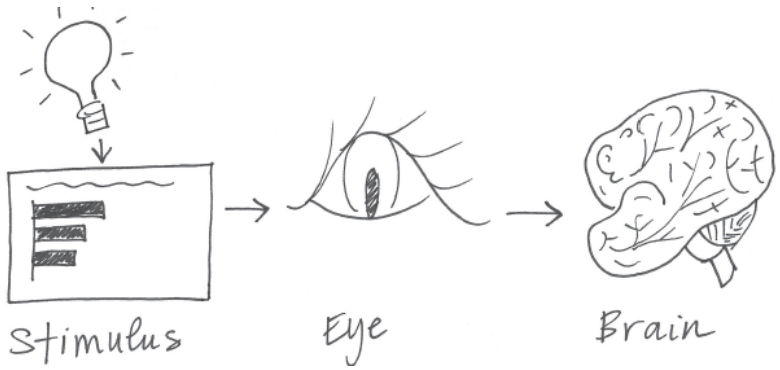
Visual Perception and Cognition

Goal: to know how our visual channel works and what properties of visual perception that we can use to generate effective visualizations.

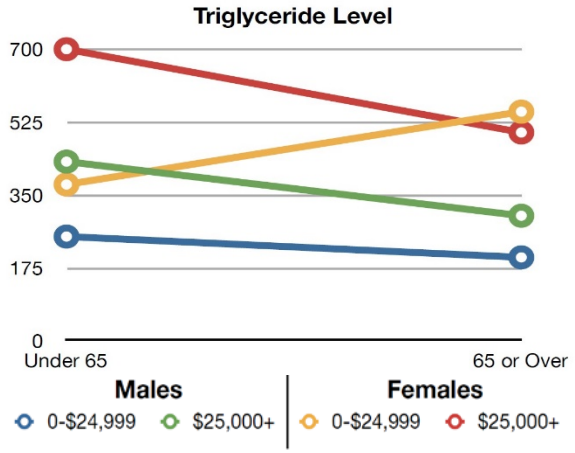
Recall

23	24	25	27	26	25	25	24	24
24	26	28	30	29	27	26	28	31
26	28	29	31	32	29	30	32	36
26	27	30	32	33	34	35	38	41
27	28	28	32	34	35	37	41	42
27	28	31	33	36	38	40	42	43
28	29	32	32	35	37	41	43	44
30	33	33	34	36	38	41	42	44
32	34	27	29	40	42	43	44	45

22-25	26-29	30-33
34-37	38-41	42-45



	Male		Female	
Income\Age	<65	65 and above	<65	65 and above
0-$24,999	250	200	375	550
$25,000+	430	300	700	500

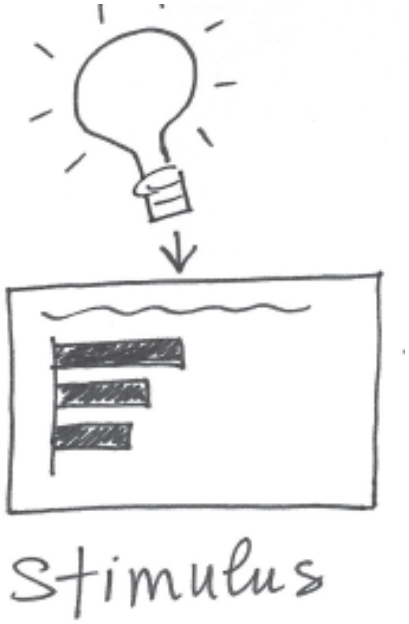


Visual representation is one effective way to convey information

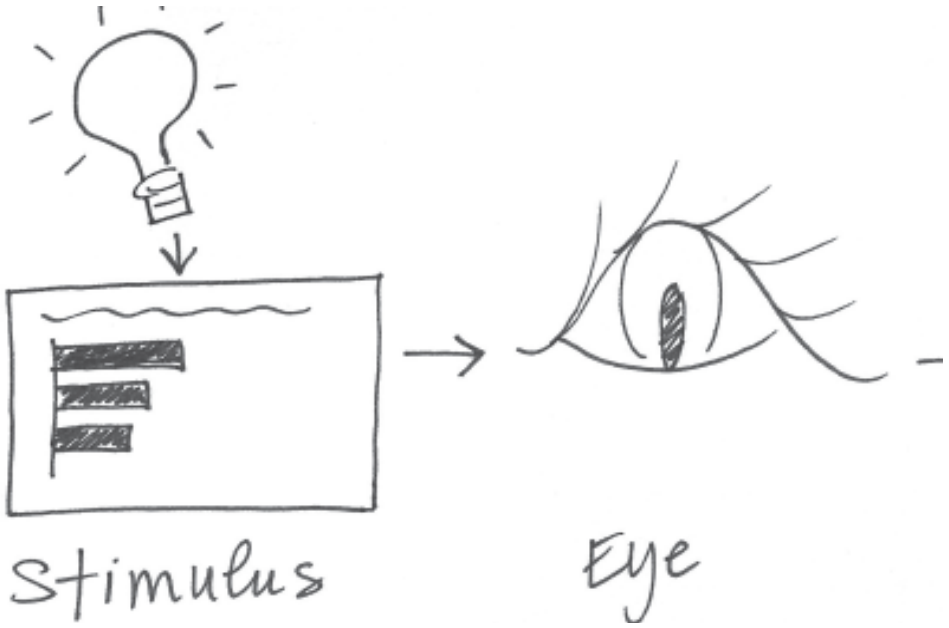
Cognitive study has shown that human visual system is the most effective channel to transport information to the brain. How?

“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



Visual stimulus

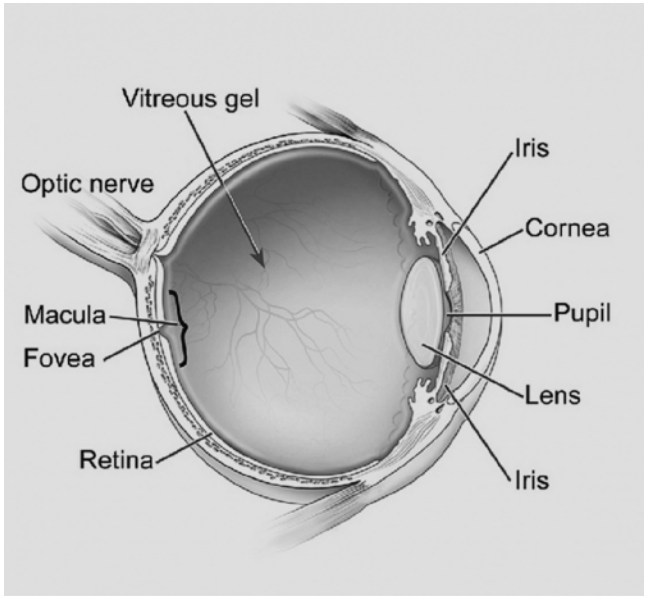


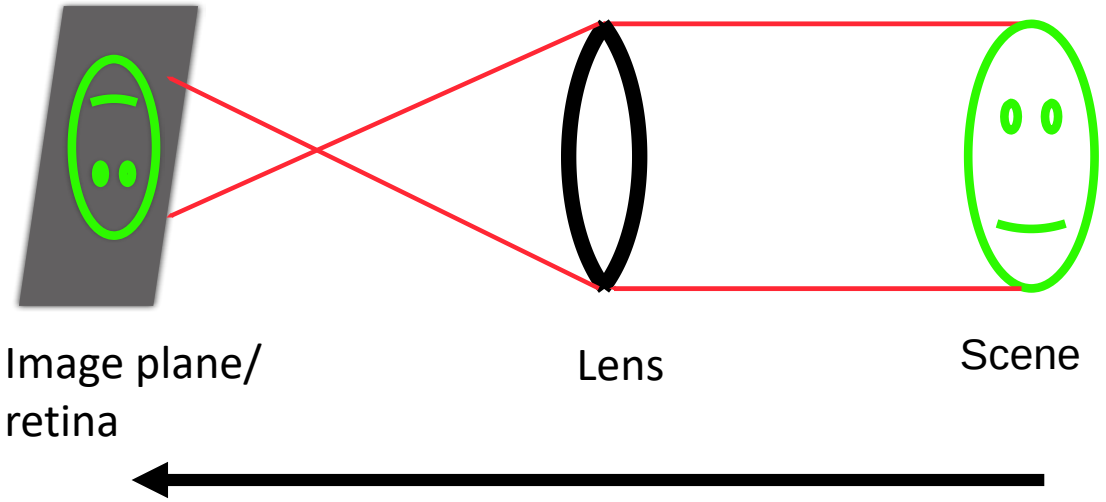
Visual stimulus

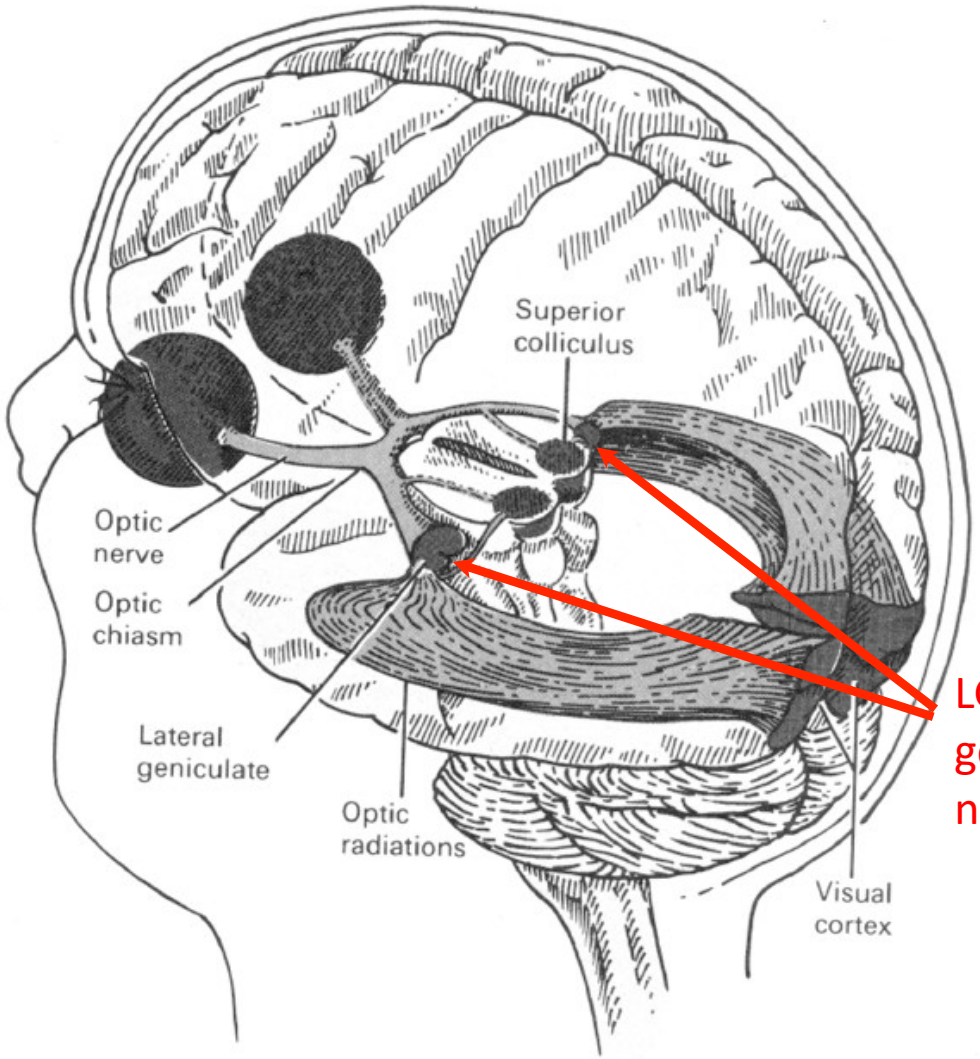
Visual perception

We see things:
Shapes, colors, sizes, texture, orientation, transparency, etc.

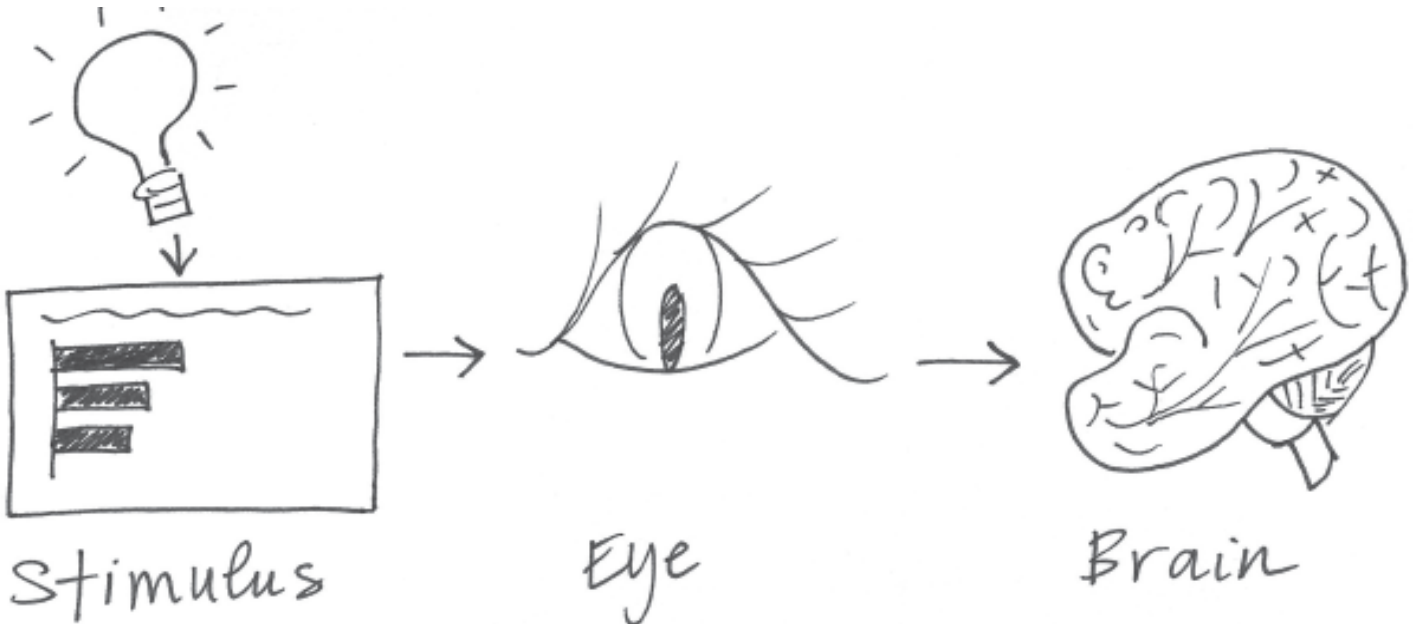
Perspective Projection and Image Formation







LGN: lateral geniculate nucleus

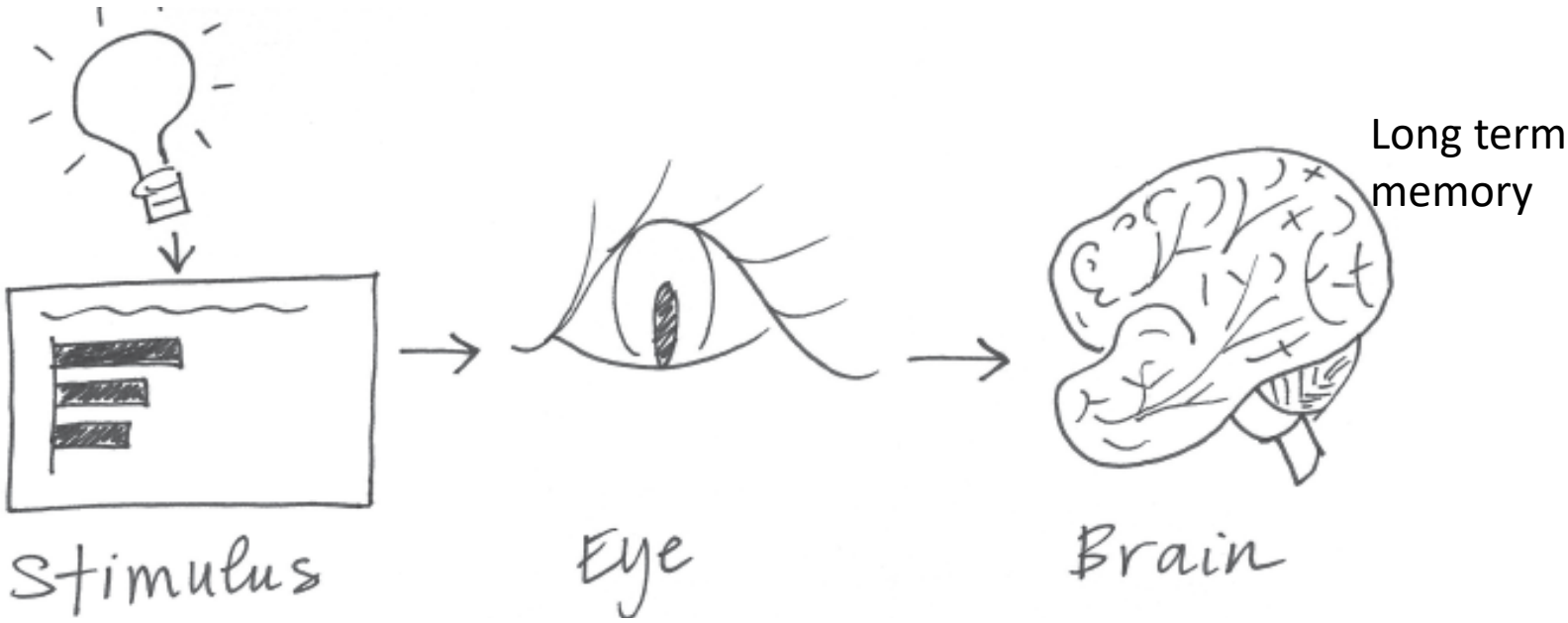


Visual stimulus

Visual perception

We see things:
Shapes, colors, sizes, texture, orientation, transparency, etc.

Visual perception is about how our brain perceives (senses) visuals



Visual stimulus

Visual perception

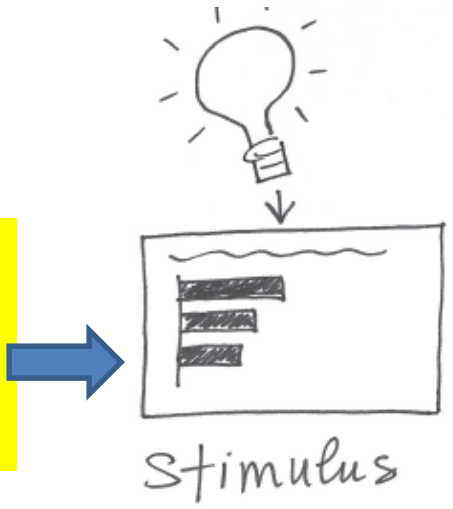
We see things:
Shapes, colors, sizes, texture, orientation, transparency, etc.

Cognition

Mental process of acquiring knowledge from perception, experiences and others:
How to interpret/ understand what we see

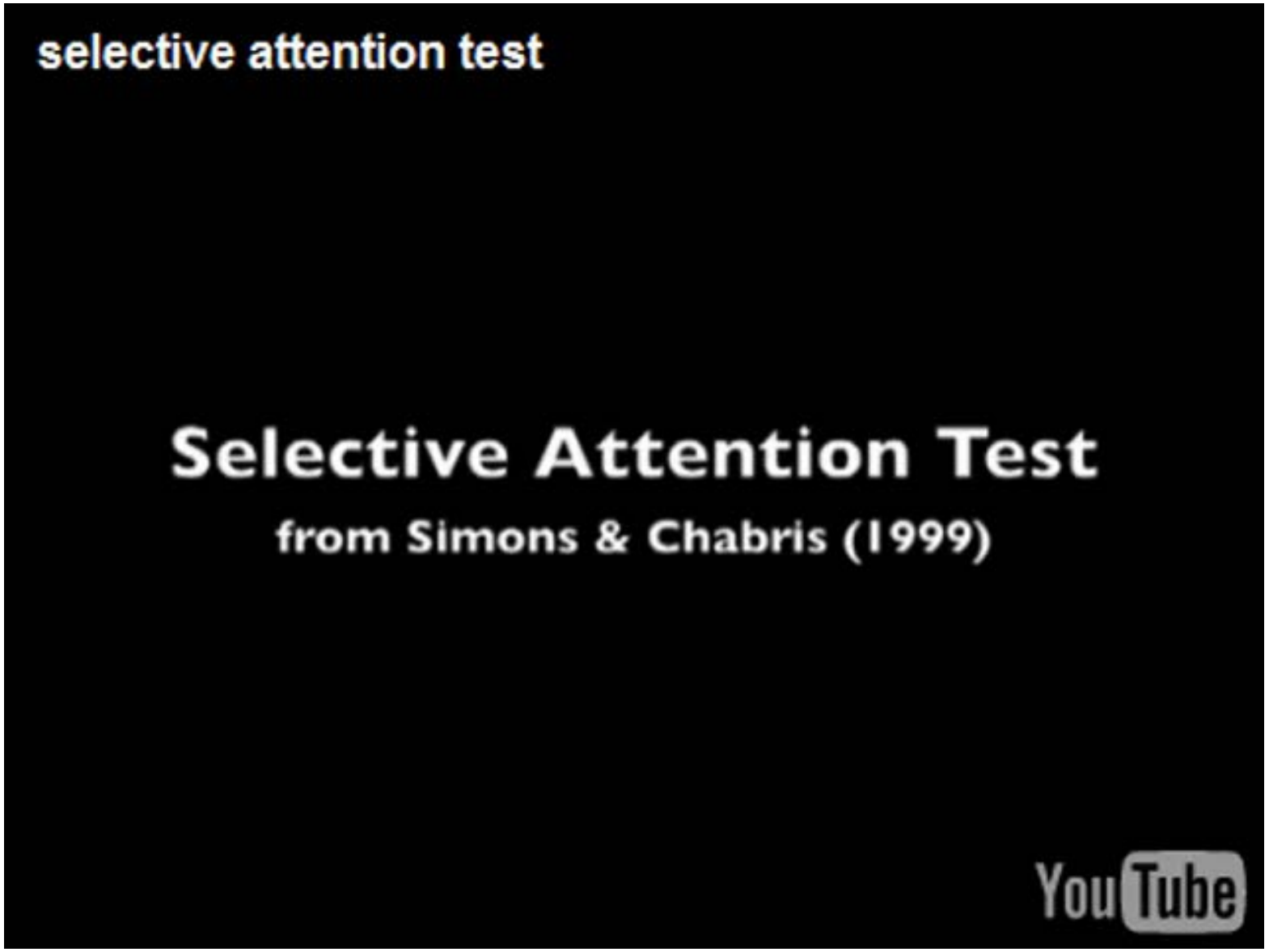
"Visualization is really about **external cognition**, that is, how resources outside the mind can be used to boost the cognitive capabilities of the mind."

We will utilize some properties of our visual perception to generate effective visualizations.

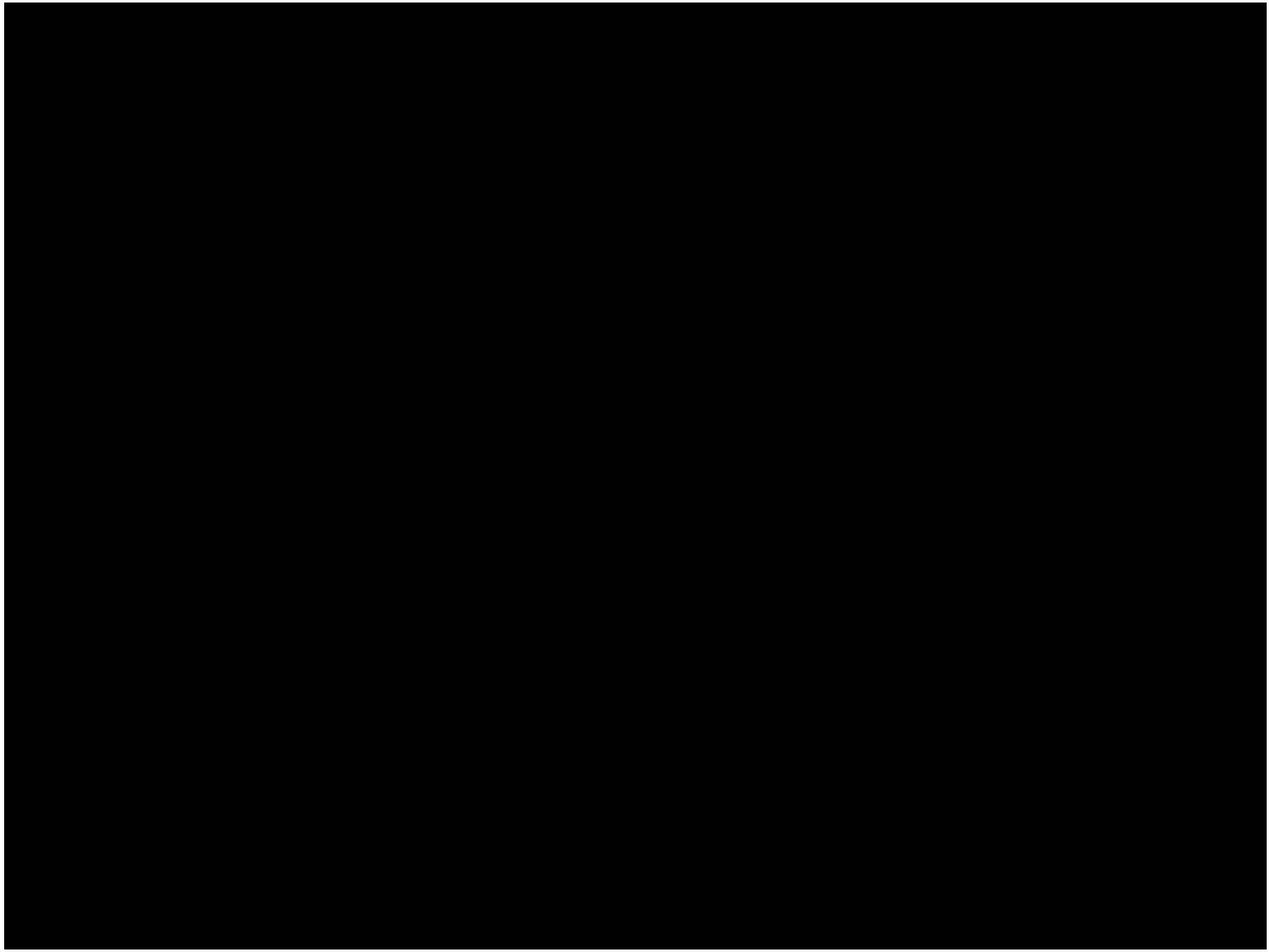


A few properties of our visual perception

Note that the following properties are not presented in an organized fashion.
We will just sample some useful properties related to the task of visualization.


selective attention test
Selective Attention Test
from Simons & Chabris (1999)
YouTube

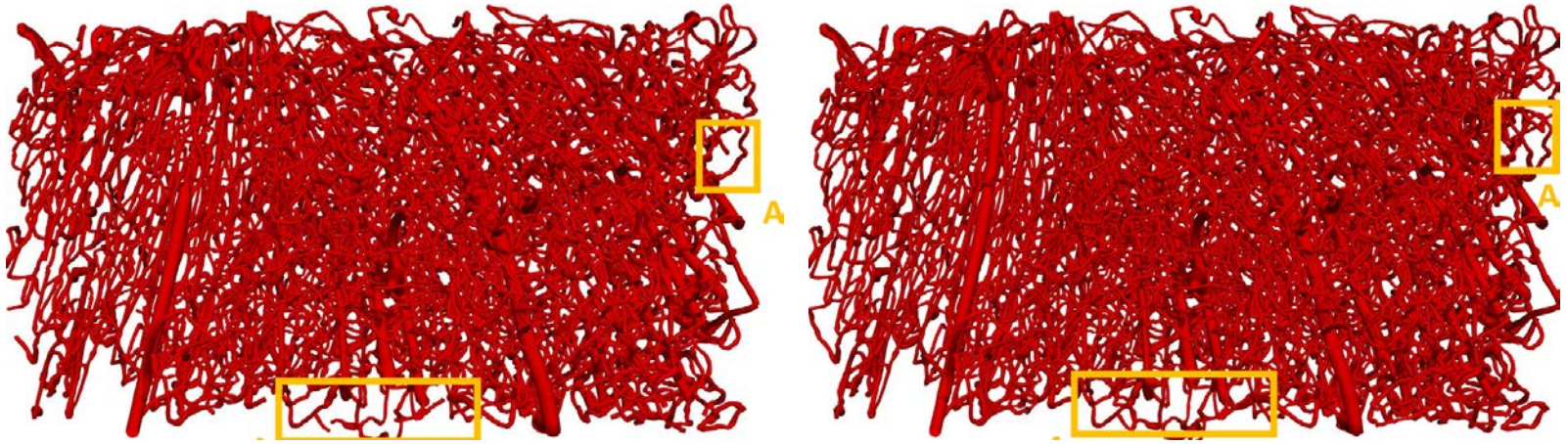
Let us look at another example



Visual Cognition Lab, UIUC

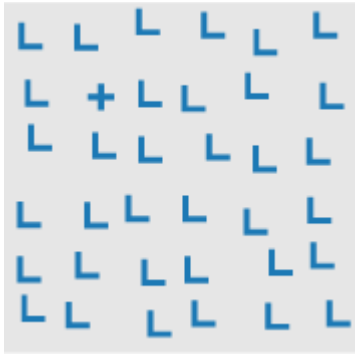
This is what is called change-blindness.

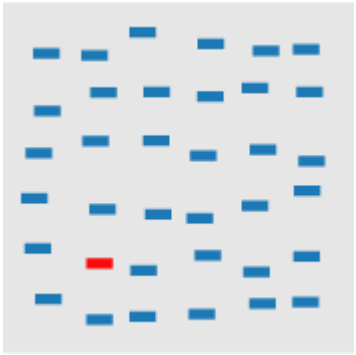
These examples tell us that people need to **pay** a lot of **attention in order to capture the (temporal) changes (and details)**.

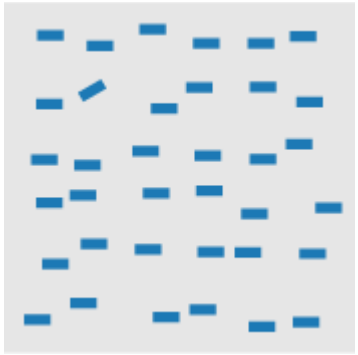


These examples tell us that people need to **pay** a lot of **attention in order to capture the (temporal) changes (and details)**.

Therefore, visualization should **emphasize /highlight changes** (or difference, anomaly) to help relieve the cognition load if changes and differences are of interest.

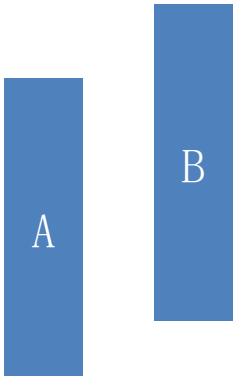






Our visual perception system is **good at** observing **relative difference in space** and is easy to be **drawn to the boundaries of different regions / objects**.

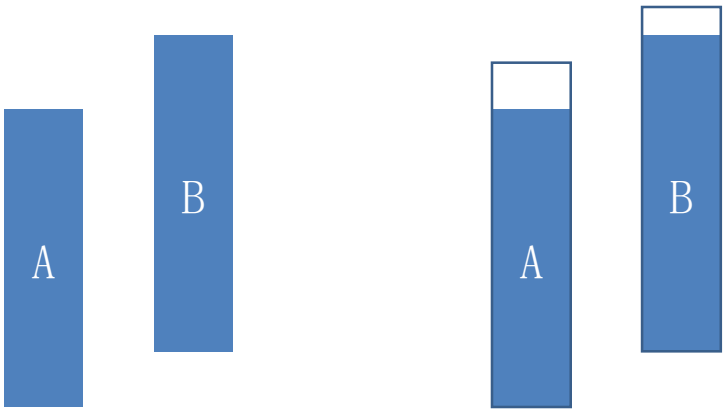
Relative vs. Absolute



Weber’s Law

We judge based on the relative difference rather than the individual absolute values.

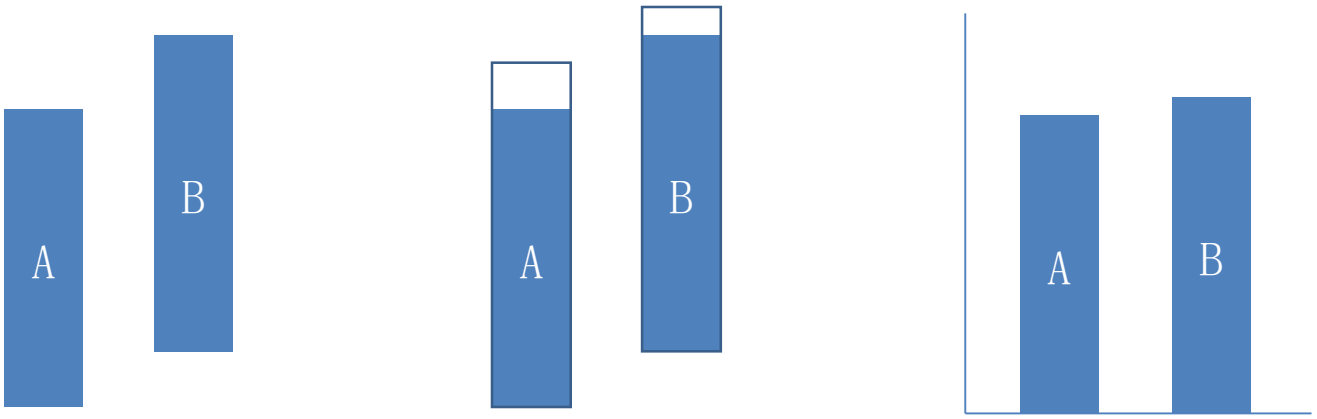
Relative vs. Absolute



Weber's Law

We judge based on the relative difference rather than the individual absolute values.

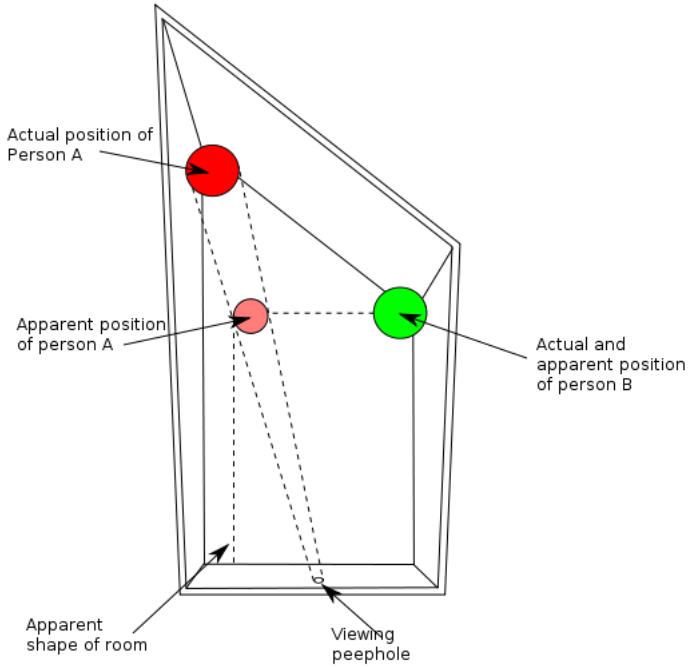
Relative vs. Absolute



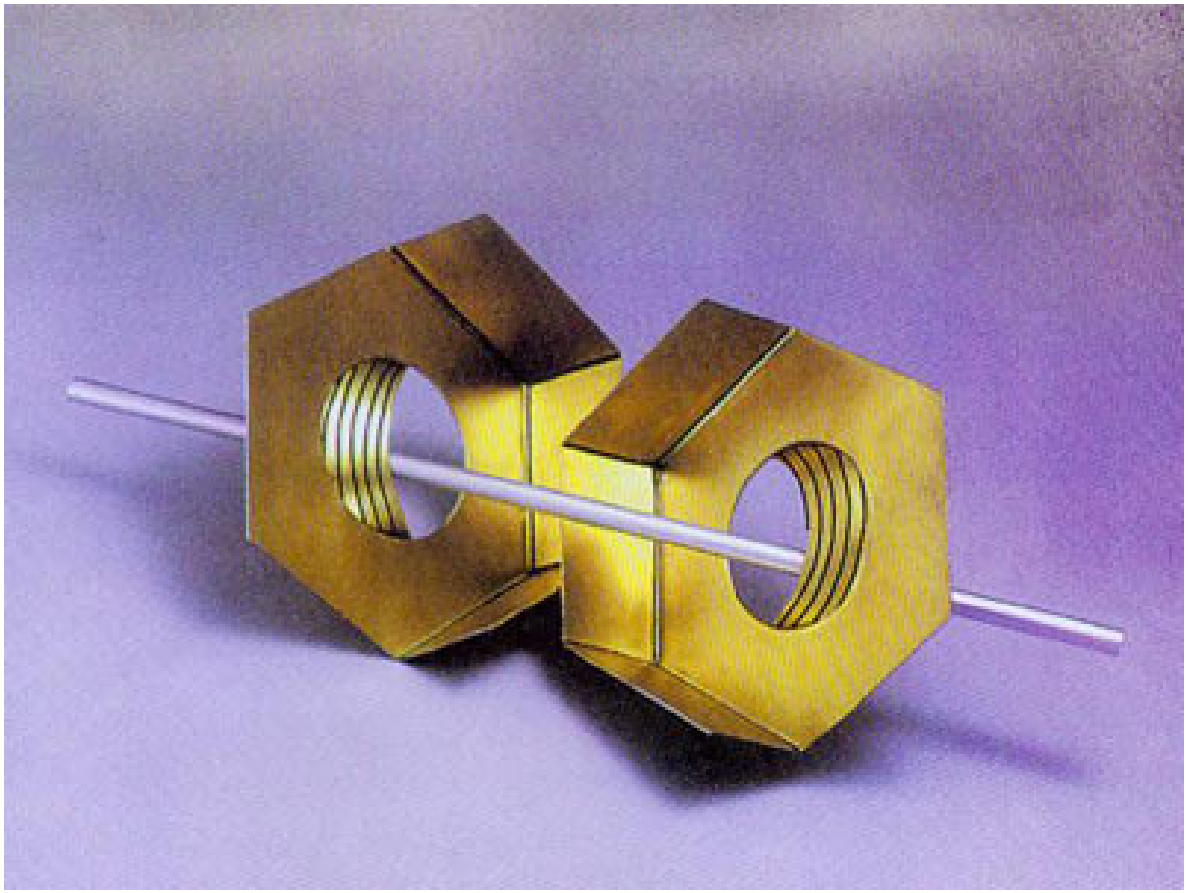
Weber's Law

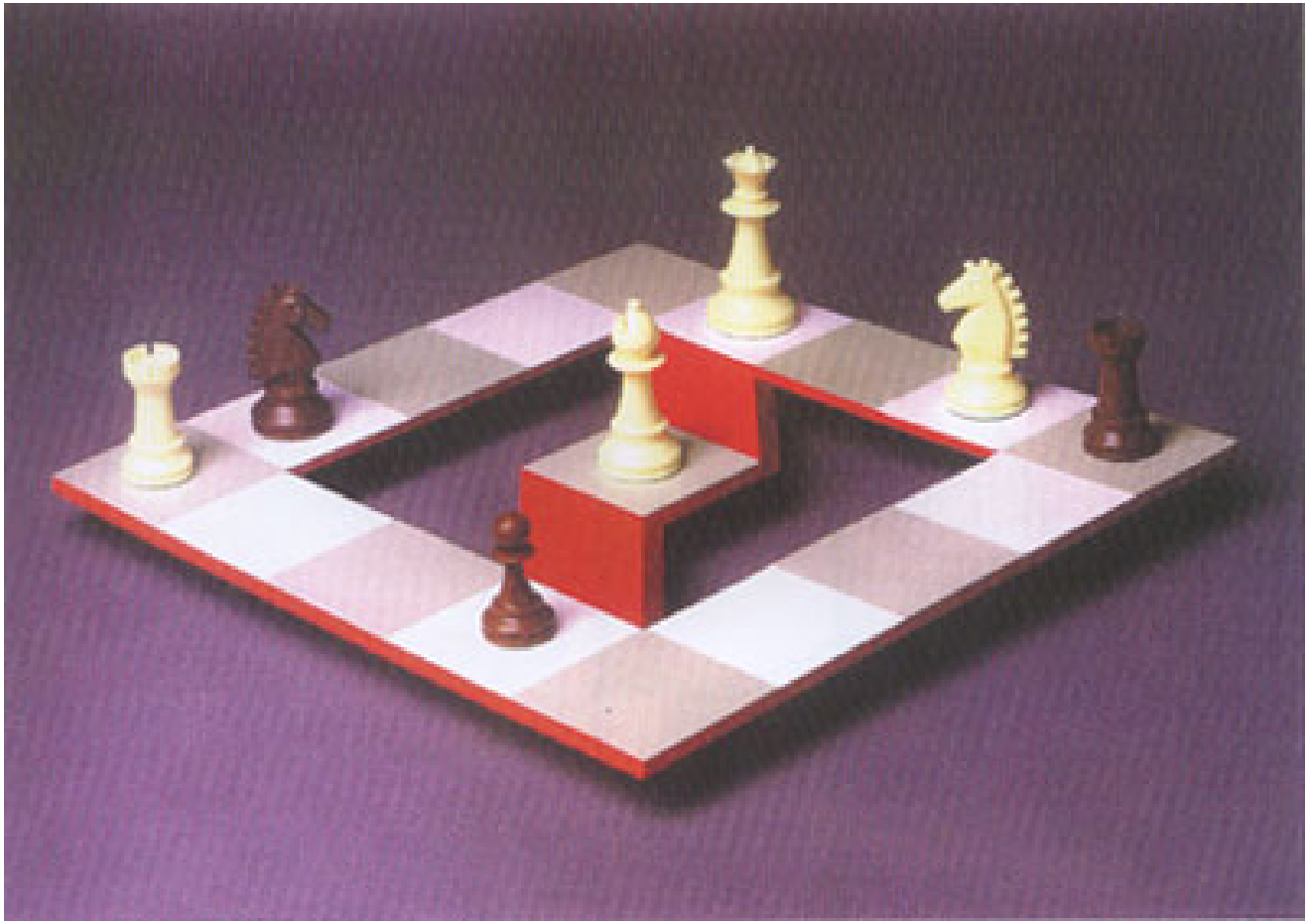
We judge based on the relative difference rather than the individual absolute values.

Perceived Sizes Are Relative



Is Seeing ALWAYS believing??

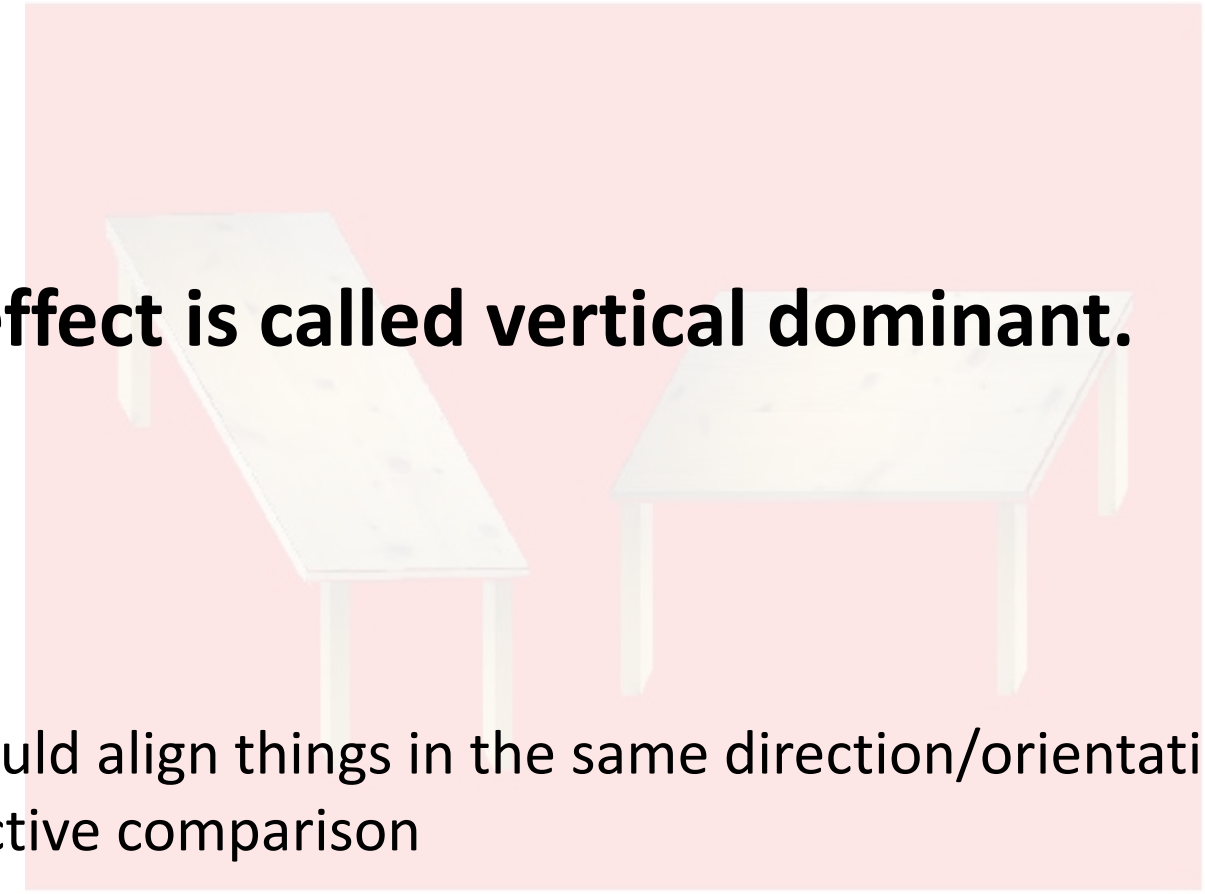




Shepard's Rotated Table

Which table is longer?

Shepard's Rotated Table



This effect is called vertical dominant.

You should align things in the same direction/orientation for an effective comparison

Which table is longer?

A couple more things about cognition via visual perception

What we **SEE** is **more** than what is actually there!

http://www.3d-street-art.com/

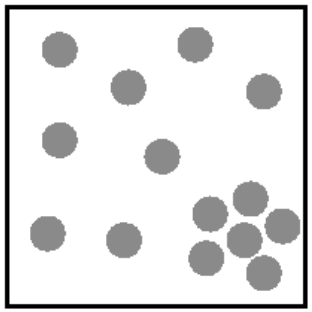
http://www.3d-street-art.com/

"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

When we create visualization, we need to consider the knowledge background of the audience. If your visualization leads to guessing, then it is not good.

Pre-attentive vs. attentive

Pre-attentive		Attentive
< 500ms	Task	> 500ms
< 10ms	Individual object	> 10ms
Parallel processing		Sequential processing

First perceive some patterns (or structures, anomalies, etc.), then start thinking what they are.

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)

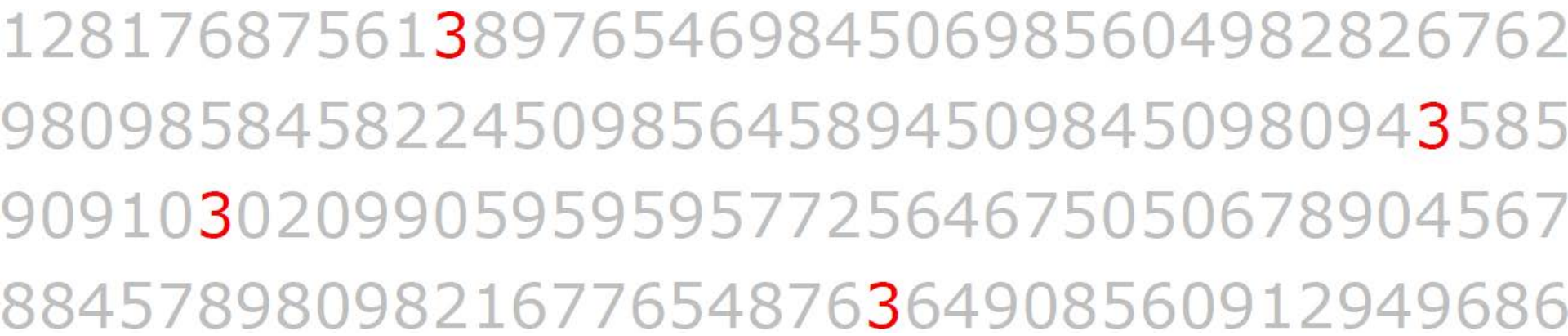
How to make things pop-out?

How many 3's?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

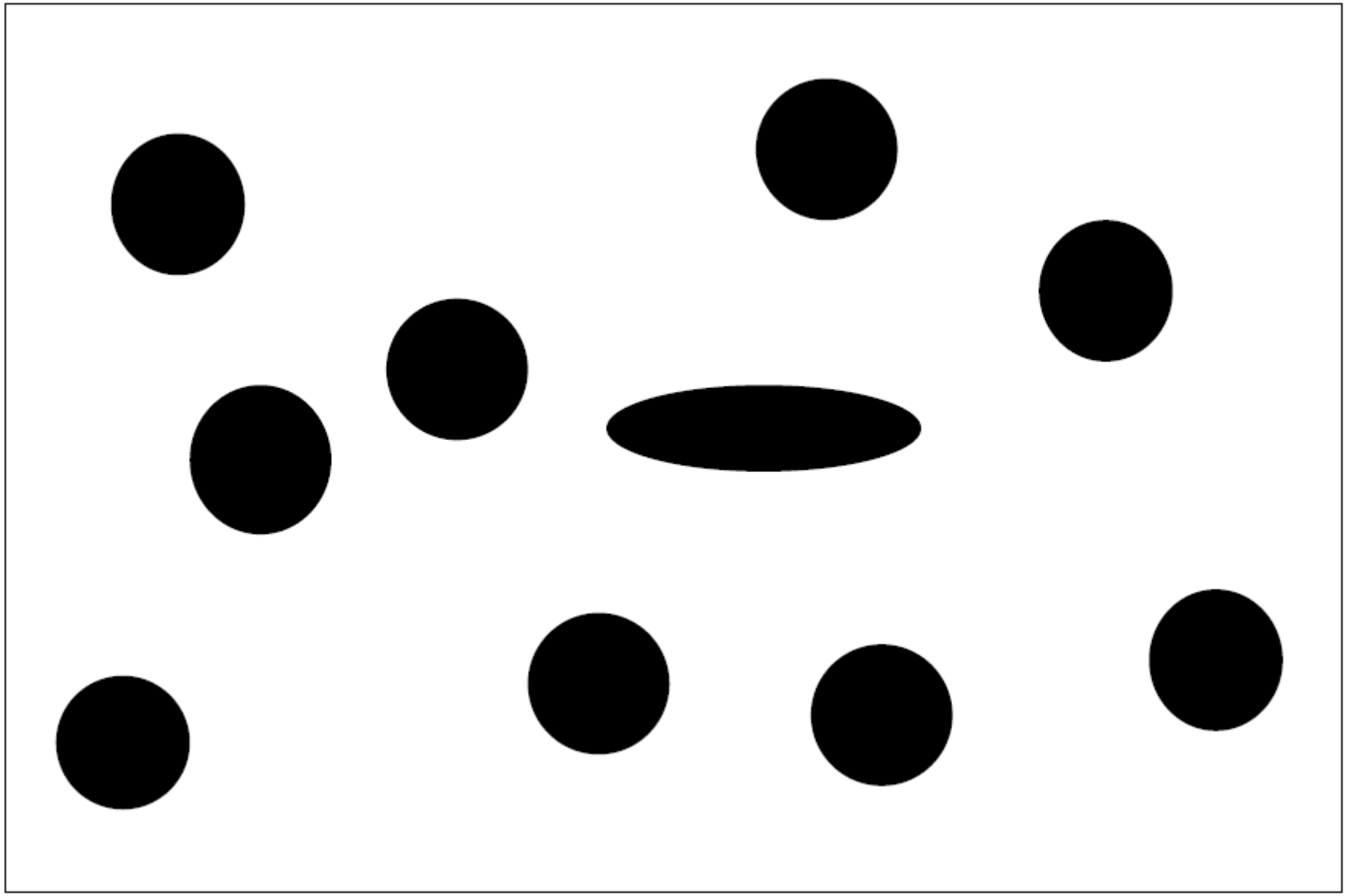
How to make things pop-out?

How many 3's?

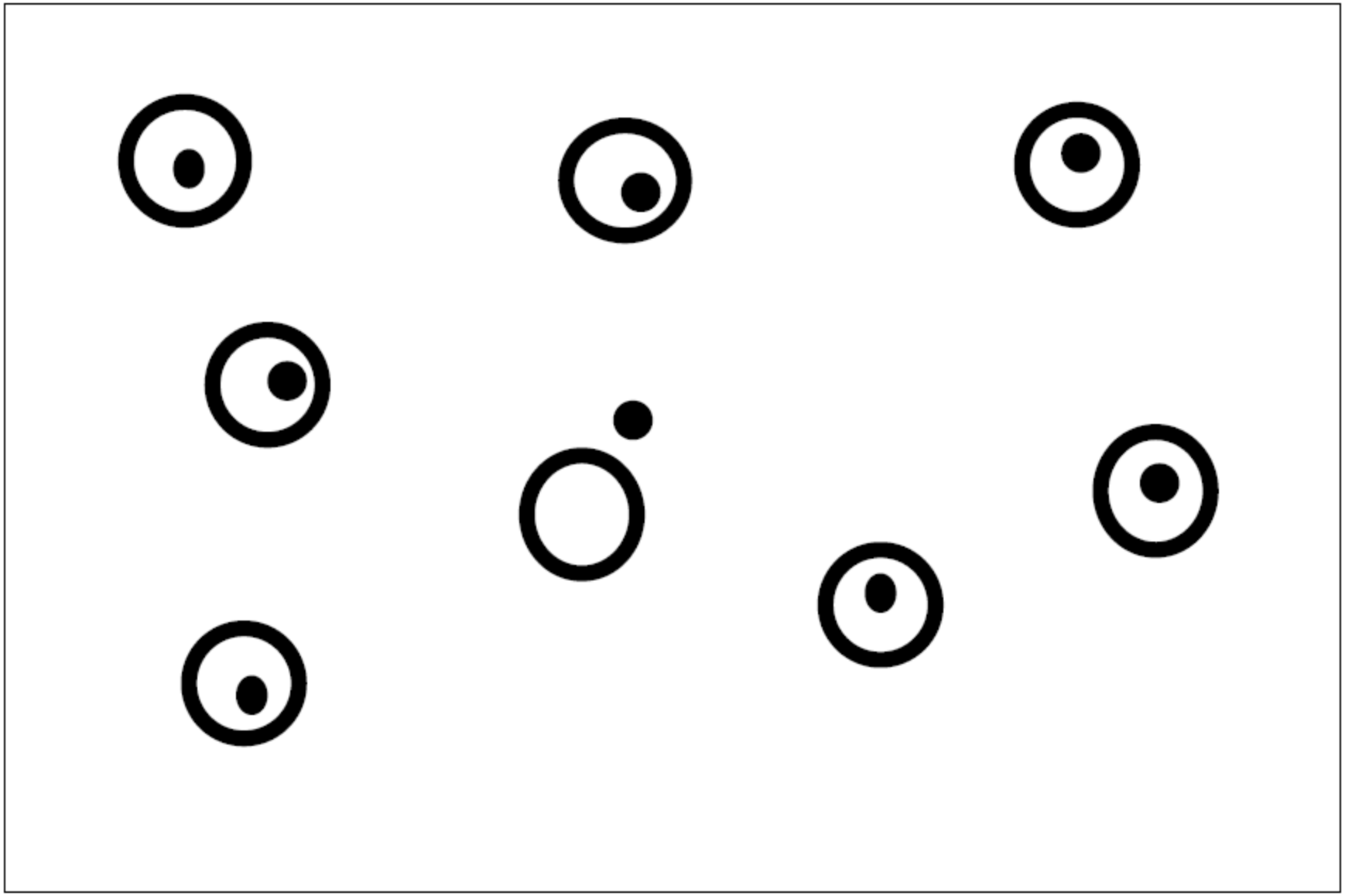


How to make things pop-out?

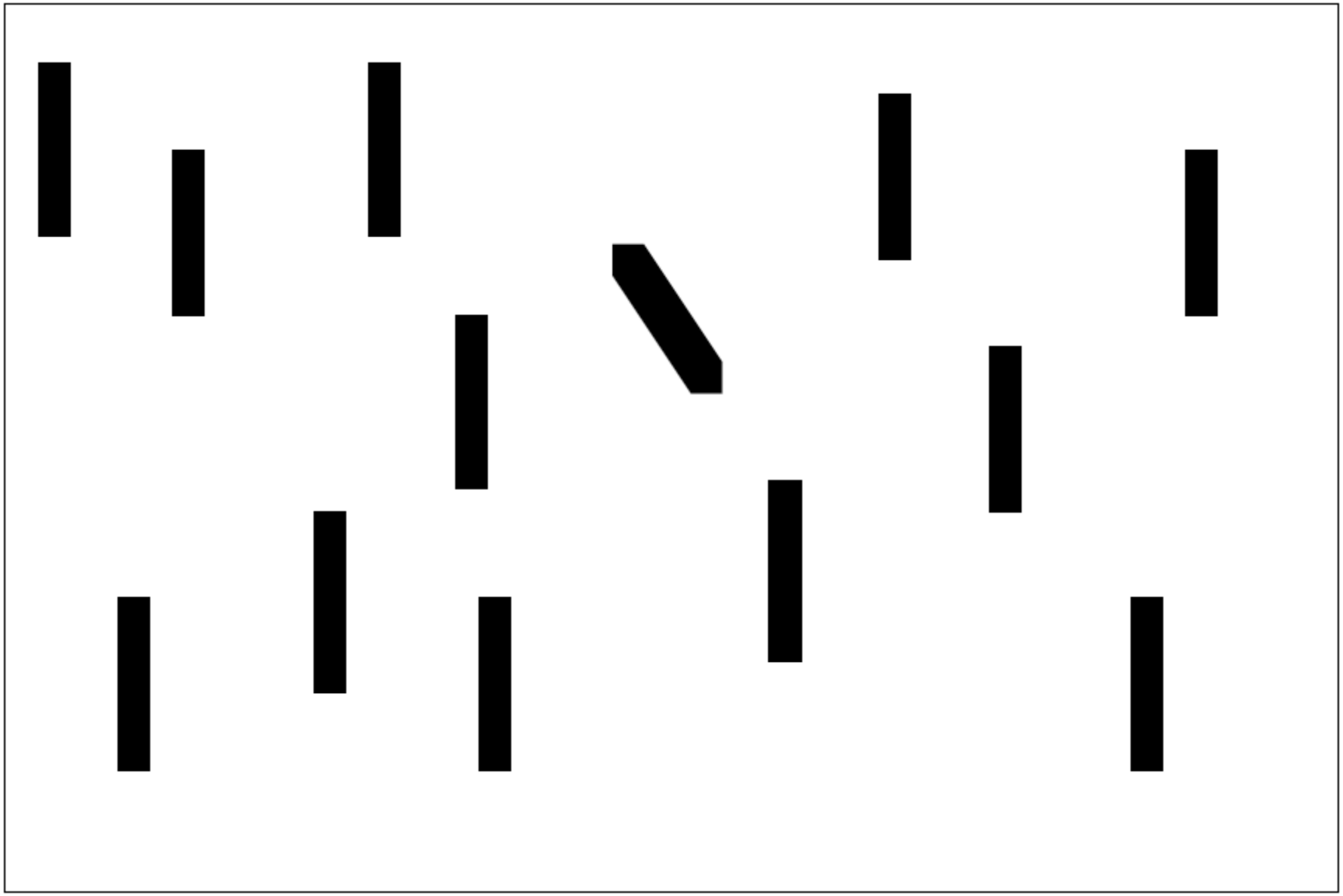
Different shapes can often pop out



A single lack of enclosure can quickly be identified pre-attentively

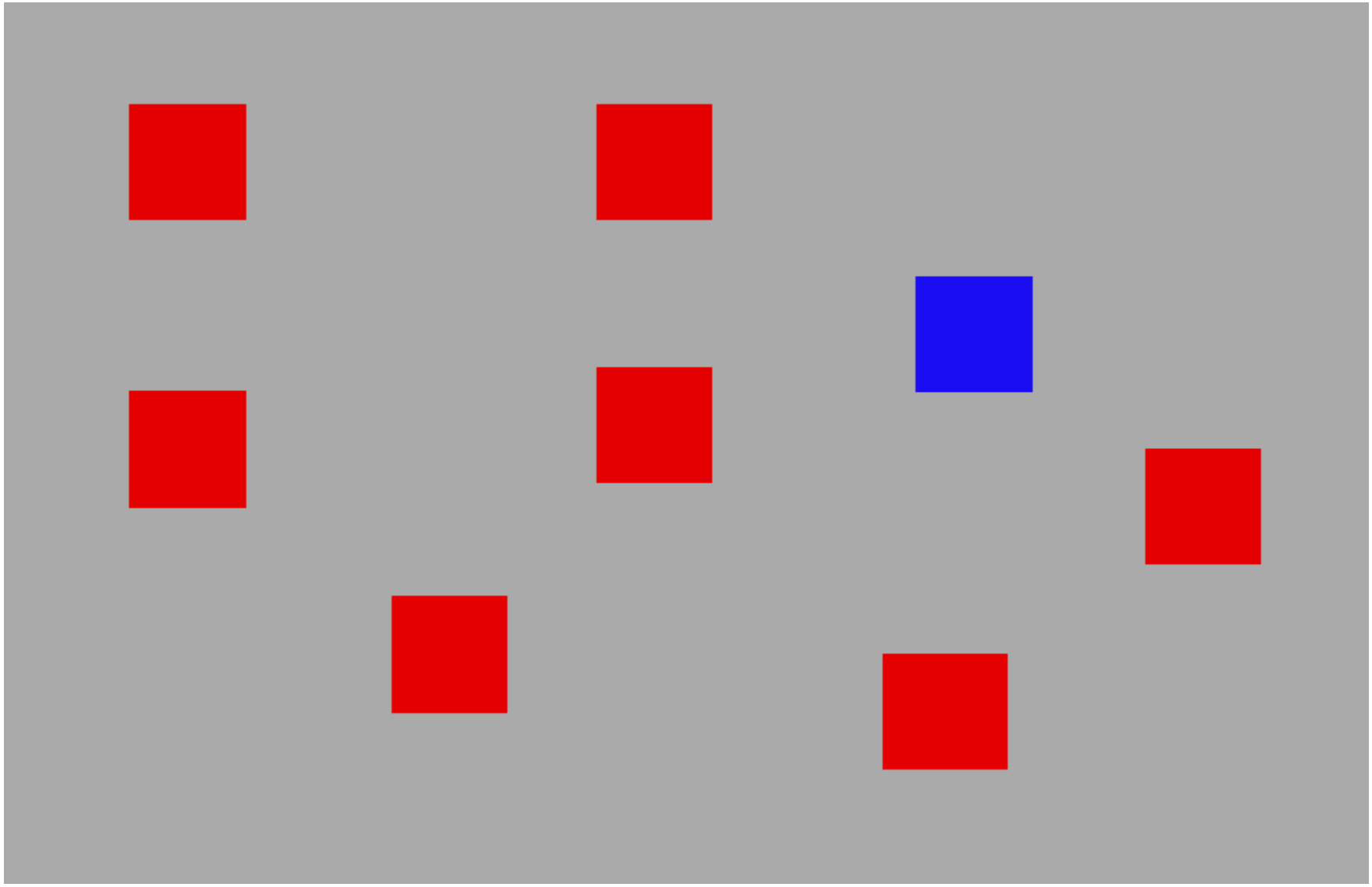


Pre-attentive processing: ‘odd one out’

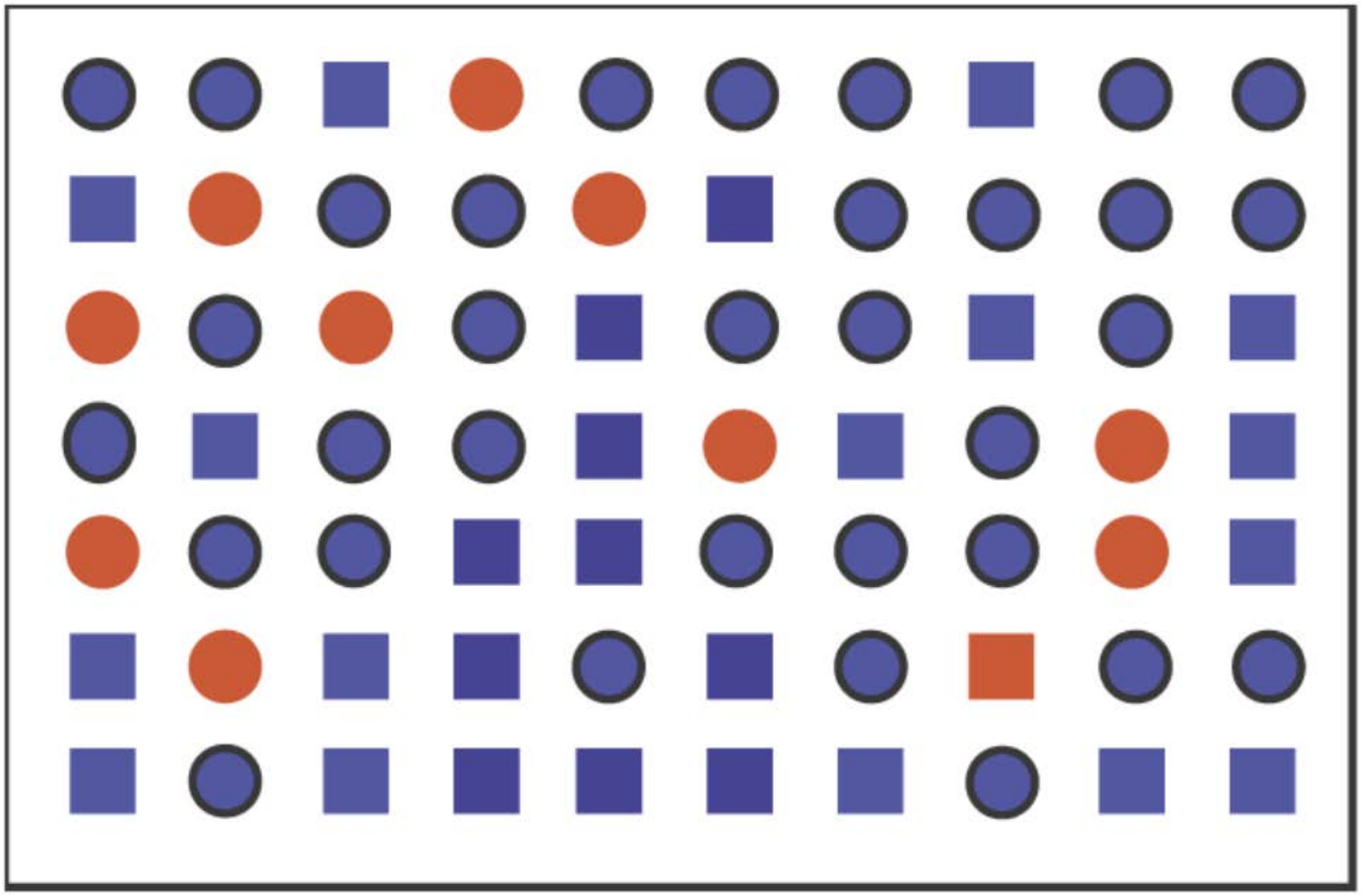


Orientation

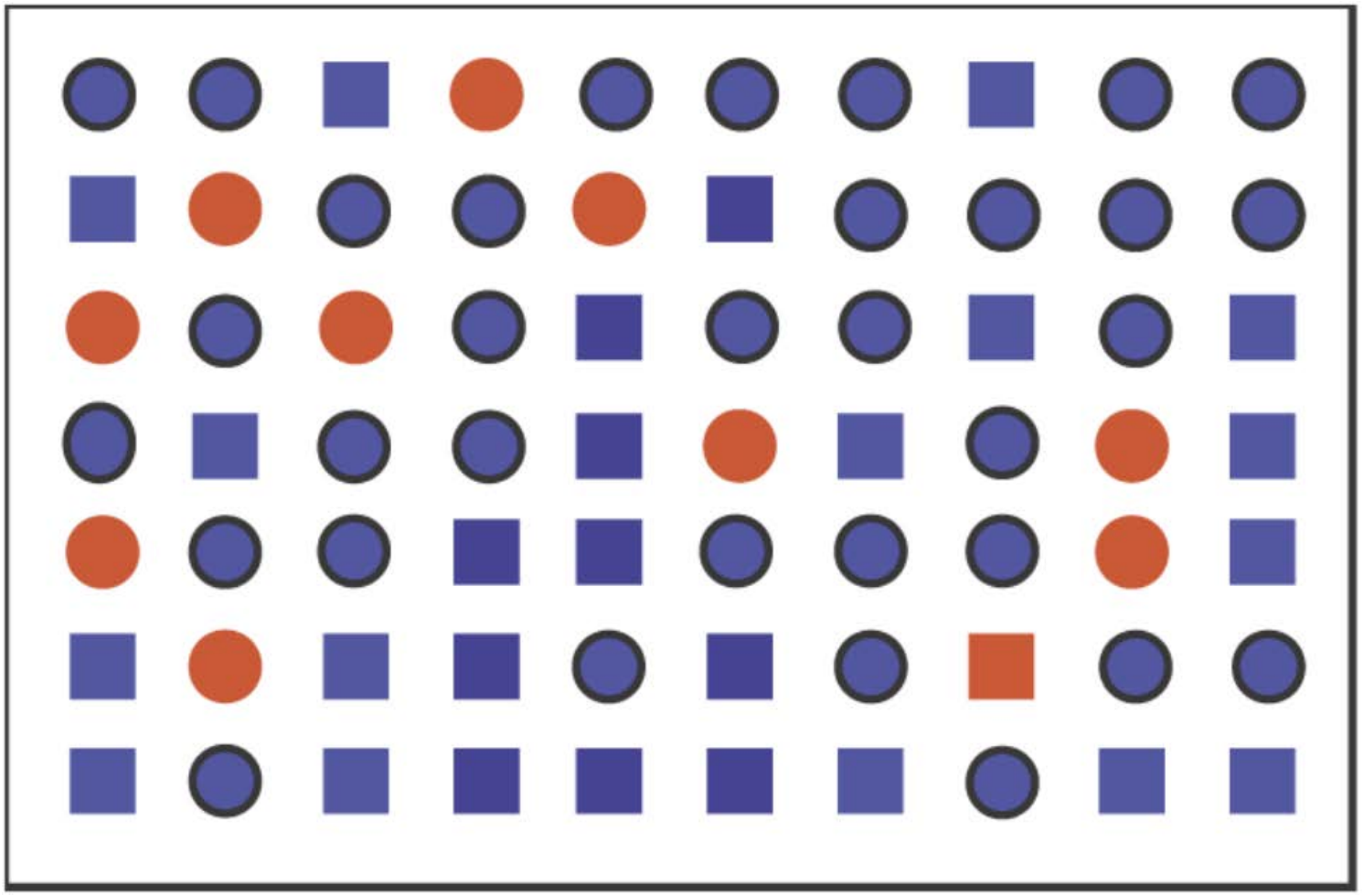
A different color can be pre-attentively identified: ‘odd one out’



But, do you notice the red square?

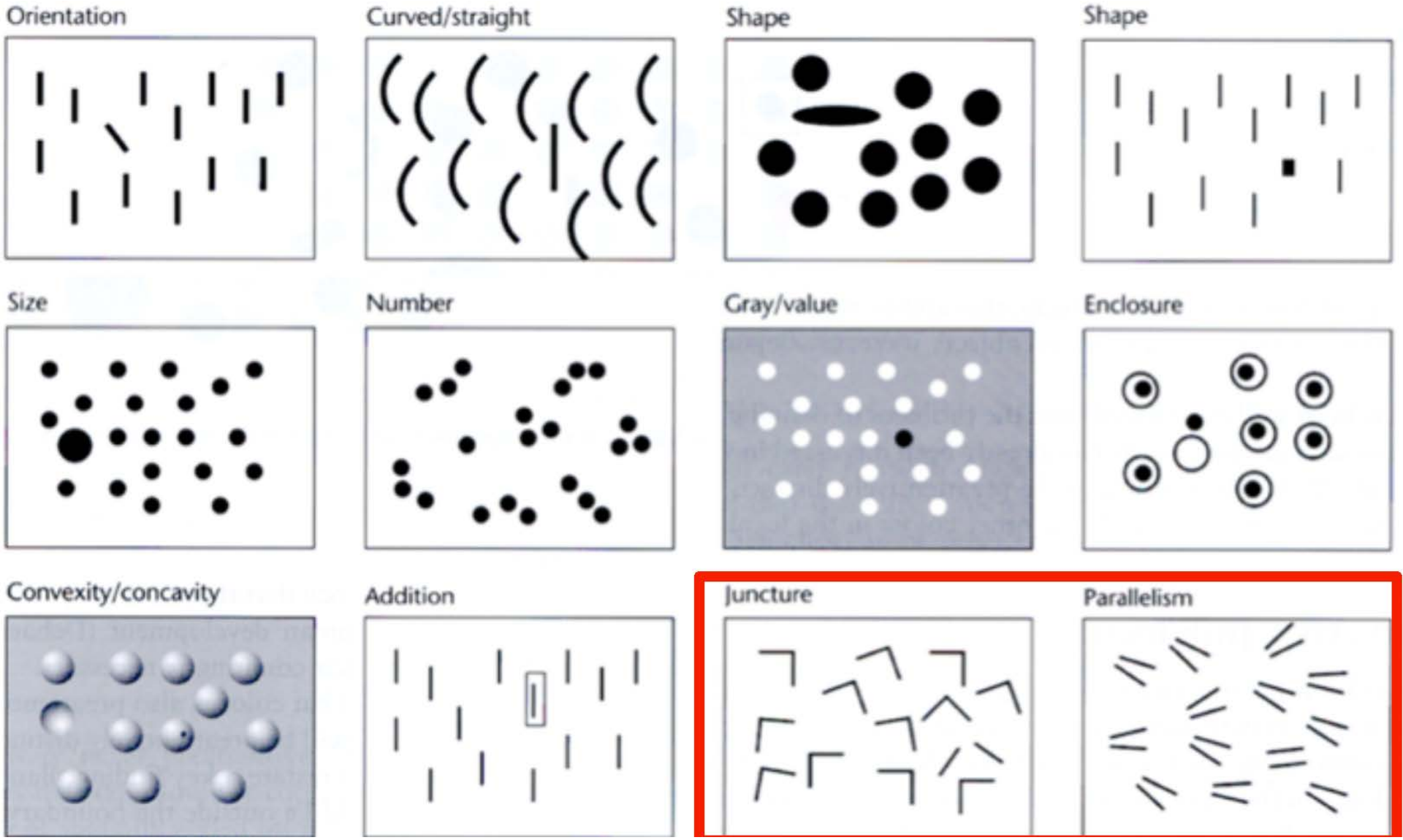


But, do you notice the red square?



With **conjunction encoding** (more than one feature, shape, color, and boundary highlight), the red square is not pre-attentively identified

Pre-attentive features - summary



Visual attributes / cues that can be used for encoding

Space

Location

Annotation

Size

Color

Brightness

Saturation

Hue

Color scheme

Transparency

Orientation

Shapes

Texture

Animation

Visual attributes / cues that can be used for encoding

Space

Location

Annotation

Size

Color

Brightness

Saturation

Hue

Color scheme

Transparency

Orientation

Shapes

Texture

Animation

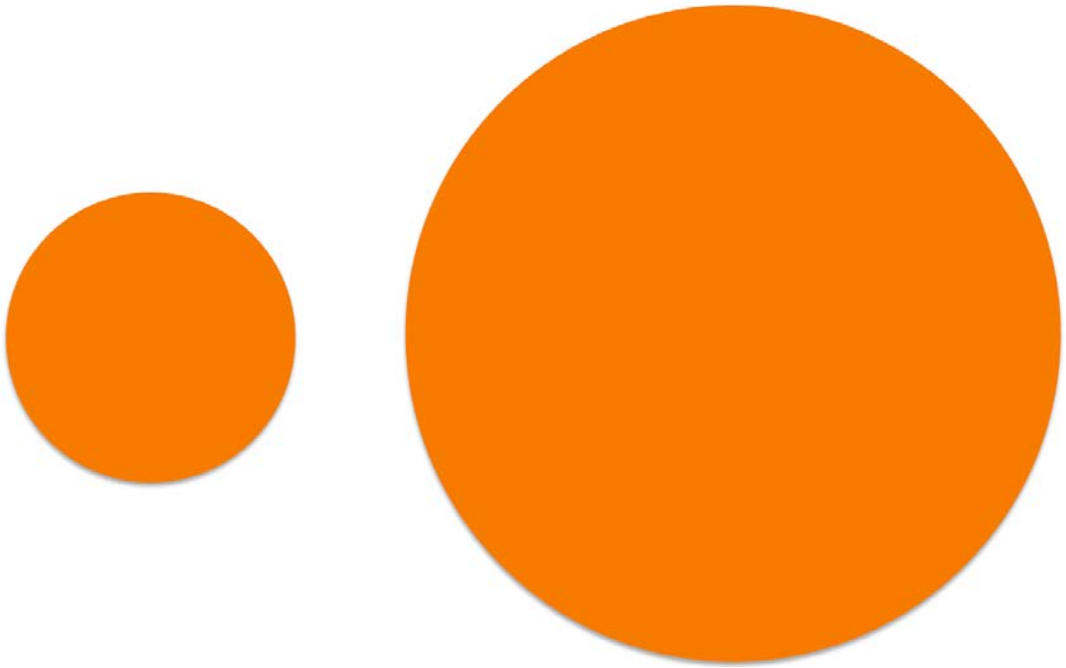
Which ones are more effective than the others?

How much bigger is the lower bar?

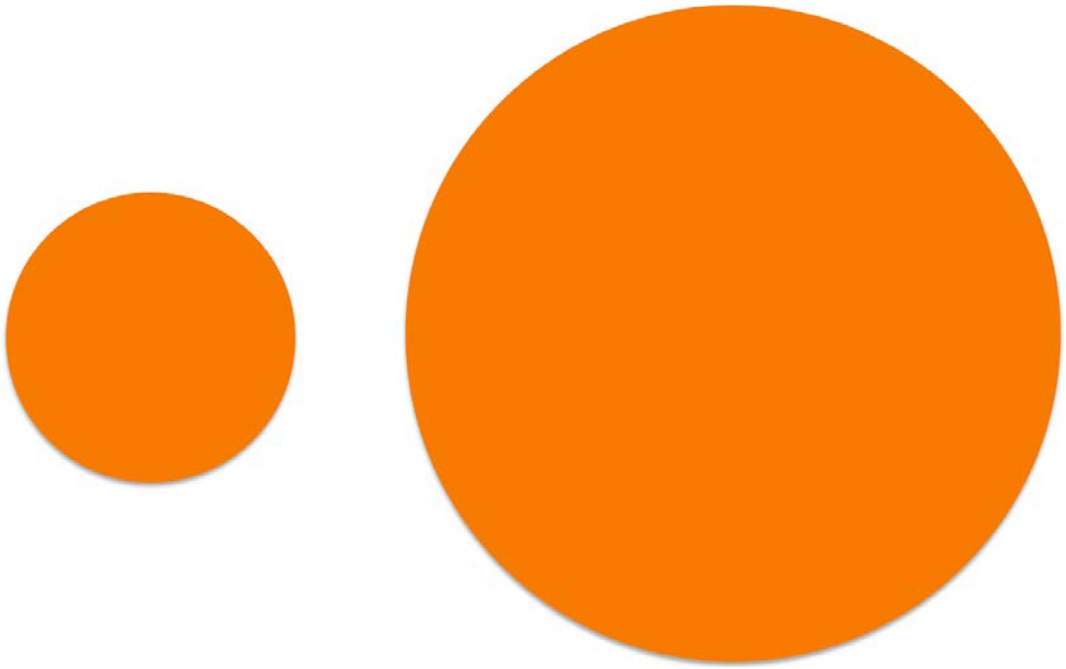
How much bigger is the lower bar?

Using the lengths of the bars to encode quantitative information

How much bigger is the right circle?



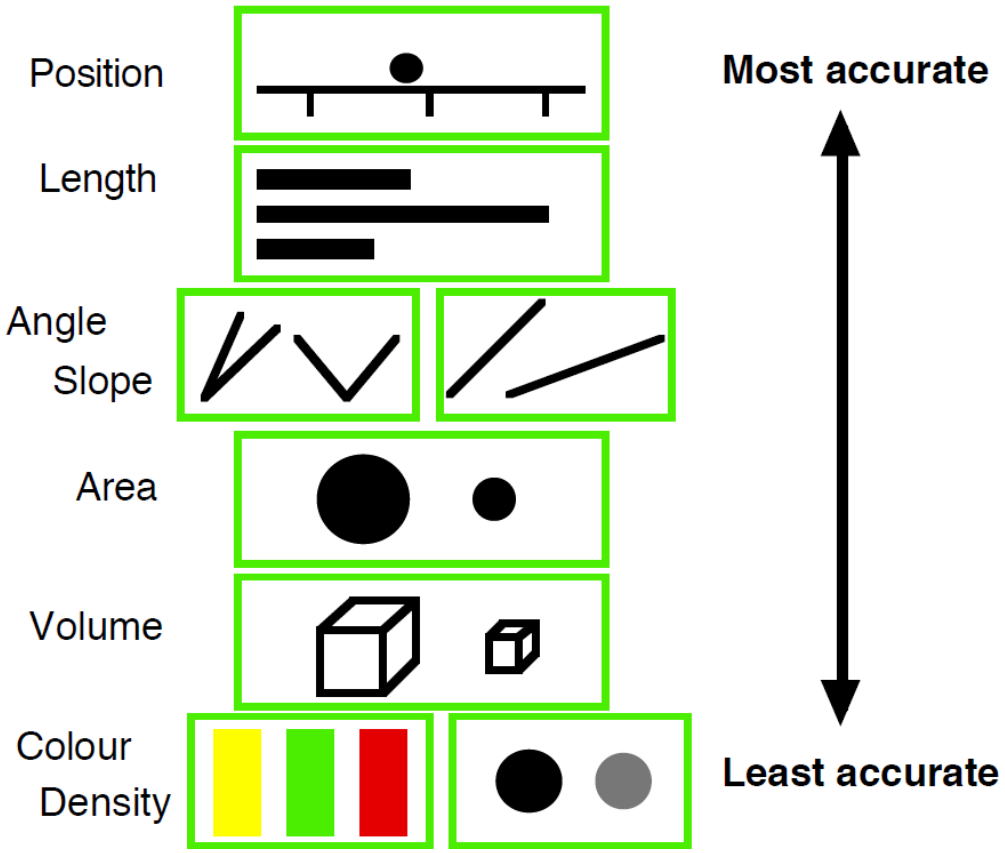
How much bigger is the right circle?



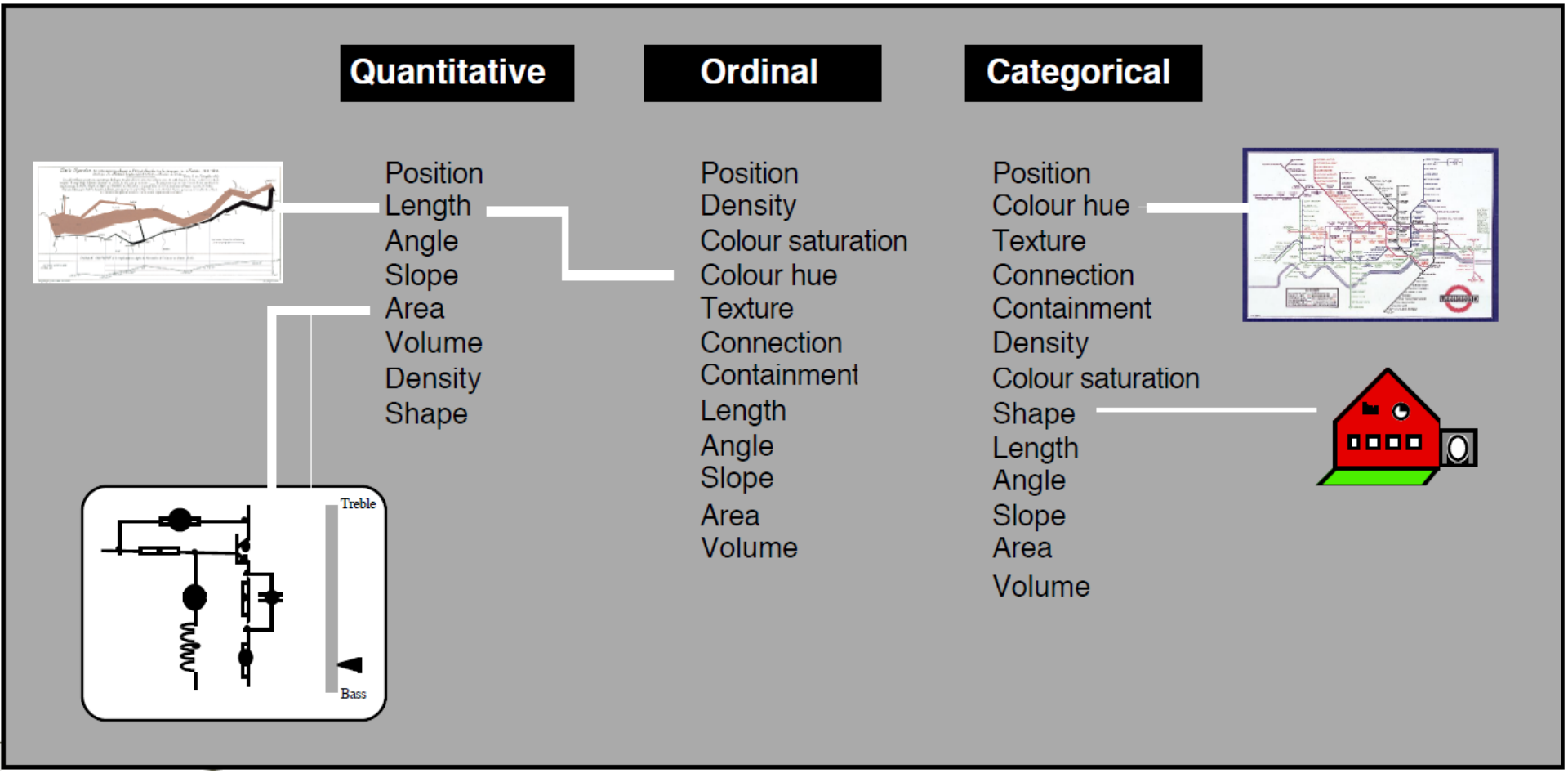
X 5

Using the areas or sizes of the disks to encode quantitative information

Accuracy of the judgement of the encoded quantity data



Quantitative, ordinal and categorical data



Guidance for the encoding of quantitative, ordinal and categorical Data (Mackinlay 1986)

Gestalt Principles

(guh·**shtaalt)**

Useful for generating effective visual representation!

Why we like to consider /separate background and fore ground when seeing things?

Why can we separate object with different shapes and/or other attributes?

What is a good shape?

……

People started thinking these questions in the beginning of 1900

proximity

We tend to think of objects that are physically close together as belonging to part of a group.

Example 1

Example 2

This can be leveraged to show category information.

From Storytelling with Data

Similarity

Objects that are of similar color, shape, size, or orientation are perceived as related or belonging to part of a group.

Example 1

Example 2

When locations have specific/intrinsic meaning

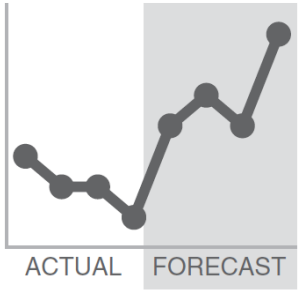
This can be leveraged in table layout to help draw our audience's eyes in the direction we want them to focus.

From Storytelling with Data

Enclosure

We think of objects that are physically enclosed together as belonging to part of a group.

Example 1



Example 2

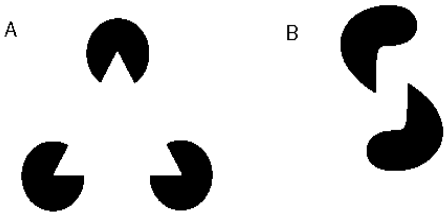
One way we can leverage the enclosure principle is to draw a visual distinction within our data.

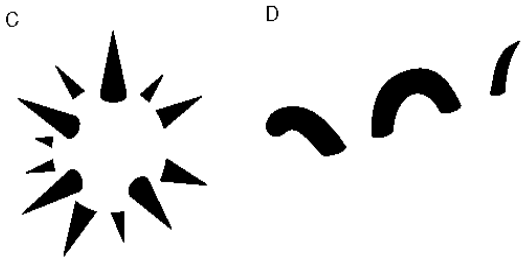
From Storytelling with Data

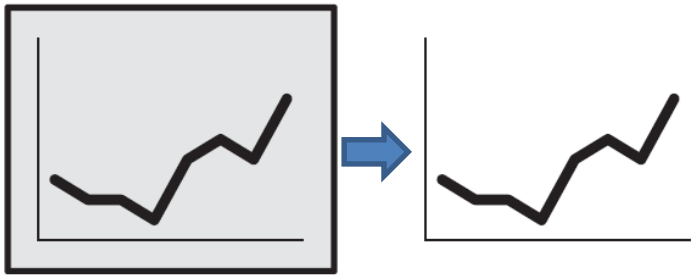
Closure

People like things to be simple and to fit in the constructs that are already in our heads.

Example 1







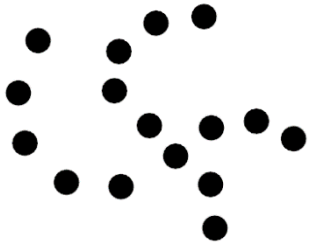
Example 2

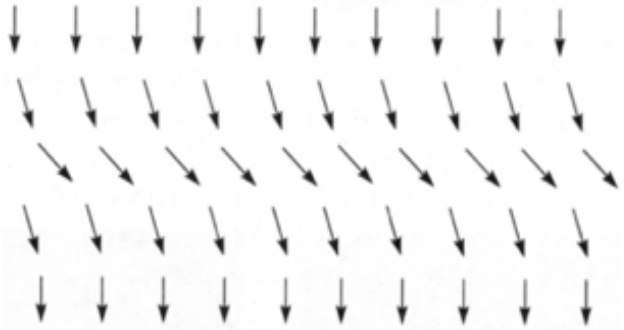
We can remove chart borders and background shading and our graph still appears as a cohesive entity.

From Storytelling with Data

Continuity

When looking at objects, our eyes seek the smoothest path and naturally create continuity in what we see even where it may not explicitly exist.





Example 1

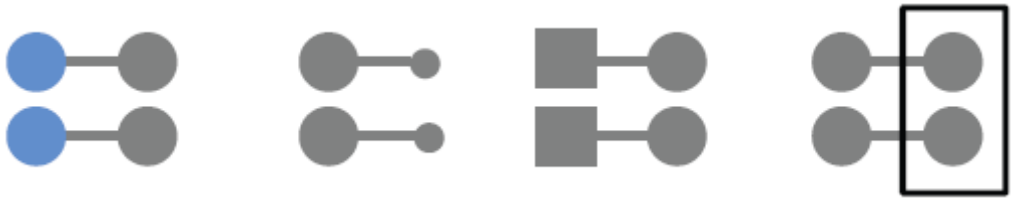
Example 2

Remove unnecessary axis if things are aligned.

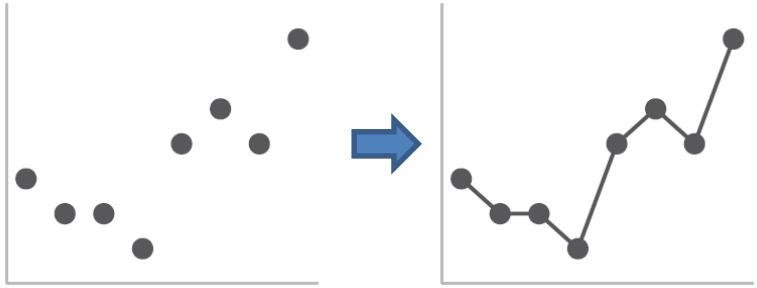
From Storytelling with Data

Connection

We tend to think of objects that are physically connected as part of a group.



Example 1



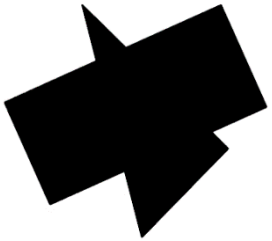
Example 2

One way that we frequently leverage the connection principle is in line plots/graphs, to help our eyes see order in the data.

From Storytelling with Data

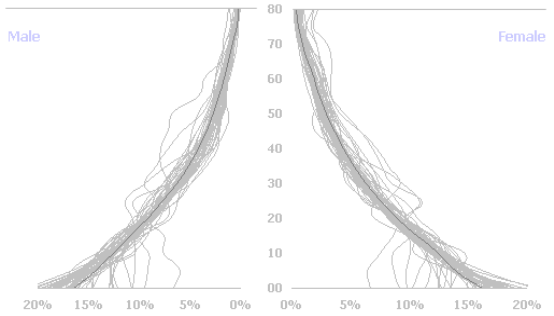
Other useful principles

Simplicity

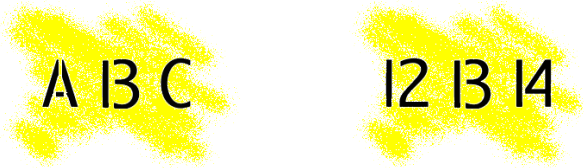


Common fate

Symmetry



Past experience



Expressiveness and Effectiveness

- **Expressiveness**

  It requires the visual representations accurately encode the information of the data that needs to be conveyed, i.e., fidelity or authentic to the data.

- **Effectiveness**

  The use of the visual attributes/cues should reflect the importance of the information (or the characteristics) of the data (e.g., make important data pop out).

The overall layout is more important than the individual elements, as the visual representation is perceived and understood as a whole in the beginning.