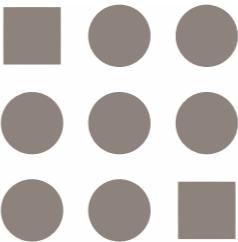
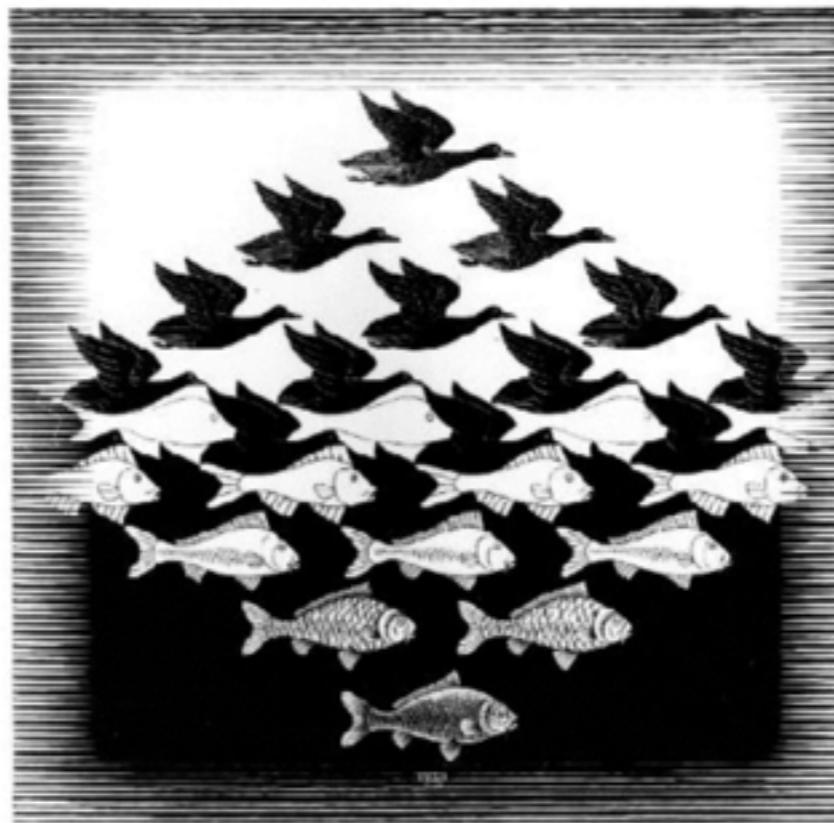


CS 171



Cognition

Johanna Beyer (jbeyer@g.harvard.edu)



Activity

Notice anything changing? Get ready!



Notice Anything Changing?



G. Alvarez, Harvard

Notice Anything Changing?



G. Alvarez, Harvard

Notice Anything Changing?



G. Alvarez, Harvard

Selective Attention

Count the number of ball tosses between
the players in white

[https://www.youtube.com/watch?
v=vJG698U2Mvo](https://www.youtube.com/watch?v=vJG698U2Mvo)

Feedback

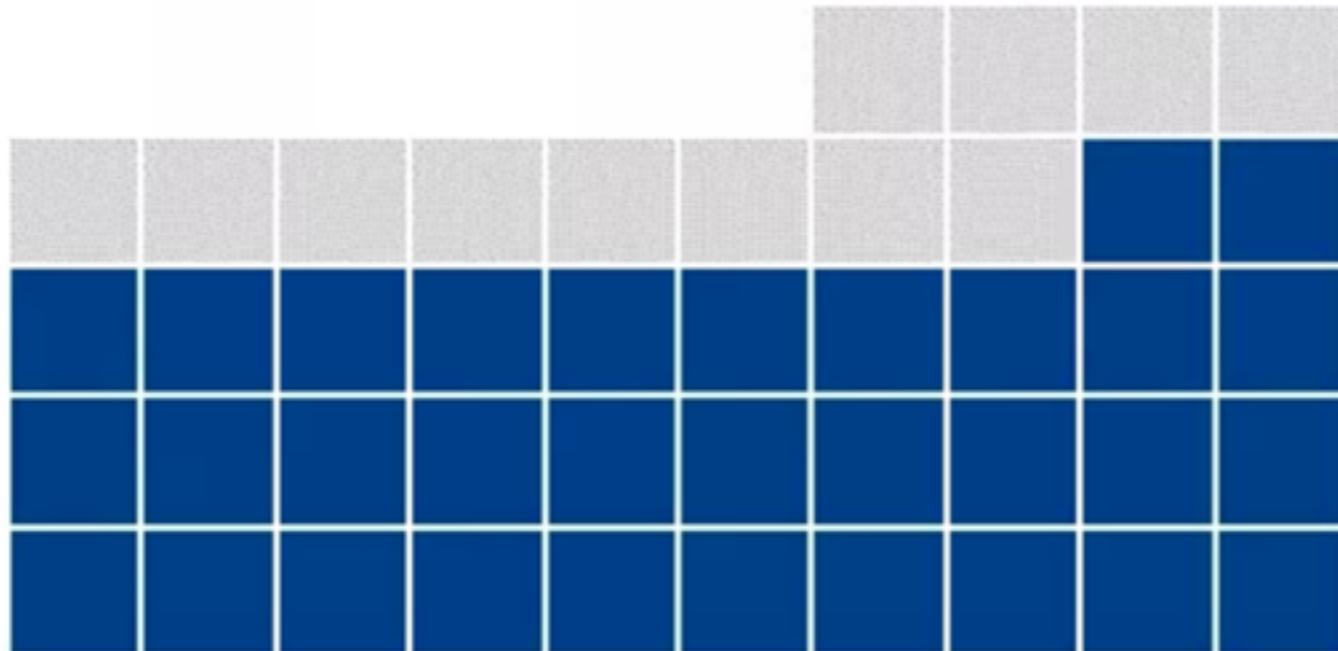
- 1)** Are there some cases in which the rainbow might be effective?
- 2)** How can I effectively encode 8 or more categorical variables
- 3)** I wasn't quite clear on how layering and contrast worked with each other

Layering



Layering

32 of 44 people agreed that they
wanted to share their own story



Design Critique

1. Functional description (no interpretation)
 - a. Bertin's marks & channels (including datatypes)
 - b. Tufte's design principles (lie-factor, data-ink ratio,...)
 - c. Preattentive attributes (contrast, color, motion,...)
 - d. Gestalt principles
2. Interpretation
 - a. Intended Goal & Audience
 - b. Do you like/dislike it? Why?

Example for 1) found here: <http://bit.ly/2xcpCQu>

Today

Visual Channels

How to encode each data item?

Visual Hierarchy

How to encode different levels of items?

Gestalt Principles

How to group items?

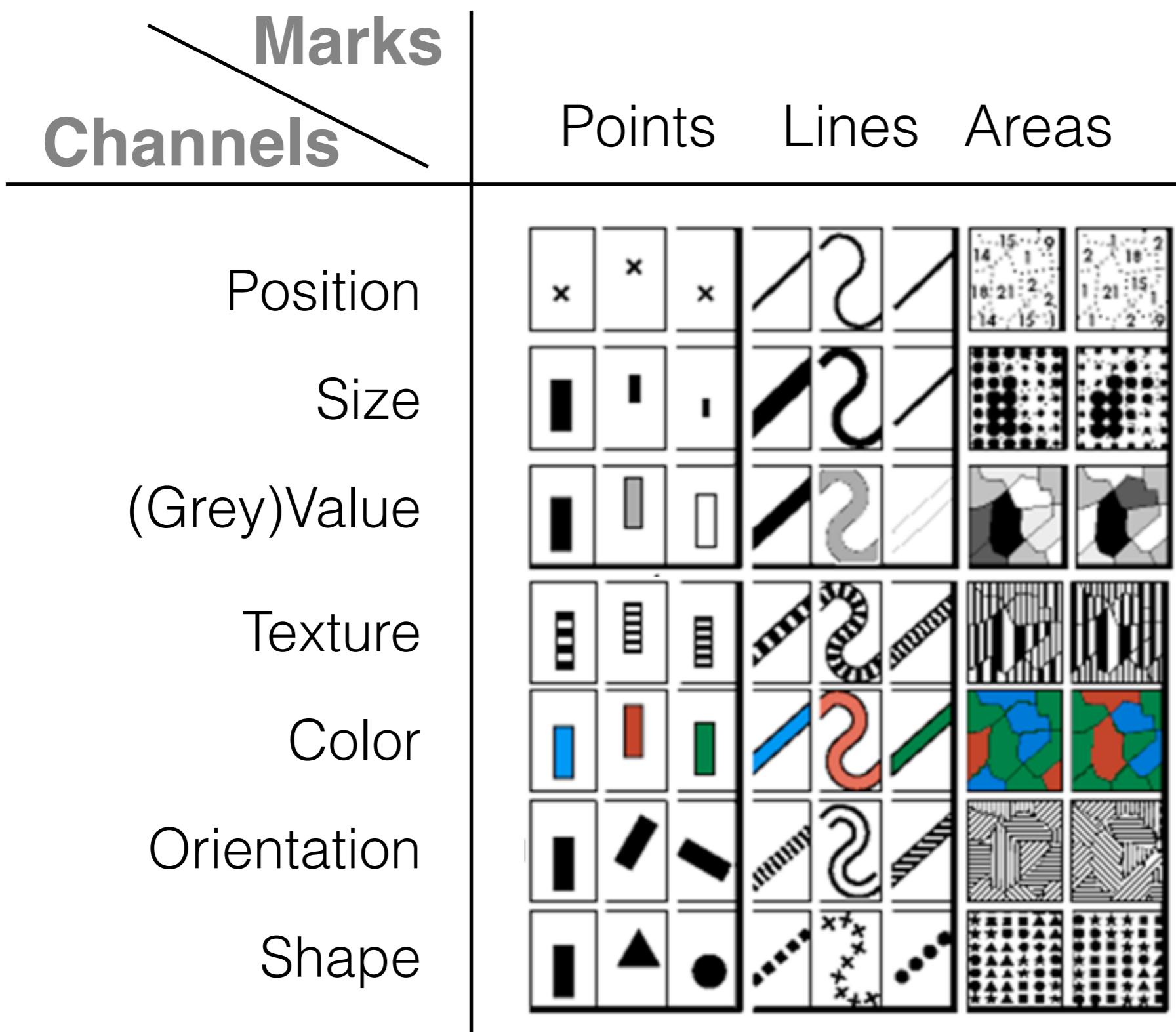
Memory, Attention, and their Limits

How to avoid cognitive overload?

Visual Channels

Name some of Bertin's visual channels.

Bertin's visual design space

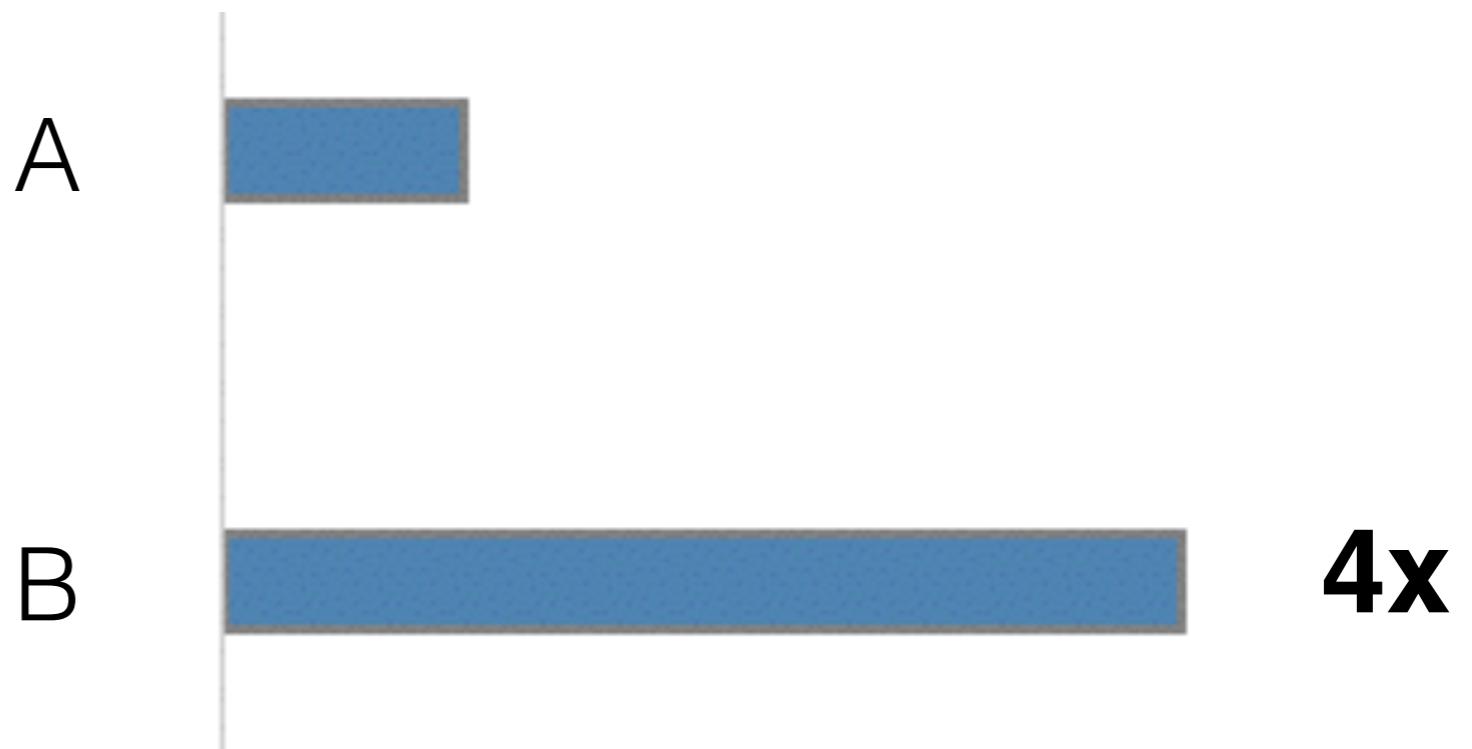


Activity

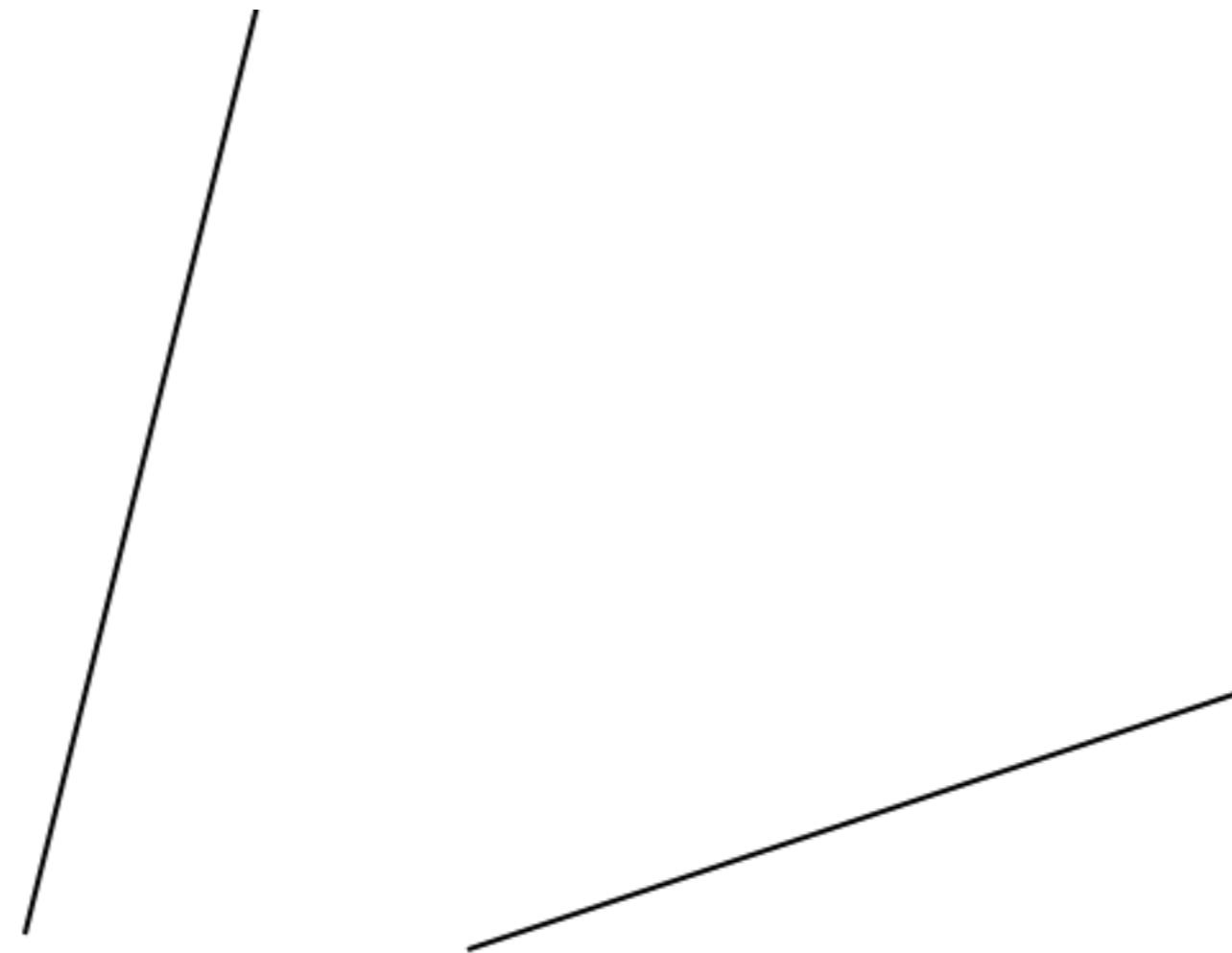
Please answer the following quiz questions by holding up fingers on your hand.



How much longer?



How much steeper slope?

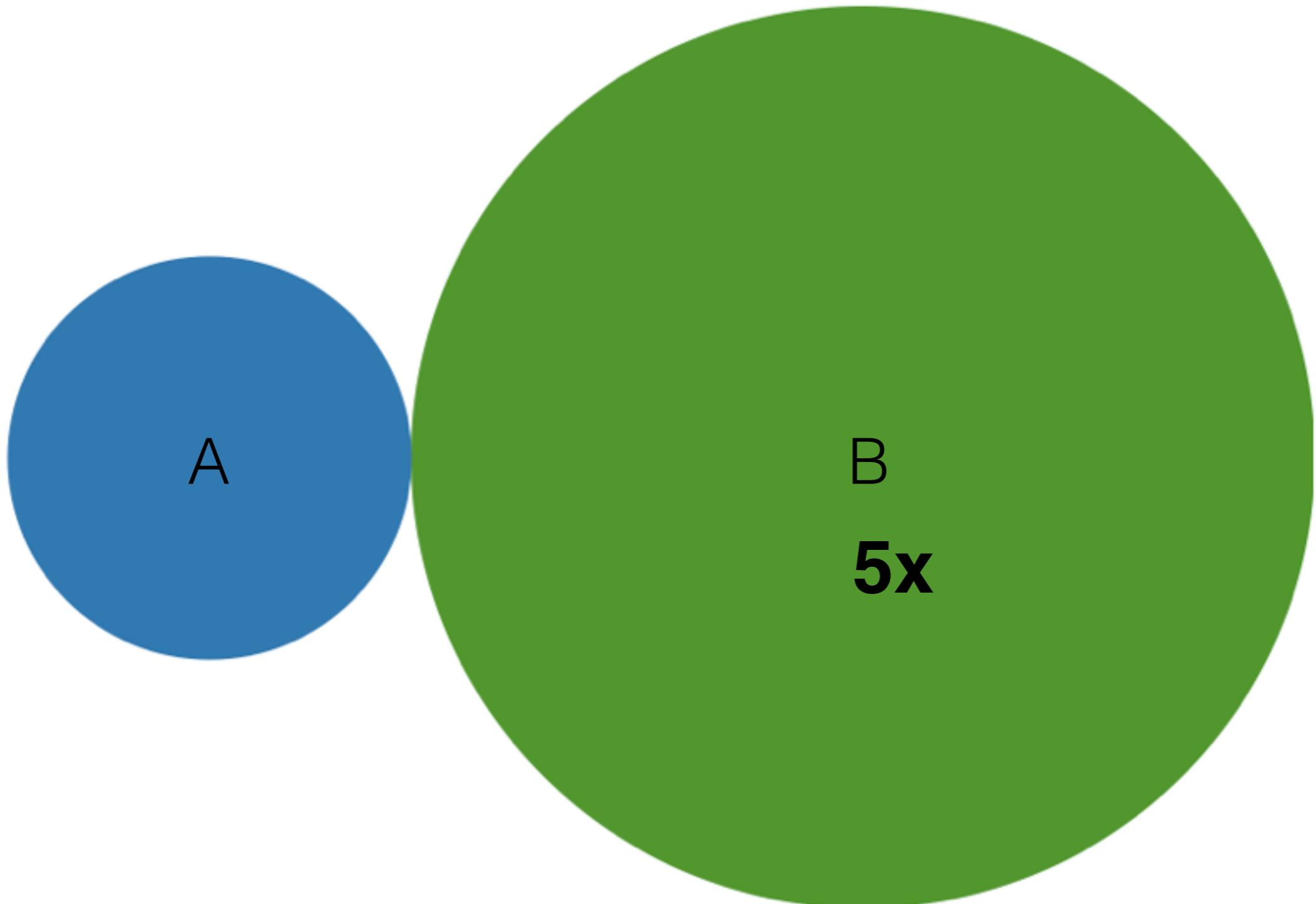


A

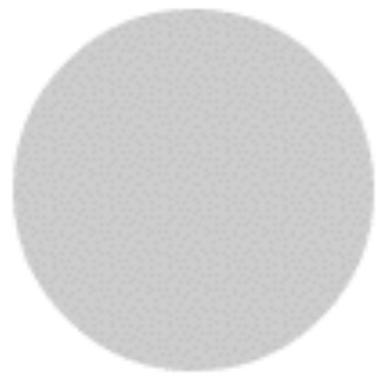
B

4x

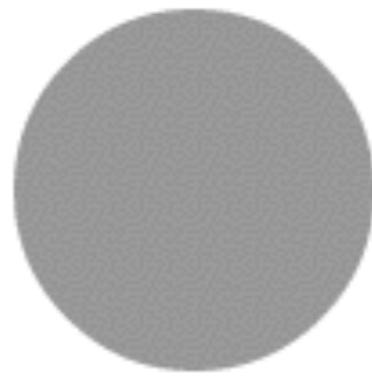
How much larger area?



How much darker?



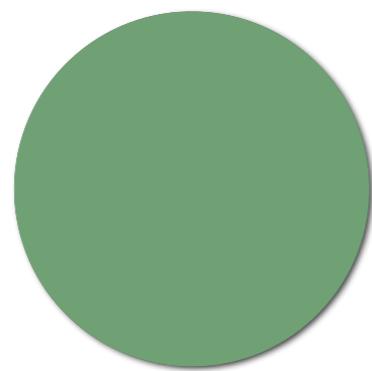
A



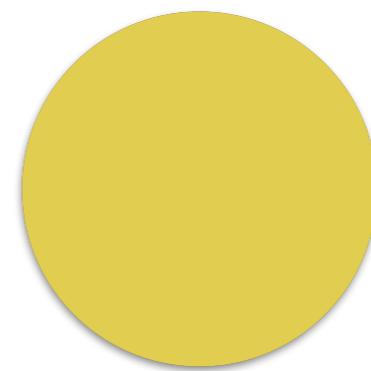
B

2x

How much bigger value?

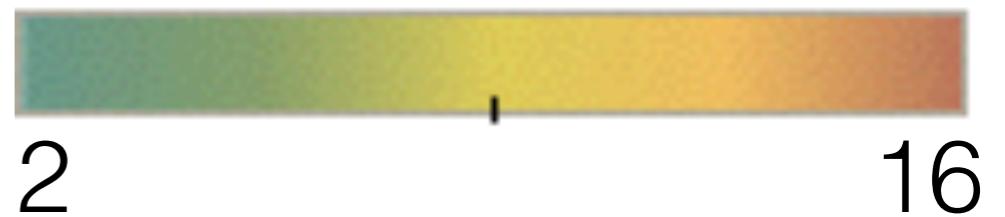


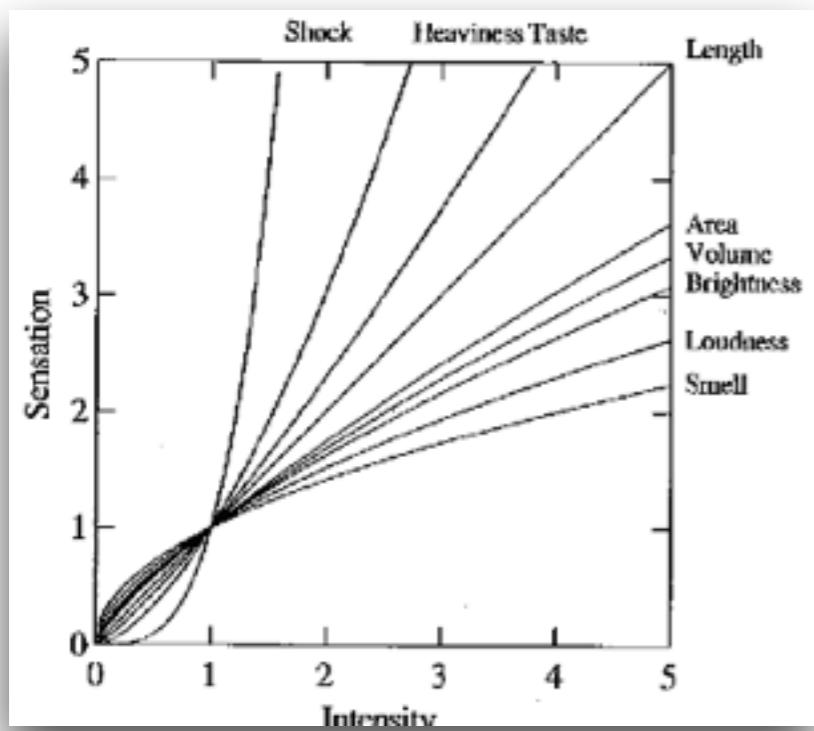
A



B

4x





Stephen's Power Law, 1961

	Nominal	Ordinal	Quantitative
Position	✓	✓	✓
Size	✓	✓	~
(Grey)Value	✓	✓	~
Texture	✓	~	✗
Color	✓	✗	✗
Orientation	✓	✗	✗
Shape	✓	✗	✗

✓ = Good

~ = OK

✗ = Bad

J. Bertin, 1967

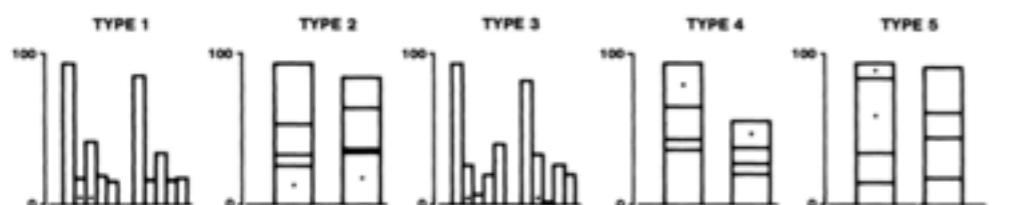


Figure 4. Graphs from position-length experiment.

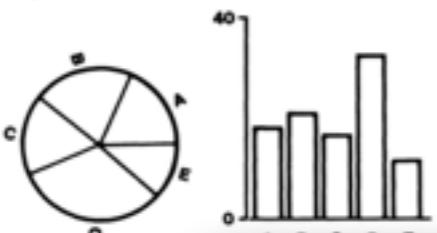
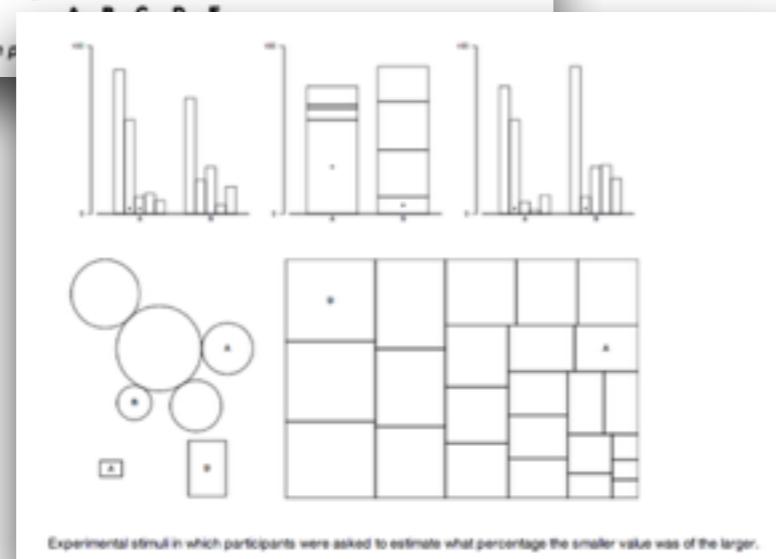
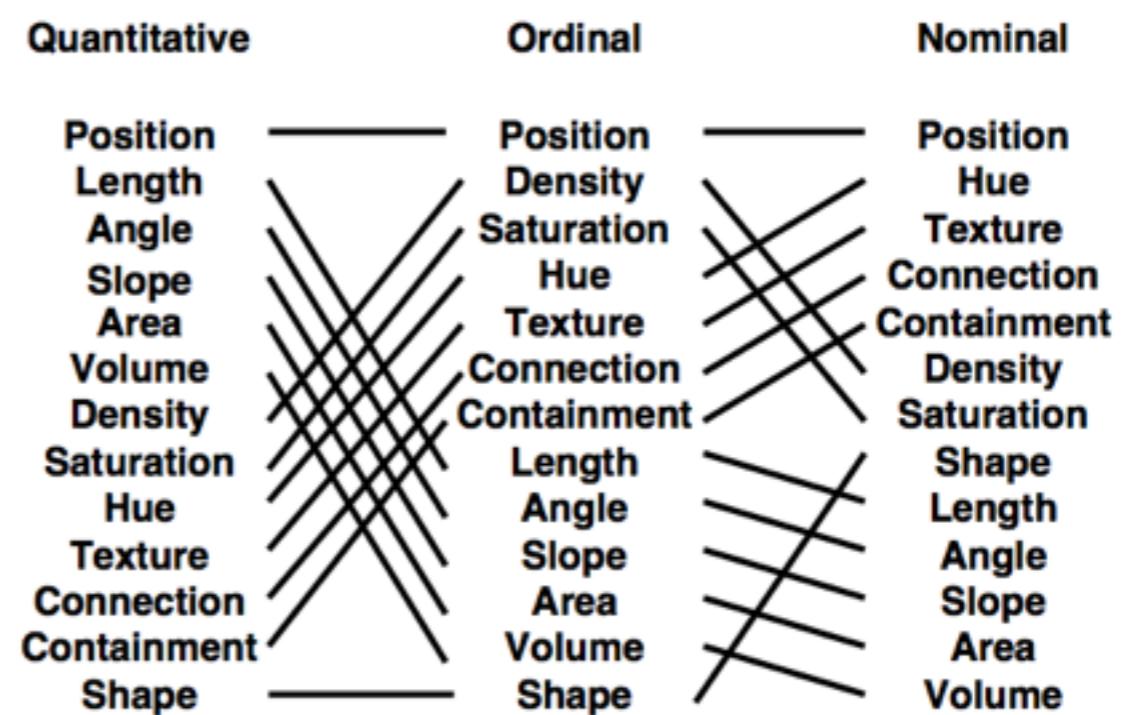


Figure 3. Graphs from position-length experiment.

Cleveland / McGill, 1984



Heer / Bostock, 2010

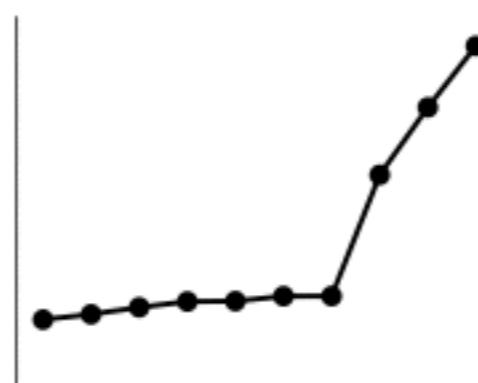


J. Mackinlay, 1986

Accuracy of channels

	Quantitative	Ordinal	Nominal	
More Accurate ↑	Position Length Angle Slope Area Density Saturation Hue Shape	Position Density Saturation Hue Length Angle Slope Area Shape	Position Hue Density Saturation Shape Length Angle Slope Area	Position Hue Density Saturation Shape Length Angle Slope Area
	••	••	••	••
	==	•••	•••	•••
	∠	•••	•••	•••
	/\	•••	•••	•••
	••	==	••	••
	•••	∠	==	==
	•••	/\	∠	∠
	•••	••	/\	/\
↓ Less Accurate	••	••	••	••

Most Effective (Quantitative)

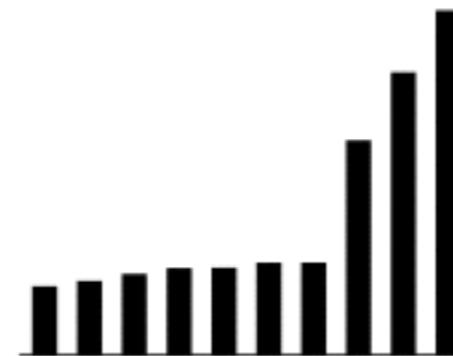


quantitative:

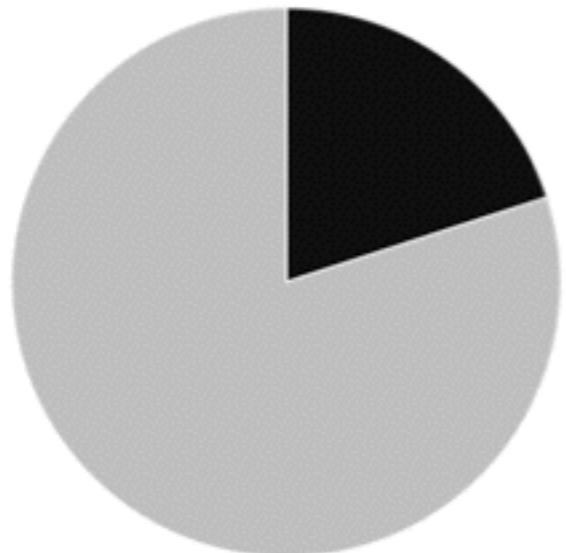
Position



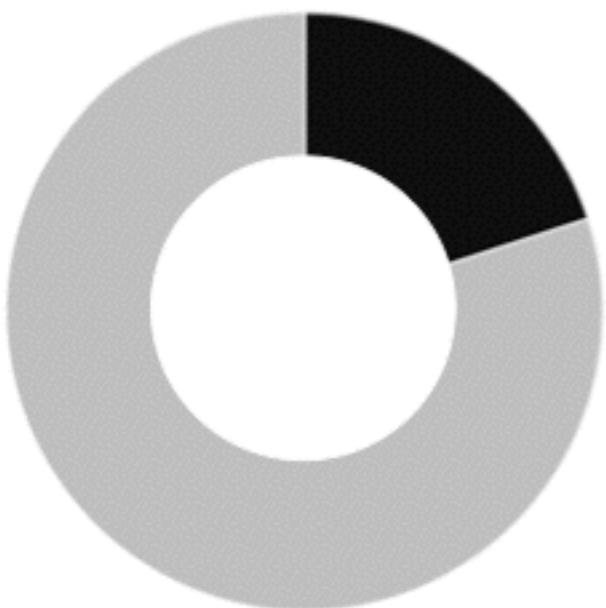
Length



Less Effective (Quantitative)

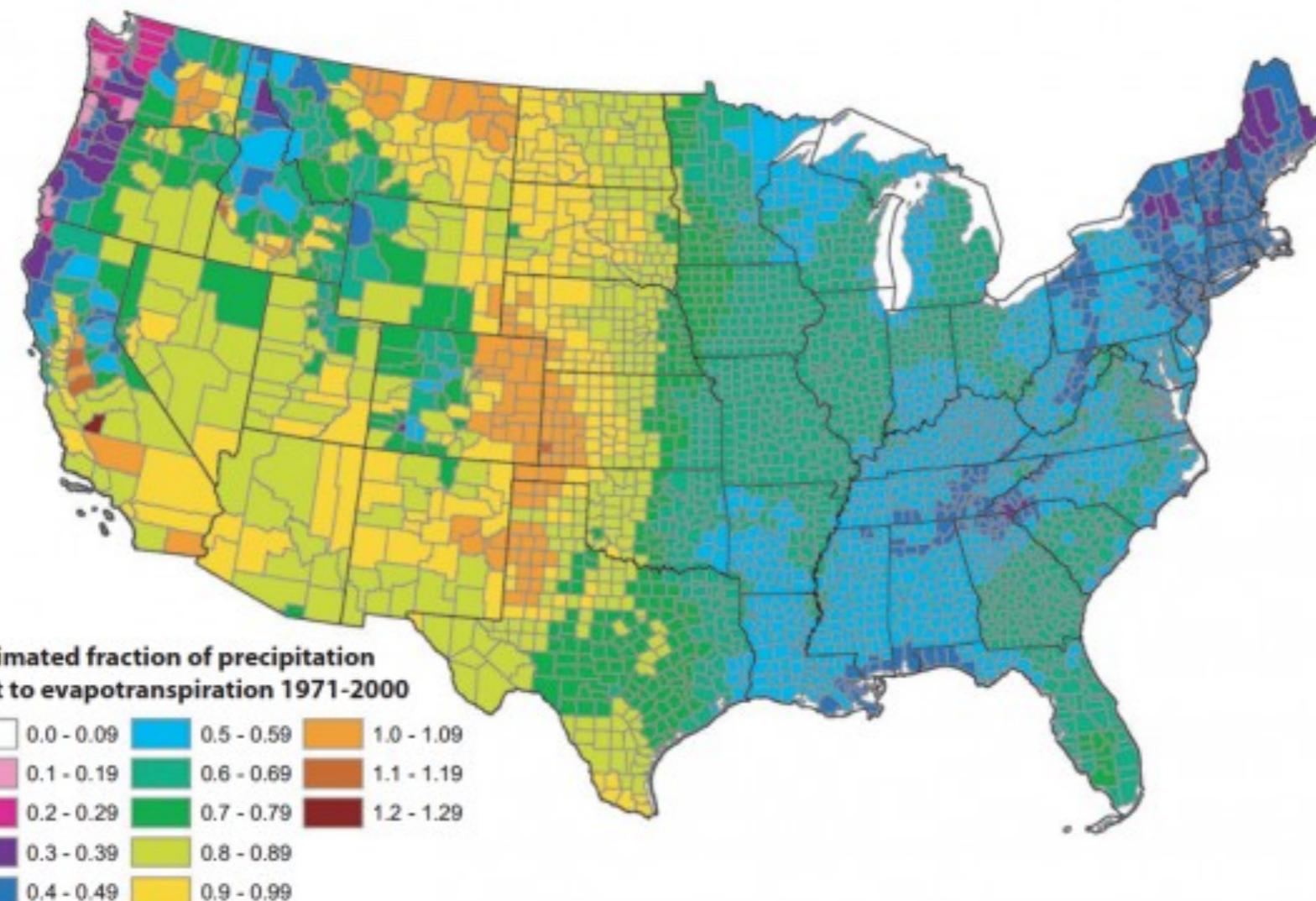


quantitative:



Least Effective (Quantitative)

SANFORD AND SELNICK



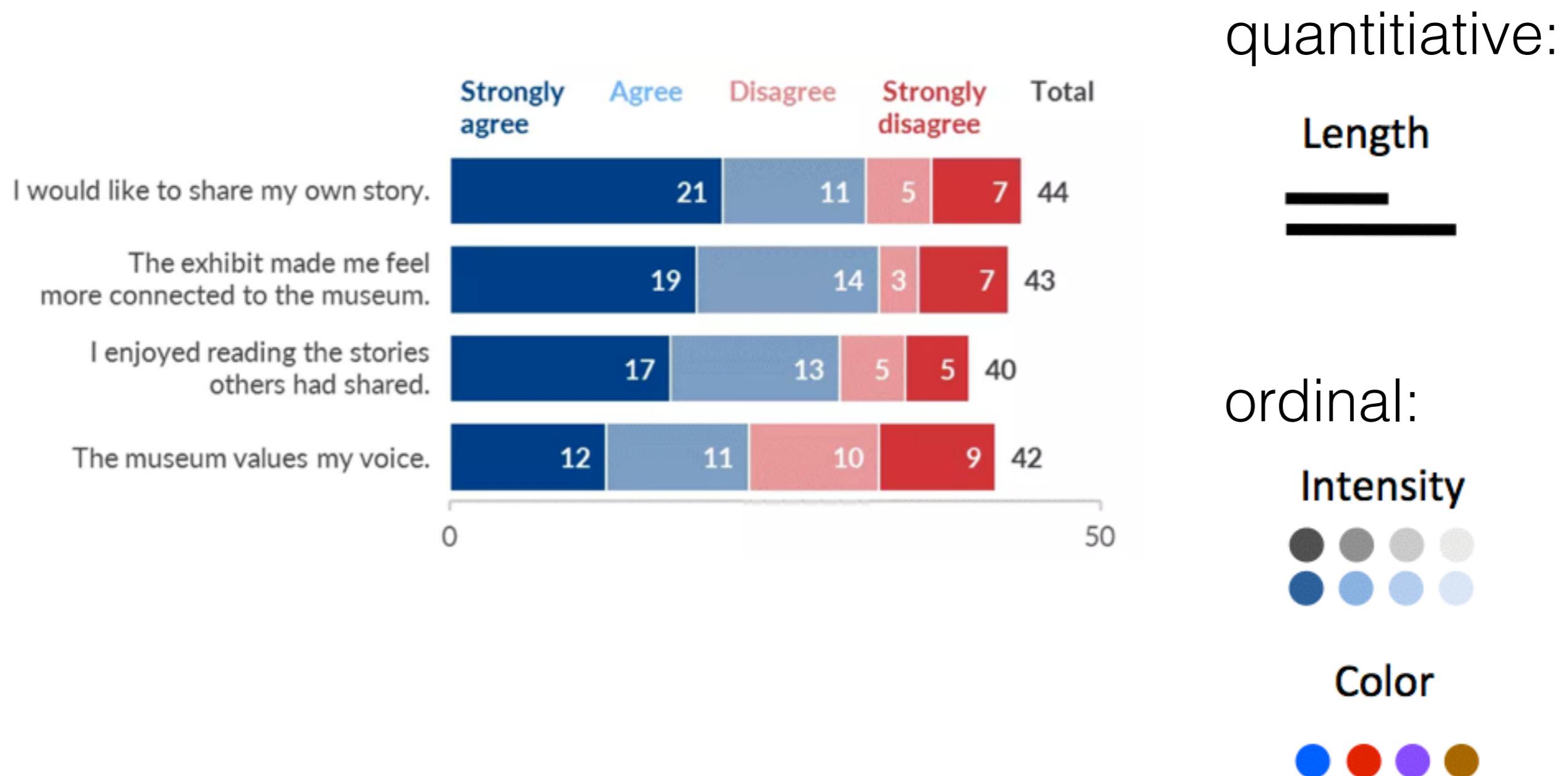
quantitative:

Color



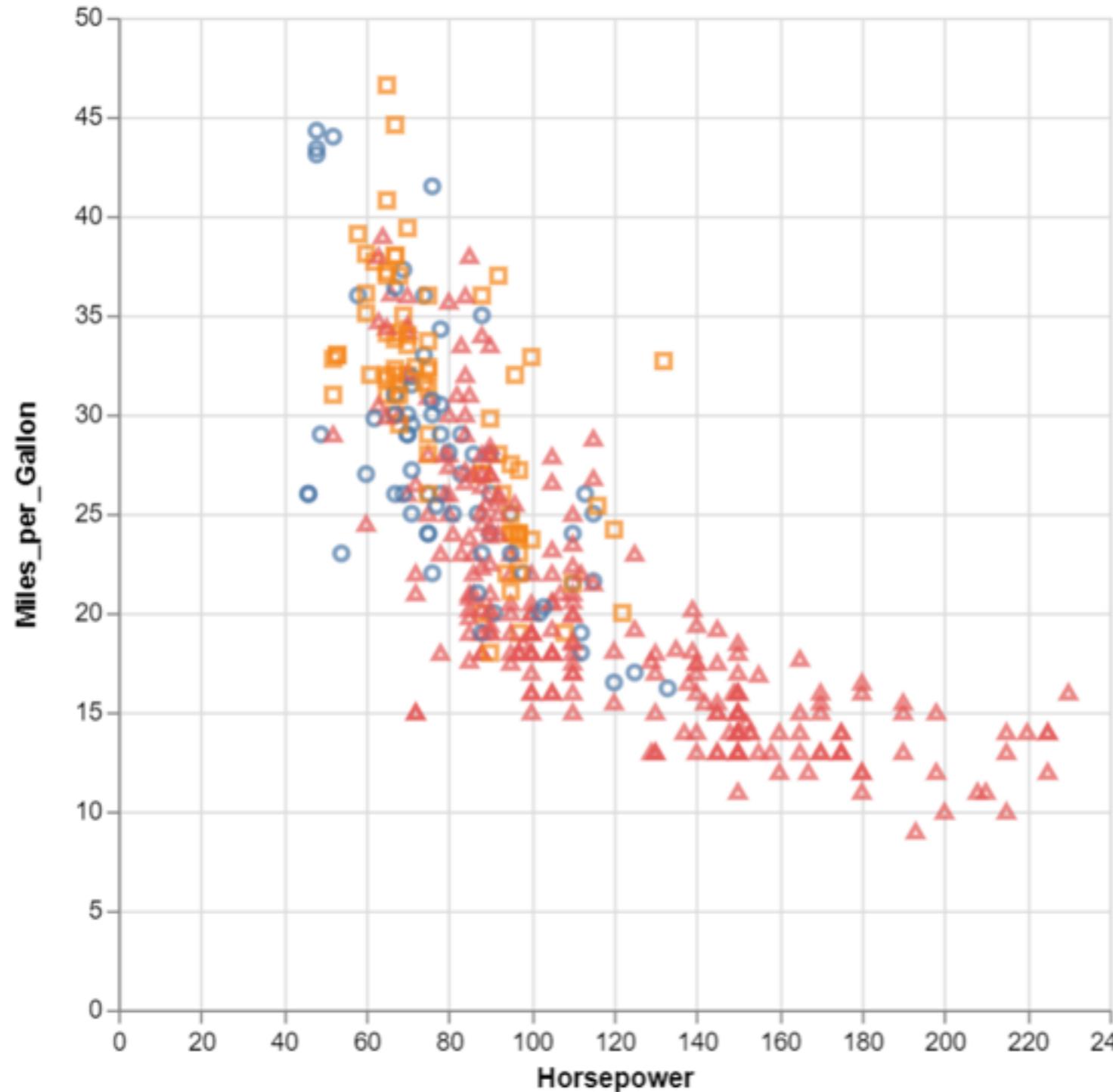
FIGURE 13. Estimated Mean Annual Ratio of Actual Evapotranspiration (ET) to Precipitation (P) for the Conterminous U.S. for the Period 1971-2000. Estimates are based on the regression equation in Table 1 that includes land cover. Calculations of ET/P were made first at the 800-m resolution of the PRISM climate data. The mean values for the counties (shown) were then calculated by averaging the 800-m values within each county. Areas with fractions >1 are agricultural counties that either import surface water or mine deep groundwater.

More Effective (Ordinal)



<http://annkemery.com/agree-disagree-scales/>

Less Effective (Ordinal)



Car Size

- small
- medium
- △ large

quantitative:

Position



ordinal:

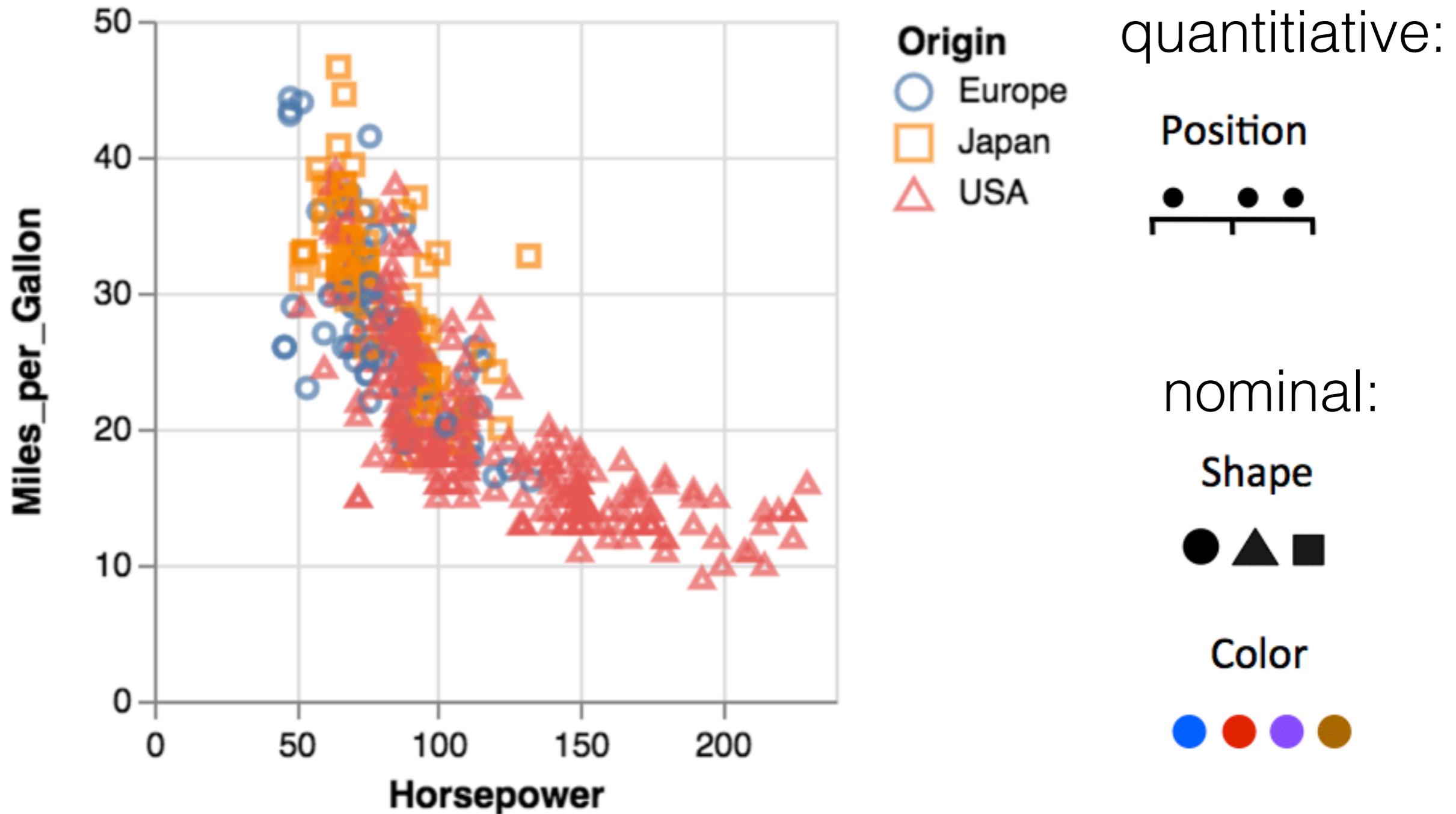
Shape



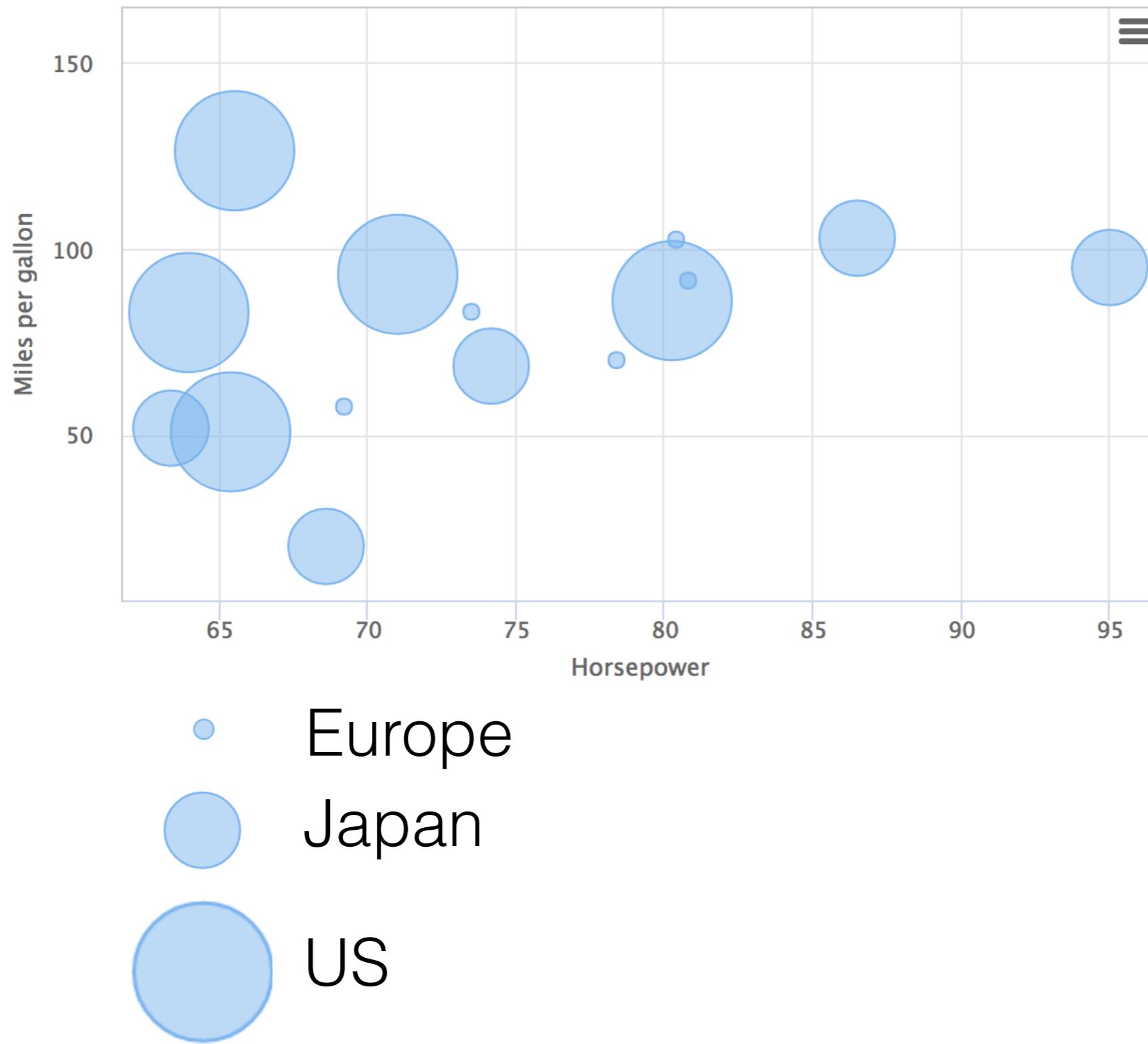
Color



More Effective (Nominal)



Less Effective (Nominal)



quantitative:

Position



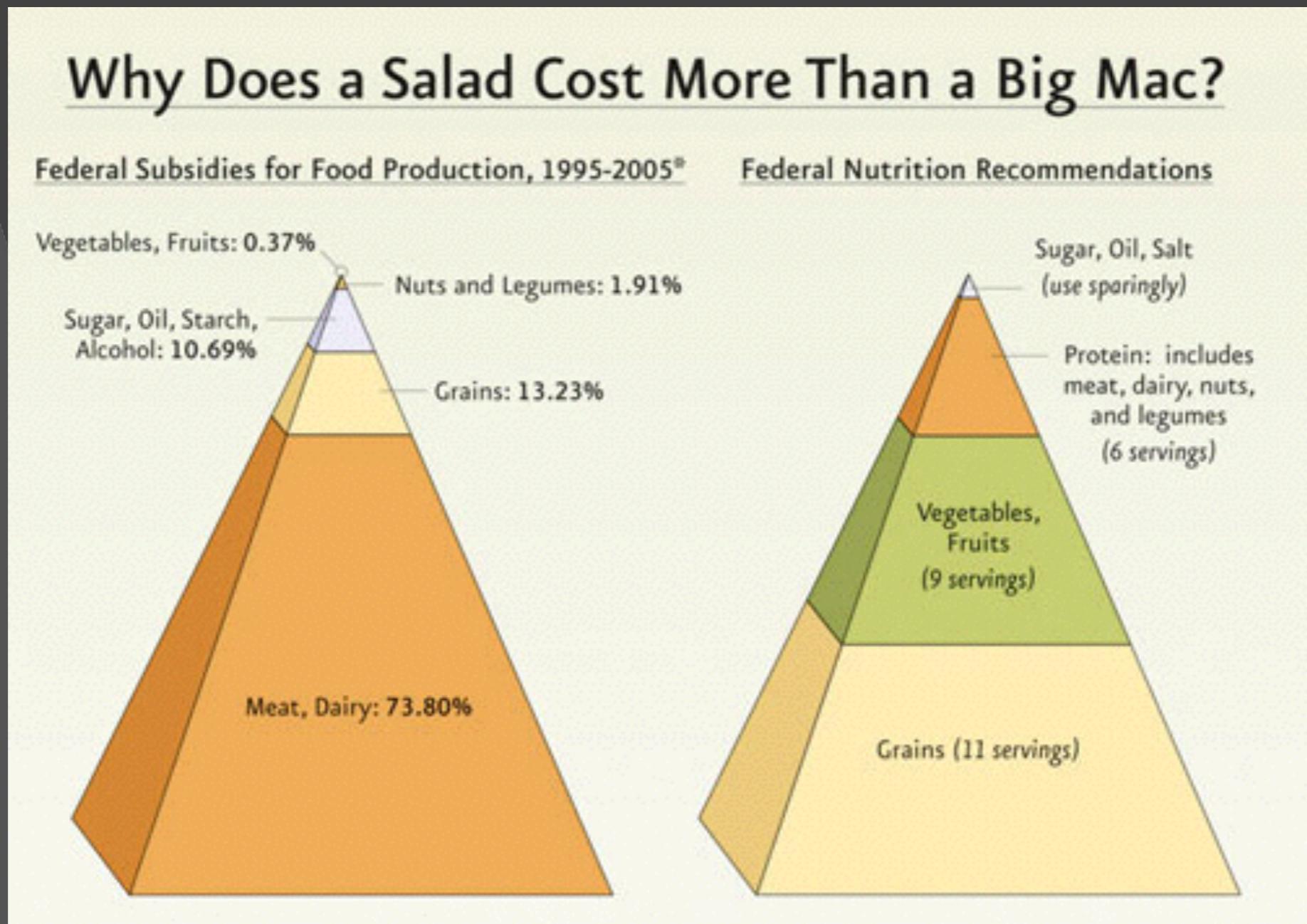
nominal:

Area



Activity

Which channels are used to encode the data? Are they effective? (1 min)



Visual Hierarchy

CS
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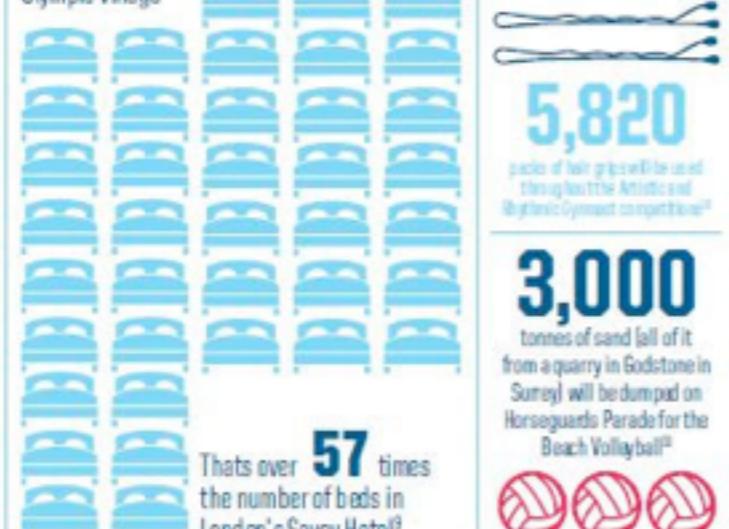
The Schweppes Abbey Well Alternative Facts and Stats of the London 2012 Olympic and Paralympic Games



10 million
litres of water will be needed to fill the swimming and diving pools at the Aquatics Centre - that's the same amount of water for **1,250,000** flushes of a toilet!⁶

Stable workers will have the fragrant job of clearing up a predicted **32,000** piles of manure from the equestrian events.⁷ Nice

17,320
beds will be housed at the Olympic Village



Athletes in the Olympic Village will consume **75,000** litres of milk over the course of the London 2012 Games. It would take

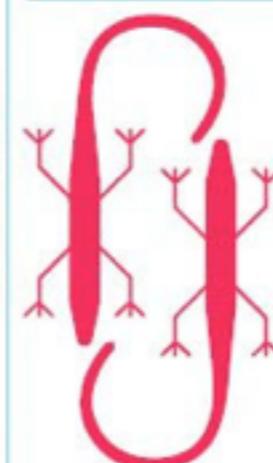
1 COW
around 10 years to produce the same amount!¹¹



Over **4,000** trees, **74,000** plants, **60,000** bulbs and **350,000** wetlands plants have been planted in the Olympic Village - that's over six times the amount of seats in the 80,000 capacity Olympic Stadium¹⁵



5 million
litres of bottled water will be supplied in the Olympic Village supplied by the official water sponsor, Schweppes Abbey Well¹⁶



2,000 newts were relocated from the Olympic Park to the Waterworks nature reserve¹³

4,000 bins in the Olympic Park will be emptied about **336,000** times throughout the London 2012 Olympic and Paralympic Games¹⁴

Competitors in the London 2012 boxing competition will get through **356** pairs of gloves¹⁵

The lightest piece of equipment is the women's Javelin which weighing a mere **600g** the same as a punnet of grapes!¹⁶



The official distance of the marathon is **42,195 metres** and the margin of error measuring the course is 0.1%¹⁷



abbey well
official water



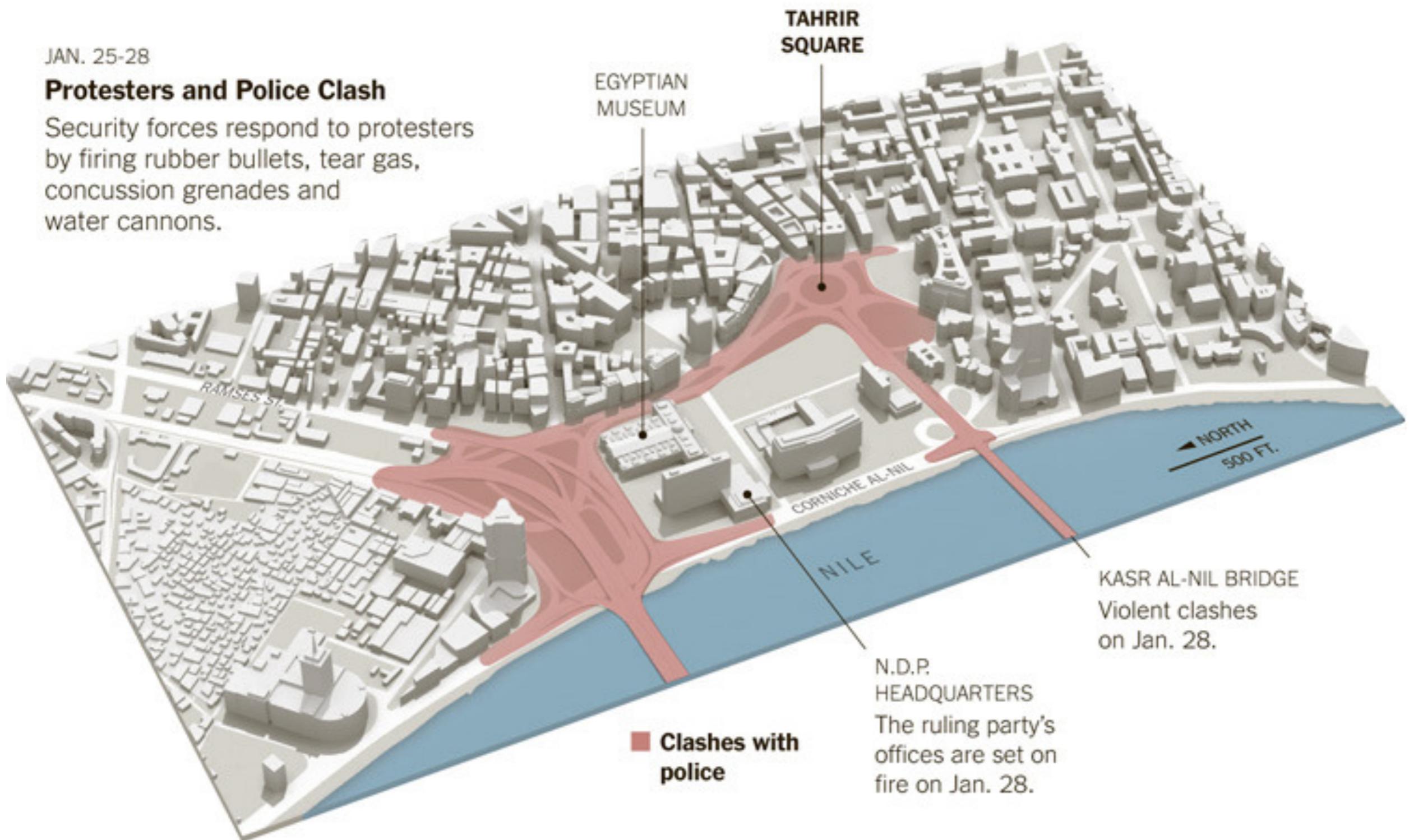
¹ LOCOG 2012 in numbers doc. ² London 2012 website. ³ LOCOG 2012 in numbers doc. ⁴ London 2012 website. ⁵ Based on 550 athletes using 1x 200ml bottle of suncream throughout the duration of event. London 2012 website. ⁶ LOCOG 2012 in numbers doc. According to <http://www.ashwells.co.uk/water/how-much-water-use-there-is> 8 flushes/fill of a toilet, 1,250,000 X 8 = 10,000,000. ⁷ Details from Young Men's Army Gymnastics who have had the discs on average 12 places in a year per day. There will be 200 athletes competing on 200 horses across the three Equestrian events. 200 X 12 places in a year = 2,400 places of manure = 200,000 piles of manure. ⁸ London 2012 website. ⁹ LOCOG 2012 in numbers doc. According to the London Savoy Hotel they have 300 beds, 57K 300 = 27,300. ¹⁰ Based on 90 artistic gymnasts and 65 rhythmic gymnasts. London 2012 website using 1 standard pack of Metagrapes each. Each pack of Kirby grapes contains 30 individual grapes. 98 X 30 = 5,820. ¹¹ Data supplied by LOCOG and London 2012 website. ¹² Athletes will consume 75,000 litres of milk a year (<https://www.dairyley.com/uk/farm-details/leek-farm-in-the-peak-district/>). 74000 litres X 10 (years) = 740,000. ¹³ London Organising Committee of the Olympic and Paralympic Games Ltd. 2012 in numbers doc. ¹⁴ LOCOG 2012 in numbers doc. ¹⁵ LOCOG 2012 in numbers doc. ¹⁶ Details from Young Men's Army Gymnastics. ¹⁷ Data supplied by Schweppes Abbey Well, who will be supplying 10,000,000 bottles of water. Each bottle is 500 ml. 10,000,000 X 500ml = 5,000,000,000 ml which equals 5 billion litres. ¹⁸ Details from Young Men's Army Gymnastics.

VS.

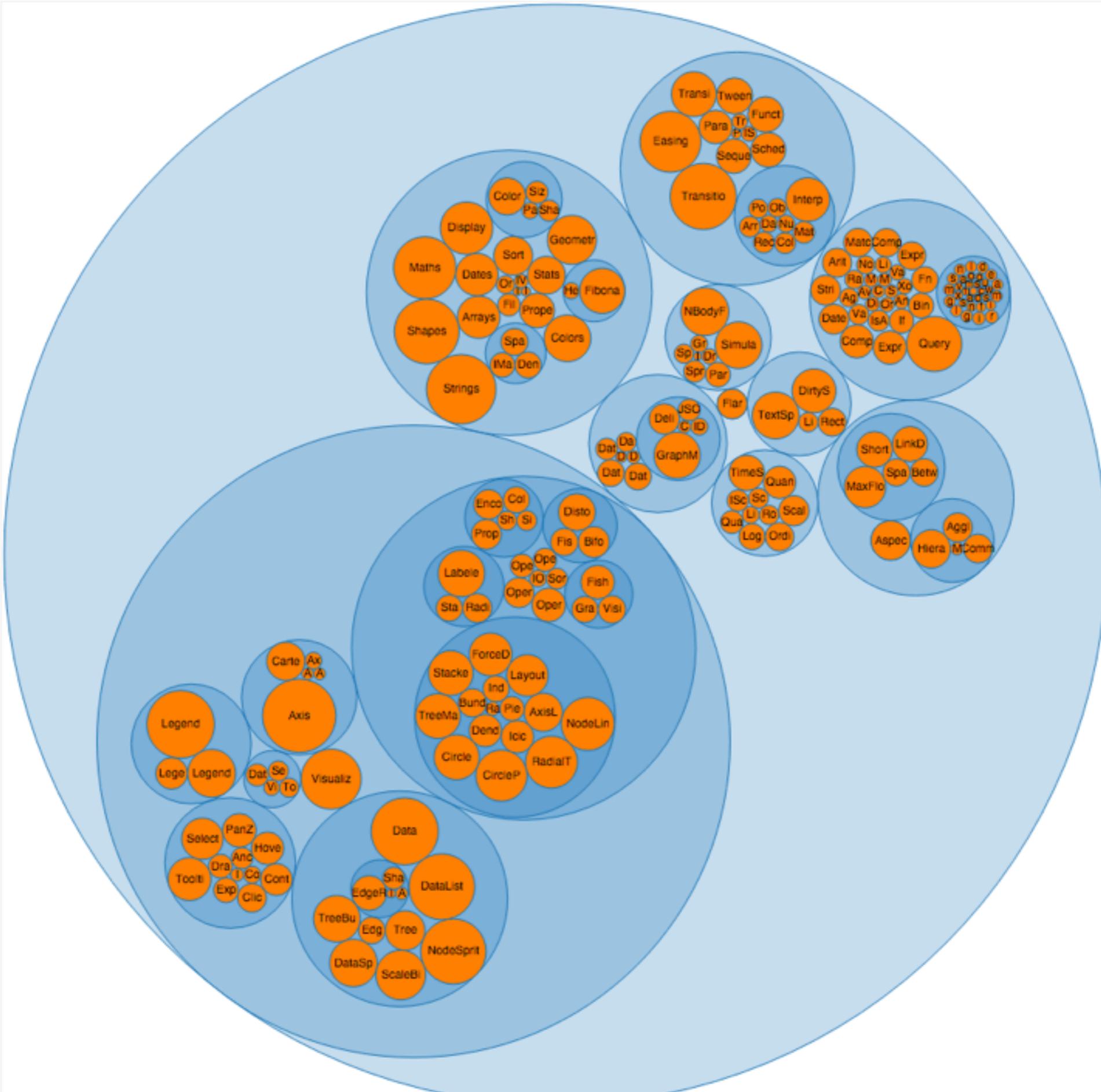
JAN. 25-28

Protesters and Police Clash

Security forces respond to protesters by firing rubber bullets, tear gas, concussion grenades and water cannons.



Circle Packing

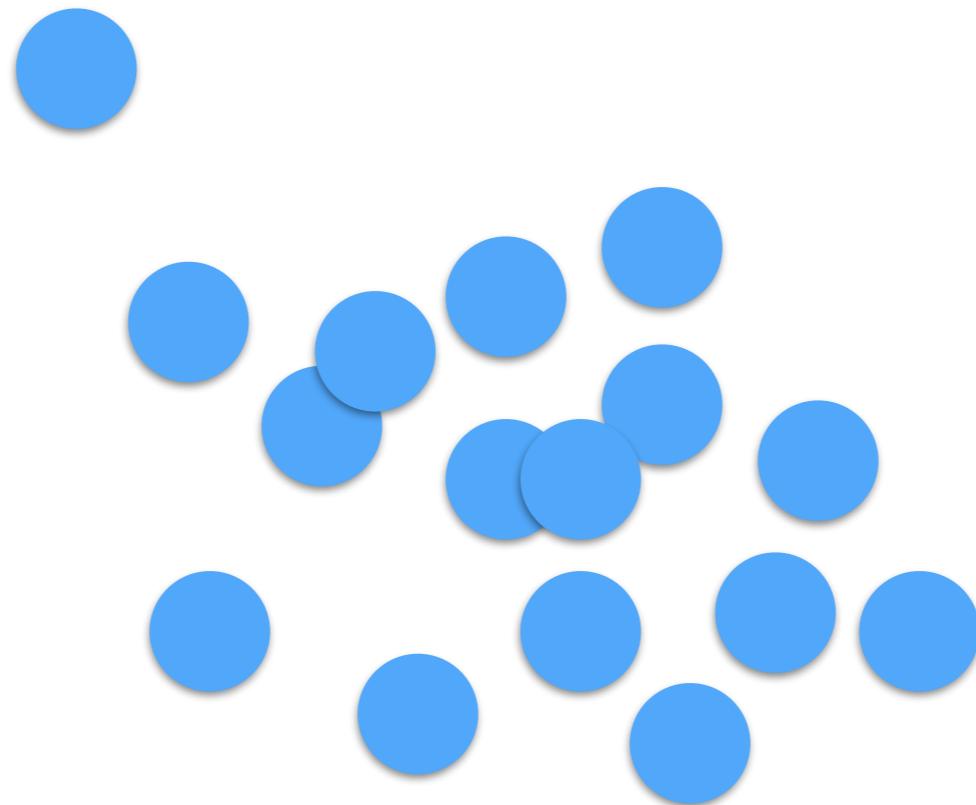


Activity

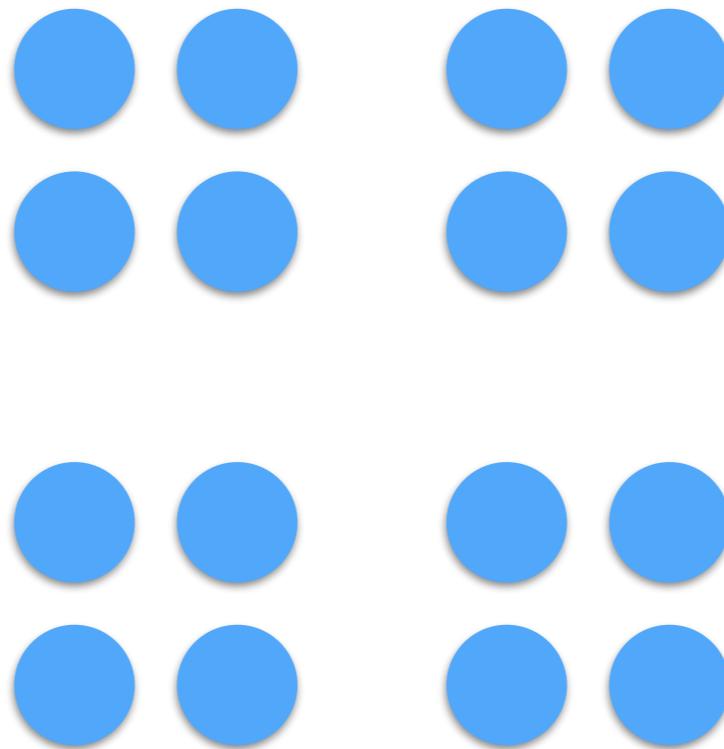
Count the dots and **shout** as soon as you have the correct number.



How many dots ?



How many dots?



Gestalt Principles

CS

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based on ...

Untersuchungen zur Lehre von der Gestalt.

II.

Von

Max Wertheimer.

Mit 56 Abbildungen im Text.

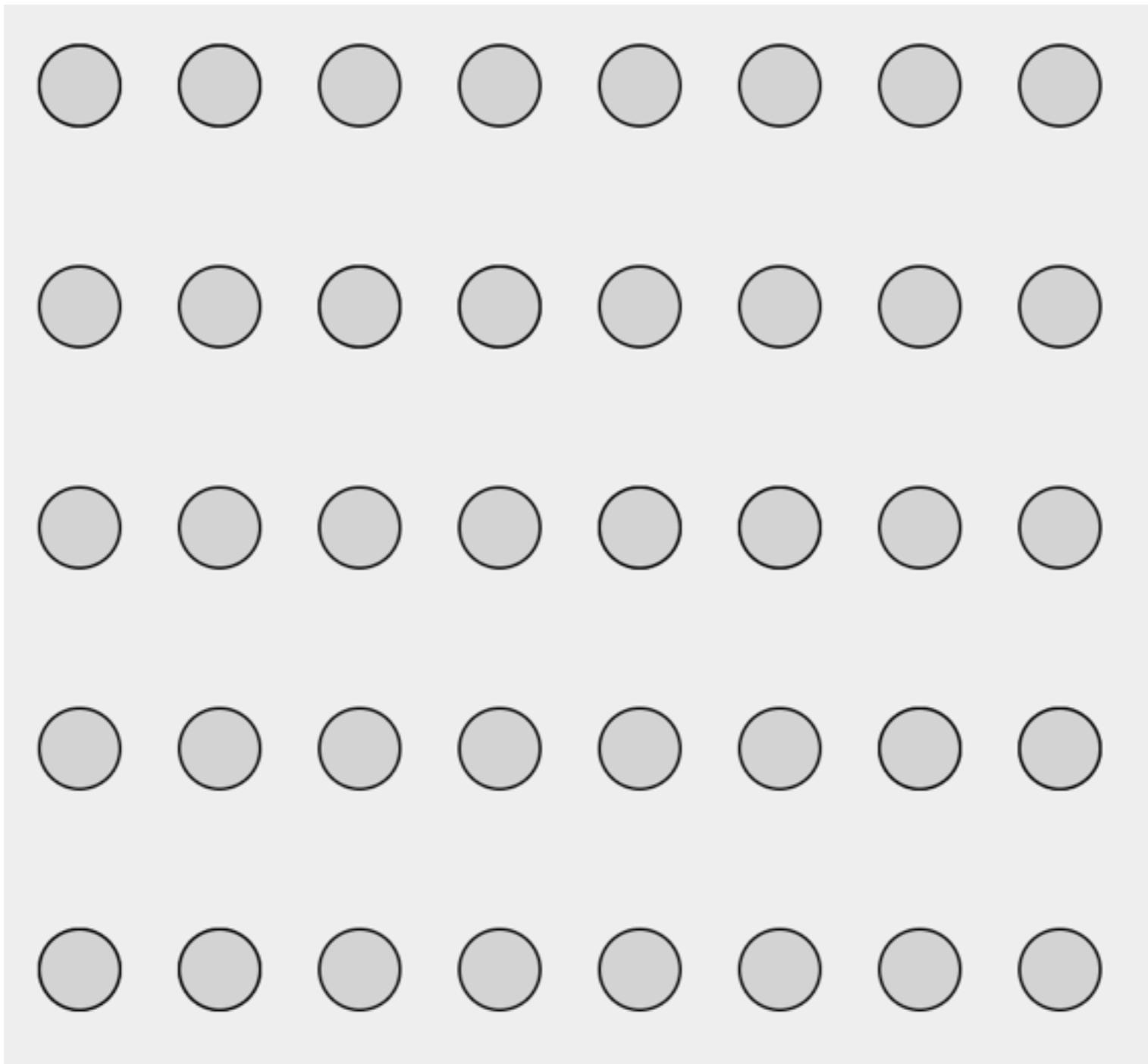
Ich stehe am Fenster und sehe ein Haus, Bäume, Himmel.

Und könnte nun, aus theoretischen Gründen, abzuzählen versuchen und sagen: da sind ... 327 Helligkeiten (und Farbtöne).

(Habe ich „327“? Nein; Himmel, Haus, Bäume; und das Haben der „327“ als solcher kann keiner realisieren.)

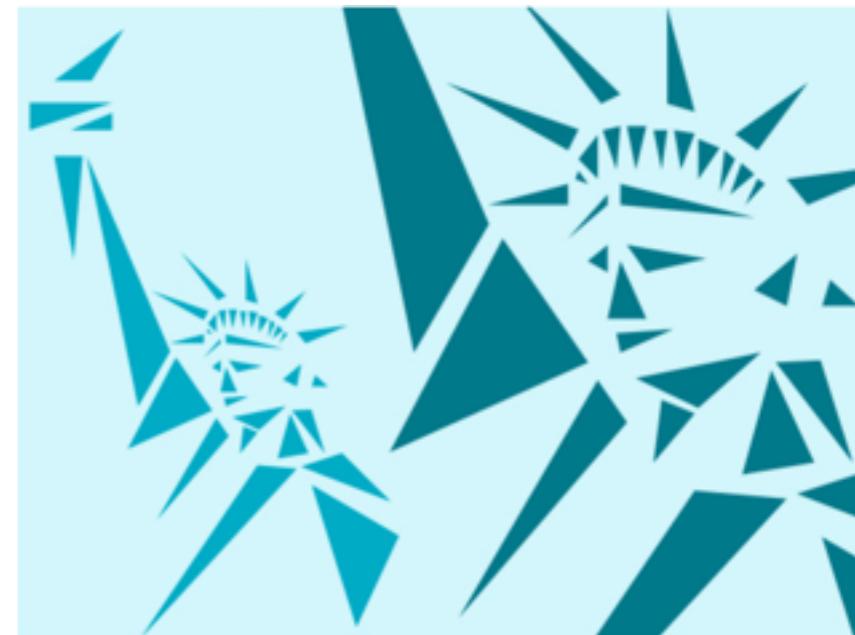
1923

Gestalt Principles

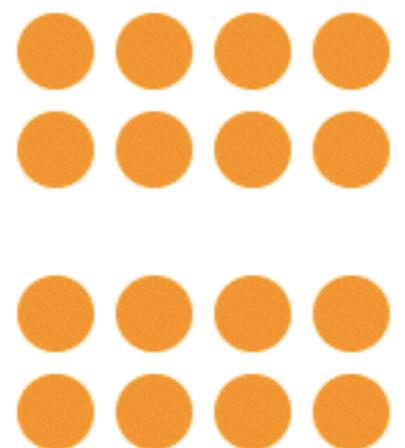
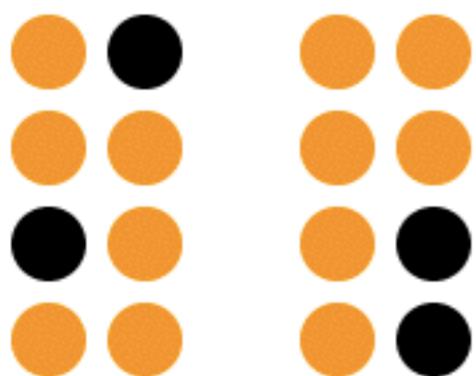
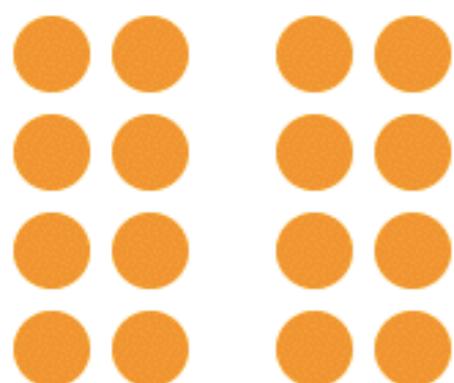
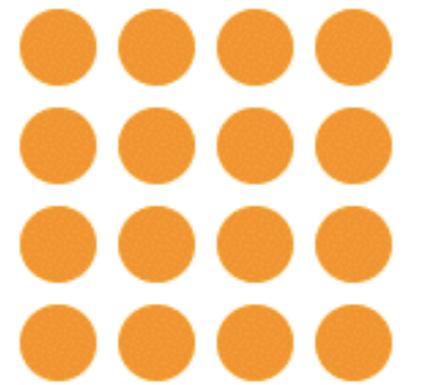


<https://emeeks.github.io/gestaltdataviz/section1.html>

Similarity

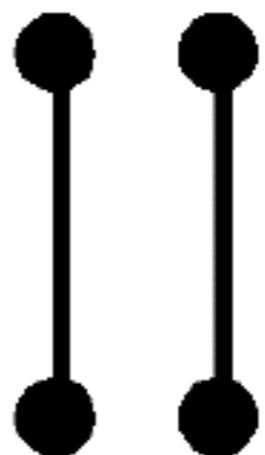


Proximity

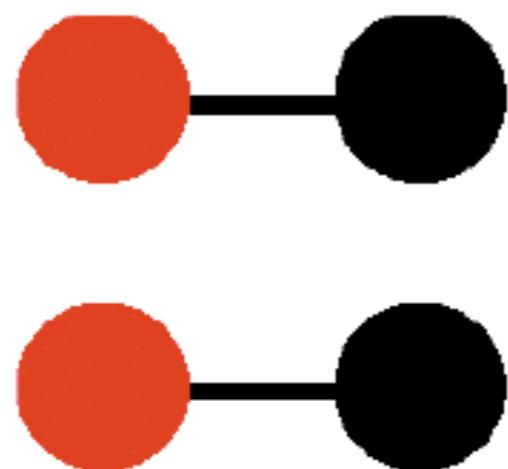


Connection

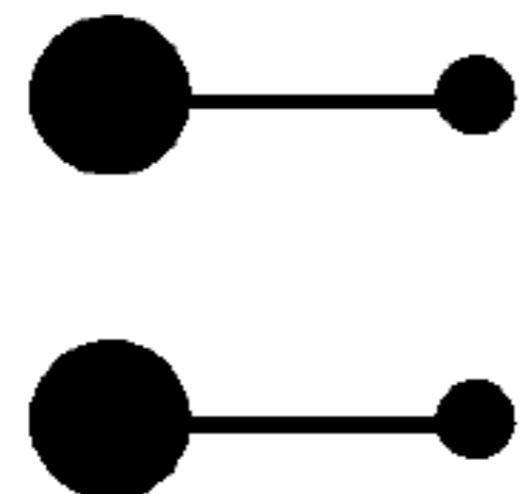
a
vs. proximity



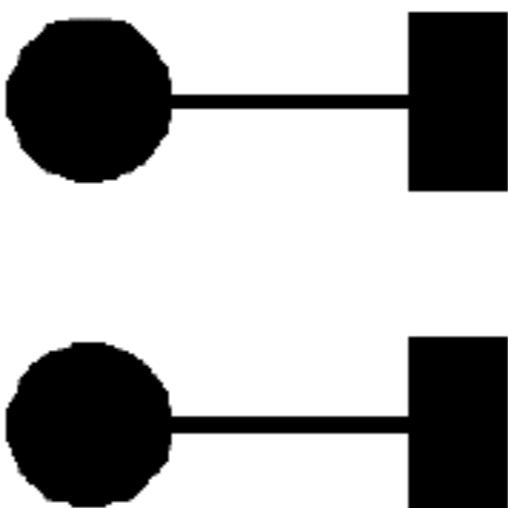
b
vs. color



c
vs. size



d
vs. shape



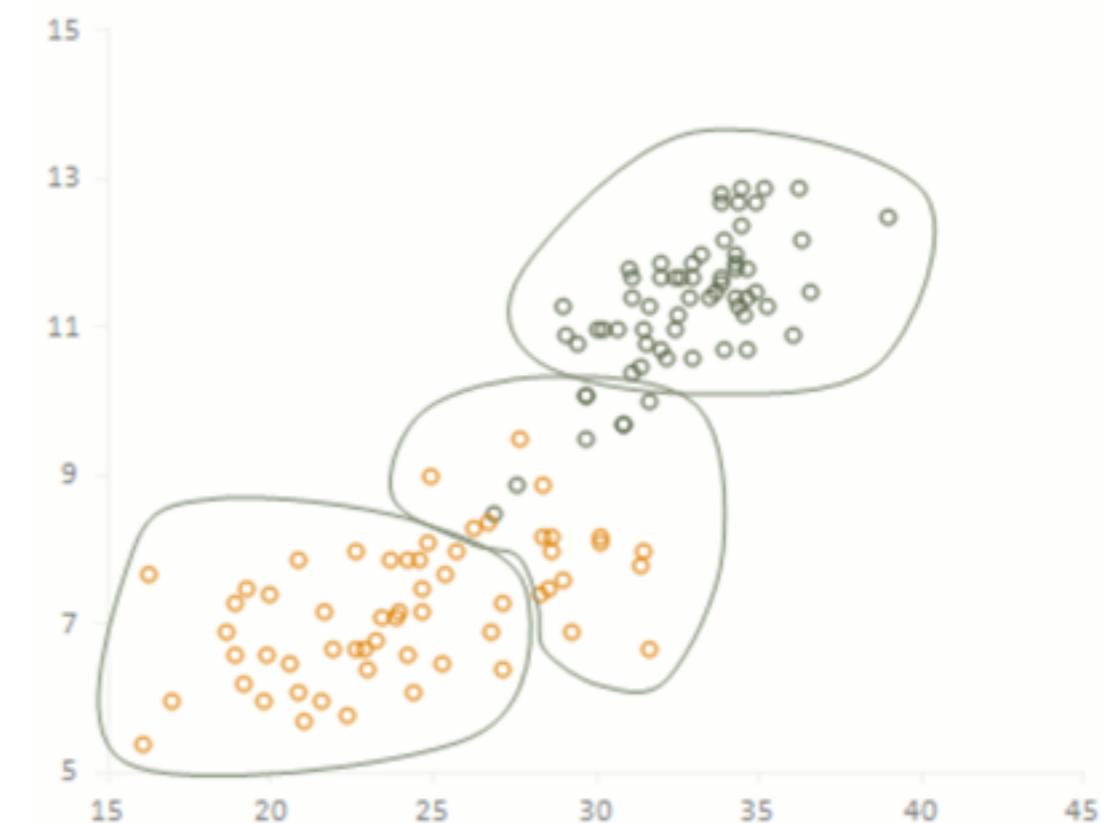
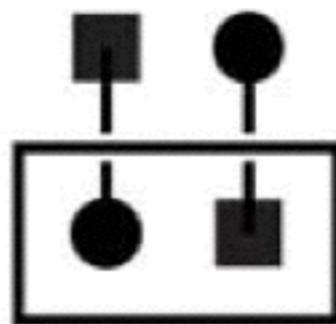
Enclosure

Similarity

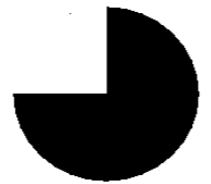
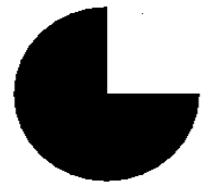


Connection

Enclosure



Closure



Continuation

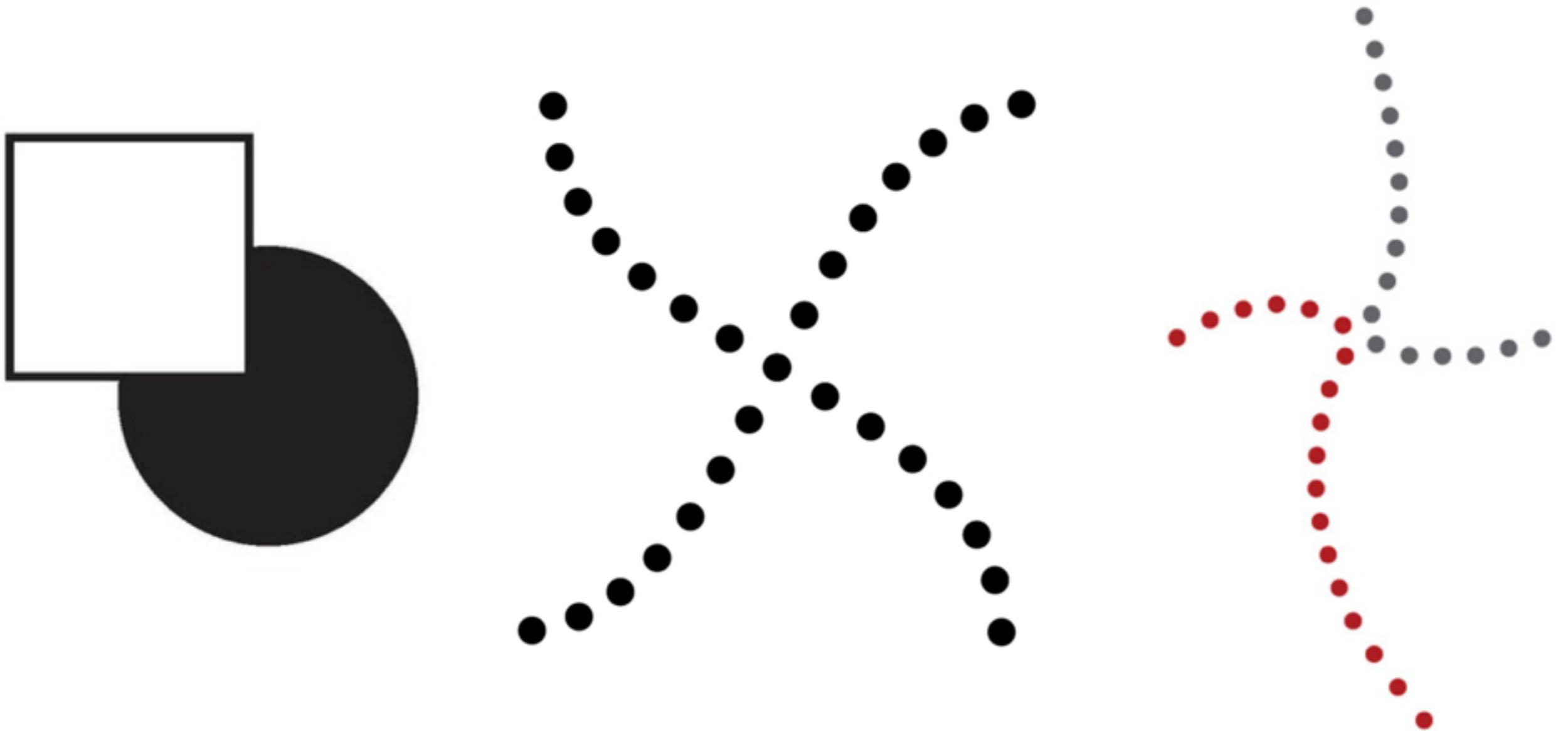


Figure-Ground Segregation

Proximity

Similarity



Closure

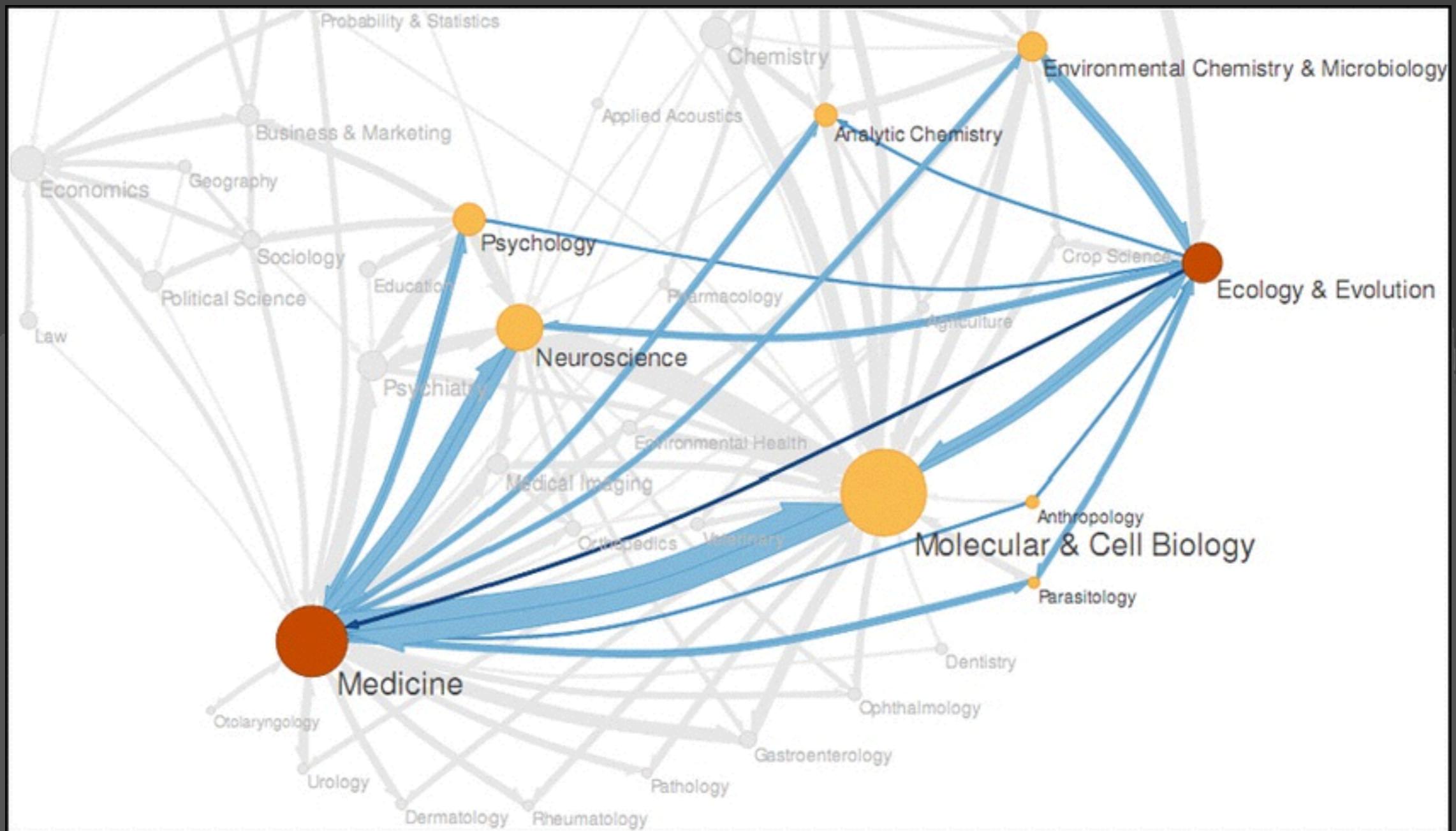
Continuity

Past Experience

Symmetry Equilibrium

Activity

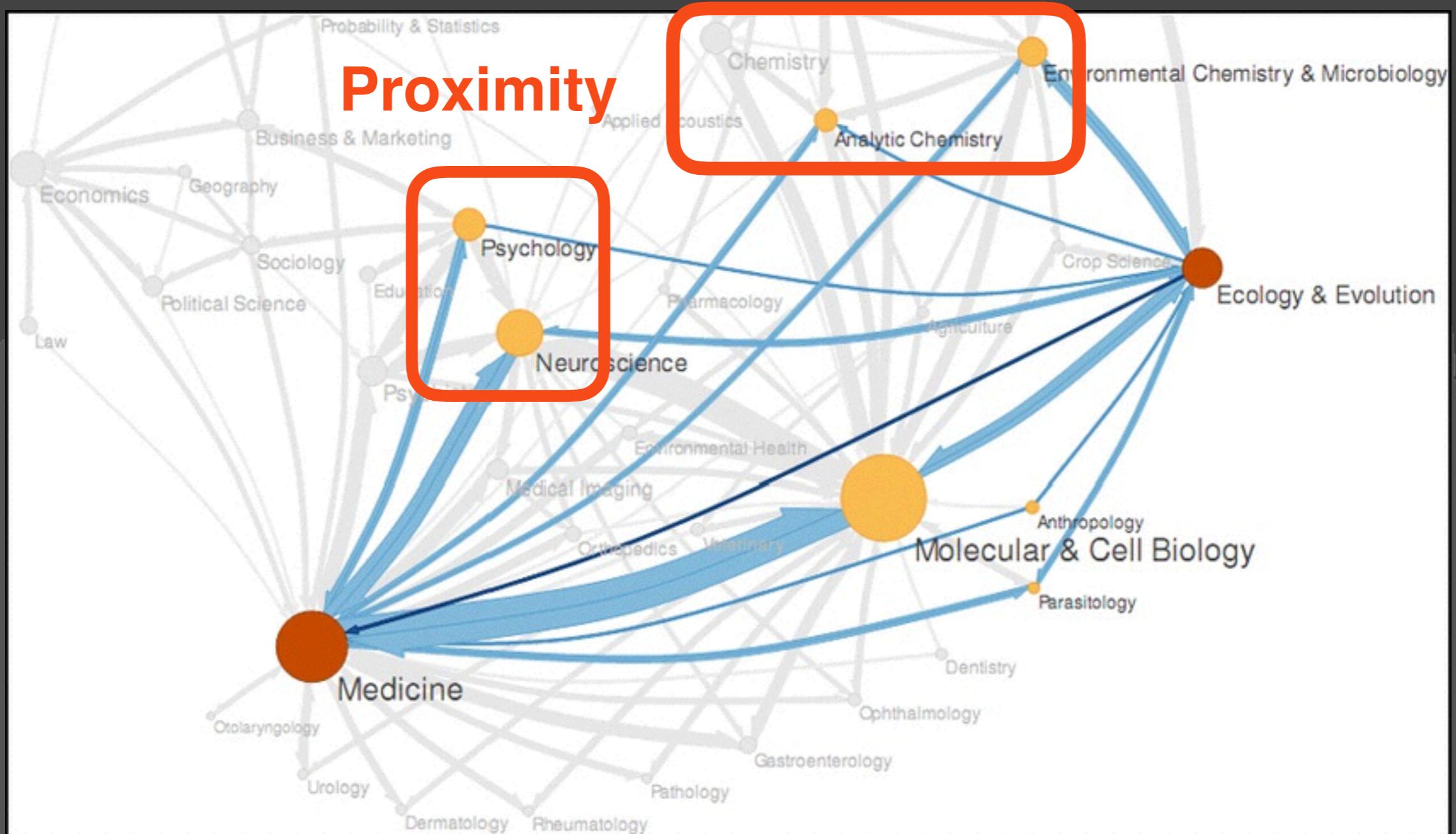
Which Gestalt principles are at work?



Rosvall and Bergstrom 2007

Activity

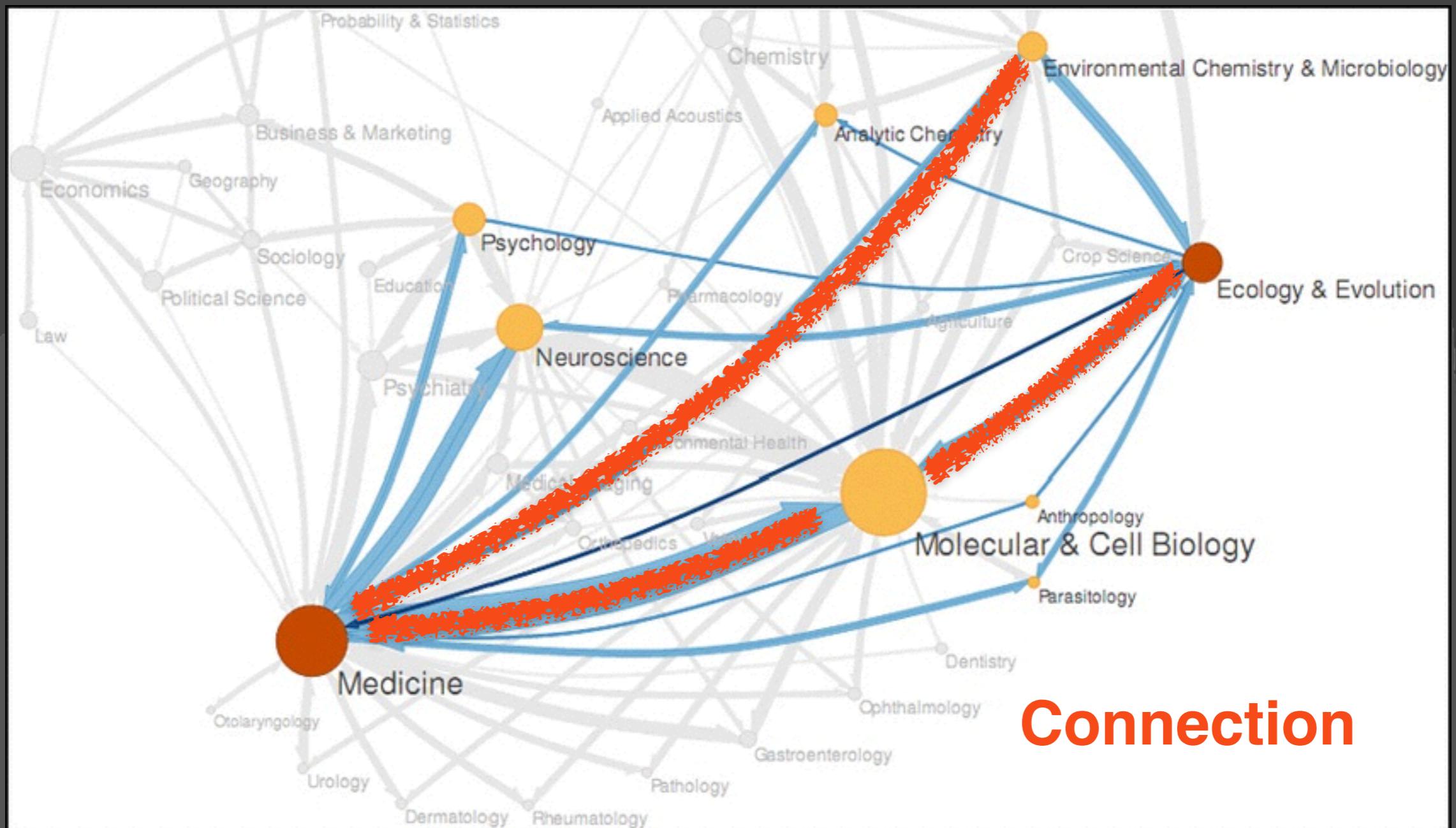
Which Gestalt principles are at work?



Rosvall and Bergstrom 2007

Activity

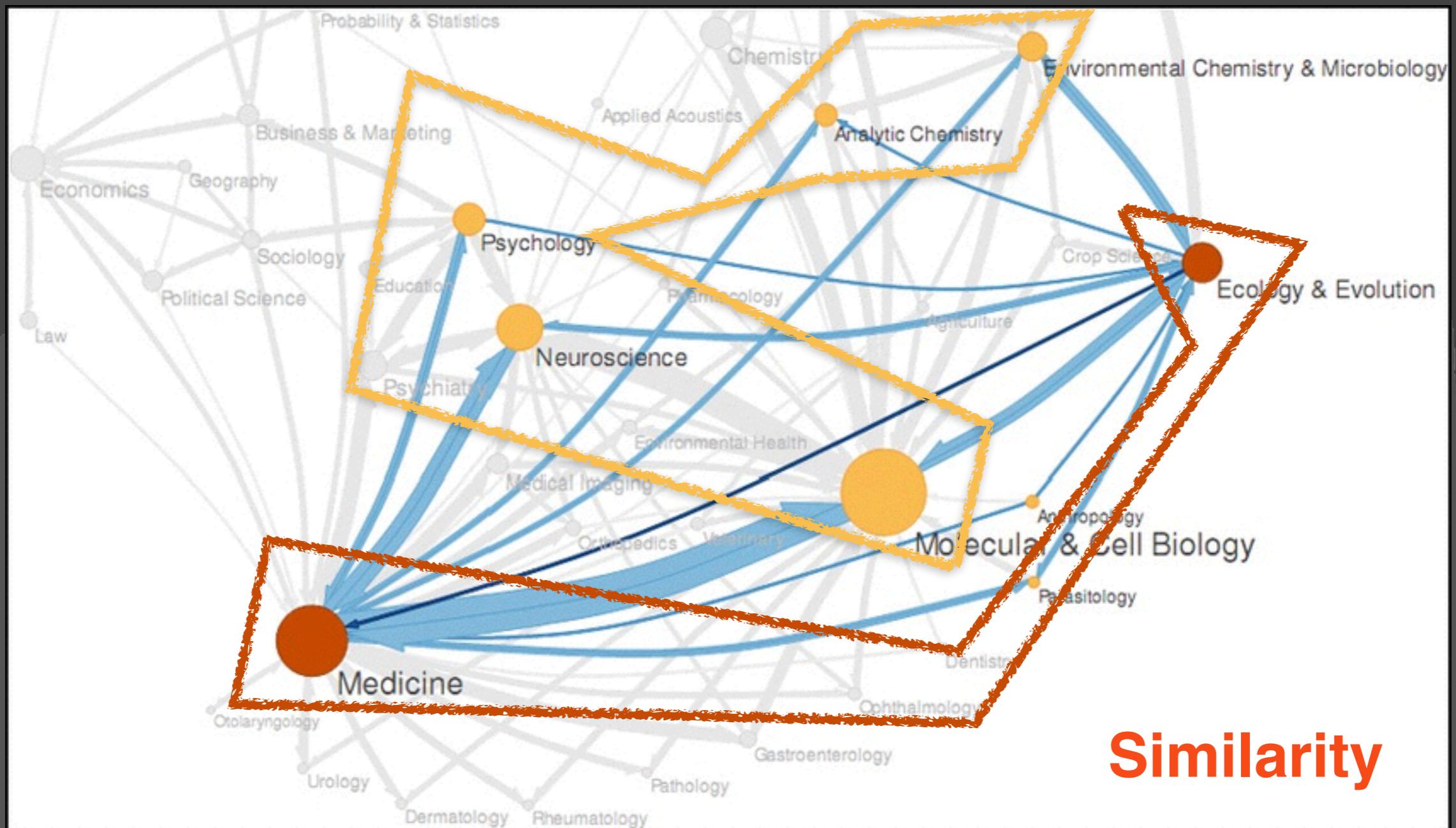
Which Gestalt principles are at work?



Rosvall and Bergstrom 2007

Activity

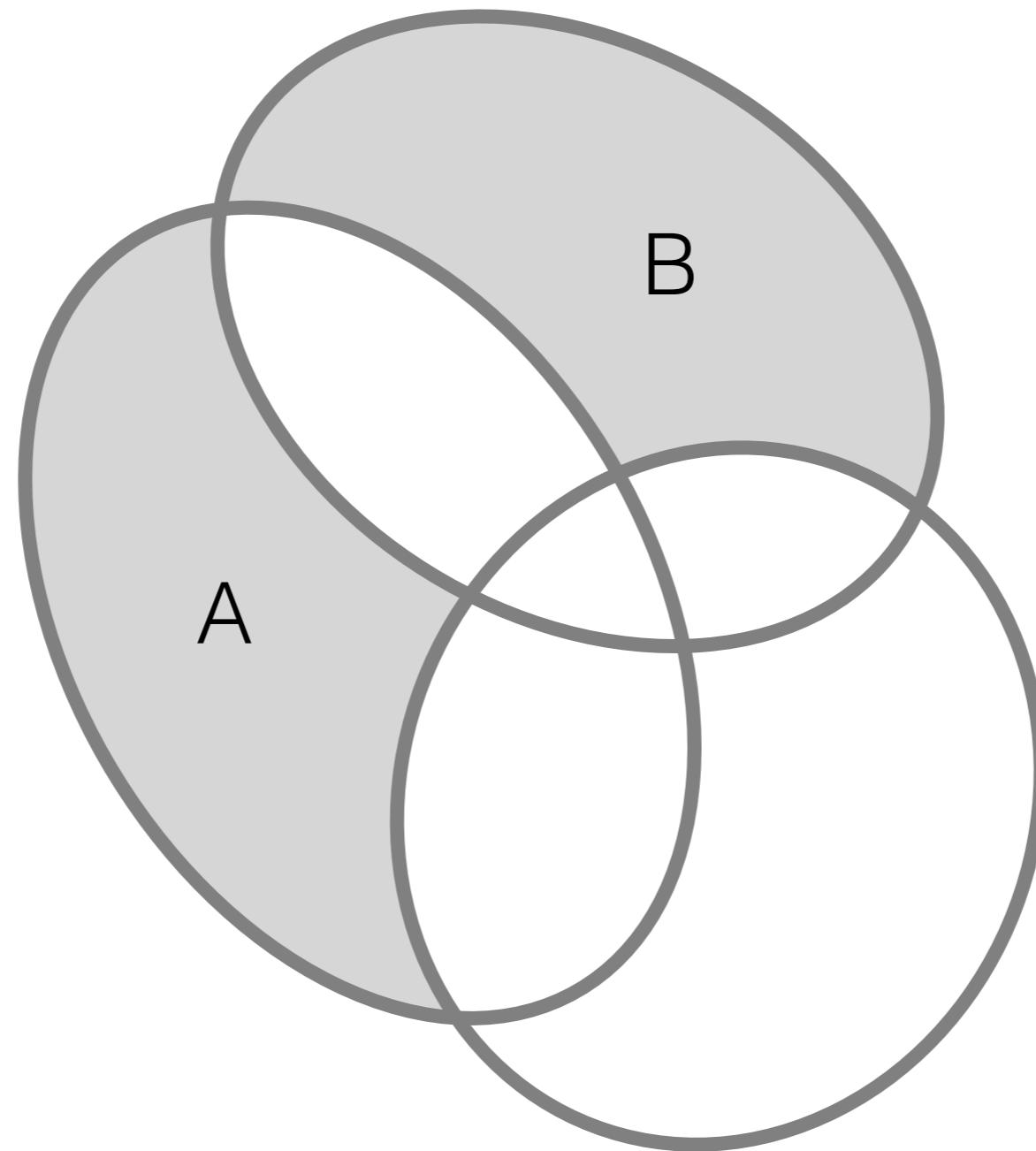
Which Gestalt principles are at work?

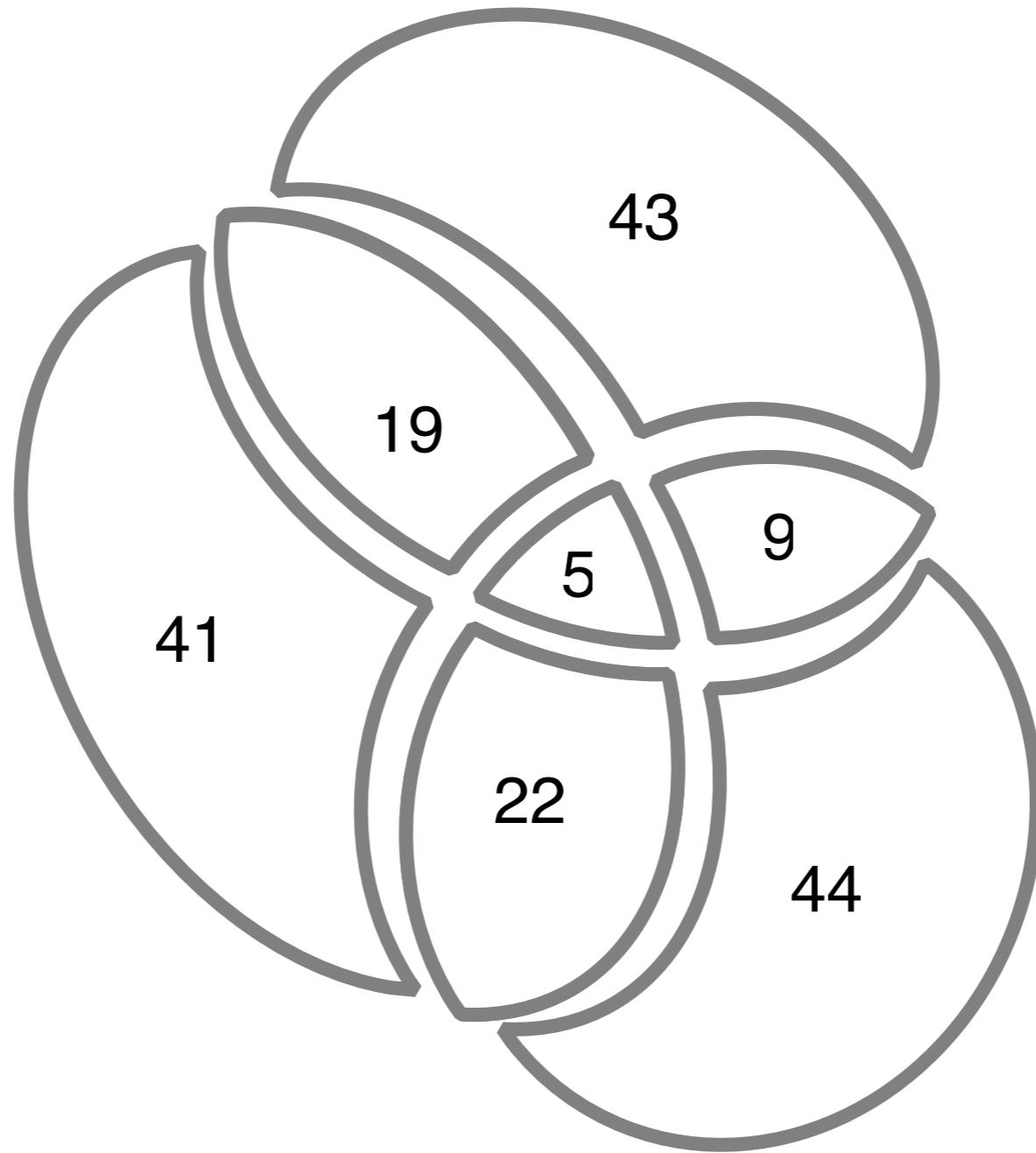


Rosvall and Bergstrom 2007

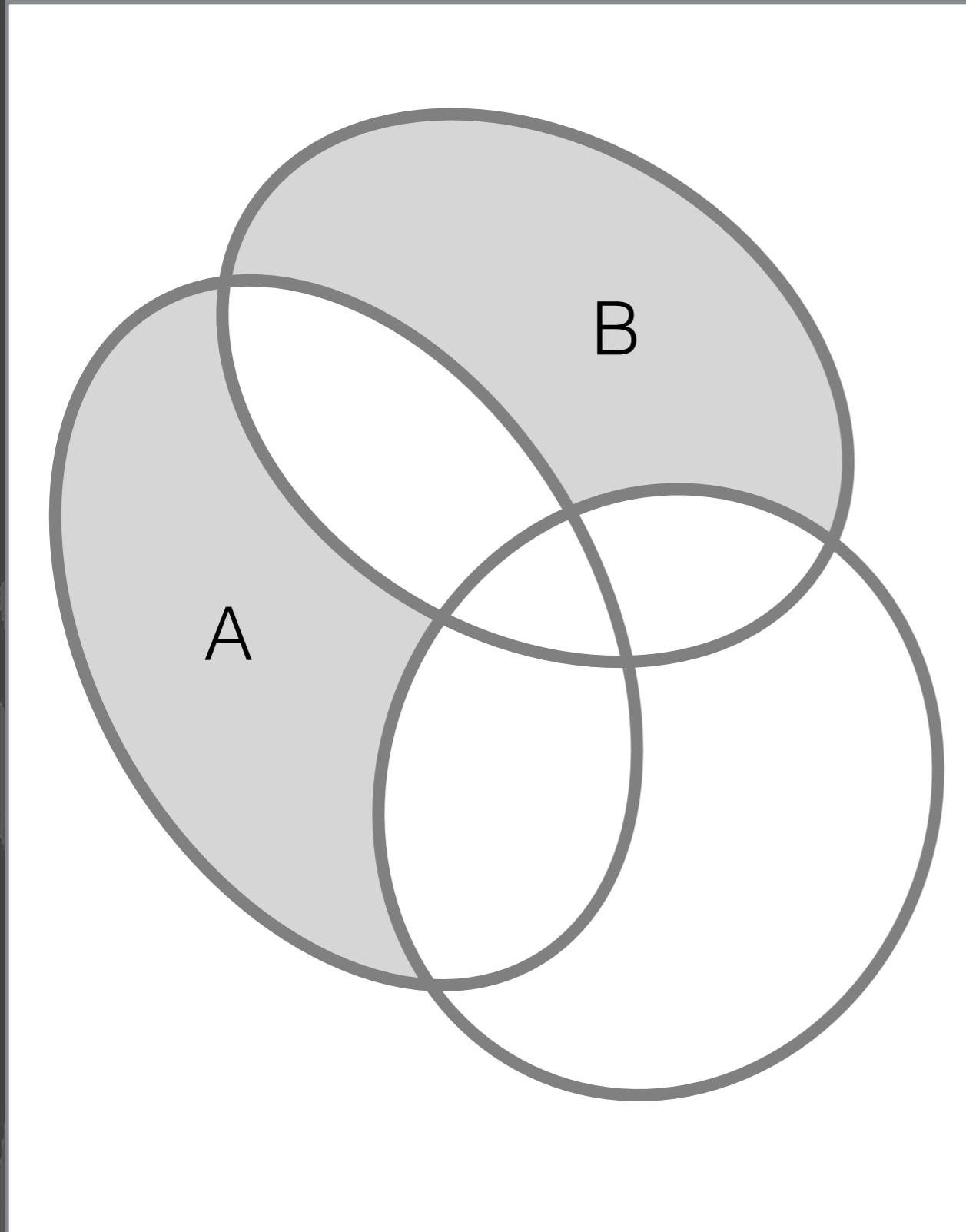
Example: Set Visualization

Element ID	Attribute(s)	Sets
Name	Age	Characteristics
Lisa	8	School, Female
Bart	10	School, Male
Homer	40	Power Plant, Male
Mr. Burns	90	Evil, Power Plant, Male





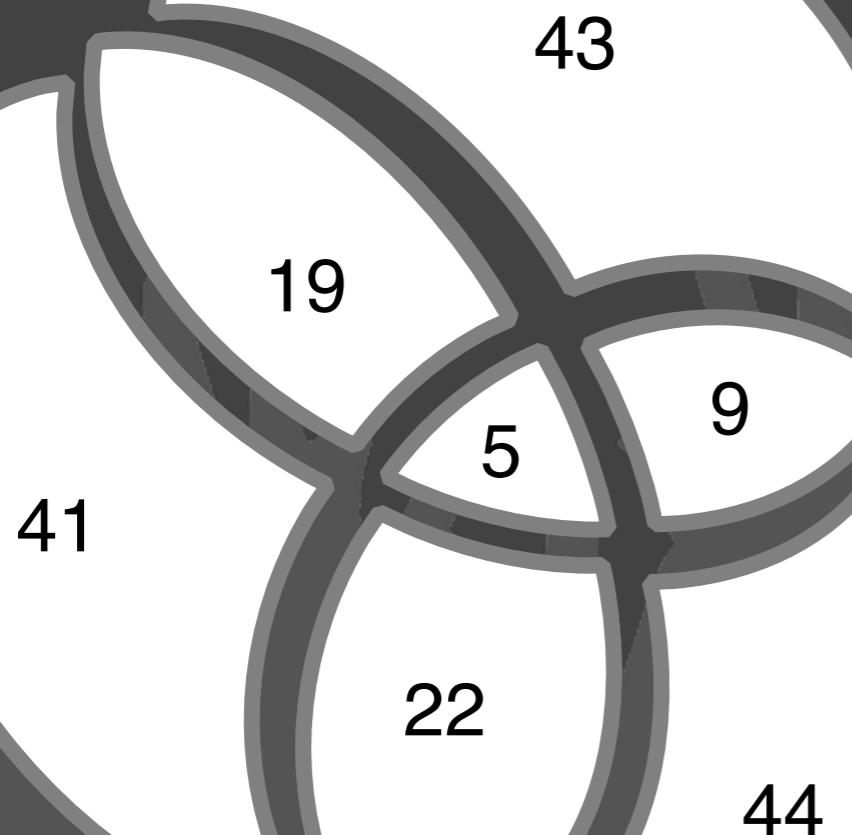
Activity



Which Gestalt principles are at work here?

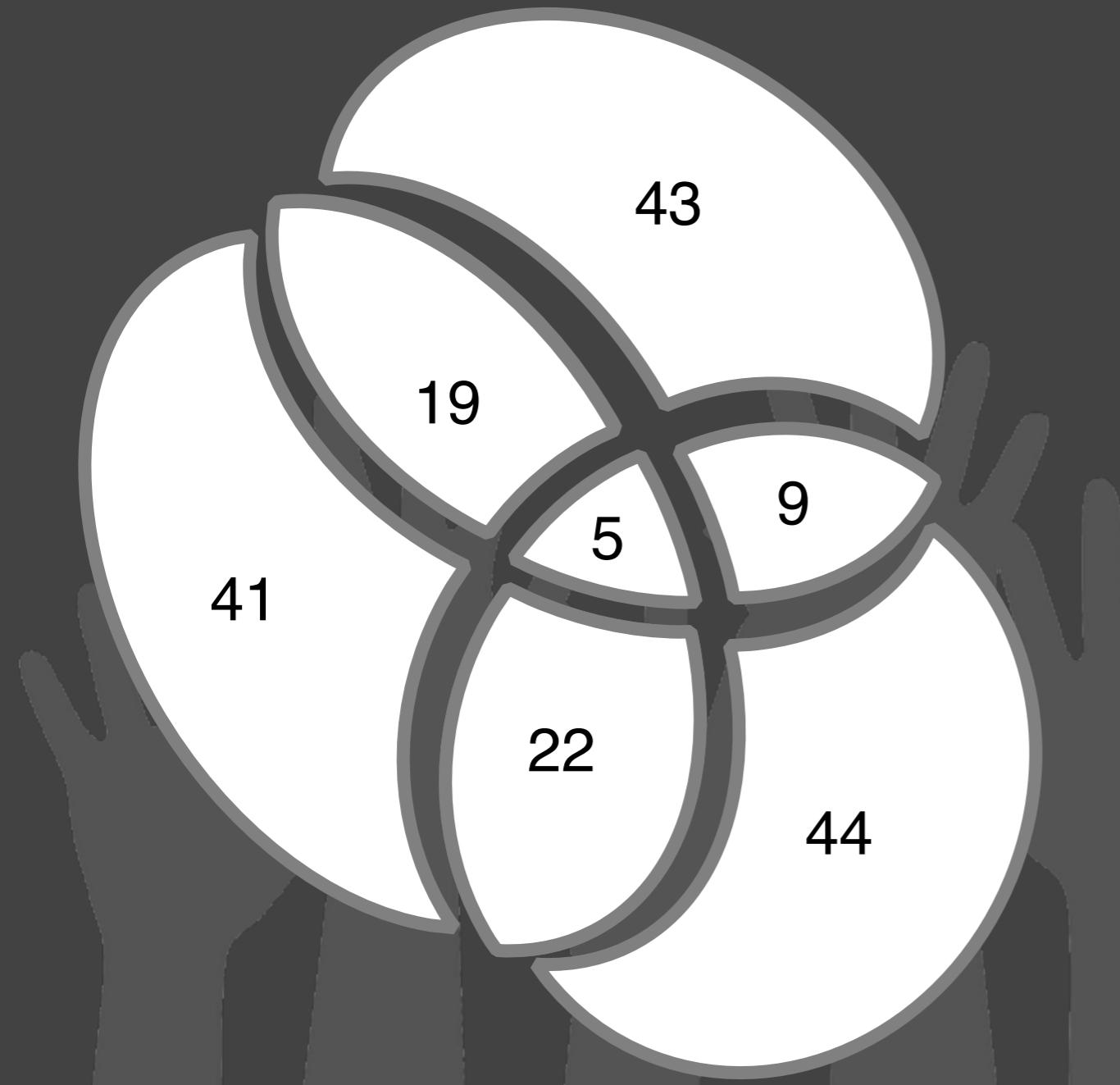
- Enclosure (intersections)
- Continuity (sets)
- Similarity (A/B)

Activity

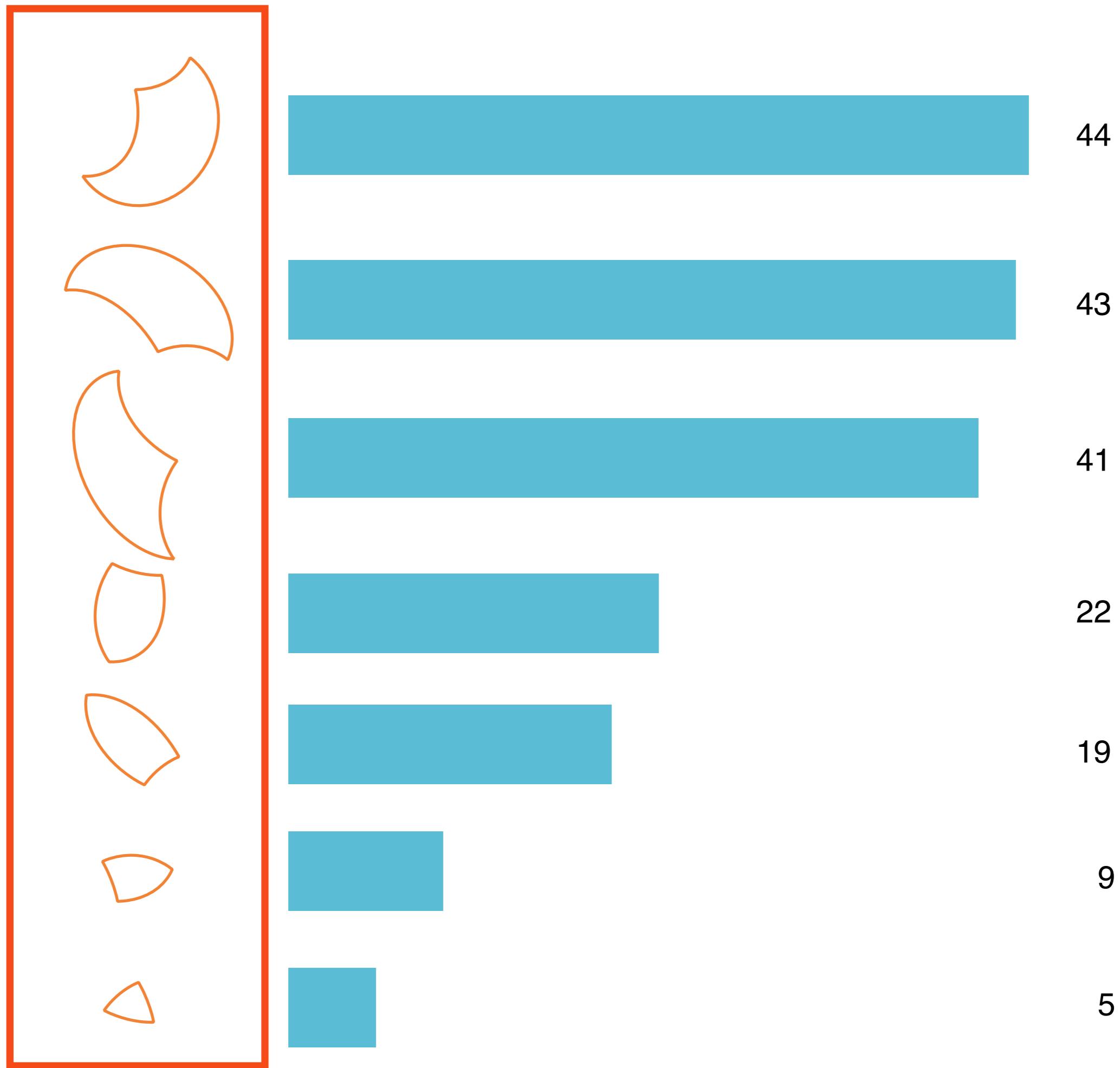


1) Create two alternative designs for data of an area-proportional Venn diagram in a scenario of three intersecting sets.
(5 min)

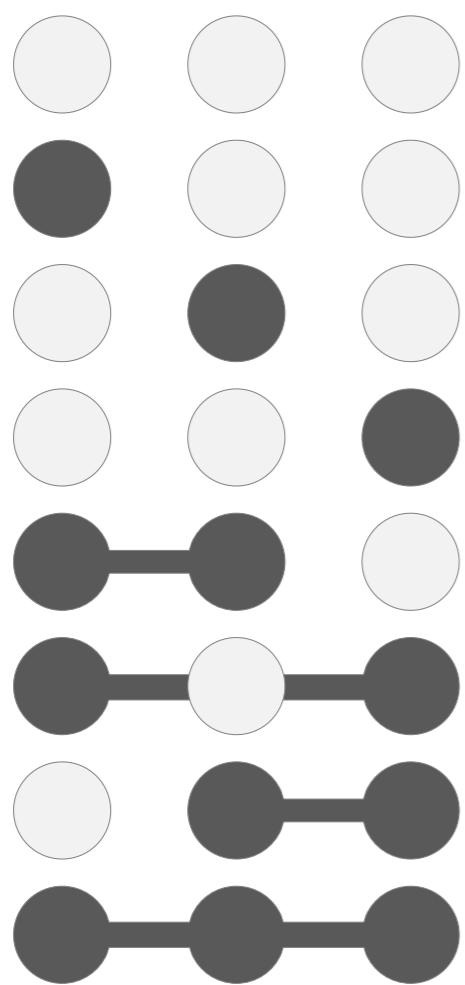
Activity



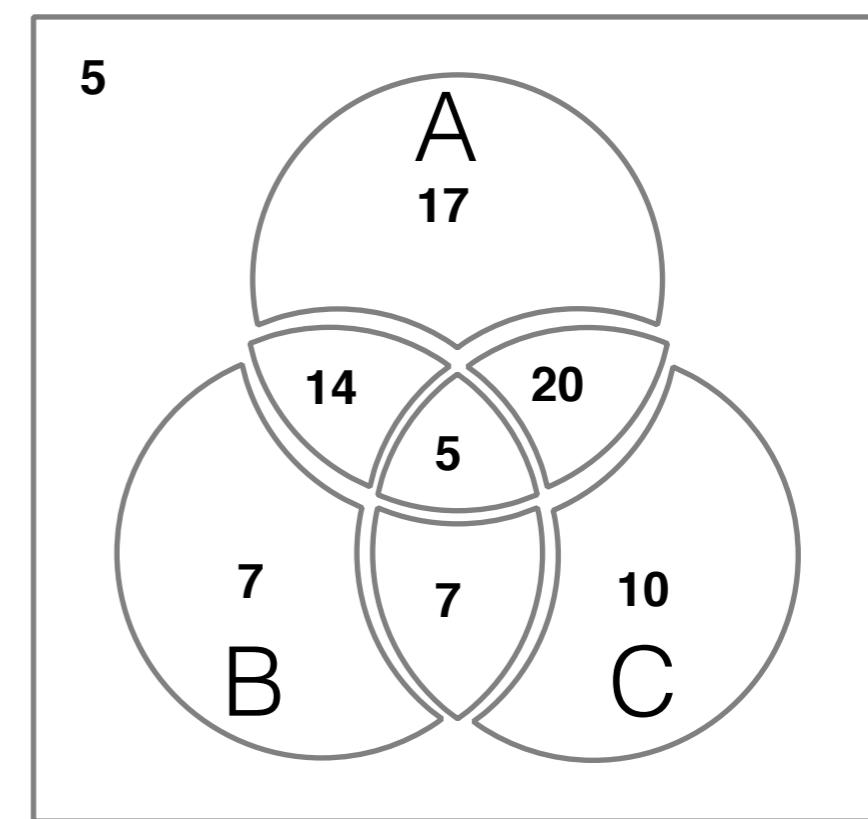
2) Discuss with your neighbor:
Which Gestalt principles did you use to encode the information?
Which questions does it answer effectively?
(3 min)



A **B** **C**



Cardinality



Memory, Attention, and their Limits

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Activity

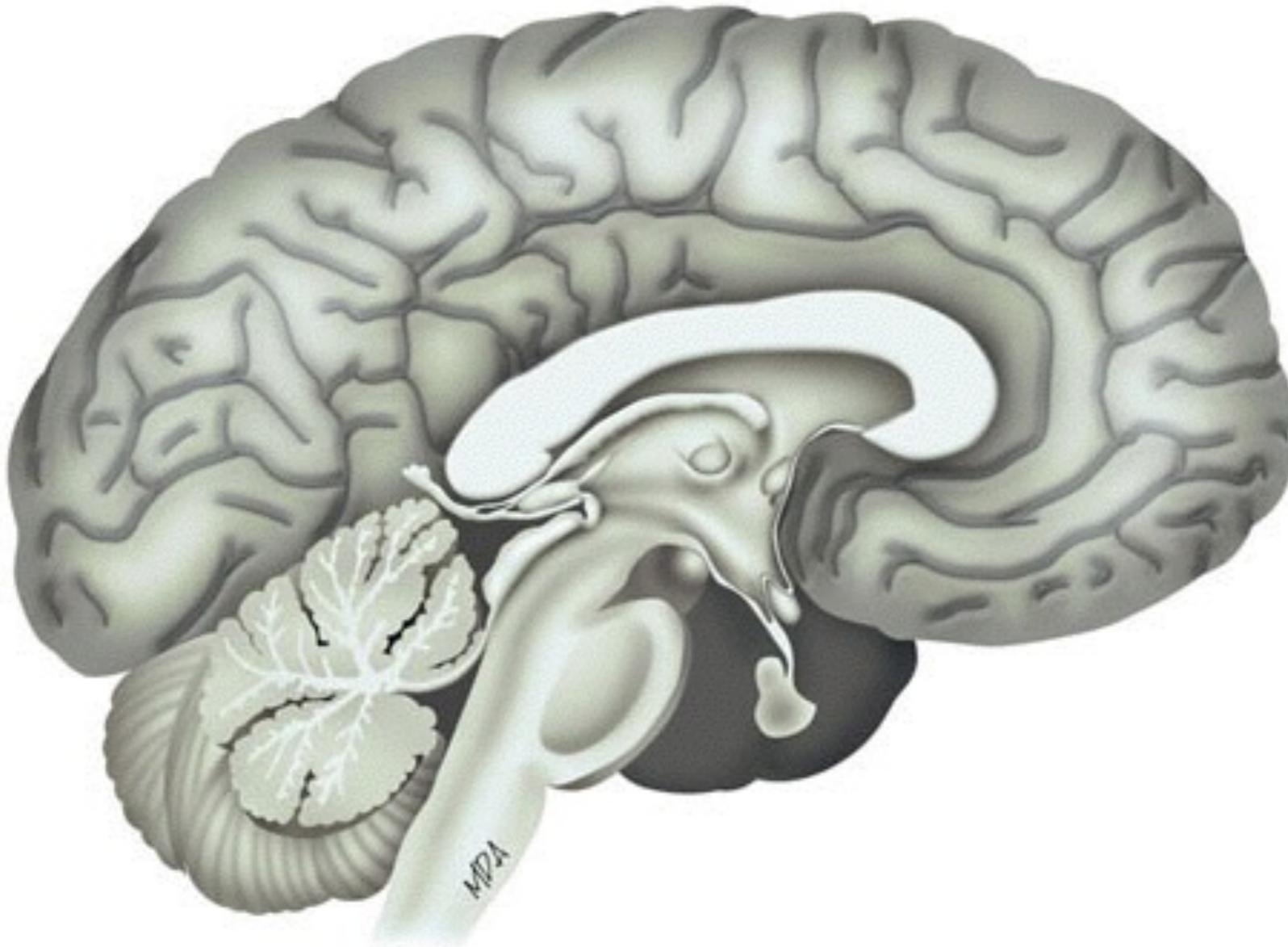
Which picture did you see last week?



-A-



-B-

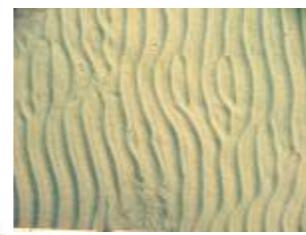


In the first 200 ms...

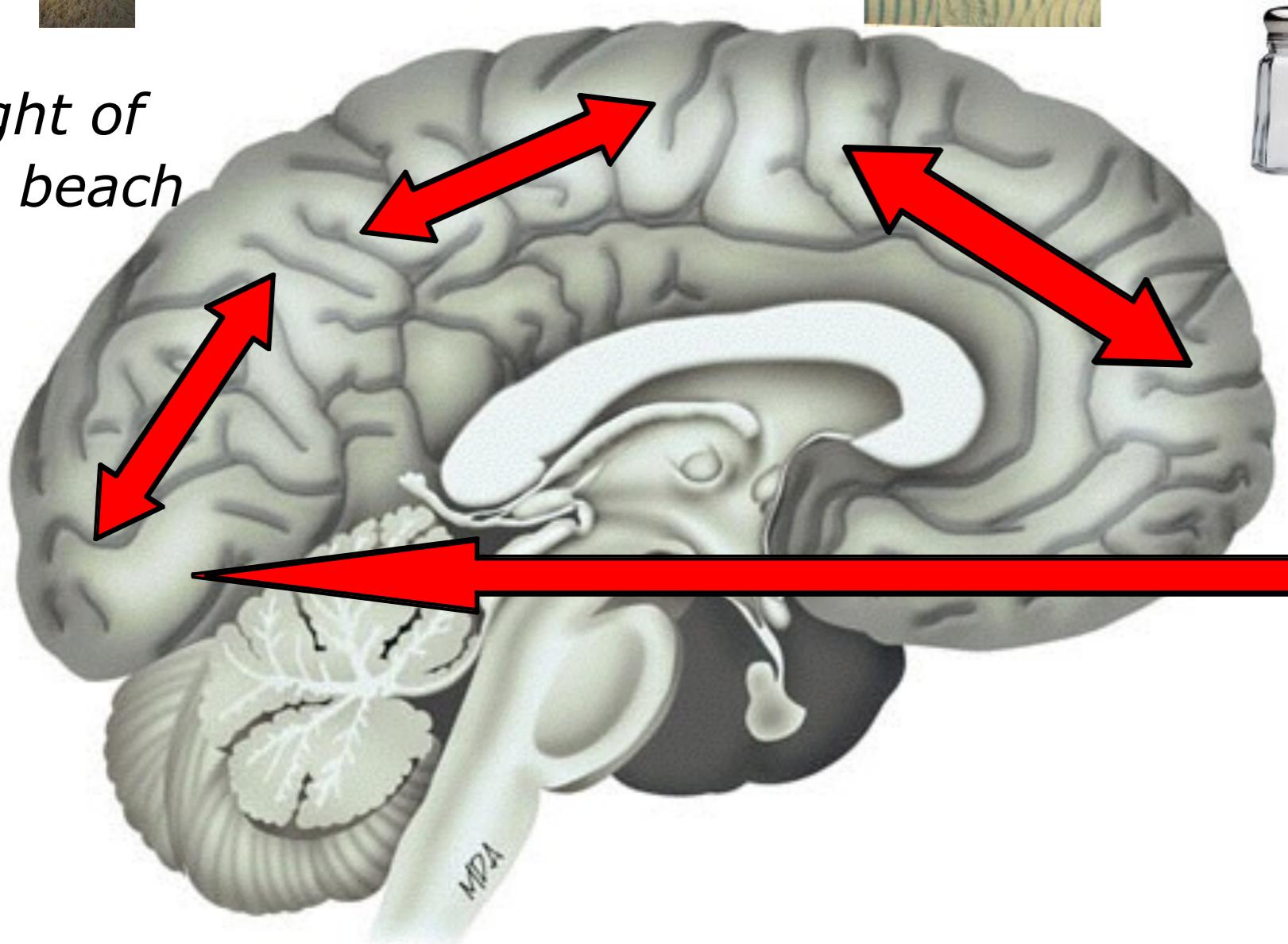
Feel of the sand



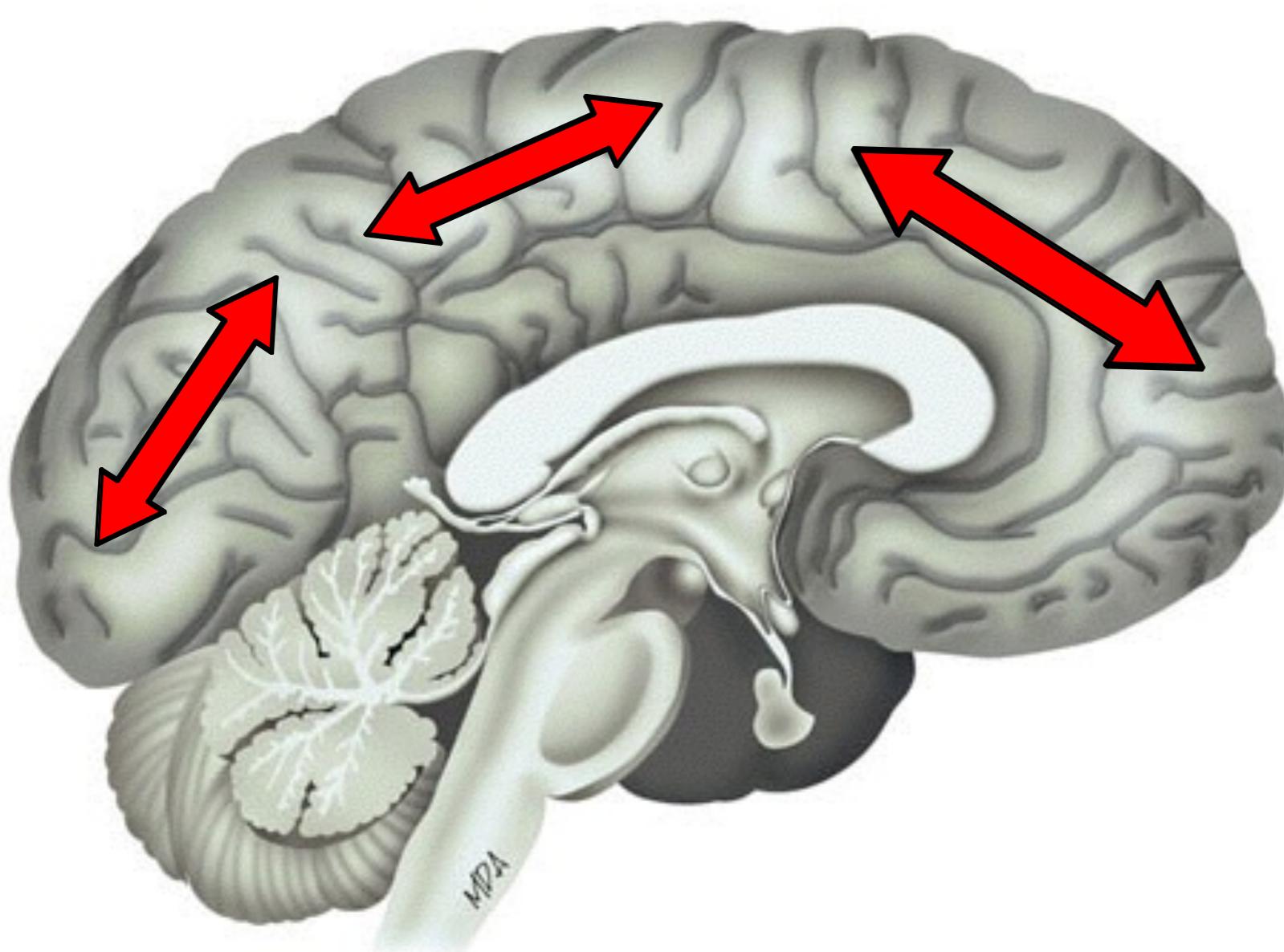
*Sight of
the beach*



Smell of the ocean



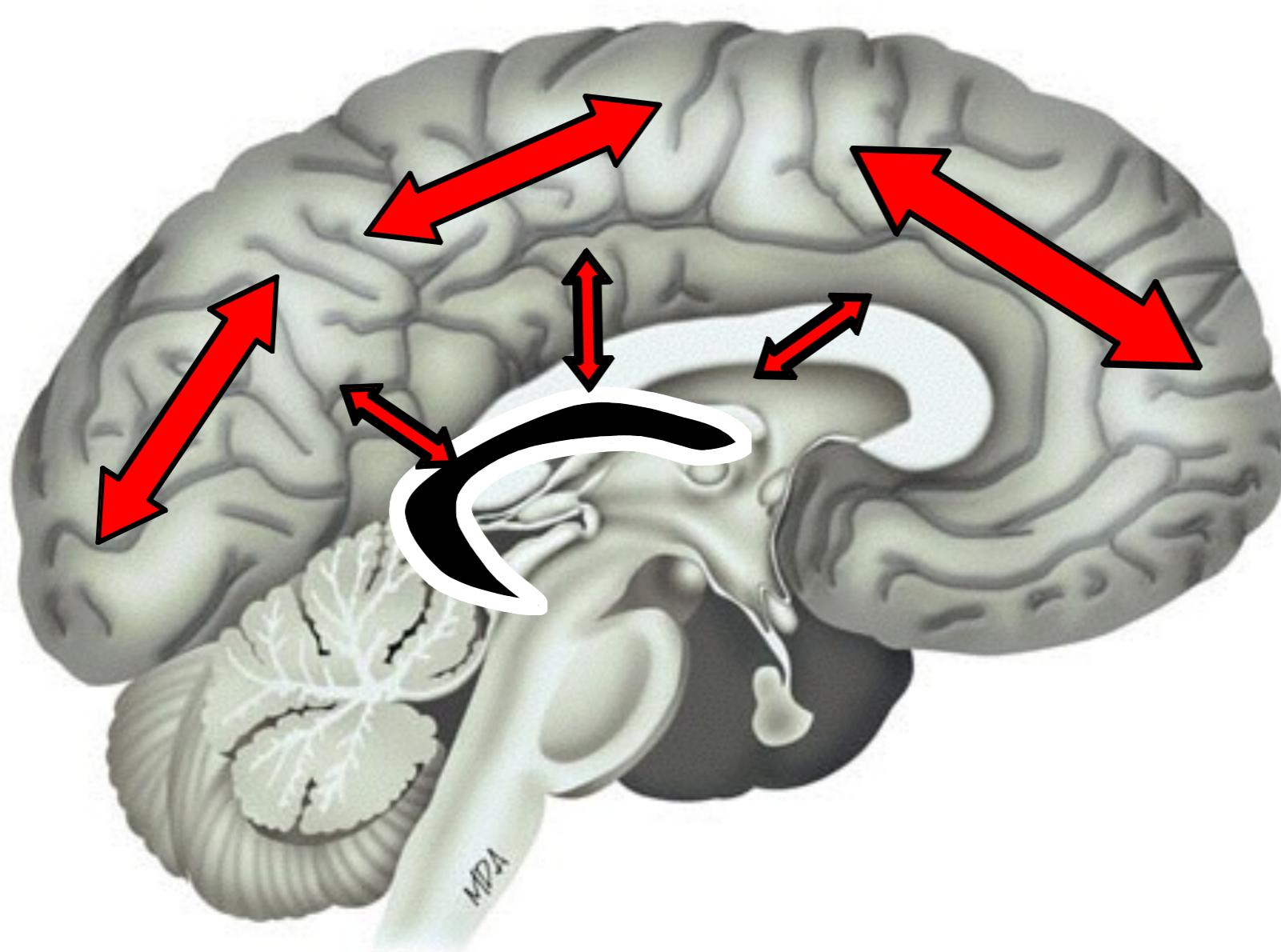
~ 2-30 seconds



visual working memory

Lossy!

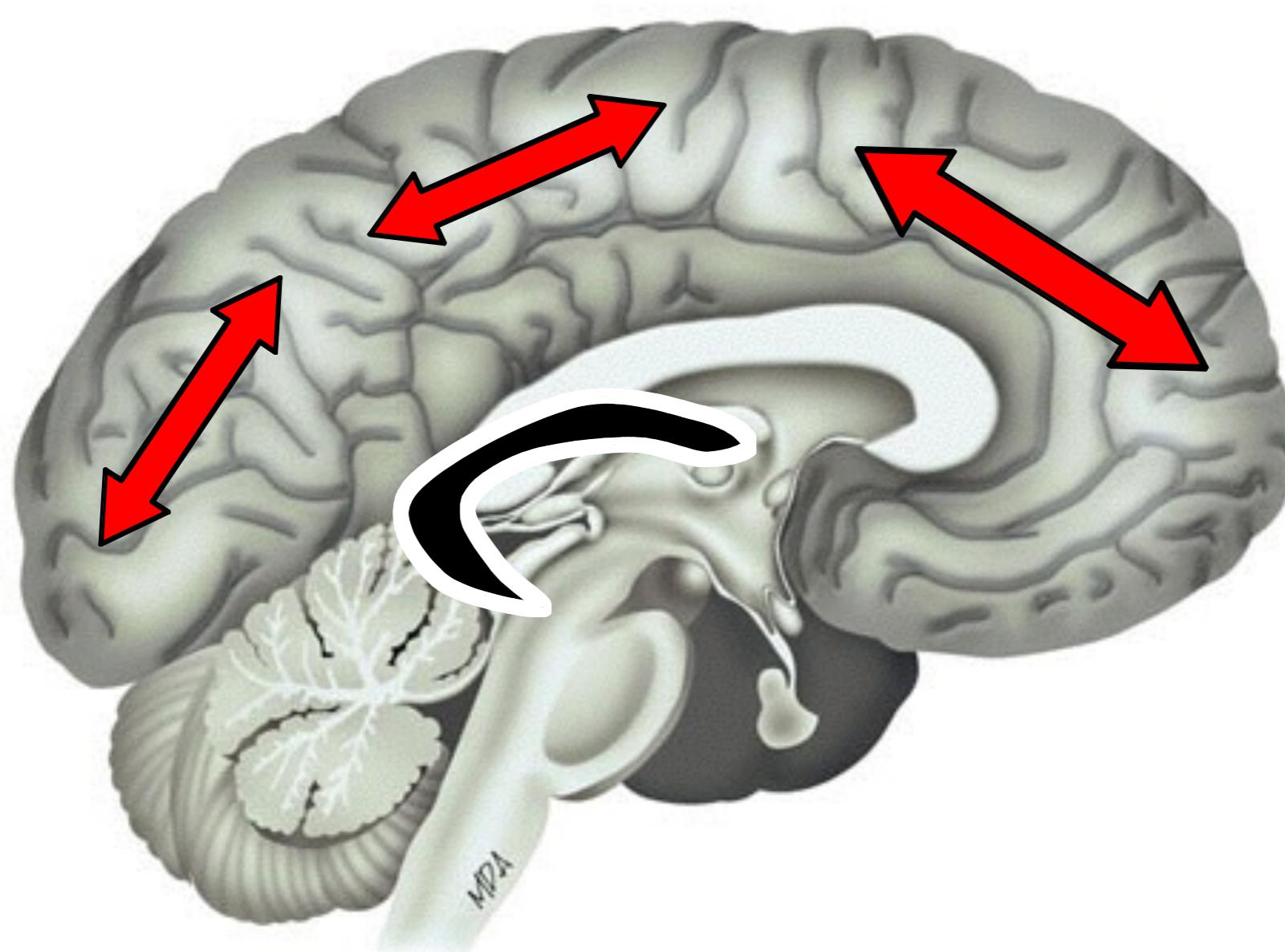
For up to 6 months to 2 years



Information is linked to hippocampus, which is necessary for long-term storage

Lossy!

After 6 months to 2 years...



Information becomes consolidated into cortex
and is incorporated into existing knowledge

Memory Cheatsheet for Visualization

- Make objects easy to identify:
 - typical member of their class
 - typical viewpoint
 - connections between parts visible
- Visual working memory is limited, but critical for effective visualization (e.g., do comparisons close to each other)
- Symbols/visuals have the ability to trigger specific associations, will be more memorable



Activity

What visual information do we get at a glance? Pay attention and remember the following picture.



Ready?



Activity

What did you see?

- Indoor / outdoor?
- Size of the space? how many people?
- Age of people?
- Color of dresses?
- Color of carpet?

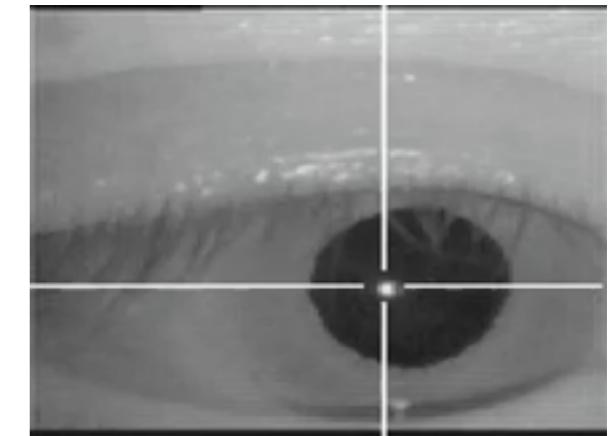
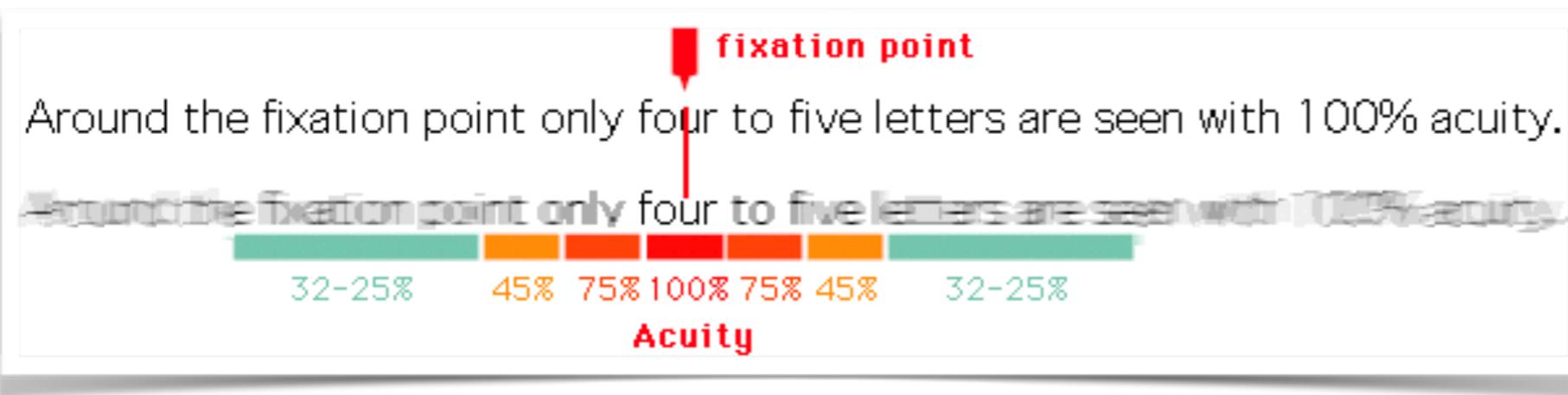


Image Gist

- Image gist gives you layout
- Can give you general categorization info but lacks details
- Later, we make use of the gist to know where to focus our attention
- We don't actually see much...

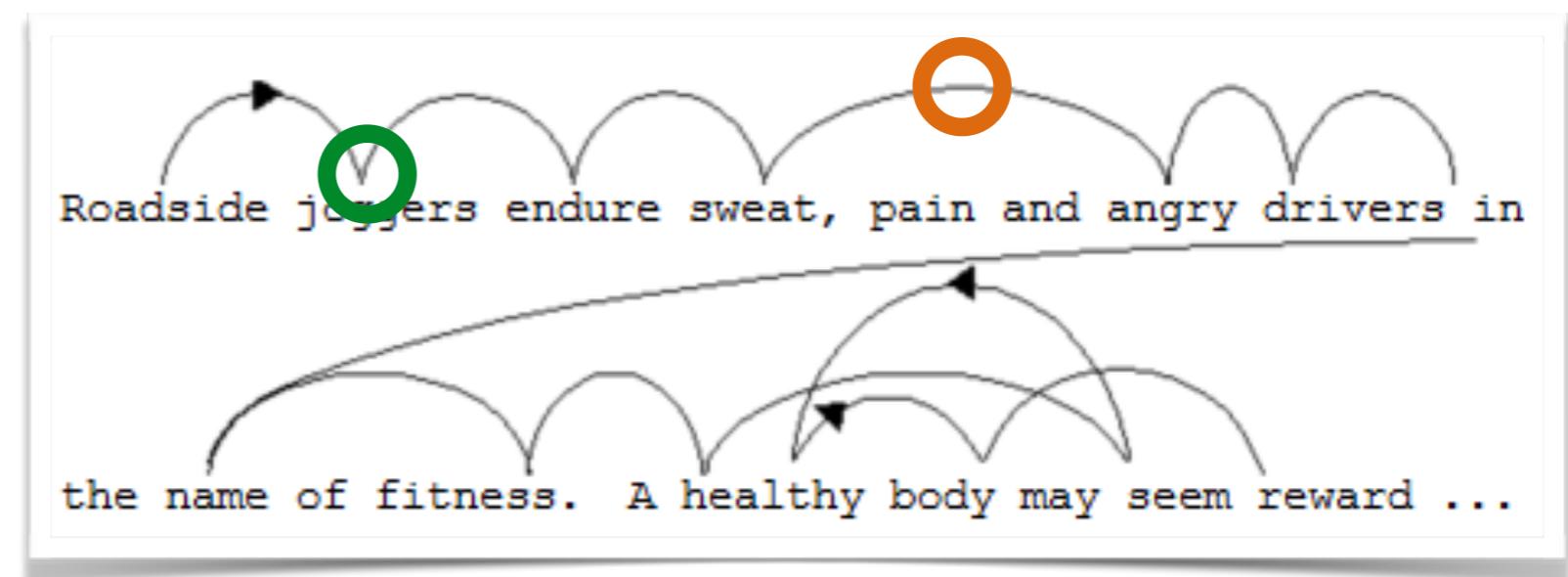
Category	Number of Voters	Percentage of Voters	Number of Votes	Percentage of Votes
Male	1,000,000	50.0%	500,000	50.0%
Female	999,999	49.9%	499,999	49.9%
Total	1,999,999	100.0%	1,000,000	100.0%
18-24	100,000	20.0%	50,000	50.0%
25-34	300,000	26.8%	180,000	46.8%
35-44	280,000	24.9%	160,000	40.0%
45-54	230,000	22.7%	130,000	32.5%
55-64	130,000	24.5%	80,000	61.5%
65+	100,000	26.7%	60,000	45.0%
18-24	5,278	17.3%	2,639	9.25%
25-34	15,565	19.8%	7,782	30.8%
35-44	14,628	28.8%	7,314	29.0%
45-54	12,000	22.0%	6,000	24.0%
55-64	10,000	19.0%	5,000	20.0%
65+	8,000	15.0%	4,000	16.0%

Exploring with eye movements

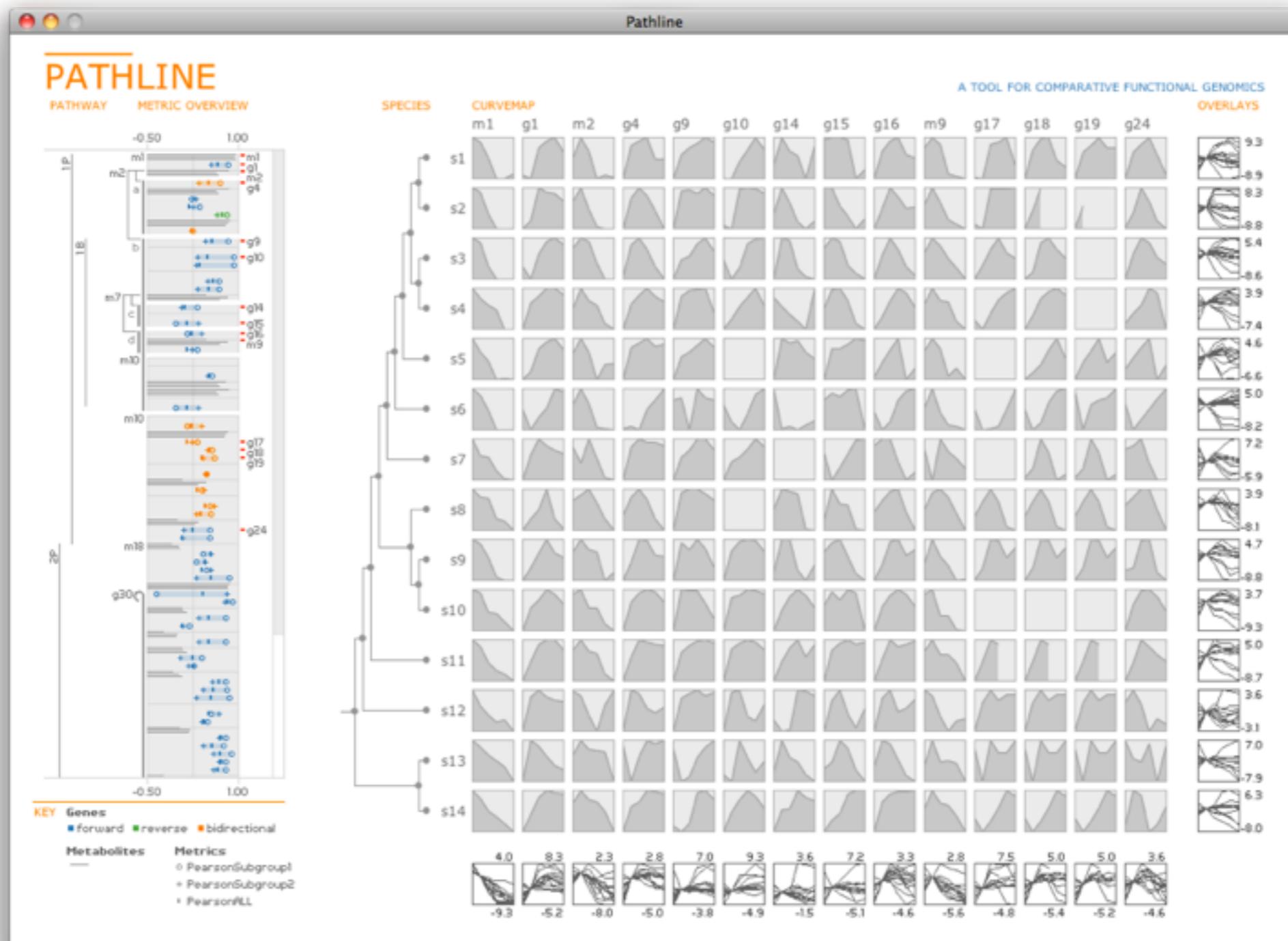


Saccadic Eye Movement

fixation (200-600ms)
saccade (20-100ms)



To ‘simulate’ gist, squint your eyes to get a blurred image

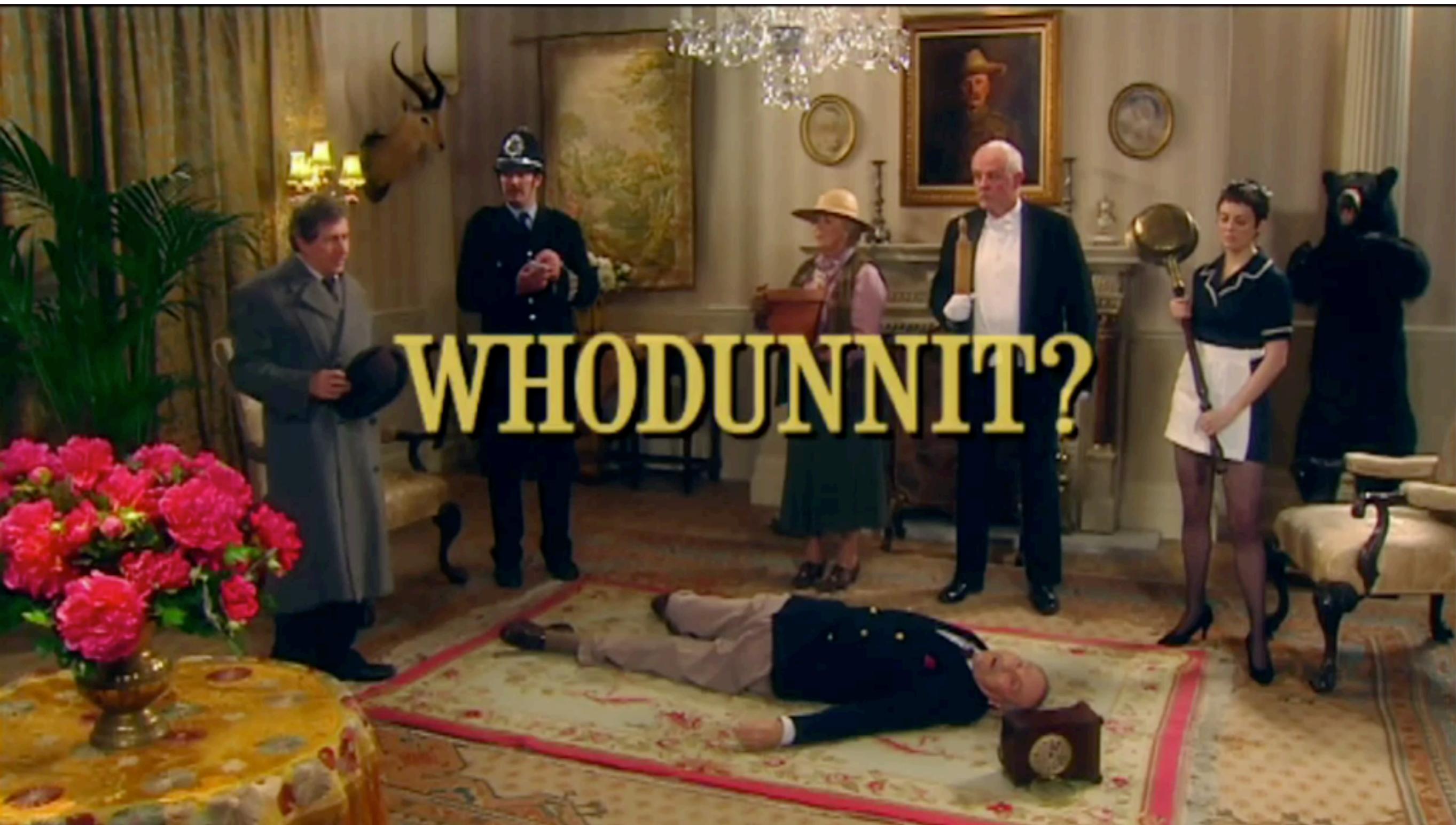


M. Meyer, B. Wong, M. Styczynski and H. Pfister. “Pathline: A Tool For Comparative Functional Genomics”, Computer Graphics Forum, 2010

Attention & Change Blindness

CS
171





WHODUNNIT?

Activity

Let's make that easier.

Raise your hand when you see the change

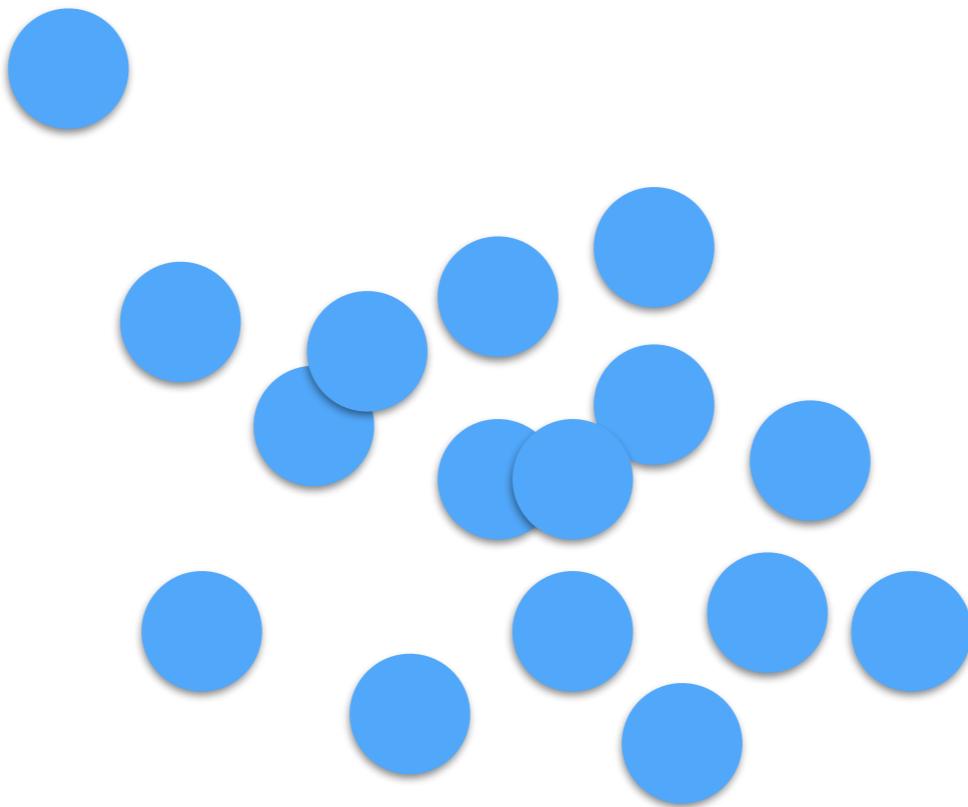




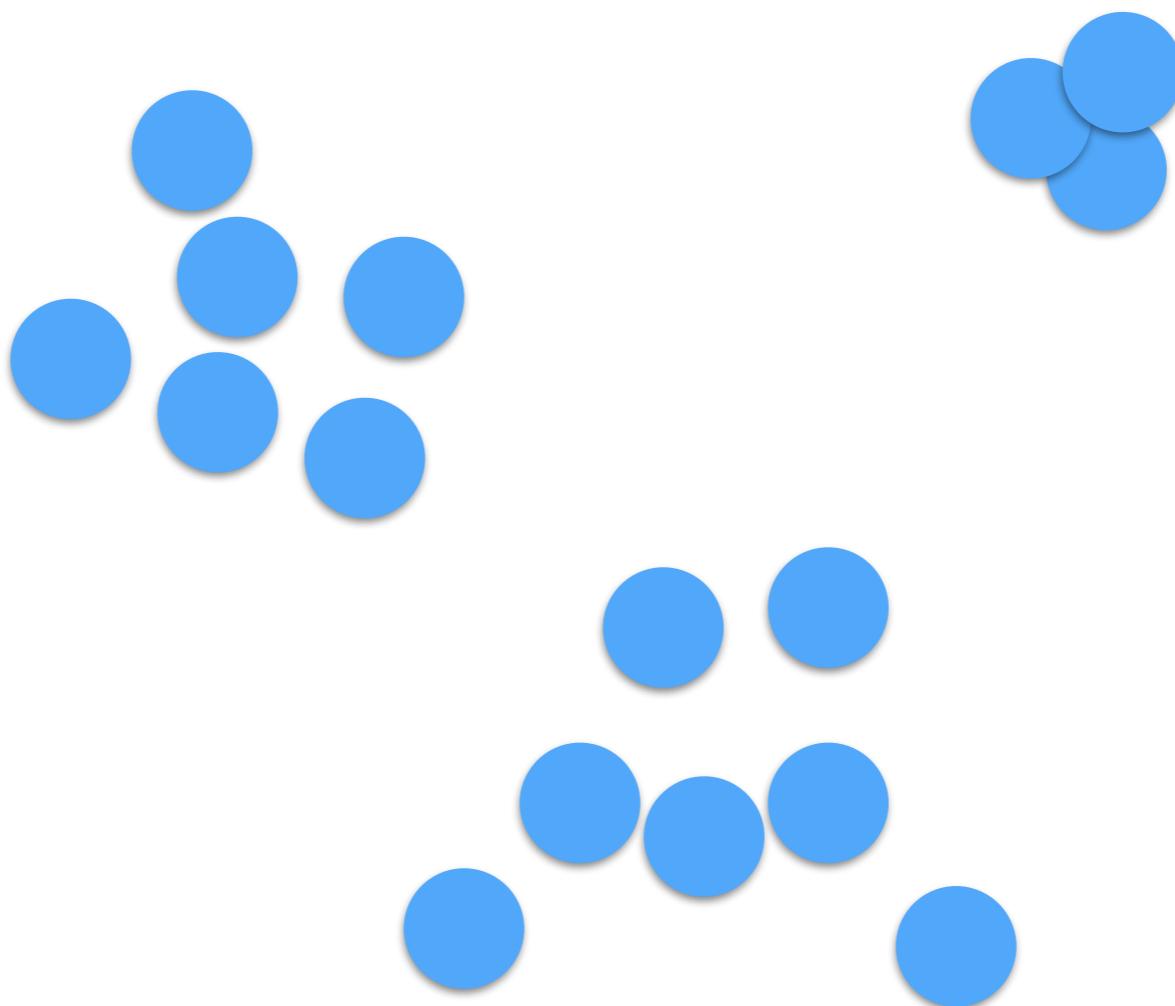
Ron Rensink 2002



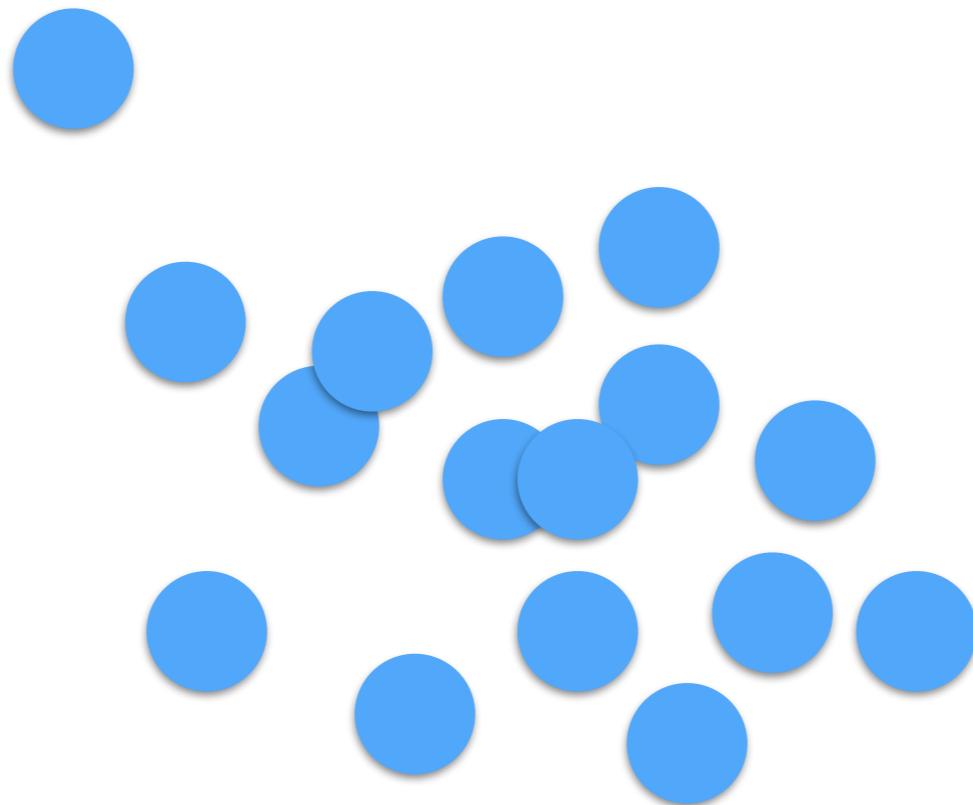
Change Blindness



Change Blindness

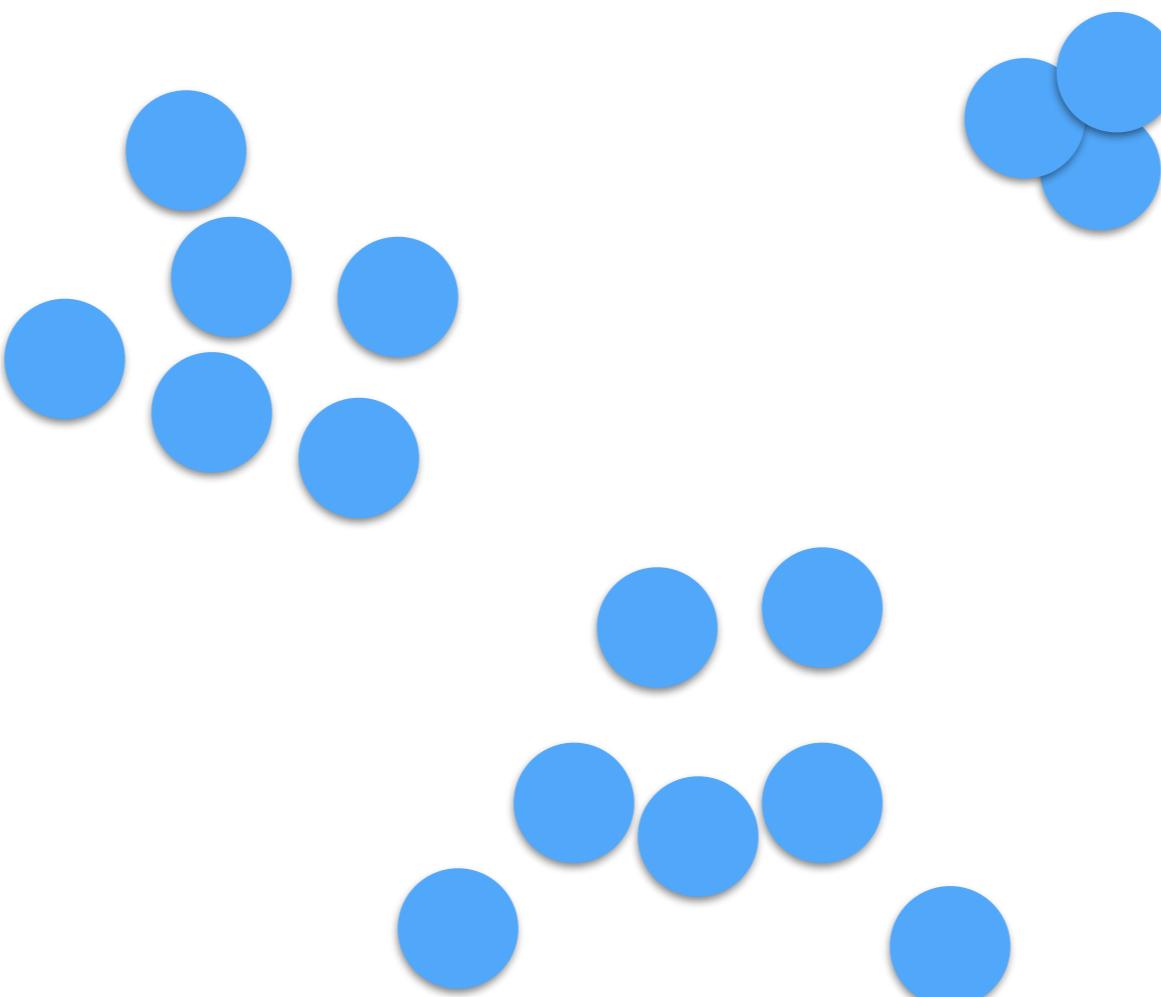


Change Blindness



transitions can help

Change Blindness



transitions can help



Today's take home message

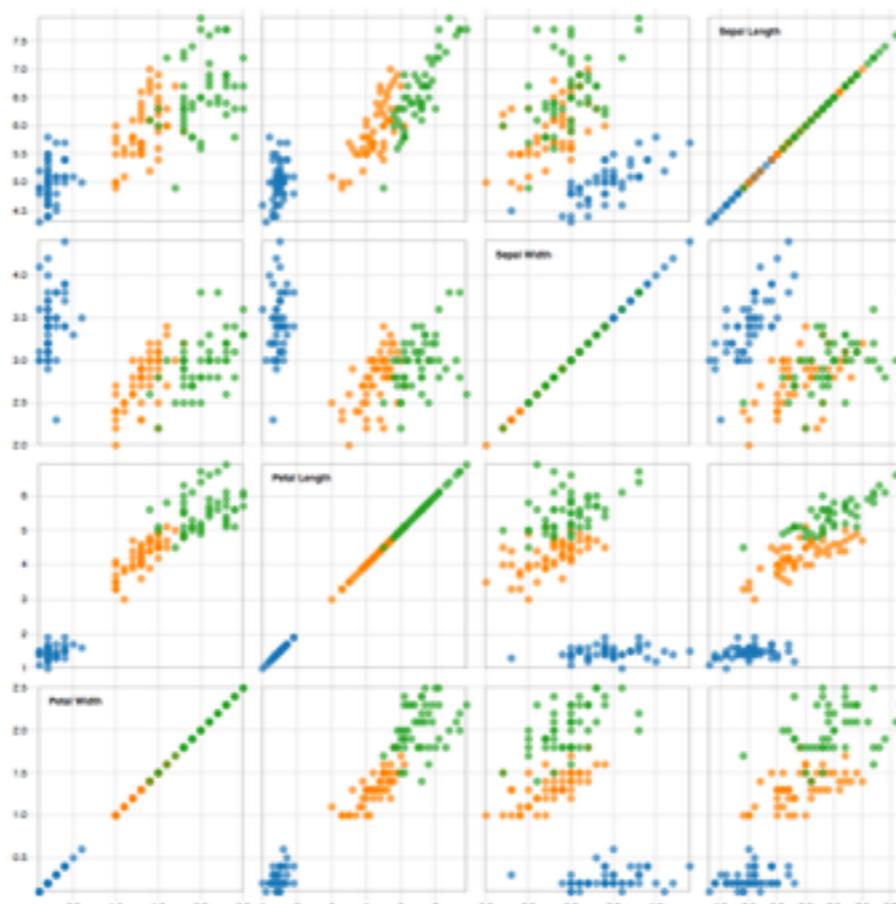
- Not all visual channels (Bertin) are equal, pick appropriate ones for your data!
- Visual hierarchy/layering can guide user attention!
- Gestalt principles help you group visual elements!
- Visual working memory is limited, reduce complexity!
- Make it easy to visually follow elements that change!

Next Two Weeks

- Networks & Maps
(Michael Behrisch)



- High-dimensional data
(Ronell Sicat)



This Thursday



- Intro to SVG and D3
- D3 book: Chapter 3 and 5

Next Tuesday

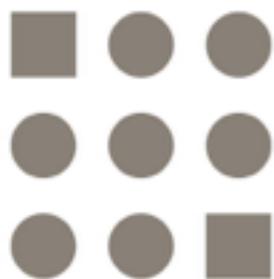


- D3 scales and axis & SVG groups
- D3 book: Chapter 7 and 8

Homework (due Monday) & Studios



- Homework 3 - early steps with D3



One minute paper @ Canvas