Visual Analytics– Mental Models and Visual Perception

Dr. Ab Mosca (they/them)

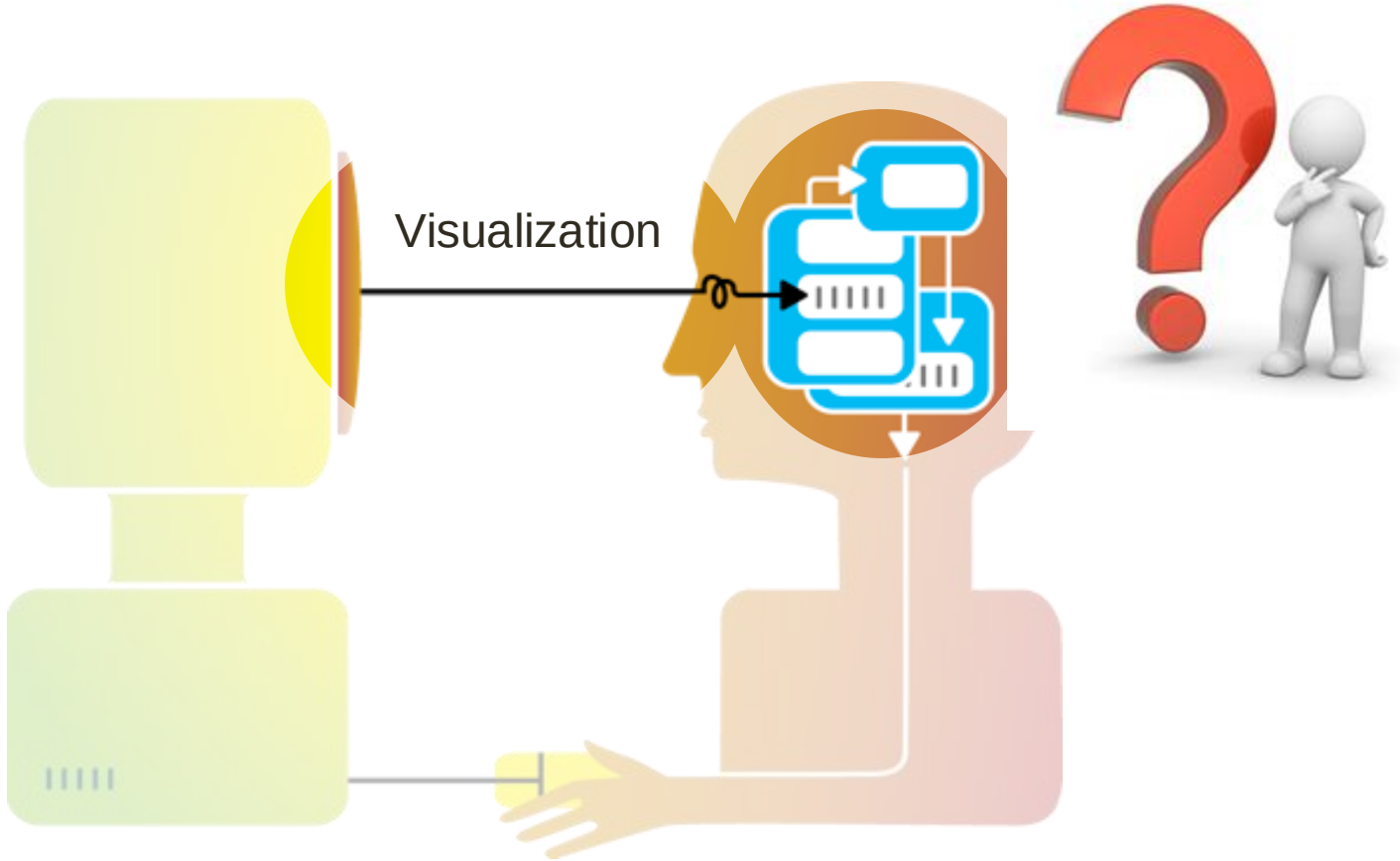
Slides based off slides courtesy of Jordan Crouser (https://jcrouser.github.io/)

Plan for Today

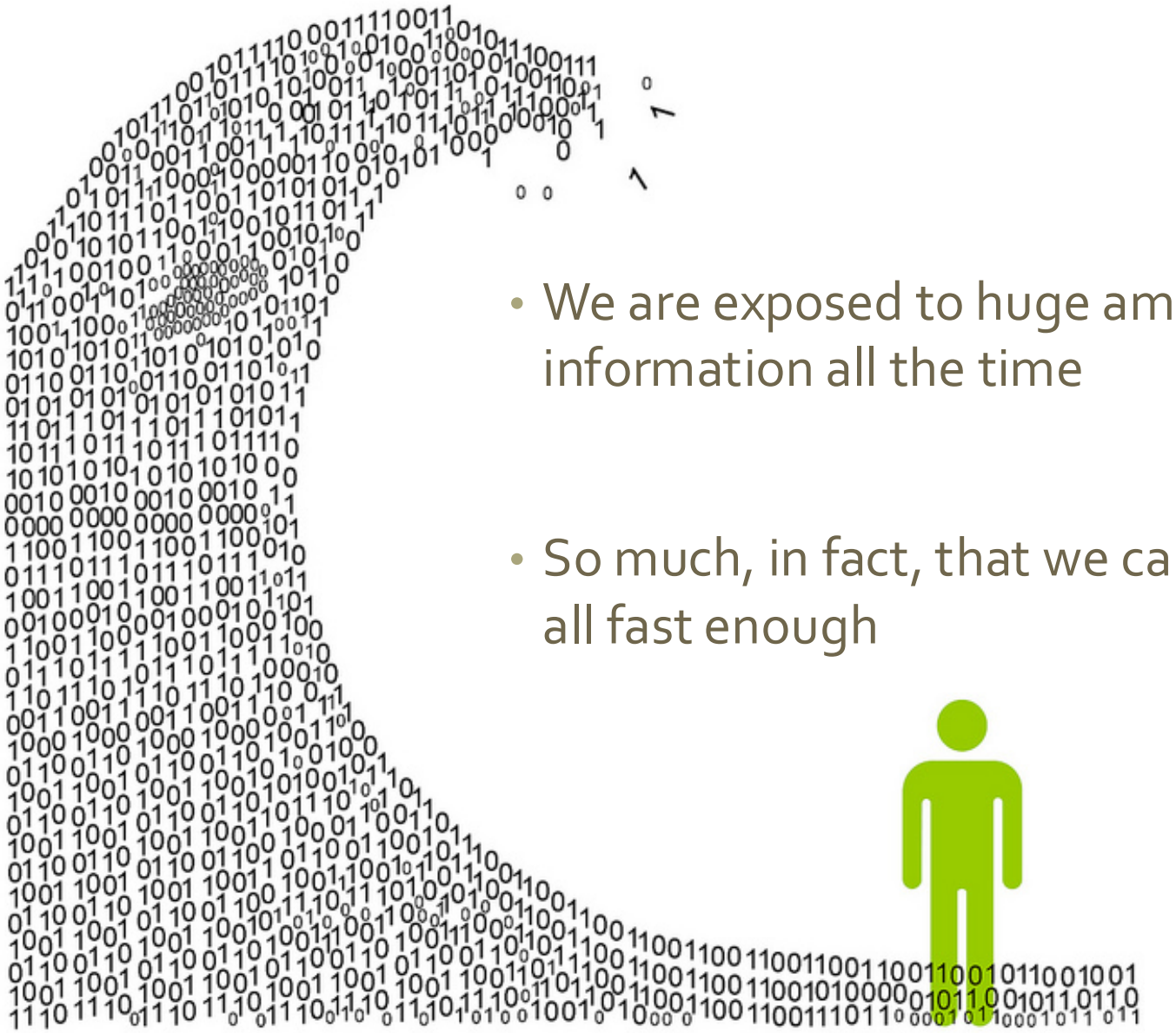
- Mental Models
- What is perception?
  - How does it work?
  - Pre-attentive processing
  - Perceptual problems
  - Estimating magnitude

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!)

Visualization helps shape *mental models*



Information overload



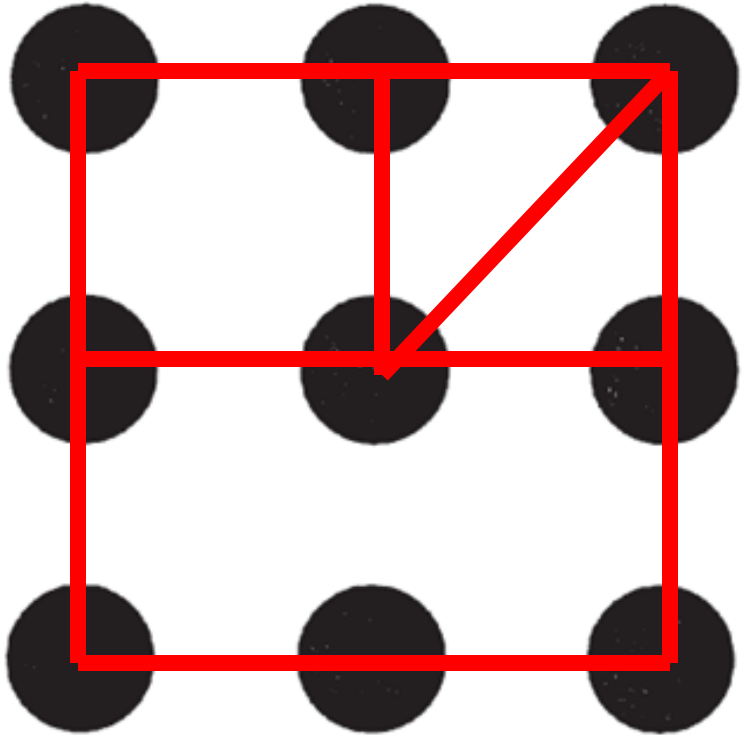
- We are exposed to huge amounts of information all the time
- So much, in fact, that we can't process it all fast enough

Mental models

To cope, we construct **mental models:** abstracted, simplified versions of the world that are more manageable

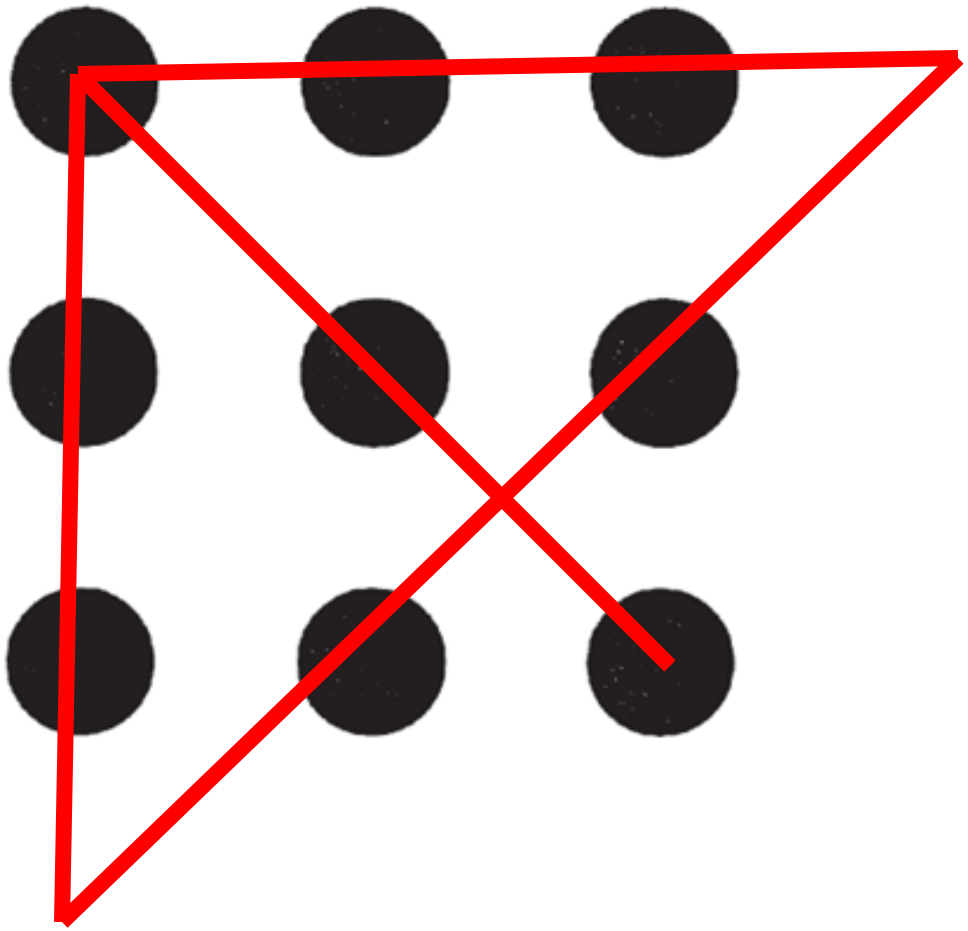
The 9-dot problem

Task 1: Connect all 9 dots using only straight lines



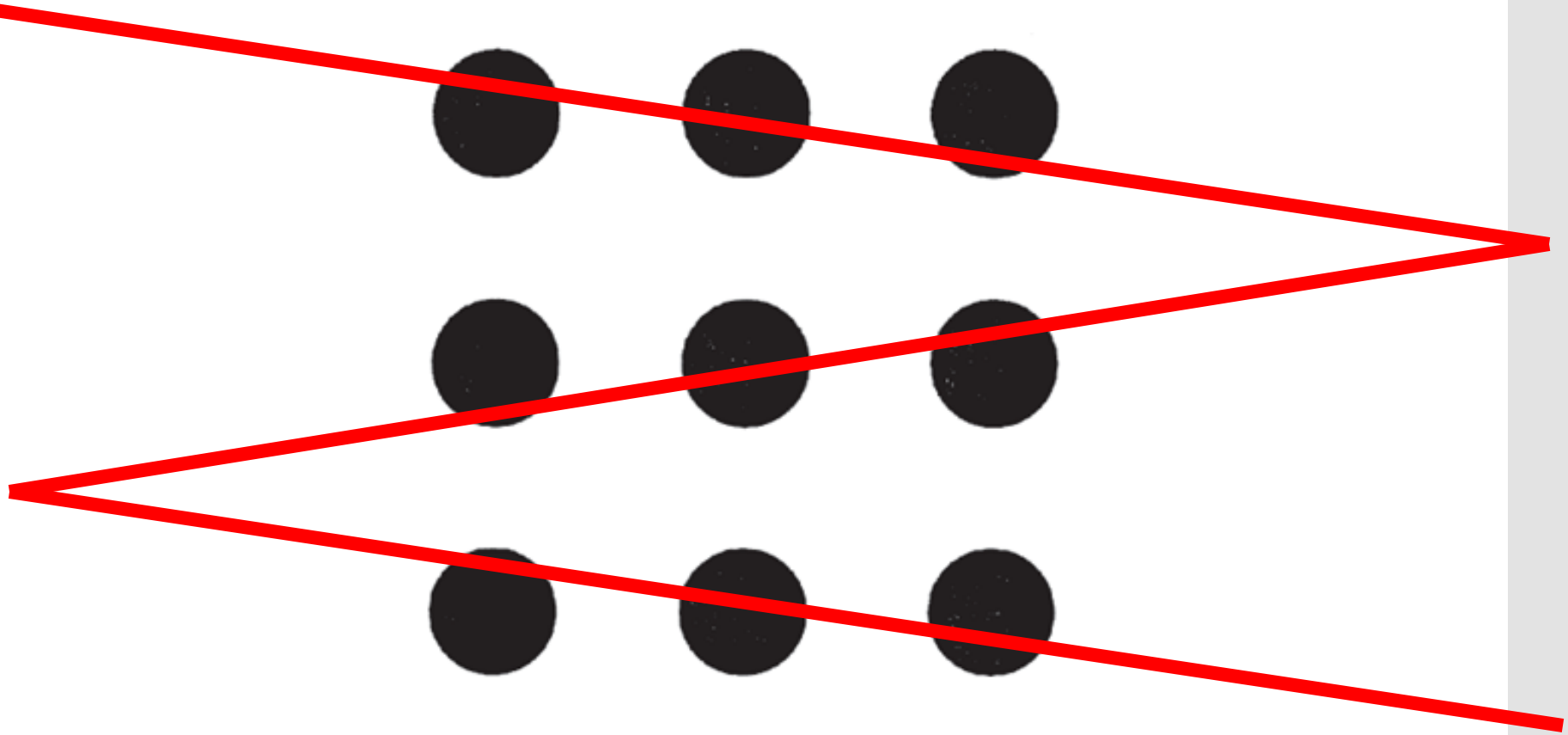
The 9-dot problem

Task 2: Connect all 9 dots using 4 straight lines



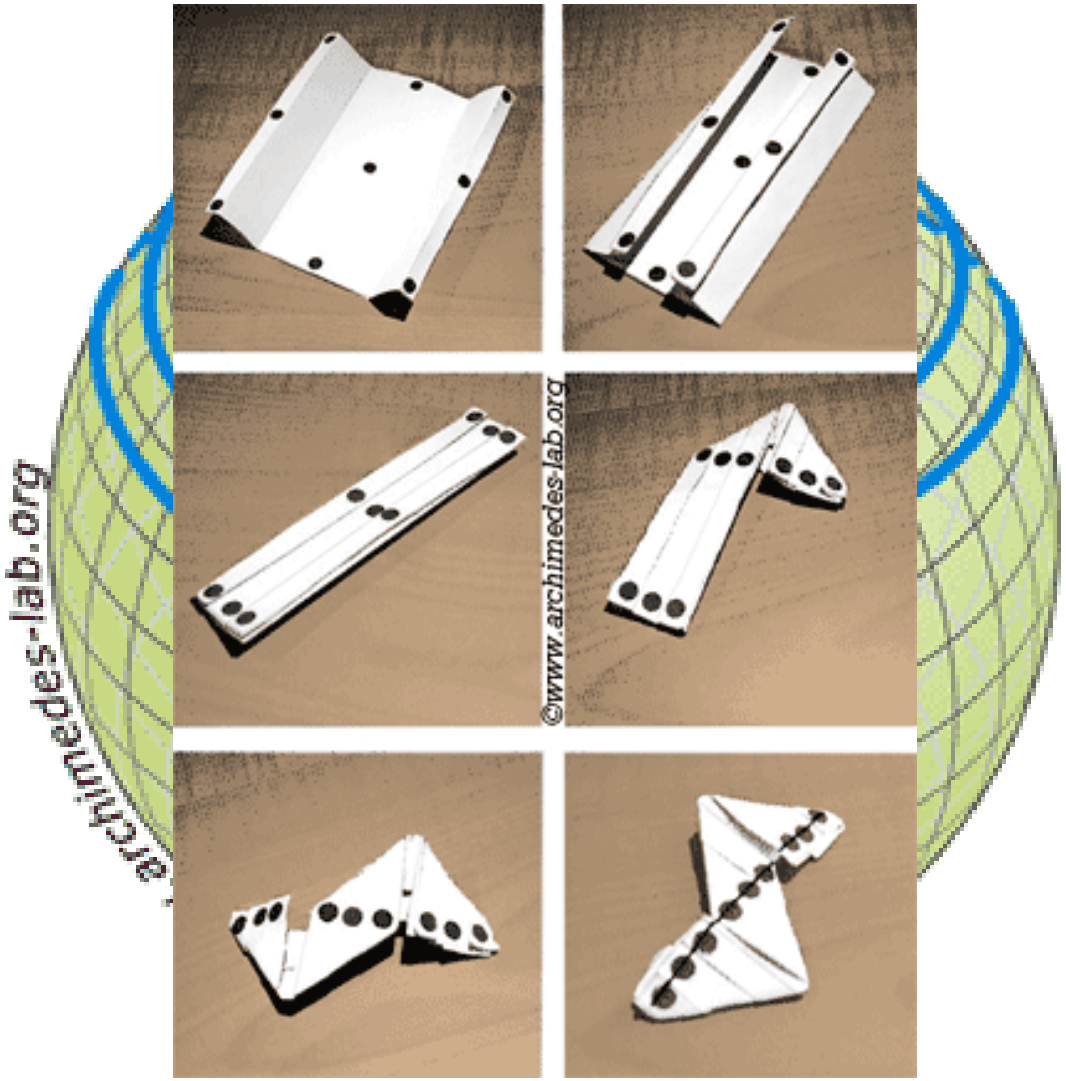
The 9-dot problem

Task 3: Connect all 9 dots using 3 straight lines



The 9-dot problem

Task 4: Connect all 9 dots using 1 straight line



Mental Models: a Sketch

Mental Models

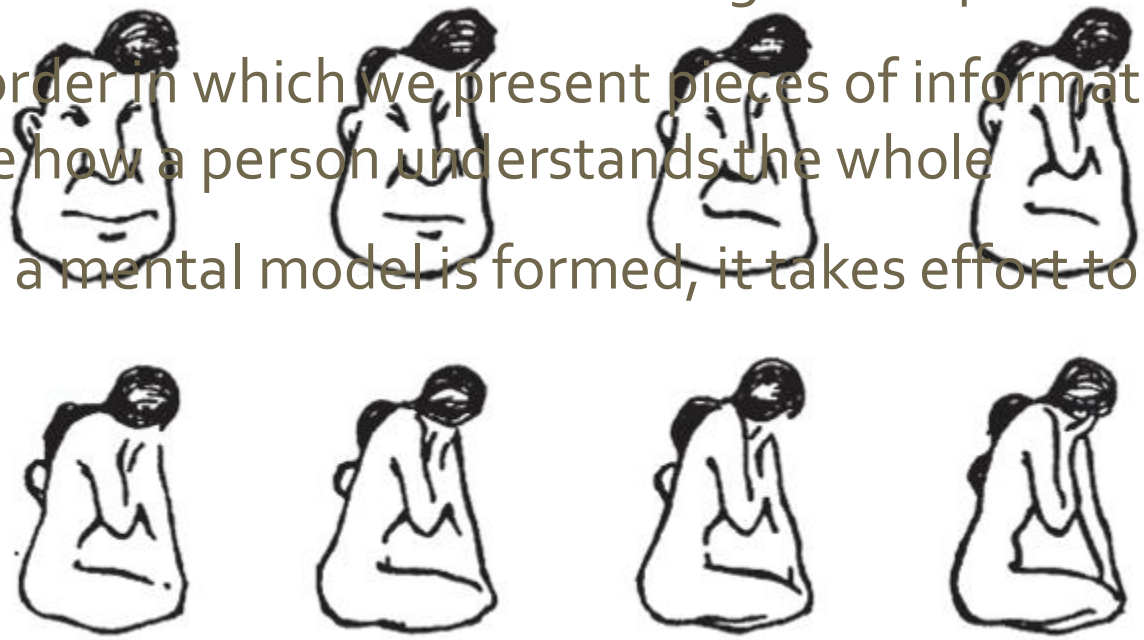
1. We tend to see what we expect to see

- Mental models are built from prior experience
- We expect new input to "fit" the existing model
- Updates are **expensive**: given input that almost fits, we'll distort information to avoid re-fitting the model
- **Expectation** is at least as strong as perception

Mental Models

2. Mental models form quickly, & update slowly

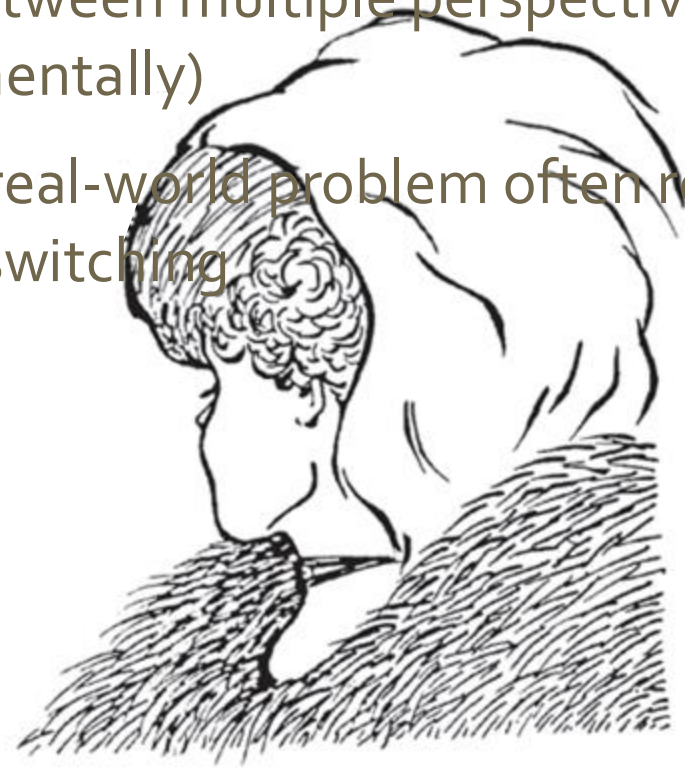
- "First impressions matter"
- Early information can have the highest impact
- The order in which we present pieces of information can shape how a person understands the whole
- Once a mental model is formed, it takes effort to alter it



Mental Models

3. New information gets incorporated into the existing model

- Integrating competing perspectives is challenging
- Switching between multiple perspectives is also difficult (visually or mentally)
- **Tricky part**: real-world problem often require such perspective switching



Mental Models

4. Initial exposure interferes with accurate perception

Blur size

128px
64px
32px
16px
8px
None

Mental Models

4. Initial exposure interferes with accurate perception

- Longer exposure to ambiguous data makes people **more confident** in their initial model
- This is true even if new data presents strong evidence that their model is **wrong**!
- Important: need to be intentional when we design, because incremental information can be **misleading**

Anyone remember what we talked about last time that related to exactly this?

Mental Models

The good:

- Well-tuned mental models let us process information quickly
- Frees up more processing power to synthesize information

The bad:

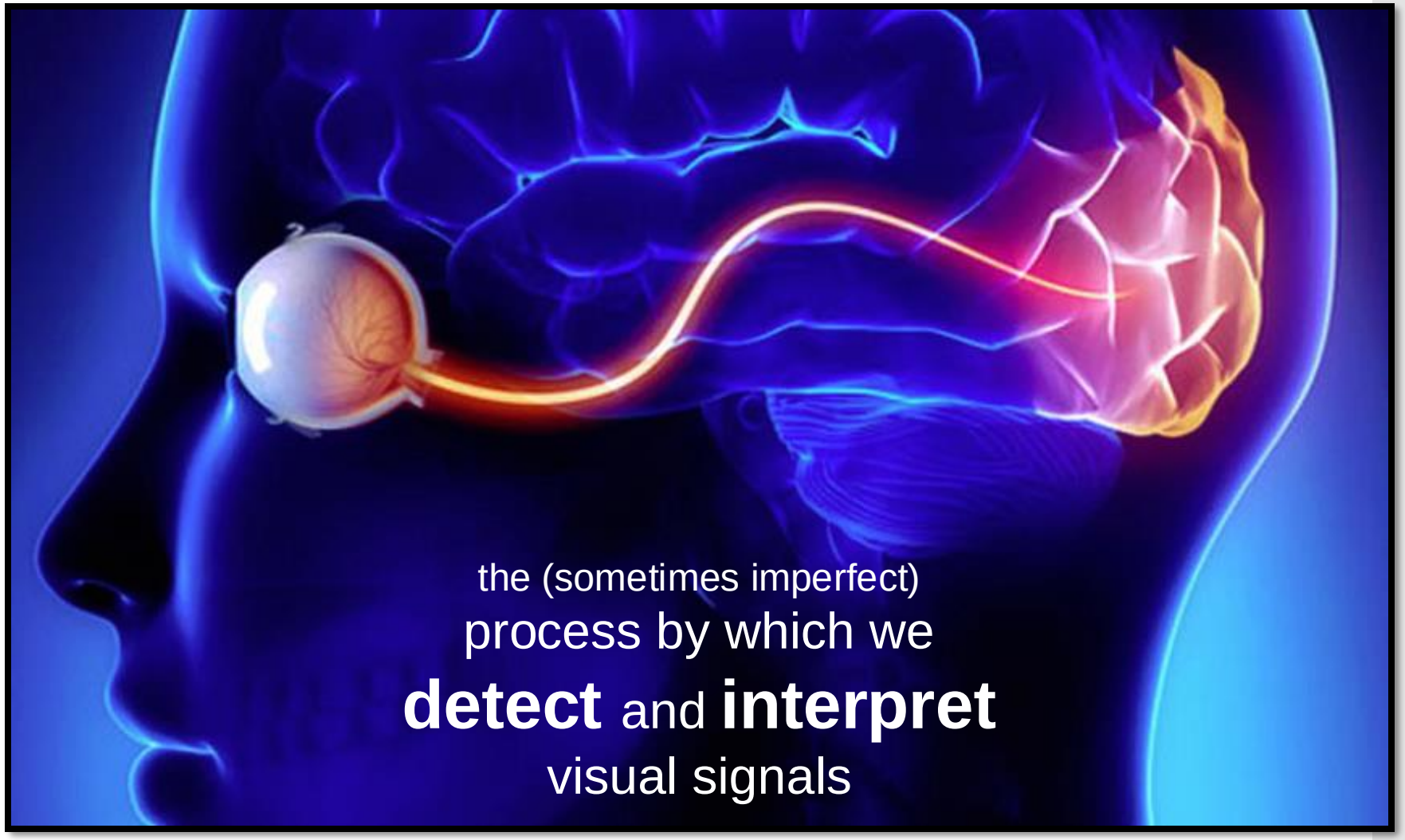
- People (esp. experts) tend not to notice information that contradicts their mental model
- A "fresh pair of eyes" can be beneficial

The ugly:

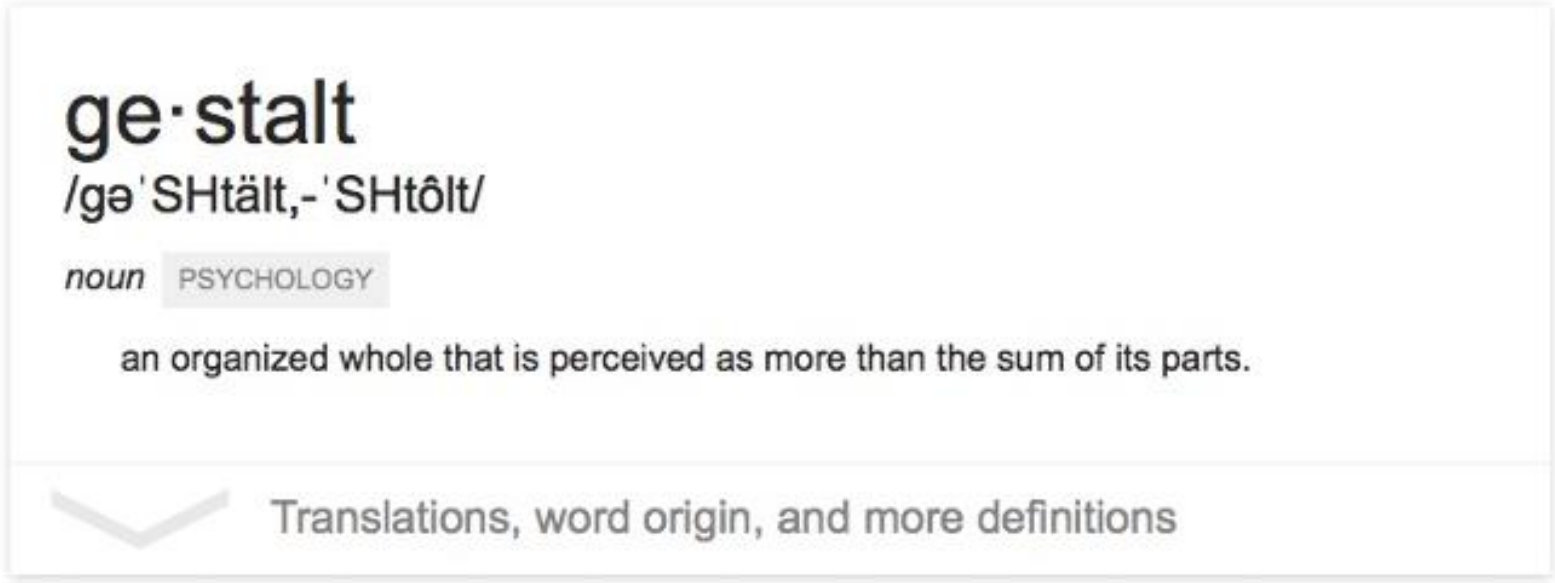
- Mental models are unavoidable: everyone has them, and they're all different
- **Key:** be aware of how mental models form, how they shape perception, and how to support (or challenge) them

What is perception?

Visual perception (def.)



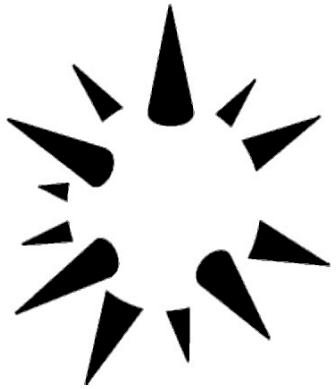
The “gestalt effect”



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

Gestalt effects

Reification

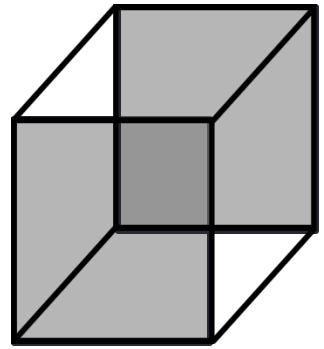


Demonstration of reification in perception from Lehar S. (2003) The World In Your Head, Lawrence Erlbaum, Mahwah, NJ. p. 52, Fig. 3.3

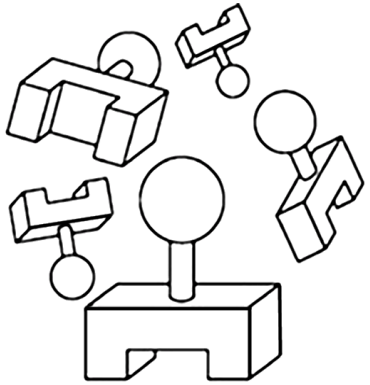
Emergence

Life Magazine: 58;7 1965-02-19, p 120.
Photographer: Ronald C James

Multistability



Invariance



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

What does this mean for visualization?

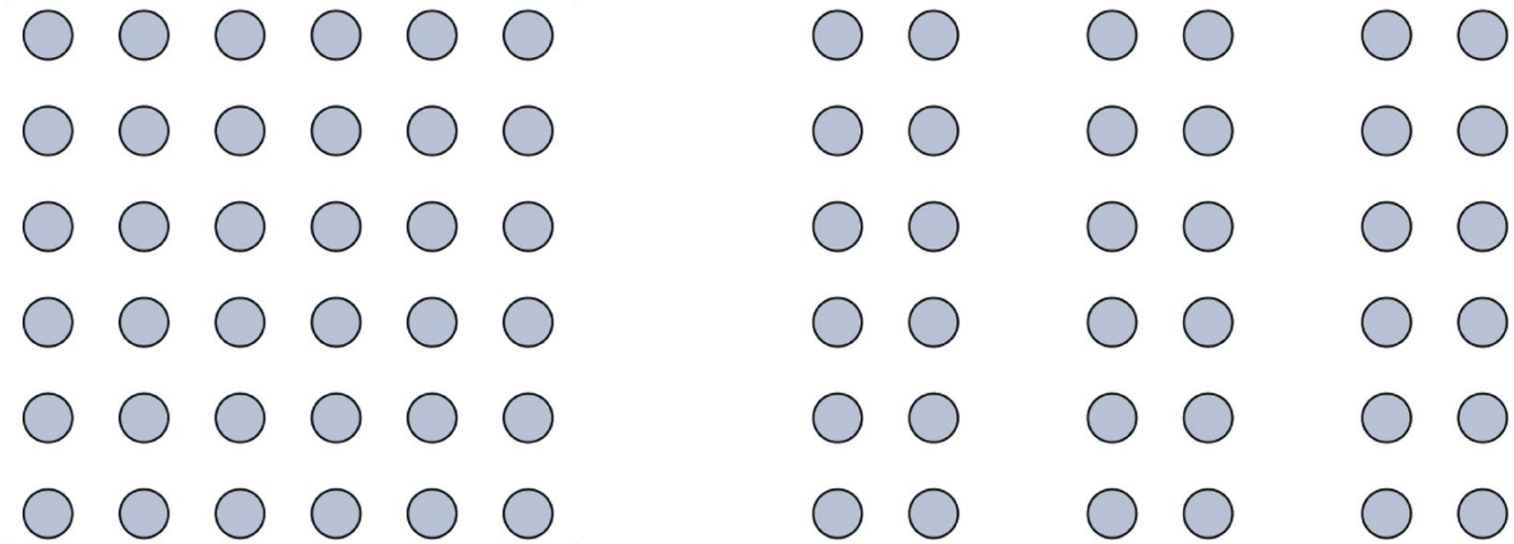
Question: what makes all this mental model stuff useful to us (designers and readers of data)?

Answer: in order to understand how people interpret and make sense of data, we need to know what **cues** they're picking up on – and how to situate those cues within a larger framework

→ 6 "Laws of Grouping"

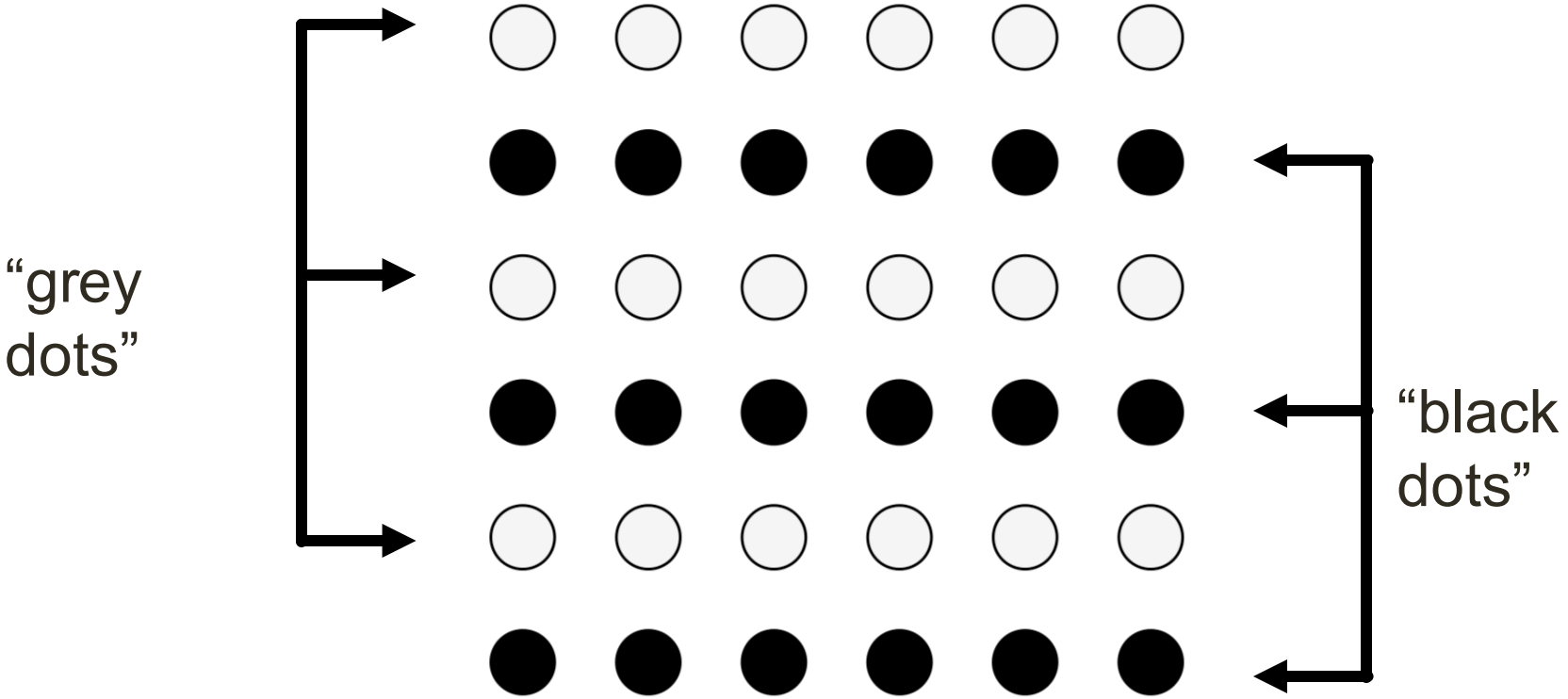
Law of Proximity

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



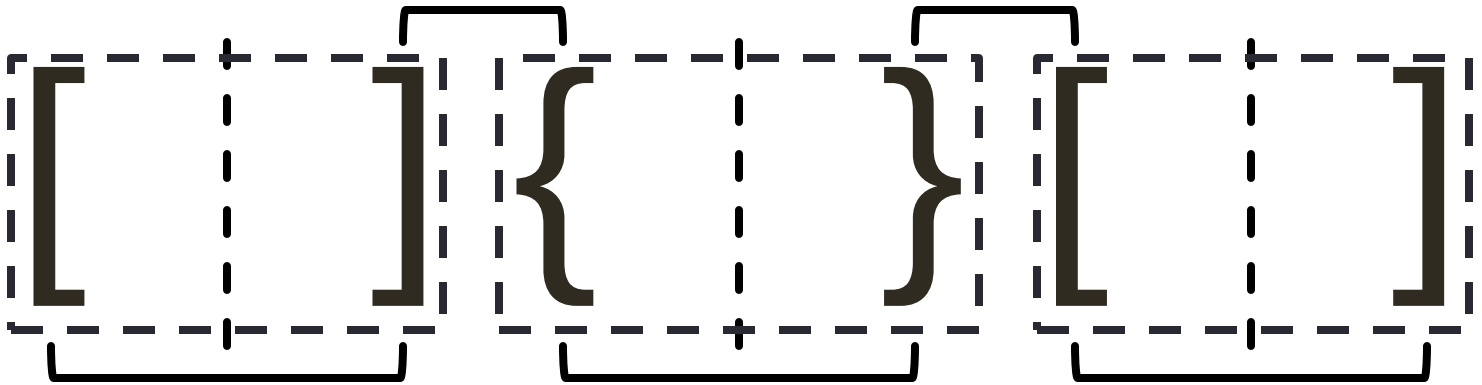
Law of Closure

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

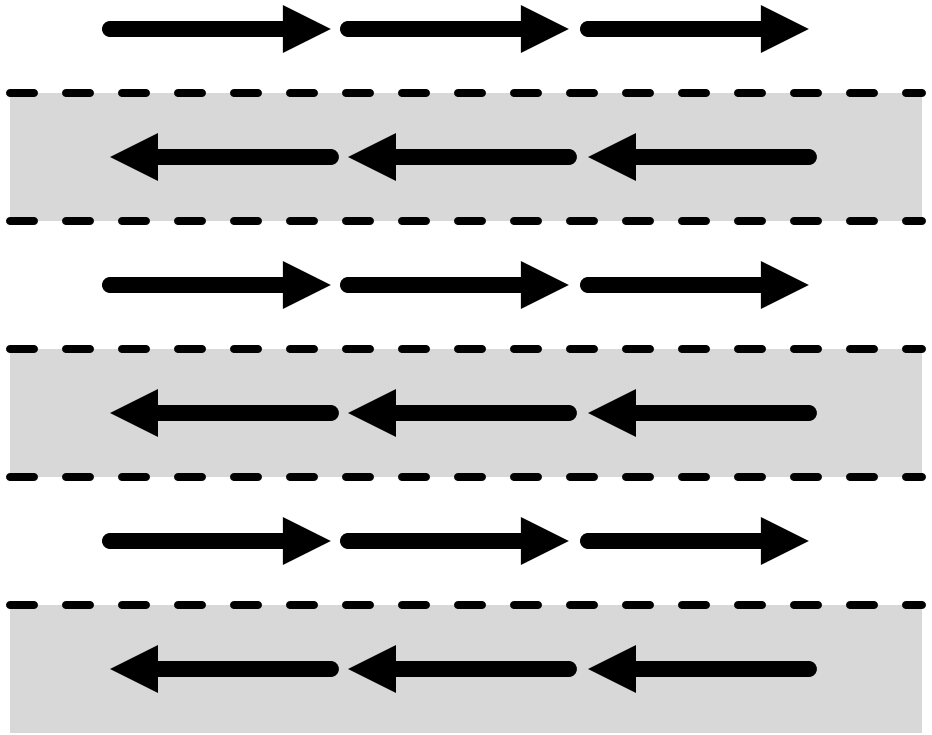
law of proximity



law of symmetry + law of similarity

Law of Common Fate

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

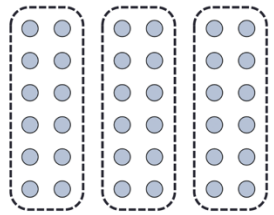


Law of Continuity

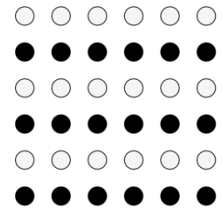
We tend to group objects along the **smoothest path**

Let's Practice

- 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

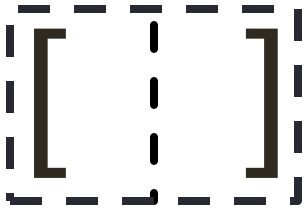


proximity

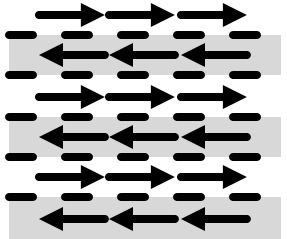


similarity

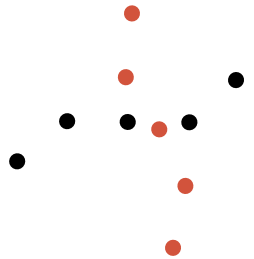
closure



symmetry

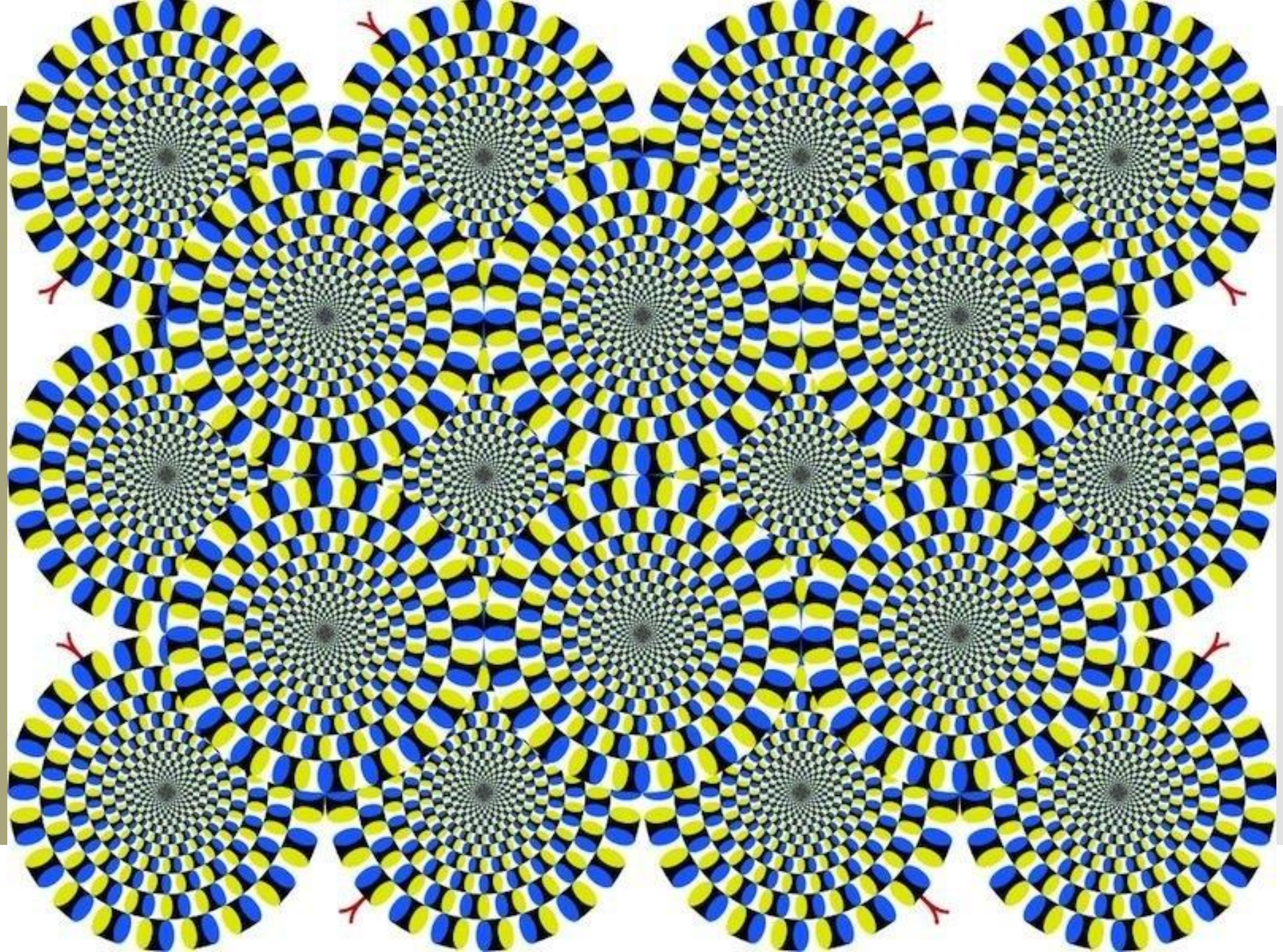


common fate

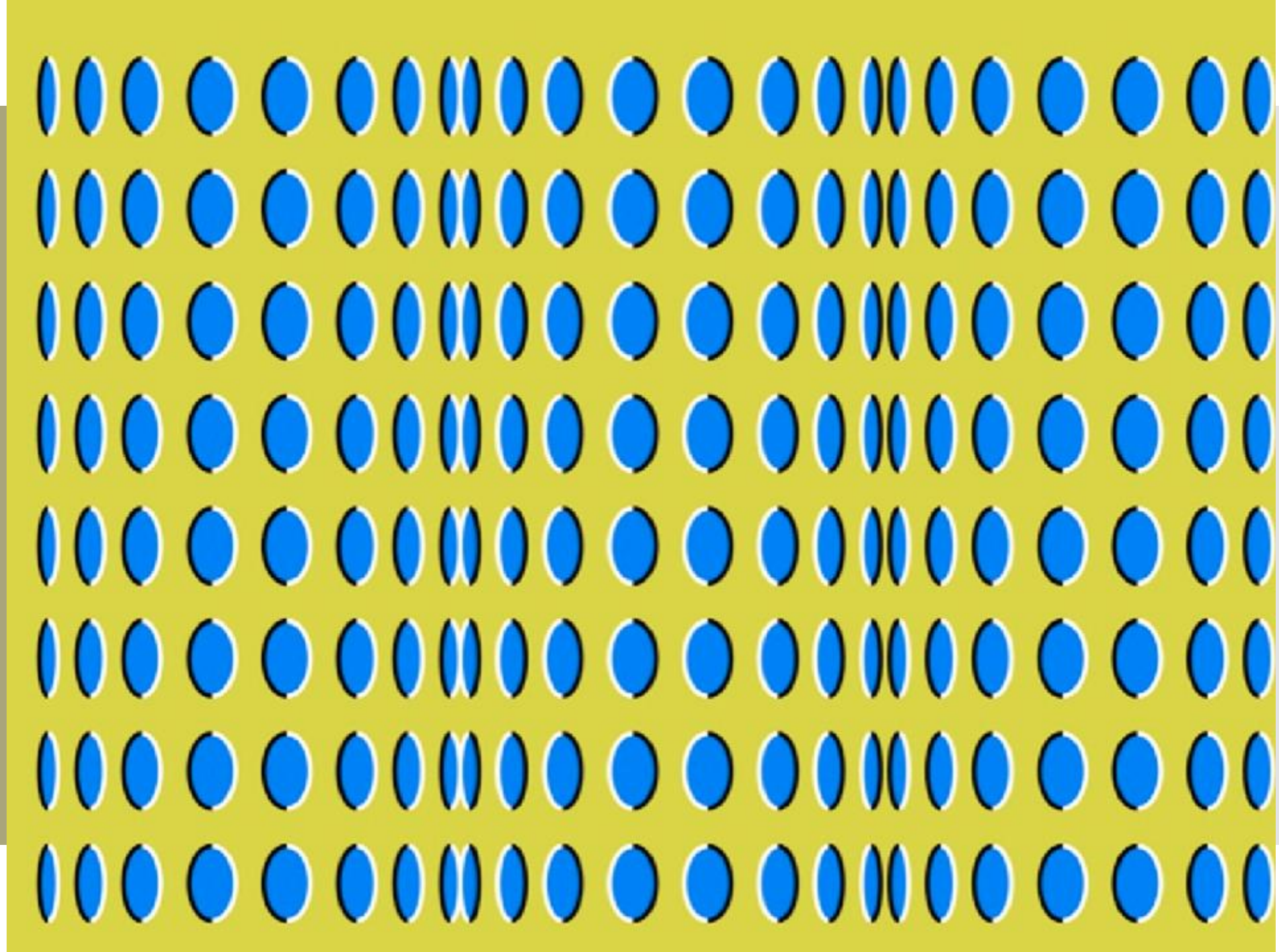


continuity

Do you see movement?

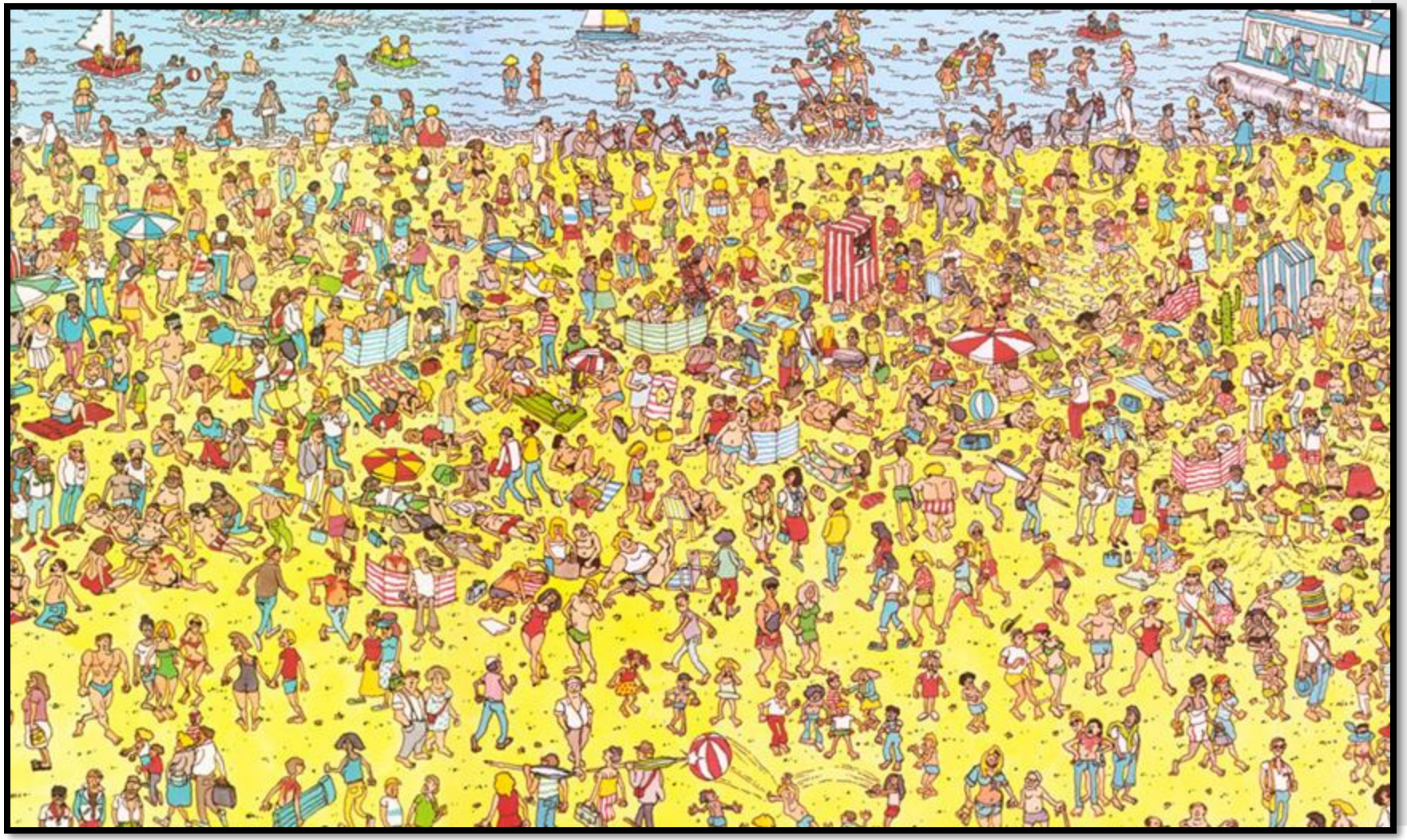


Do you see movement?



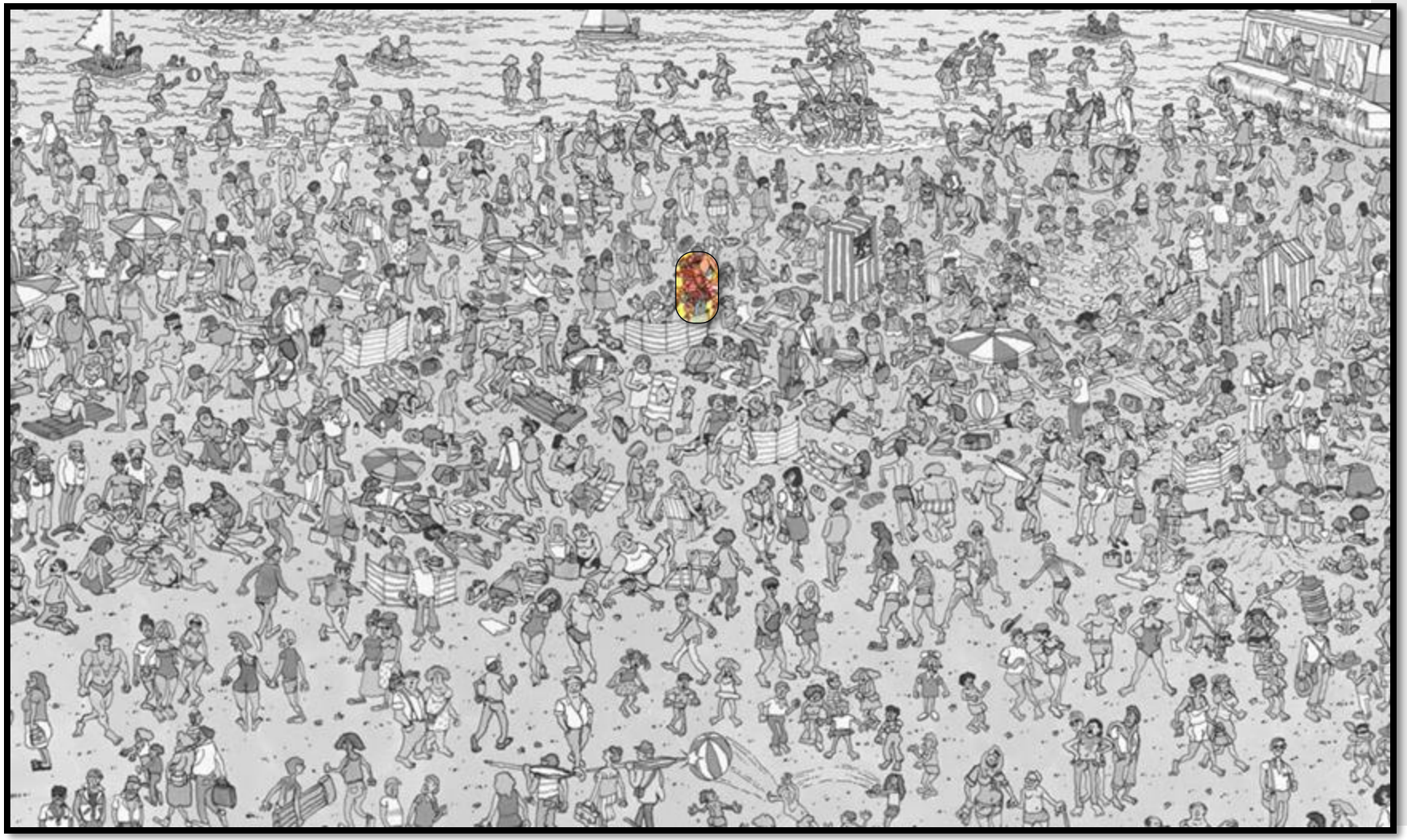
Visual perception

Some things are processed slowly



Visual perception

Others are incredibly fast

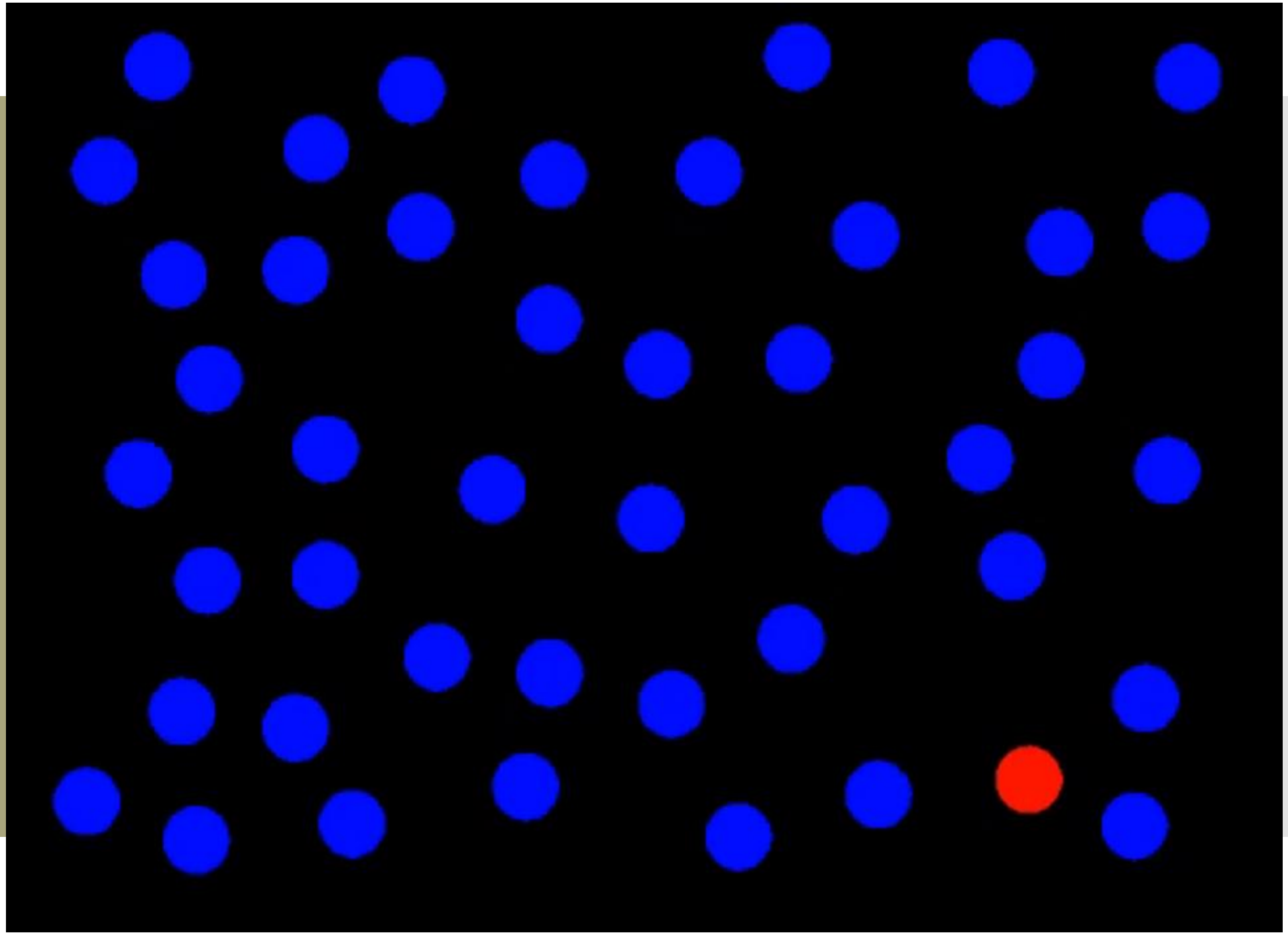


Visual perception

Fast = “pre-attentive processing”

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

Perception: Pre-attentive Processing



Perception: Pre-attentive Processing

What did you see?

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

128176875613897654698450698562498282676298098584582245198564589450984599859435859891330249945959595772564675750678974567884578981982167765487636496856091294968 6

How many zeros are there?

Attentive counting

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

Pre-attentive counting

1281768756138976546984506985604982826762

9809858458224509856458945098450980943585

9091030209905959595772564675050678904567

8845789809821677654876364908560912949686

How many threes are there?

Pre-attentive processing for visualization

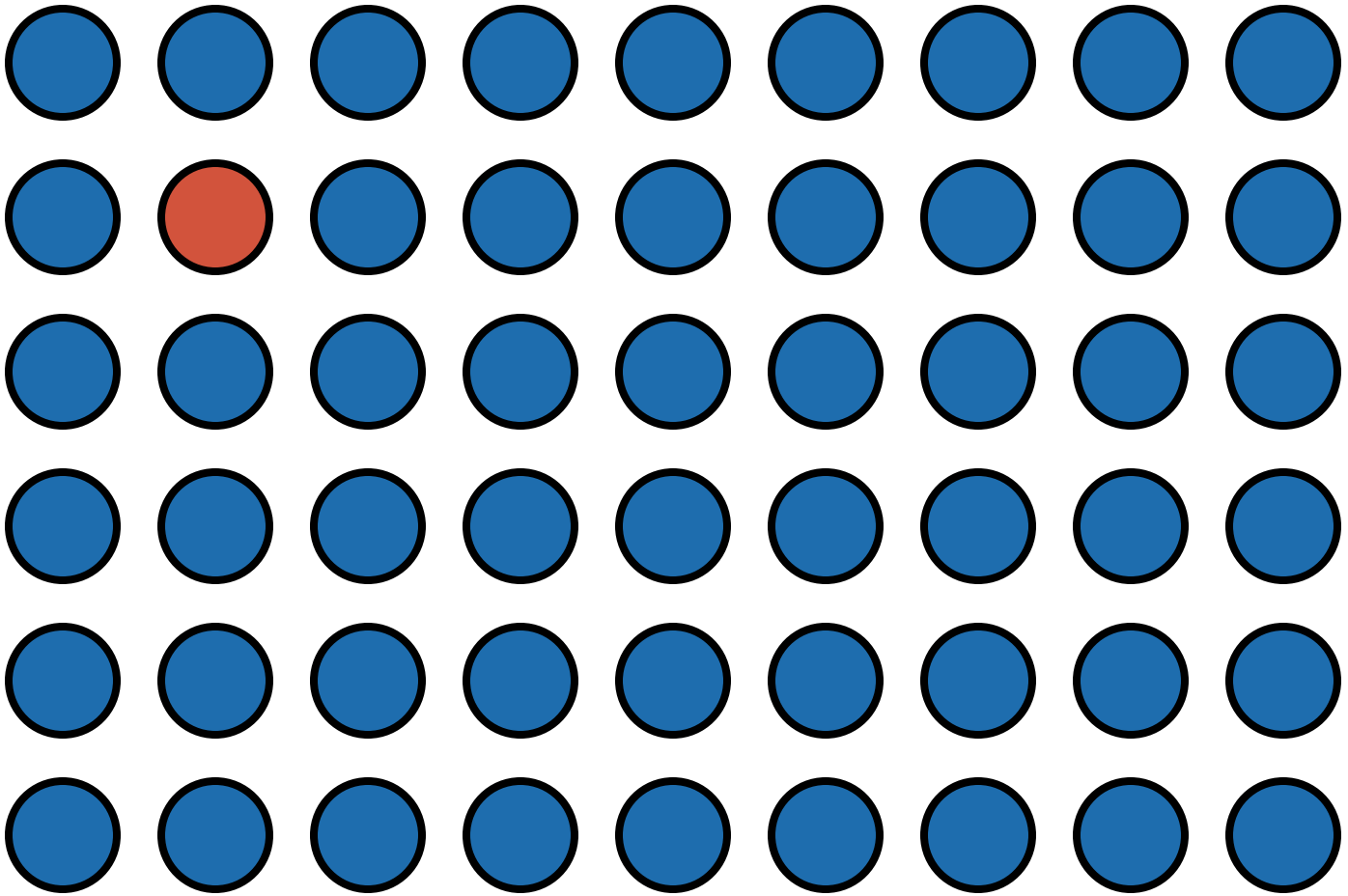
Question 1: how do we (vis designers) use pre-attentive processing to our advantage?

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

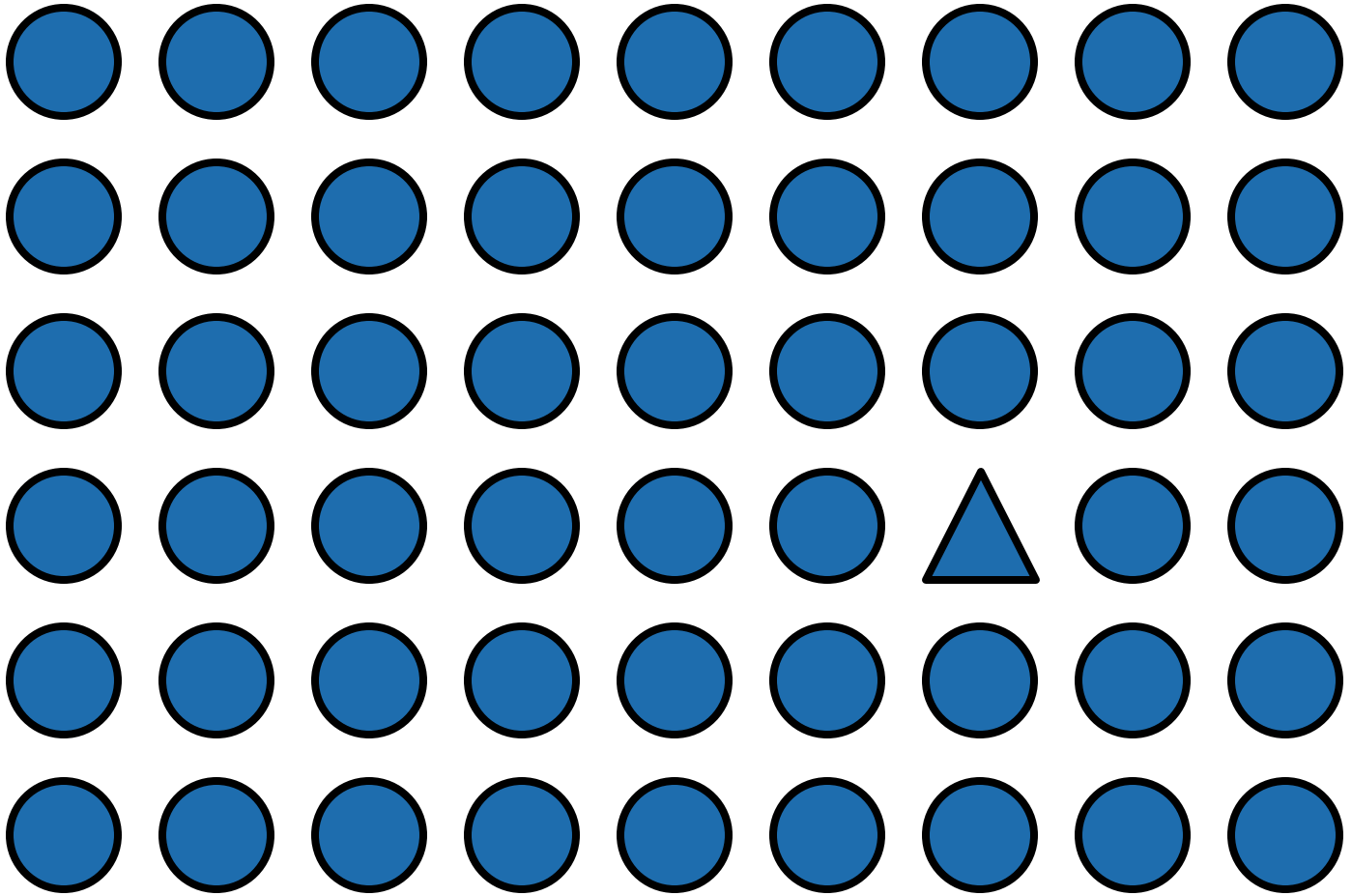
Pre-attentive processing for visualization

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

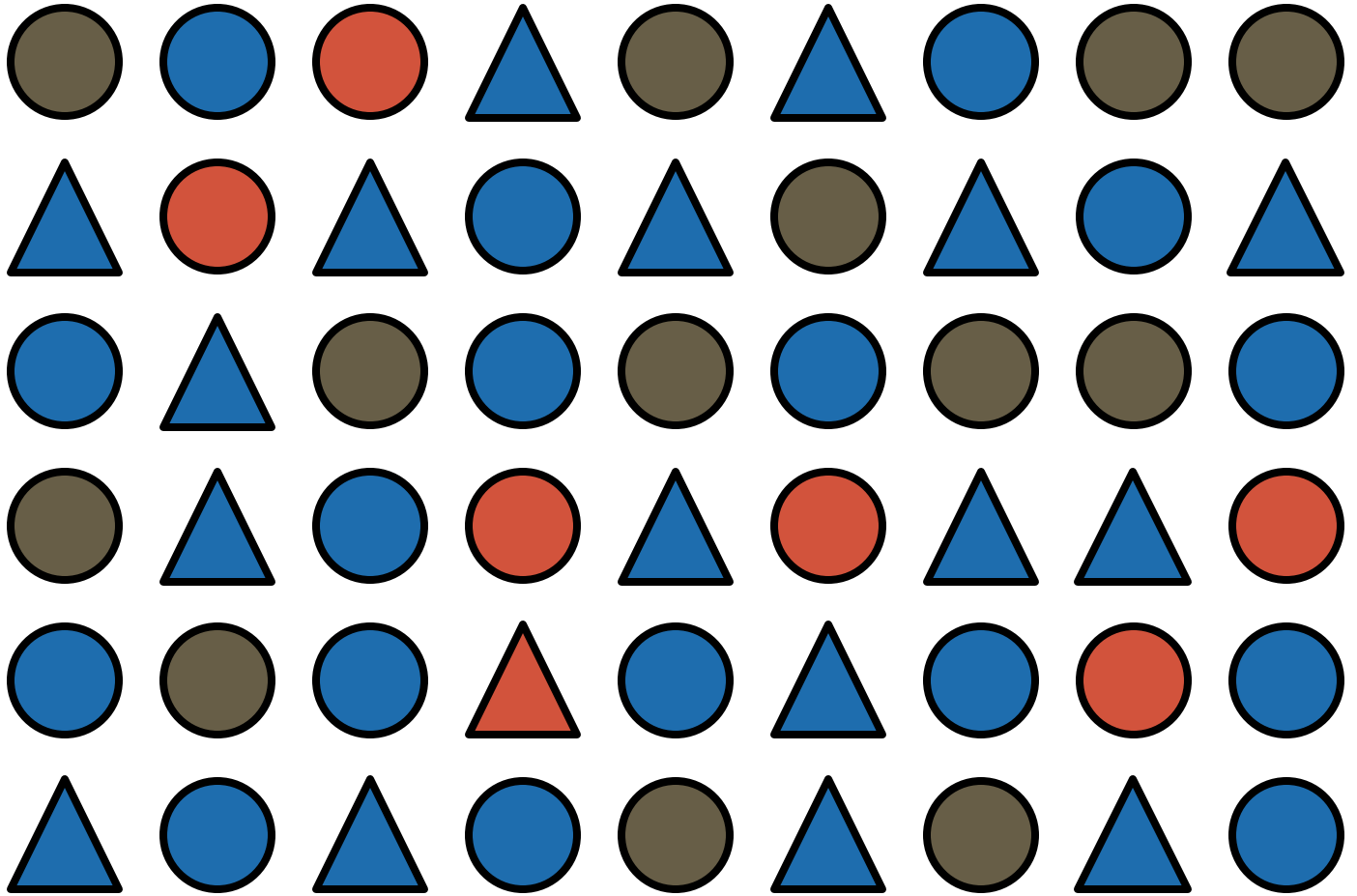
Pre-attentive processing: color (hue)



Pre-attentive processing: shape (curvature)



Pre-attentive processing: shape + color?



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 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

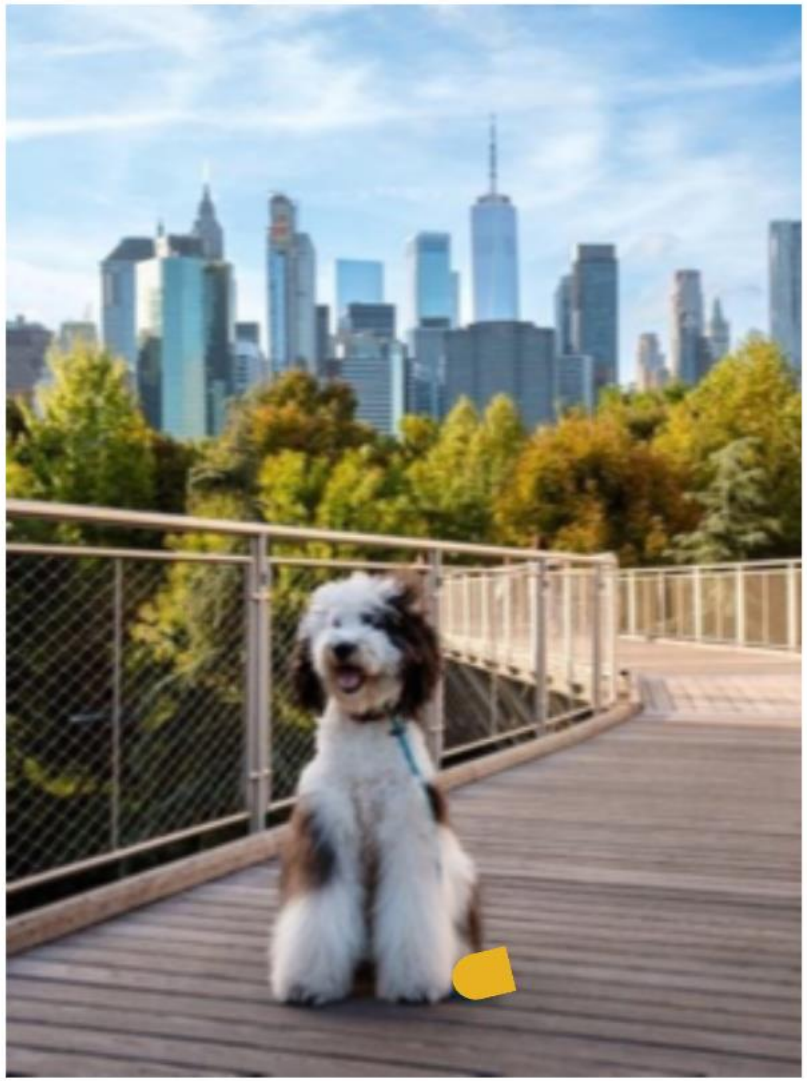
- Whatever draws our eyes draws our attention
- This can be useful
- It can also be problematic:

Pre-attentive processing for visualization: The downsides

Ex. flicker can cause change blindness

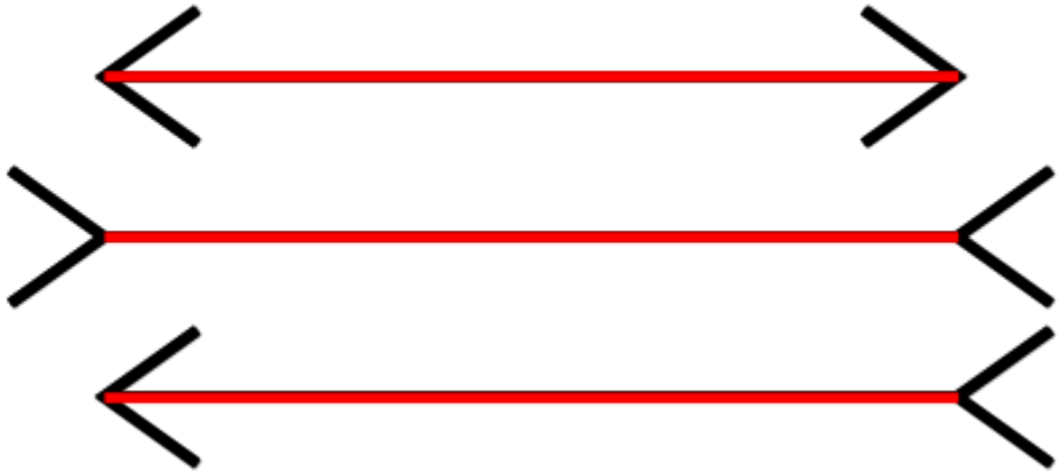
Pre-attentive processing for visualization: The downsides

Can you see it now?



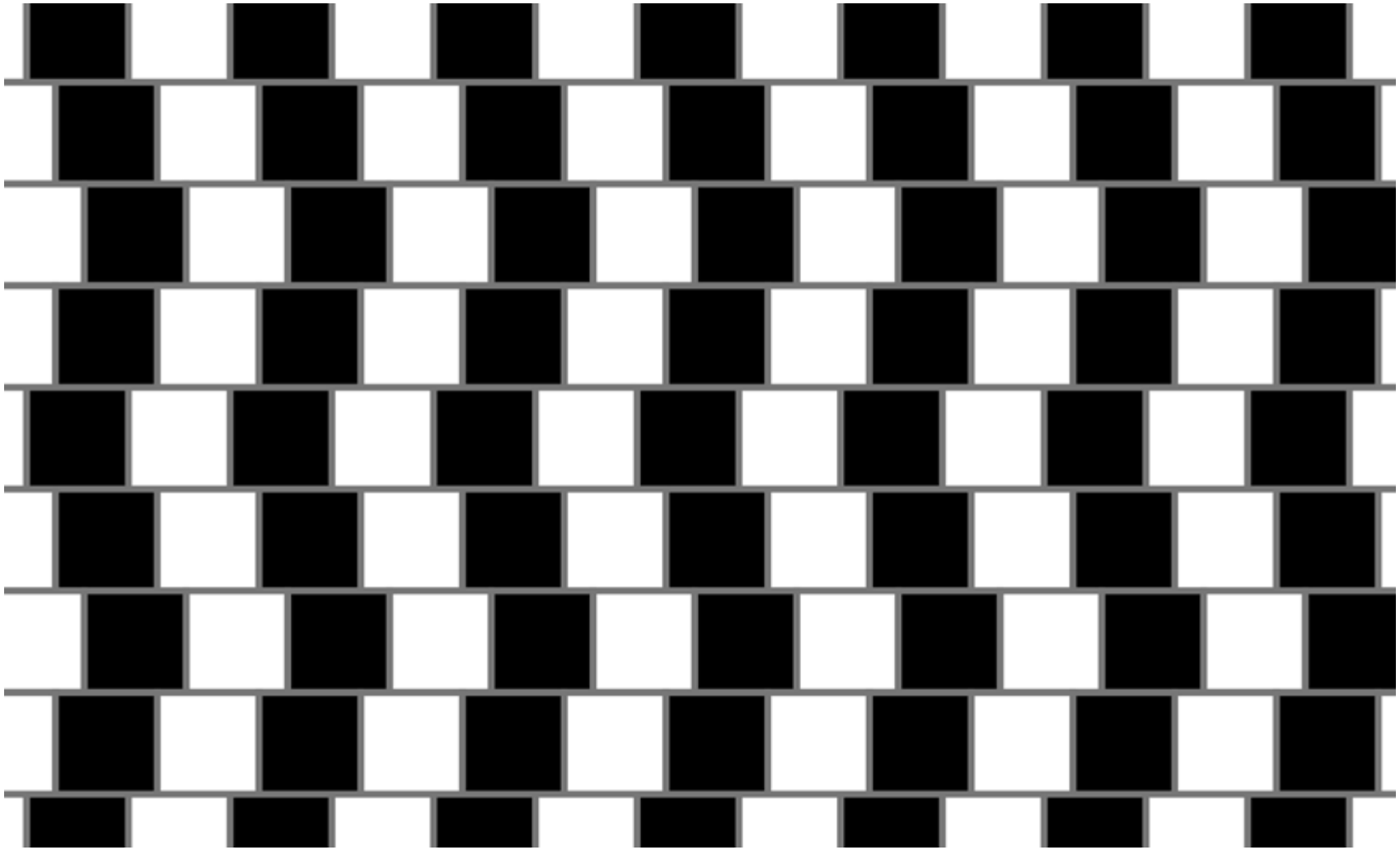
Pre-attentive processing for visualization: The downsides

Sometimes gestalt & pre-attention compete



Pre-attentive processing for visualization: The downsides

Sometimes gestalt & pre-attention compete



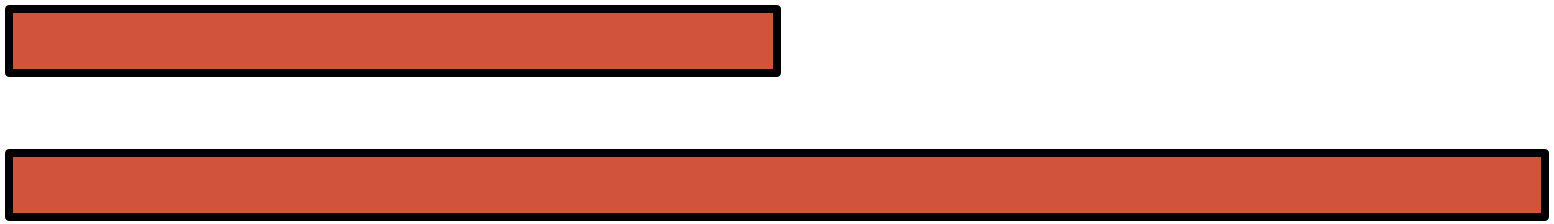
Attentive processing

Okay, what about **attentive** processing?

Attentive processing

Magnitude estimation

Question: How much **bigger** is the lower bar?

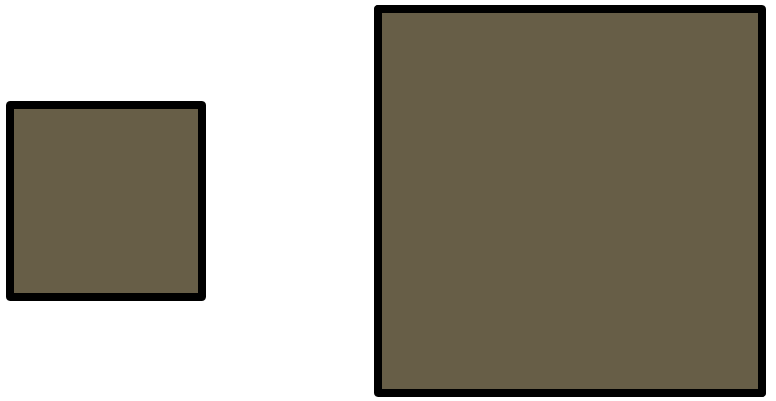


Answer: 2X

Attentive processing

Magnitude estimation

Question: How much **bigger** is the right square?

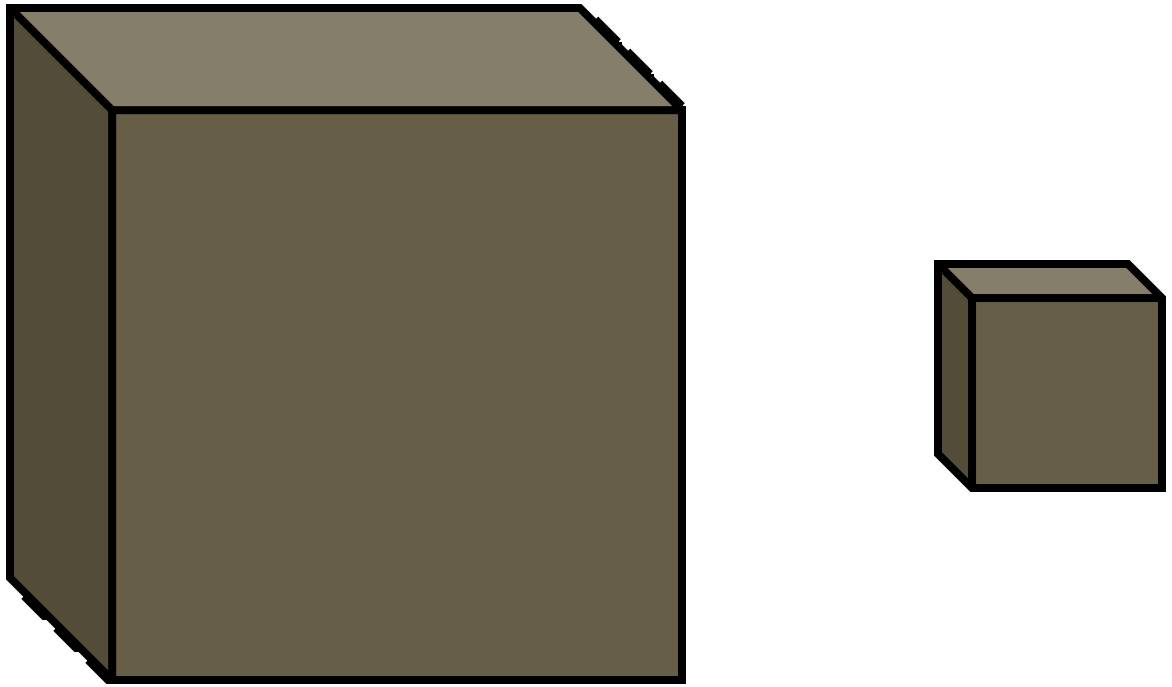


Answer: 4x

Attentive processing

Magnitude estimation

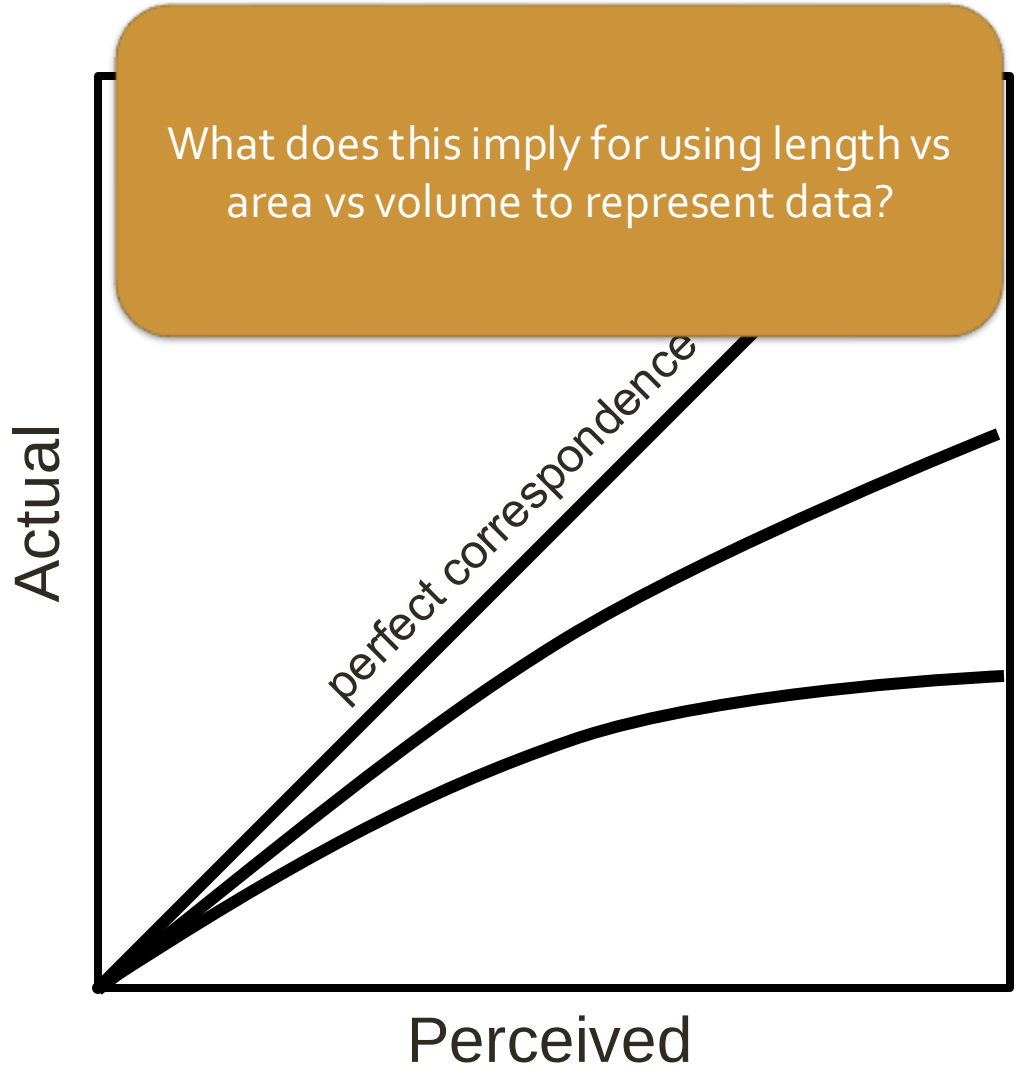
Question: How much **bigger** is the left cube?



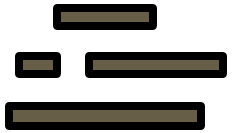
Answer: 27x

Attentive processing

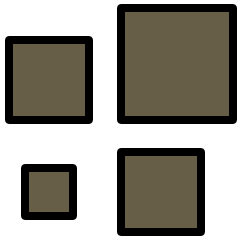
"Apparent" magnitude



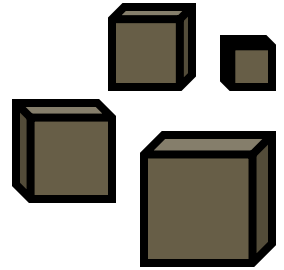
Length
estimate correctly



Area
under-estimate



Volume
way under-estimate



http://makingmaps.net/2007/08/28/perceptual-scaling-of-map-symbols/