

Communicating with Data – Perception and Color

Dr. Ab Mosca (they/them)

Slides based off slides courtesy of Jordan Crouser (<https://jcrouser.github.io/>)

Plan for Today

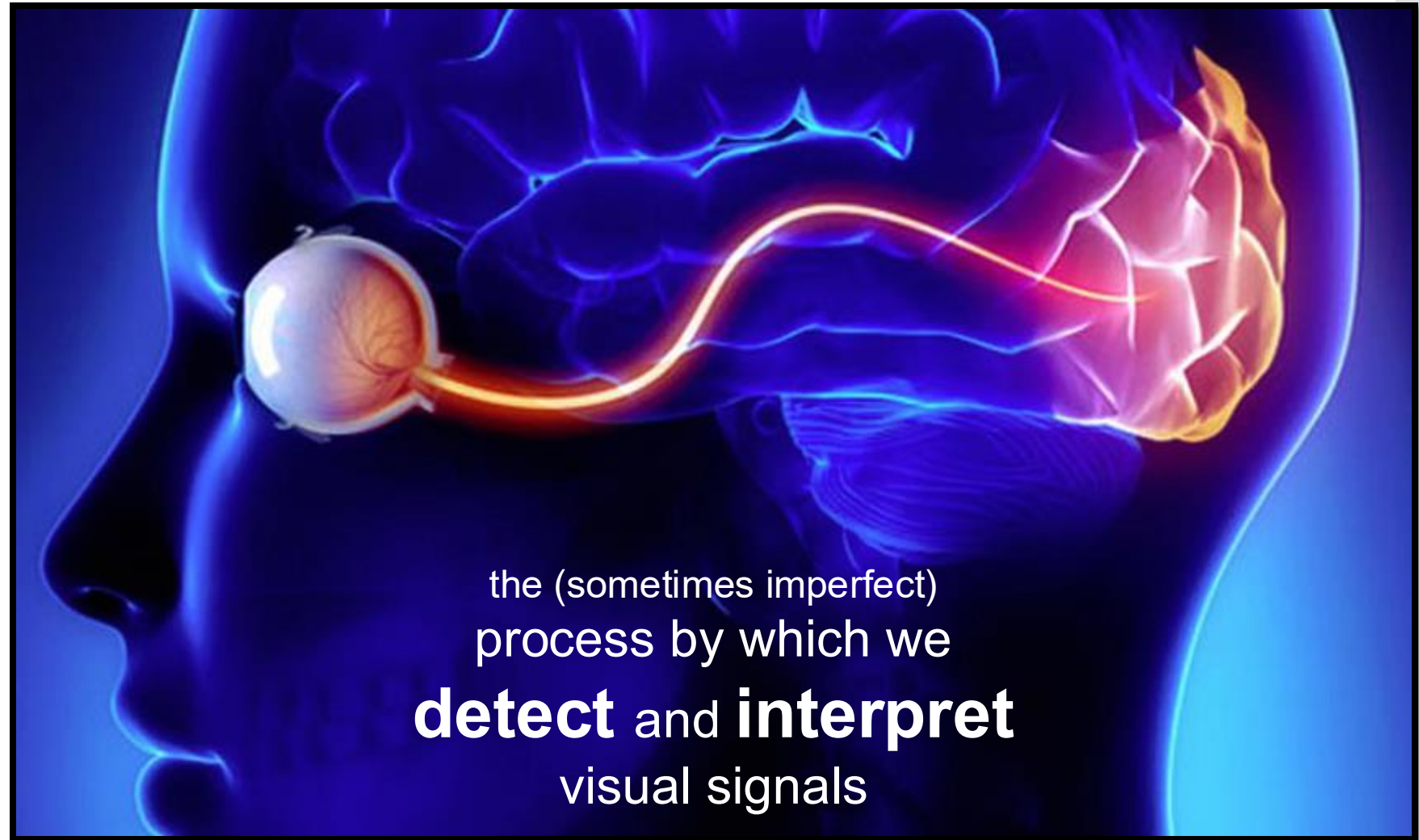
- What is perception?
 - How does it work?
 - Pre-attentive processing
 - Gestalt Psychology
 - Attentive processing
- Color 101
 - How we see color
 - What this means for visualization
 - More perceptual problems
- Takeaways

Note: I'm going to flash a bunch of slides quickly today. If that doesn't work for you, you are welcome to step out, close your eyes, etc.. (none of us will be offended and I will fill you in on anything crucial you missed!)

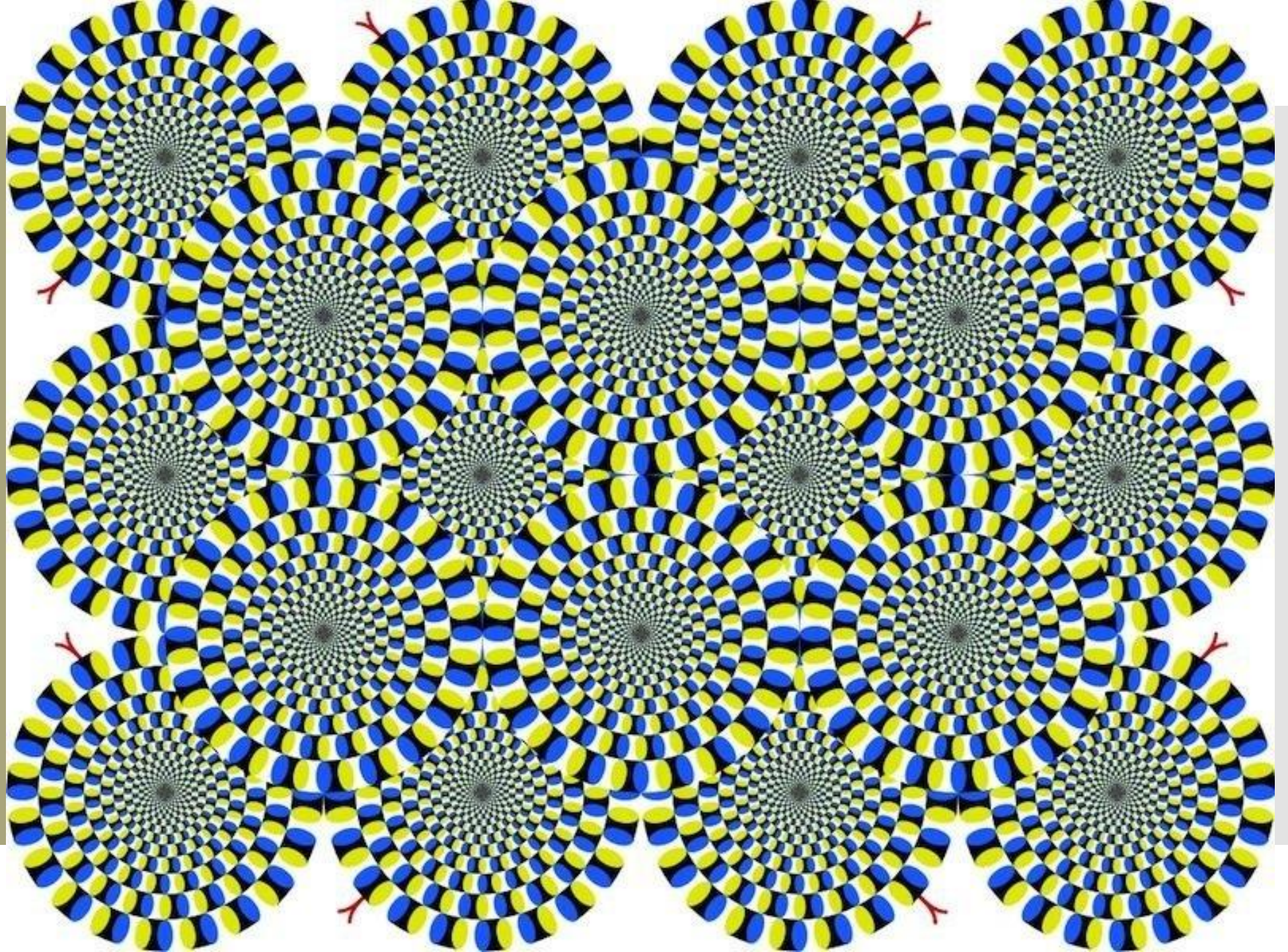
What is
perception?



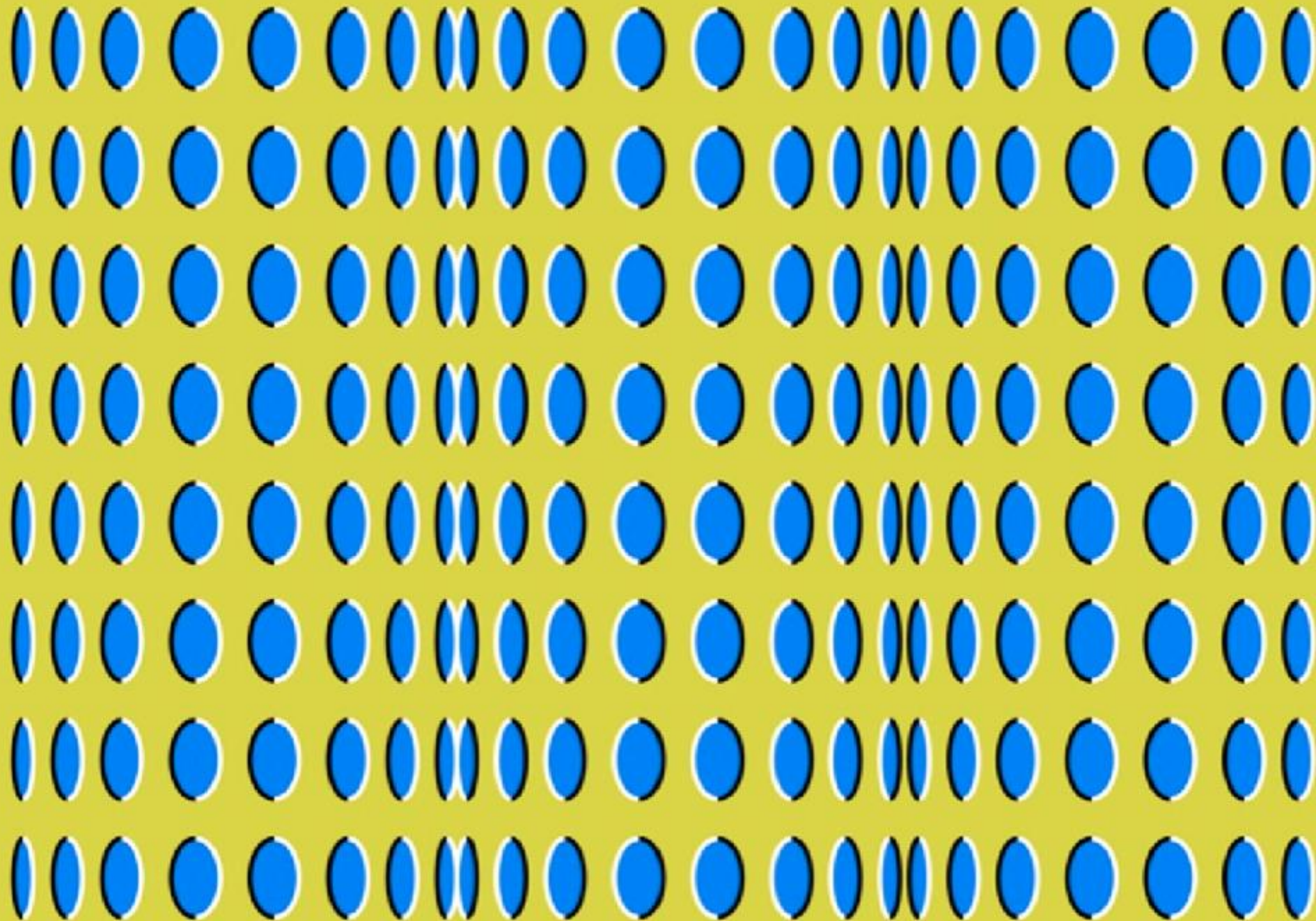
Visual perception (def.)



Do you see
movement?

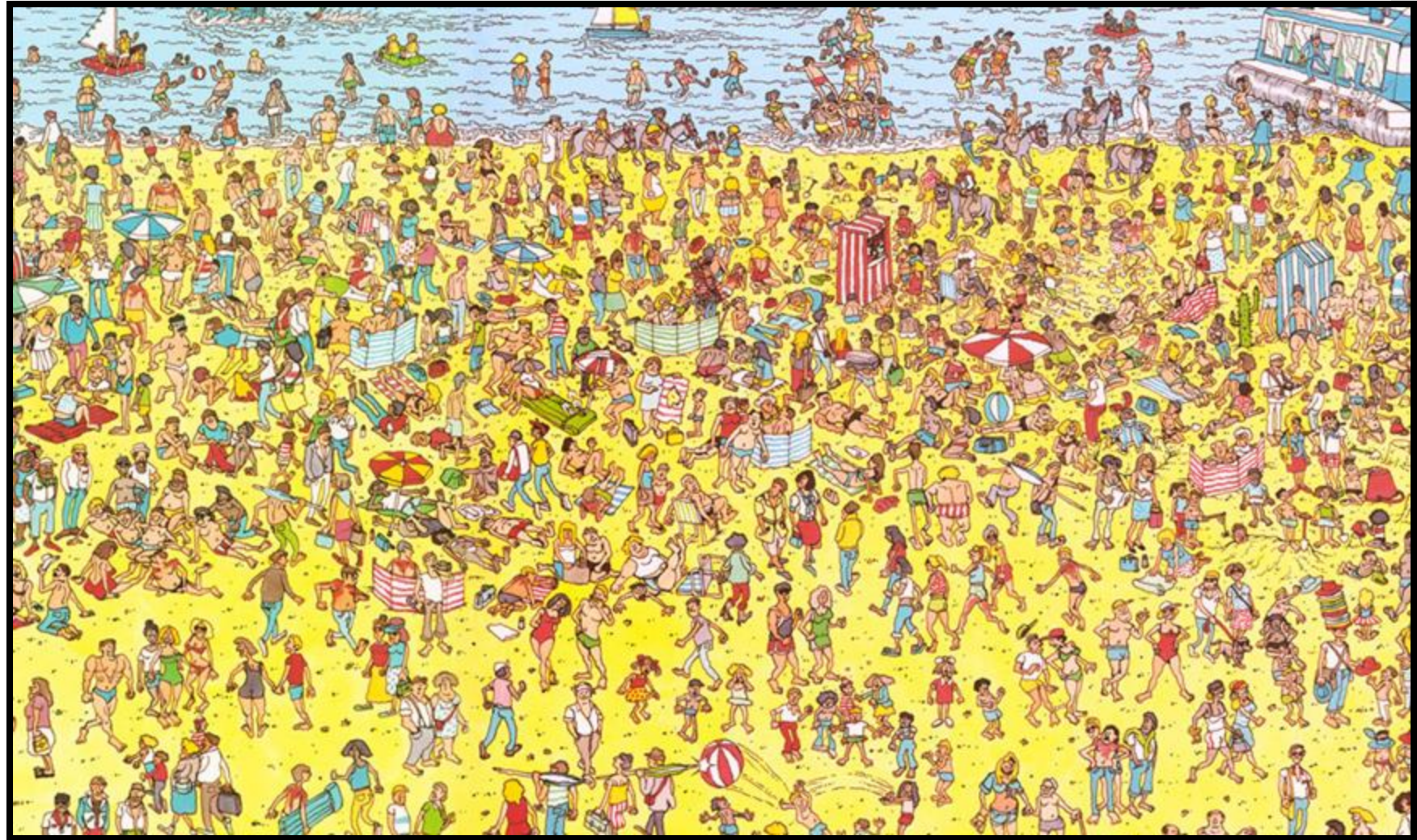


Do you see
movement?



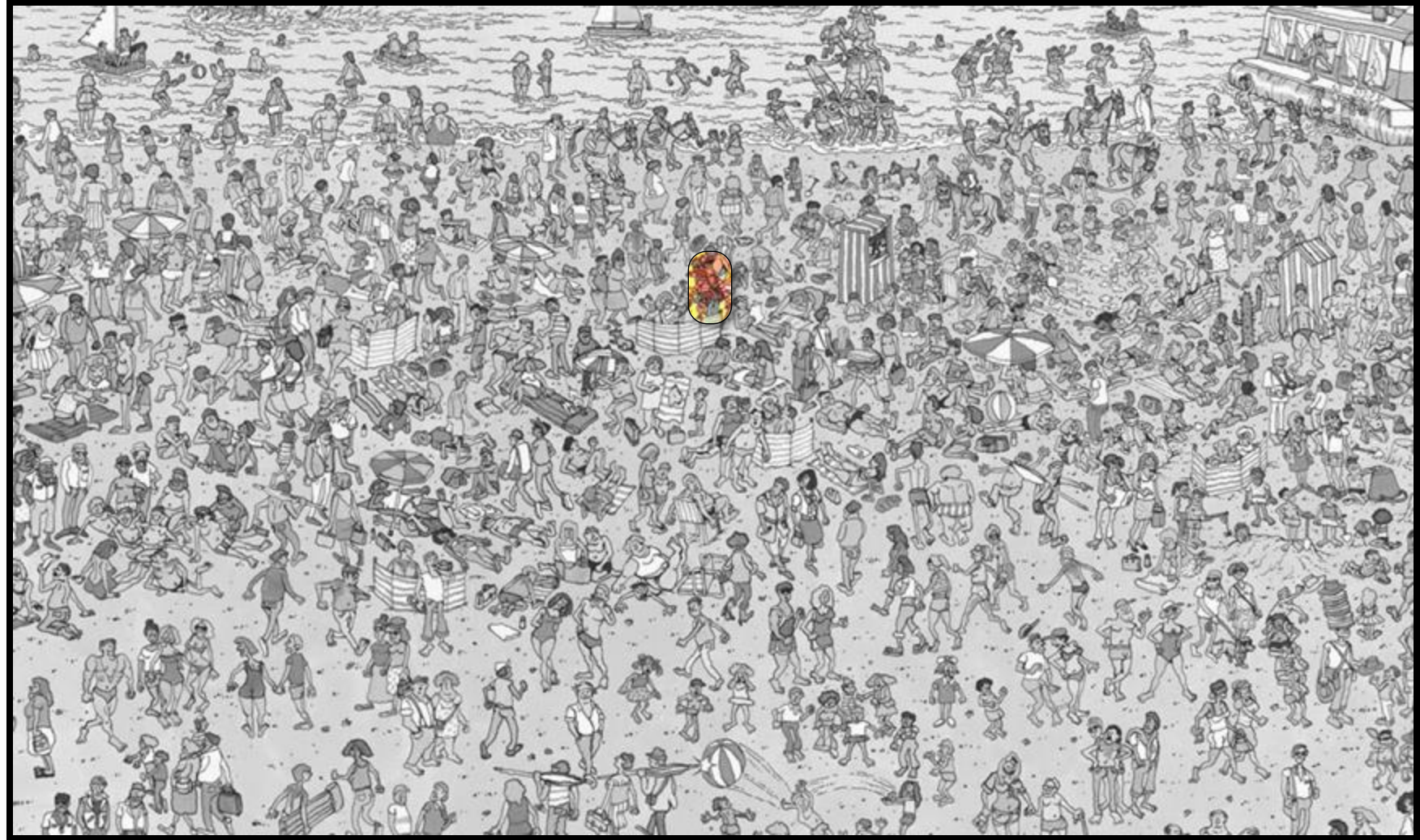
Visual perception

Some things are processed slowly



Others are incredibly fast

Visual
perception

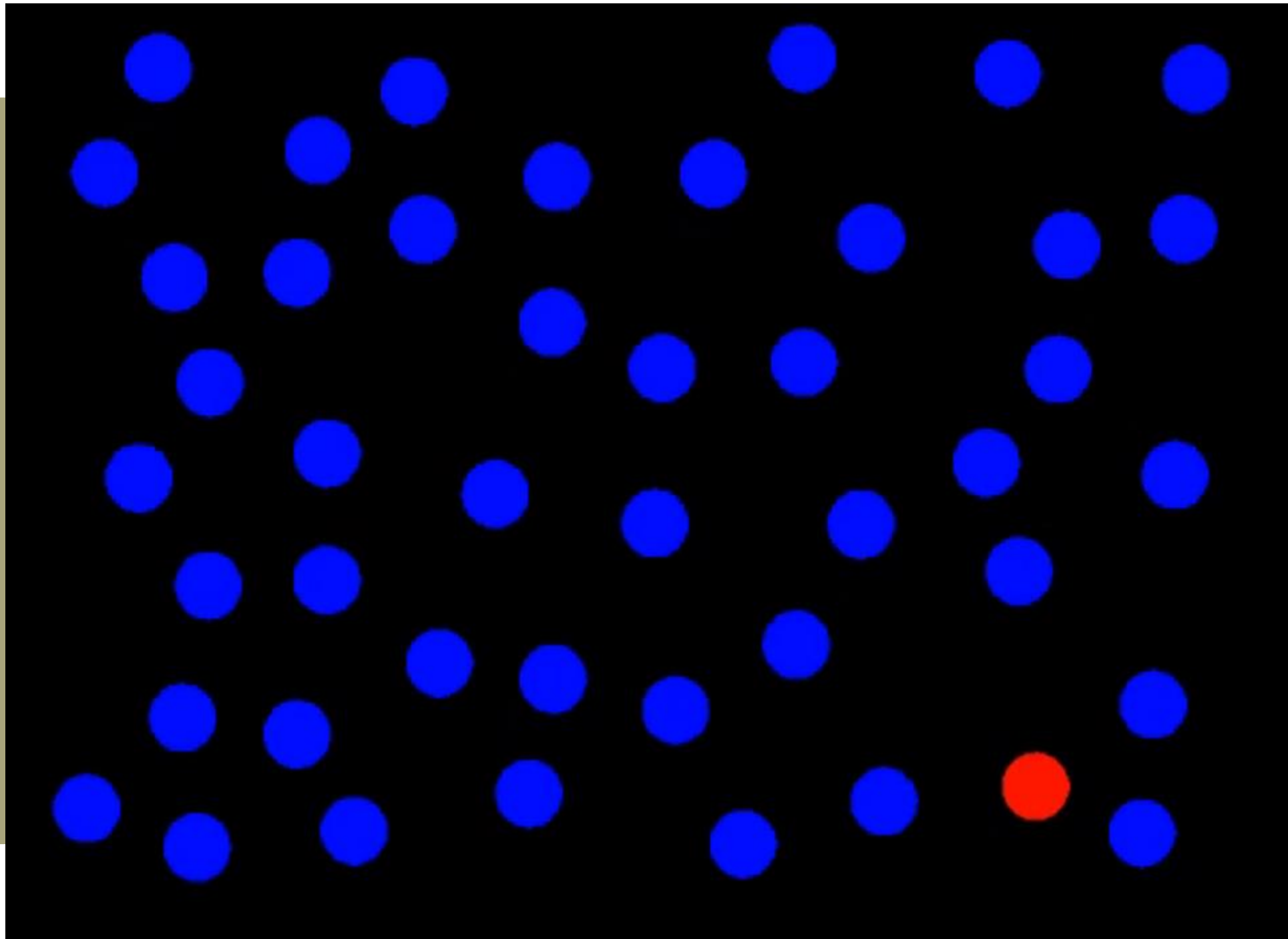


Pre-attentive processing

Fast = “pre-attentive processing”

- Things that happen in <200ms of visual stimulation
- Performed in parallel across the entire visual field
- Example...

Pre-attentive
processing



What did you see?

Pre-attentive
processing



Pre-attentive processing

“An understanding of what is processed pre-attentively is probably the **most important** contribution that visual science can make to data visualization” (Ware, 2004, p. 19)

Pre-attentive processing facilitates:

- Target detection (presence or absence)
- Boundary detection / grouping
- Region tracking
- Counting and estimation

Pre-attentive processing facilitates:

- Target detection (presence or absence)
 - Boundary detection / grouping
 - Region tracking
 - Counting and estimation
-
- On the next slide I want you to count how many zeros you see as fast as you can. Raise your hand (do not shout the number) when you have the answer.

Attentive counting

1281768756138976546984506985624982826762
9809858458224519856458945098459985943585
9891330249945959595772564675750678974567
8845789819821677654876364968560912949686

How many zeros are there?

Attentive
counting

We'll do the same on the next slide for threes.

Pre-attentive counting

12817687561**3**8976546984506985604982826762
980985845822450985645894509845098094**3**585
90910**3**0209905959595772564675050678904567
8845789809821677654876**3**64908560912949686

How many threes are there?

Pre-attentive processing for visualization

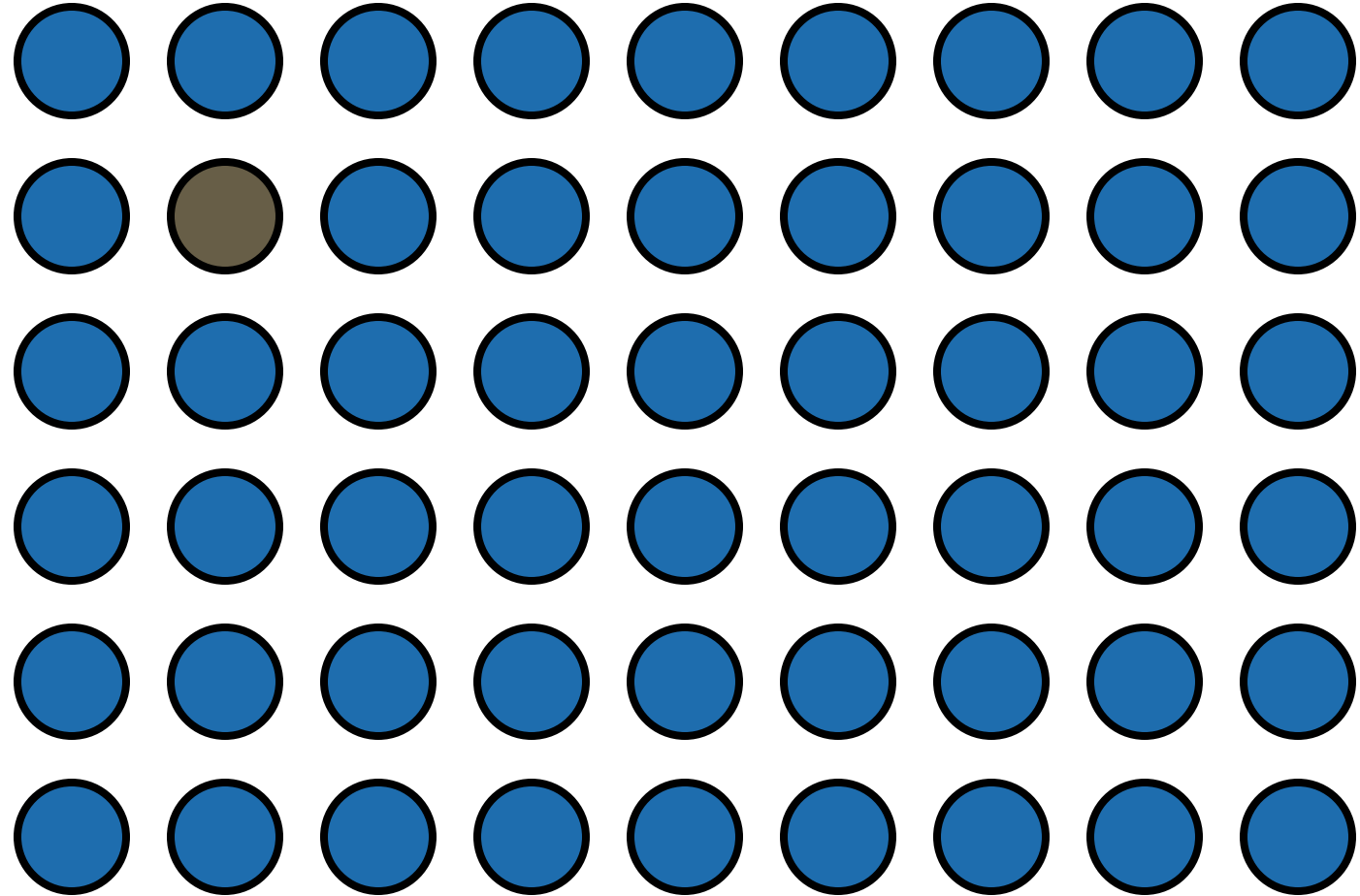
Question 1: how do we (vis designers) use pre-attentive processing to our advantage?

Question 2: what do we need to watch out for?

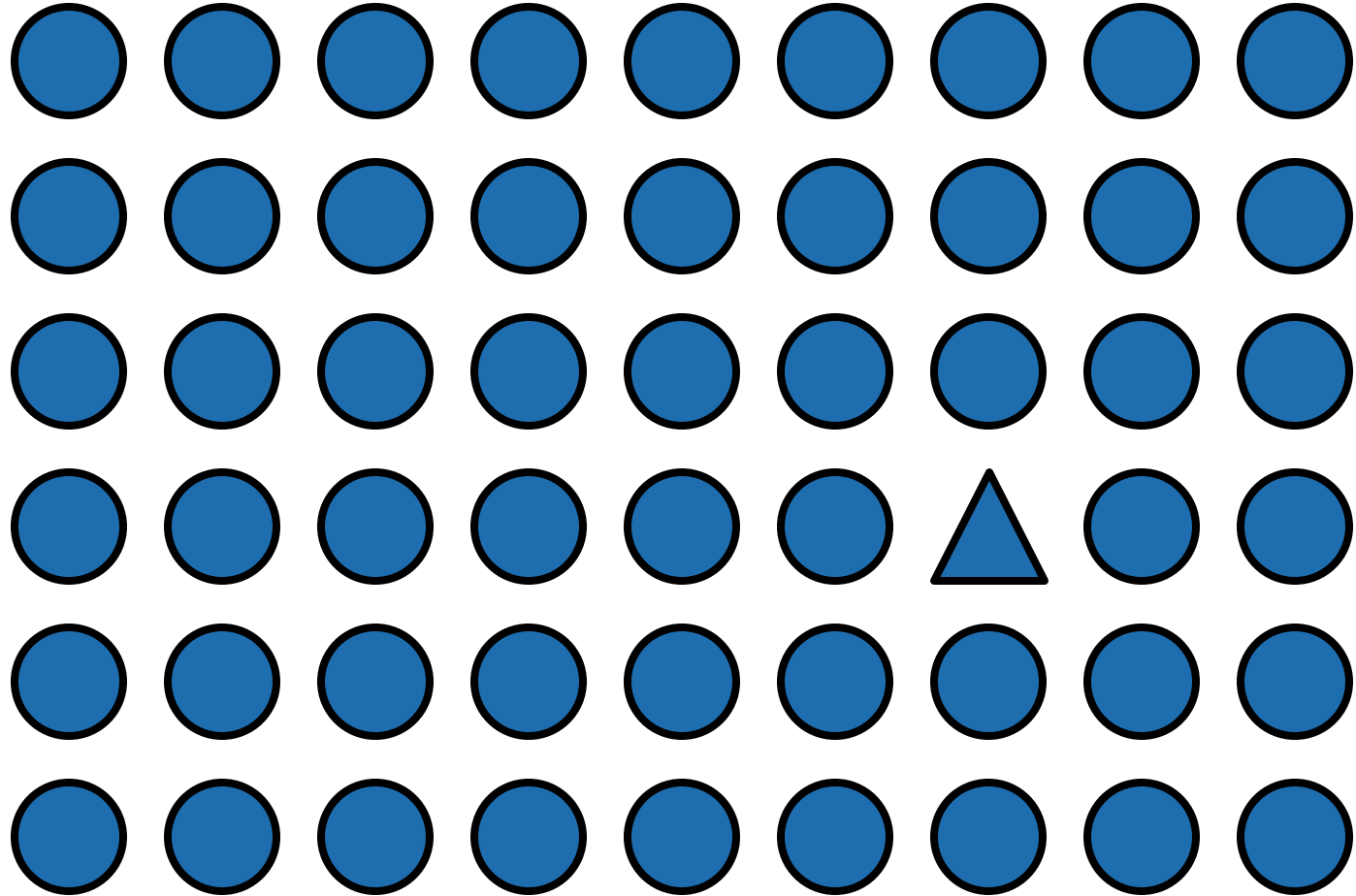
Pre-attentive processing for visualization

There's only one instance of something on each of the next slides. What is it?

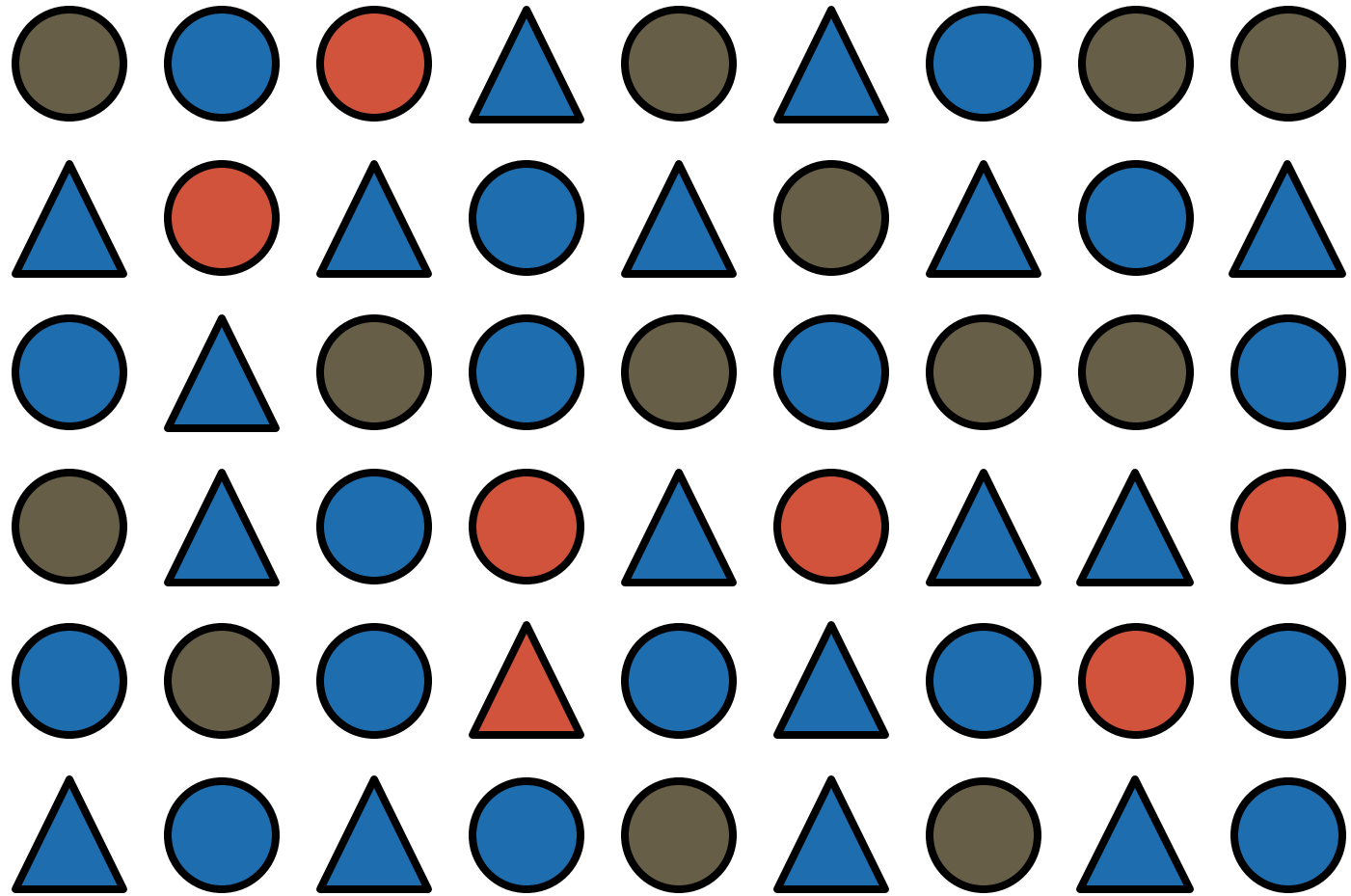
Pre-attentive
processing:
hue



Pre-attentive
processing:
shape
(curvature)



Pre-attentive
processing:
shape + hue?



Discussion:
what's going
on here?

Answer: this is called “conjunction”

- If you search for **red** things, you get a bunch of **red** circles (as well as the **red triangle**).
- Similarly, if you search for **triangles**, you get a bunch of **blue triangles** (as well as the **red triangle**).
- Either way, you have to search through them all one by one!

Pre-attentive processing for visualization

For each of the next slides, is there a boundary (i.e. are there multiple regions)? If yes, what are the regions?

Pre-attentive
processing:
hue

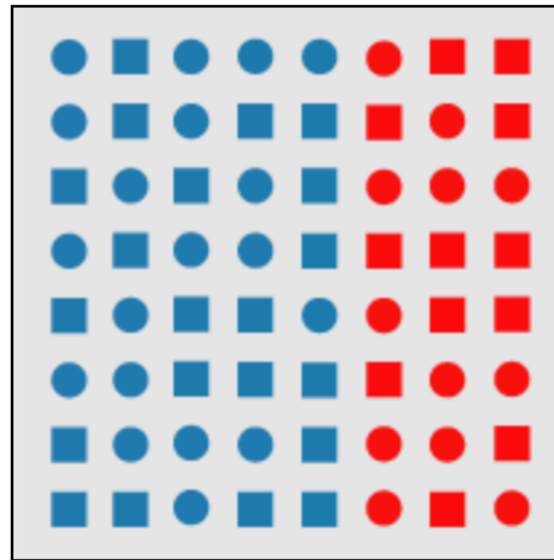
Pre-attentive
processing:
shape
(curvature)

Pre-attentive
processing:
hue + shape

Discussion:
what's going
on here?

Answer: this is called “feature hierarchy”

- During boundary detection, the visual system favors hue over shape



(b)

Pre-attentive processing for visualization

- Whatever draws our eyes draws our attention
- This can be useful
- It can also be problematic:

Pre-attentive
processing for
visualization:
The downsides

Ex. flicker can cause change blindness



The “gestalt effect”

ge·stalt

/gə 'SHtält,- 'SHtôlt/

noun PSYCHOLOGY

an organized whole that is perceived as more than the sum of its parts.

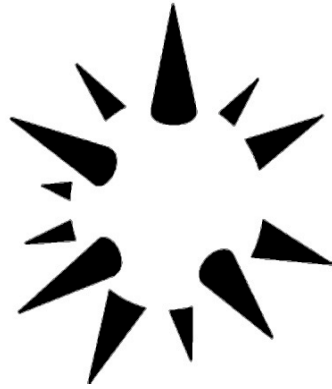


Translations, word origin, and more definitions

Our brain's ability to generate whole forms, instead of just collections of unrelated elements

Gestalt effects

Reification



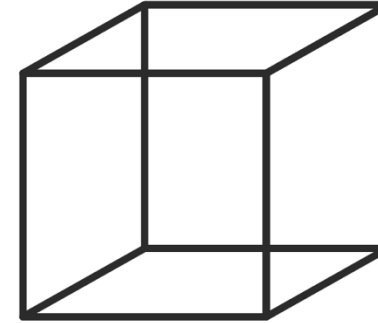
Demonstration of reification in perception from Lehar S. (2003) The World In Your Head, Lawrence Erlbaum, Mahwah, NJ. p. 52, Fig. 3.3

Emergence



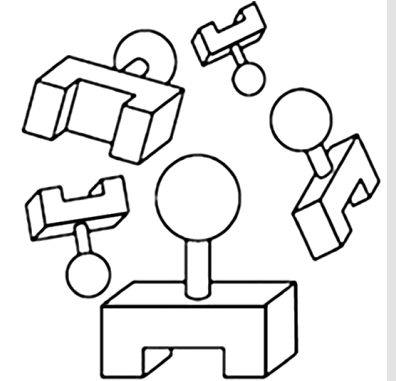
<https://www.interaction-design.org/literature/topics/gestalt-principles#docs-internal-guid-f7074e47-7fff-b4dc-f0f5-966e09f6b4e7>

Multistability



<https://www.interaction-design.org/literature/topics/gestalt-principles#docs-internal-guid-f7074e47-7fff-b4dc-f0f5-966e09f6b4e7>

Invariance

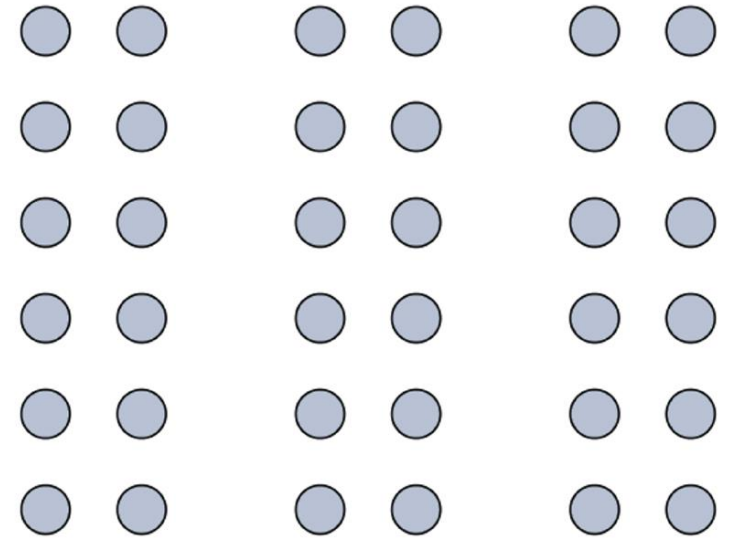
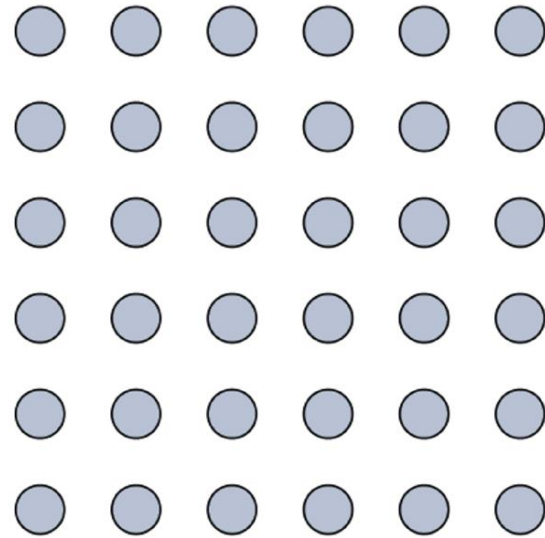


Demonstration of invariance in perception from Lehar S. (2003) The World In Your Head, Lawrence Erlbaum, Mahwah, NJ. p. 53, Fig. 3.5

→ 6 “Laws of Grouping”

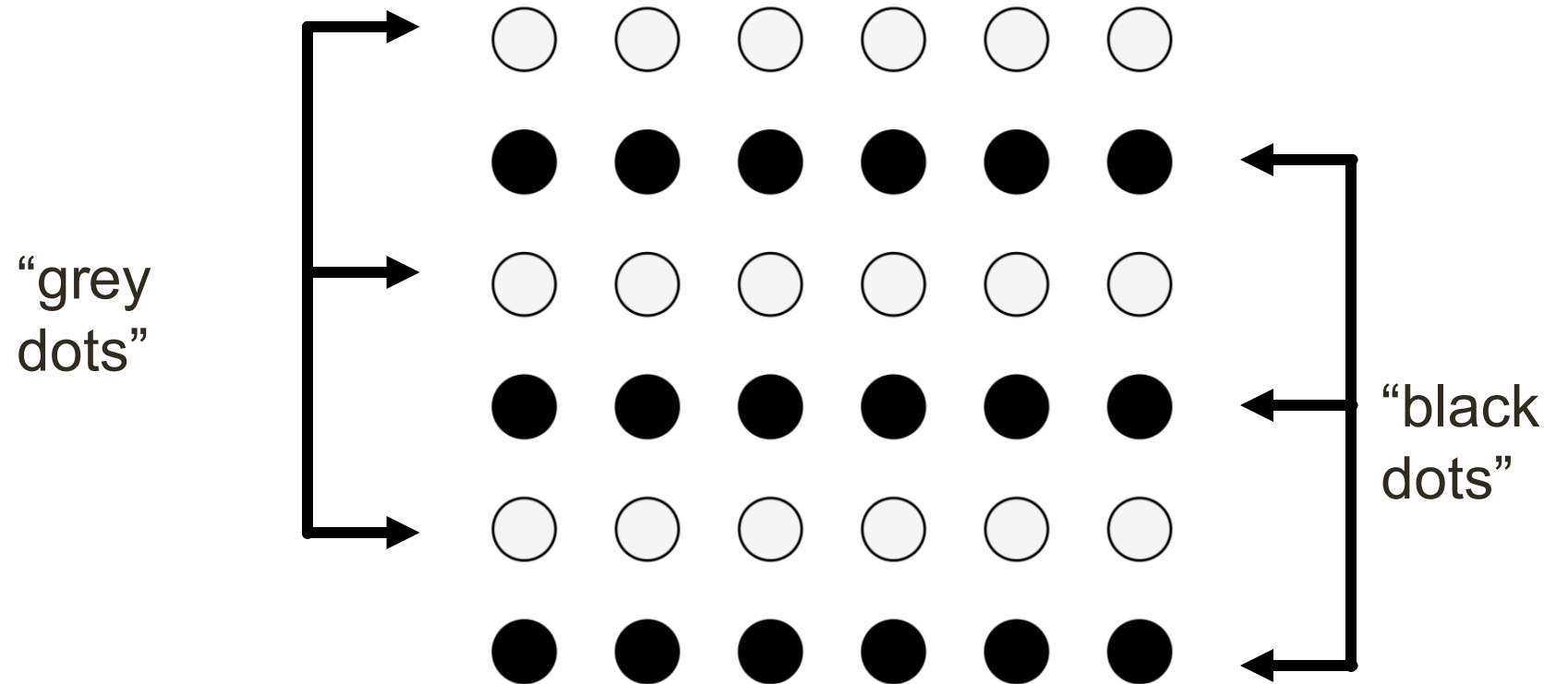
Law of Proximity

We interpret objects that are **close** to each other as a group



Law of Similarity

We interpret objects that are **visually similar** to each other as a group



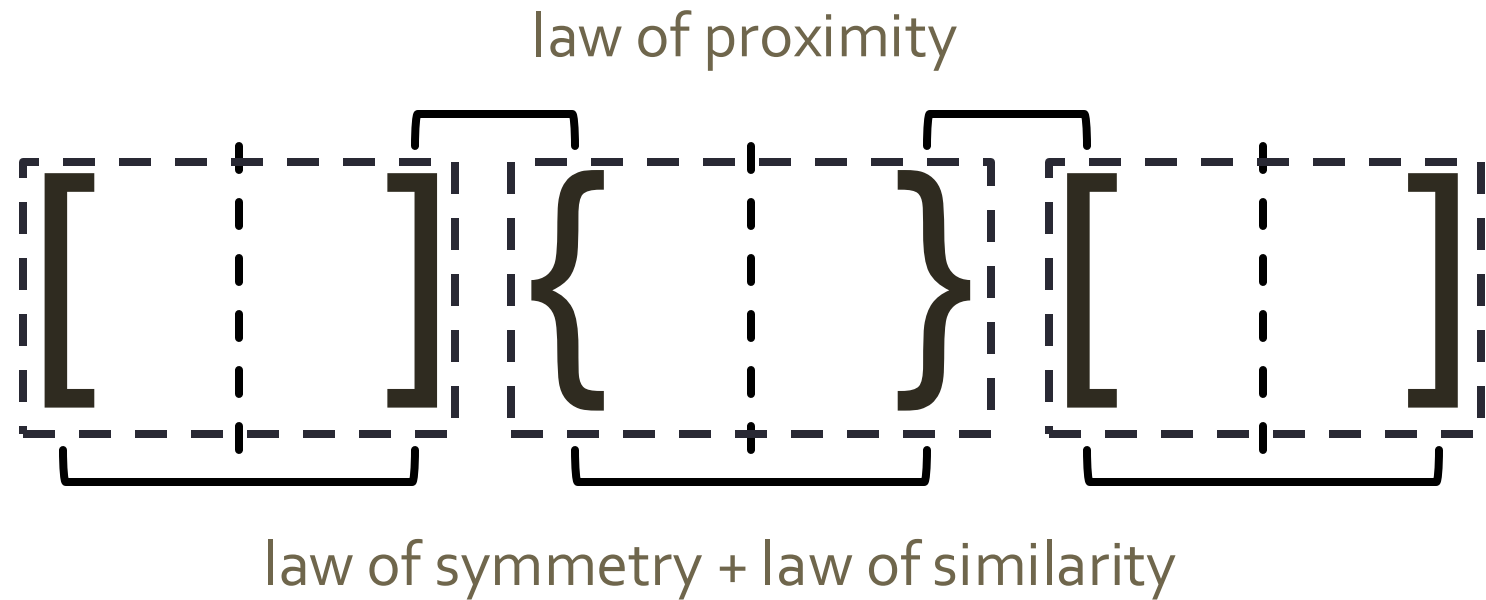
Law of Closure

When parts of a picture are missing, we fill in the visual gap



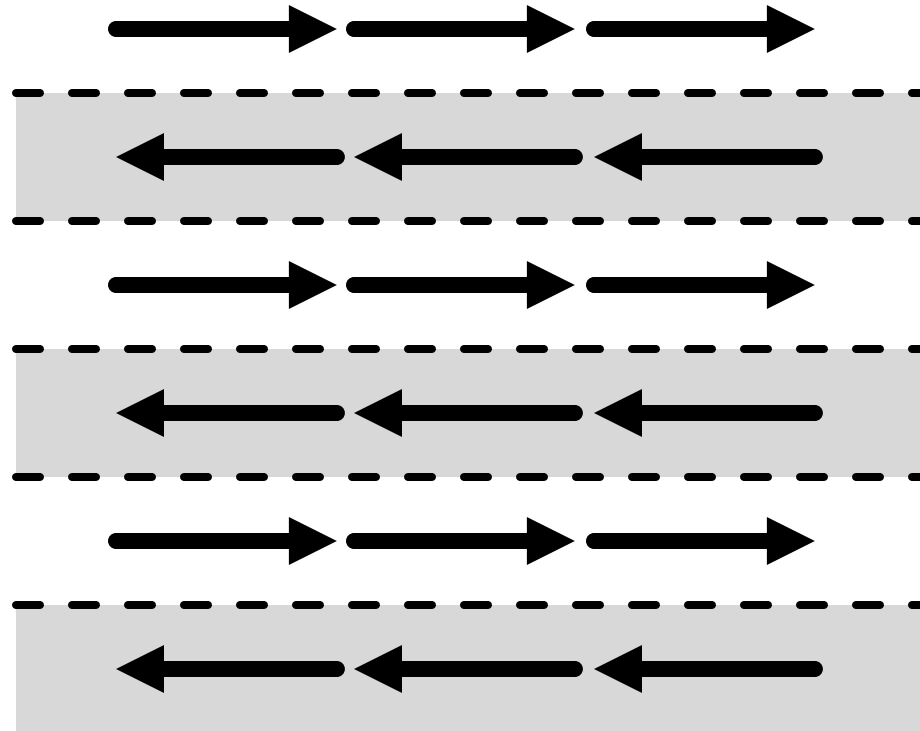
Law of Symmetry

We perceive objects as being symmetrical, arranged around a center point



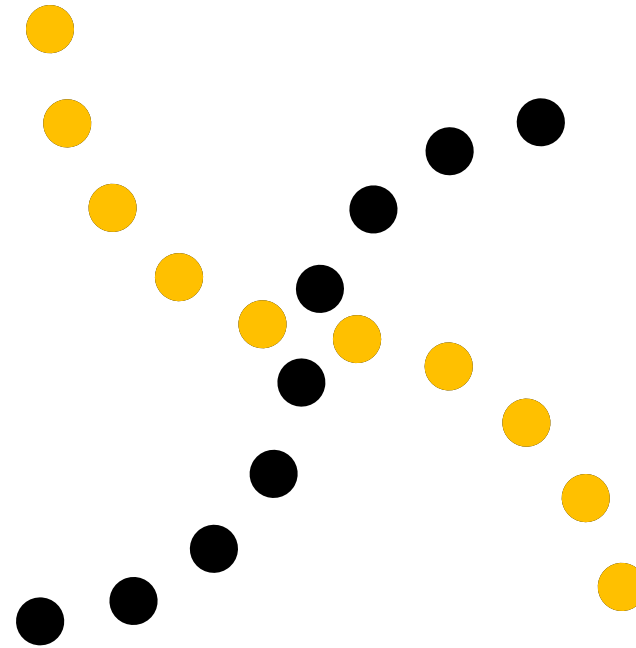
Law of Common Fate

We group objects that we perceive to be moving along the same path



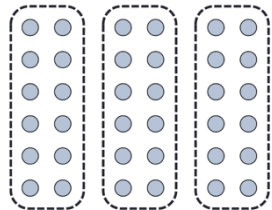
Law of Continuity

We tend to group objects along the **smoothest path**

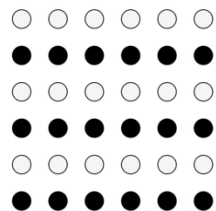


Let's Practice ~10 minutes

- Break into teams of 3
- Choose a visualization from the Tableau Vis of the Day collection: <https://public.tableau.com/app/discover/viz-of-the-day>
- **Goal:** identify as many examples of the Laws of Grouping (Gestalt Principles) in action in your sample visualization as you can
- Be prepared to present your findings to the class



proximity



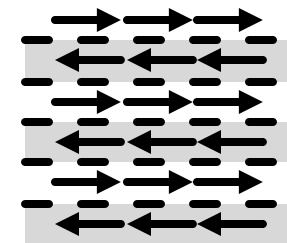
similarity



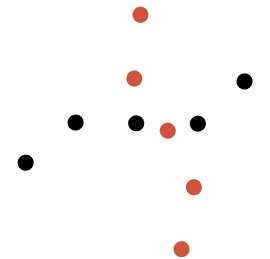
closure



symmetry



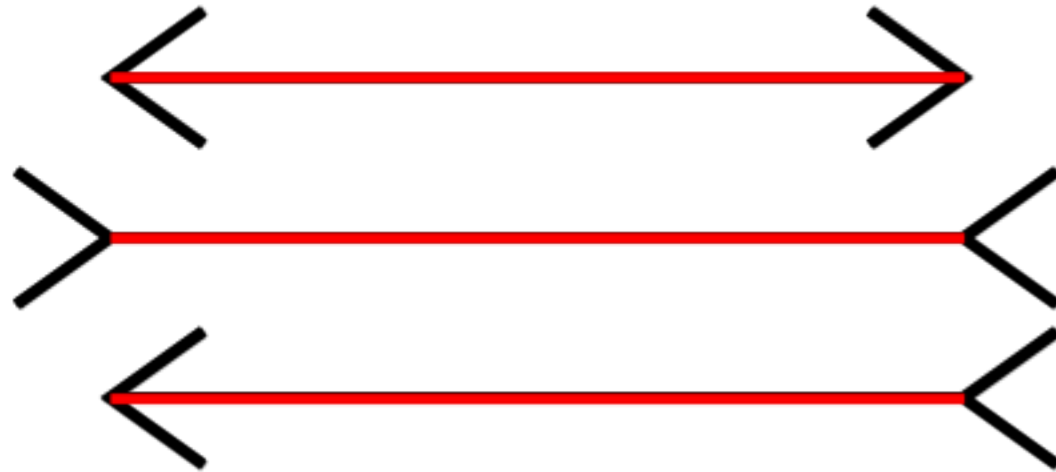
common fate



continuity

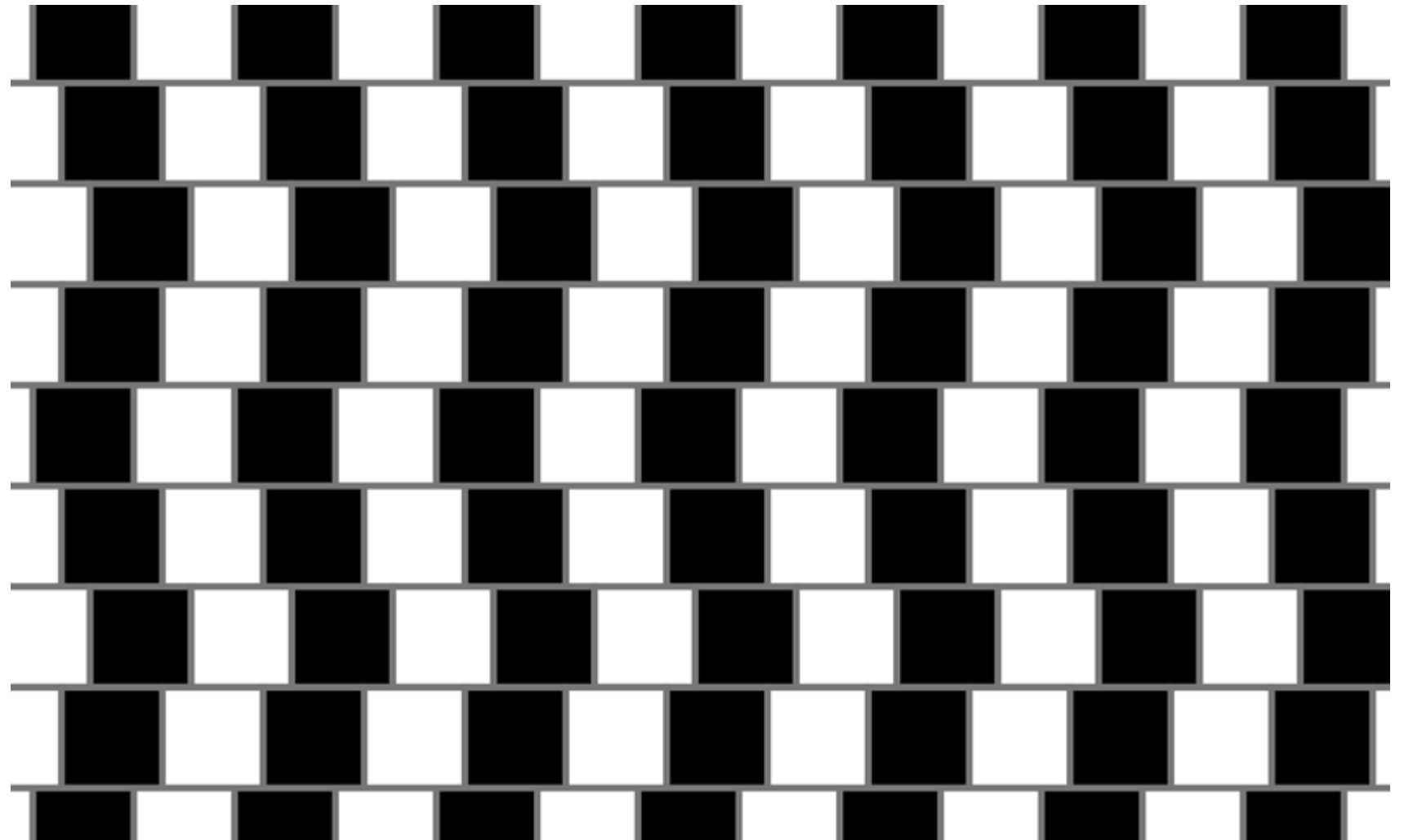
Pre-attentive
processing for
visualization:
The downsides

Sometimes gestalt & pre-attention compete



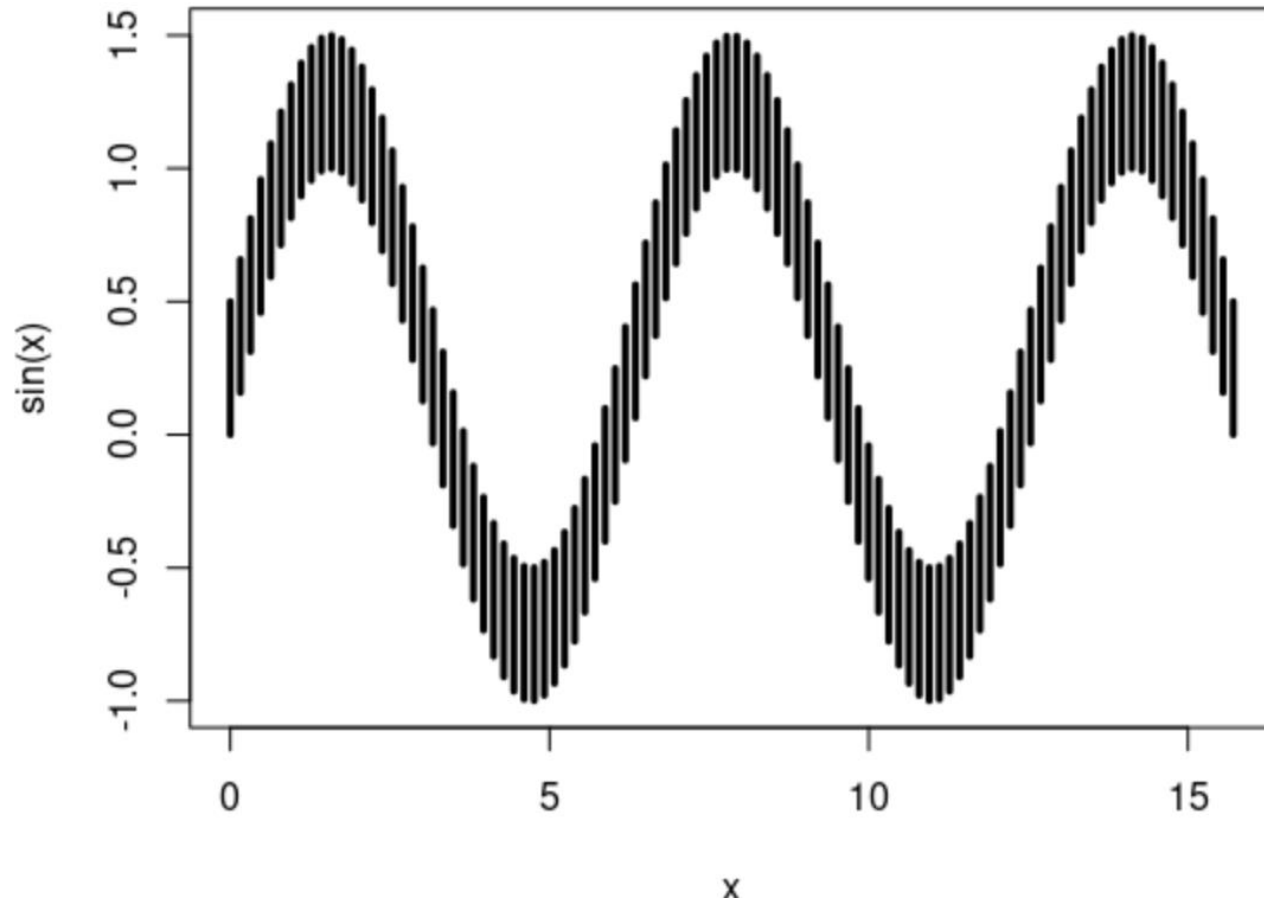
Pre-attentive
processing for
visualization:
The downsides

Sometimes gestalt & pre-attention compete



Pre-attentive processing for visualization: The downsides

Sometimes gestalt & pre-attention compete

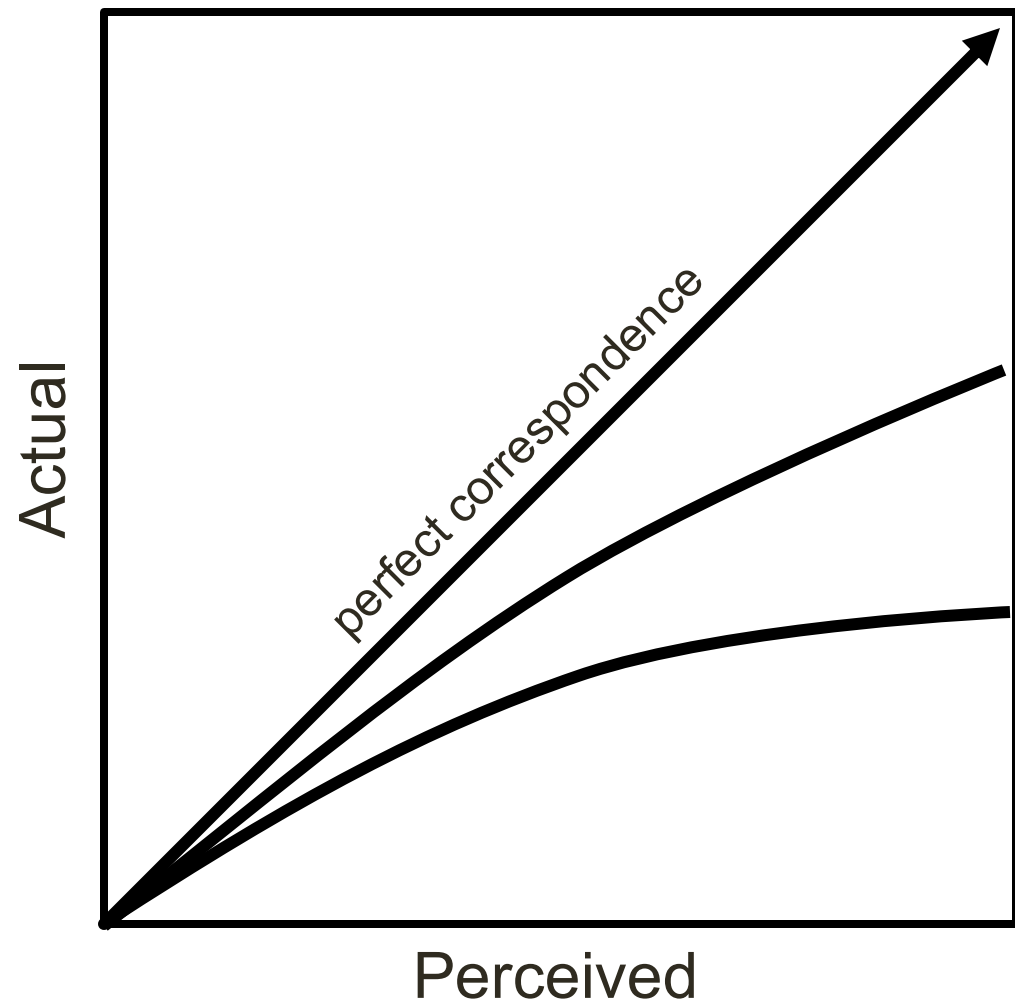


Attentive processing

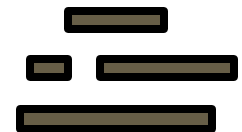
Okay, what about **attentive** processing?

Attentive processing

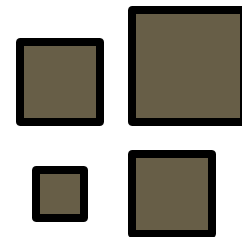
"Apparent" magnitude



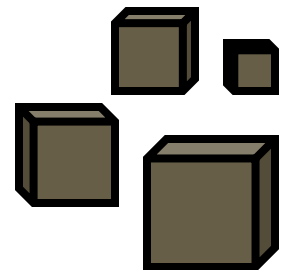
Length
estimate
correctly



Area
under-
estimate

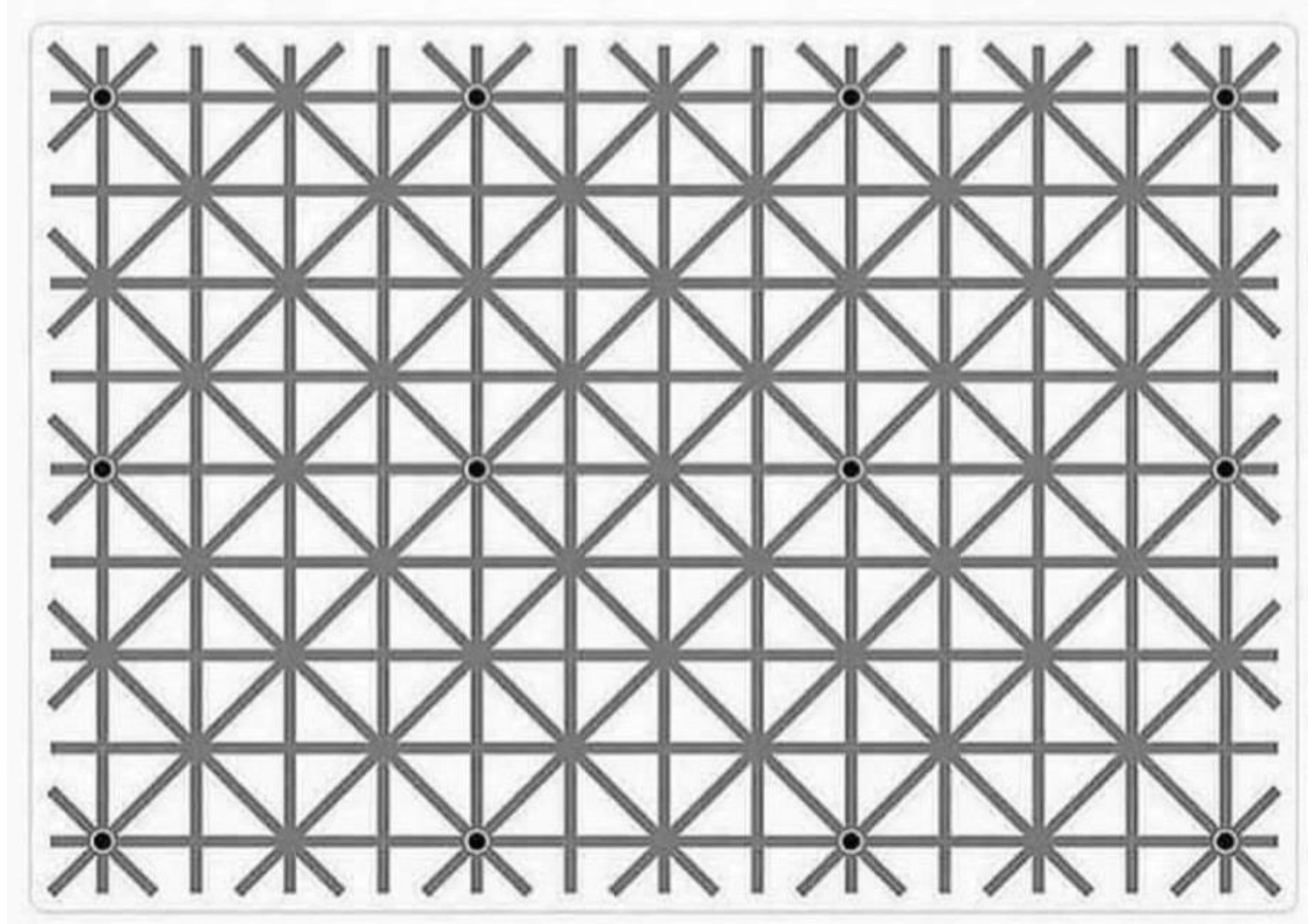


Volume
way under-
estimate



Attentive
processing

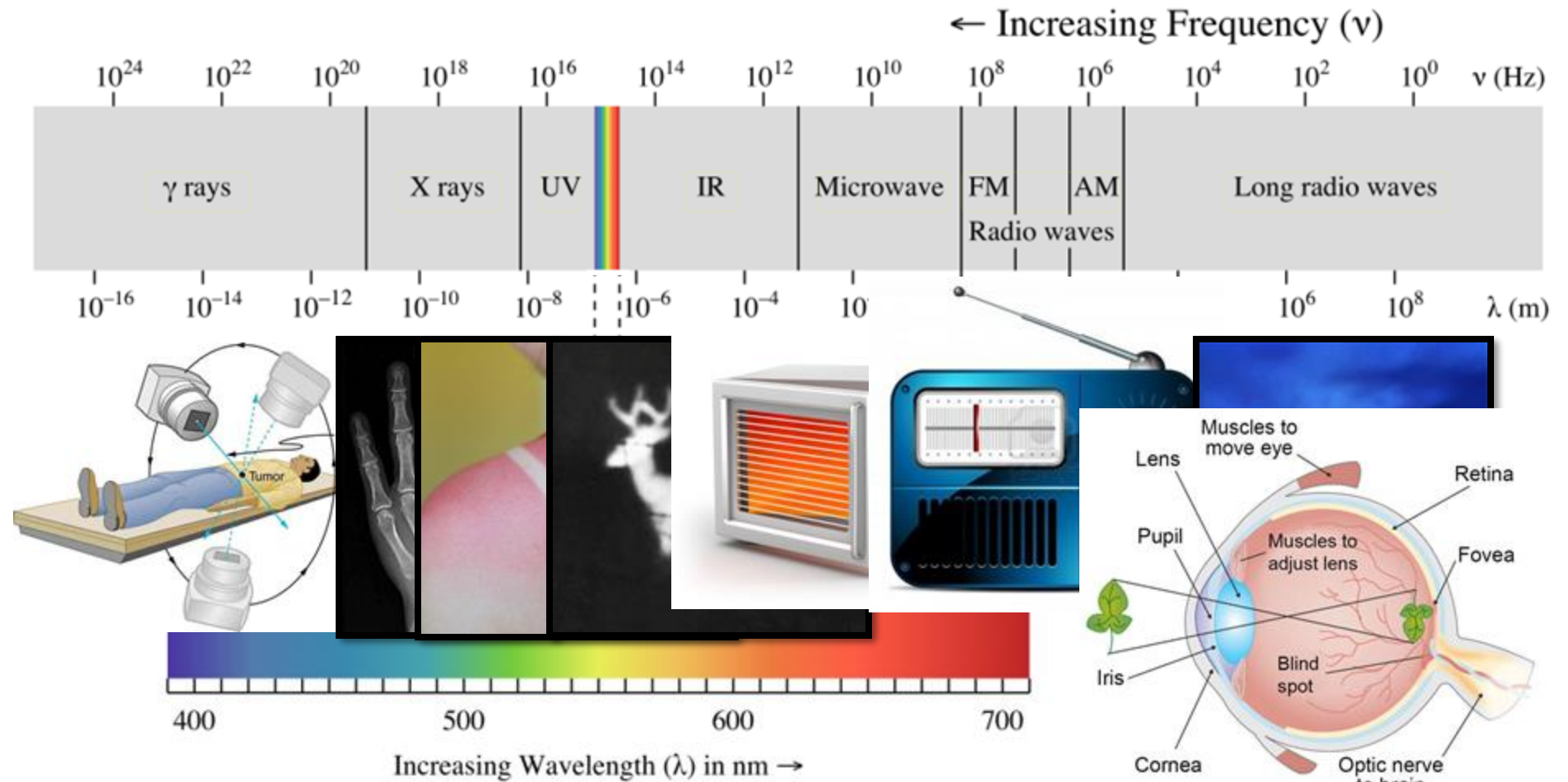
Short term “working” memory is limited



Color 101

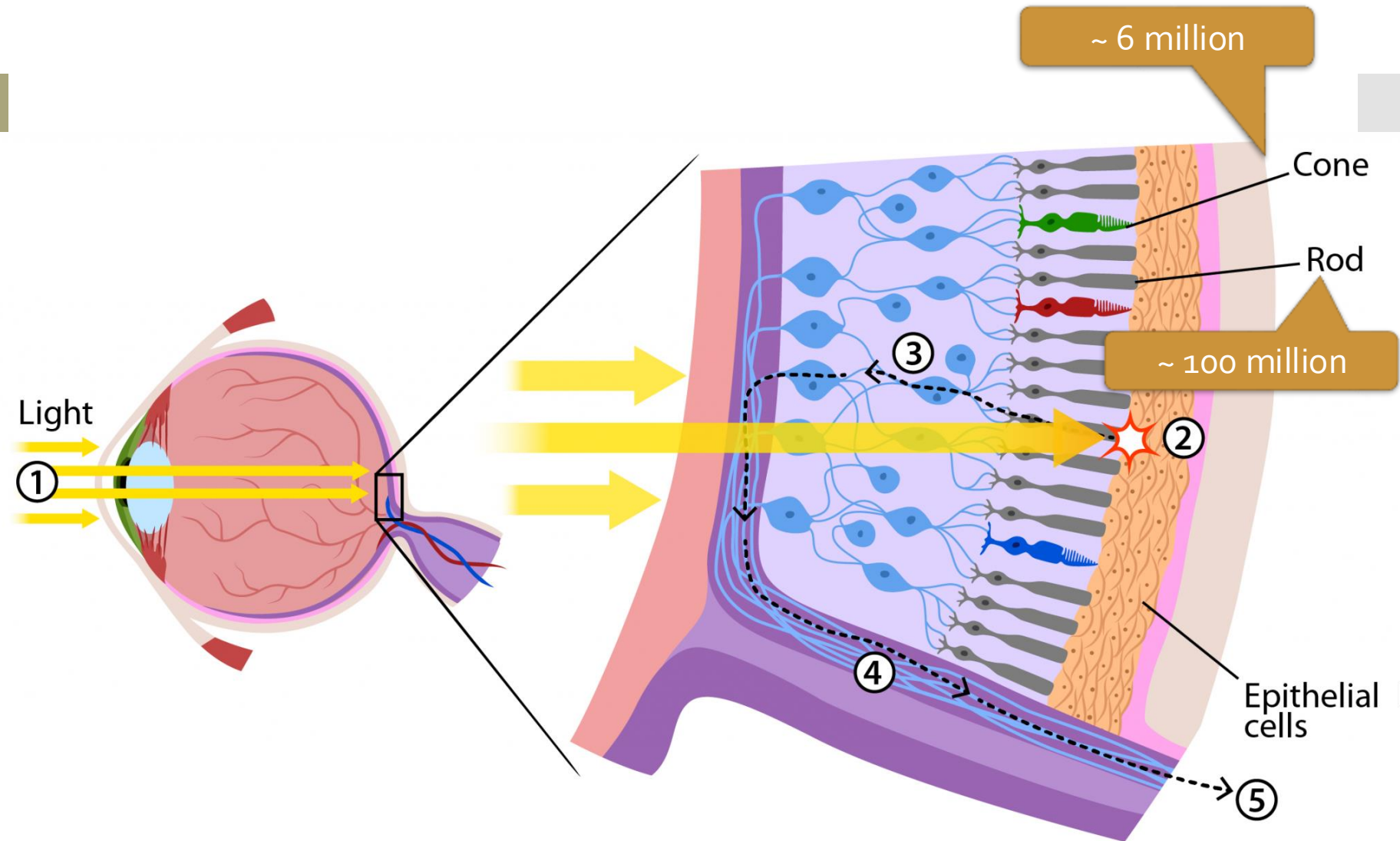


Kinds of light



Eye diagram courtesy ASU

How we see color



Color phenomena



Caveat 1: color is perceived in context

Color
phenomena



Which small square is **darker green**?

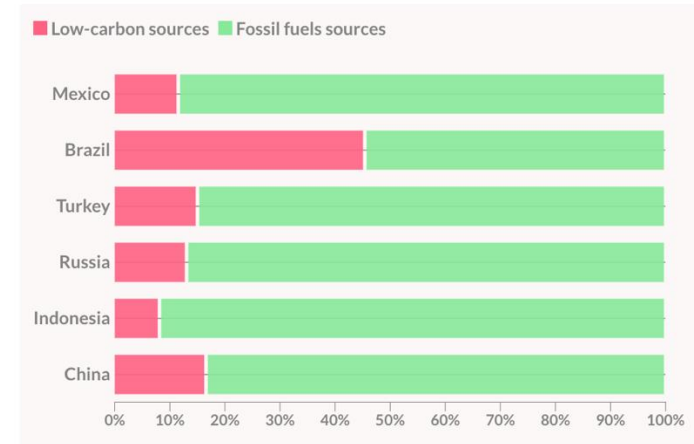
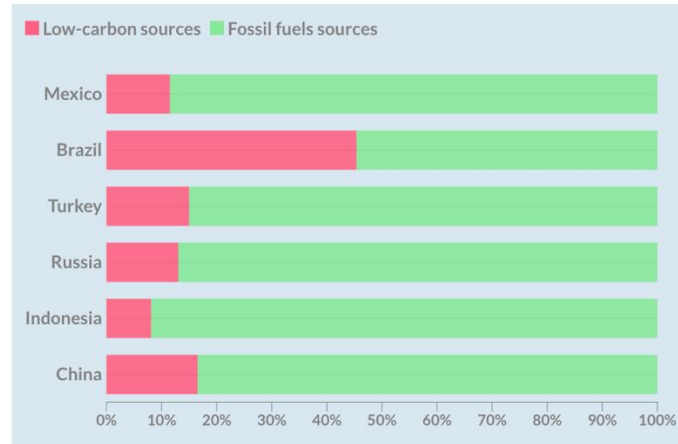
Caveat 2: difference is relative

Color
phenomena



- Be careful when layering colors

Color phenomenon



❌ (large text only)



CONTRAST
L^{*} 50.5

✅ (for icons & graphics)



CONTRAST
L^{*} 38.5

❌



CONTRAST
L^{*} 0.0

✅



CONTRAST
L^{*} 62.2

✅ (for icons & graphics)



CONTRAST
L^{*} 50.3

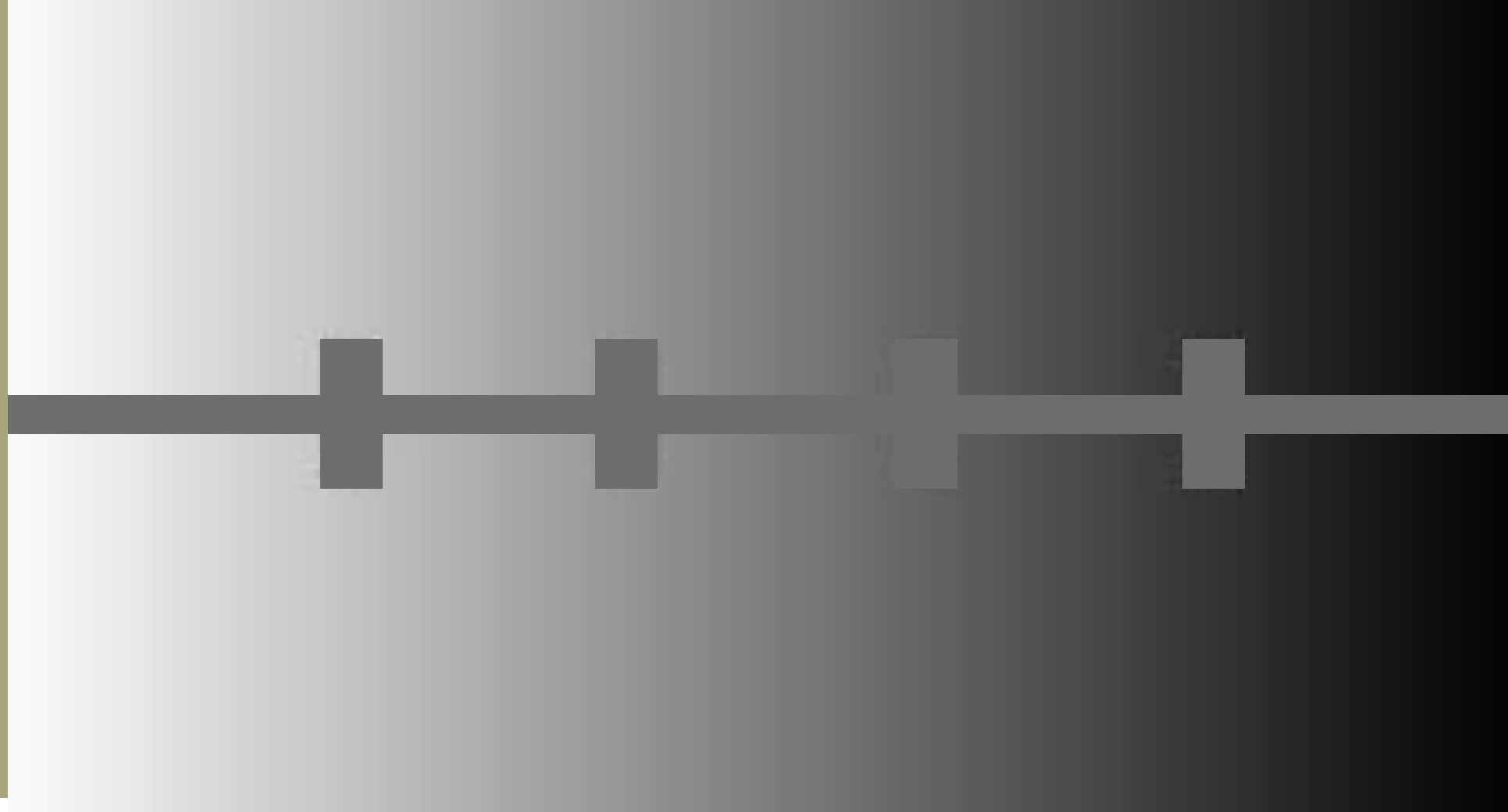
✅ (for icons & graphics)



CONTRAST
L^{*} 18.8

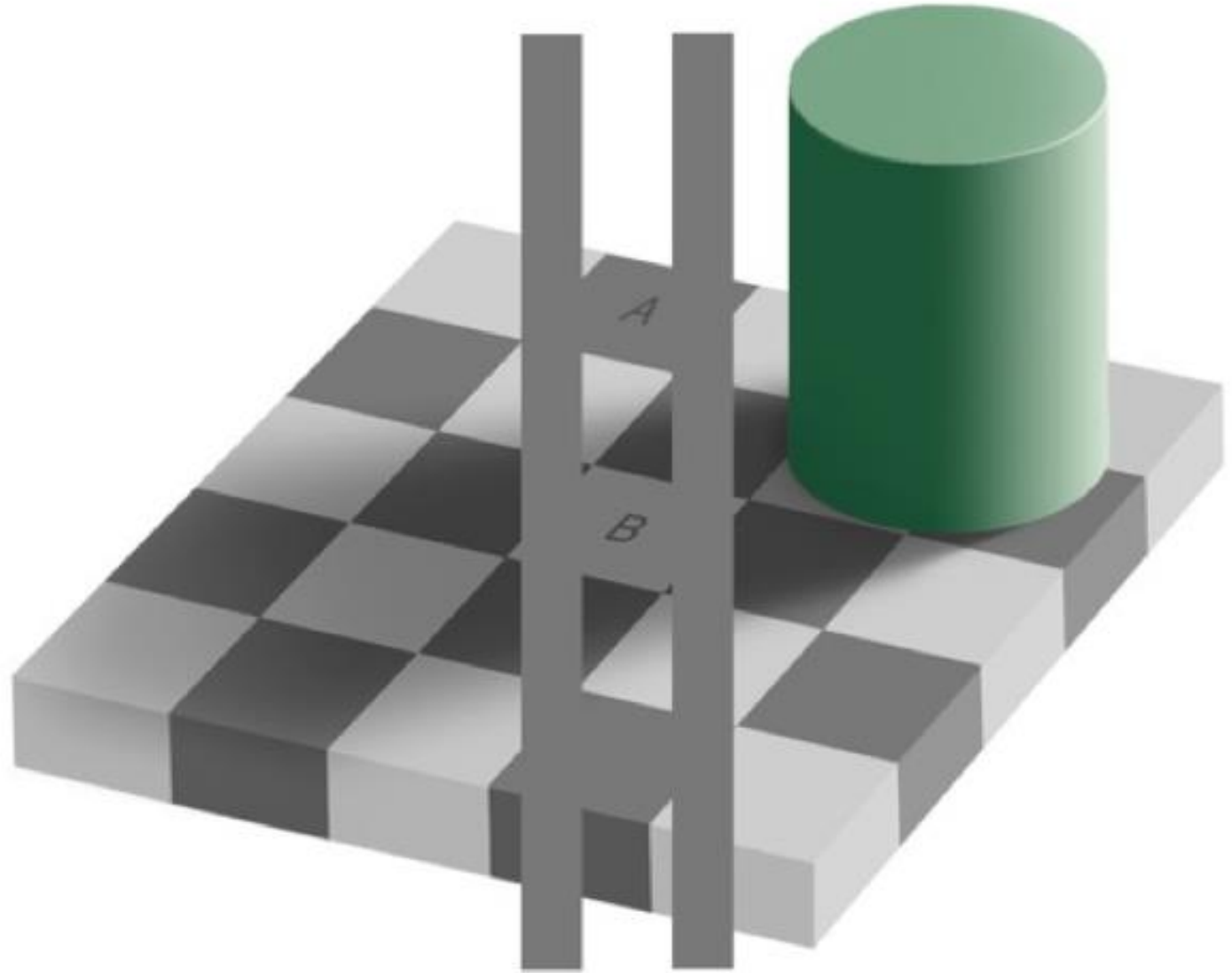
Caveat 2a: so are brightness and contrast

Color
phenomena



Caveat 3: mental models > perception

Color
phenomena

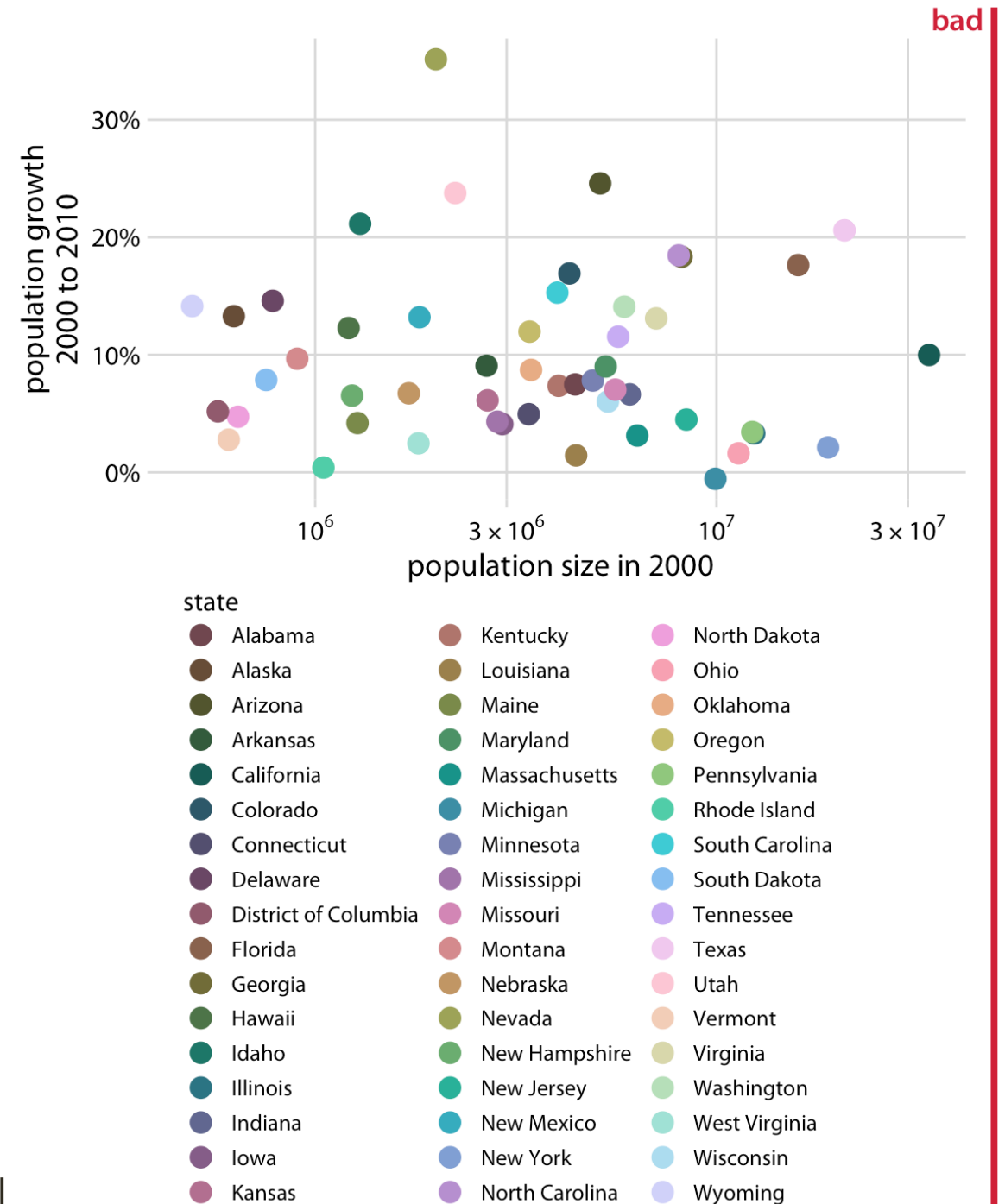


Color Problems

- Using a poor color scheme can also cause issues with your visualization

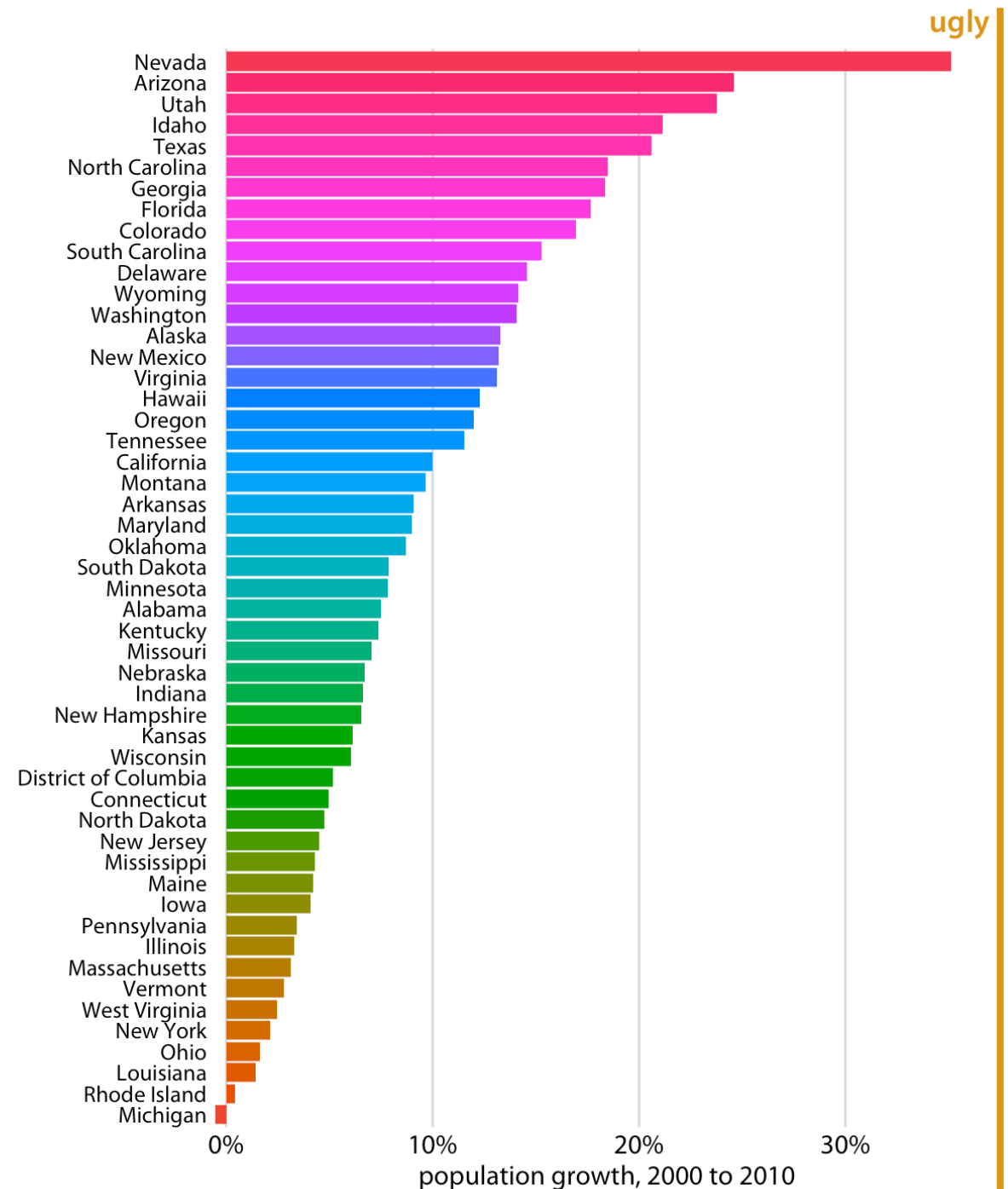
Color Problems

- Hue mapped to too many categories



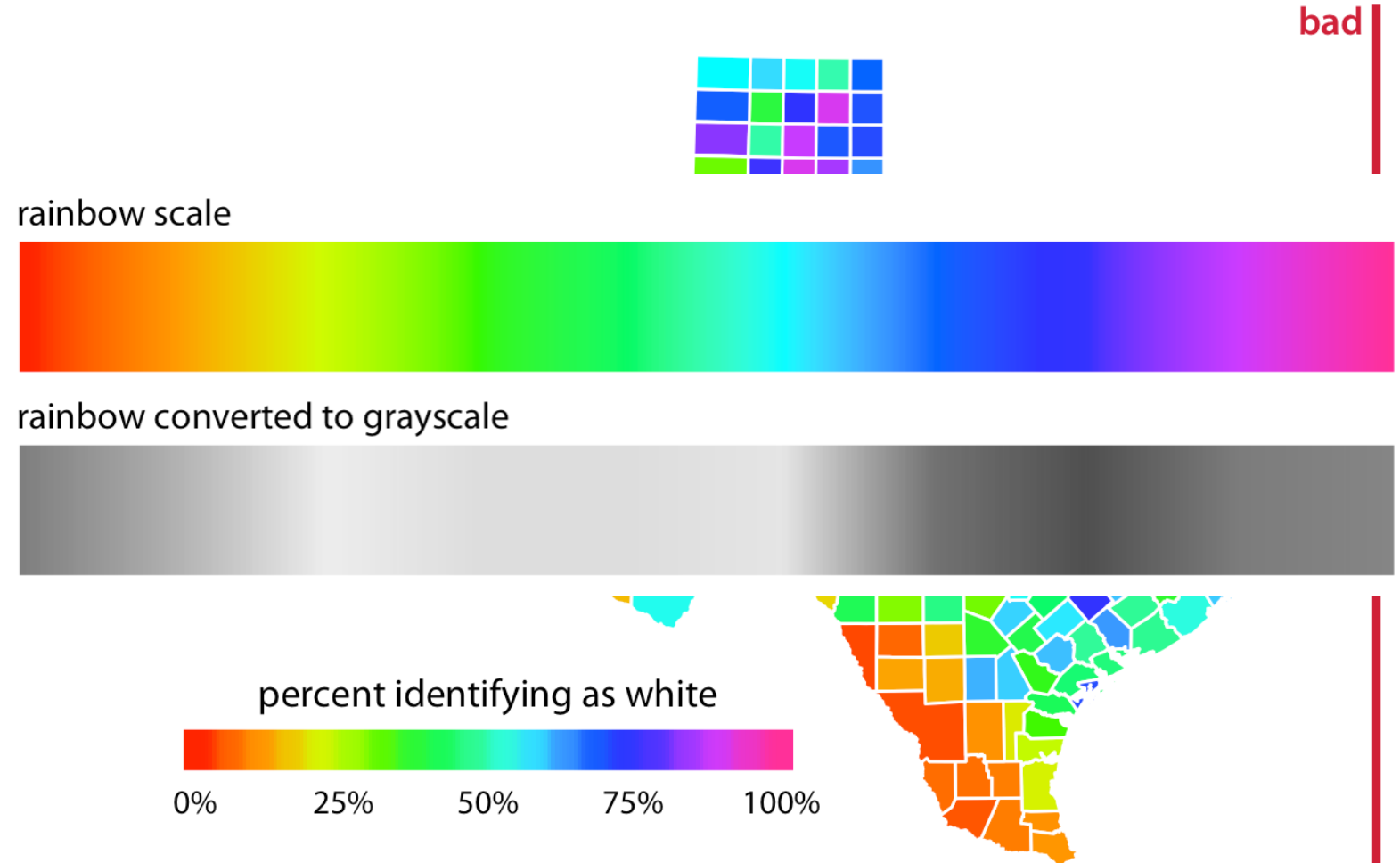
Color Problems

- Hue not mapped to data



Color Problems

- Rainbow obscures real patterns (it is not monotonic)



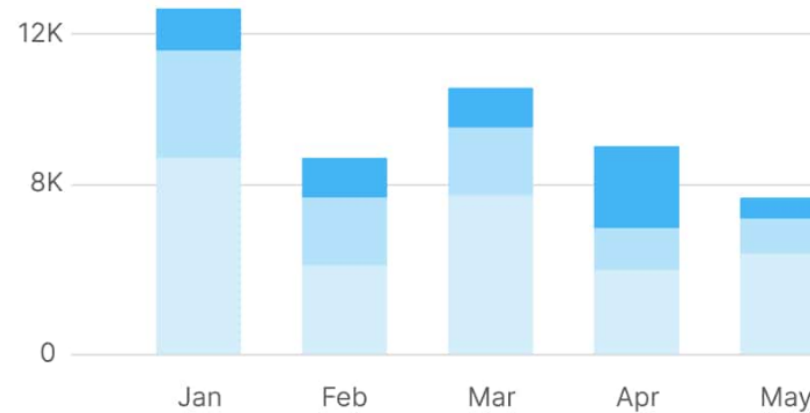
Color Problems

- Similar colors are hard to differentiate

✕ Similar colors

Product Sales

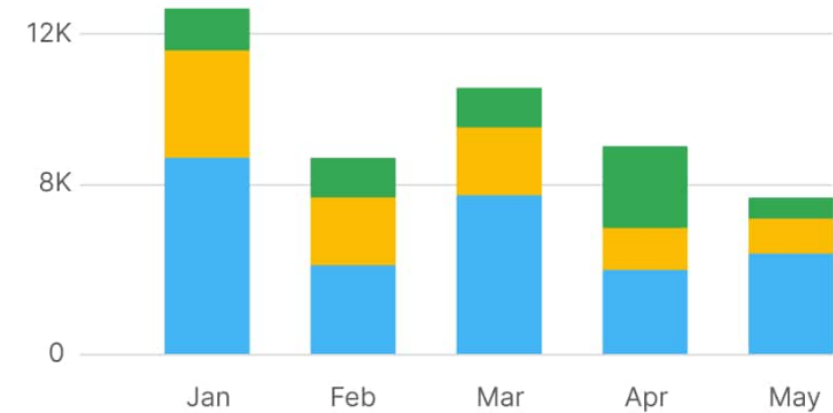
□ Clothing □ Equipment □ Accessories



✓ Different colors

Product Sales

■ Clothing ■ Equipment ■ Accessories



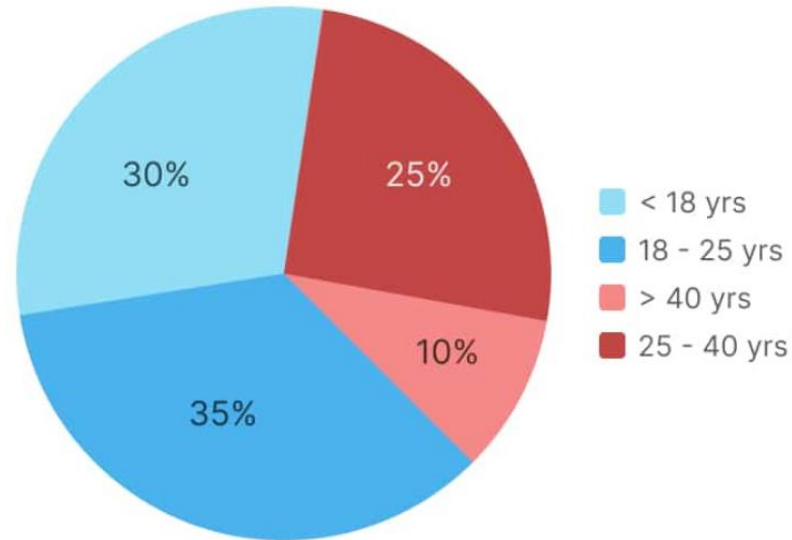
<https://matthewstrom.com/writing/how-to-pick-the-least-wrong-colors/>

Color Problems

- Similar colors imply relationships

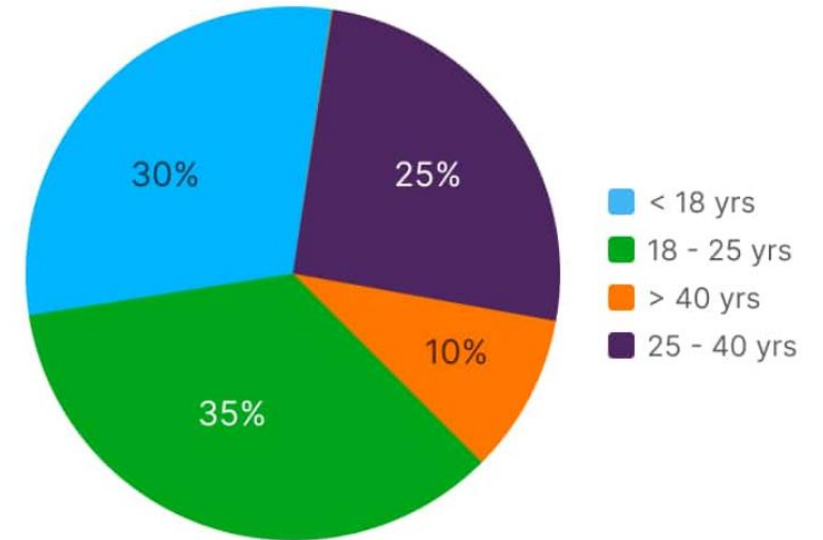
✗ Uneven color distribution

Age distribution of users

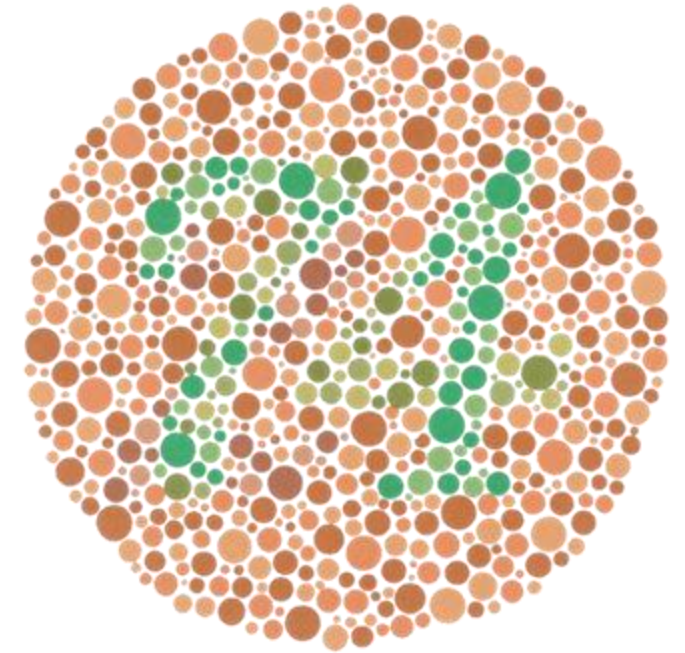


✓ Even color distribution

Age distribution of users



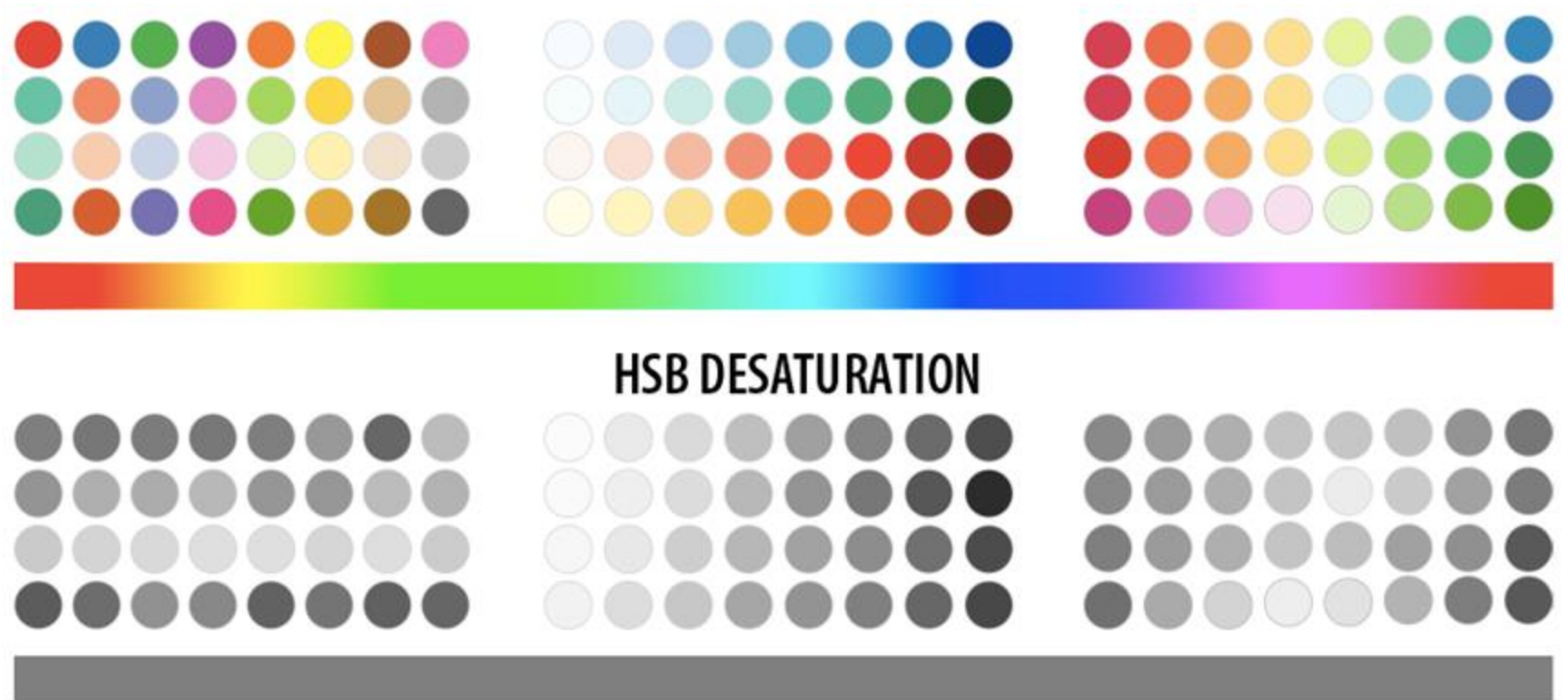
“colorblindness”



1 out of every 8 people has just 2 types of color receptors (rather than 3)

What happens
when you
print?

- Need color scheme that converts well to grey scale



Colorbrewer palettes

- colorbrewer.org provides a whole bunch of palettes that can help us avoid these issues
- This makes life a lot easier for us!

QUALITATIVE

set1



set2



pastel2



dark2



SEQUENTIAL

blues



greens



reds



ylorbr



DIVERGING

spectral



rdylbu



rdylgn



piyg



Colorbrewer palettes

QUALITATIVE

set1



set2



pastel2



dark2

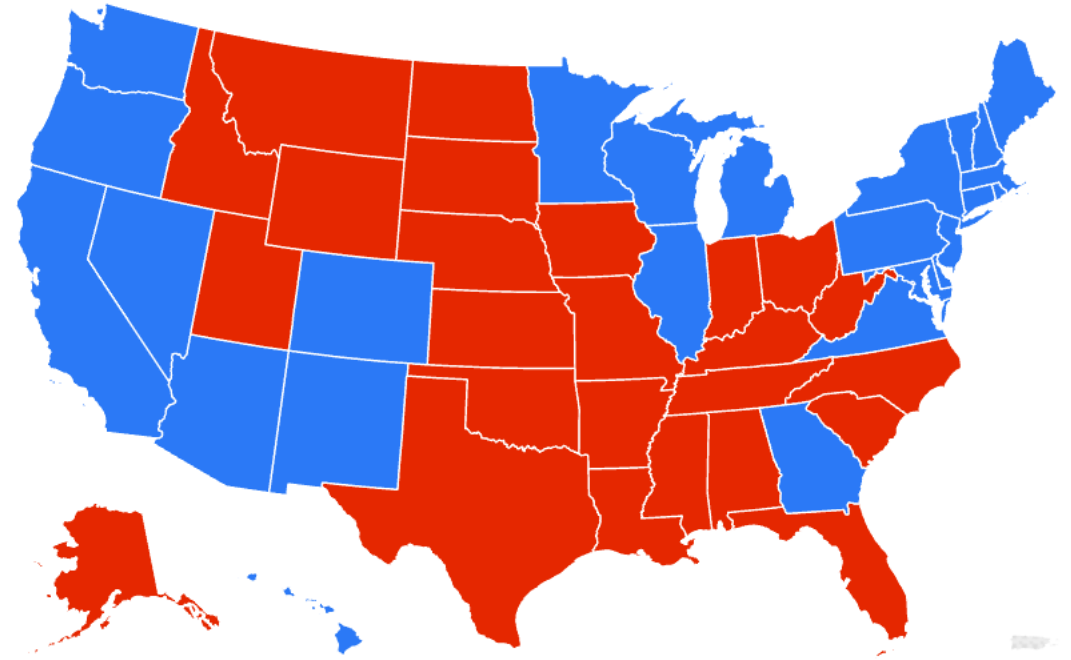


Good for nominal data

Categorical color palette

2020 Presidential election: winner per state

■ Democrat ■ Republican



Source: [The Cook Political Report](#) • Created with the Flourish [Projection Map](#) template

Colorbrewer palettes

SEQUENTIAL

blues



greens



reds



ylorbr

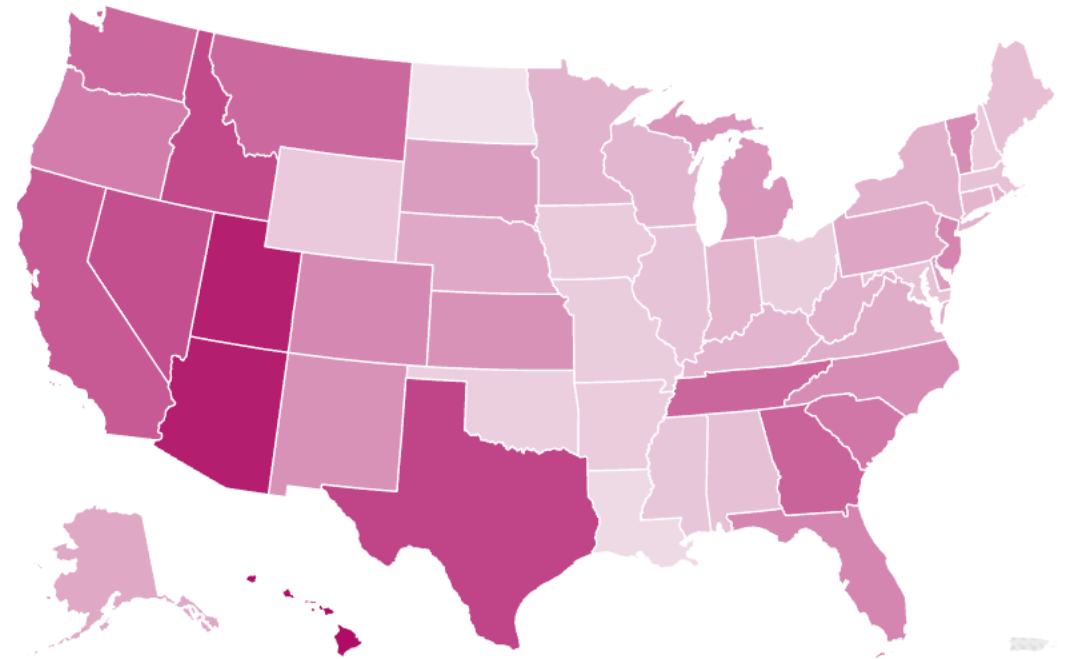


Good for sequential ordinal
& quantitative data

Sequential color palette

2020 Presidential election: vote change (%)

5.1  33.9



Source: [The Cook Political Report](#) • Created with the Flourish [Projection Map](#) template

Colorbrewer palettes

DIVERGING

spectral



rdylbu



rdylgn



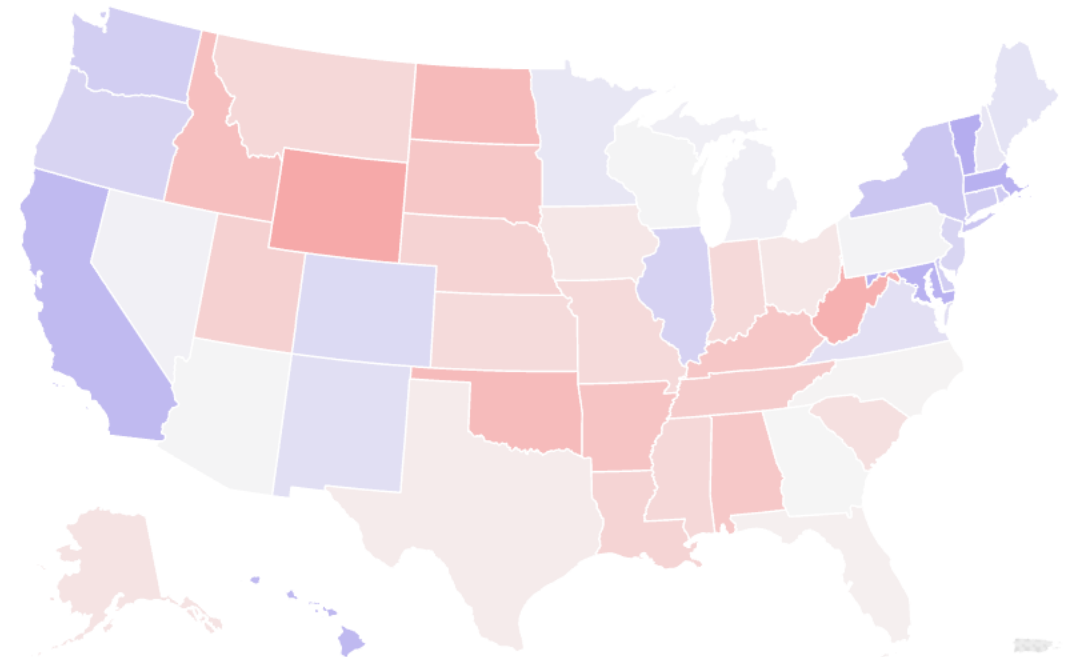
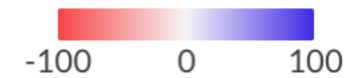
piyg



Good for diverging ordinal
& quantitative data

Diverging color palette

2020 Presidential election: margin of victory (%)



Source: [The Cook Political Report](#) • Created with the Flourish [Projection Map](#) template

Takeaways: Perception

- Visualization is about more than just aesthetics
- There are compelling **cognitive reasons** why some visualization techniques are helpful and others aren't
- The choices we make about **visual mappings** can have a significant effect on performance

Your turn!

- Find a partner and open Tableau
- Choose a dataset from the course website
- Create a visualization that shows an interesting trend using one of the three color channels
- Modify color usage in your visualization so that the interesting trend is lost

Discussion

- What did you try?
- What did you learn about the data?
- Can you imagine a scenario that might incline someone to choose your “bad” visualization instead of a better one?