Perception

DSC 106: Data Visualization

Sam Lau
UC San Diego

Join at
slido.com
#5872 640

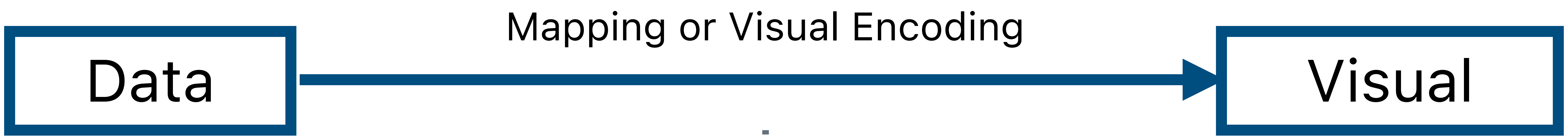
Announcements

Lab 2 due tomorrow 1/19.

Project 1 also due tomorrow 1/19.

FAQs:

1. How does project grading work? You get 9/10 points if you follow all the project requirements. Can get more if your project goes above and beyond requirements (see project page for more details).
2. OH now have signup forms to distribute checkoffs, see Ed for more details.



Expressiveness

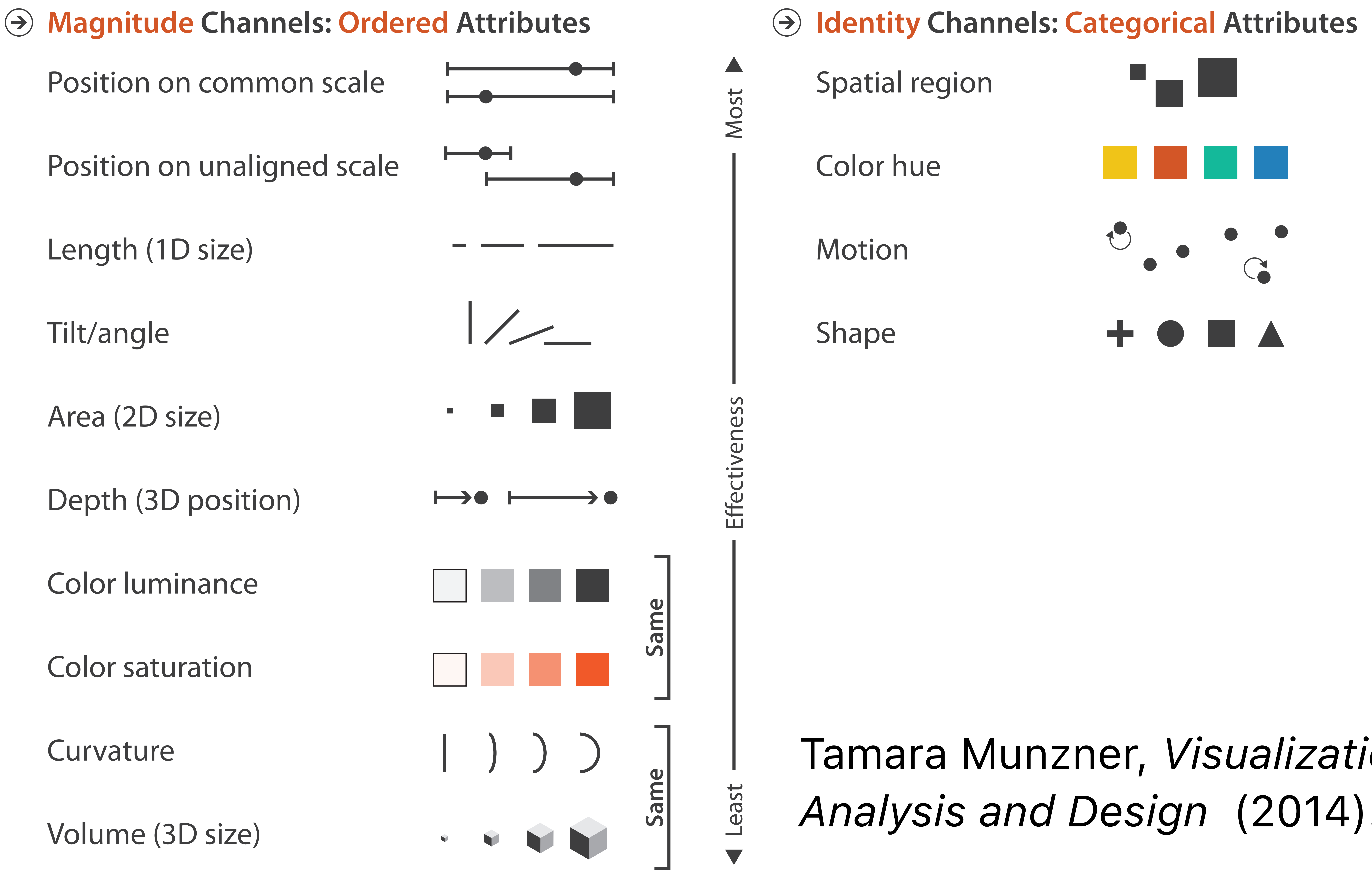
A set of facts is *expressible* in a visual language if the sentences (i.e. the visualizations) in the language express *all the facts in the set of data, and only the facts in the data.*

Effectiveness

A visualization is more *effective* than another if the information it conveys *is more readily perceived* than the information in the other visualization

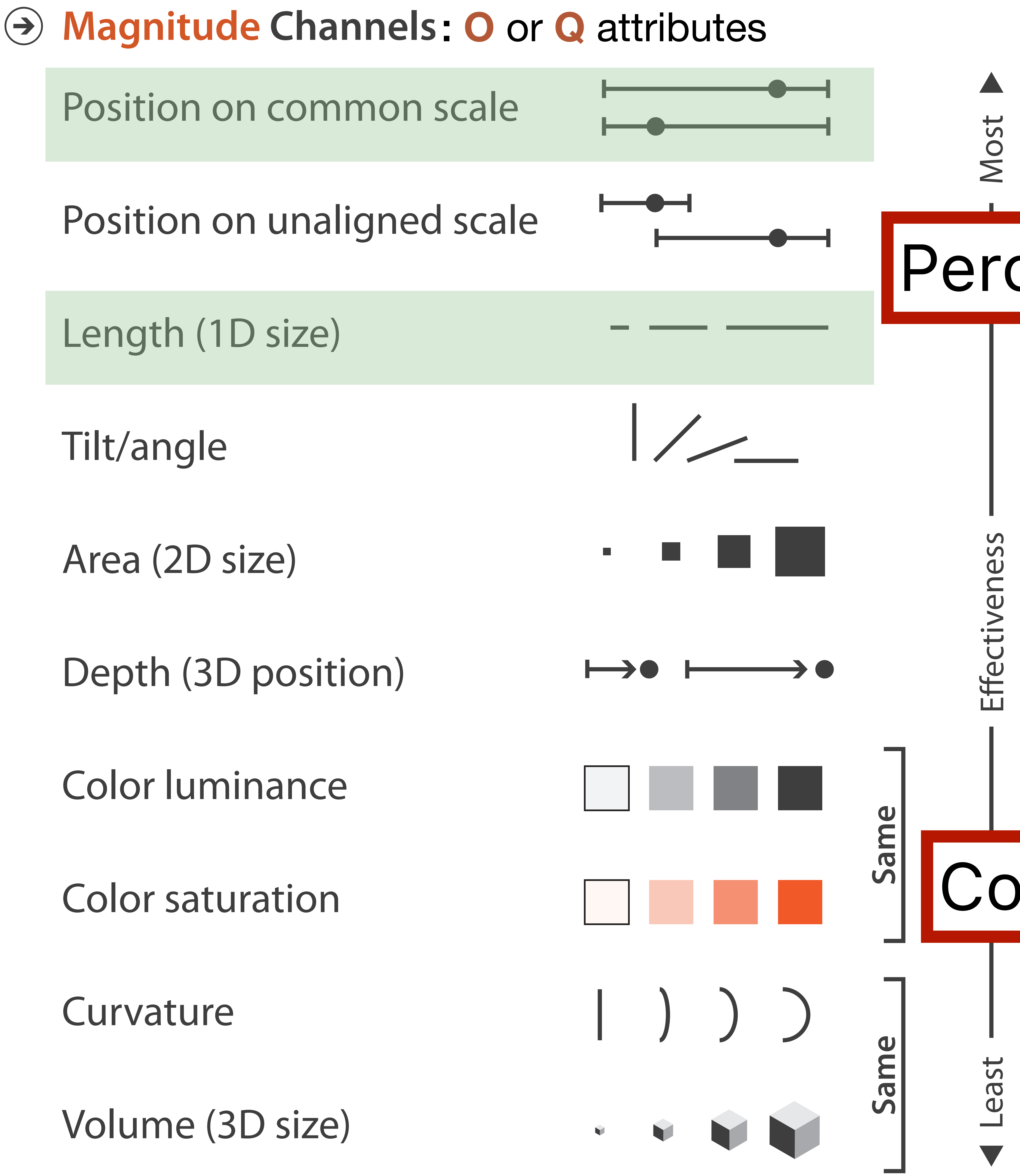
Mackinlay, Jock. "Automating the design of graphical presentations of relational information." *Acm Transactions On Graphics (Tog)* 5.2 (1986): 110-141.

Channels: Expressiveness Types and Effectiveness Ranks

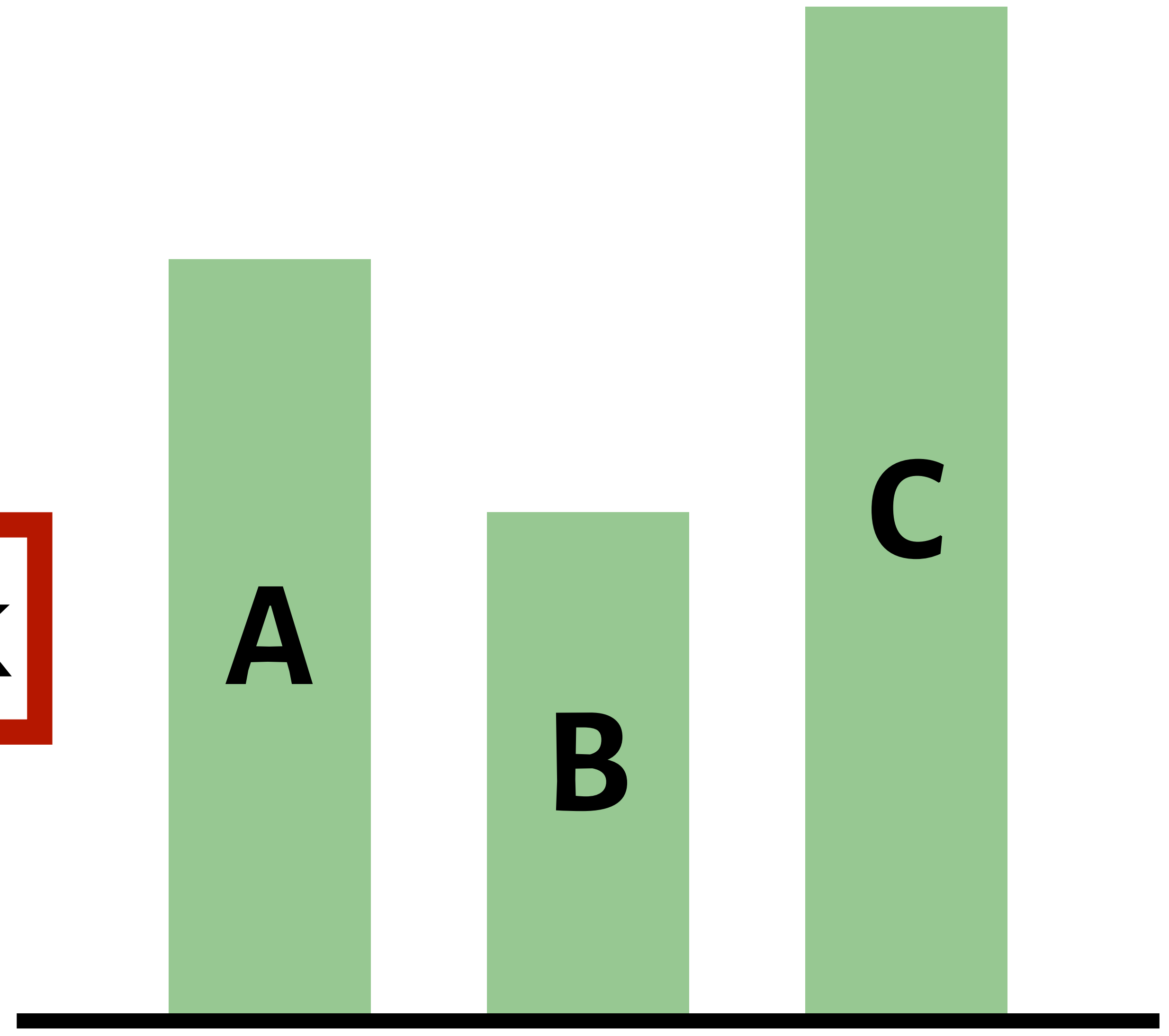


Tamara Munzner, *Visualization Analysis and Design* (2014).

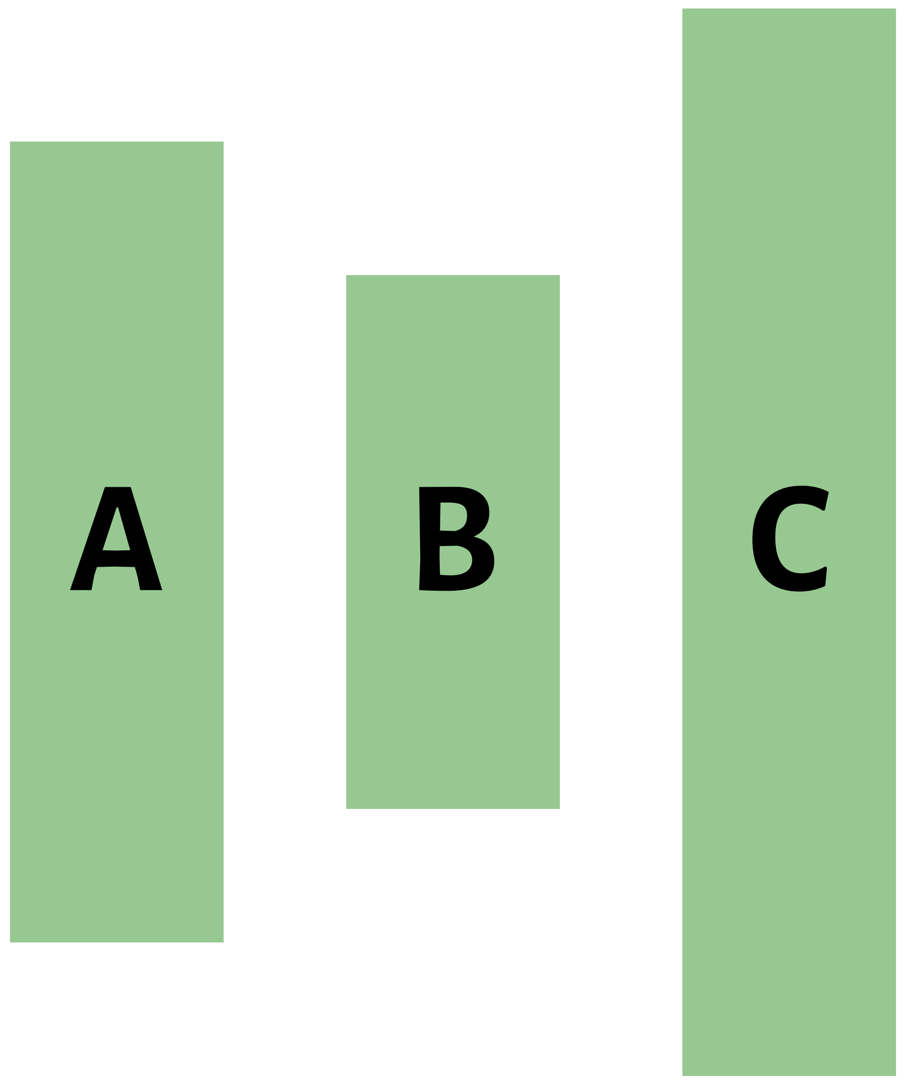
Channels: Expressiveness Types and Effectiveness Ranks



Perceptual work



Cognitive work



Graphical Perception

The ability of viewers to interpret visual (graphical) encodings of information and thereby decode information in graphs.

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Discriminability: how easy is it to tell two things apart?

Which is brighter?

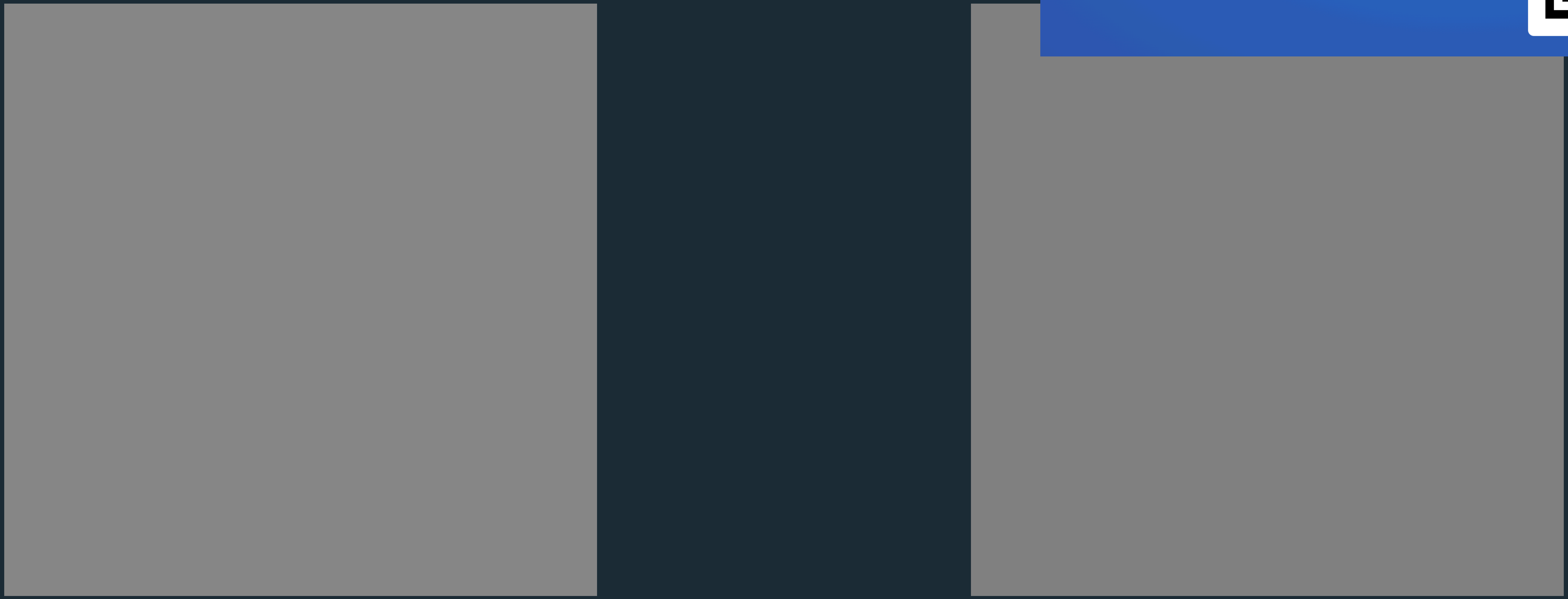
Join at
slido.com
#5872 640

rgb(128, 128, 128)

rgb(144, 144, 144)

Which is brighter?

Join at
slido.com
#5872 640



Just Noticeable Difference (jnd)

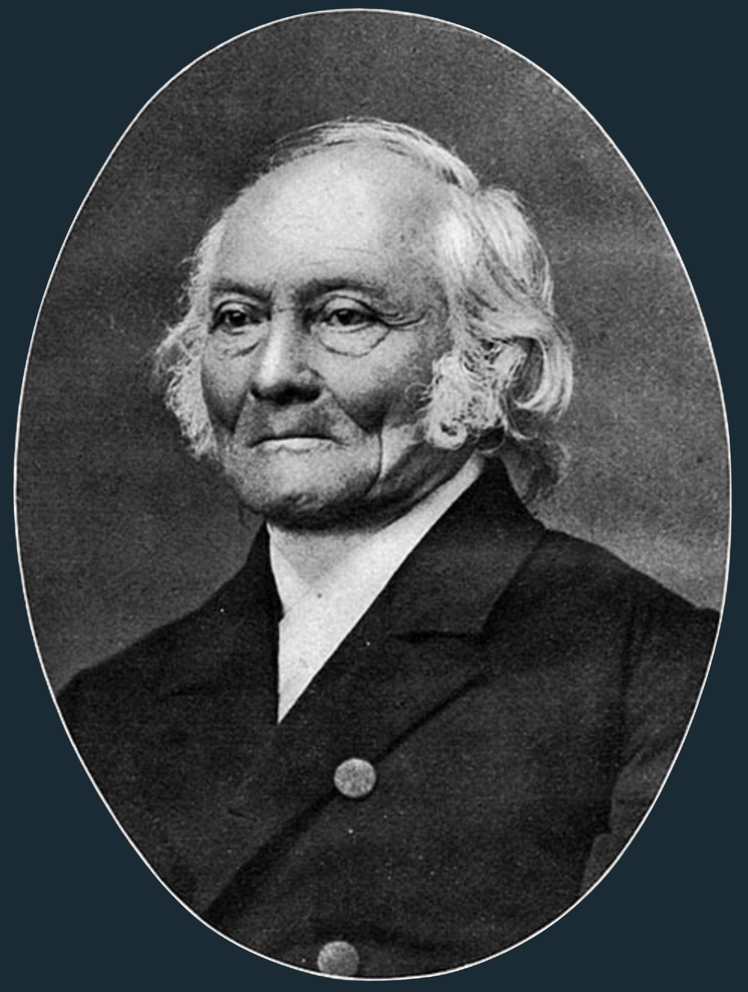
Scale Factor
(Determined Empirically)

Change of Intensity

$$\Delta S = k \frac{\Delta I}{I}$$

Perceived Change

Physical Intensity

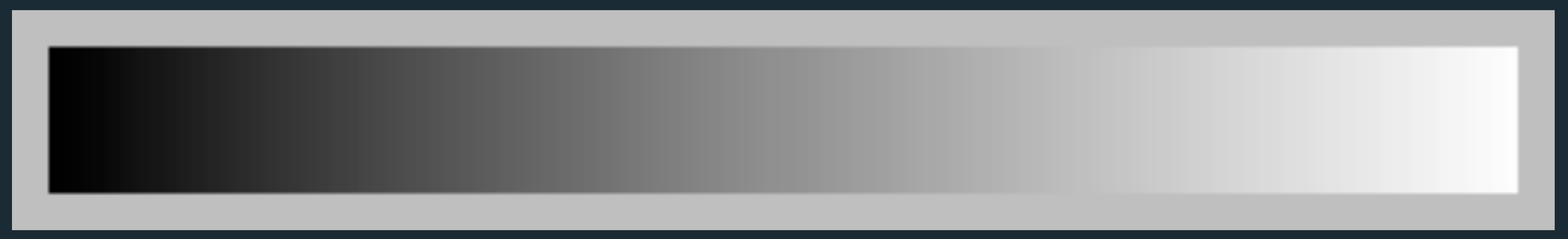


Ernst Weber
(1795 – 1878)

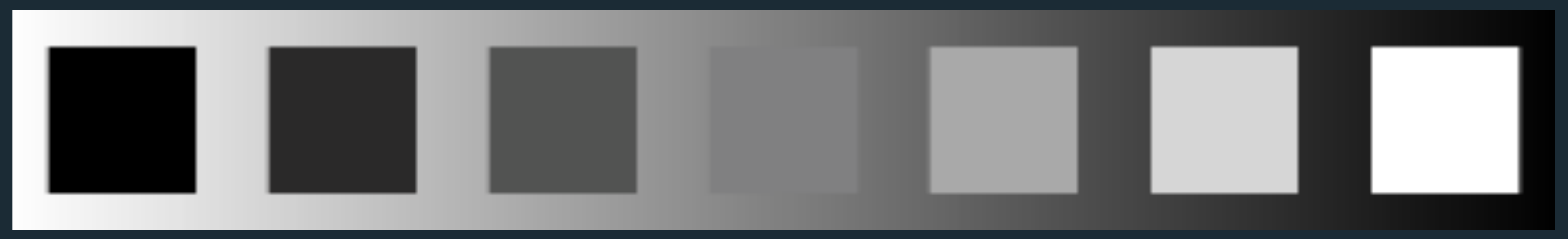
German physician and a founder of experimental psychology.

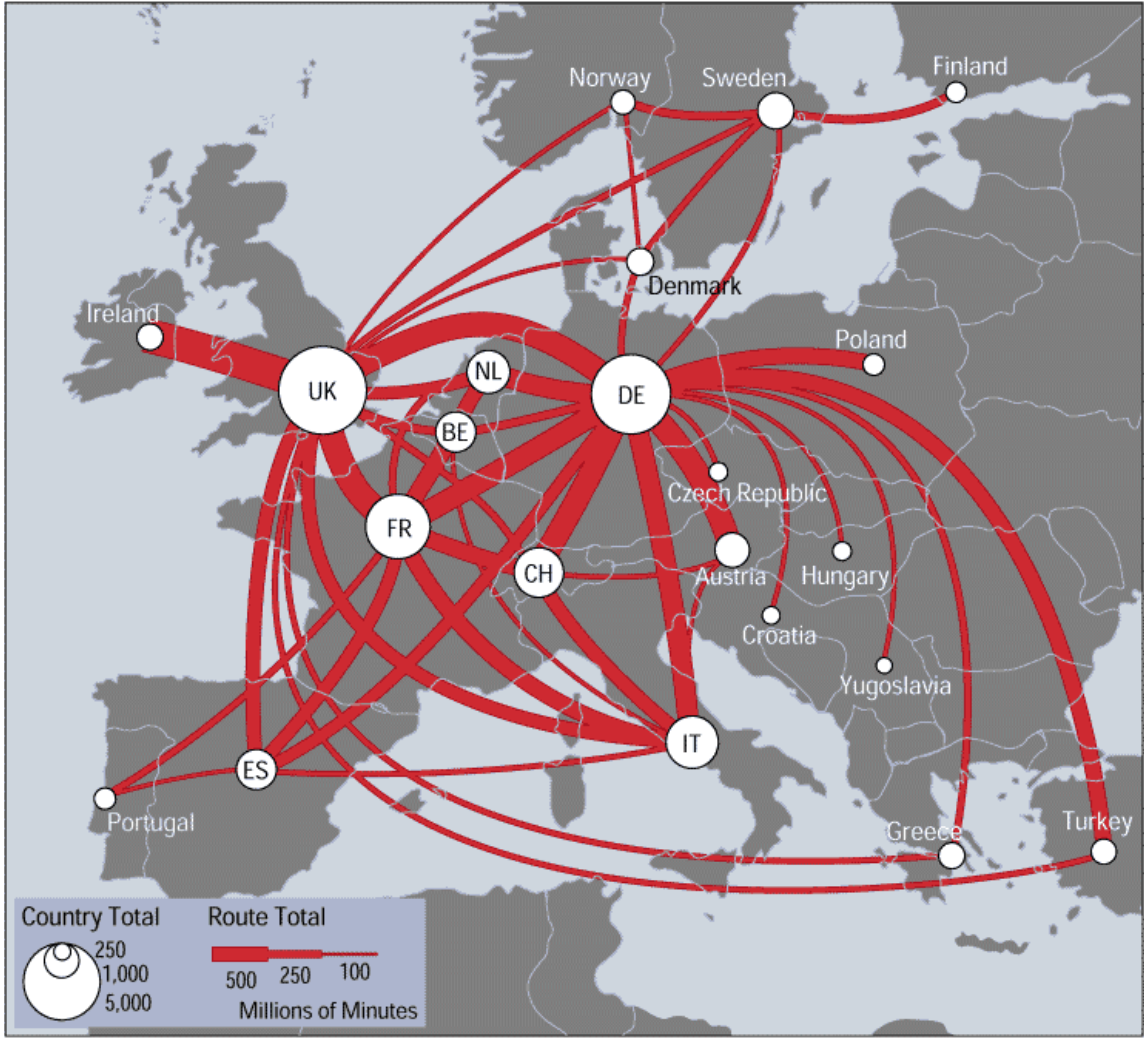
Ratios more important than magnitude.

Most continuous variation in stimuli are perceived in discrete steps.



vs.




Norway
Sweden
Finland
Denmark
Ireland
Poland
UK
NL
DE
BE
Czech Republic
FR
CH
Austria
Hungary
Croatia
Yugoslavia
IT
ES
Portugal
Greece
Turkey
Country Total
250
1,000
5,000
Route Total
500
250
100
Millions of Minutes

http://www.visualcomplexity.com/vc/project.cfm?id=905

Signal Detection

Discriminability: how easy is it to tell two things apart?

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Accuracy: how correctly can we read off values?

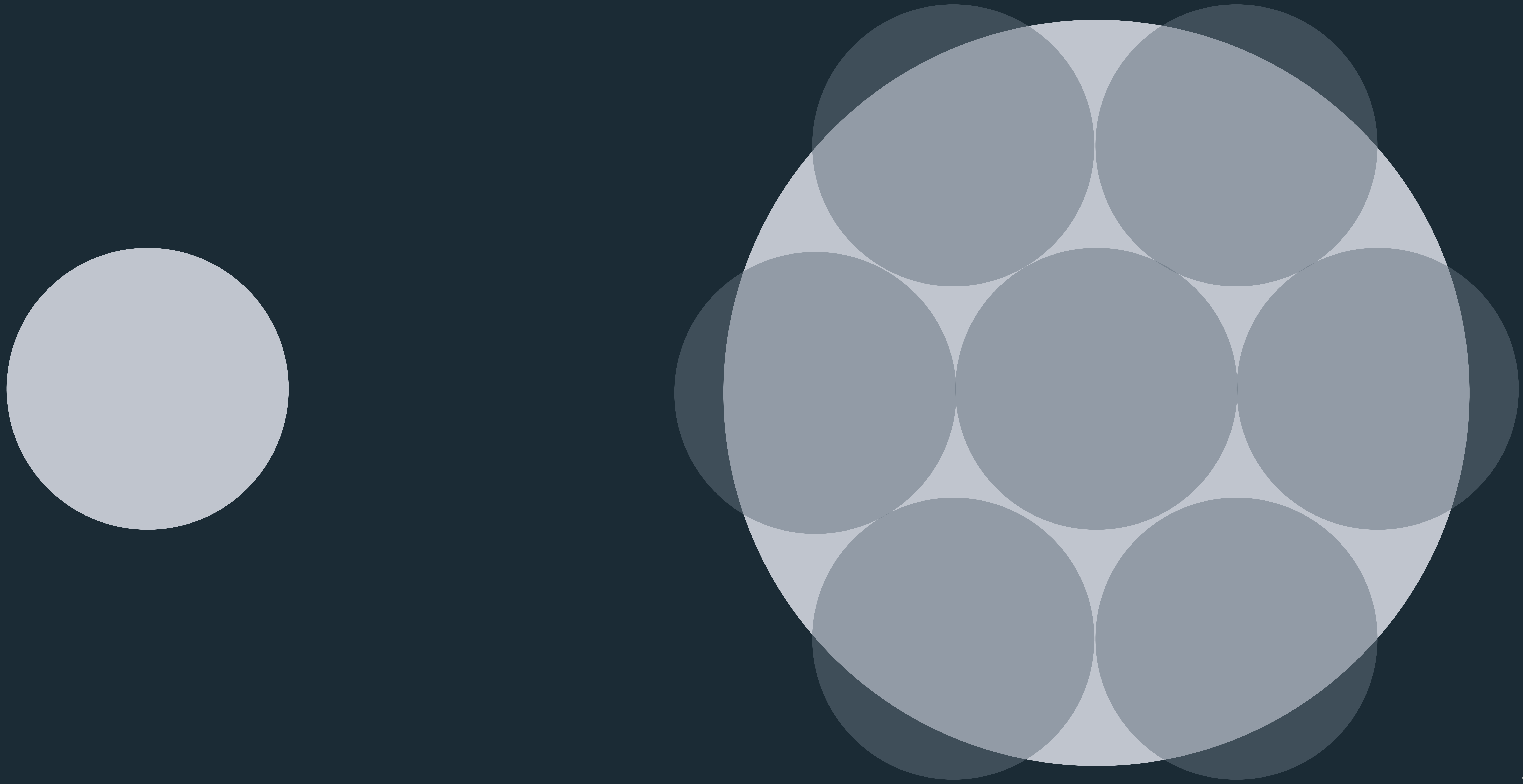
How much larger is the area of the big circle?

Join at
slido.com
#5872 640

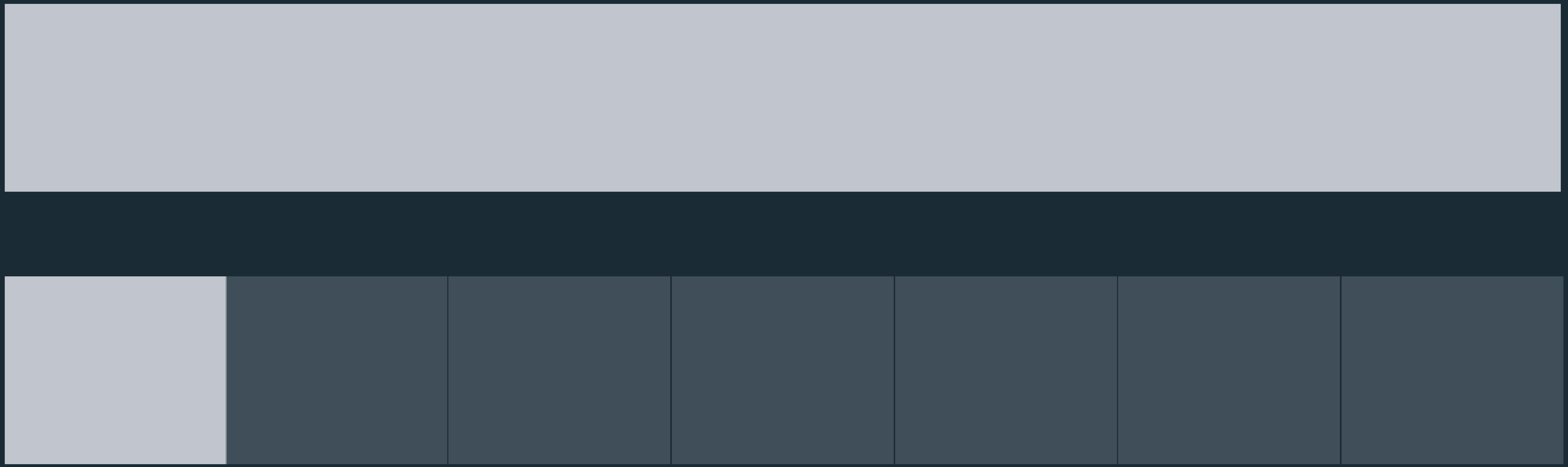
How much longer is the big bar?

Join at
slido.com
#5872 640

How much larger is the area of the big circle?



How much longer is the big bar?



Stevens' Power Law

S. S. Stevens (1906 – 1972)

American psychologist, founded Harvard's Psychoacoustics Lab.

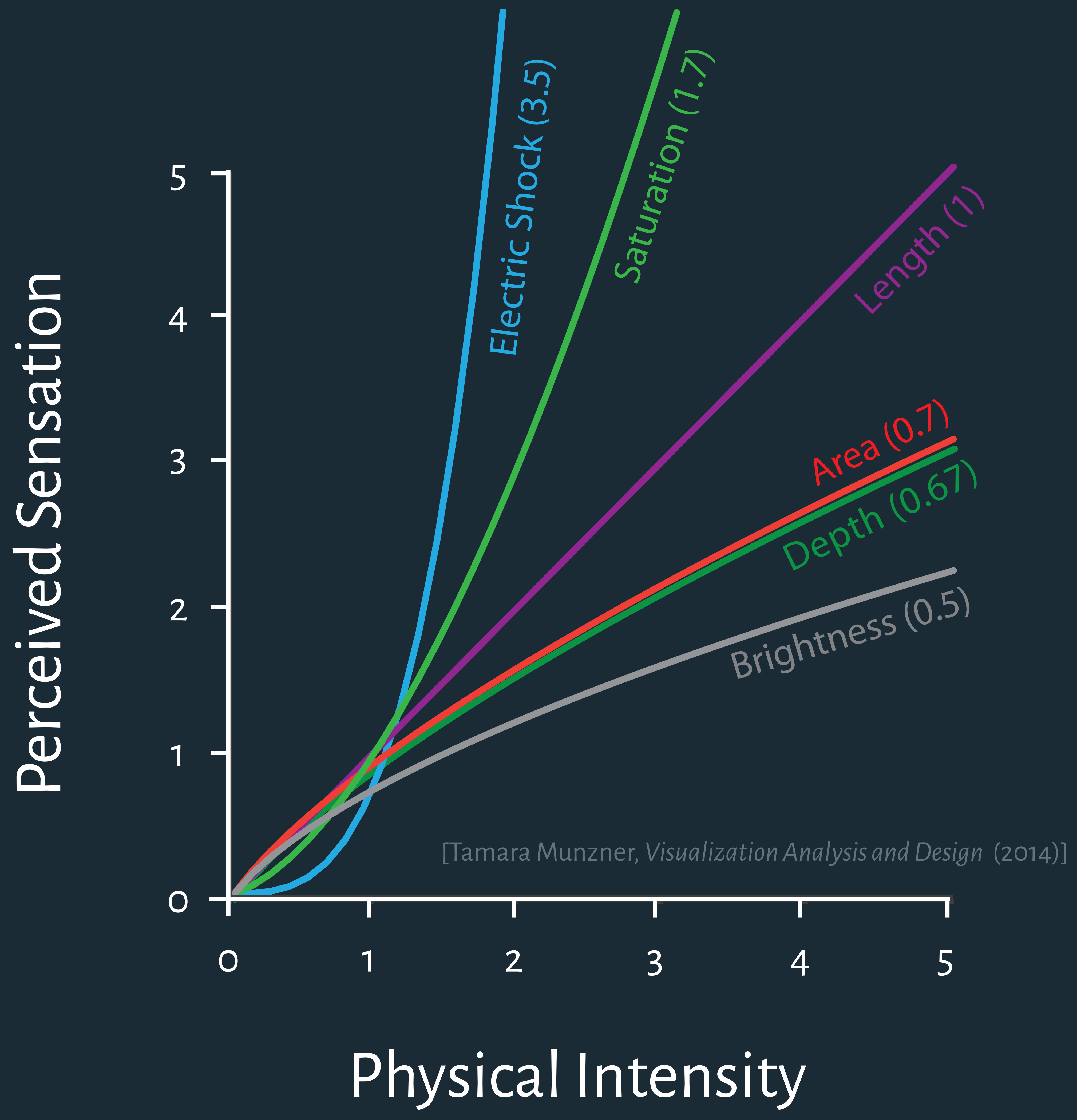
Physical Intensity

$$S = I^p$$

Perceived Sensation

Exponent
(Determined Empirically)

p < 1 = **under**estimation
p > 1 = **over**estimation

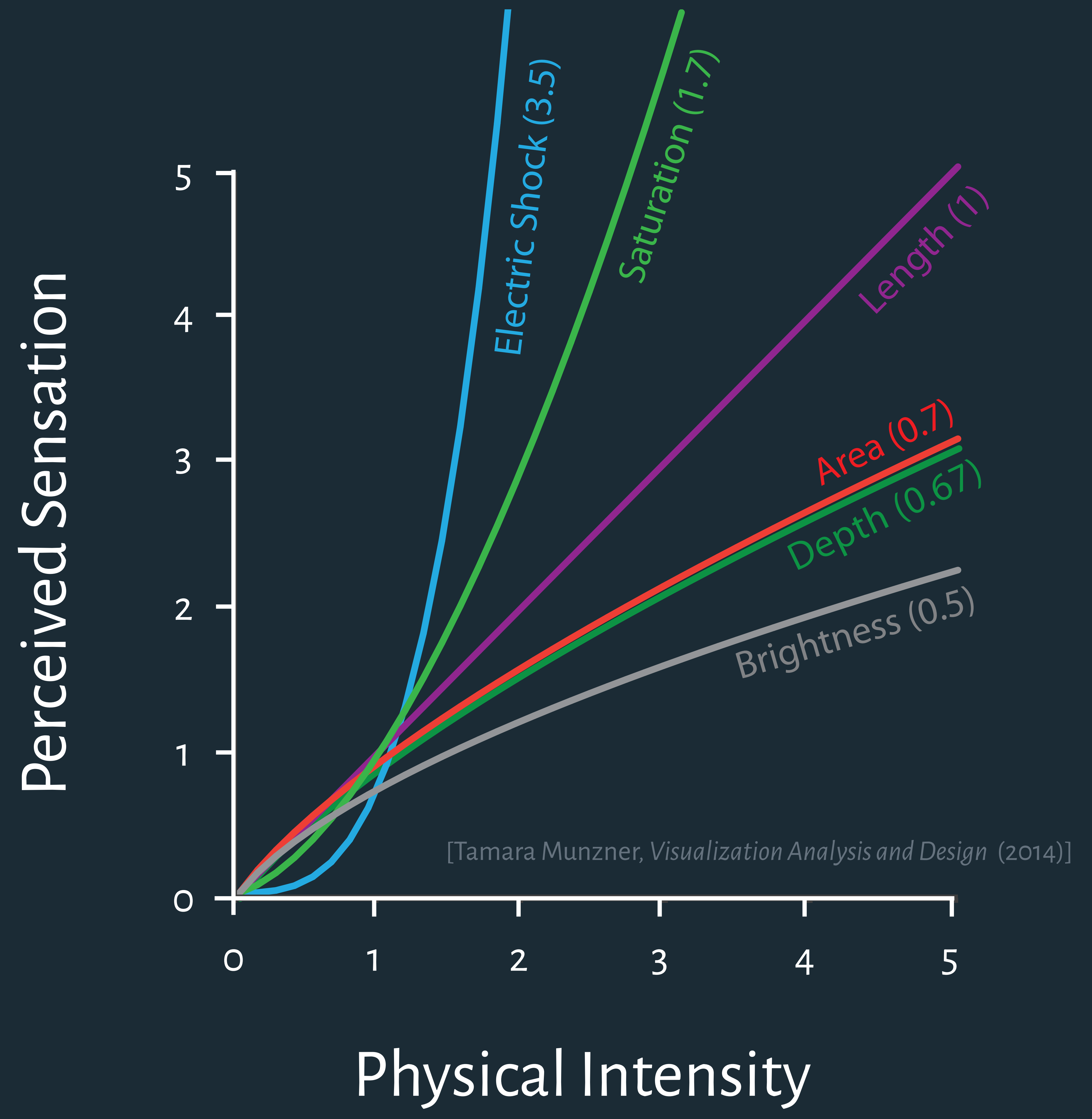


Predicts bias, not necessarily accuracy!

Stevens' Power Law

$$S = I^p$$

Sensation	Exponent
Loudness	0.6
Brightness	0.33
Smell	0.55 (Coffee) – 0.6 (Heptane)
Taste	0.6 (Saccharin) – 1.3 (Salt)
Temperature	1.0 (Cold) – 1.6 (Warm)
Vibration	0.6 (250 Hz) – 0.95 (60 Hz)
Duration	1.1
Pressure	1.1
Heaviness	1.45
Electric Shock	3.5



Graphical Perception Studies

Figure 4. Graphs from position–length experiment.

What proportion is the smaller marked section of the larger?

Cleveland, William S., and Robert McGill. "Graphical perception: Theory, experimentation, and application to the development of graphical methods." 1984

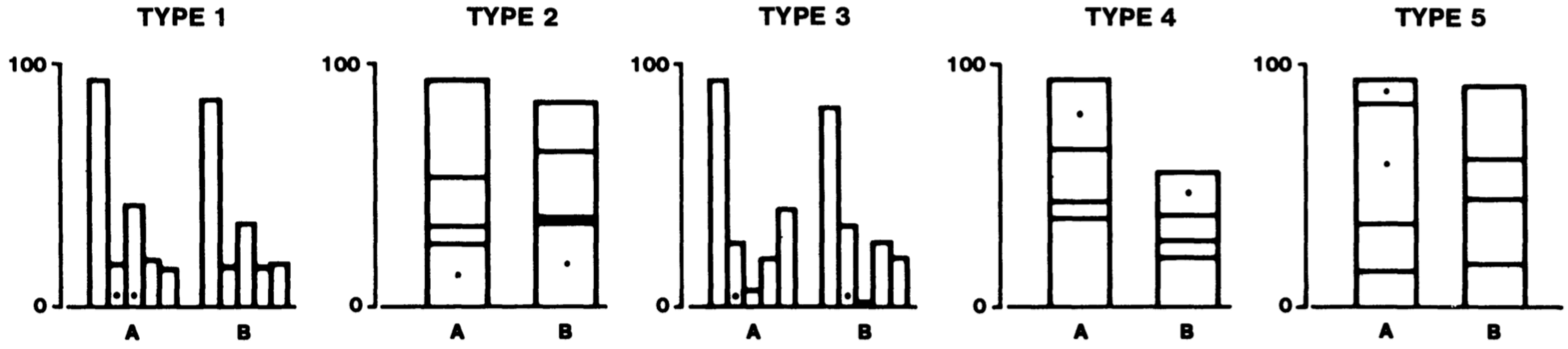
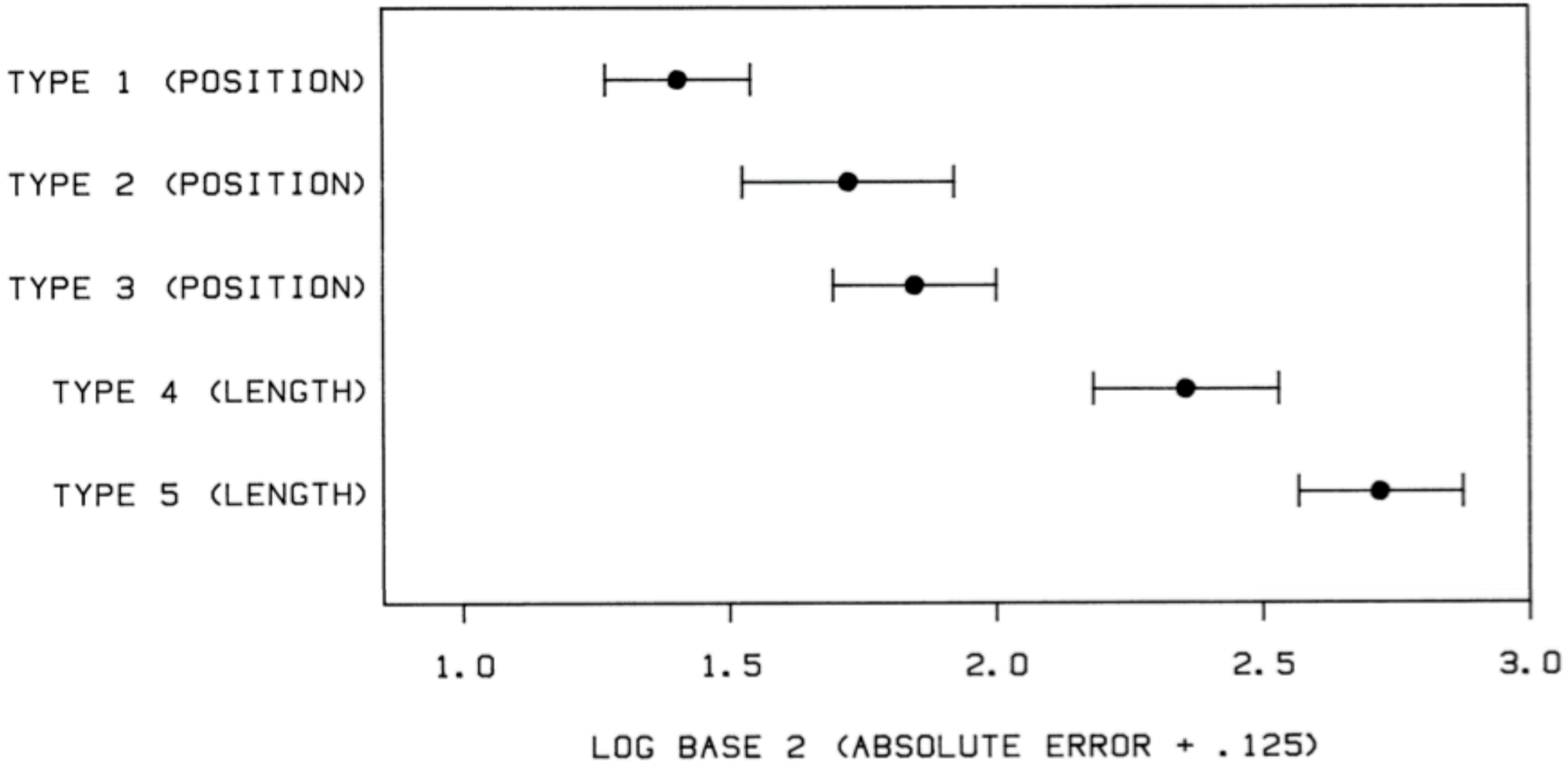
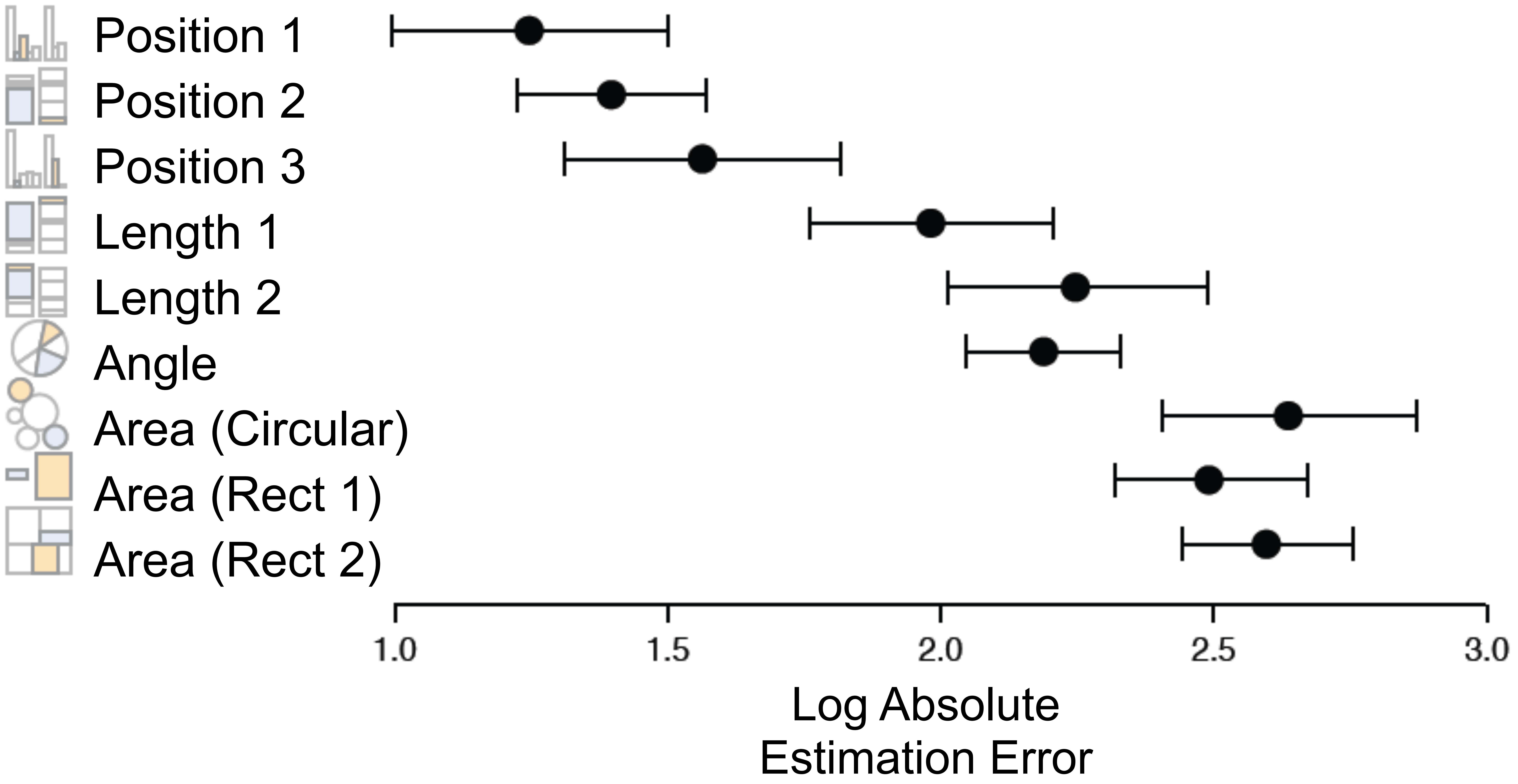


Figure 4. Graphs from position–length experiment.





Heer, Jeffrey, and Michael Bostock. "Crowdsourcing graphical perception: using mechanical turk to assess visualization design." *CHI 2010*

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Accuracy: how correctly can we read off values?

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Pop Out: how easy is it to spot some values from the rest?

How many 3's?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

[Based on a slide from John Stasko]

How many 3’s?

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

[Based on a slide from John Stasko]

Pre-Attentive Processing

How immediately does our visual system perceive differences in a scene?

Pre-Attentive: immediately recognize variation with little or no conscious effort (<200–250 ms).

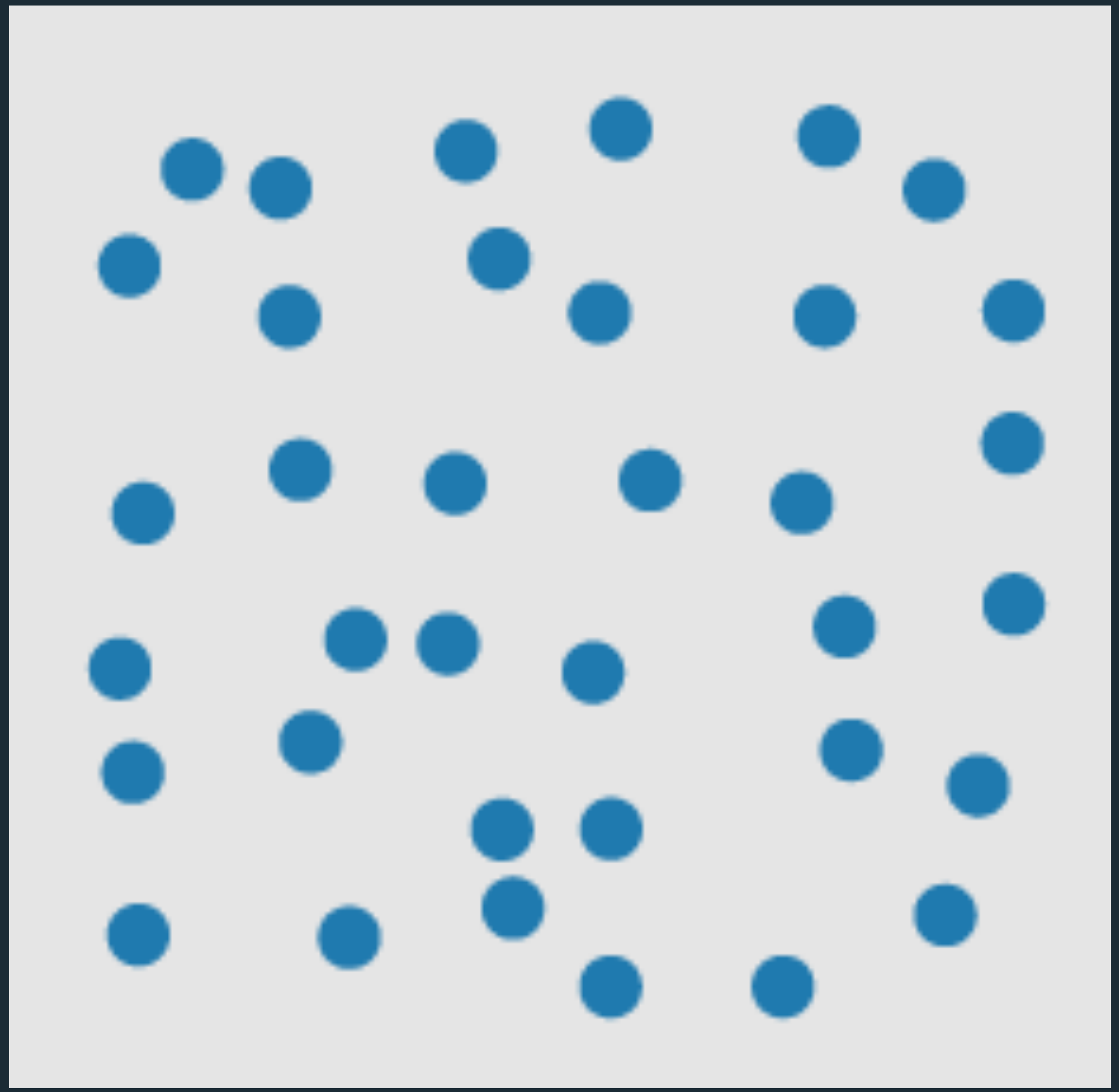
Attentive: Takes some deliberate effort to perceive differences.

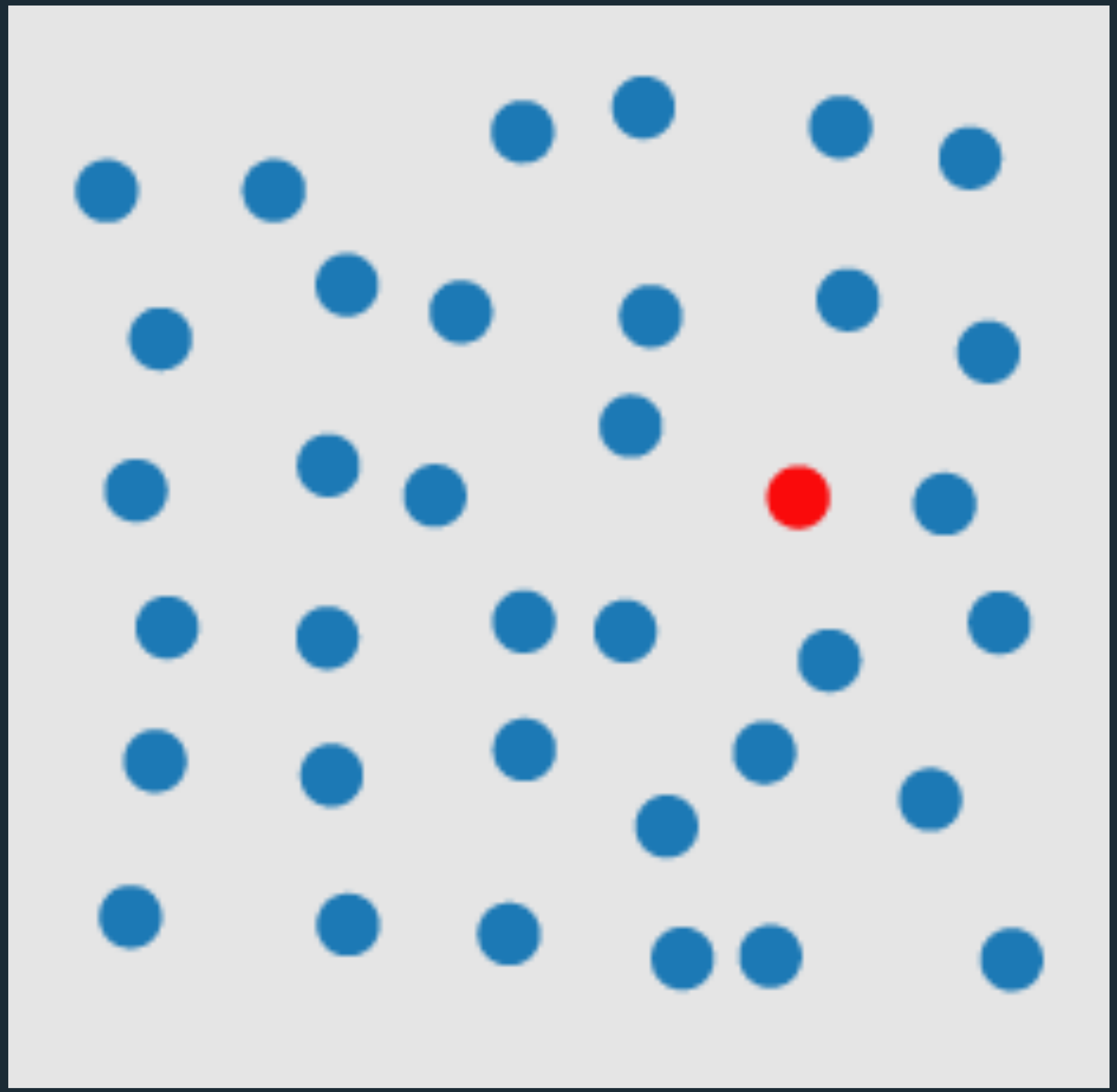
Pre-Attentive Processing

Pre-Attentive: immediately recognize variation with little or no conscious effort (<200–250 ms).

Attentive: Takes some deliberate effort to perceive differences.

Visual Pop-Out: Color





[Healey & Enns 2012]

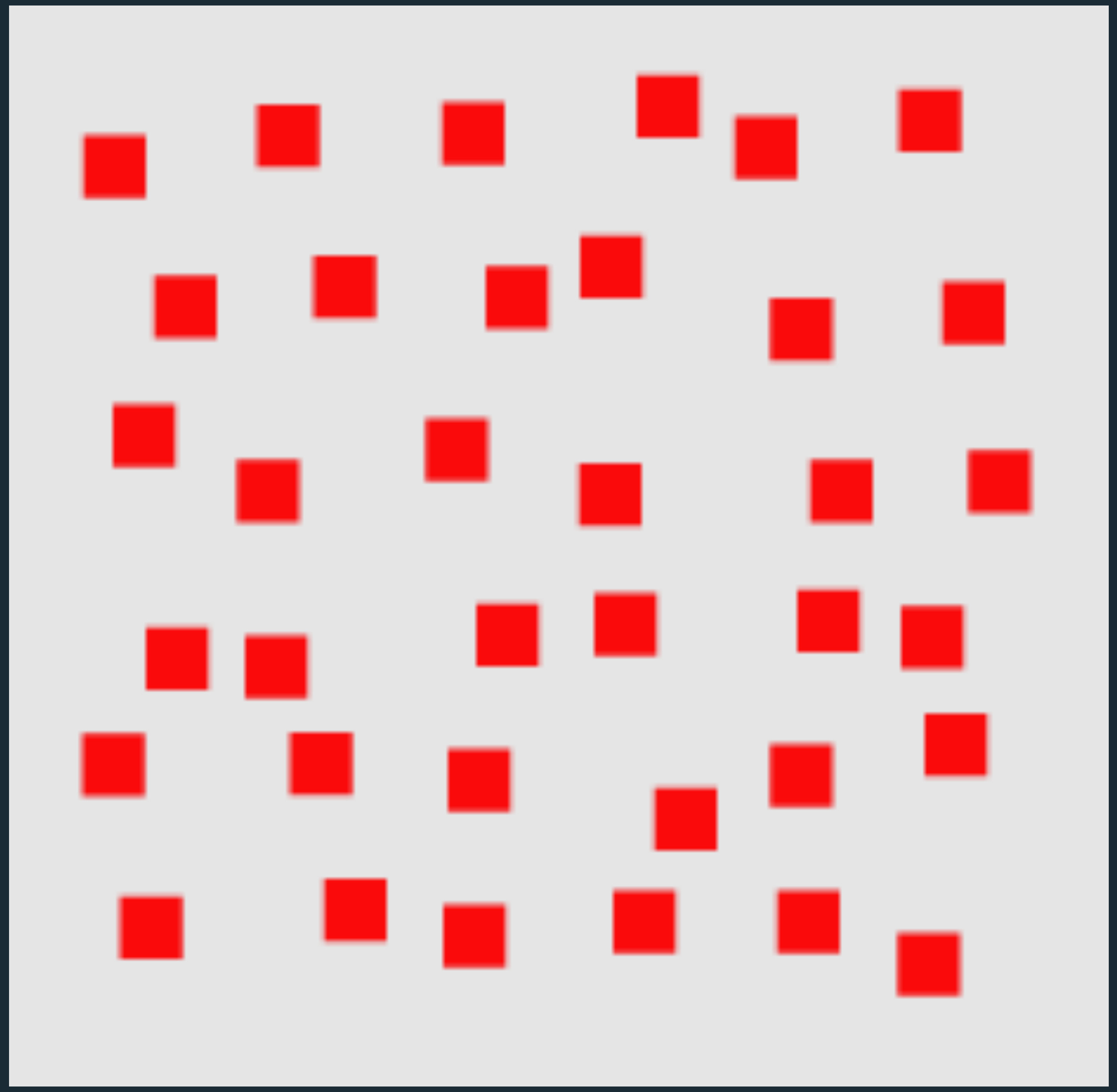
Pre-Attentive Processing

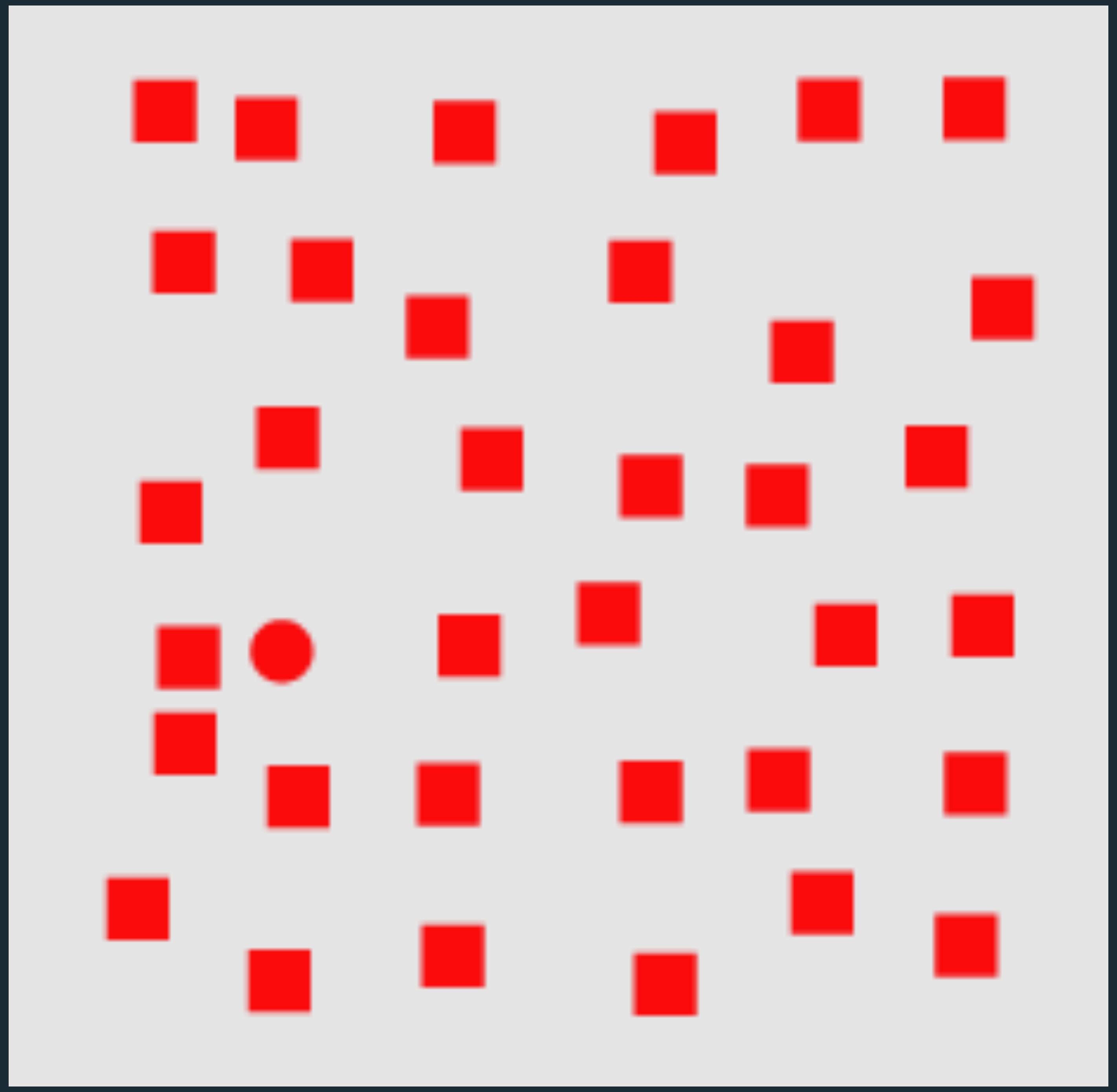
Pre-Attentive: immediately recognize variation with little or no conscious effort (<200–250 ms).

Attentive: Takes some deliberate effort to perceive differences.

Visual Pop-Out: Color

Visual Pop-Out: Shape





[Healey & Enns 2012]

Pre-Attentive Processing

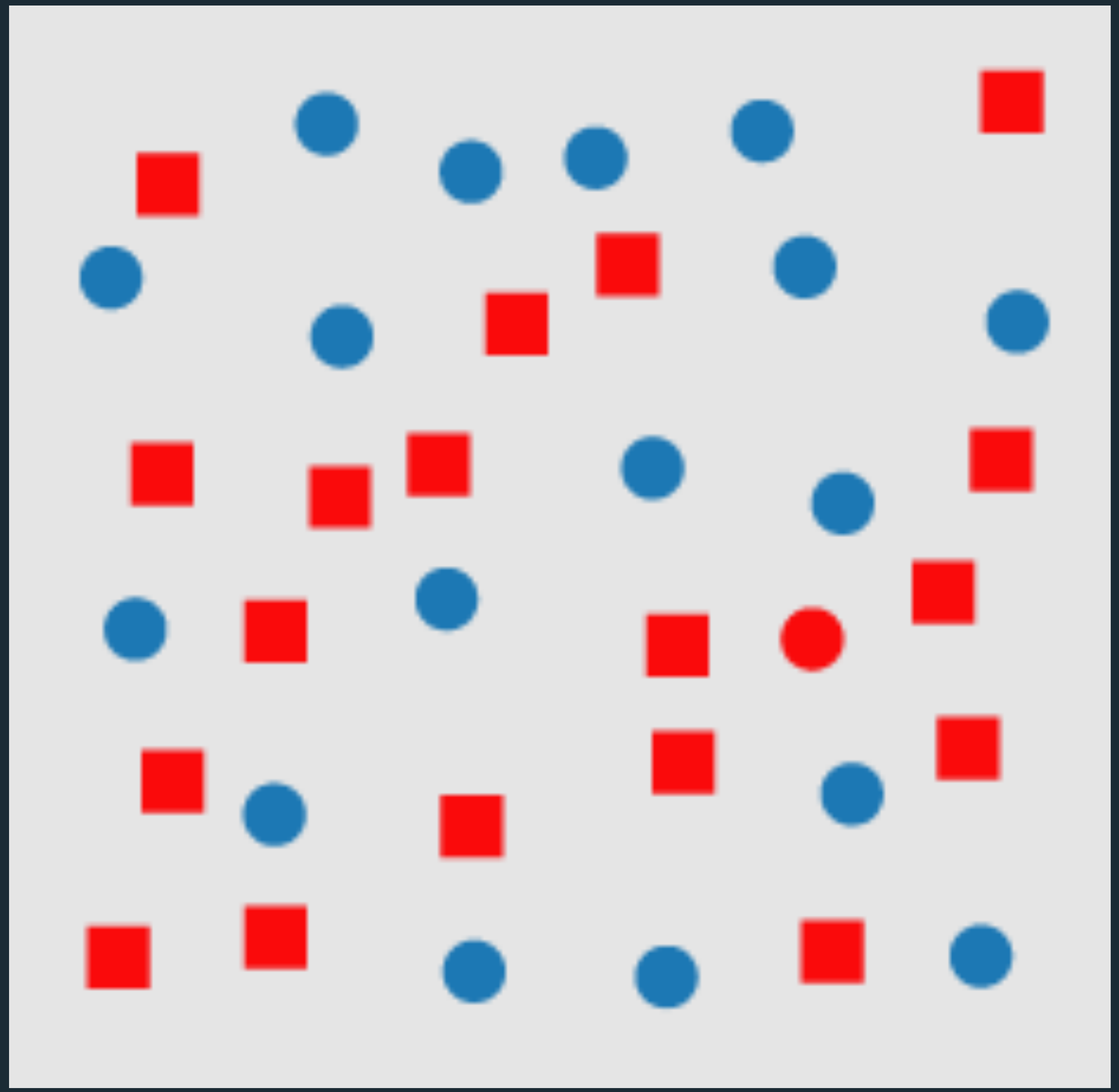
Pre-Attentive: immediately recognize variation with little or no conscious effort (<200–250 ms).

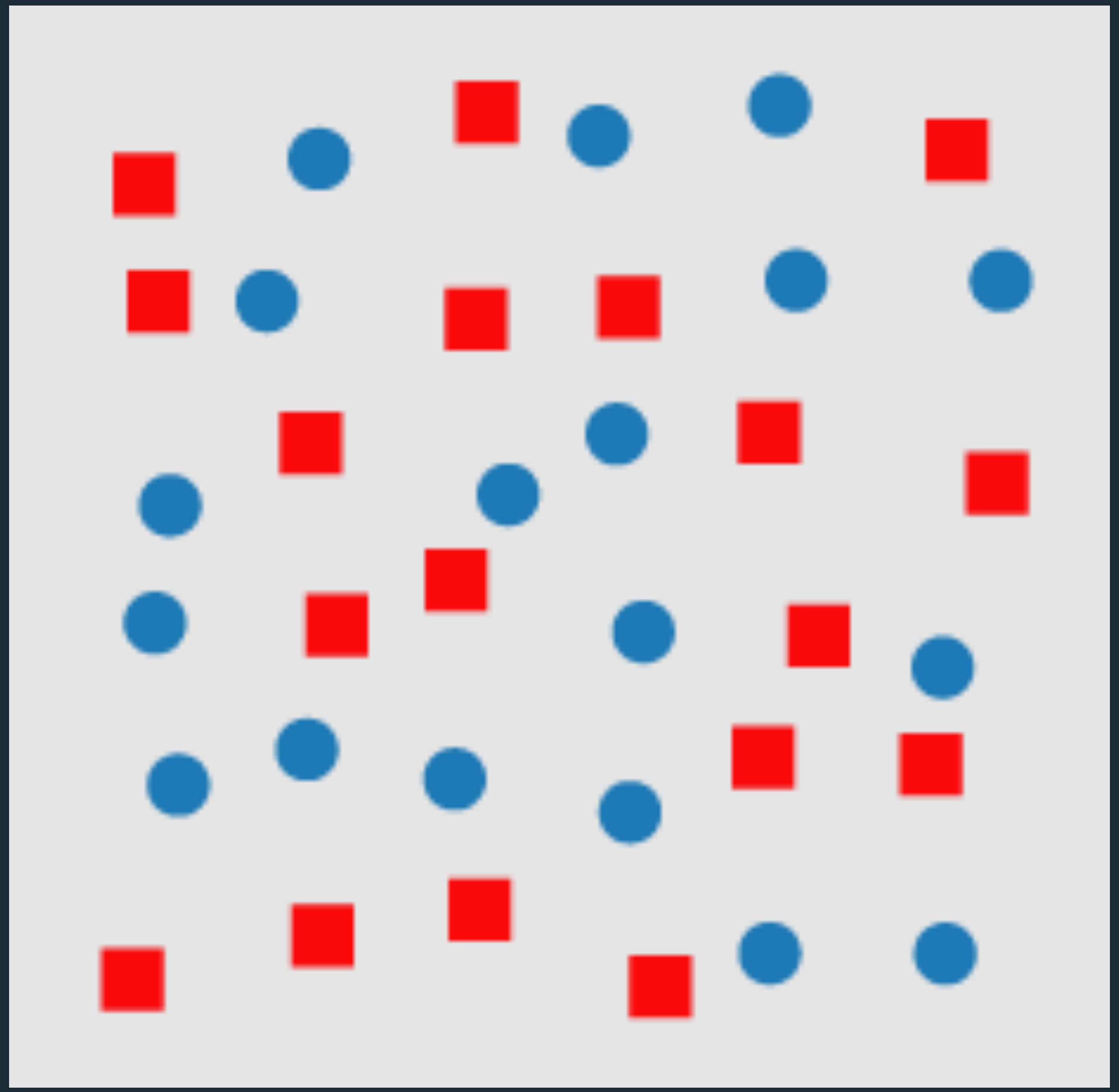
Attentive: Takes some deliberate effort to perceive differences.

Visual Pop-Out: Color

Visual Pop-Out: Shape

Feature Conjunctions





[Healey & Enns 2012]

Pre-Attentive Processing

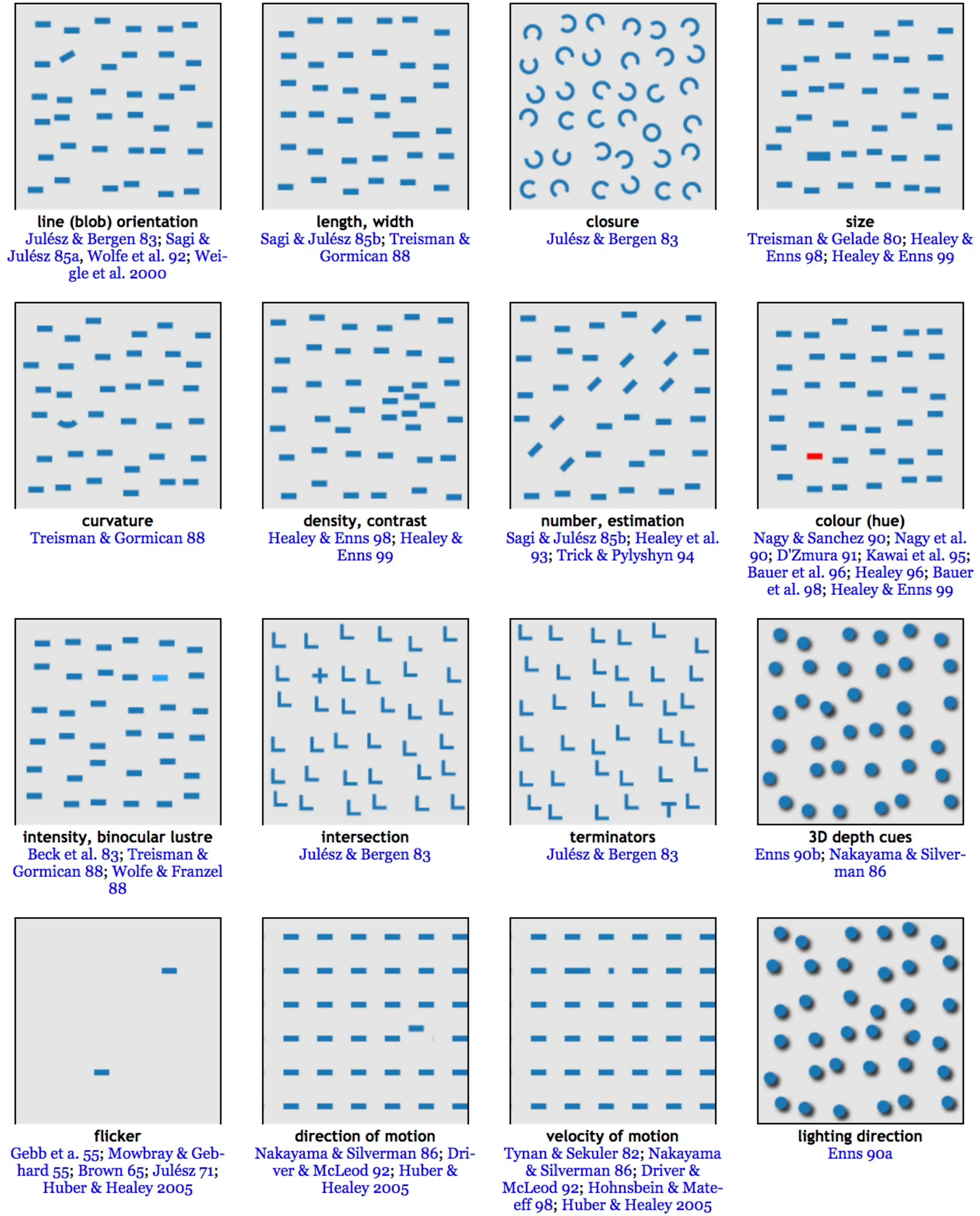
Visual Pop-Out: Color

Visual Pop-Out: Shape

Feature Conjunctions

Conjunctions are *not* pre-attentive except for spatial conjunctions:

- Motion & 3D disparity
- Motion & color
- Motion & shape
- 3D disparity & color
- 3D disparity & shape



[Healey & Enns 2012]

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Pop Out: how easy is it to spot some values from the rest?

Selective Attention

Gestalt Grouping

Signal Detection

Magnitude Estimation

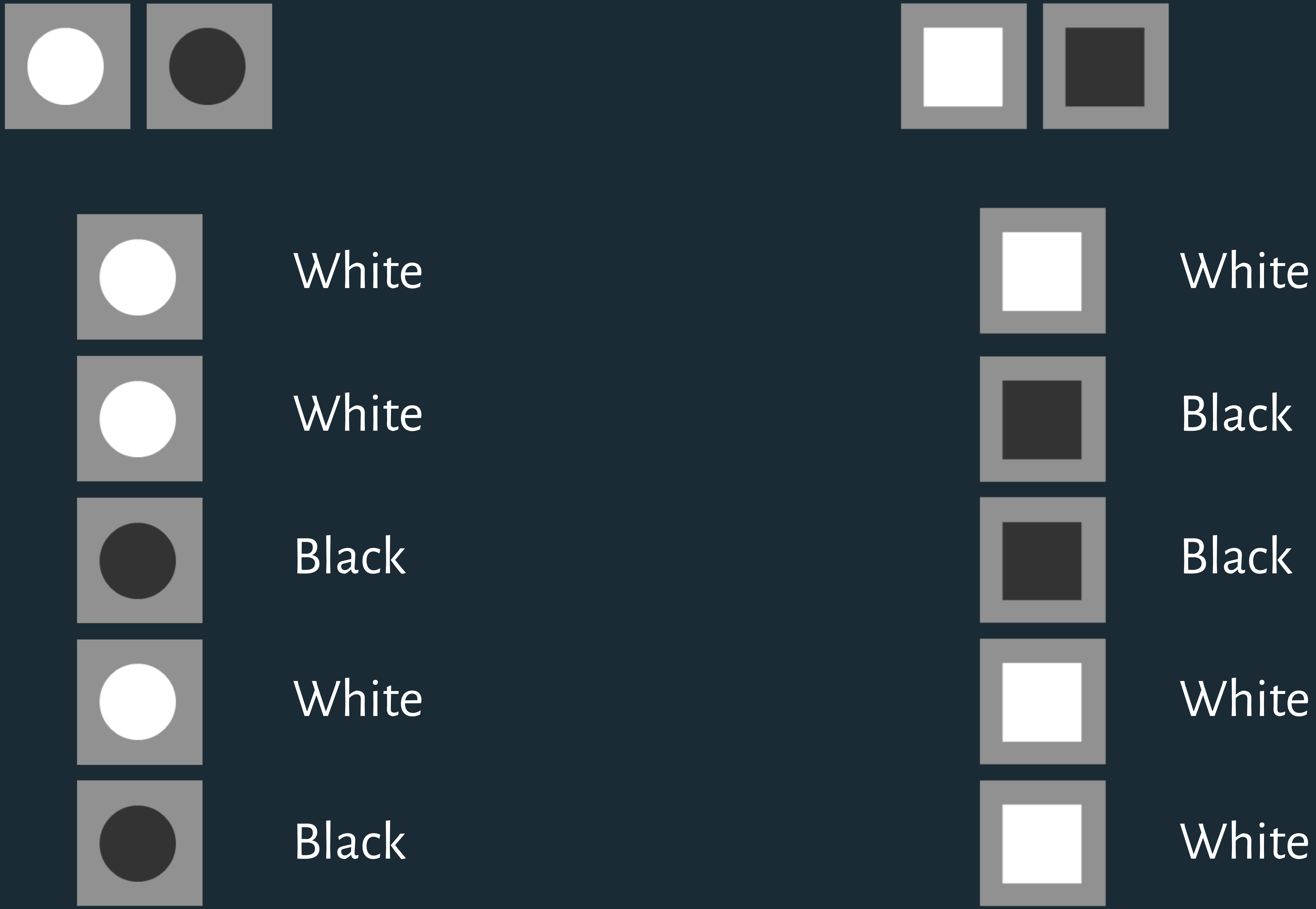
Pre-Attentive Processing

Selective Attention

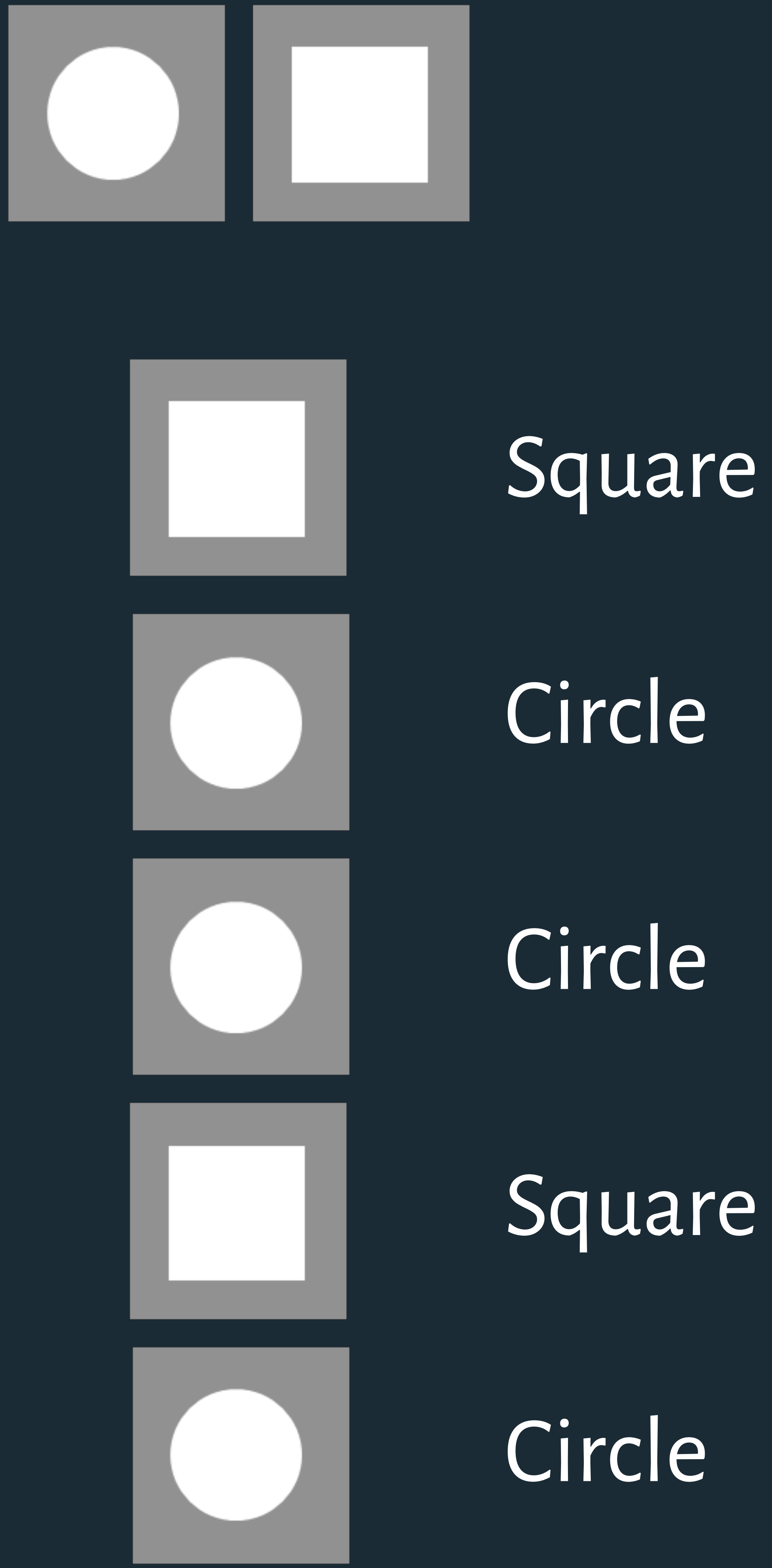
Separability: how much interaction occurs between attributes?

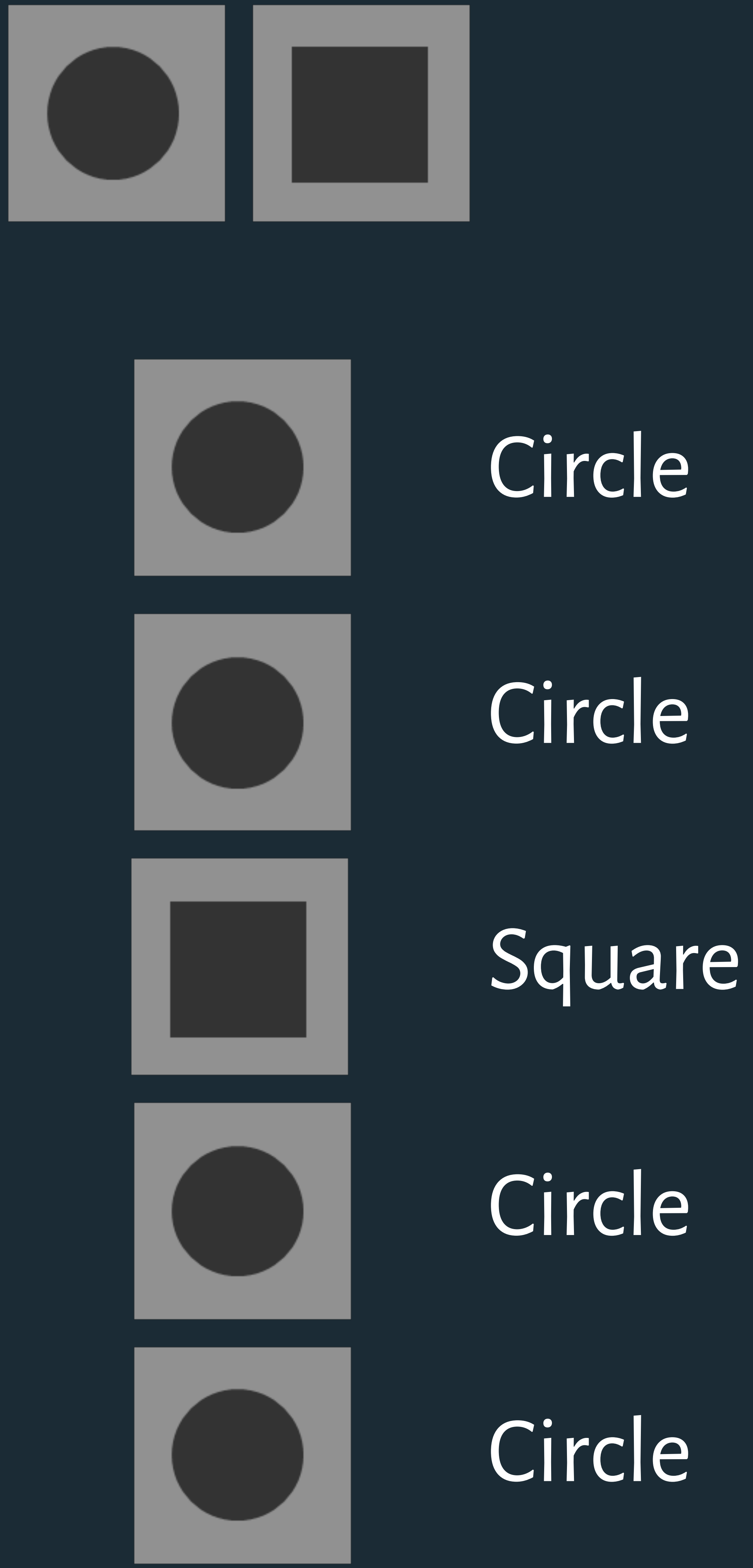
Gestalt Grouping

One-Dimensional: Lightness



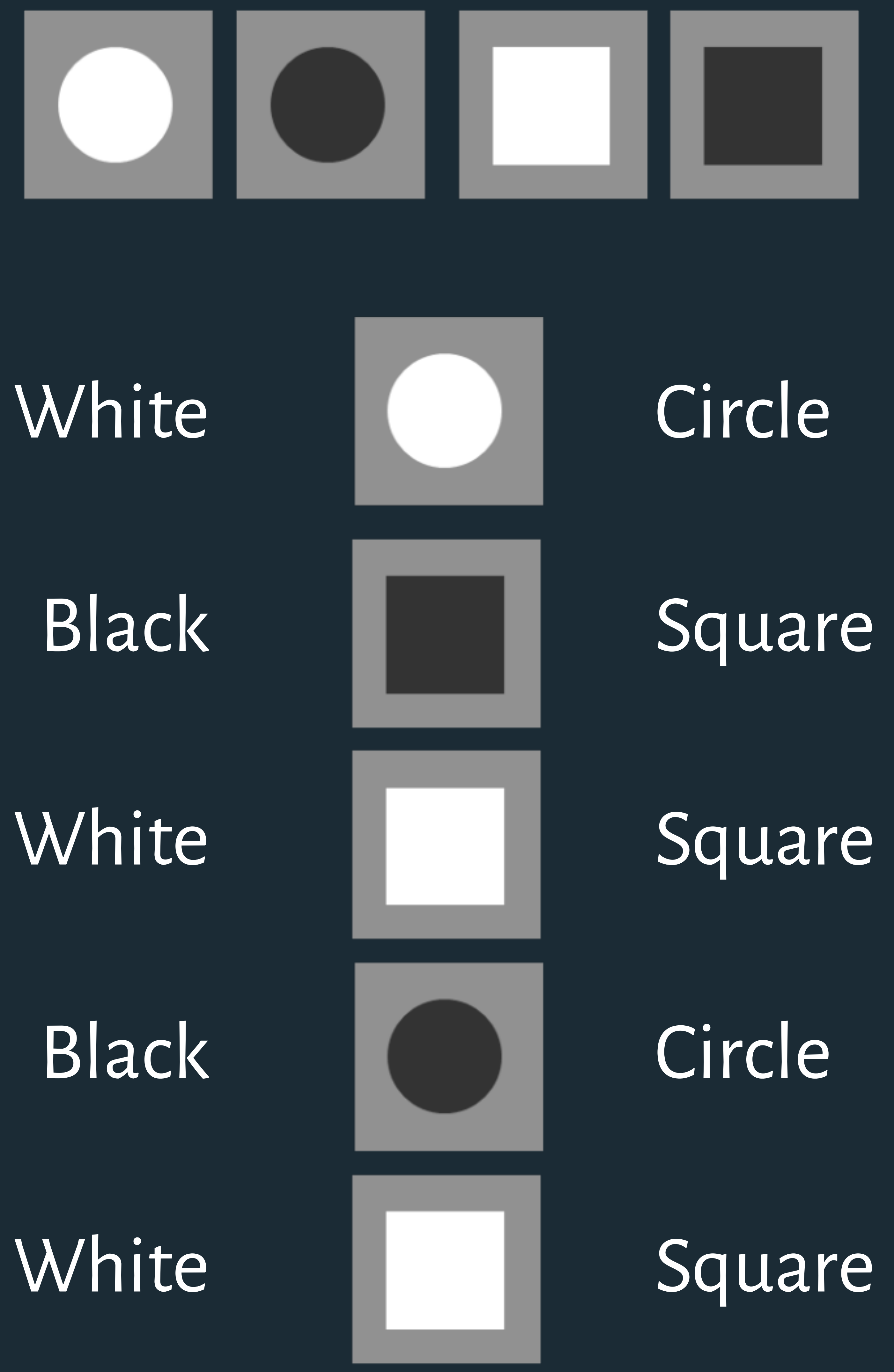
One-Dimensional: Shape





Redundant: Shape & Lightness

Orthogonal: Shape & Lightness



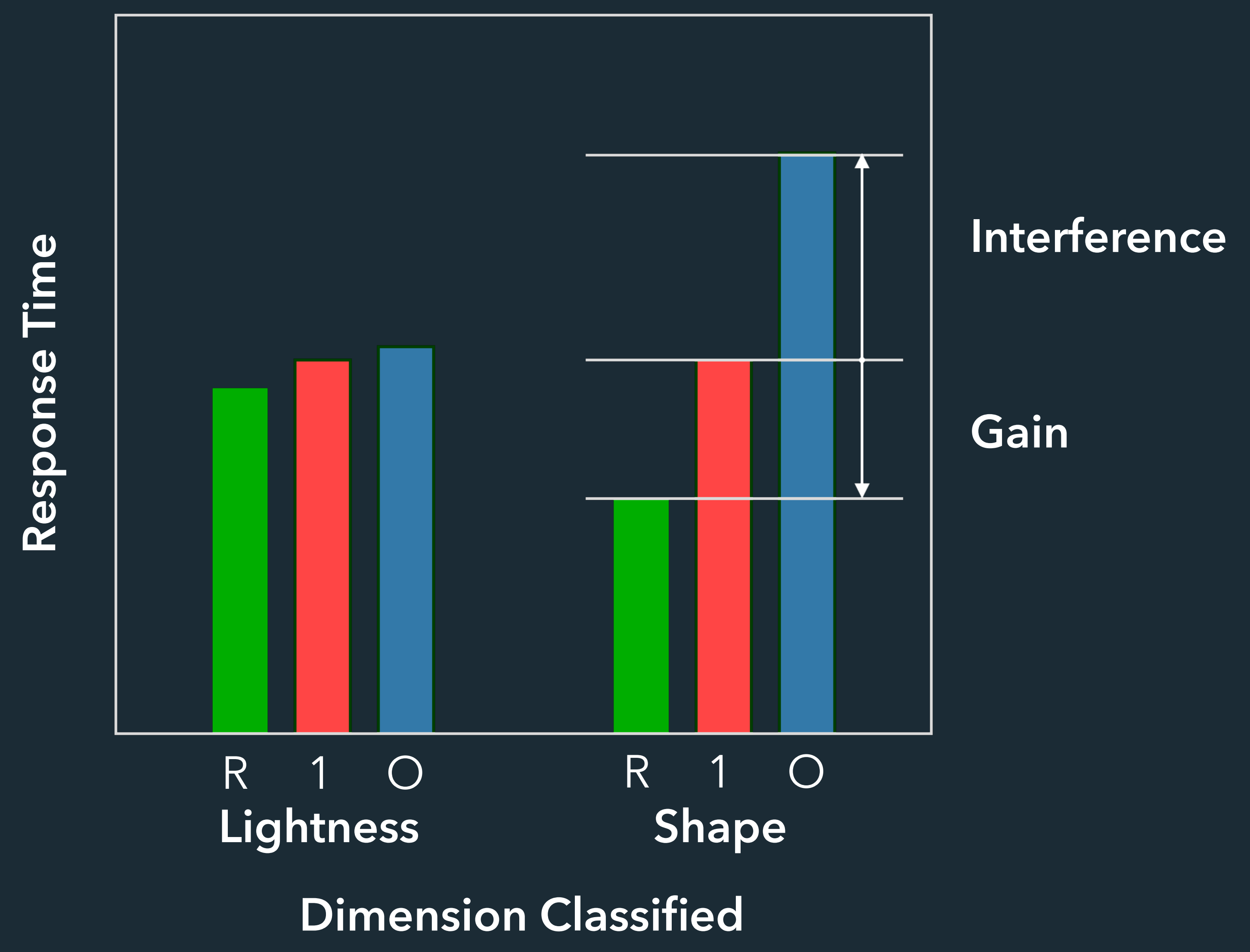
Principles

Redundancy Gain

Improved performance when both dimensions provide the same information.

Filtering Interference

Difficulty in ignoring one dimension while attending to another.



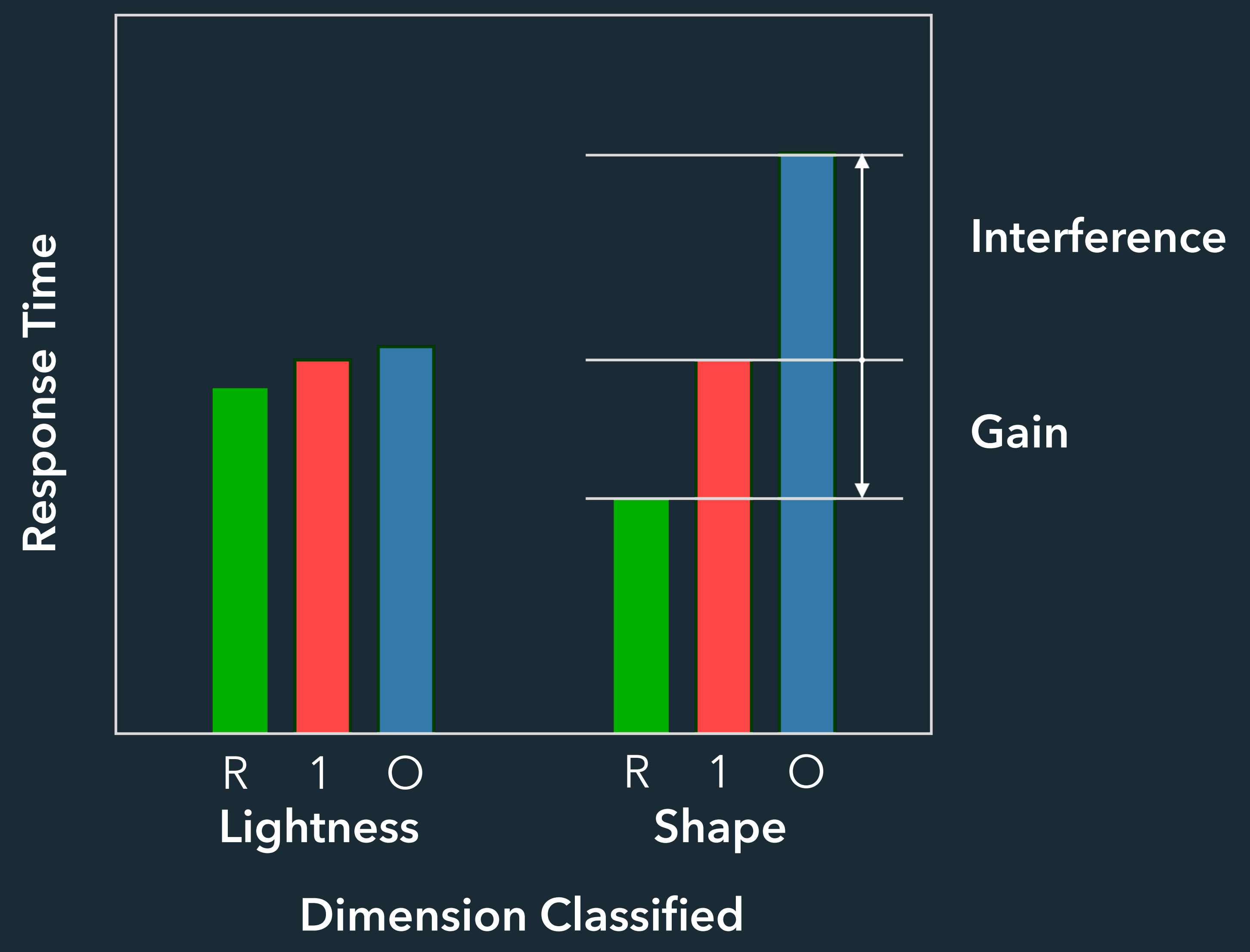
Principles

Redundancy Gain

Improved performance when both dimensions provide the same information.

Filtering Interference

Difficulty in ignoring one dimension while attending to another.



Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

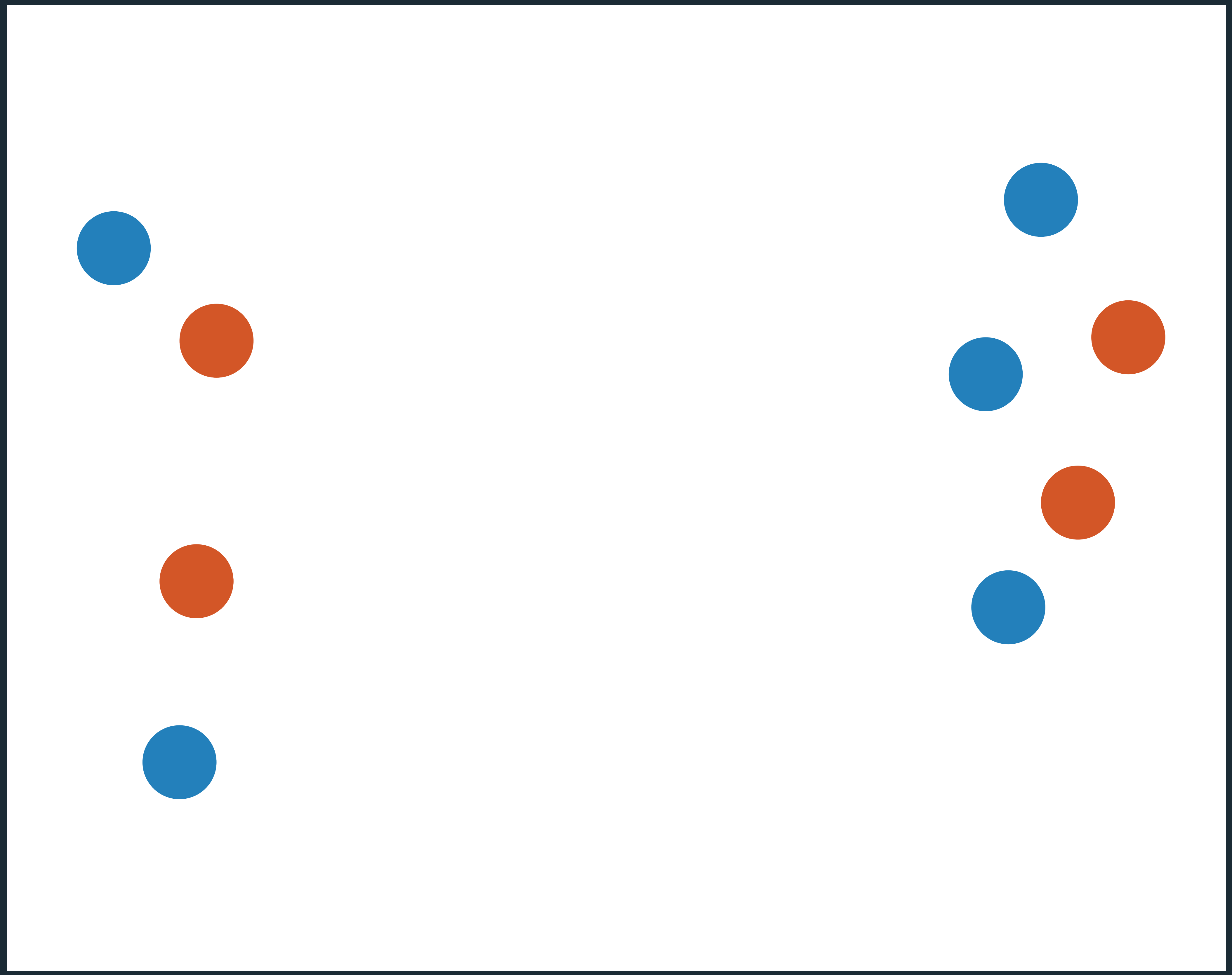
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Position & Hue (Color)?



[Tamara Munzner, *Visualization Analysis and Design* (2014)]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

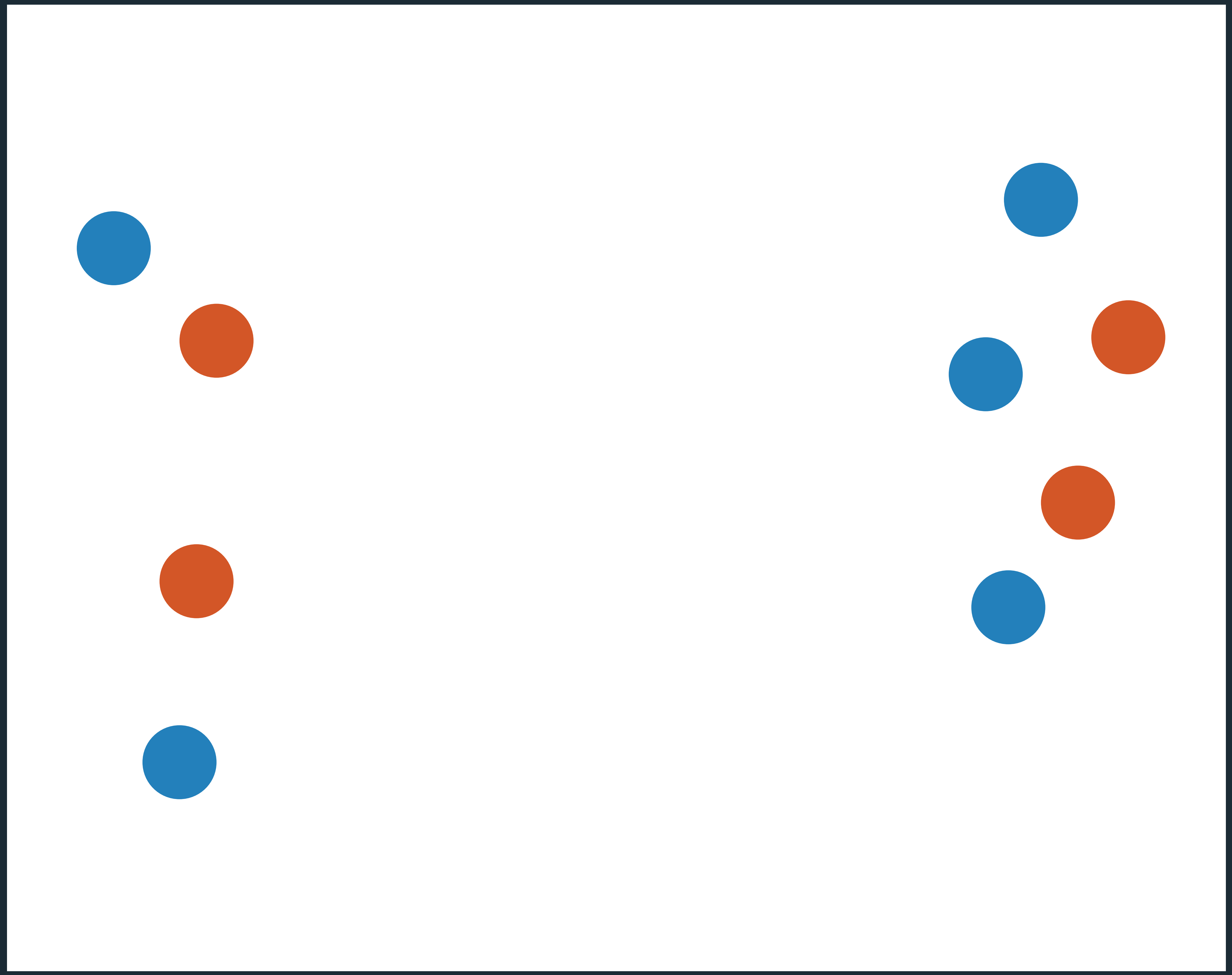
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Position & Hue (Color)?



[Tamara Munzner, *Visualization Analysis and Design* (2014)]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Size & Orientation?

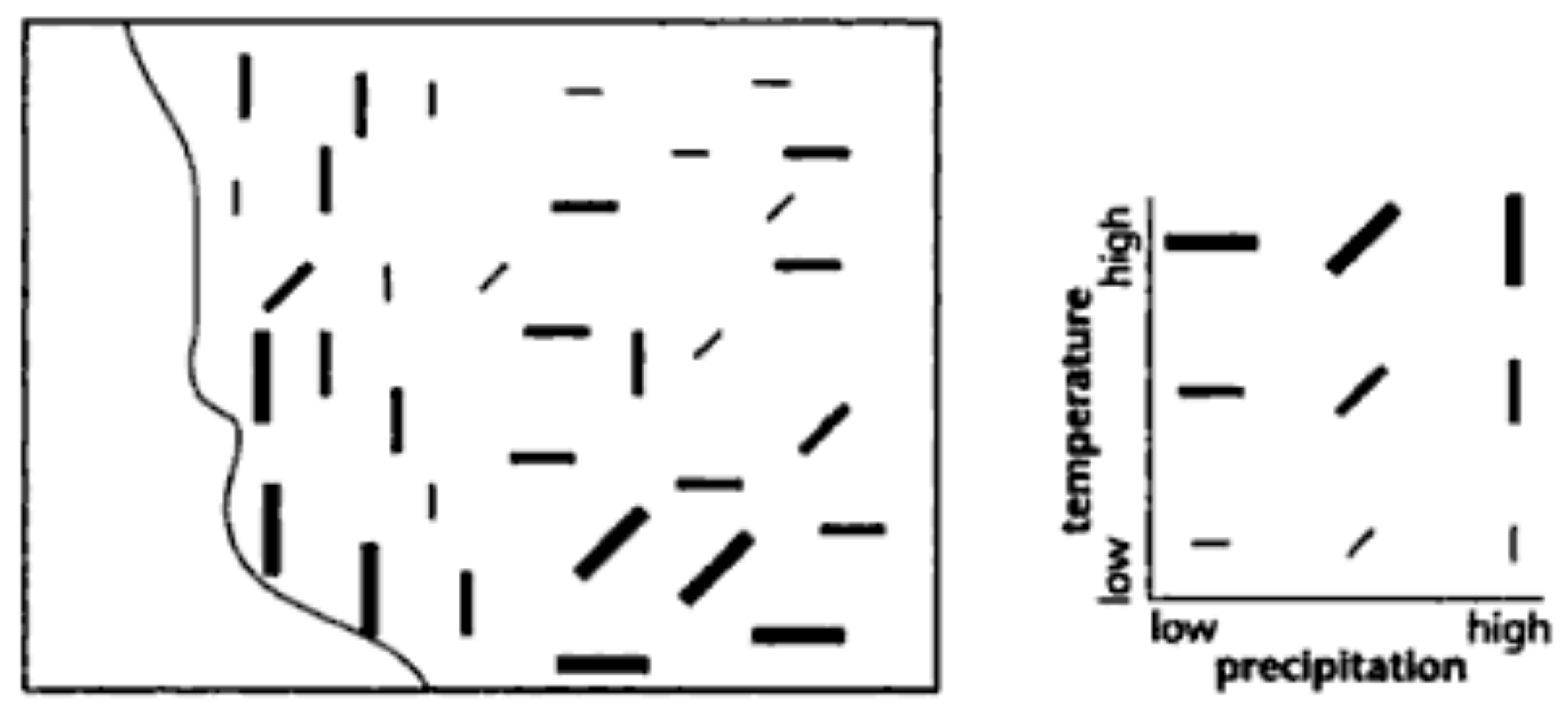


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Size & Orientation?

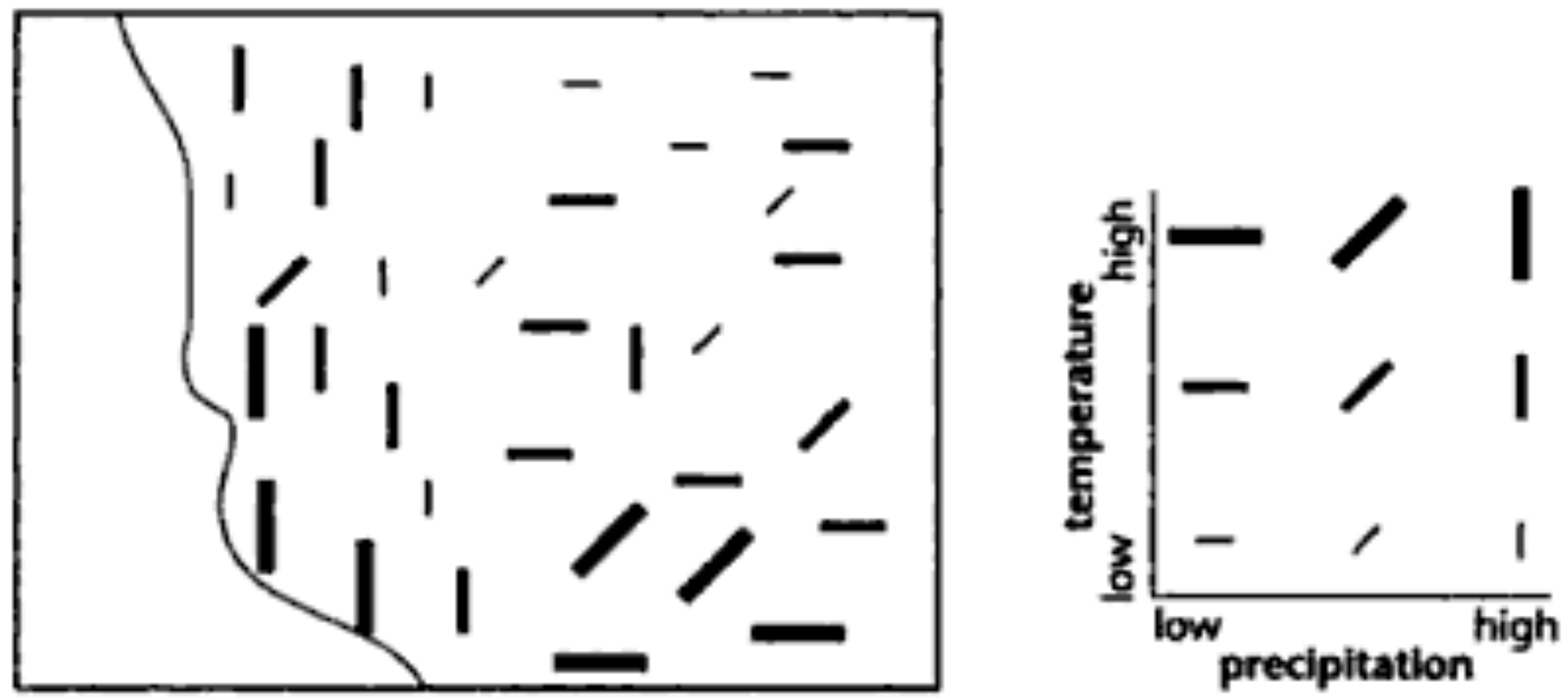


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

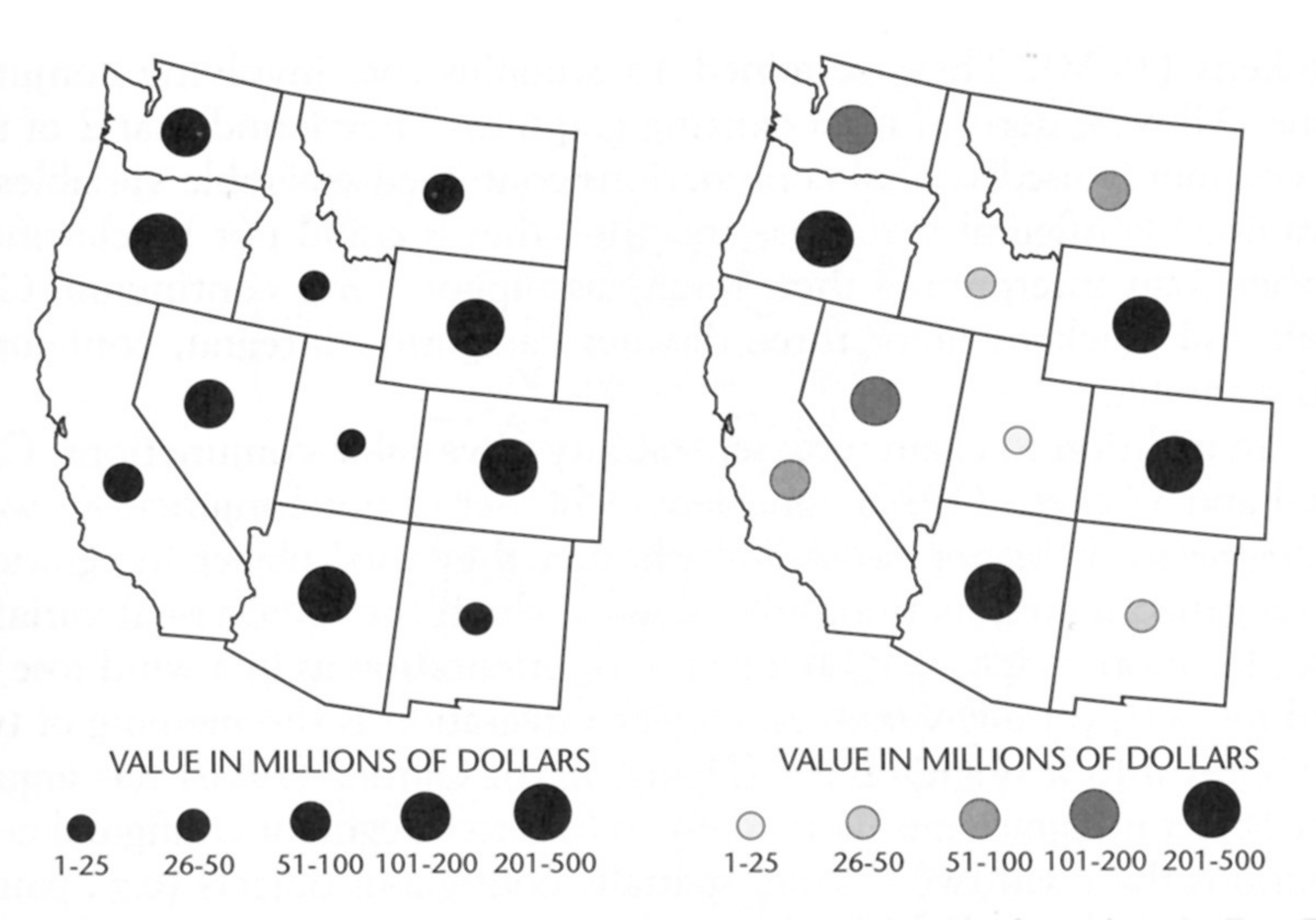
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Size & Value?



[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

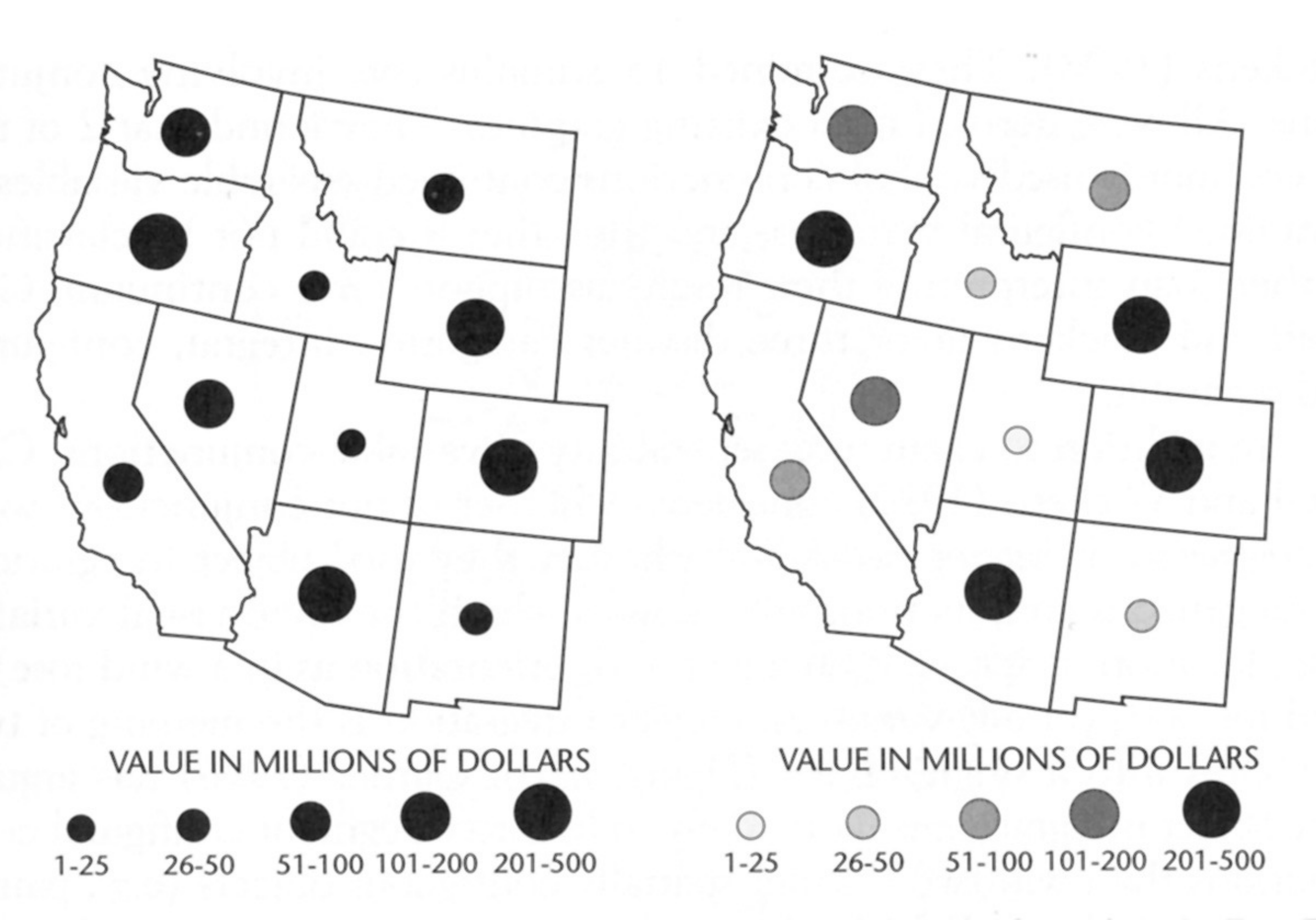
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Size & Value?



[MacEachren 1995]

[Simon Scarr, *South China Morning Post*. 2012]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Shape & Size?

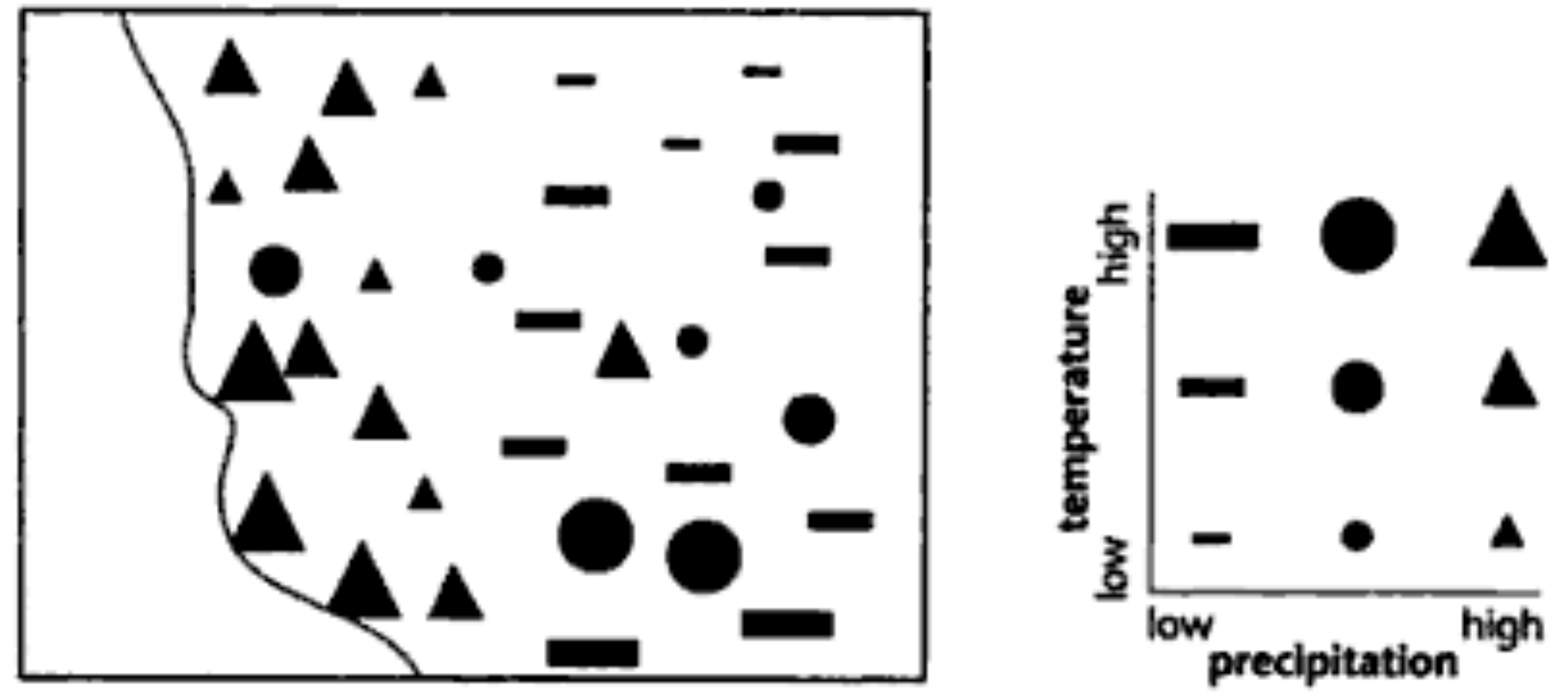


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Shape & Size?

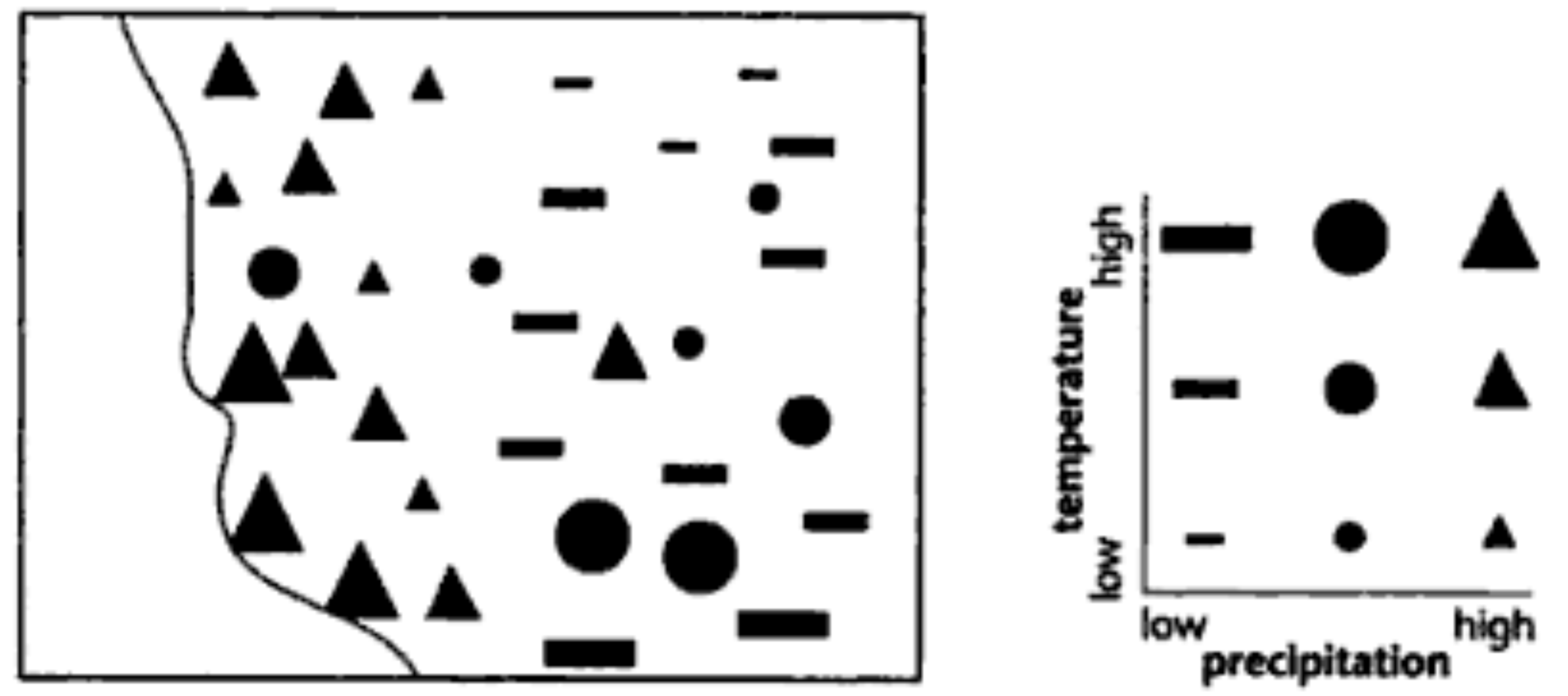


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Width & Height?

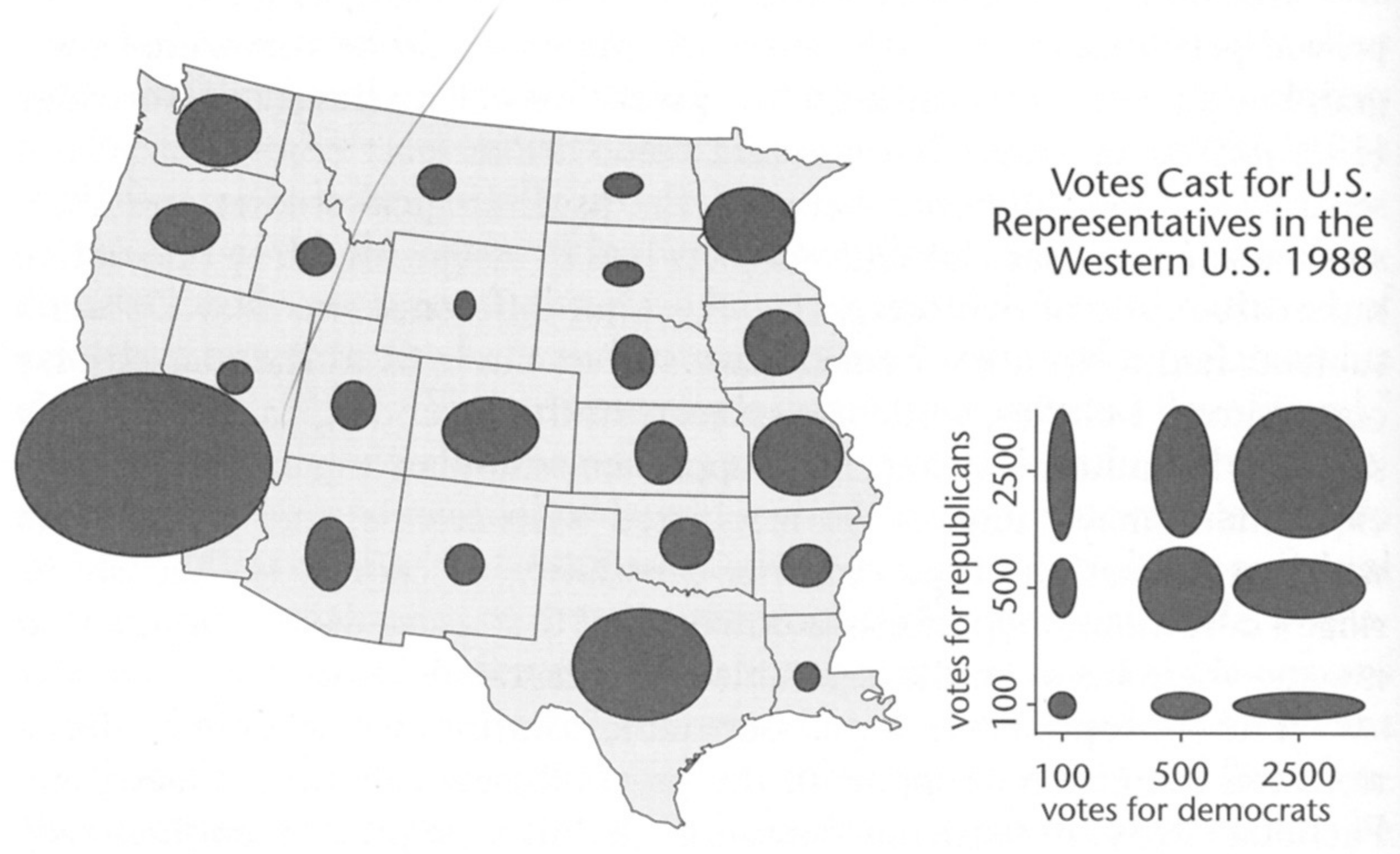


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Width & Height?

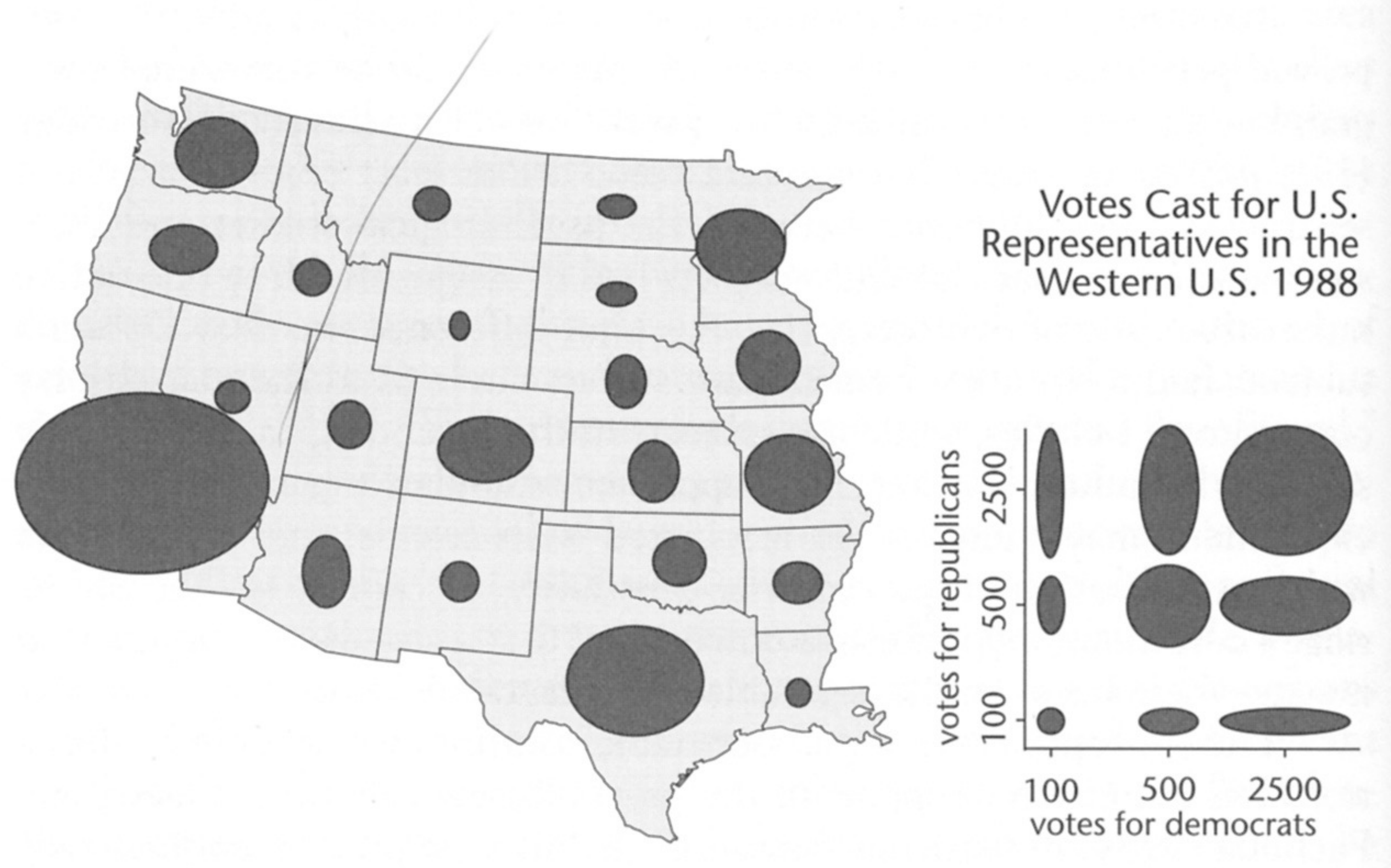


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

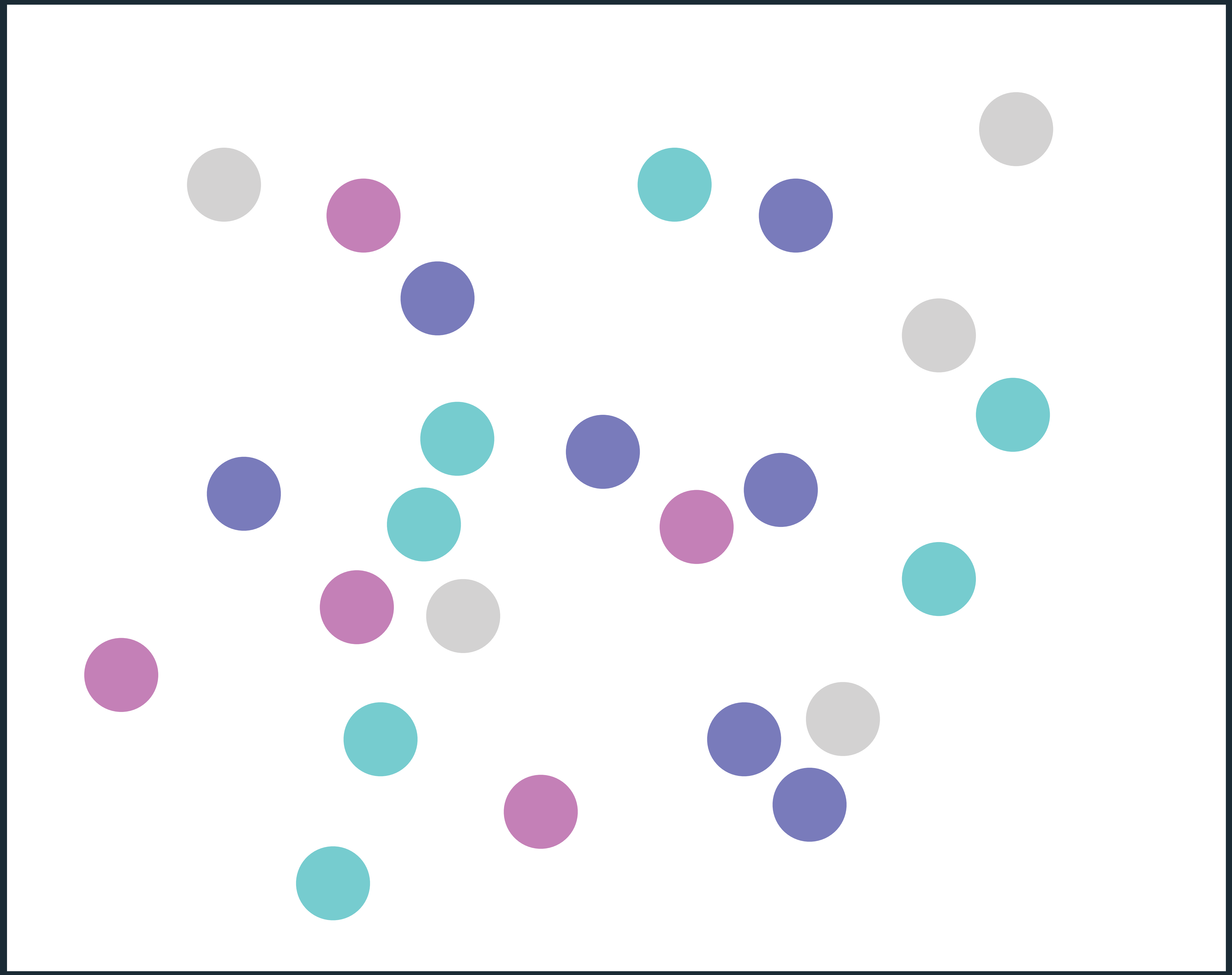
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Red & Green / Yellow & Blue?



[Tamara Munzner, *Visualization Analysis and Design* (2014)]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

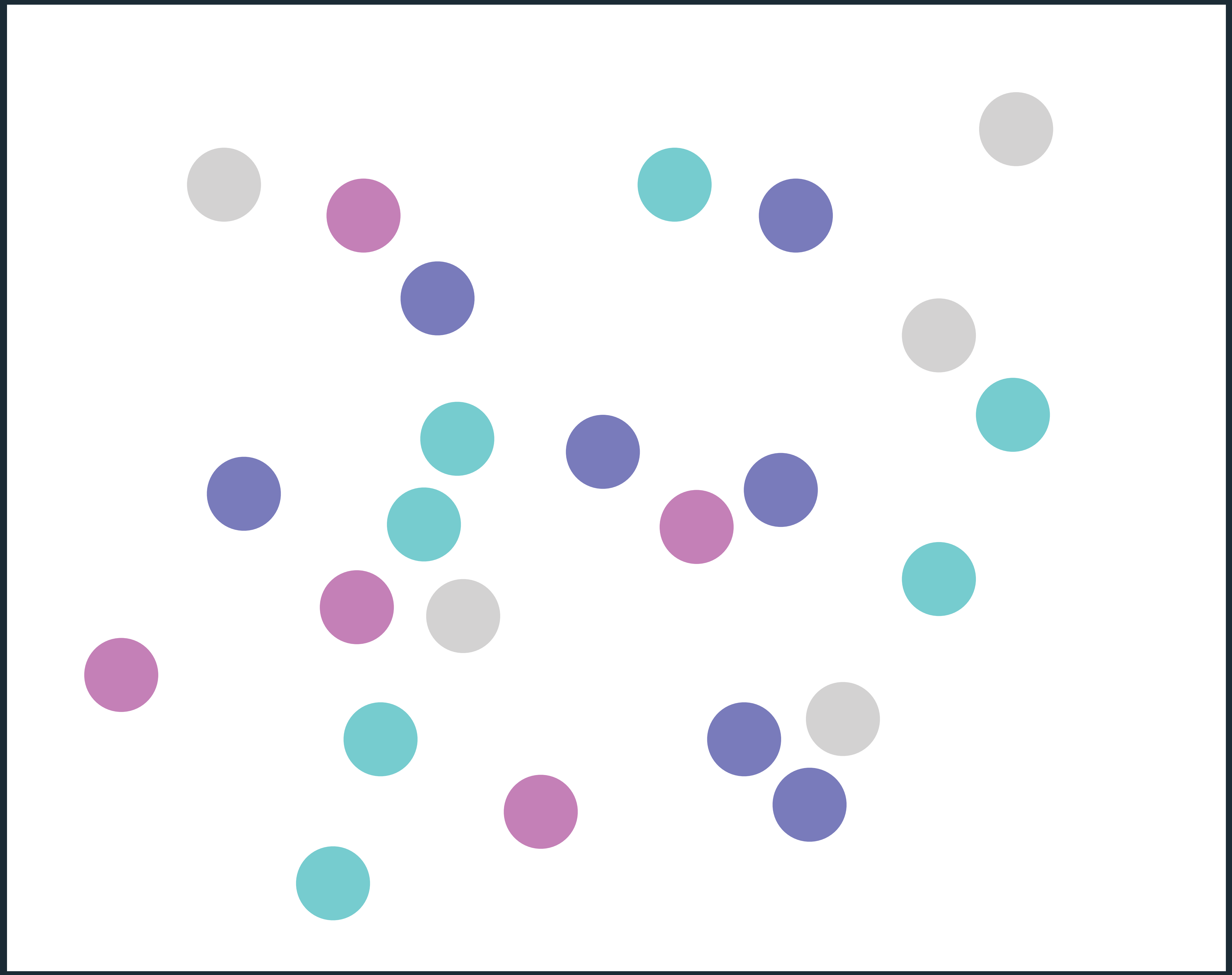
Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

Red & Green / Yellow & Blue?



[Tamara Munzner, *Visualization Analysis and Design* (2014)]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

blue

yellow

red

green

orange

purple

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

blue

yellow

red

green

orange

purple

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

Only interference. No redundancy gain.

Asymmetric

One dimension is separable from the other, but not vice versa.

blue

yellow

red

green

orange

purple

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Separability: how much interaction occurs between attributes?

Gestalt Grouping

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

Symmetry

Connectedness

Continuity

Closure

Common Fate

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

Symmetry

Connectedness

Continuity

Closure

Common Fate

Ambiguous – vase or faces?

Unambiguous (?)

http://visual-memory.co.uk/daniel/Modules/FM21820/visper07.html

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

Symmetry

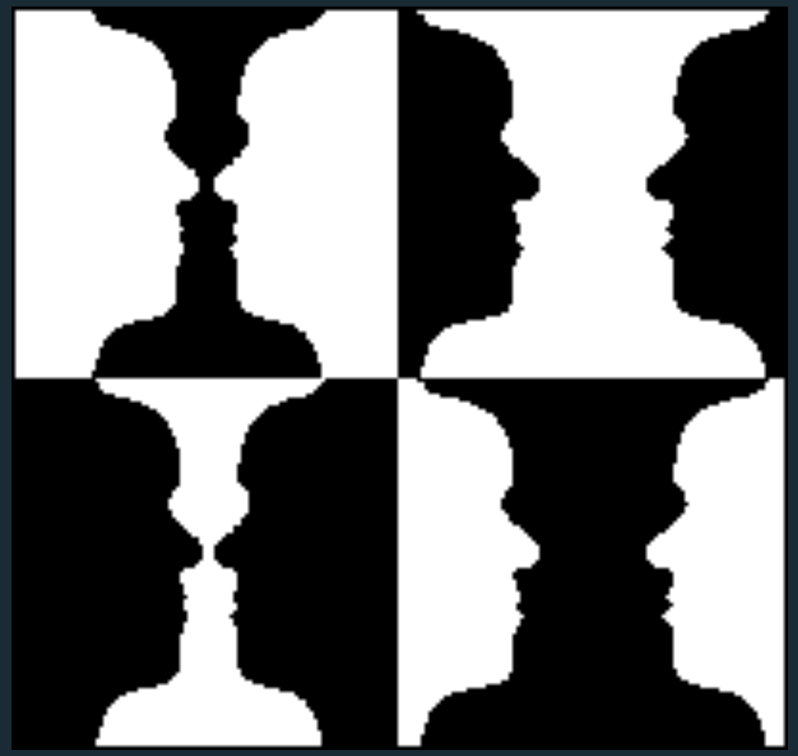
Connectedness

Continuity

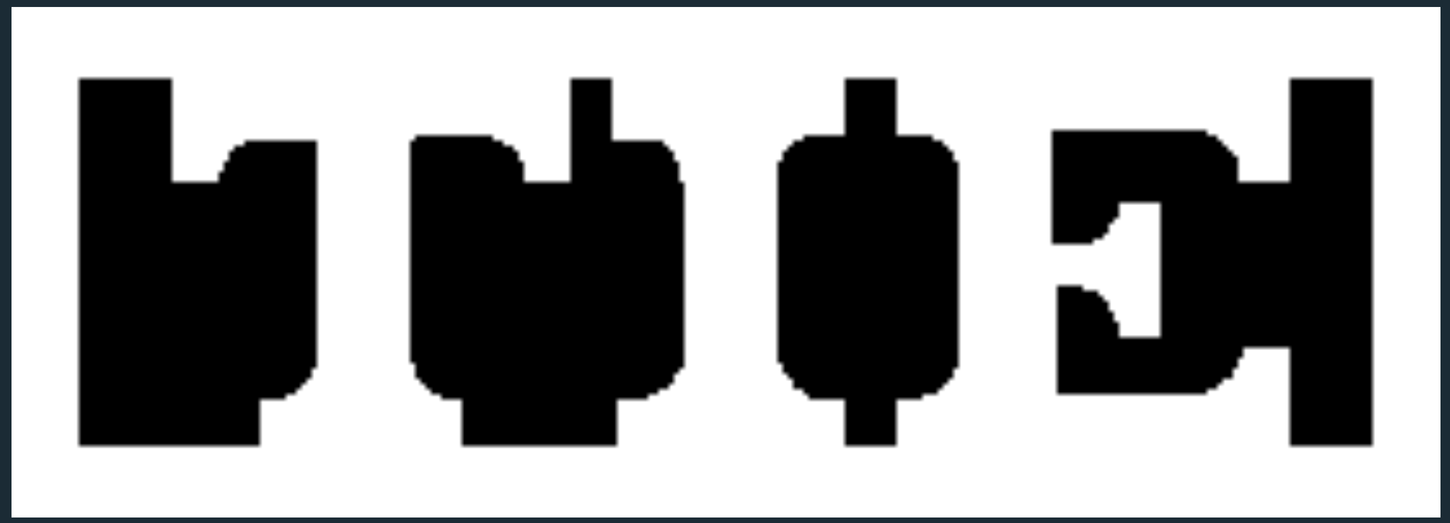
Closure

Common Fate

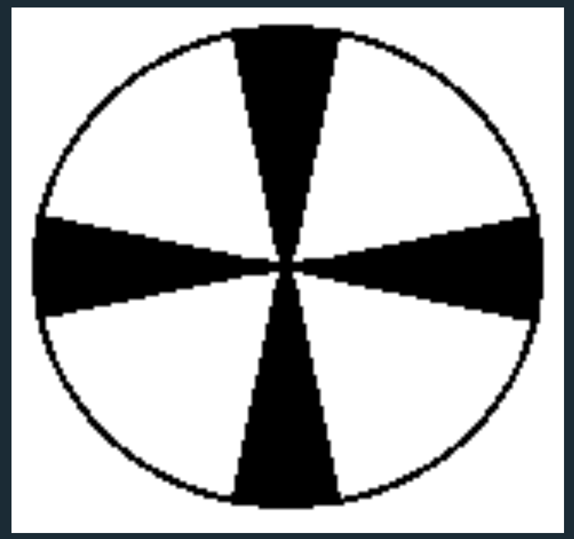
Ambiguous – vase or faces?



Unambiguous (?)

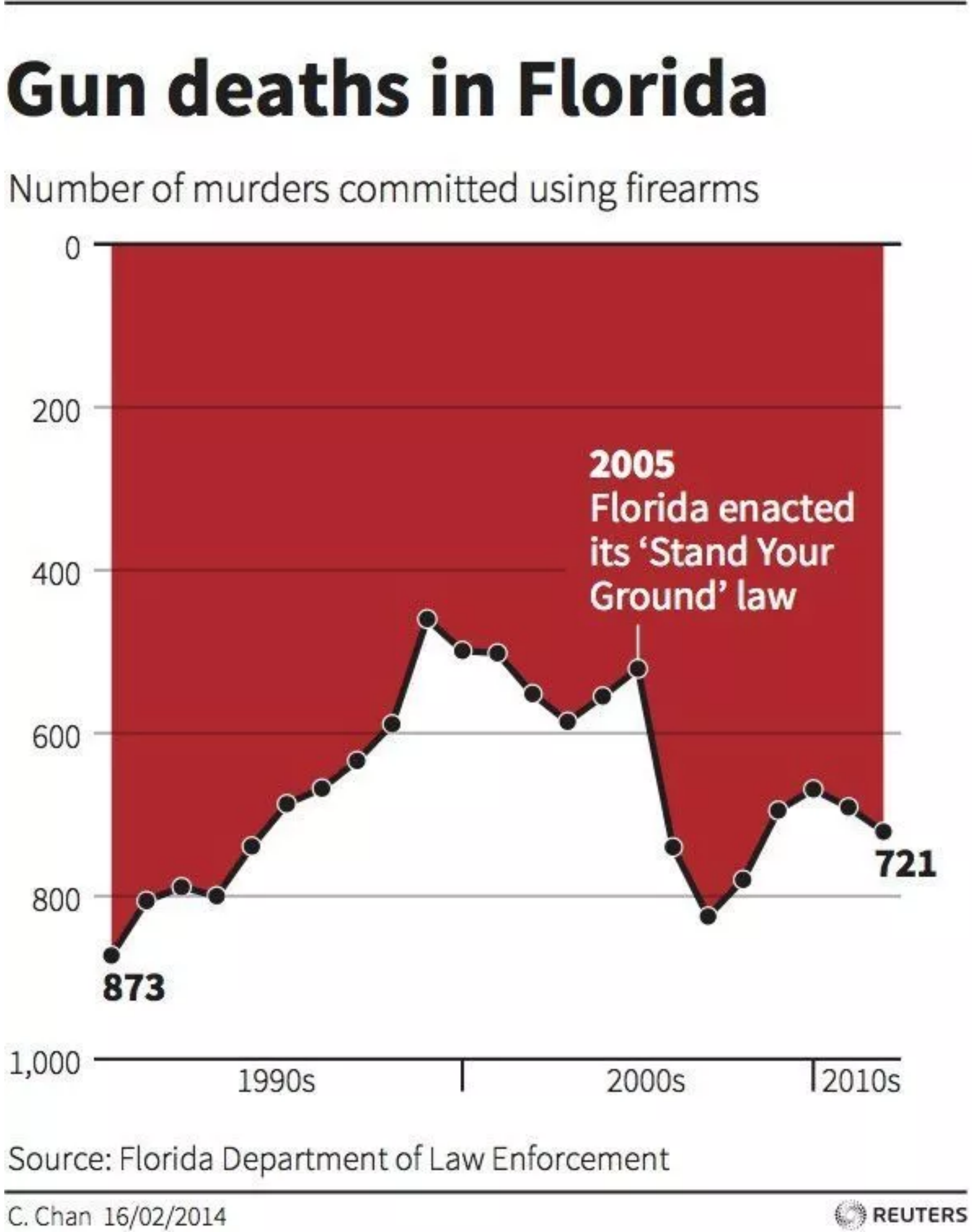


Principle of *surroundedness*.



Principle of *relative size*.

http://visual-memory.co.uk/daniel/Modules/FM21820/visper07.html


Gun deaths in Florida
Number of murders committed using firearms
0
200
400
600
800
1,000
2005
Florida enacted its 'Stand Your Ground' law
873
721
1990s
2000s
2010s
Source: Florida Department of Law Enforcement
C. Chan 16/02/2014
REUTERS

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

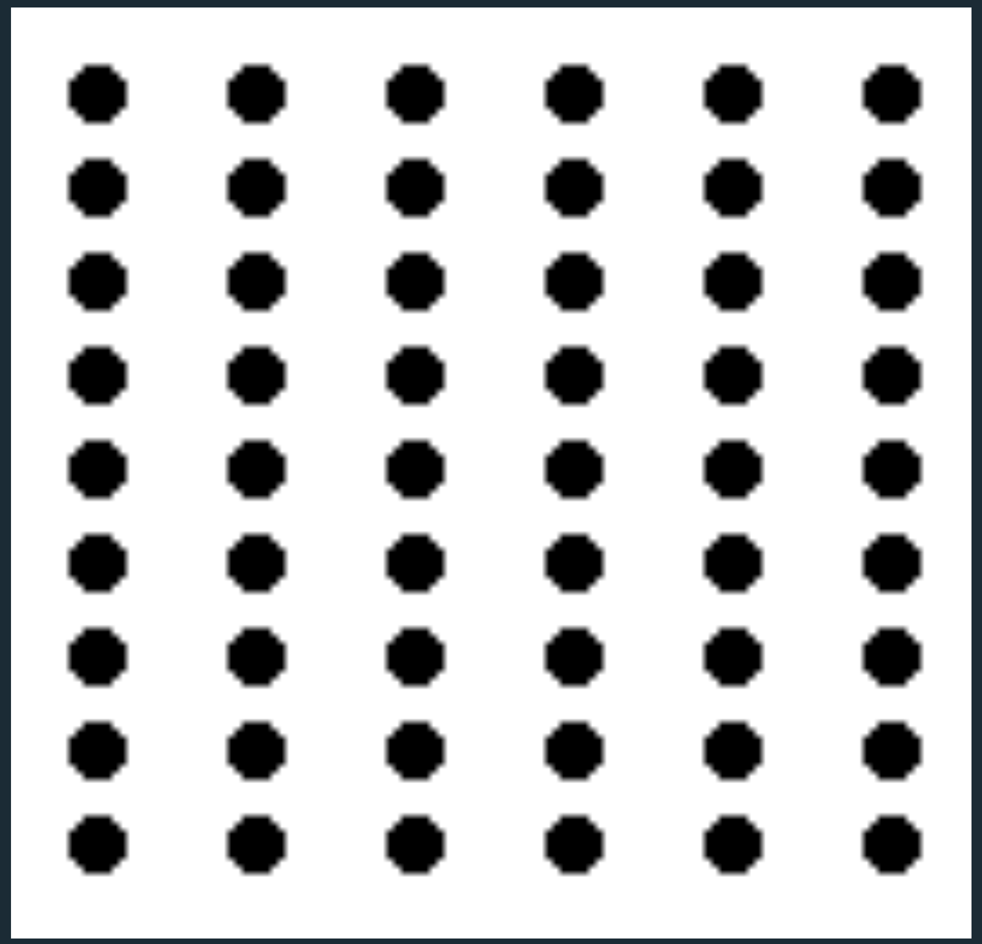
Symmetry

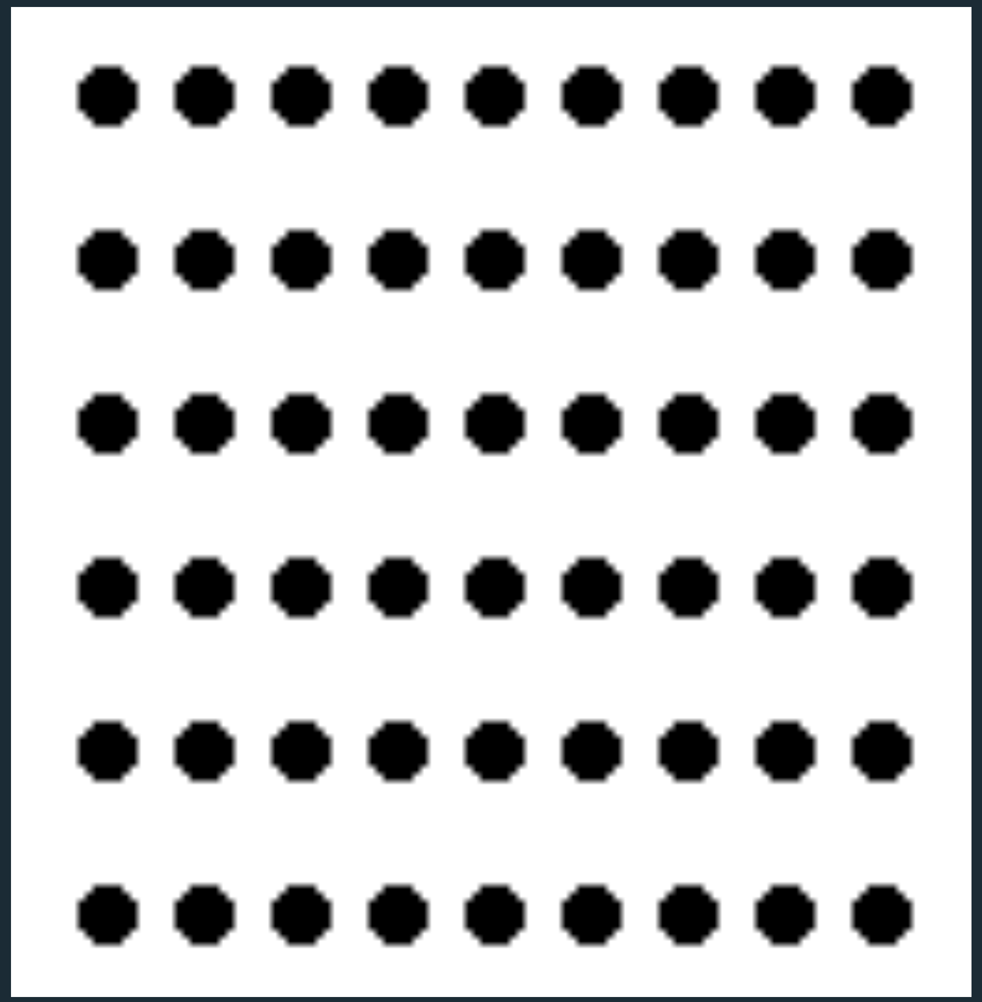
Connectedness

Continuity

Closure

Common Fate





http://visual-memory.co.uk/daniel/Modules/FM21820/visper07.html

METRICS

HANNAH FAIRFIELD

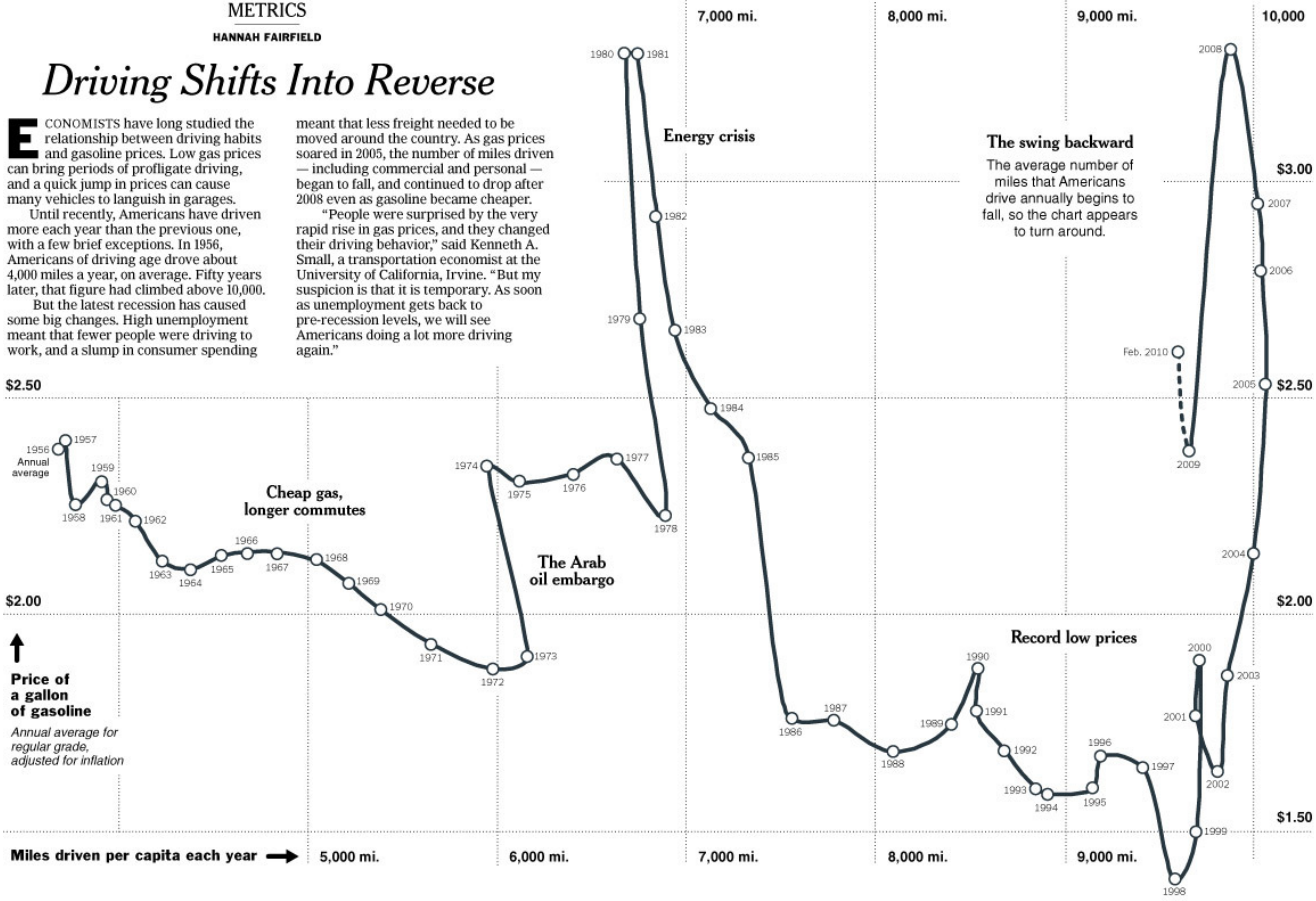
Driving Shifts Into Reverse

ECONOMISTS have long studied the relationship between driving habits and gasoline prices. Low gas prices can bring periods of profligate driving, and a quick jump in prices can cause many vehicles to languish in garages.

Until recently, Americans have driven more each year than the previous one, with a few brief exceptions. In 1956, Americans of driving age drove about 4,000 miles a year, on average. Fifty years later, that figure had climbed above 10,000.

But the latest recession has caused some big changes. High unemployment meant that fewer people were driving to work, and a slump in consumer spending meant that less freight needed to be moved around the country. As gas prices soared in 2005, the number of miles driven — including commercial and personal — began to fall, and continued to drop after 2008 even as gasoline became cheaper.

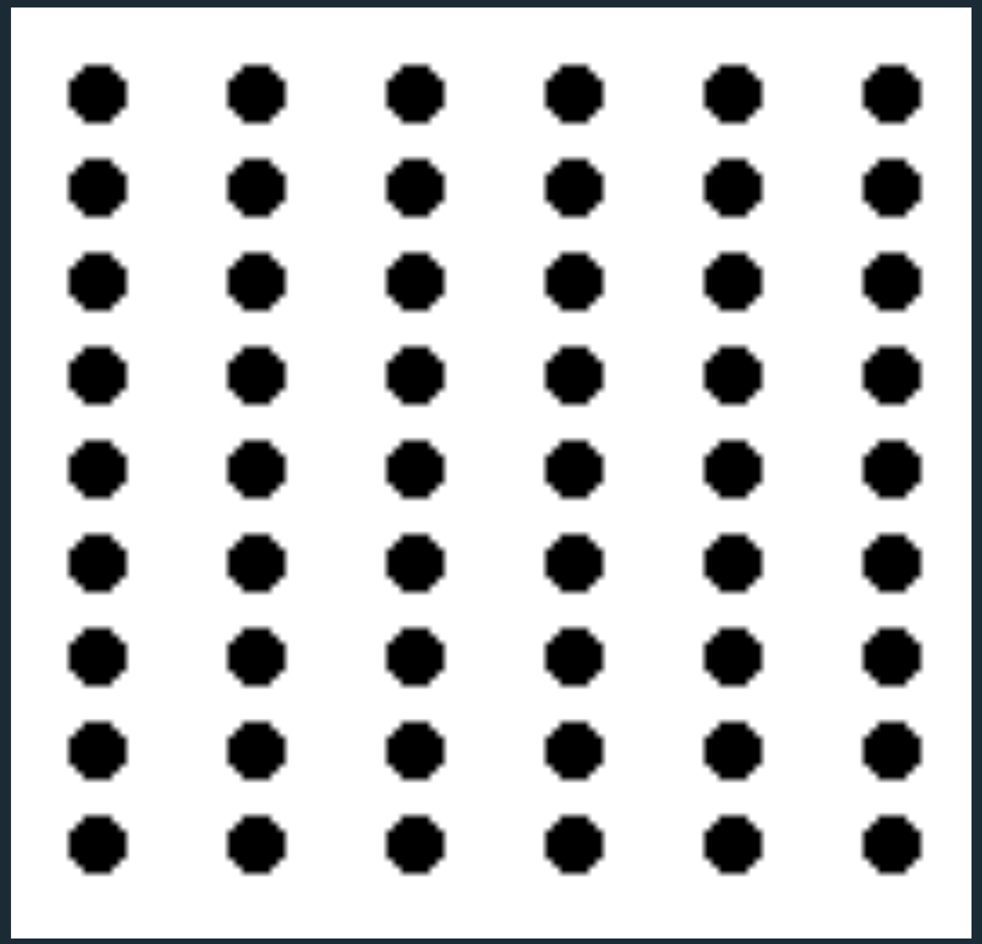
"People were surprised by the very rapid rise in gas prices, and they changed their driving behavior," said Kenneth A. Small, a transportation economist at the University of California, Irvine. "But my suspicion is that it is temporary. As soon as unemployment gets back to pre-recession levels, we will see Americans doing a lot more driving again."

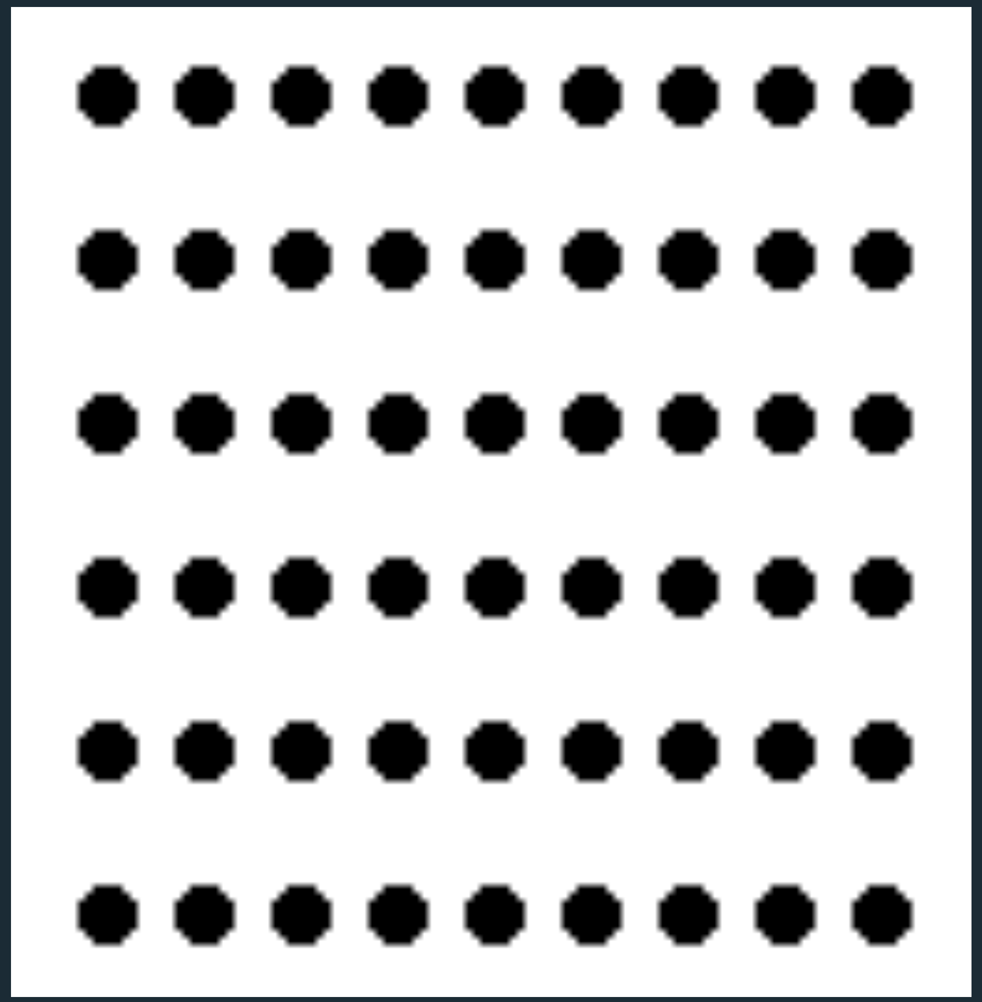


Gestalt Principles

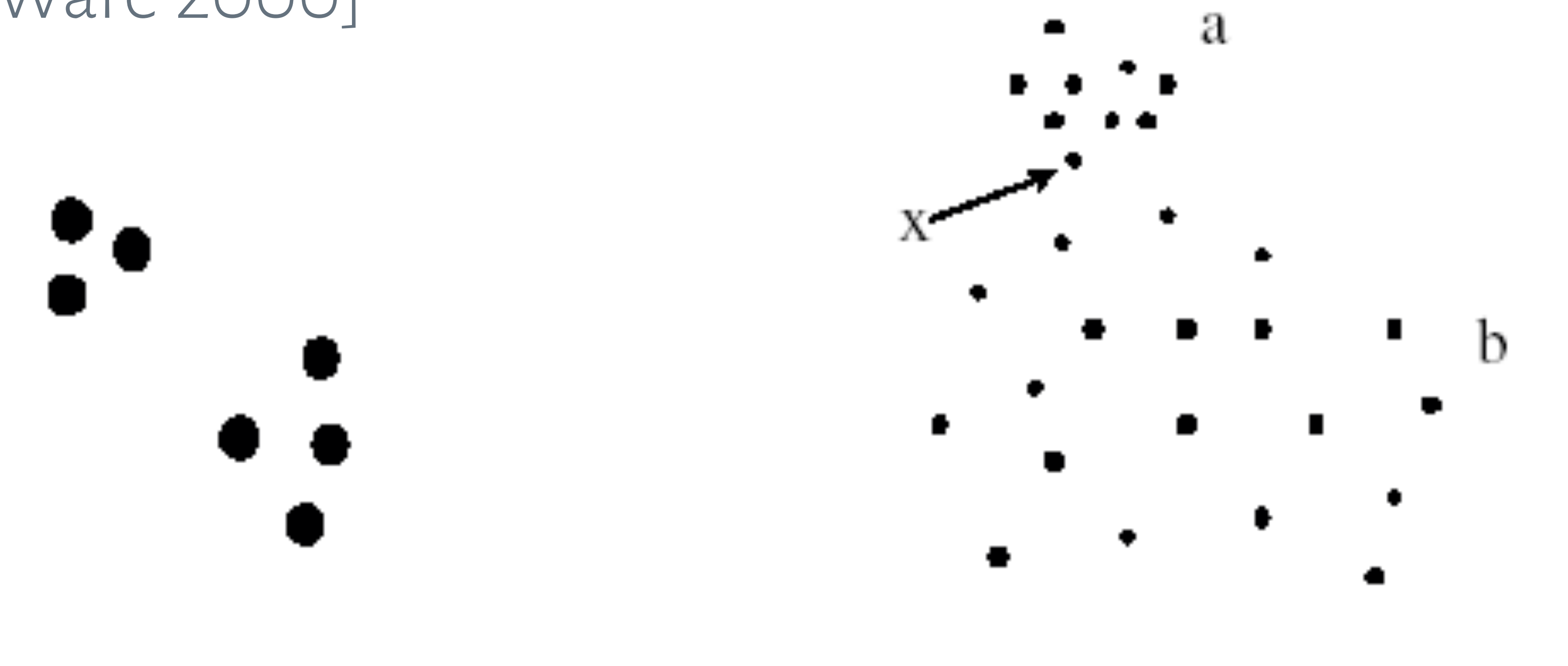
pragnänz: we favor the simplest and most stable interpretations

- Figure / Ground
- Proximity
- Similarity
- Symmetry
- Connectedness
- Continuity
- Closure
- Common Fate





[Ware 2000]



Principle of *concentration*.

http://visual-memory.co.uk/daniel/Modules/FM21820/visper07.html

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

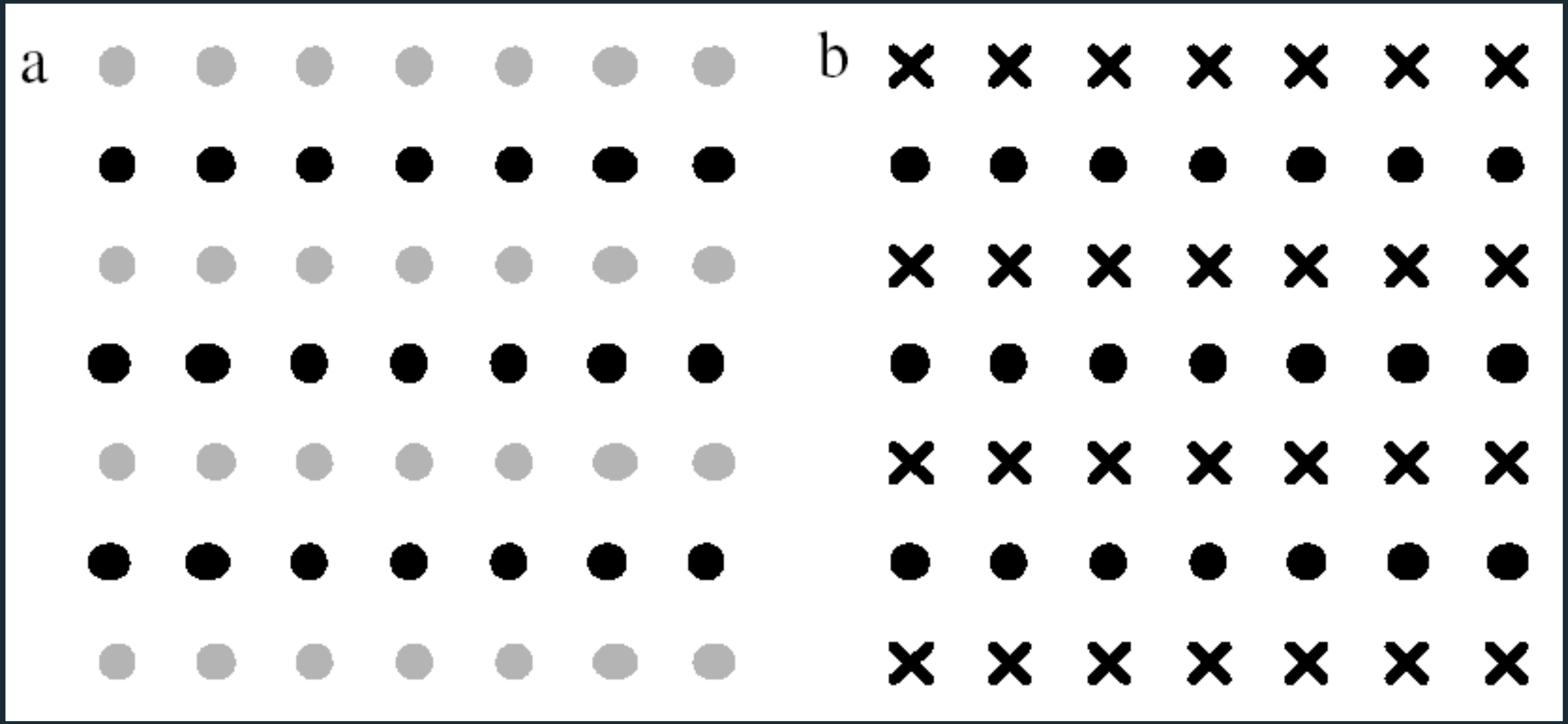
Symmetry

Connectedness

Continuity

Closure

Common Fate

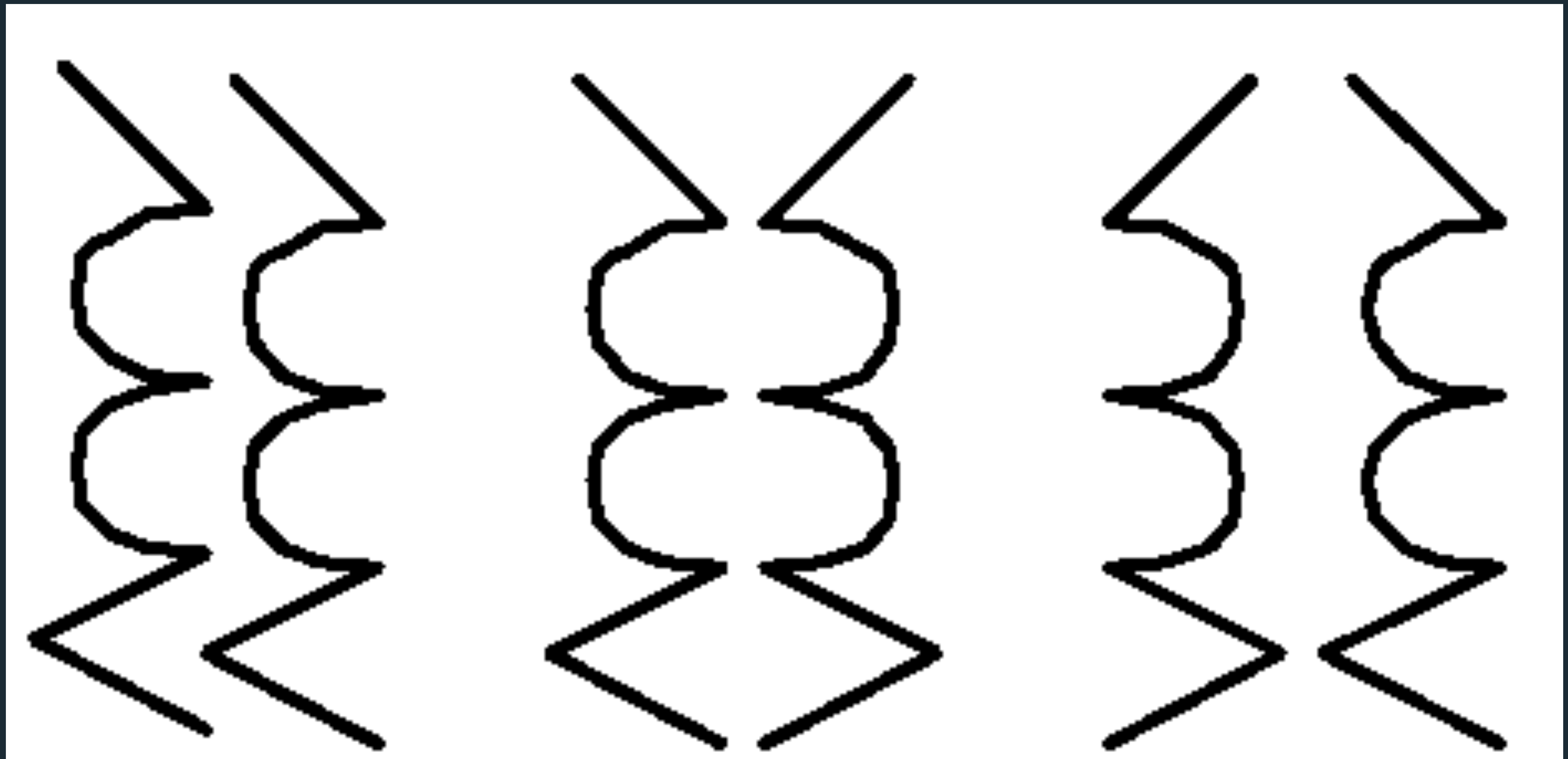


Rows dominate due to similarity. [Ware 2004]

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

- Figure / Ground
- Proximity
- Similarity
- Symmetry
- Connectedness
- Continuity
- Closure
- Common Fate



[Ware 2004]

Bilateral symmetry gives the strong sense of a figure.

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

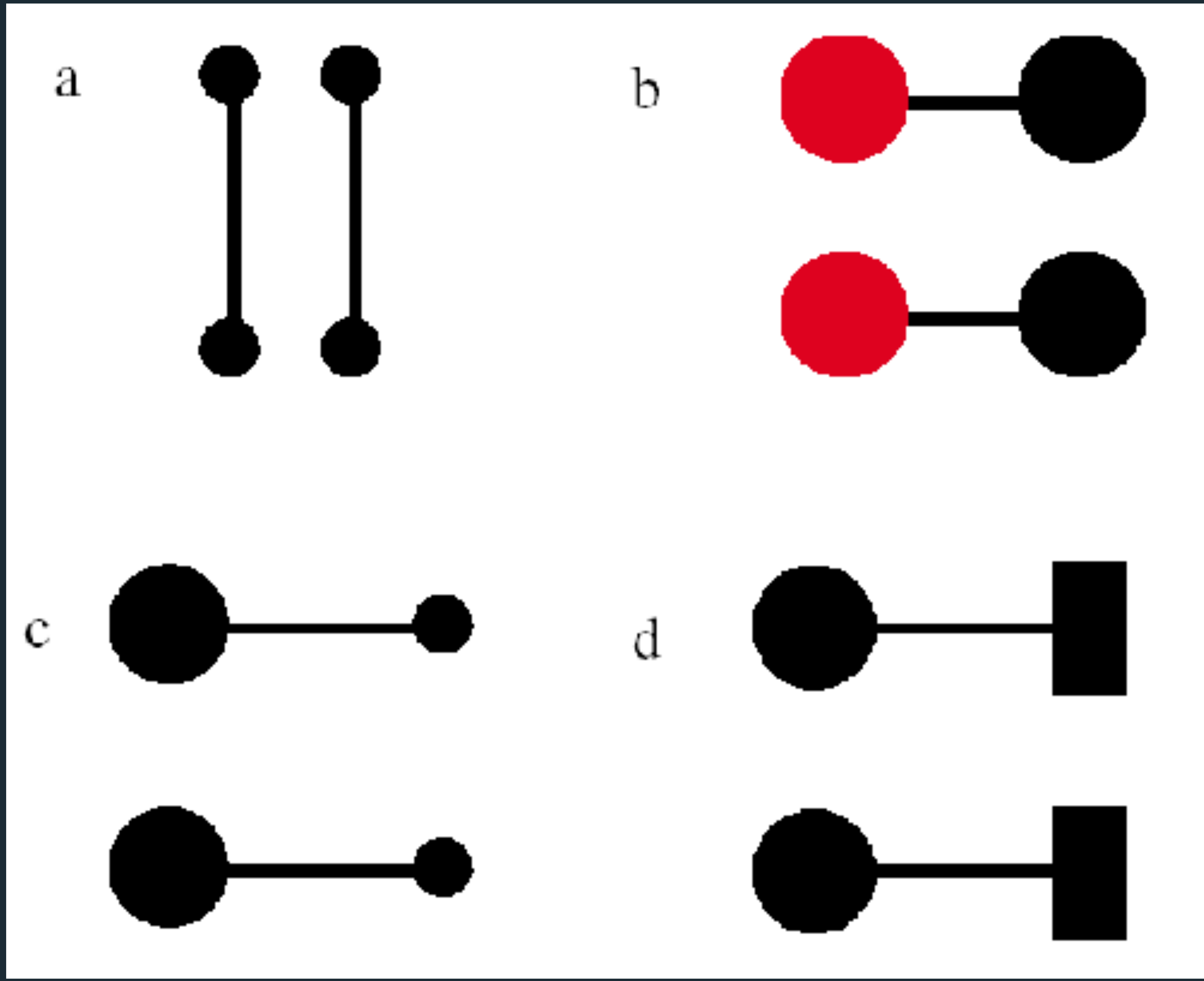
Symmetry

Connectedness

Continuity

Closure

Common Fate



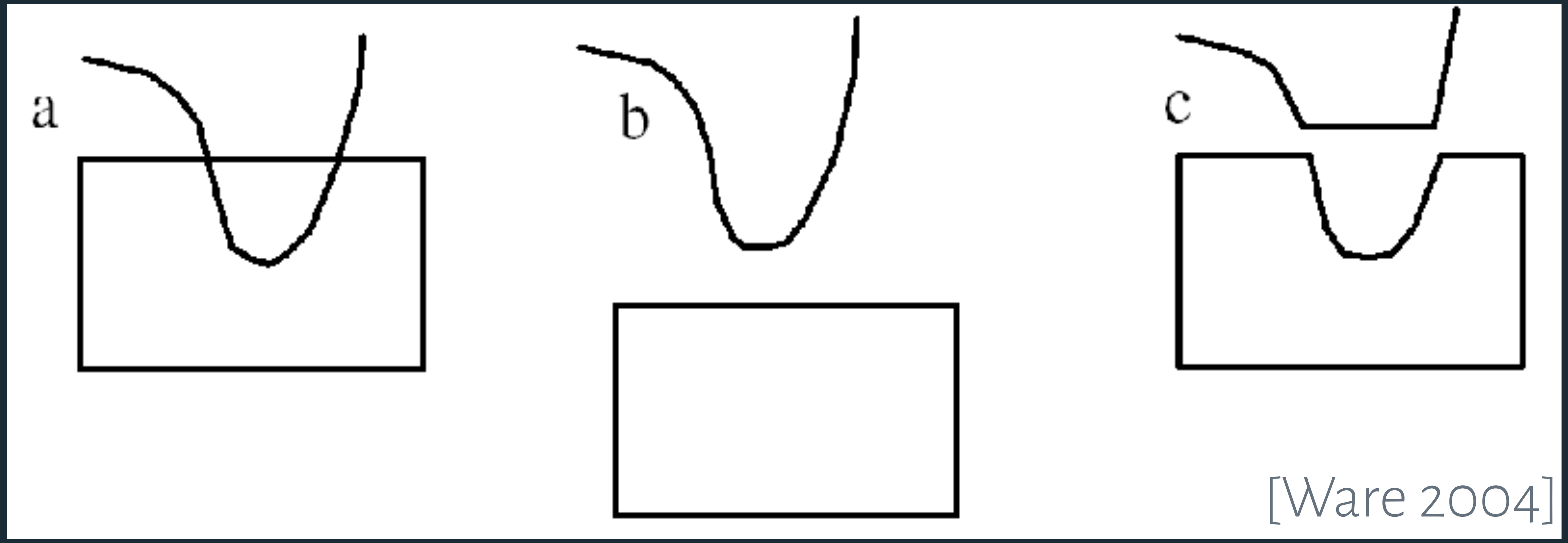
[Ware 2004]

Connectedness overrules proximity, size, color, shape, etc.

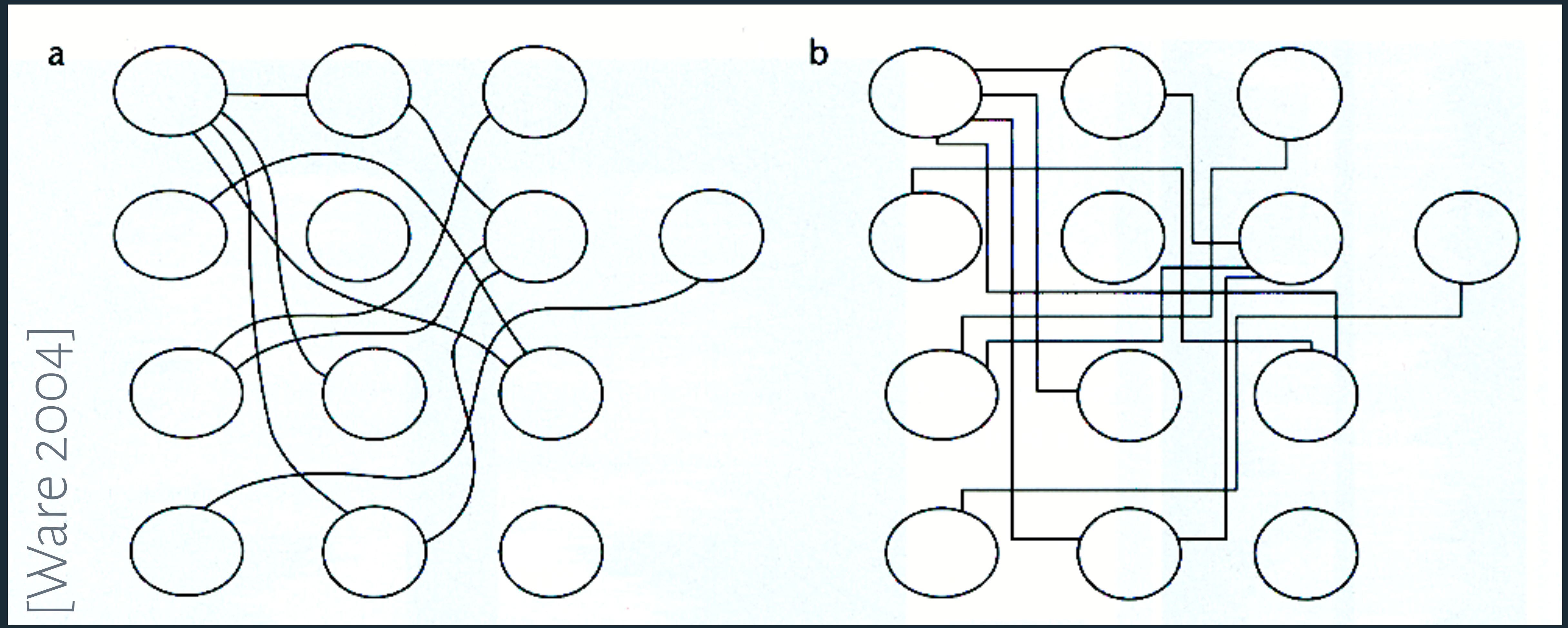
Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

- Figure / Ground
- Proximity
- Similarity
- Symmetry
- Connectedness
- Continuity
- Closure
- Common Fate



We prefer smooth, not abrupt, changes.



Connections are clearer with smooth contours.

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

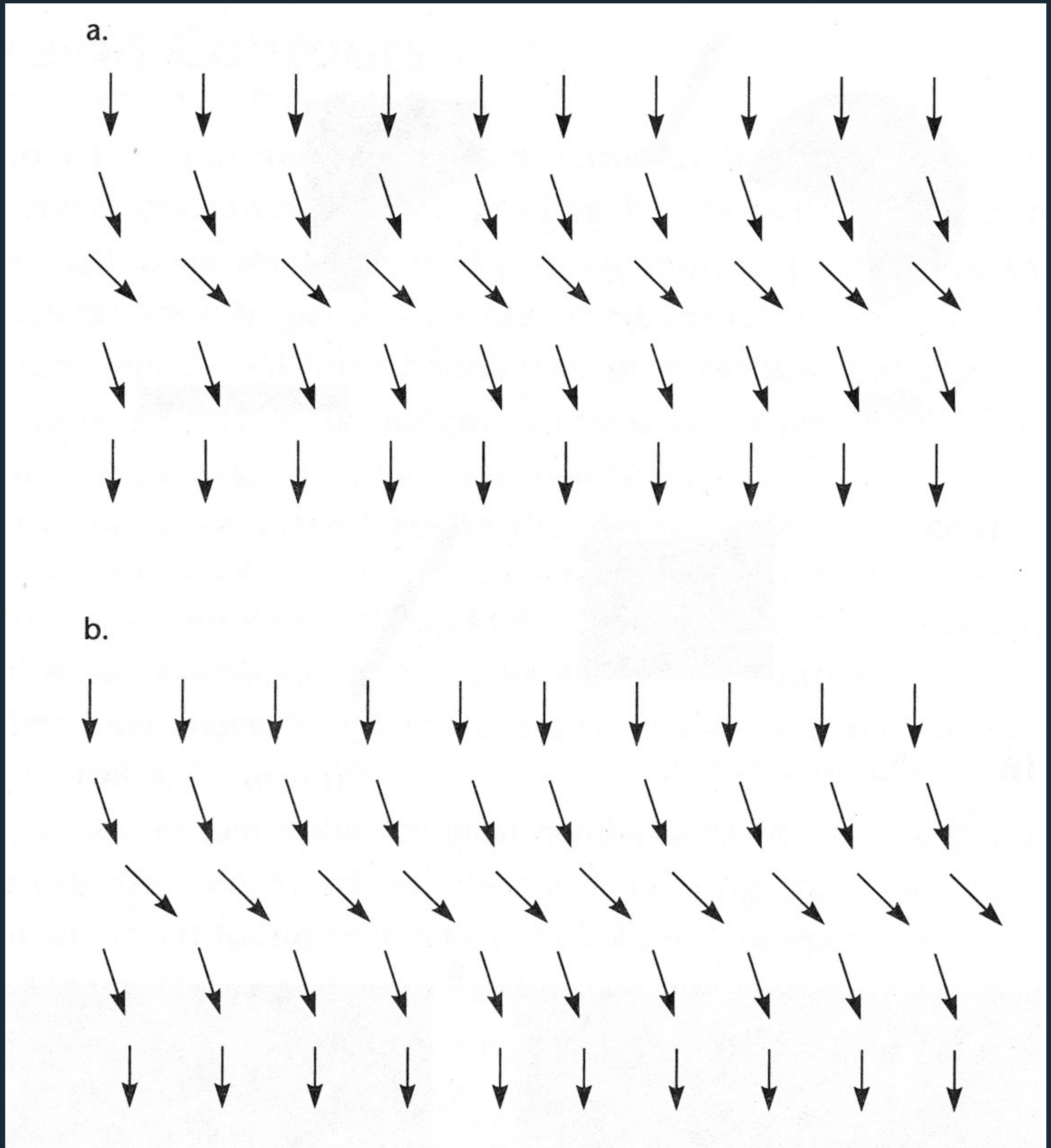
Symmetry

Connectedness

Continuity

Closure

Common Fate



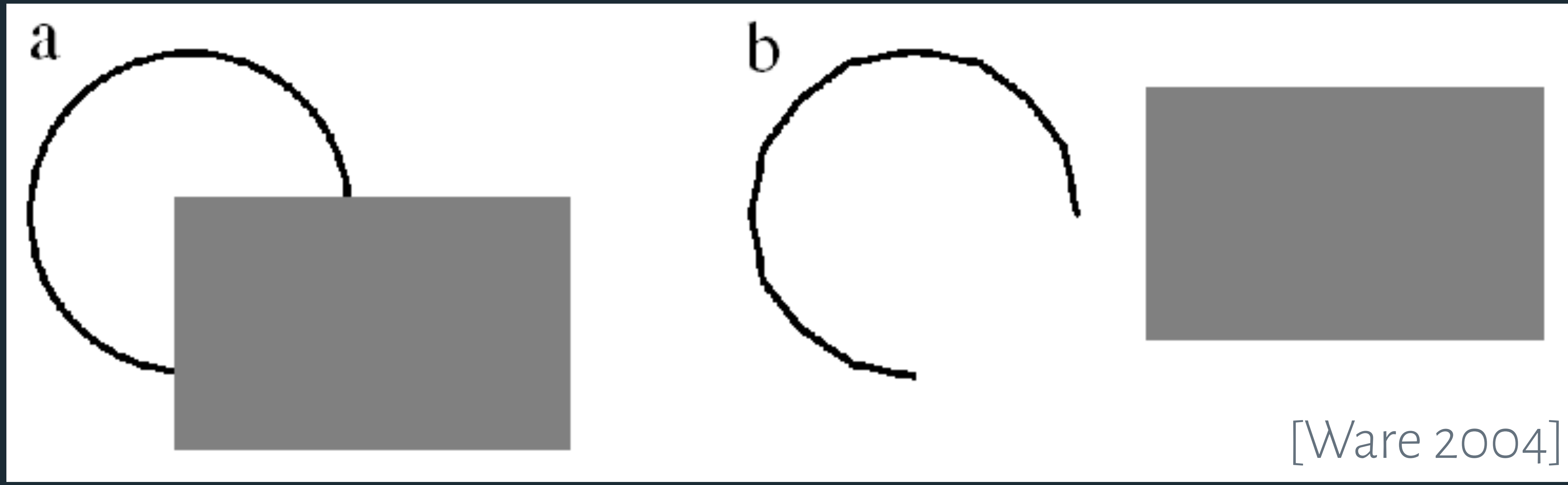
Prefer field that shows smooth continuous contours

[Ware 2004]

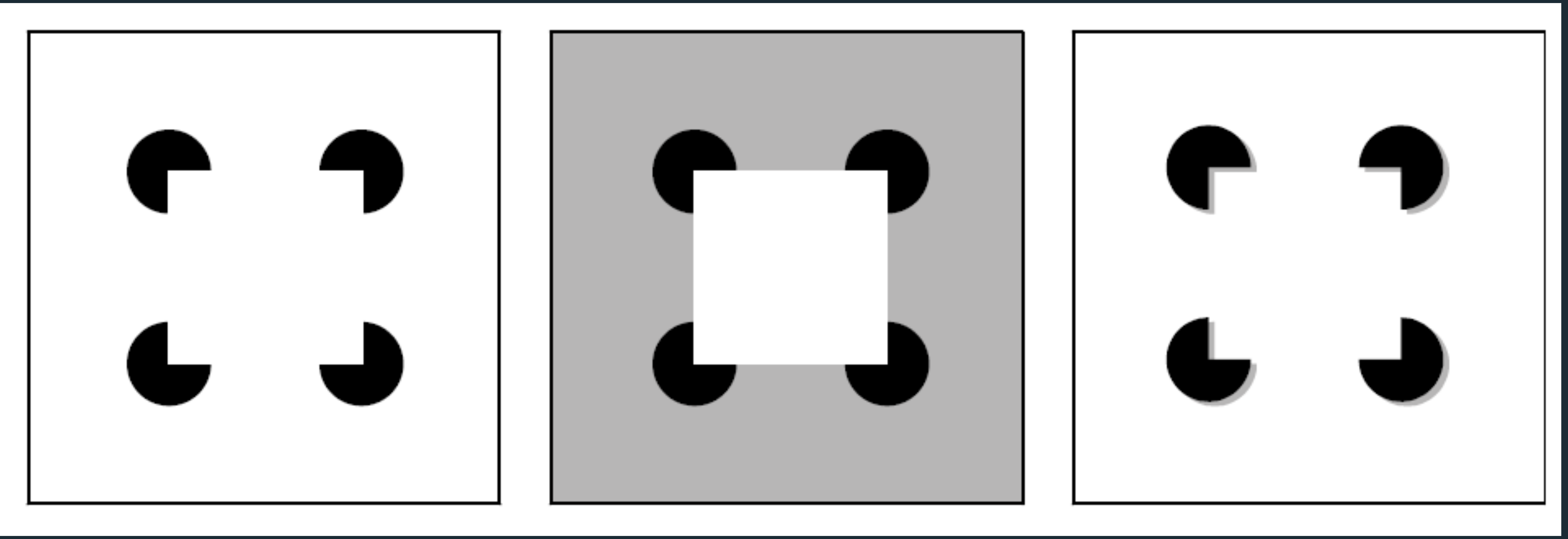
Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

- Figure / Ground
- Proximity
- Similarity
- Symmetry
- Connectedness
- Continuity
- Closure
- Common Fate



We see a circle behind a rectangle, not a broken circle.



[Durand 02]

Illusory contours

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

Figure / Ground

Proximity

Similarity

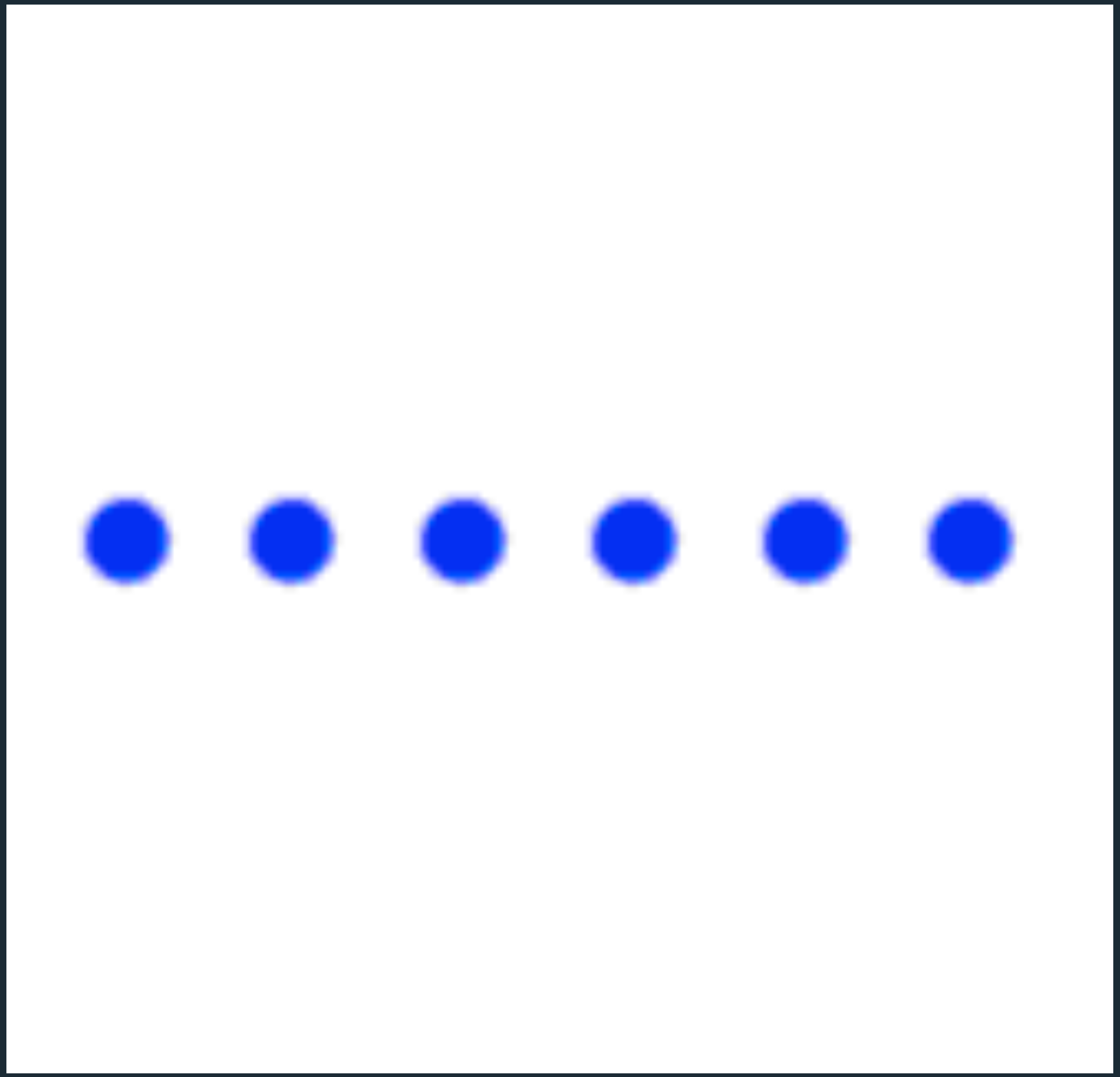
Symmetry

Connectedness

Continuity

Closure

Common Fate



Dots moving together are grouped.

Signal Detection	Use 4-5 steps for most channels, hard for people to distinguish more
Magnitude Estimation	Even a direct map to e.g. area or brightness won't always work.
Pre-Attentive Processing	Use channels that are pre-attentive for callouts e.g. color, shape.
Selective Attention	...but be careful with combinations of channels!
Gestalt Grouping	Use these to improve annotations, coloring, animations.