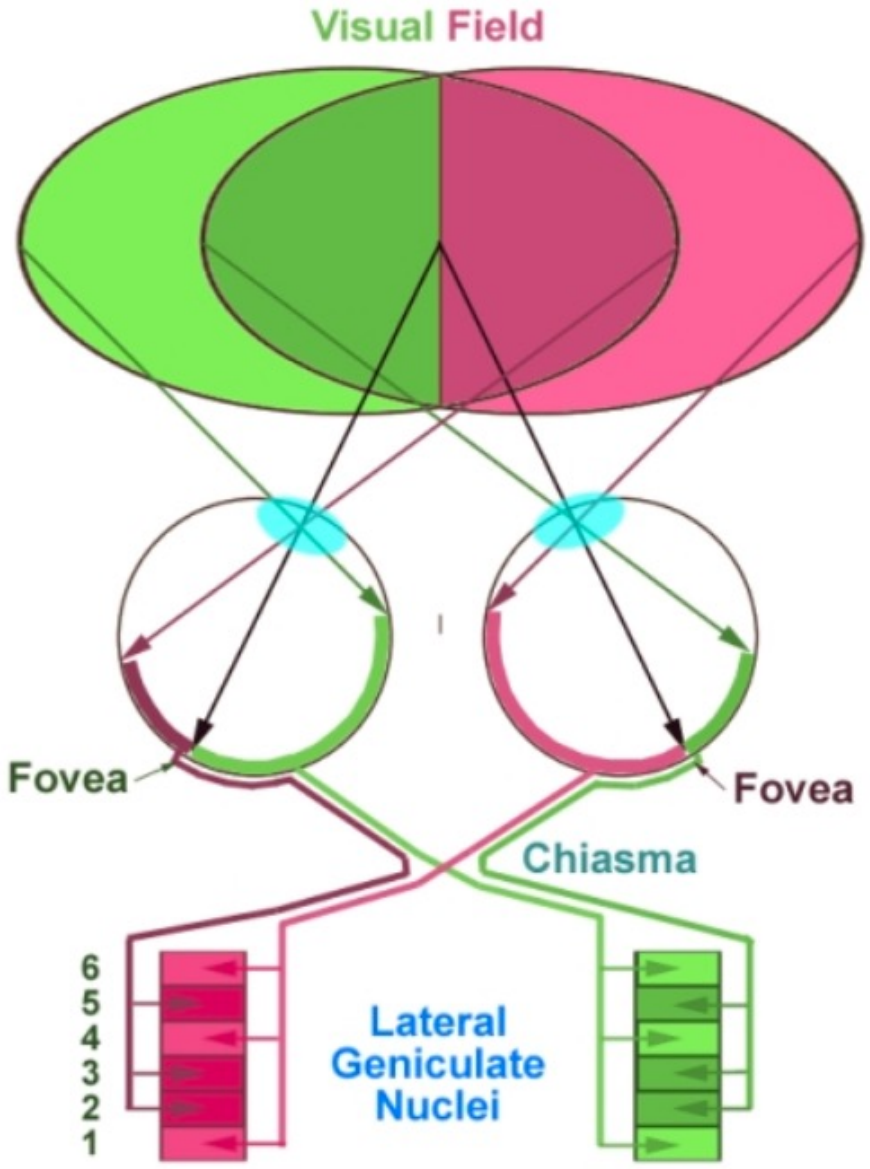

白露
White Dew


19
立夏
Beginning
of Summer


5
大雪
Major Snow

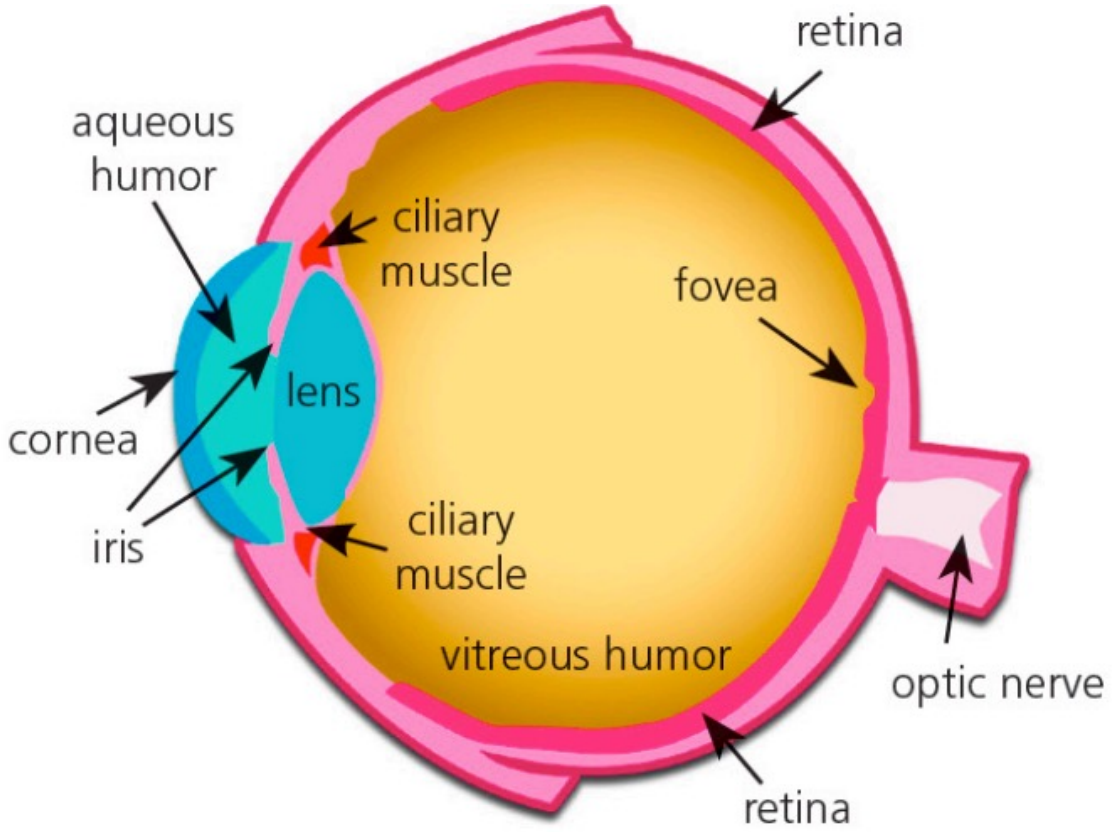
I.I Vision System

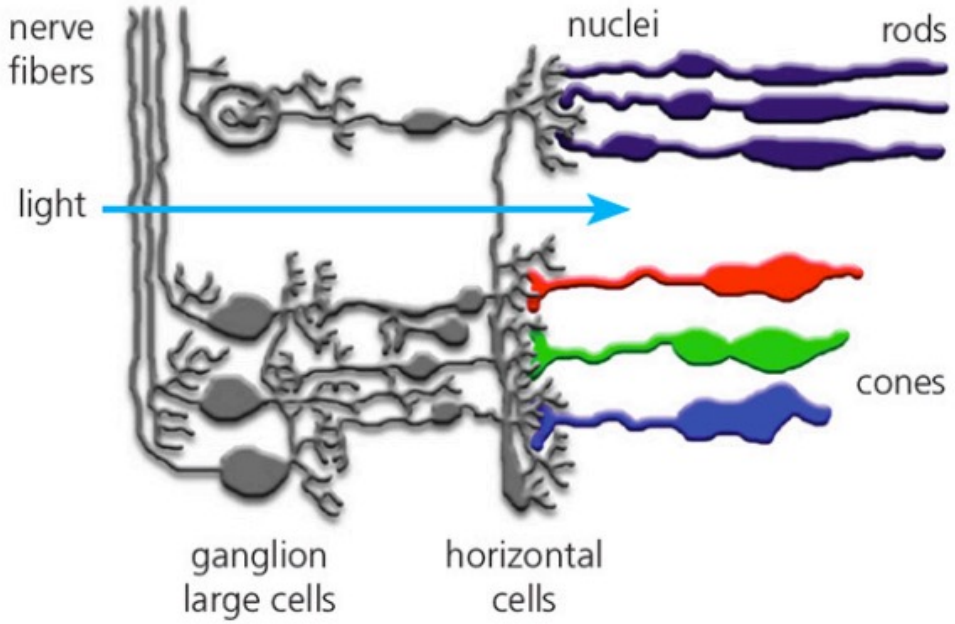
- Sensitivity
  - Luminance 10^{-6} ~ 10^{7} mL
- Acuity
  - Angle & focus: detect, align
  - Movement tracking
- Adaptation
  - Distance, lighting → fatigue
- Deficiency
  - Age-related degeneration
  - Short/far sight
  - Color blind (8% male, 0.5% female)



Photoreceptors in Retina

Rods detect changes in light and adapt the eye to help us see





Cones distinguish Colors

OUTLINE

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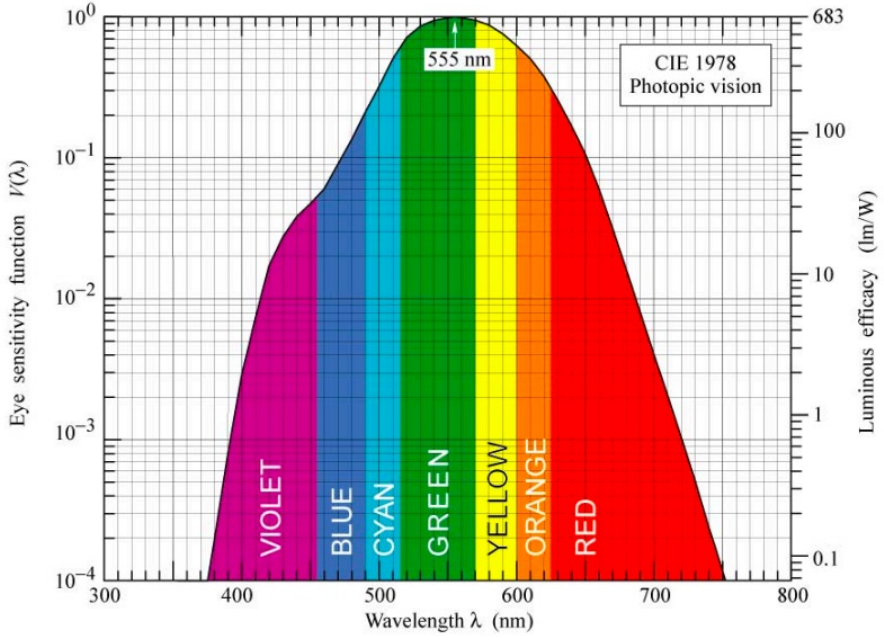
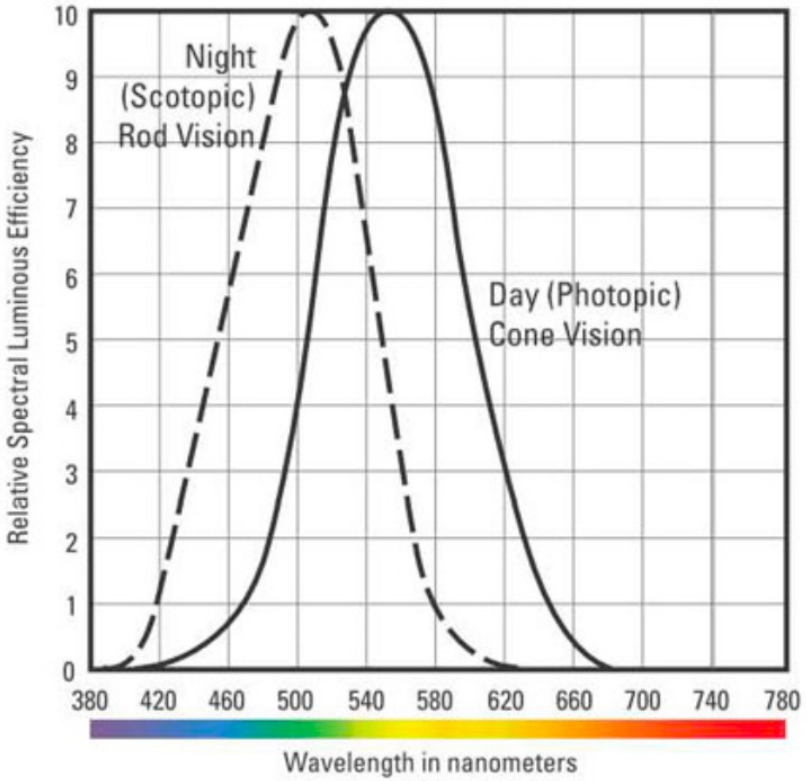


Fig. 16.7. Eye sensitivity function, $V(\lambda)$, (left ordinate) and luminous efficacy, measured in lumens per Watt of optical power (right ordinate). $V(\lambda)$ is greatest at 555 nm. Also given is a polynomial approximation for $V(\lambda)$ (after 1978 CIE data).



I.I Color Vision

- Wavelengths 0.4 – 0.7 micrometers
- Varying sensitivity to different colors

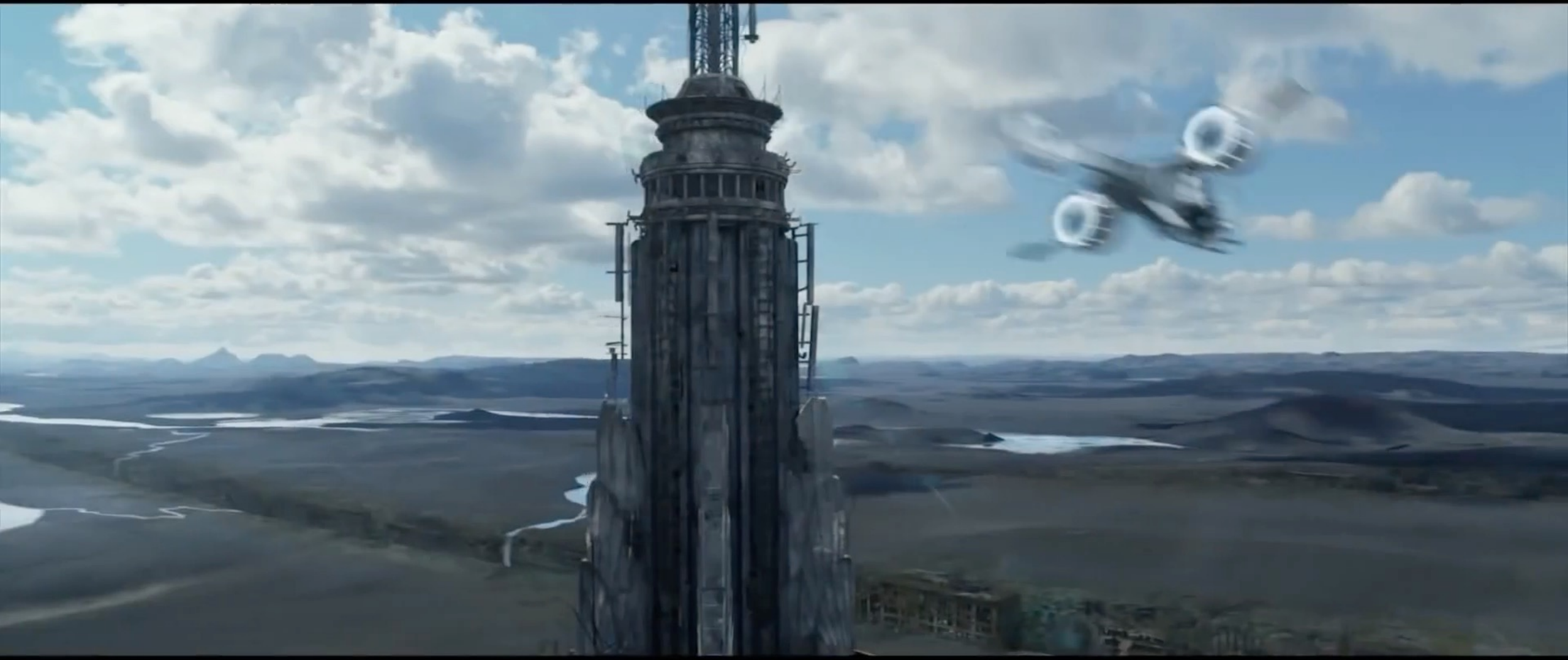
White + Gold or Blue + Black?

- Stress, fatigue, disease and medications
- Cultural, regional and ethnic differences
- Eyewear…

Color Psychology

Perception affected by surroundings

SOURCE: OBLIVION



Psychophysical Effect of Color Light

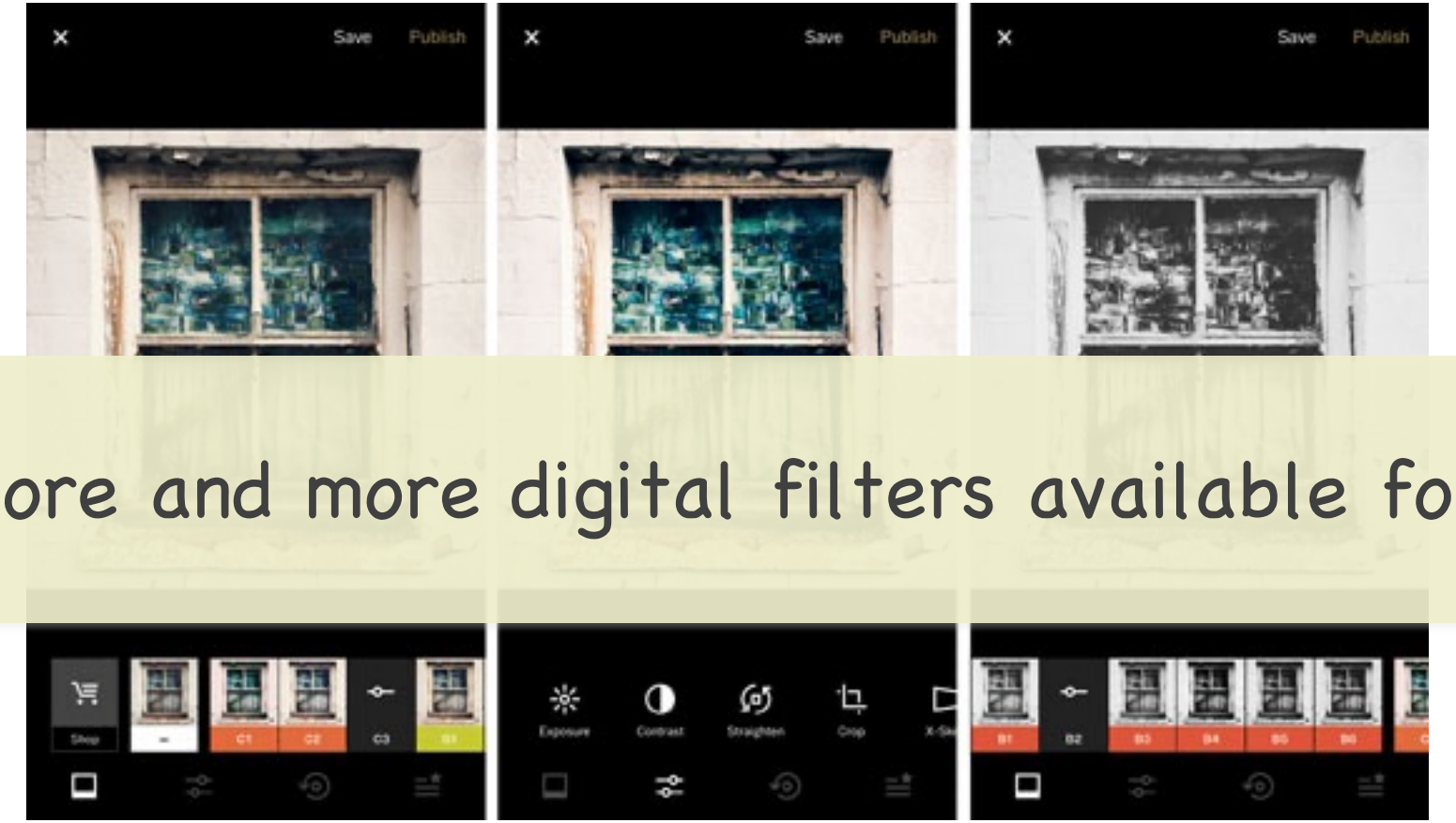
https://www.bloomberg.com/news/articles/2015-04-22/airlines-add-mood-lighting-to-chill-passengers-out

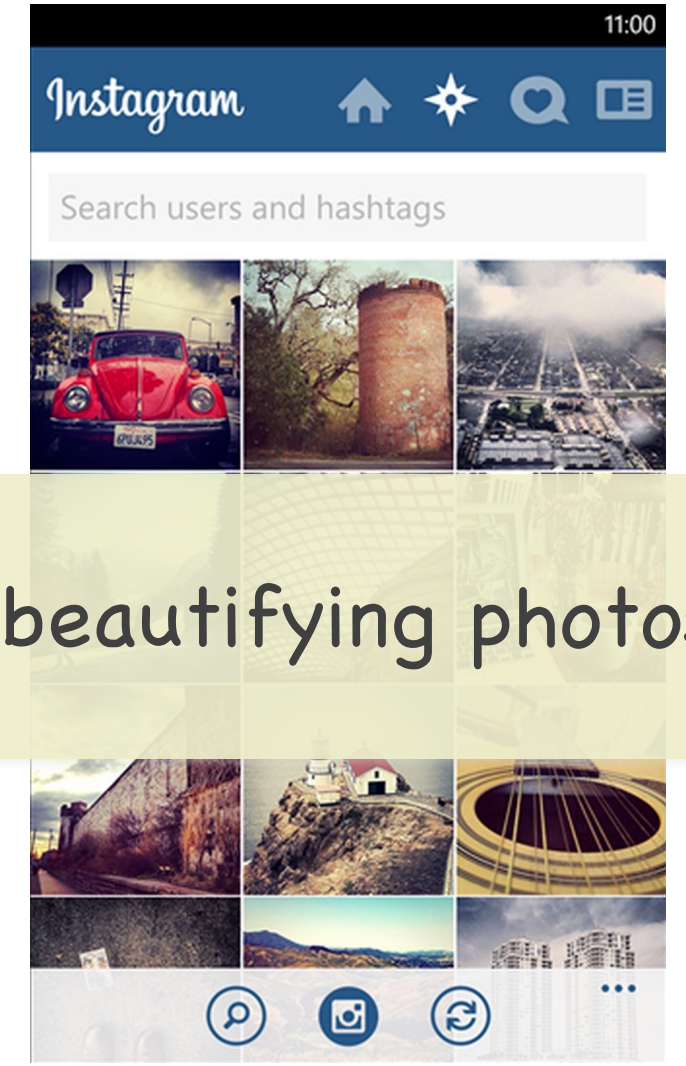
Psychophysical Effect of Color Light

https://www.scientificamerican.com/article/q-a-why-is-blue-

Reconstructing the UI based on the Perceived Semantics Derived from Curation Data

Motivation





More and more digital filters available for beautifying photos

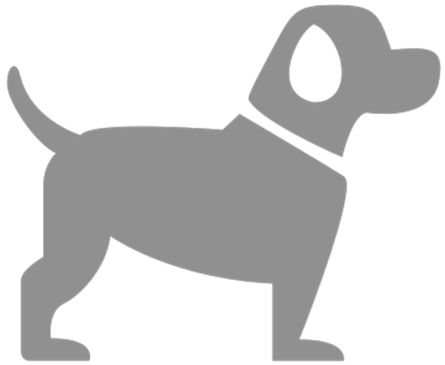
📌 Study I – Online Survey

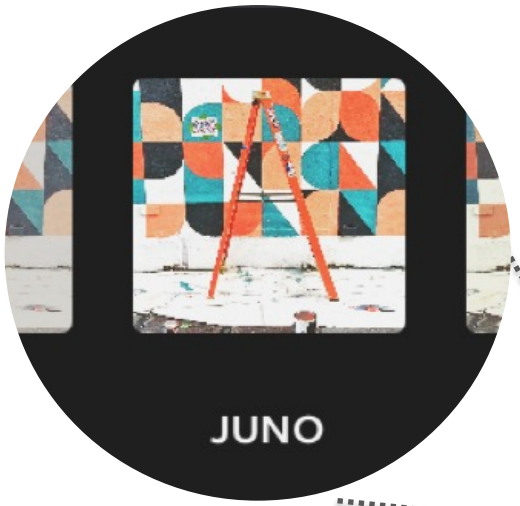
We conducted a survey on MTurk with **225** digital filter users:

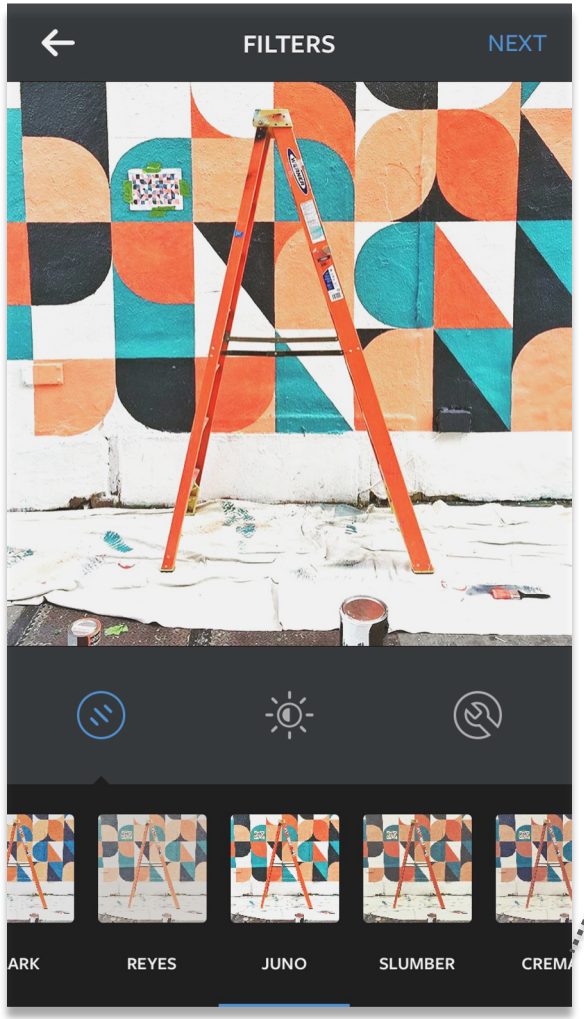
Only **35%** users feel it **easy** to find a desired filter.

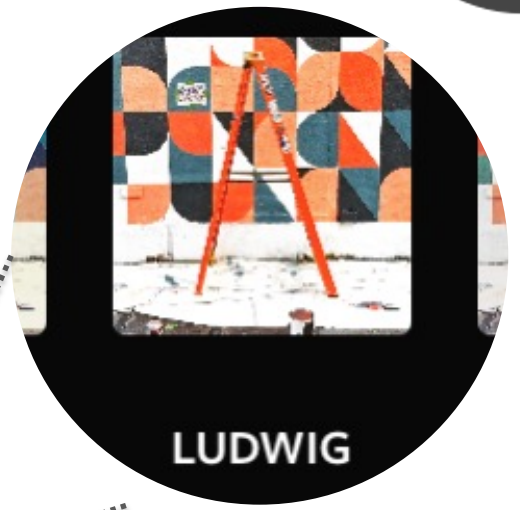
Why? The top two reasons are:
Too many filter options and **ambiguous filter names**

Motivation

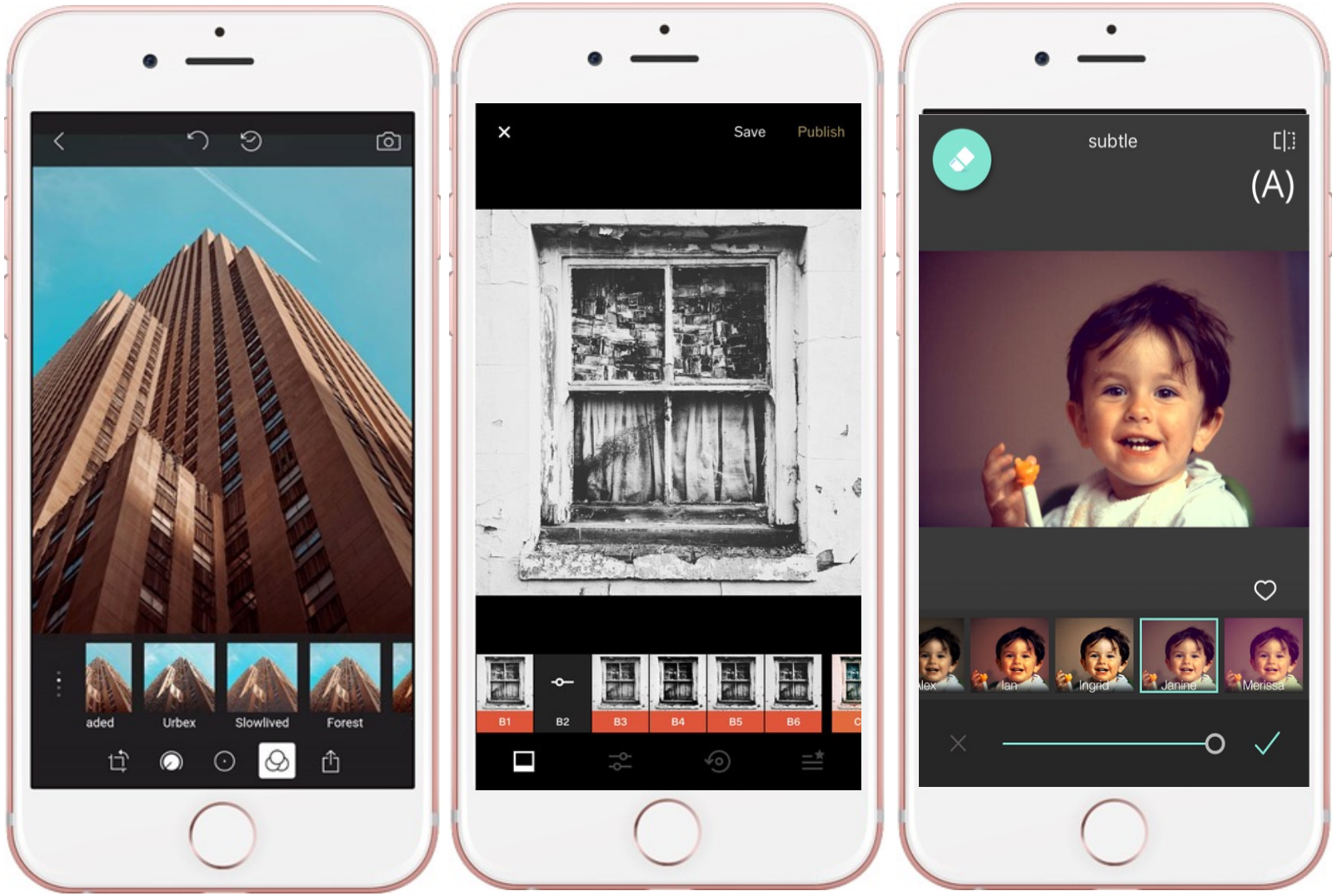








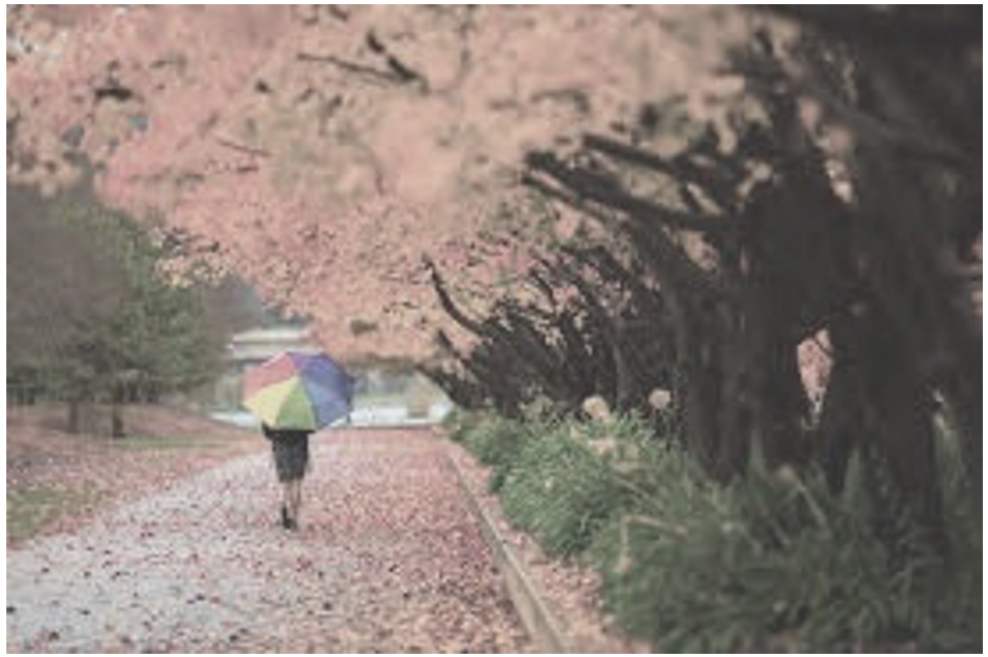
Motivation



Applications	*# filters*	*Categories*
Facebook	7	N/A
VSCO	10	N/A
Flickr	11	N/A
Snapseed	11	N/A
MOLDIV	31	12
Instagram	40	N/A
SNOW	41	N/A
Meitu	51	4
PhotoWonder	58	4
Pixlr	112	8
B612	117	N/A

Motivation

Q How to design UI to better facilitate exploration in a vast filter repository?



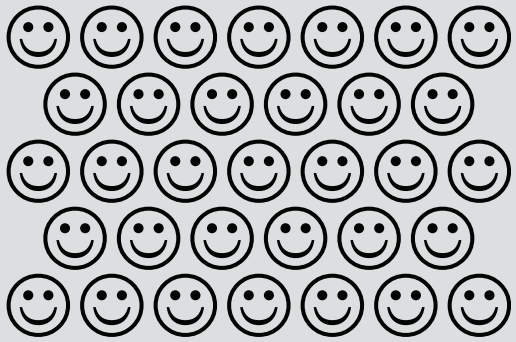
Golden Autumn [Nature]

Motivation

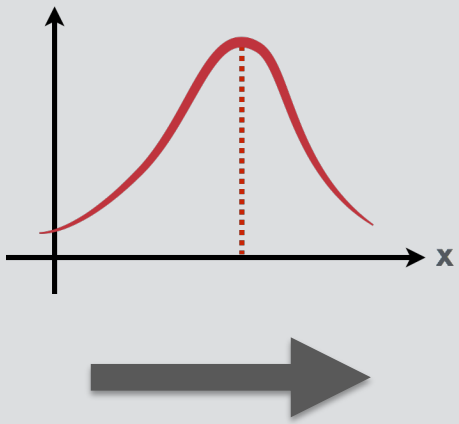
Naming and organizing color filters:

- Need to be intuitive
- Make sense to general users

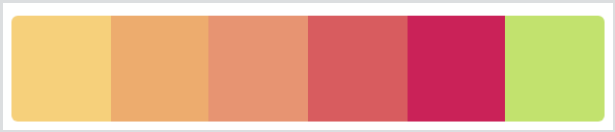
A Data-Driven Solution !



Crowd Wisdom
(Learned from Data)



Darkness[Descriptive]



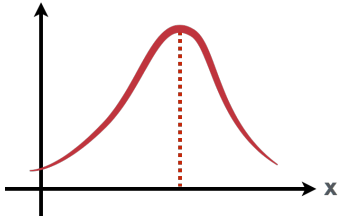
Happy[Emotion]

Ocean[Nature]

...

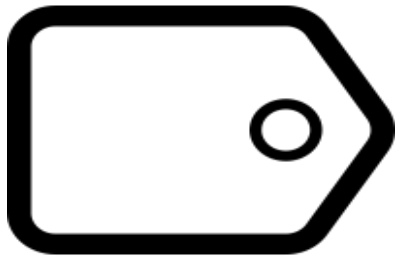
Method

Color Effect



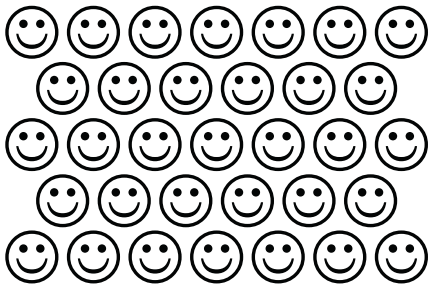
Name

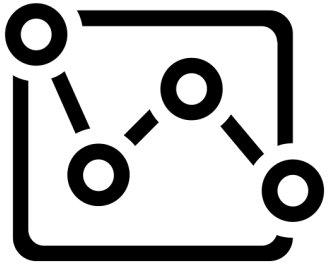
Category



Crowd Wisdom
(Learned from Data)

Word Analysis





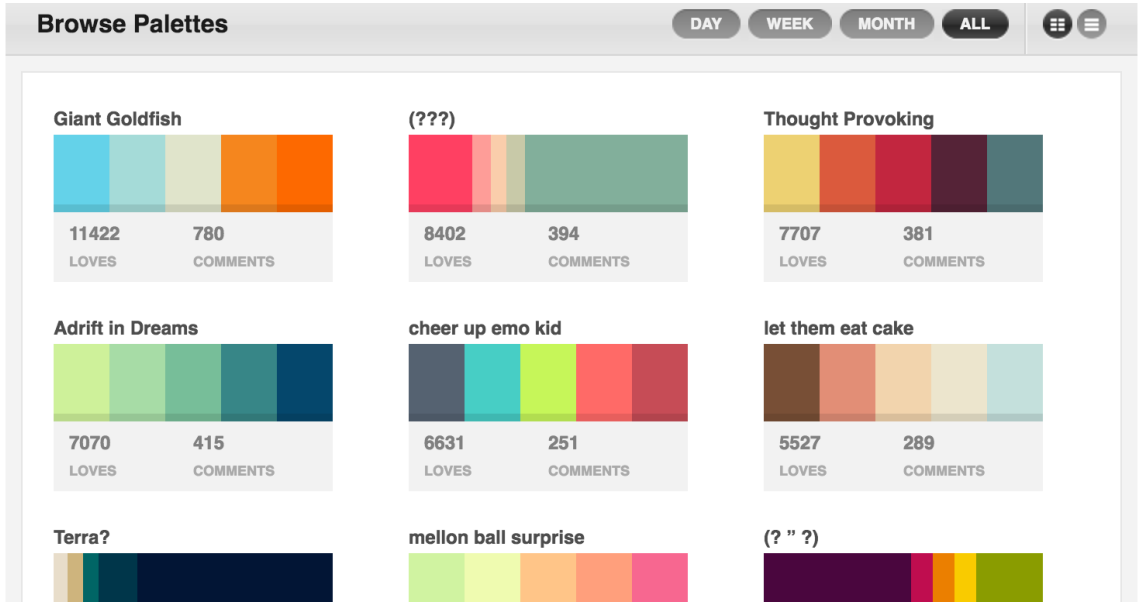
COLOURLovers

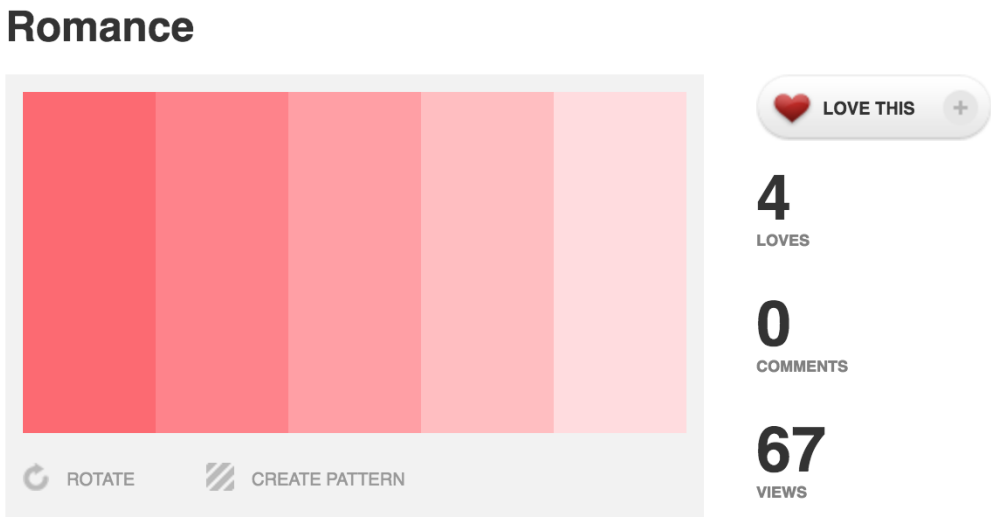
Explore Over a Million Color Palettes

SEARCH

You'll find over 4,606,581 user-created color palettes to inspire your ideas. Get the latest palettes RSS feed or use our color palette maker to create and share your favorite color combinations.

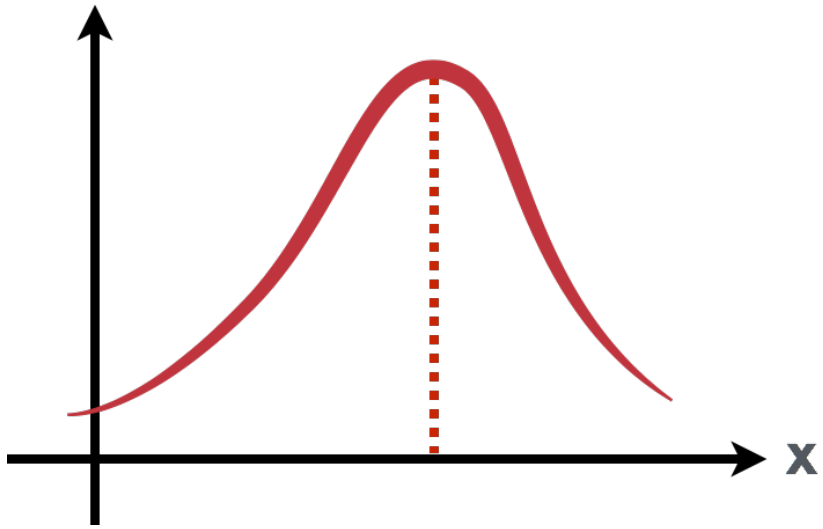
NEW | MOST LOVED | MOST COMMENTS | MOST FAVORITES



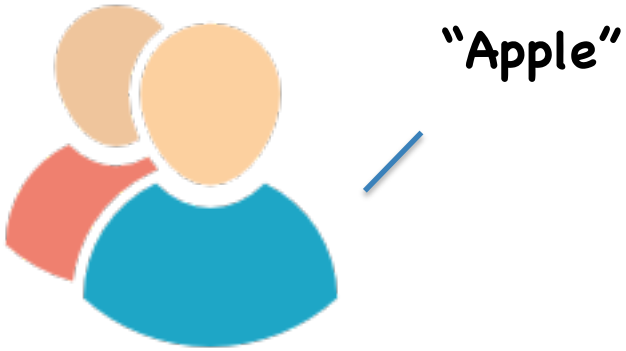


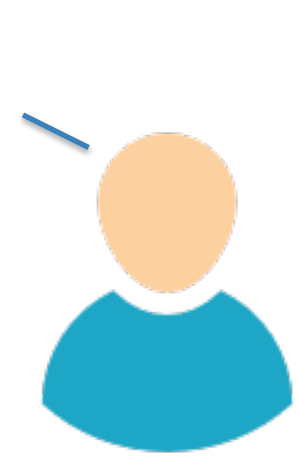
Method

The basic idea:



$$w = \arg max\ P(w|C)$$





Method

Name

Categor
y

Challenges:

- Visual similarity variation
- Proportion awareness
- Maximize crowd consensus

Codebook Representation

$$w = \arg\max_{w} \sum_{i} P(w|c_i)P(c_i|c)$$

Method

$$P(w|c) = \sum_{c_i \in \zeta} P(w|c_i) P(c_i|c)$$

Color theme codebook generation

C_1

$\{W_{11}, W_{12}, W_{13} \ldots\}$

C_2

$\{W_{21}, W_{22}, W_{23} \ldots\}$

...

C_k

$\{W_{k1}, W_{k2}, W_{k3} \ldots\}$

Method

Name

Categor
y

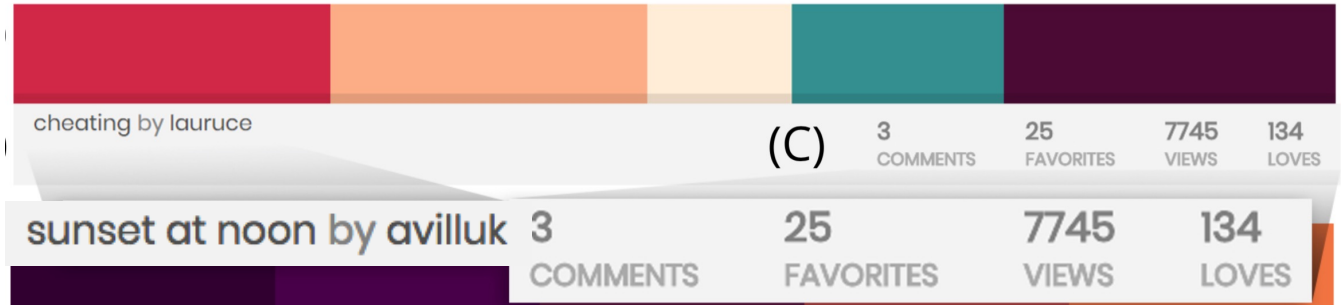
Challenge:

- Semantically similar variation
- Color theme distance
- Maximize crowd consensus

$$P(w|c) = \sum_{c_i \in \zeta} P(w|c_i) P(c_i|c)$$

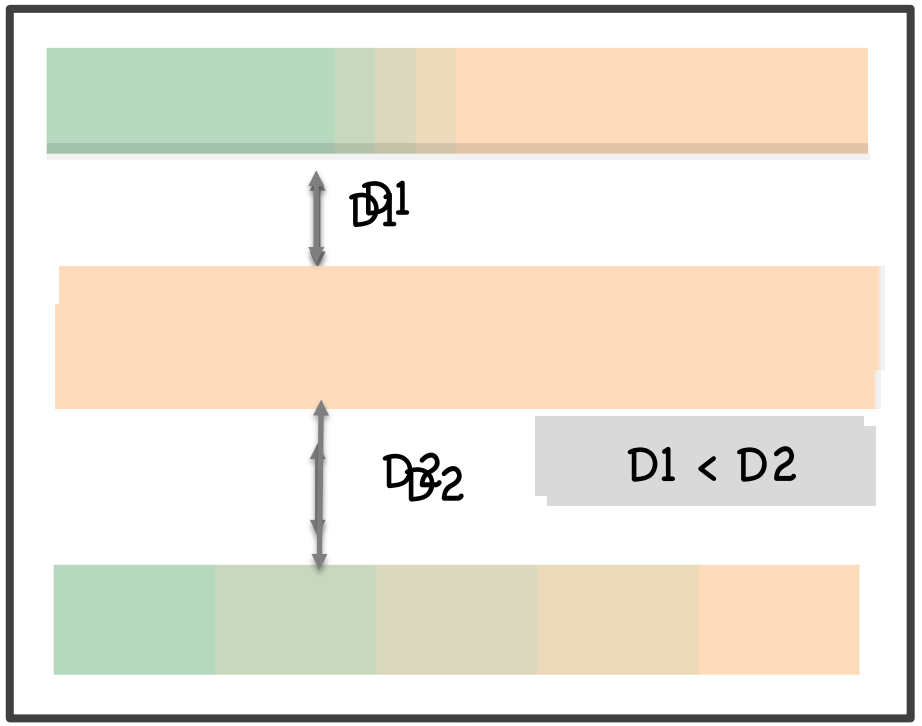
Proportion Aware Distance

Method



Earth Mover's Distance

Proportion Aware Distance



$$dist(c_x, c_y) = EMD(c_x, c_y) = \frac{\sum_{i=1}^{5}\sum_{j=1}^{5} f_{ij}^{*} d_{ij}}{\sum_{i=1}^{5}\sum_{j=1}^{5} f_{ij}^{*}}$$

Method

Name

Categor
y

Incorporating User Ratings

583 FAVORITES | 61208 VIEWS | 1381 LOVES

$$\arg\max_{w} \lambda r(c,w) + P(w|C)$$

Challenge:

- Semantically similar variation
- Color theme distance
- Maximize crowd consensus

Method

Name → Category

"romantic"

"sad"

"leaves"

"ocean"

"happy"

Word2Vec →

1	0	1	1	0
0	0	1	1	0
1	1	1	0	0
0	0	1	1	0

K-Means →

WordNet

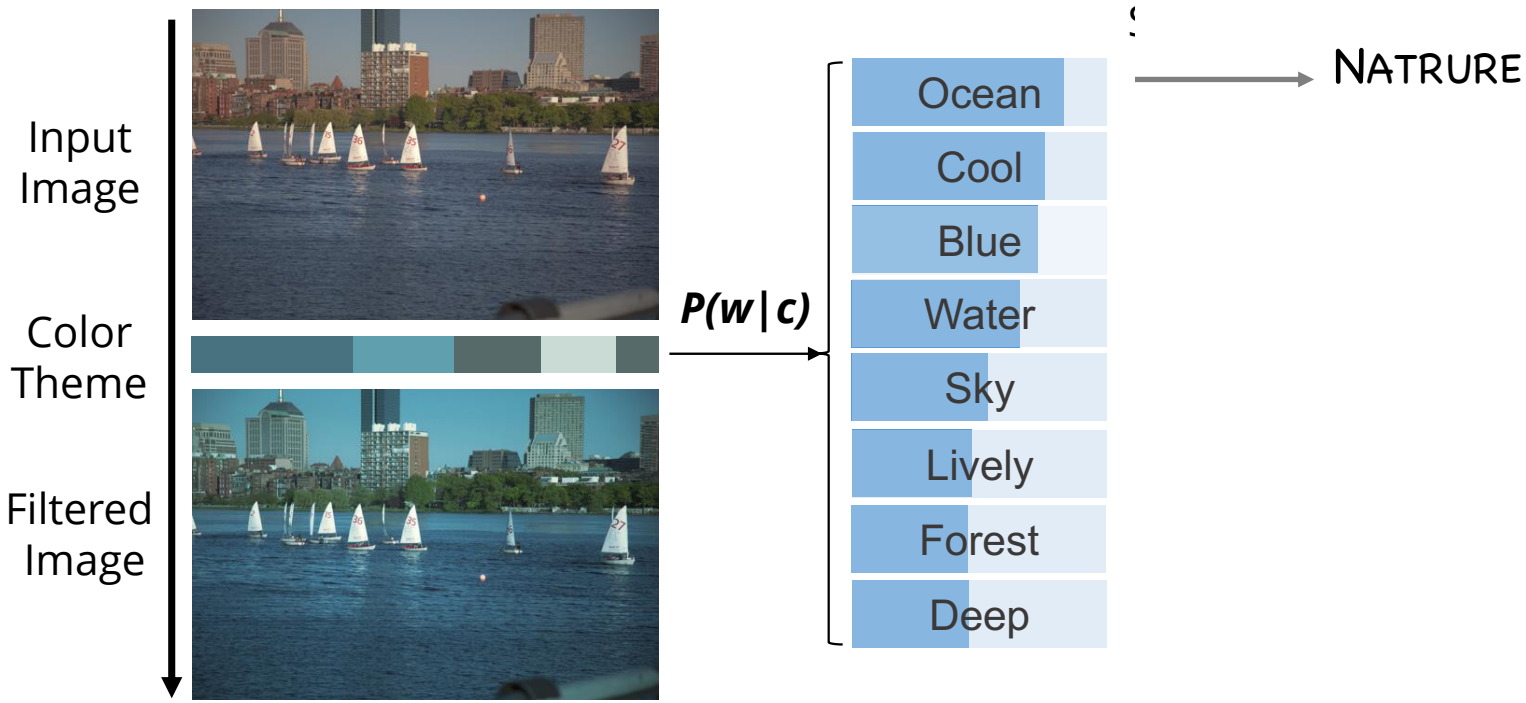
NATRURE: "ocean" "leaves"

EMOTION: "sad" "happy"

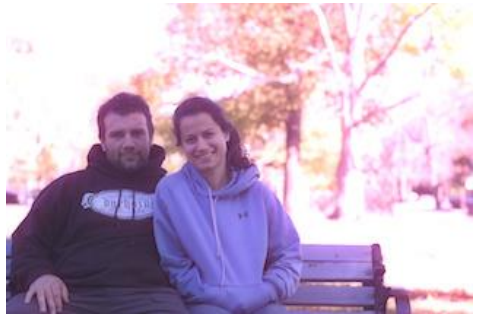
DESCRIPTIVE: "romantic"

Method


Color Effect
Name
Category


Input Image
Color Theme
Filtered Image
P(w|c)
Ocean
Cool
Blue
Water
Sky
Lively
Forest
Deep
NATRURE

Results

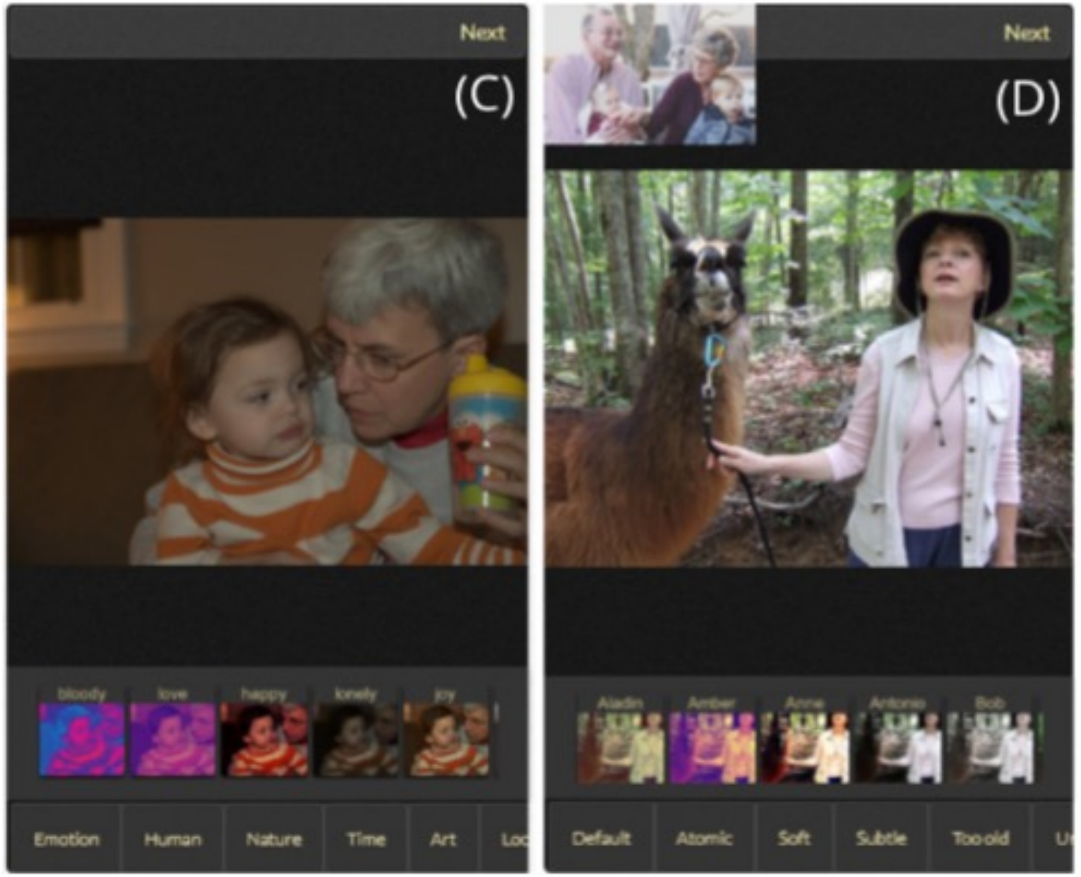
Input Image	Filtered Results			
				
Color Theme:				
Baseline:	Fred [DEFAULT]	Elenore [UNICOLOR]	Amy [UNICOLOR]	Laila [SOFT]
Processed:	Ocean [NATURE]	Strawberry [SUBSTANCE]	Sunset [TIME]	Romantic [DESCRIPTIVE]
				
Color Theme:				
Baseline:	Karen [DEFAULT]	Per [SOFT]	Lucas [DEFAULT]	Jyler [VINTAGE]
Processed:	Autumn [TIME]	Blossom [NATURE]	Lonely [EMOTION]	Refresh [DESCRIPTIVE]

📌 Study II - IN-LAB USER STUDY

How does the derived filter semantics support filter exploration?

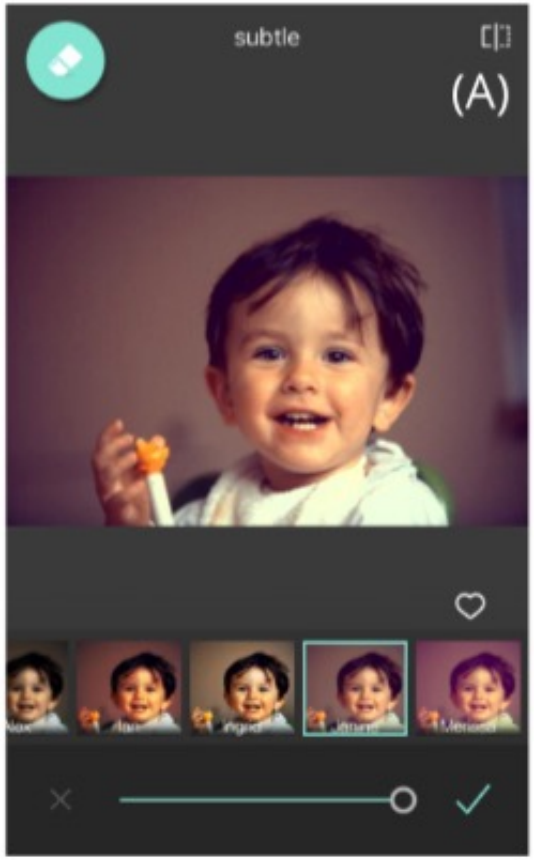
A within-subjects in-lab experiment with **24** participants

- **Filter Browsing:** explore the prototype and choose their favorite filter
- **Filter Searching:** modify the input image to make it as similar to the target image as possible

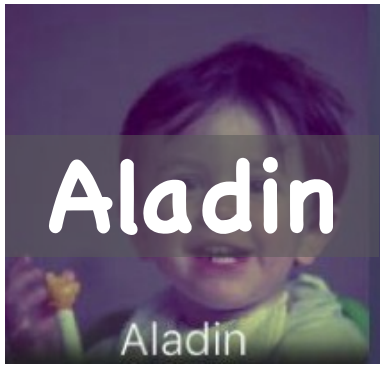


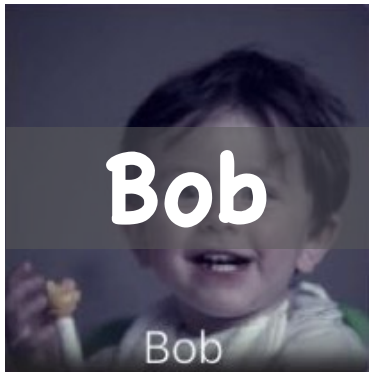
Study II - IN-LAB USER STUDY

Pixlr — Baseline

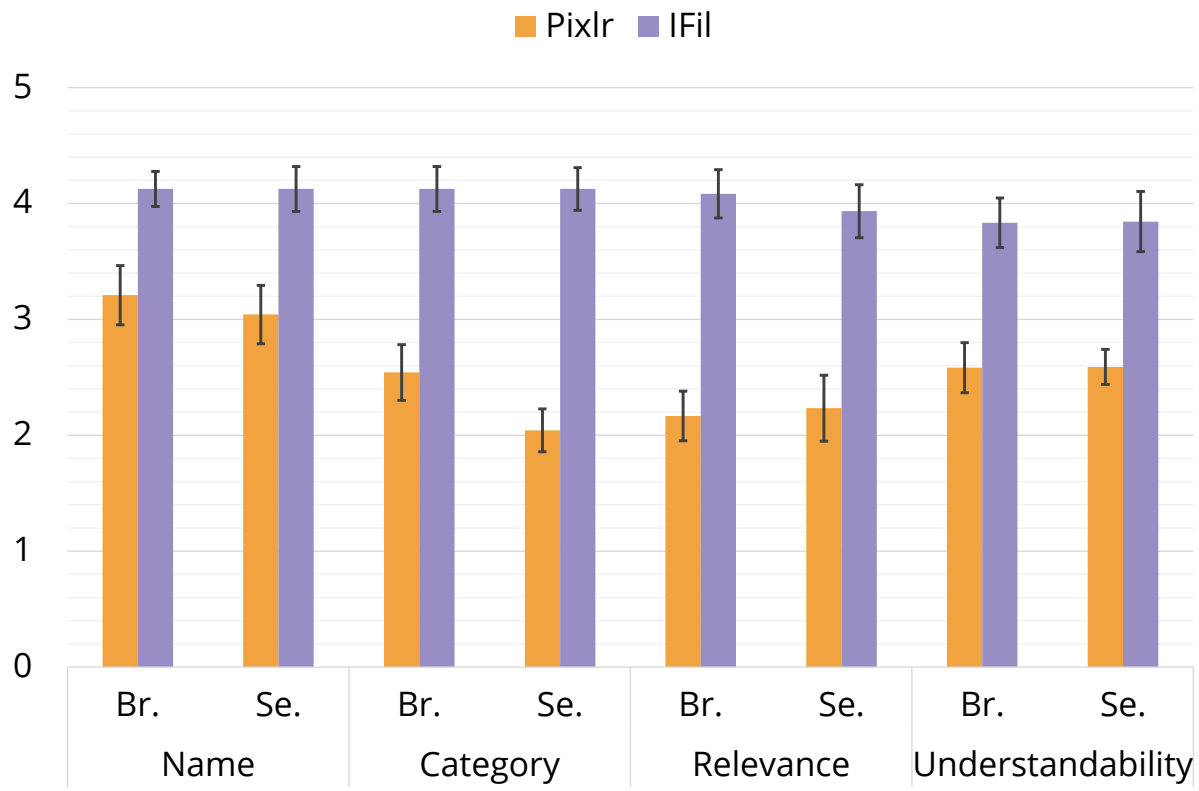


112 filters with designer-defined names (e.g. Fred, Carl), organized into **eight** categories (e.g. Default, Subtle)





Study II - IN-LAB USER STUDY



Interview feedback

- Filter effects are more predictable
- Easier to recall
- Easier for direct search

Study III - ONLNE USER STUDY

amazon mechanical turk beta

We conducted an online crowd study to determine the effects of **Semantics** with **110** MTurk workers were involved in the study.

Study III - ONLNE USER STUDY

Conditions		Clicks		Prop_Clicks	
		Mean	SD	Mean	SD
Browse	Semantics	8.35	8.79	0.79	0.28
	Baseline	17.31	20.38	0.62	0.27
Search	Semantics	14.88	18.08	0.78	0.33
	Baseline	15.33	22.7	0.61	0.3

$$F(1, 58) = 4.32, p = 0.04, \eta^2 = 0.168$$

Significantly less clicks are needed with the filter semantics!

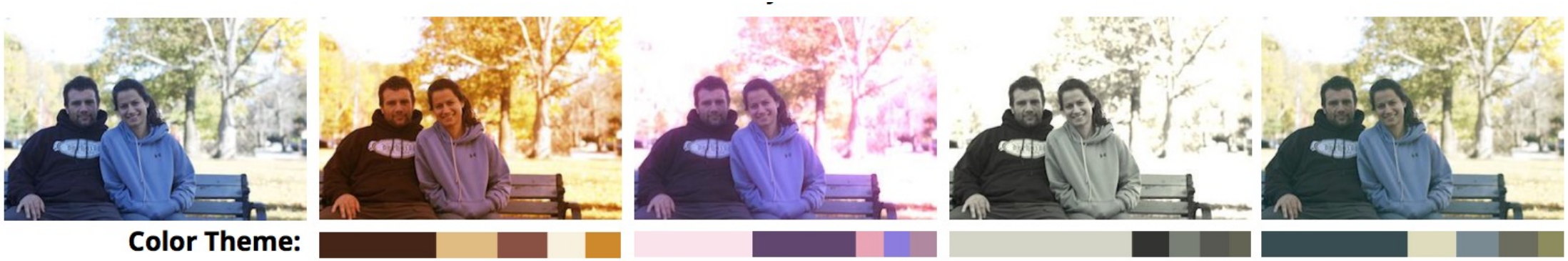
* **Clicks** denotes the number of clicks
* **Proportion of Clicks** represents the number of clicks in the filter area, as a proportion of the total number of clicks on the screen

- The effect is greater in **Browsing** task
- When splitting the data into expert and casual users, there is **significant** difference for **casual users** but not for experts

📌 Discussion

Findings:

- Users find it hard to locate a desired filter with existing filter apps
- The derived color theme semantics can increase filter findability and boost the user experience
- Users' perceived filter semantics can be modeled from online social curation data without the need of expensive human labels.



📌 Conclusion

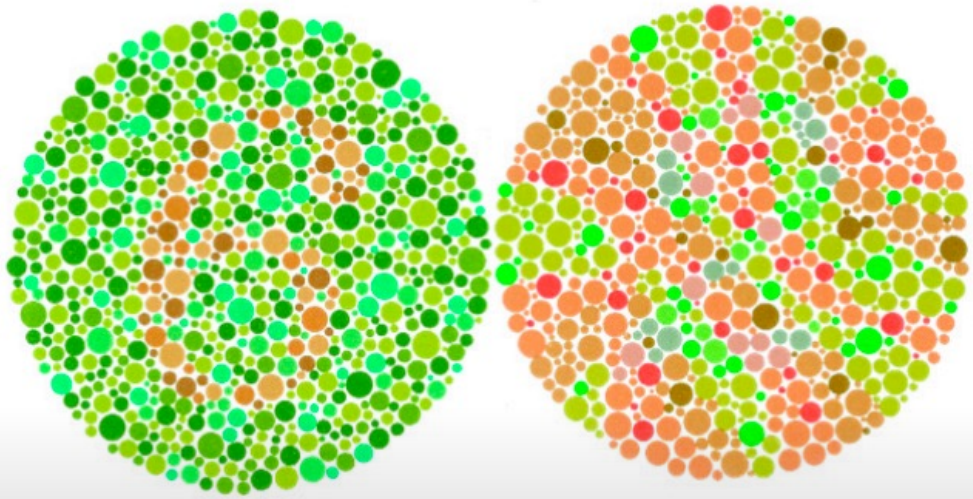
Goal: Understand and model user perception towards mobile UI and facilitate UI generation for better user experience

Method: data-driven approaches

Evaluation: qualitative and quantitative analysis

Contribution: improve the existing computational framework for automatic design assessment

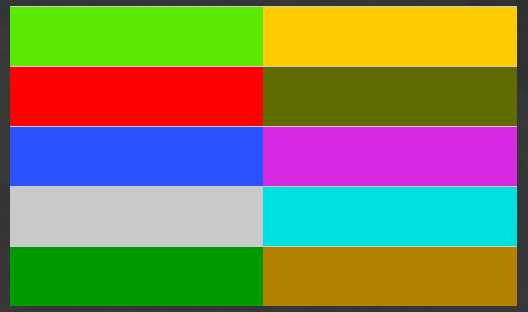
Color Sensitivity
Color Deficiency



Just Noticeable Difference (JND)

Color Deficiency (Also known as "color blindness")

- Trouble discriminating colors
  - besets about 4.5% of population (~8% men, ~.5% women)
- Two main types
  - different photopigment response most common
    - reduces capability to discern small color diffs
  - red-green deficiency is best known
    - lack of either green or red photopigment → can't discriminate colors solely dependent on Red & Green

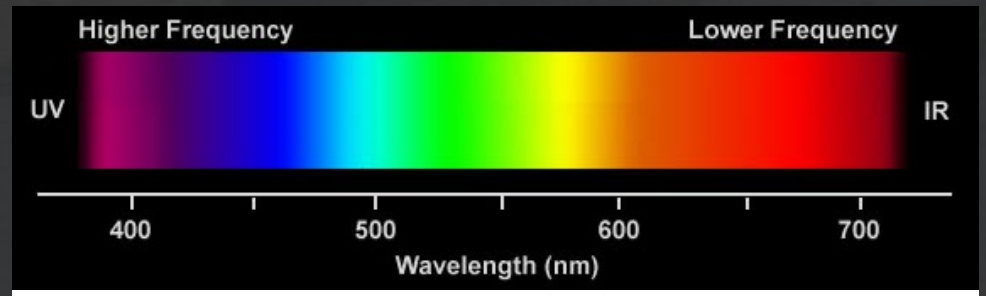


Difficult pairs for severe red deficient person to discern
https://www.color-blindness.com/red-green-color-blindness/

Color Guidelines

Avoid simultaneous display of highly saturated, spectrally extreme colors

- e.g., no cyans/blues at the same time as reds, why?
  - refocusing!



bad →

The Falklands Society

- desaturated combinations are better → pastels

Use the Hue Circle

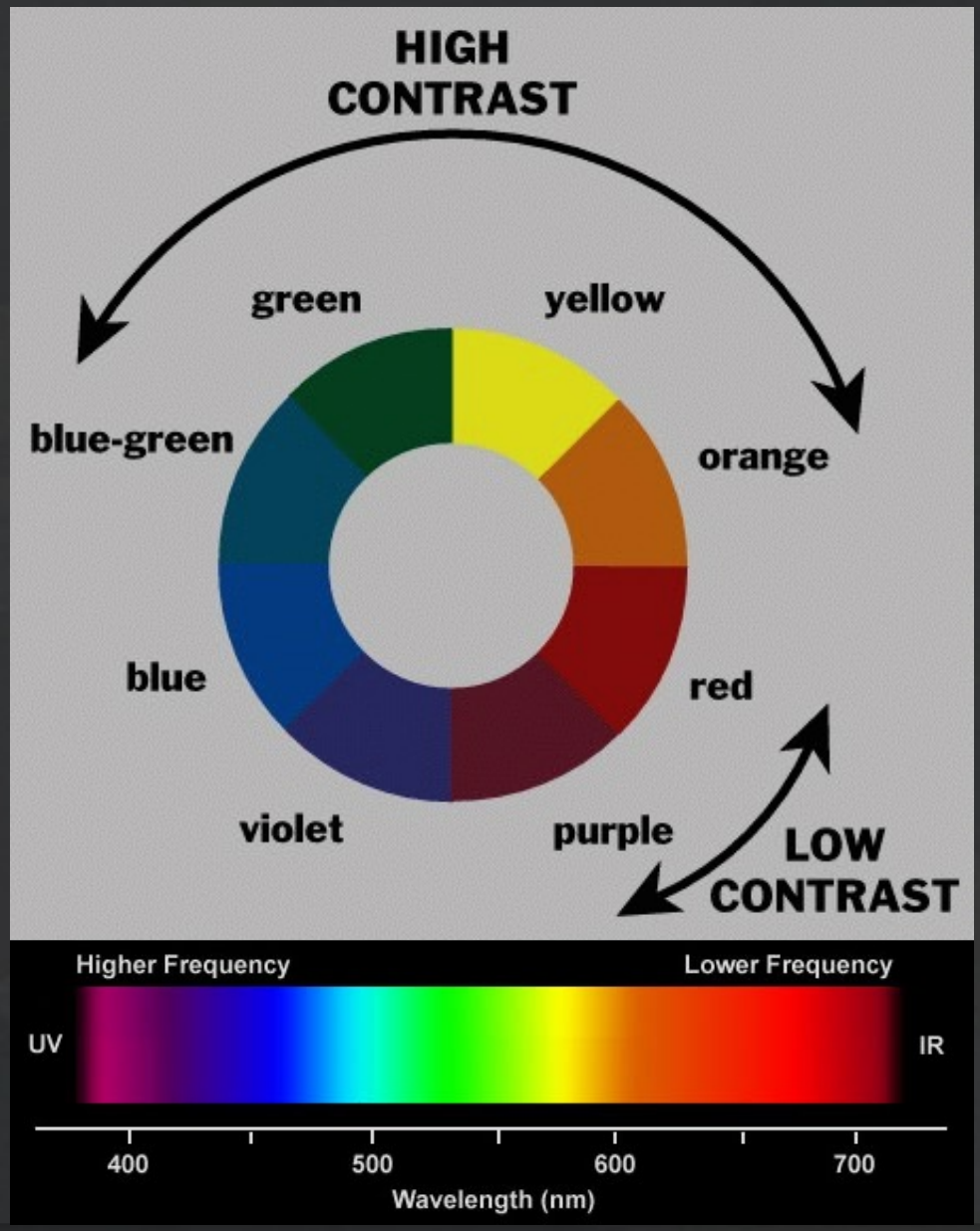
Pick non-adjacent colors

- opponent colors go well together

red & green

or

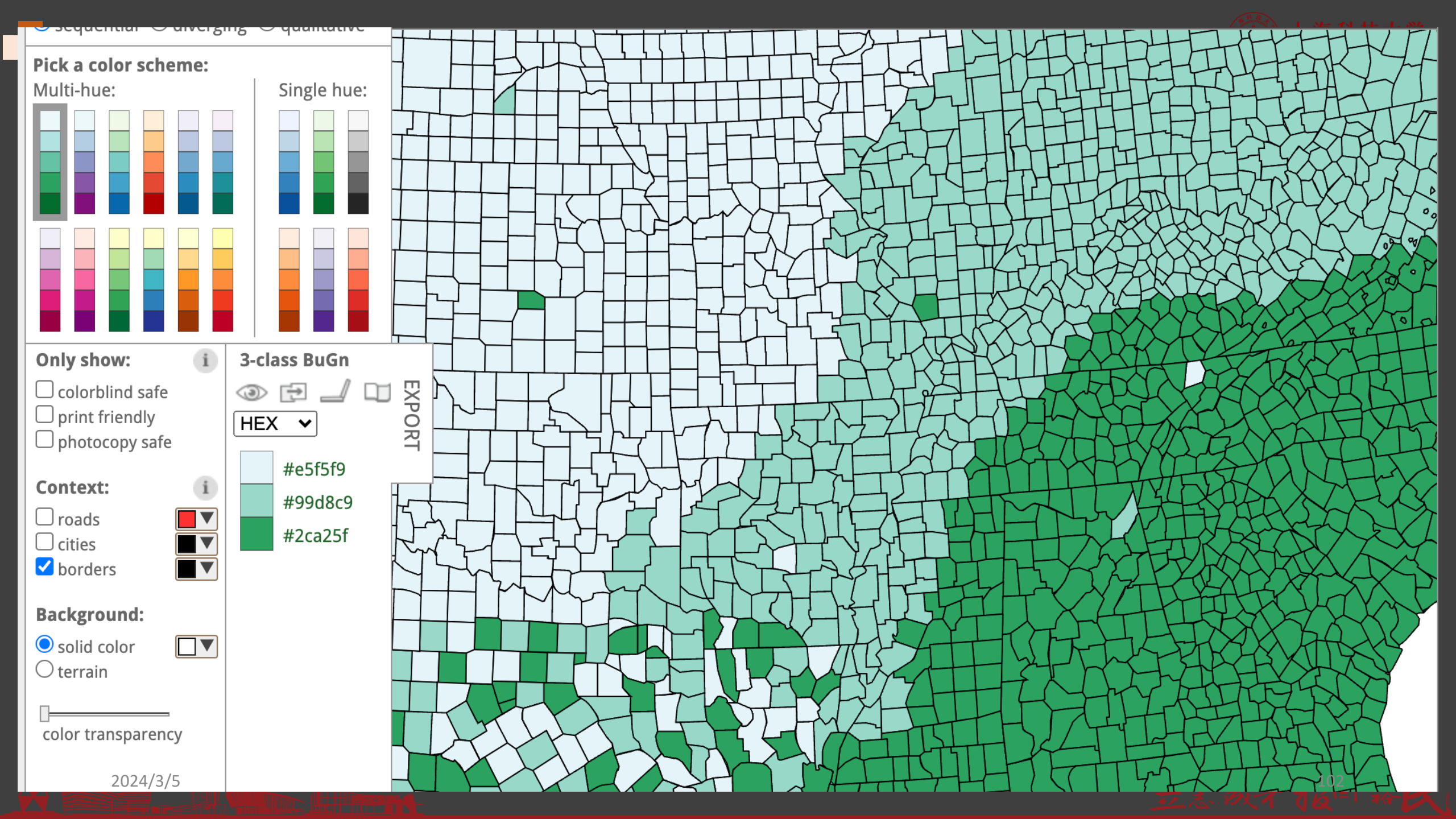
yellow & blue



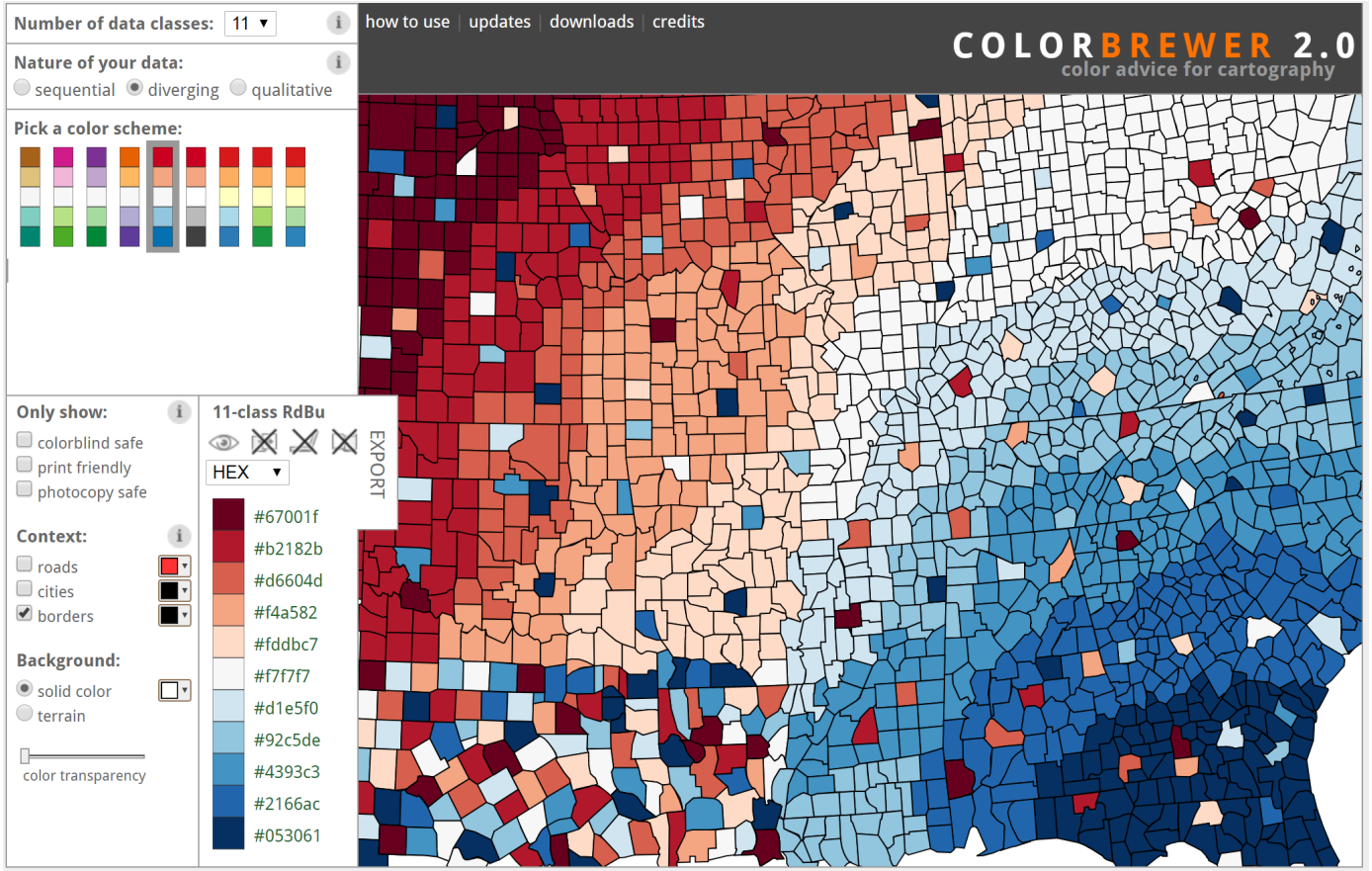
Color Guidelines (cont.)

- Avoid pure blue for text, lines & small shapes
- Avoid adjacent colors that differ only in blue

- Blue makes a great background color


Pick a color scheme:
Multi-hue:
Single hue:
Only show:
colorblind safe
print friendly
photocopy safe
Context:
roads
cities
borders
Background:
solid color
terrain
color transparency
3-class BuGn
HEX
#e5f5f9
#99d8c9
#2ca25f
EXPORT
2024/3/5

ColorBrewer



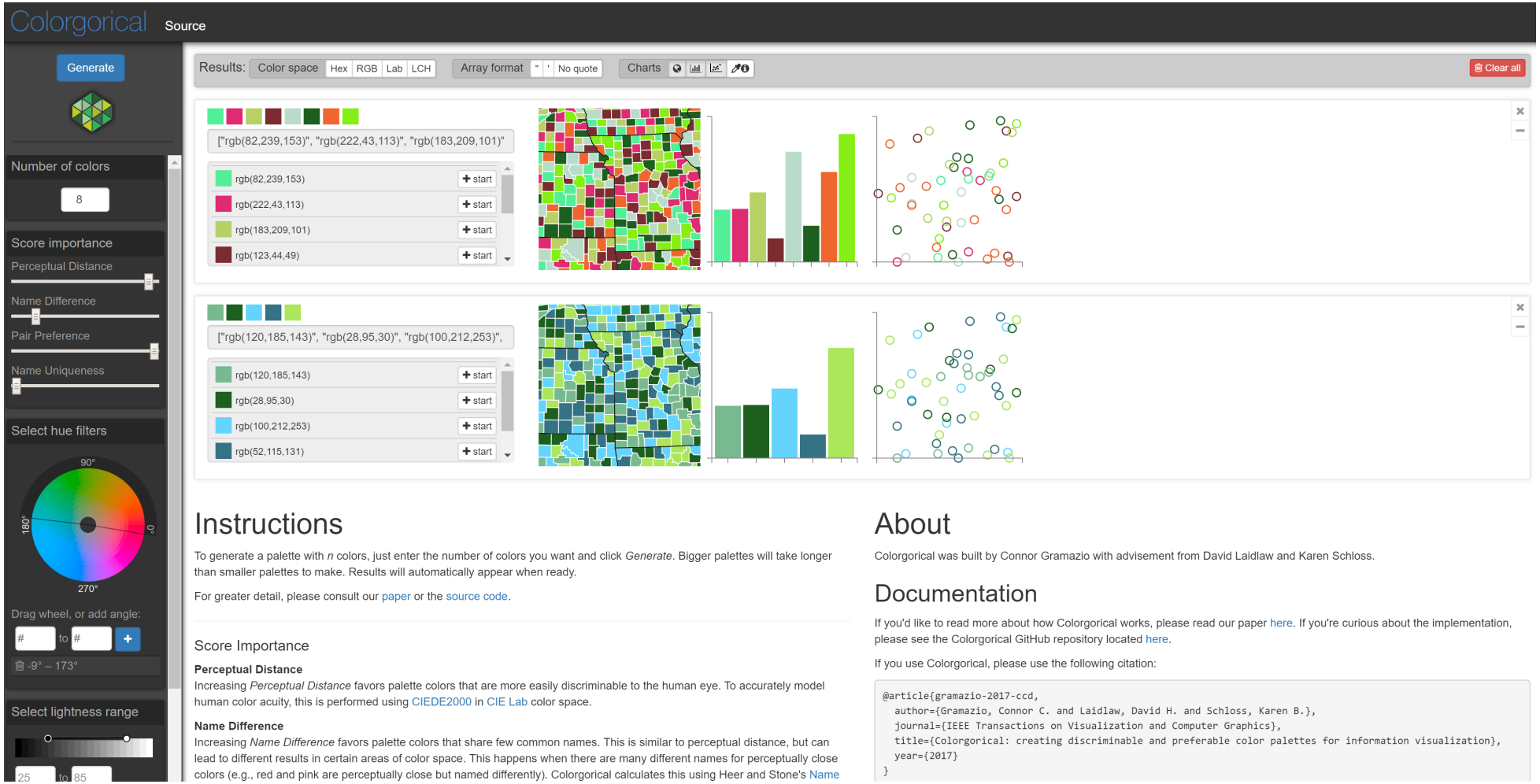
http://colorbrewer2.org

Color Farm

D1EDFF 38BBFF F22117 01E748 181544 2B67F5

http://color.farm

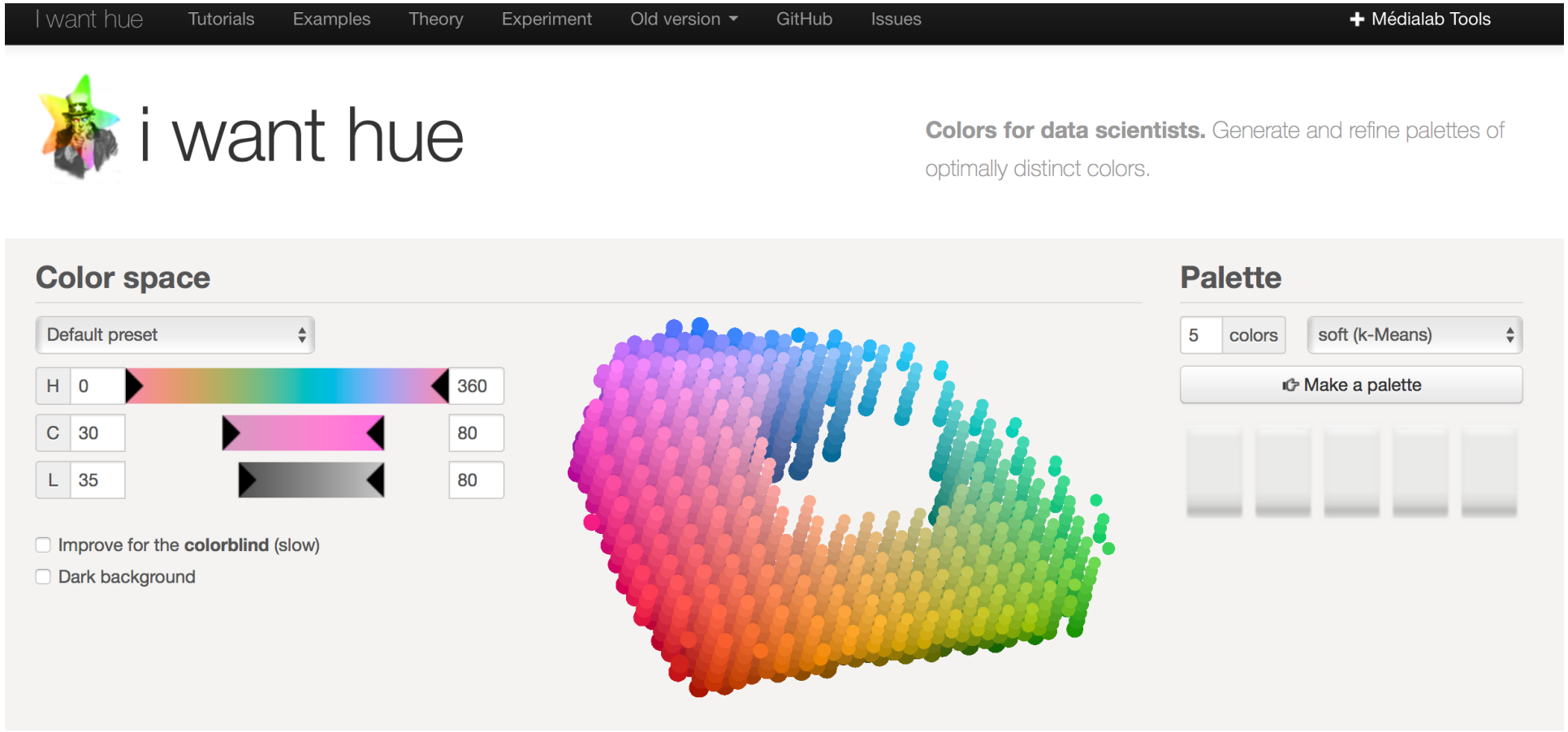
Colorgorical



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

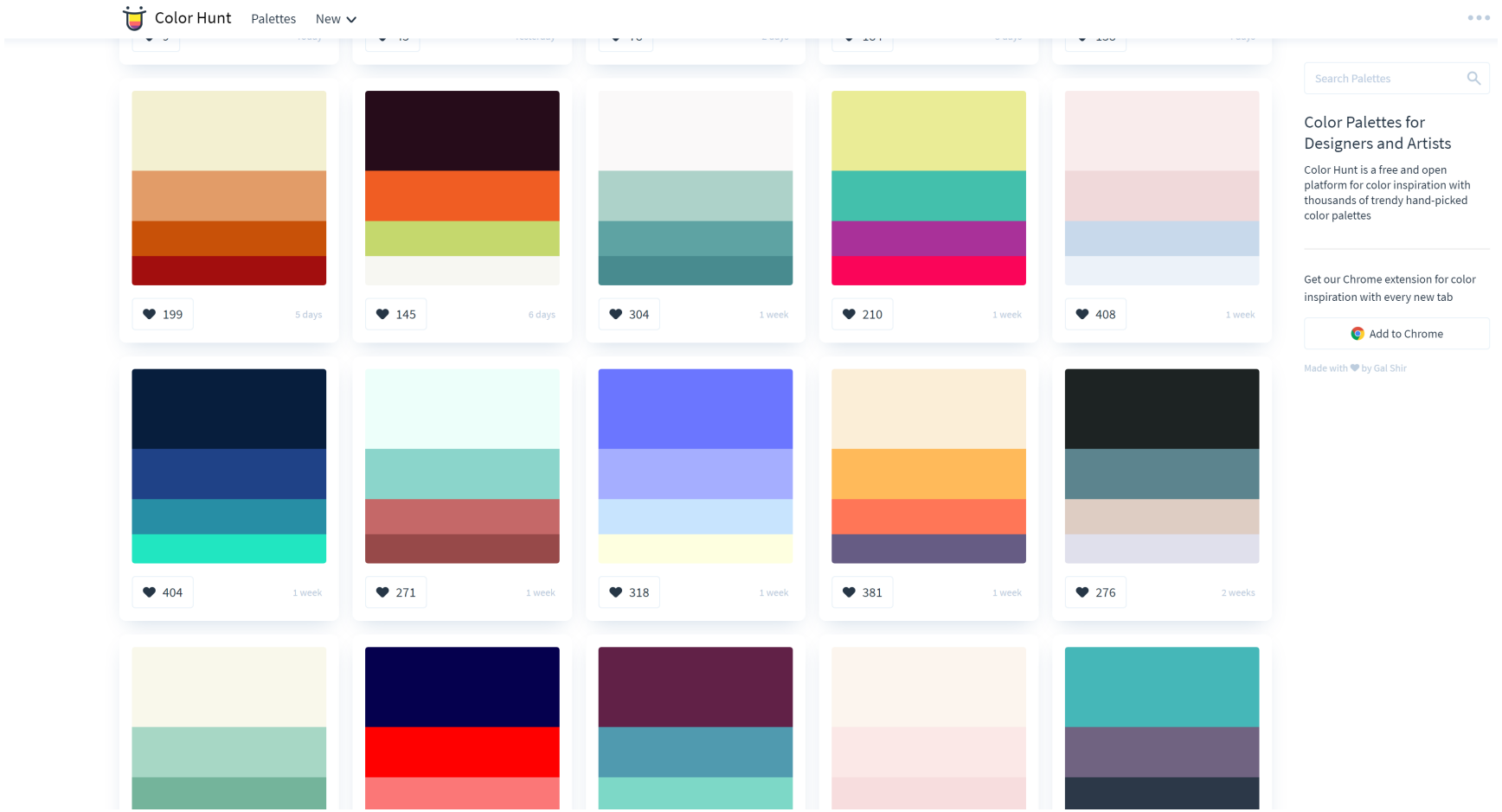
Gramazio C C, Laidlaw D H, Schloss K B. Colorgorical: Creating discriminable and preferable color palettes for information visualization[J]. IEEE transactions on visualization and computer graphics, 2017, 23(1): 521-530.

I want hue



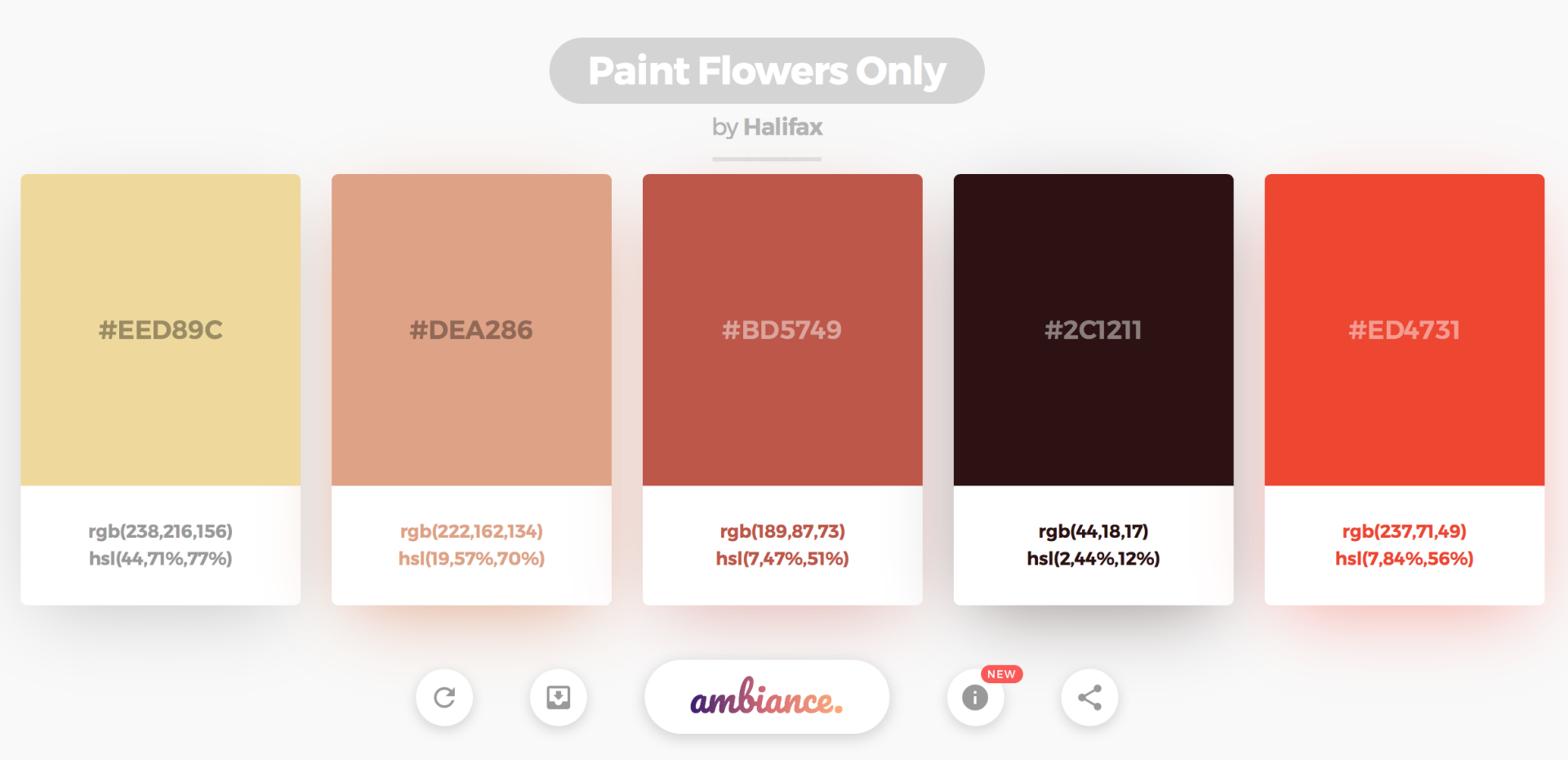
http://tools.medialab.sciences-po.fr/iwanthue/

Color Hunt



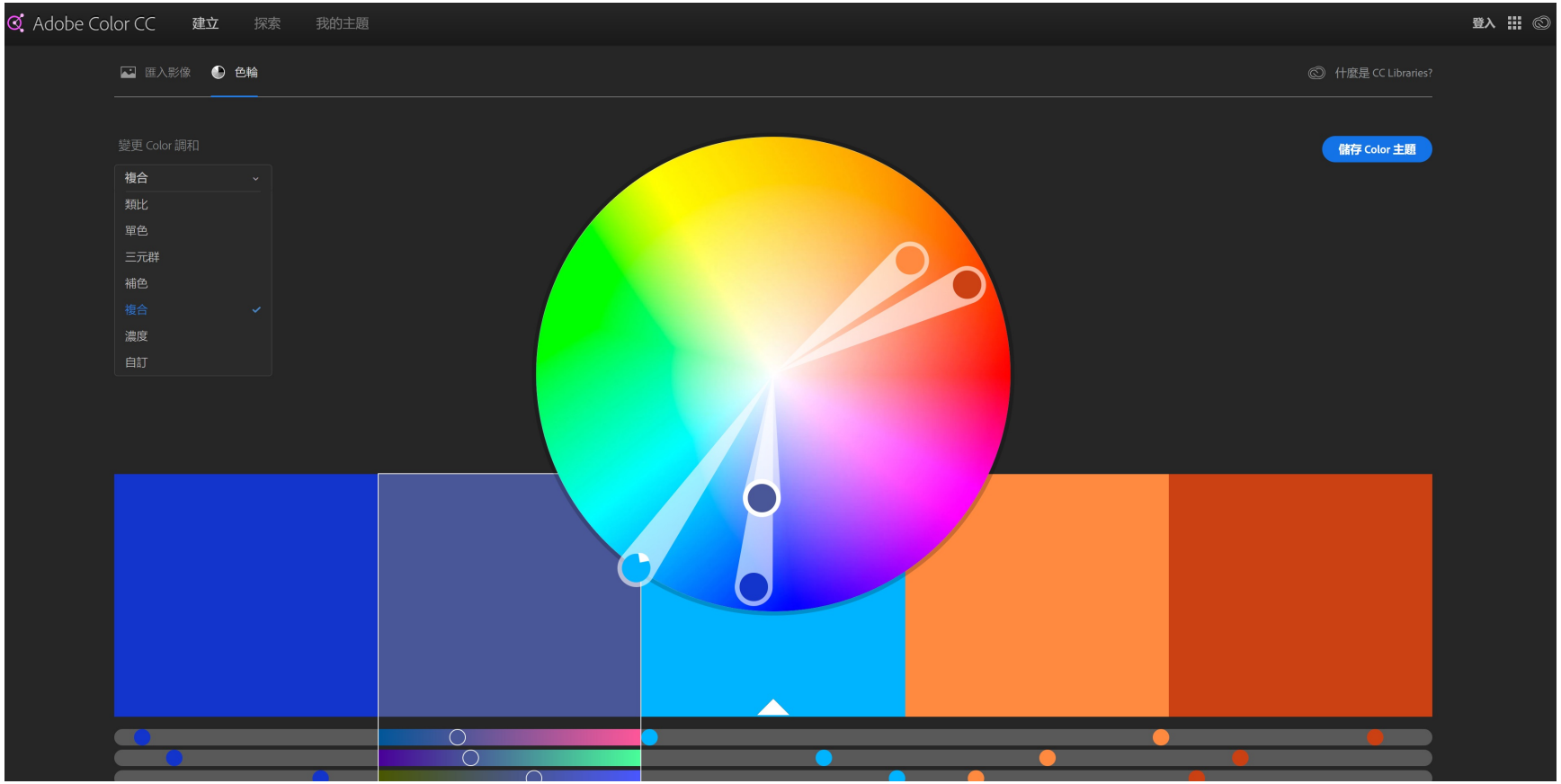
https://colorhunt.co/

Ambiance



ambiance.somethingjustlikethis.com

Color Wheel



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

Scatterplots are everywhere!

Microsoft Excel

Problem

- Given a dataset X of m classes with a color palette C of p colors $(p \geq m)$

Classic and Going topic

上海科技大学 ShanghaiTech University

InfoVis: Perception & Cognition 2
Session Chair: Karen Schloss

Mitigating the Attraction Effect with Visualizations (J)
Authors: Evanthia Dimara, Gilles Bailly, Anastasia Bezerianos, Stev
Video Preview

Face to Face: Evaluating Visual Comparison (J)
Authors: Brian David Ondov, Nicole Jardine, Niklas Elmqvist, Steve
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 Char Visualization Complexity (J)
Authors: Eugene Wu, Remco Chang, Abigail Mosca, Gabriel Ryan
Video Preview

Correlation Judgment and Visualization Features: A Compar (T)
Authors: Fumeng Yang, Lane Harrison, Ronald A. Rensink, Steven I Remco Chang
Video Preview

InfoVis: Perception & Cognition 1
Session Chair: Danielle Szafir

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

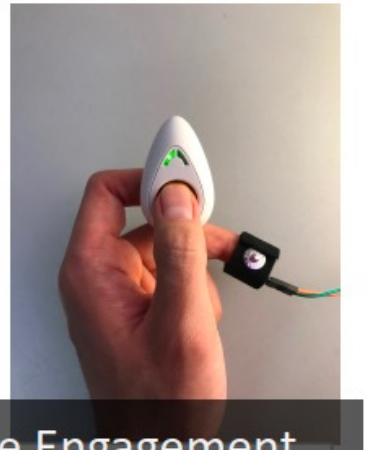
Image-based Aspect Ratio Selection (J)
Authors: Yunhai Wang, Zeyu Wang, Chi-Wing Fu, Hansjörg Schmauder, Oliver Deussen, Daniel Weiskopf
Video Preview

http://ieeevis.org/year/2018/info/papers-sessions

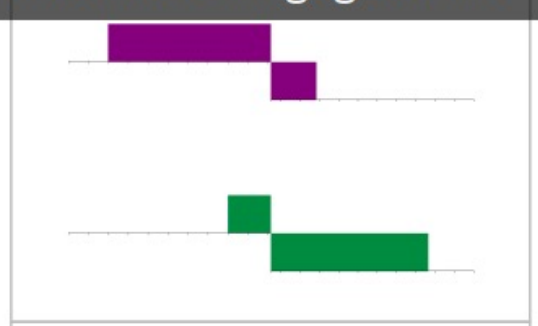
Retrospective Reflection on Data, Value, Action

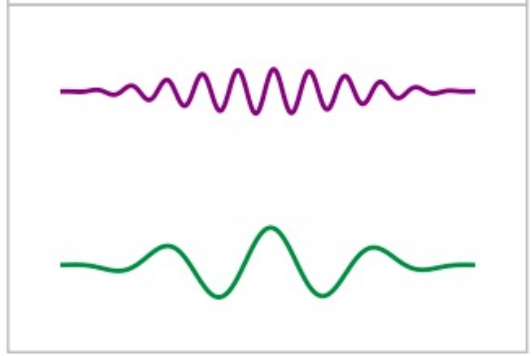
Sun, Z., Wang, S., Yang, W., Yürüten, O, Shi, C., and Ma, X. (2020). "A Postcard from Your Food Journey in the Past": Promoting Self-Reflection on Social Food Posting. In *Proc. DIS2020*.

Sun, Z., Reani, M., Li, Q., and Ma, X. (2020). Fostering Engagement in Technology-Mediated Stress Management: A Comparative Study of Biofeedback Designs. *International Journal of Human-Computer Studies (IJHCS)*. 102430.

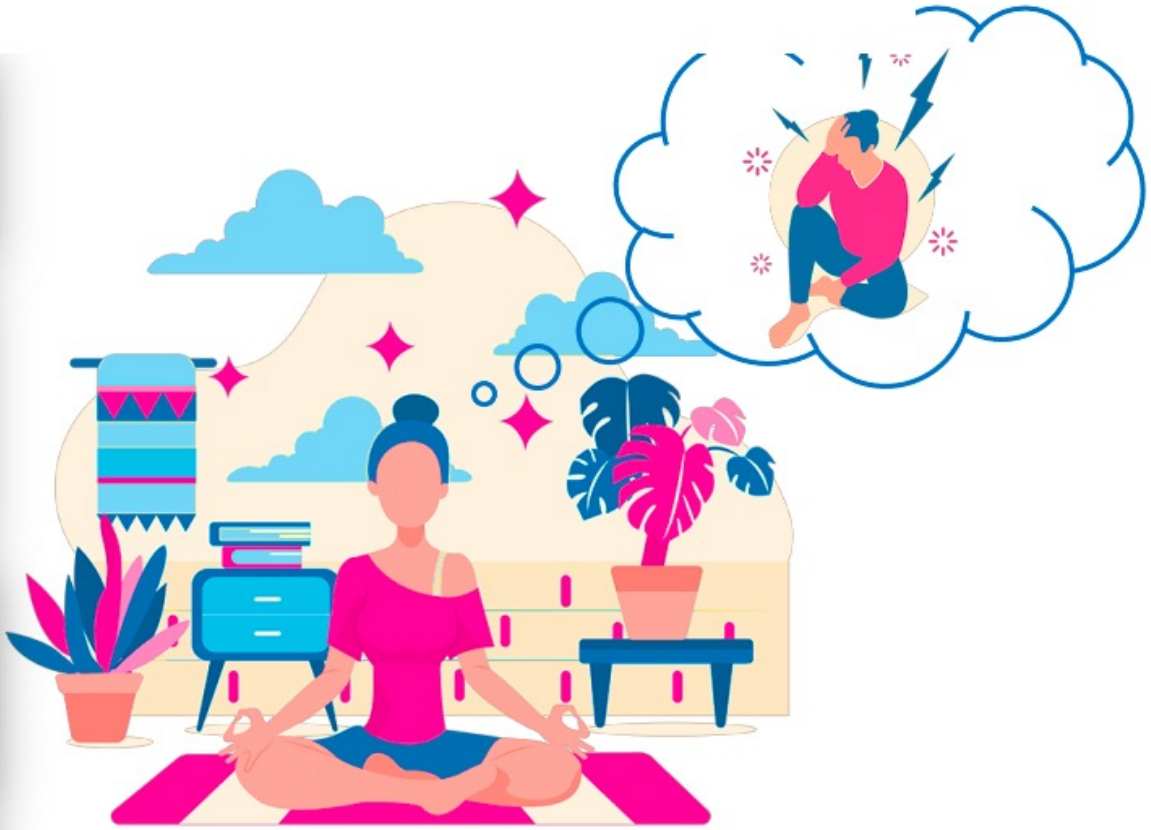


Introspective Reflection on Realtime Engagement



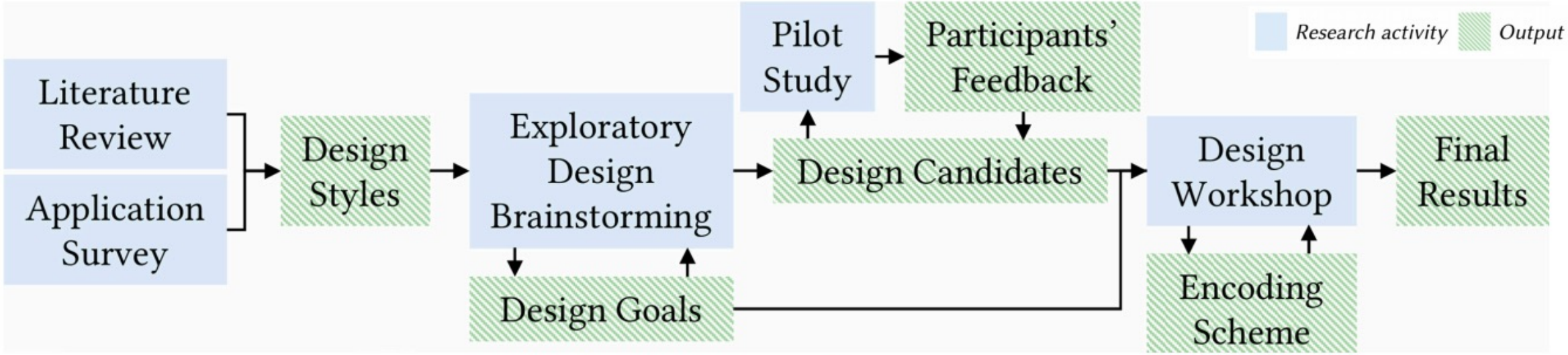


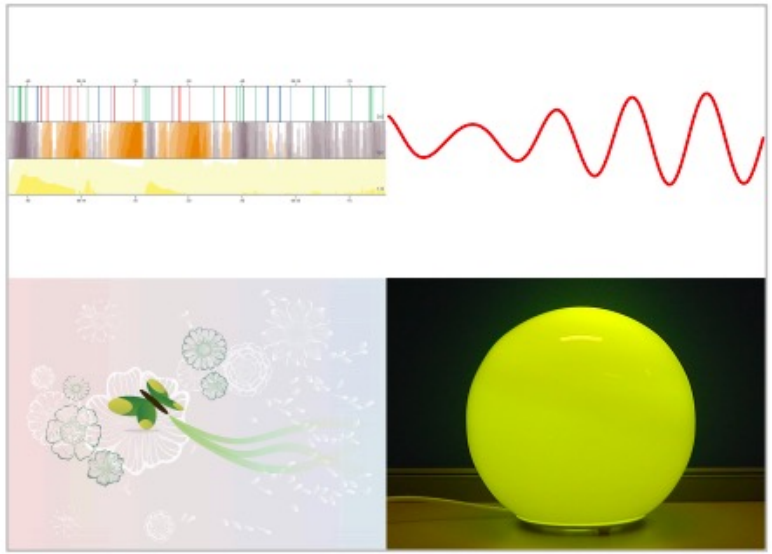
“What would be a proper visual design for on-the-fly stress management exercise?”



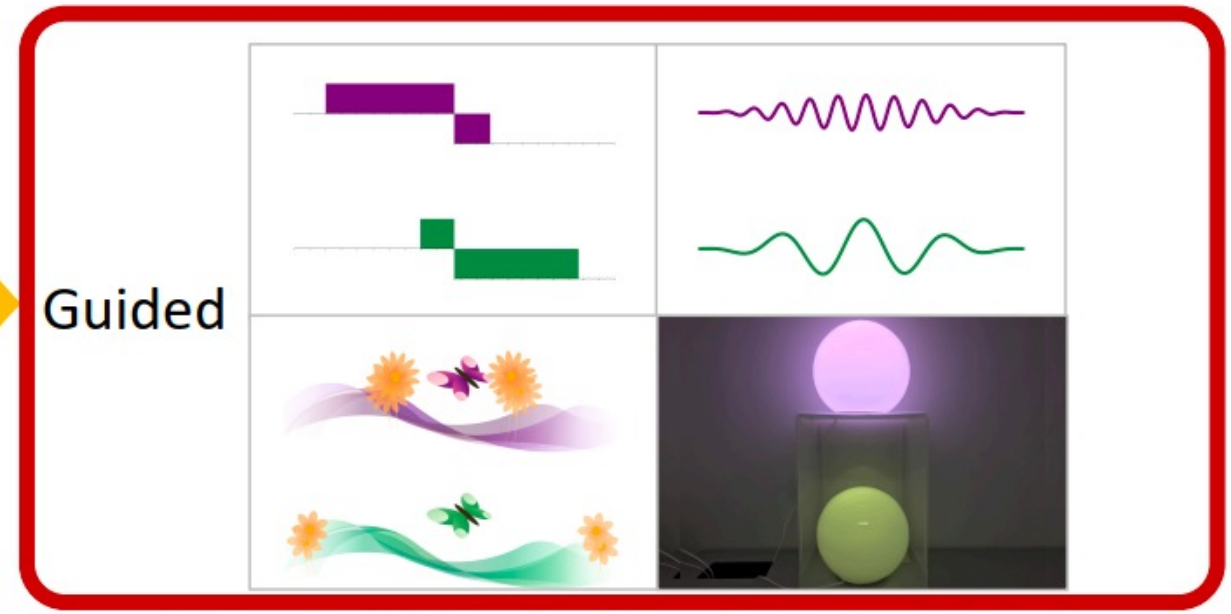
Engaging and Non-judgmental

Image source: https://www.anahana.com/wellness-resources/breathing-exercise





Self → Guided



Sun, Z., Cao, N. and Ma, X., 2017, May. Attention, comprehension, execution: effects of different designs of biofeedback display. In *Proceedings of the 2017 CHI Conference Extended Abstracts on Human Factors in Computing Systems* (pp. 2132-2139).

https://zhdsun.github.io/projects/pdr/

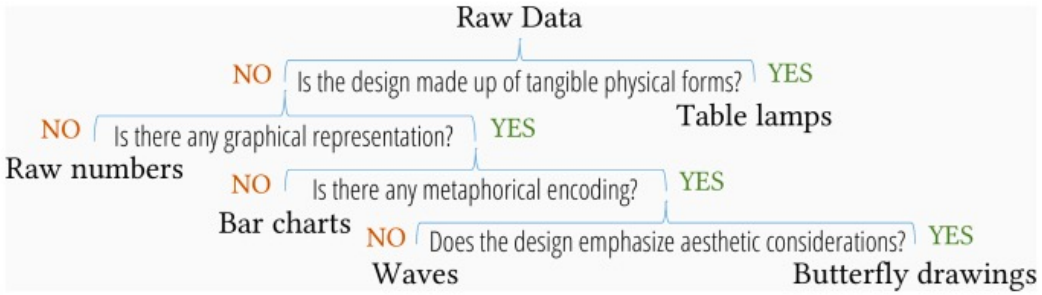
Sun, Z., Reani, M., Li, Q., and Ma, X. (2020). Fostering Engagement in Technology-Mediated Stress Management: A Comparative Study of Biofeedback Designs. *International Journal of Human-Computer Studies (IJHCS).* 102430.

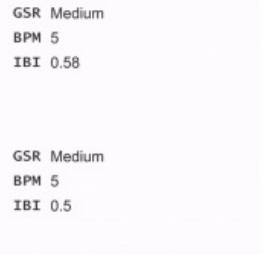
https://zhdsun.github.io/projects/bdr/

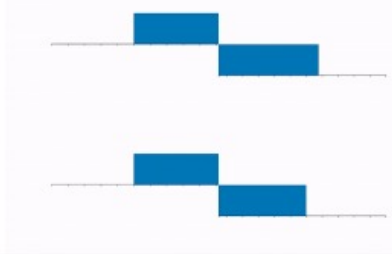
Galvanic skin response (**GSR**): Ordinal (low, medium, high)
Beats per Minute (**bpm**): Continuous (integer)
Inter-Beat Interval (**IBI**): Continuous (floating)

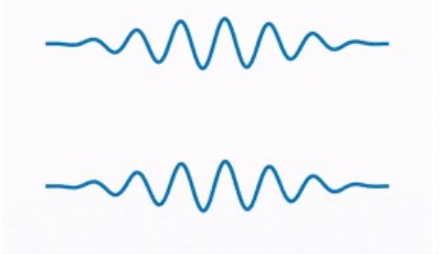
Name	Examples	Name	Examples
Color Luminance/Brightness		Color Hue	
Color Saturation		Rhythm/Frequency	
Length (1D size)		Countable object (Numerosity)	
Area (2D size)		Text content	Low Medium High
Number	1.1 1.2 1.3 1.1	Icon/Shape	
Tilt/Angle		Spatial region	
Curvature		Symbol/Metaphor	
Transparency		Texture/Pattern	

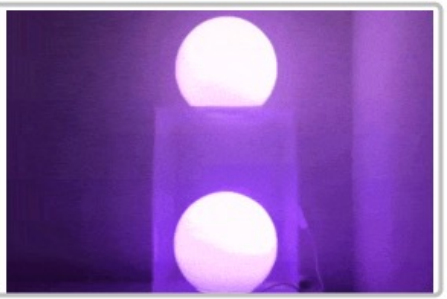
Name	Design Choices	Categorical Data	Discrete Data	Continuous Data
Bar charts	Bar chart	The color of the bar	The length of the left bar	The length of the right bar
Waves	A single sine wave	The color of the wave	The number of complete sine waves	The amplitude of the wave
Butterfly drawings	A butterfly with flowery background	The color of the butterfly	The size of the flowers	The horizontal position of the flowers
Table lamps	Multi-color lighting	Color hue	Brightness	Color saturation

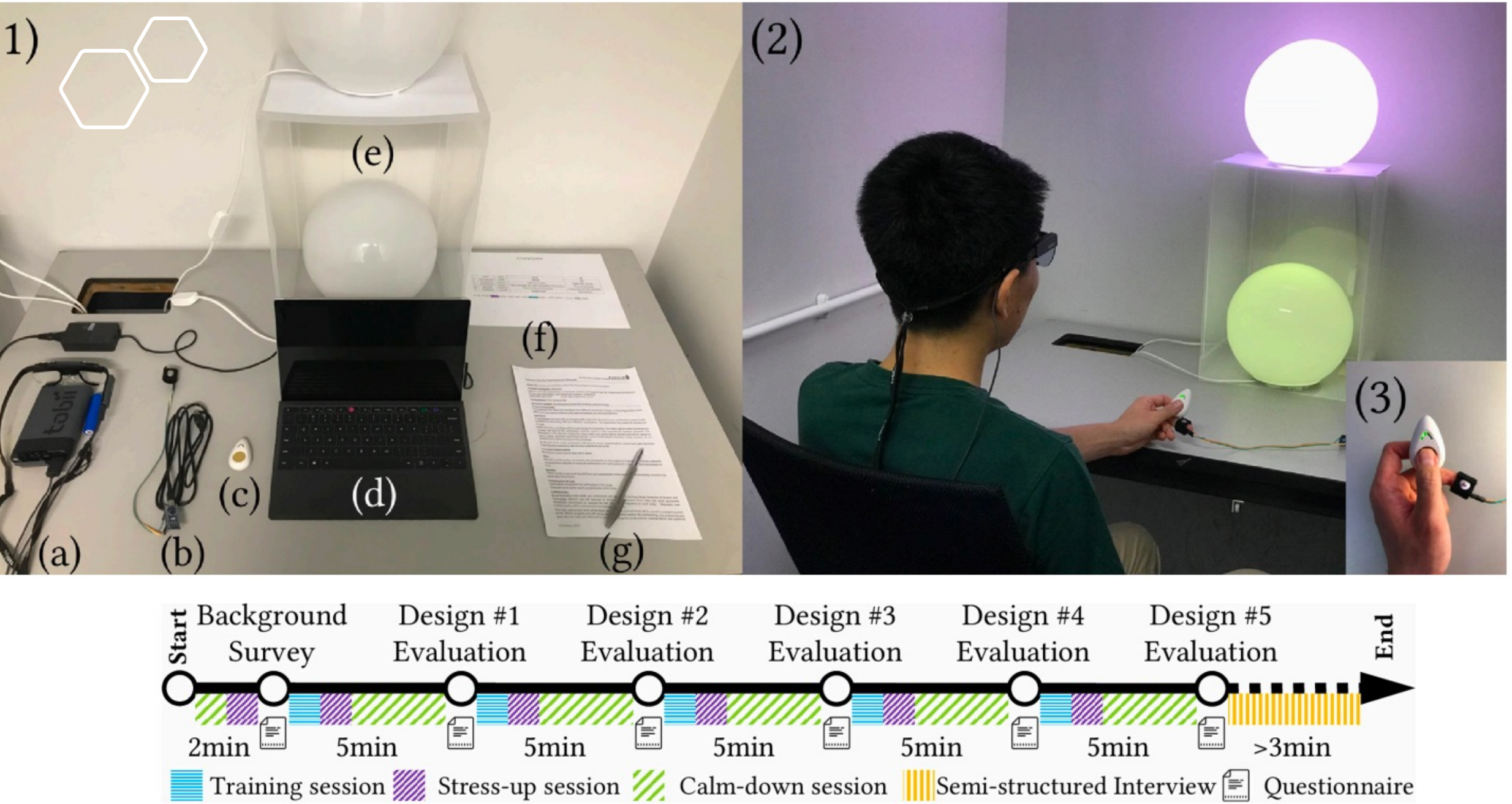










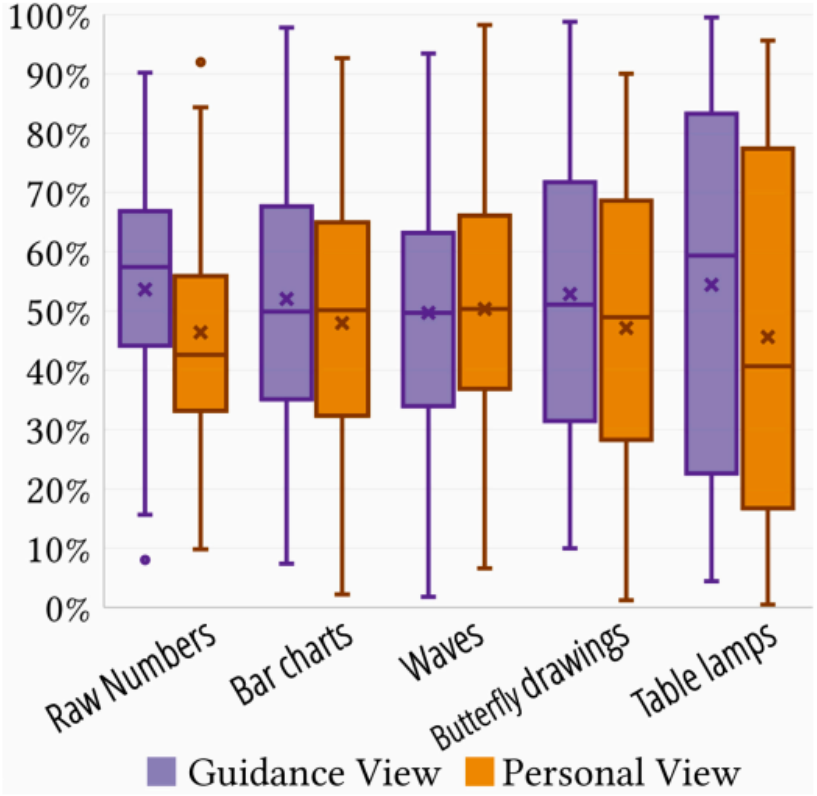

1)
(a)
(b)
(c)
(d)
(e)
(f)
(g)
(2)
(3)
Start
Background Survey
Design #1 Evaluation
Design #2 Evaluation
Design #3 Evaluation
Design #4 Evaluation
Design #5 Evaluation
End
2min
5min
5min
5min
5min
5min
>3min
Training session
Stress-up session
Calm-down session
Semi-structured Interview
Questionnaire

Perceived Engagement

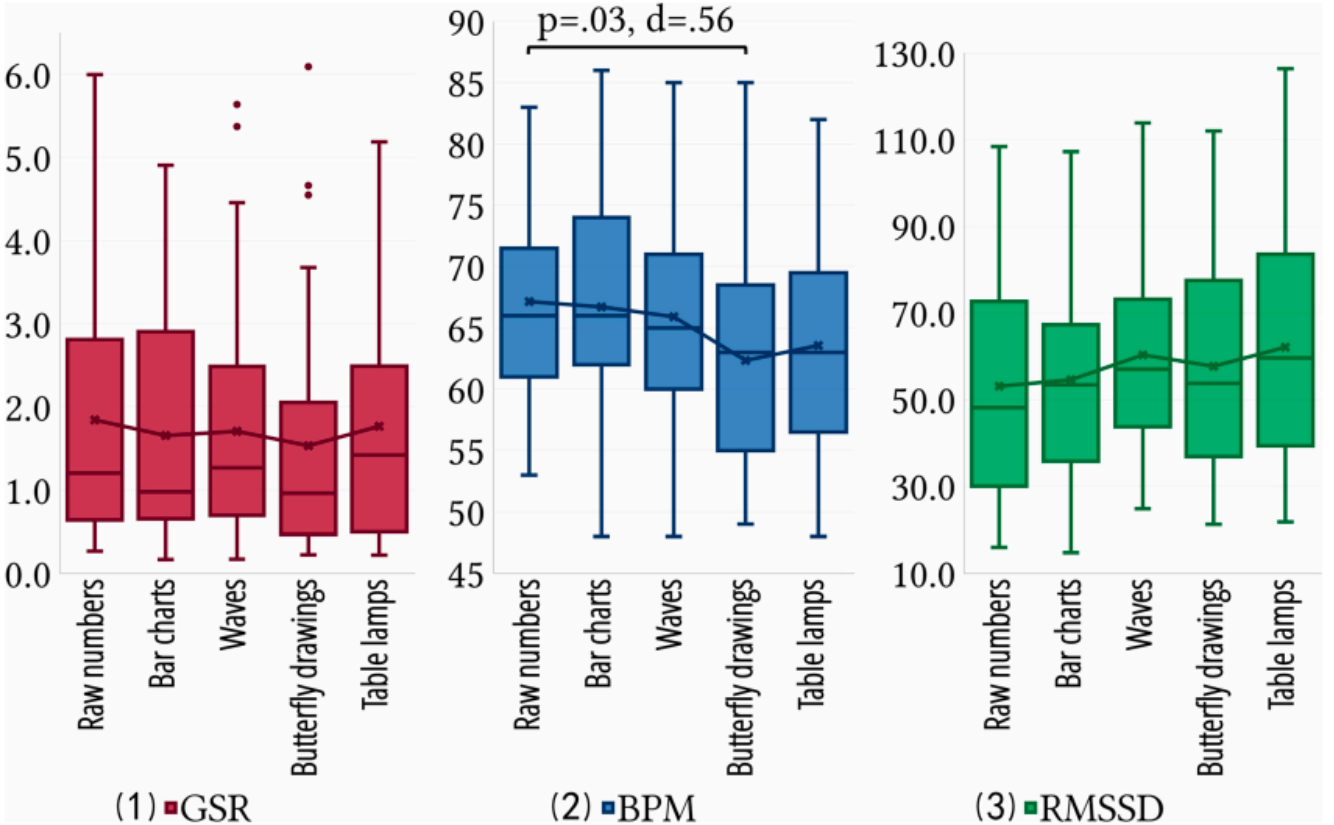
(Friedman's ANOVA test)

Attributes	M_N		M_C		M_W		M_B		M_L	df	χ^2	p	W
Perceived usability	3.49		3.37		3.69		3.31		3.20	4	4.34	4.339	0.03
Aesthetics	1.97	<	2.69	<	3.57	<	4.31	=	4.17	4	86.32	<0.001	0.62
Novelty	2.49	<	2.74	<	3.46	<	4.20	=	4.23	4	63.29	<0.001	0.45
Focused attention	2.80	=	3.09	<	3.69	=	3.86	=	3.94	4	31.61	<0.001	0.23
Felt involvement	2.37	<	2.77	<	3.74	=	4.09	=	4.17	4	61.57	<0.001	0.44
Endurability	2.71	=	3.06	<	3.57	=	3.57	=	3.77	4	26.96	<0.001	0.19

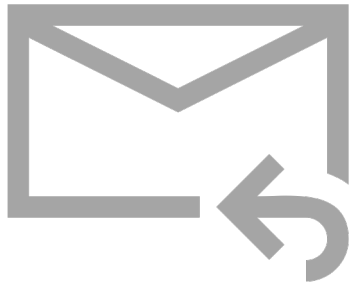
Gaze Behavior



Stress Management



Questions?
Thank you ☺



Quan Li

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