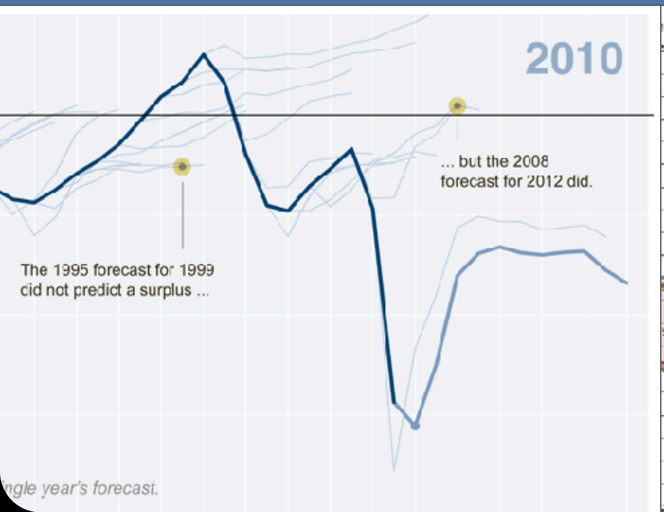
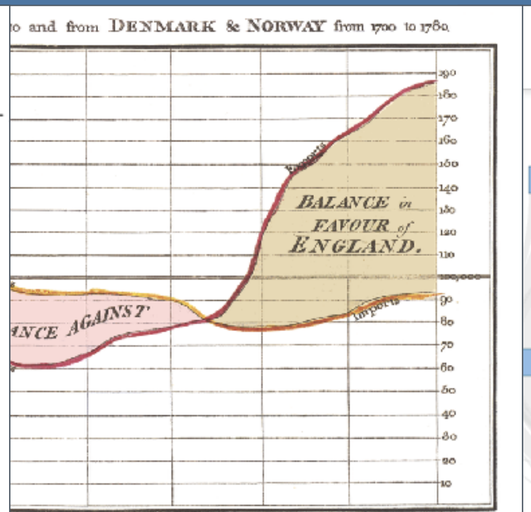
Interactive Visualization & Society

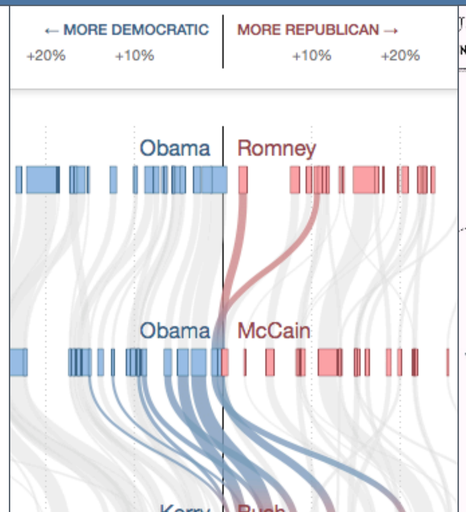
https://vis-society.github.io

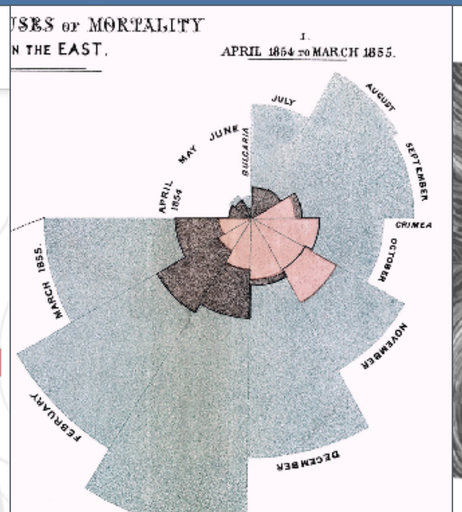
Effective Design: Designing for Graphical Perception

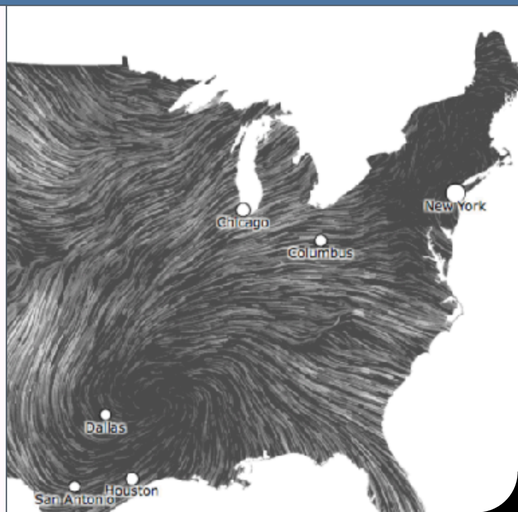
Arvind Satyanarayan, Catherine D'Ignazio, and Crystal Lee







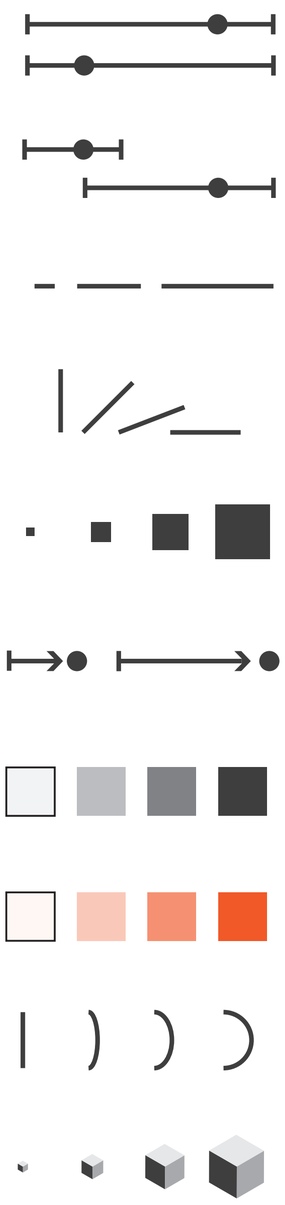




Channels: Expressiveness Types and Effectiveness Ranks

Magnitude Channels: O or Q attributes

- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)



Most

Effectiveness

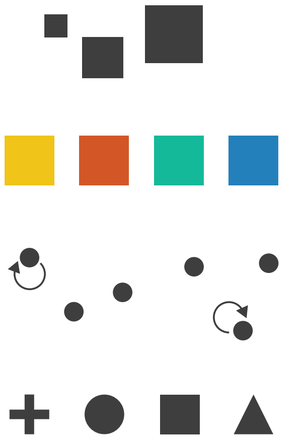
Least

Same

Same

Identity Channels: N attributes

- Spatial region
- Color hue
- Motion
- Shape



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

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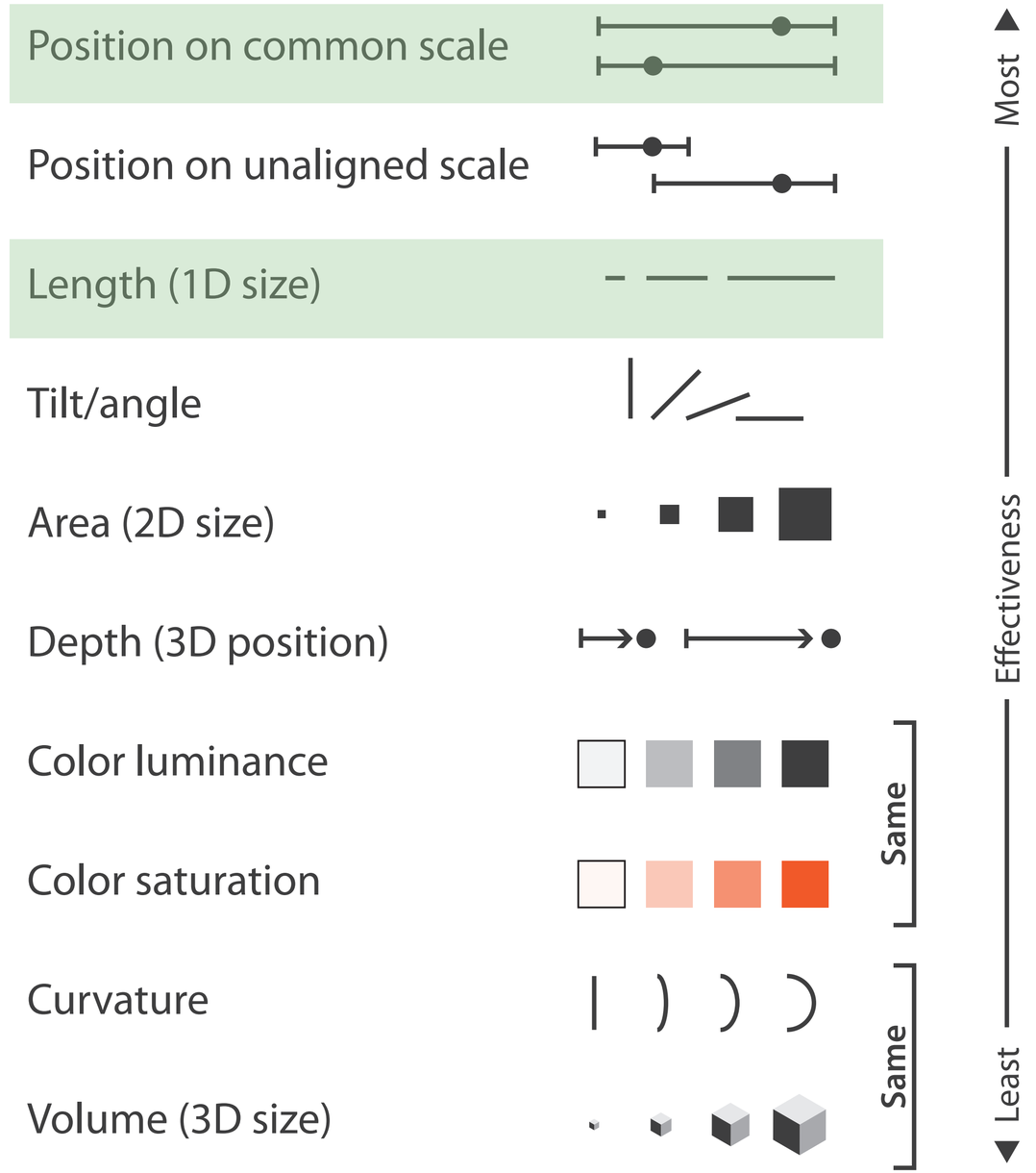

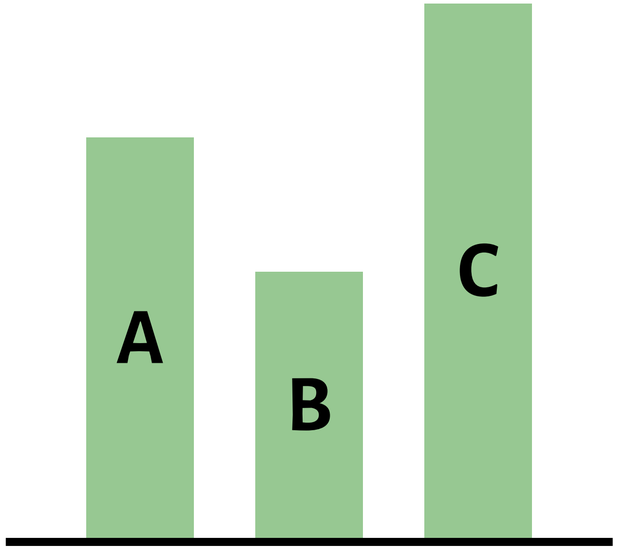

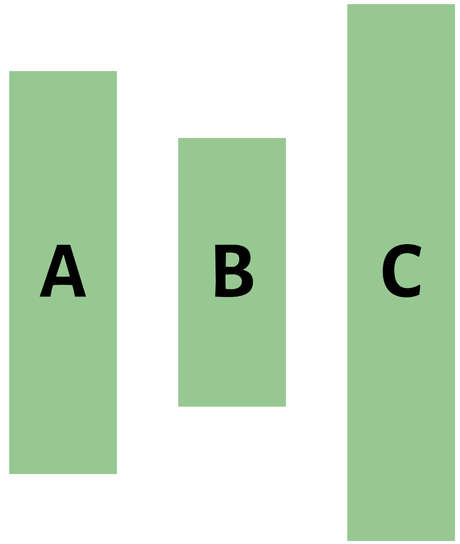

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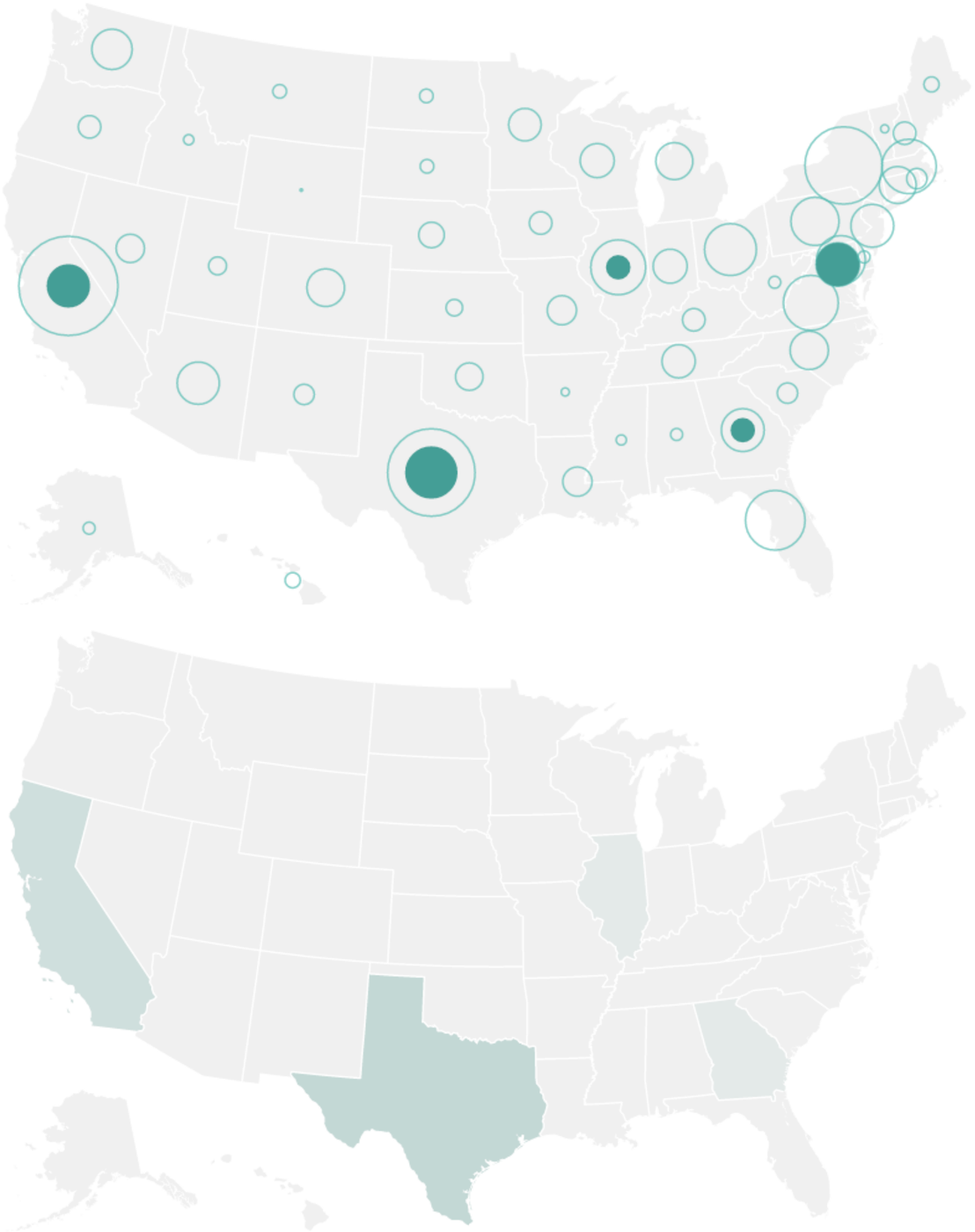
Most ▲ Effectiveness ▼ Least

Same

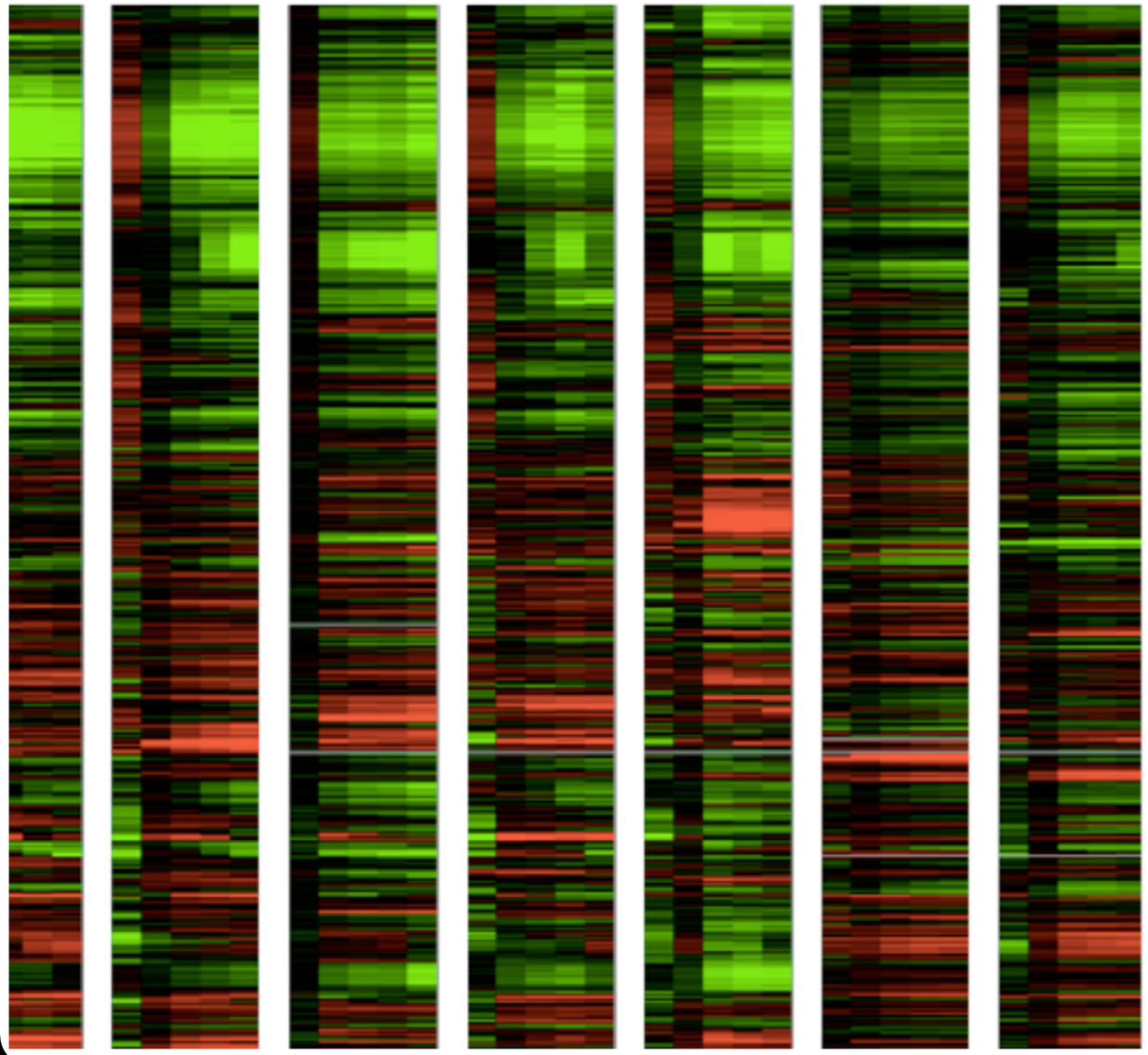
Same

Same

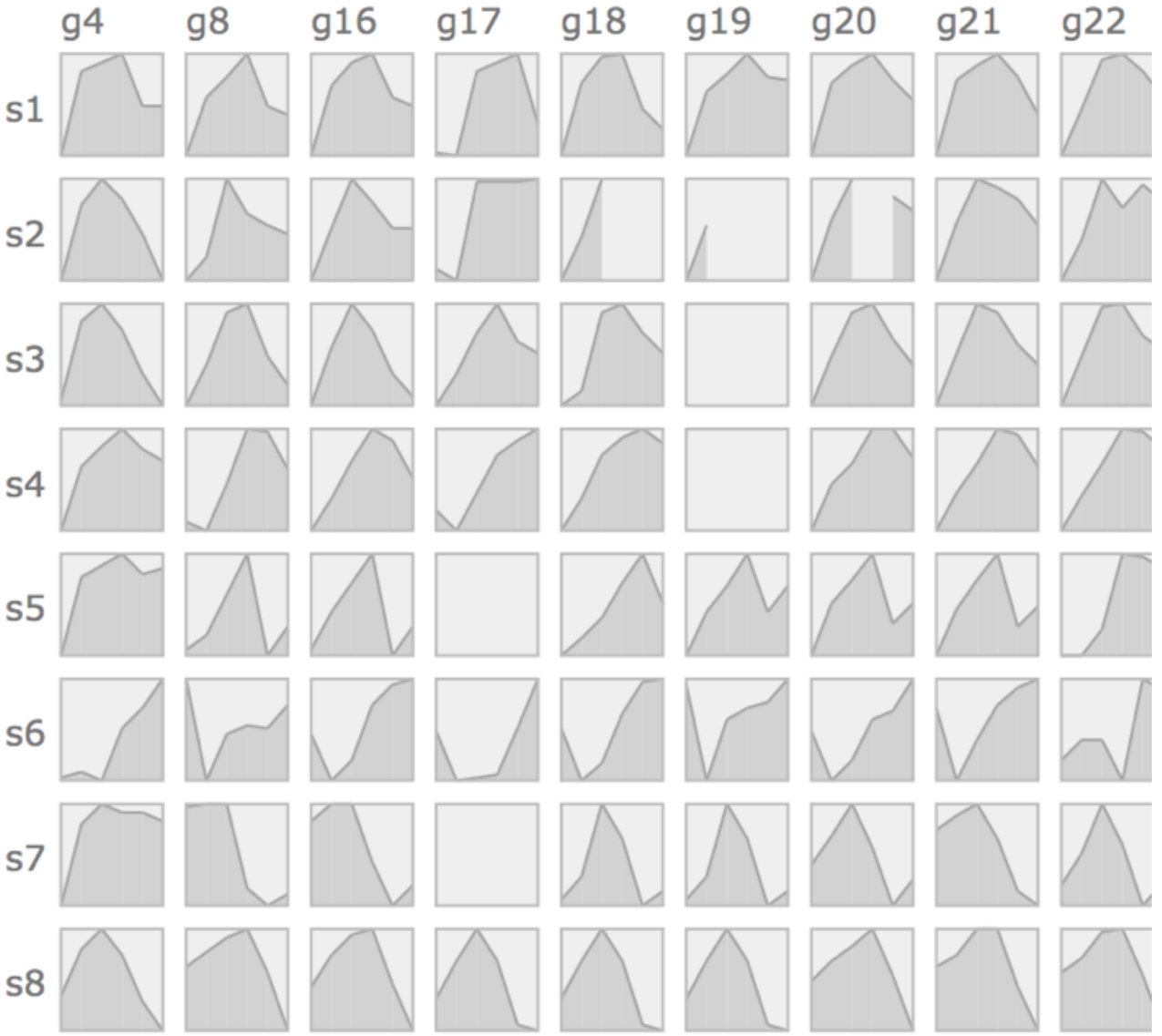


Gene Expression Time-Series [Meyer et al. '10]

Color Encoding



Position Encoding



Artery Visualization [Borkin et al '11]

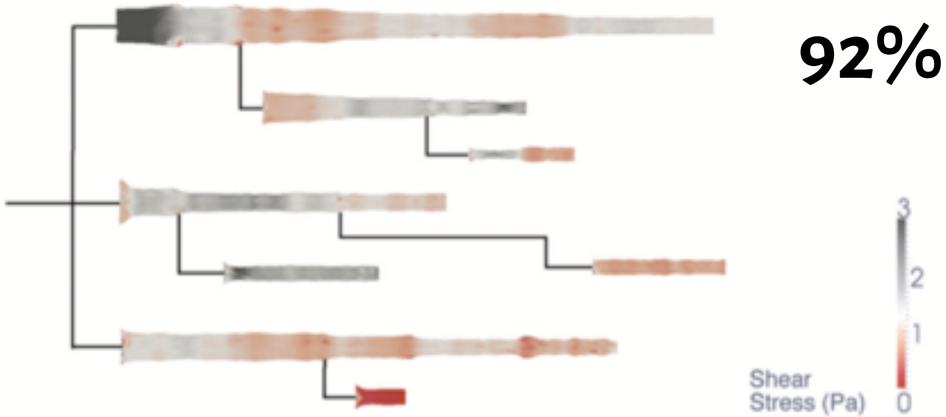
Rainbow Palette

Diverging Palette

2D

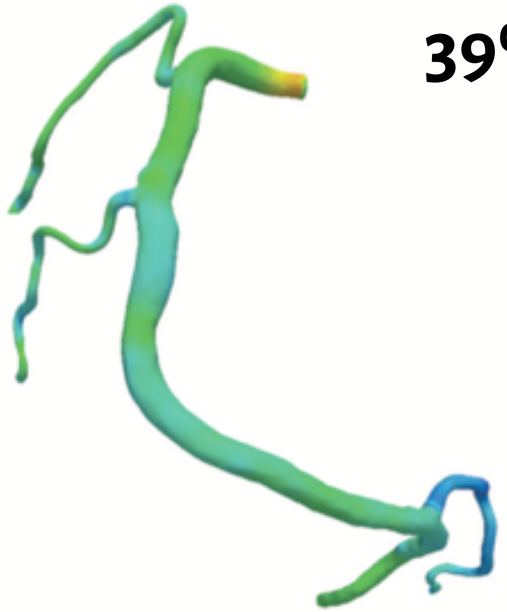
62%

92%

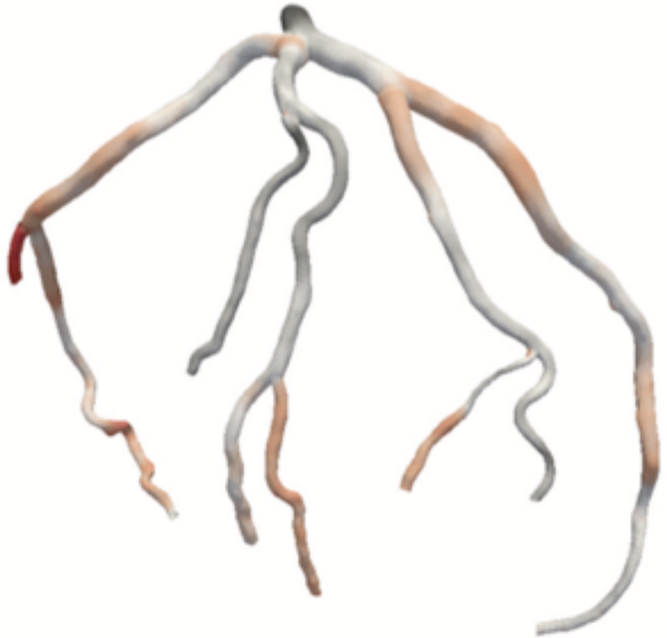


3D

39%



71%



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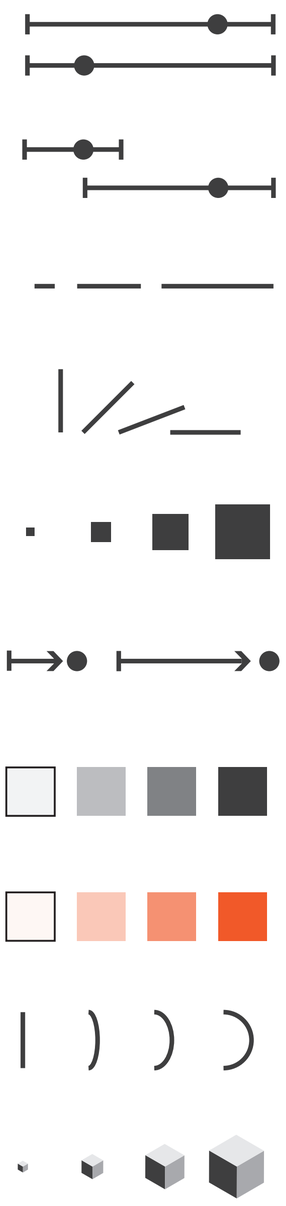

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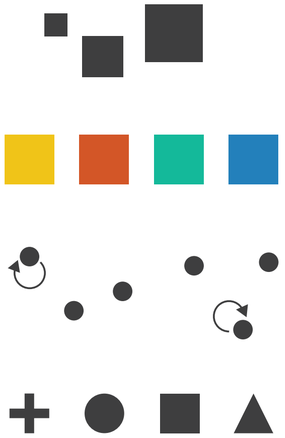


Tamara Munzner, *Visualization Analysis and Design* (2014).

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Signal Detection

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

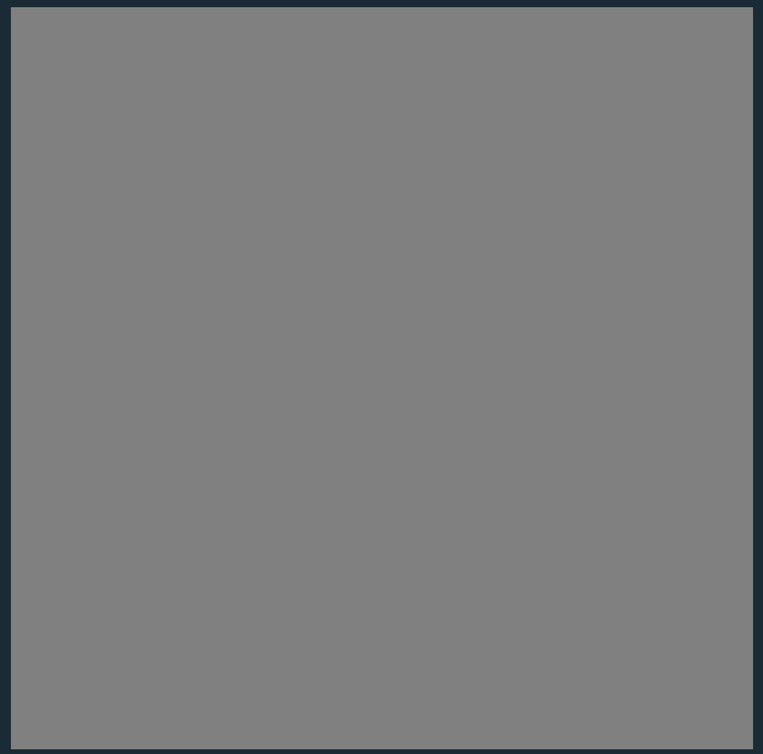
Magnitude Estimation

Pre-Attentive Processing

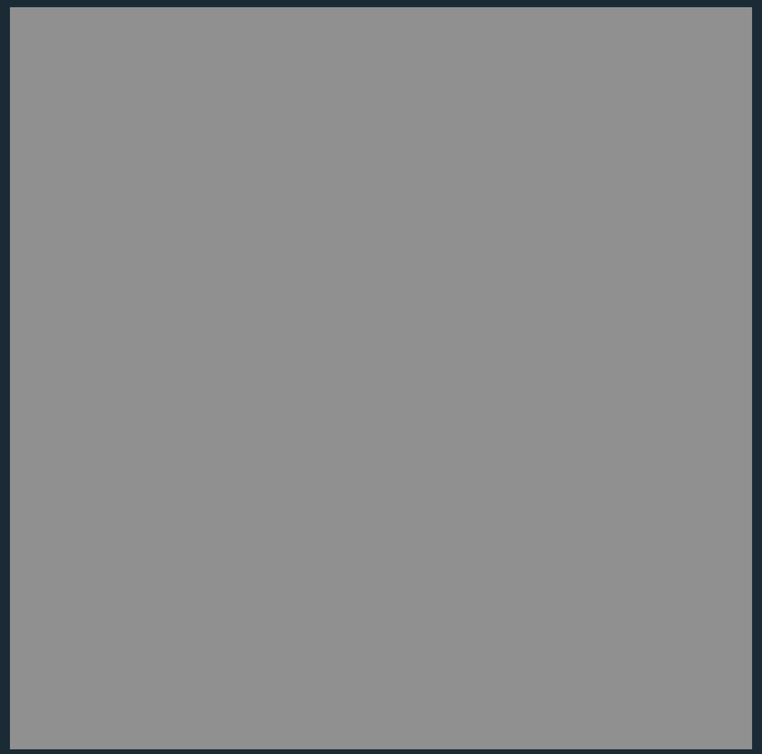
Selective Attention

Gestalt Grouping

Which is brighter?

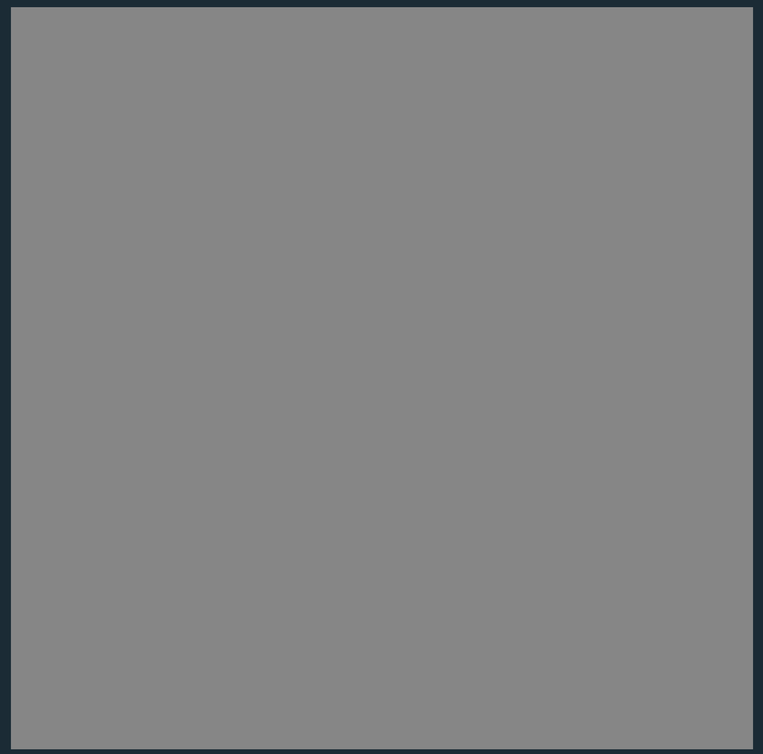


rgb(128, 128, 128)

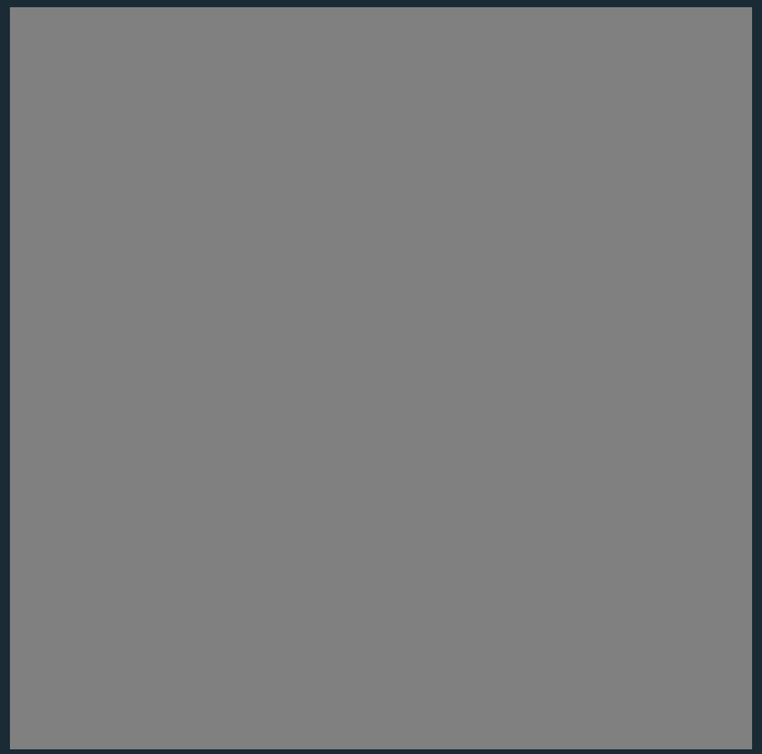


rgb(144, 144, 144)

Which is brighter?



rgb(134, 134, 134)



rgb(128, 128, 128)

Just Noticeable Difference (jnd)

Ernst Weber
(1795–1878)

German physician and a founder of experimental psychology.

Scale Factor
(Determined Empirically)

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

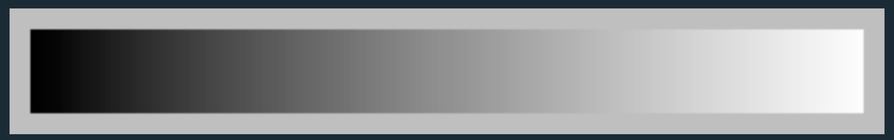
Change of Intensity

Perceived Change

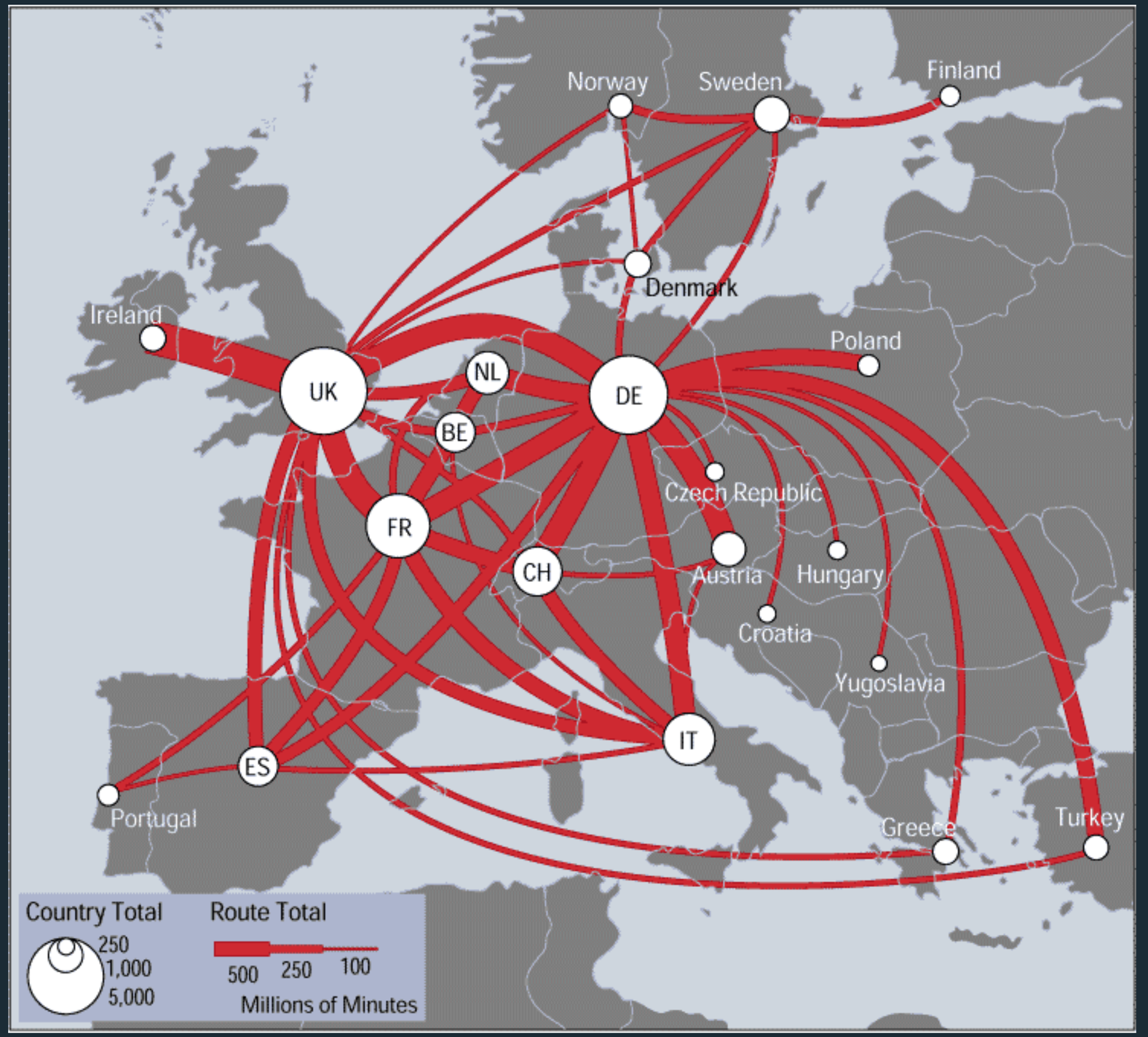
Physical Intensity

Ratios more important than magnitude.

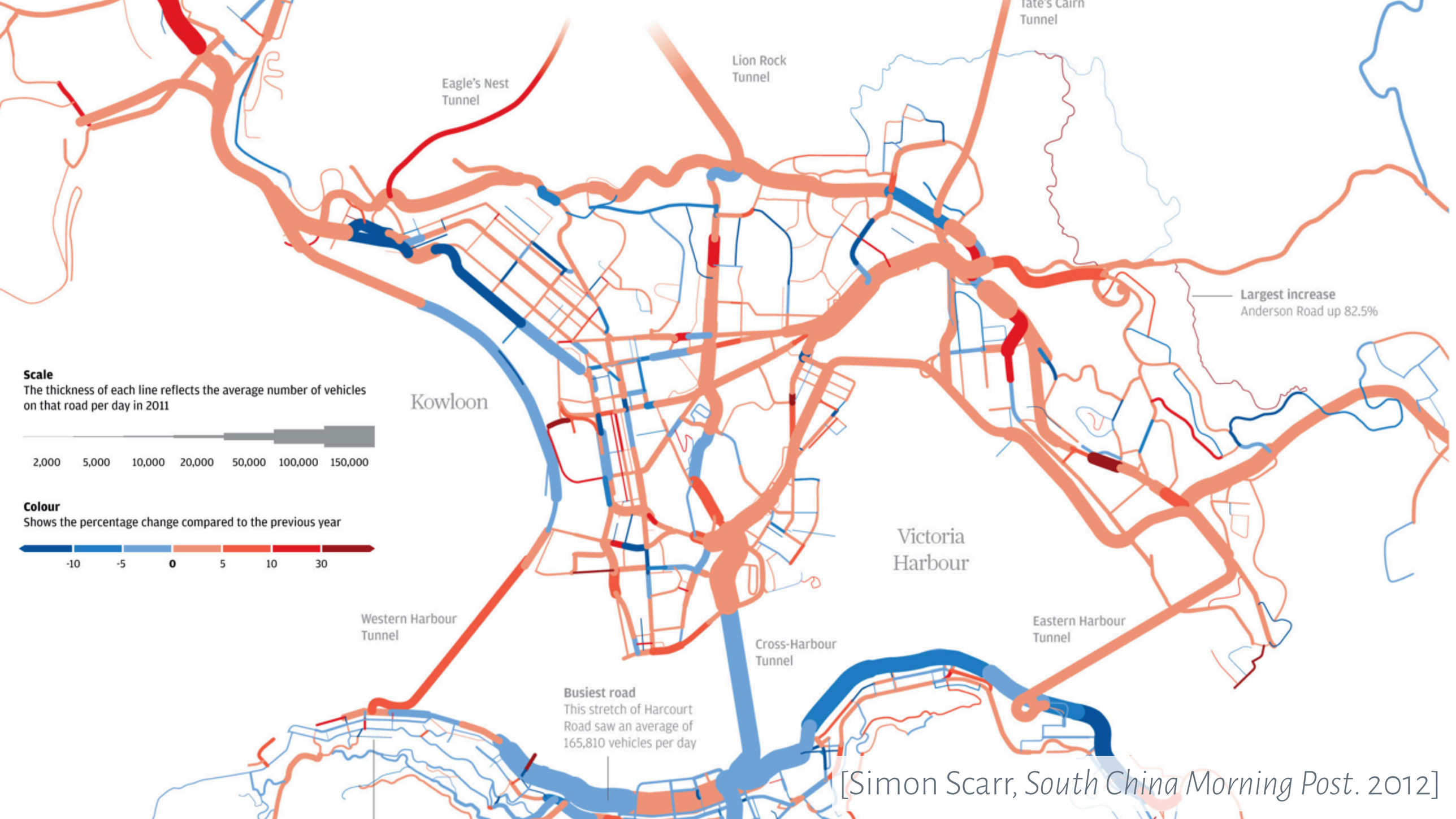
Most continuous variation in stimuli are perceived in discrete steps.



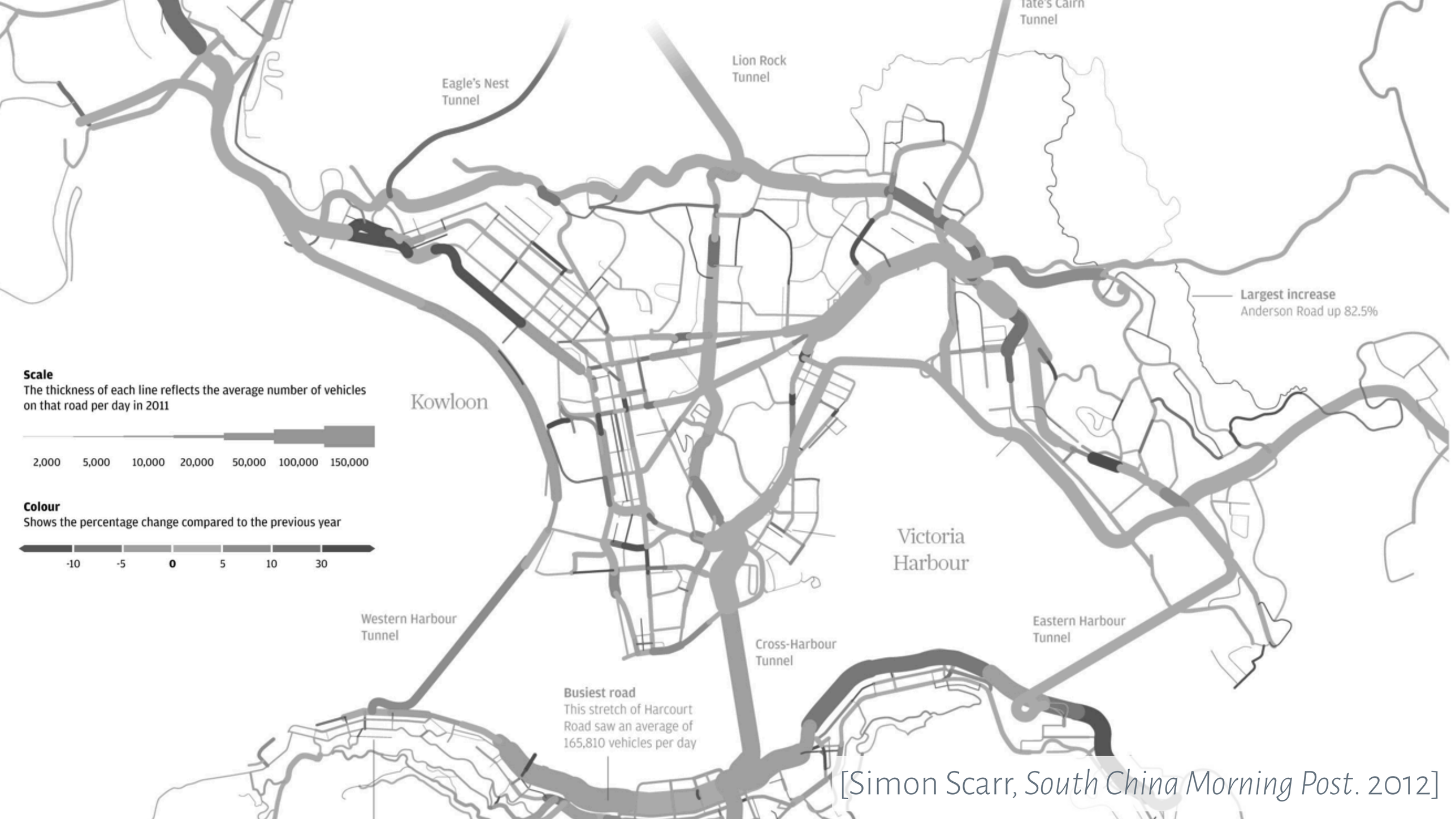
vs.



[Telegeography, Inc. 2000]



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



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Pre-Attentive Processing

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Gestalt Grouping

Signal Detection

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

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Accuracy: how correctly can we read off values?

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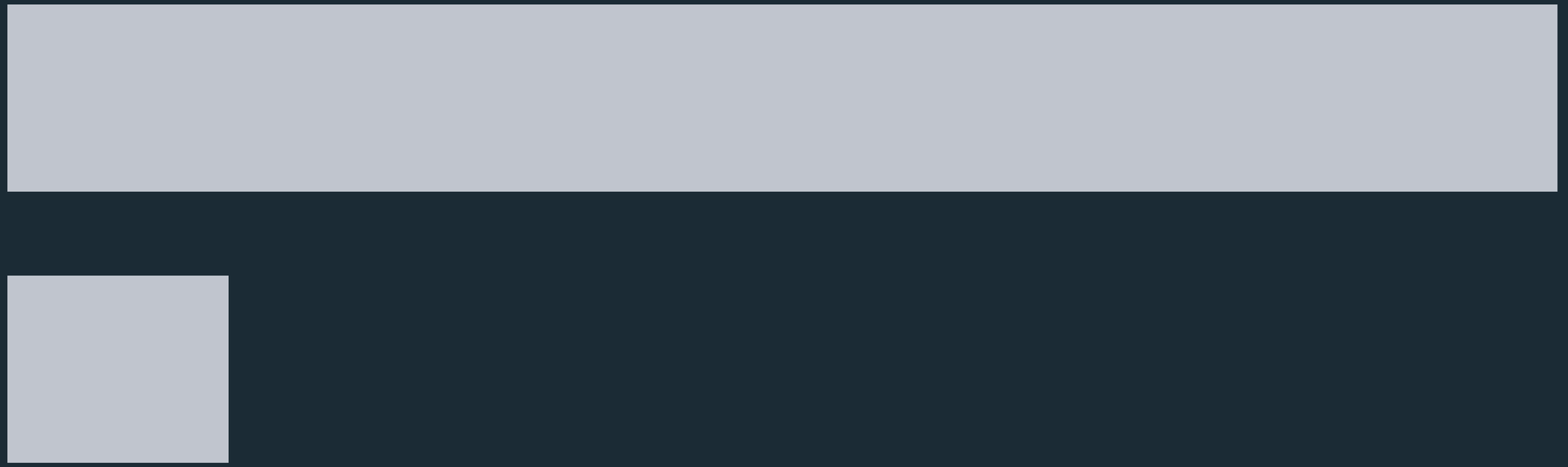
Gestalt Grouping

How much larger is the area of the big circle?

How much longer is the big bar?



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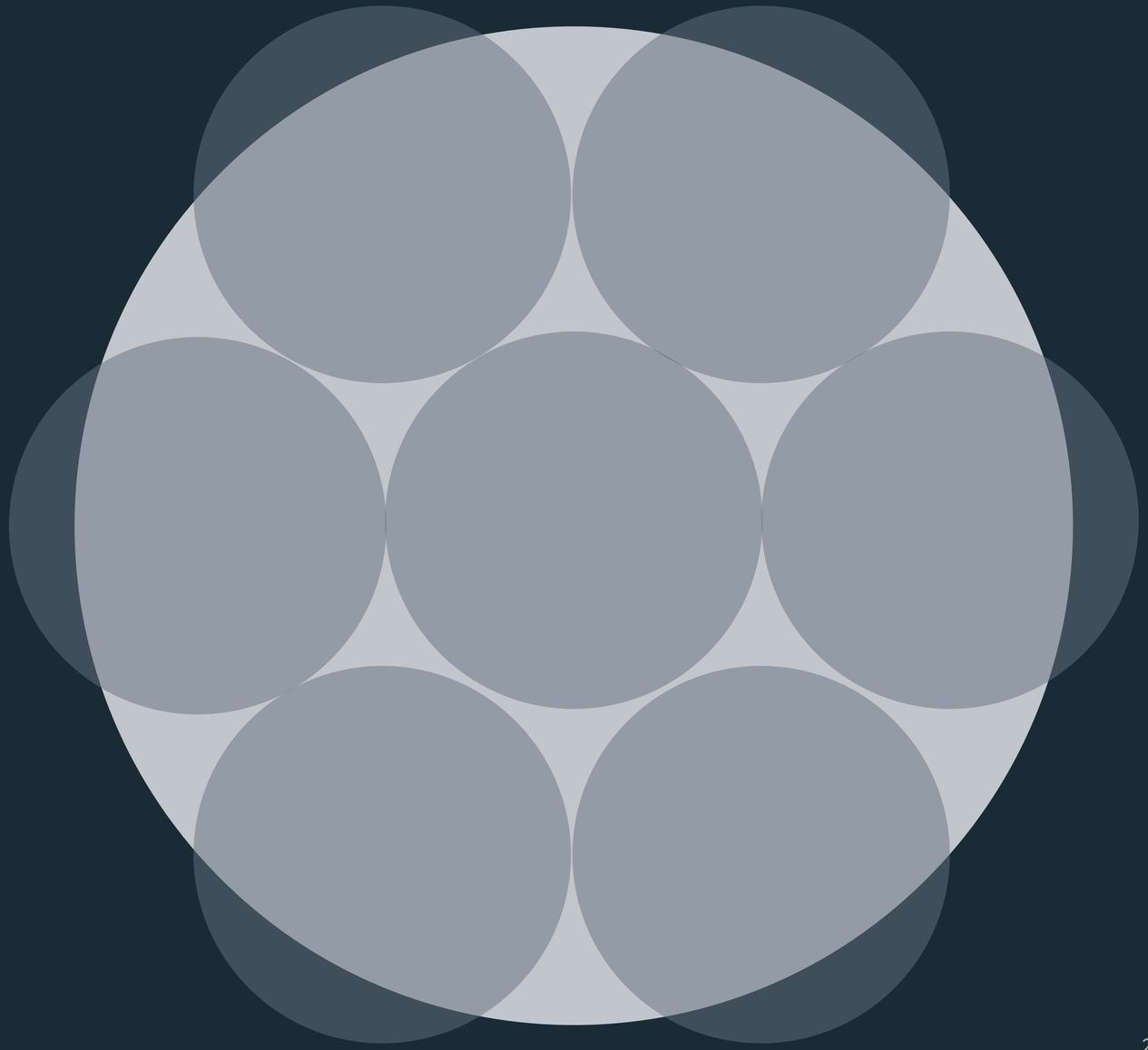
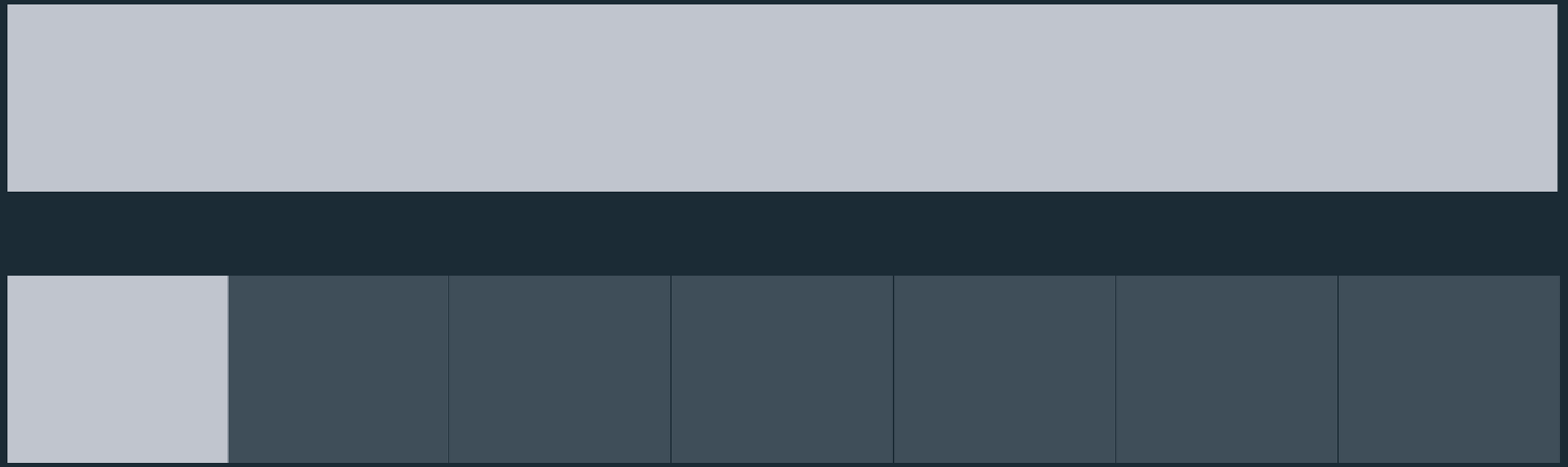


How much longer is the big bar?



Stevens' Power Law

S. S. Stevens (1906–1972)

American psychologist, founded Harvard's Psychoacoustics Lab.

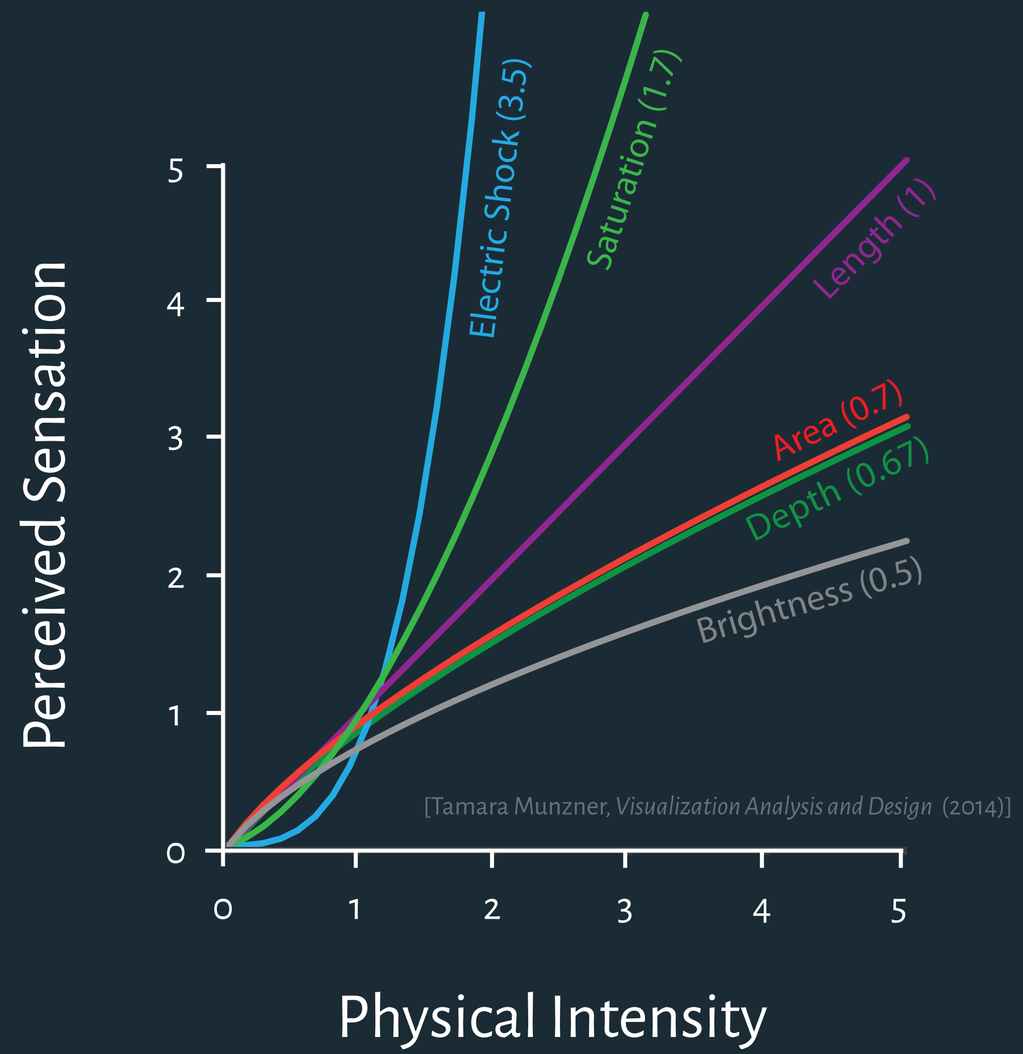
Physical Intensity

$$S = I^p$$

Perceived Sensation

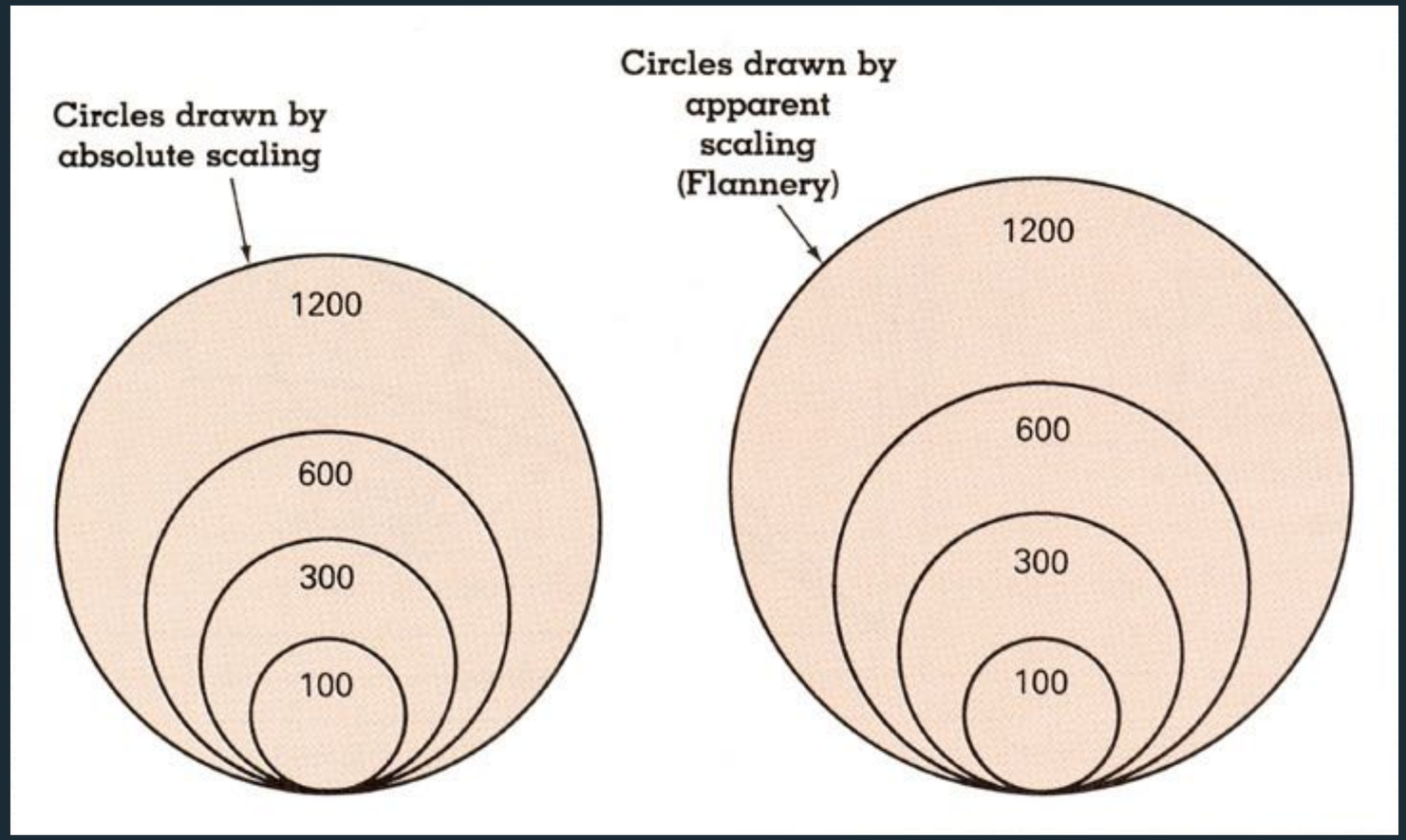
Exponent
(Determined Empirically)

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



Predicts bias, not necessarily accuracy!

Stevens' Power Law



[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]

$S = 0.98A^{0.87}$ [Flannery 71]

Signal Detection

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

Selective Attention

Gestalt Grouping

How many 3's?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496 86

[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

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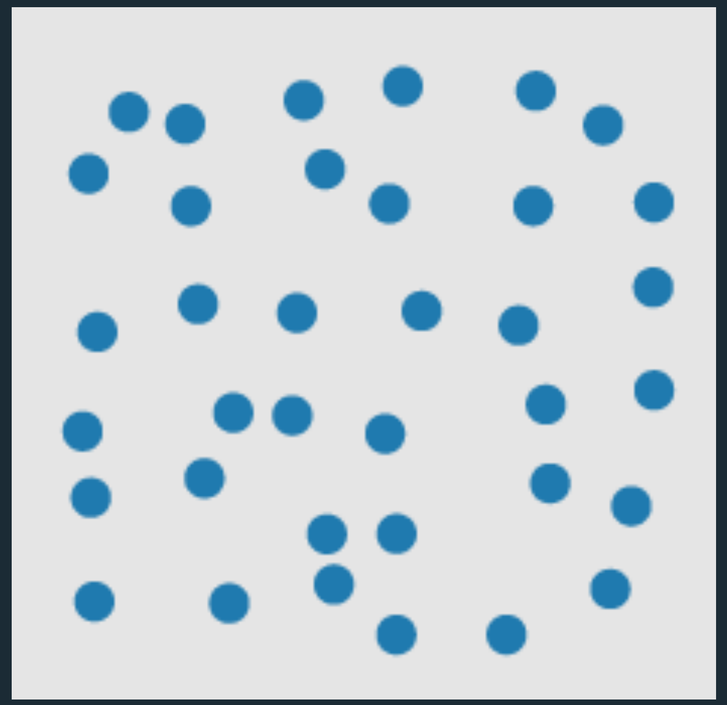
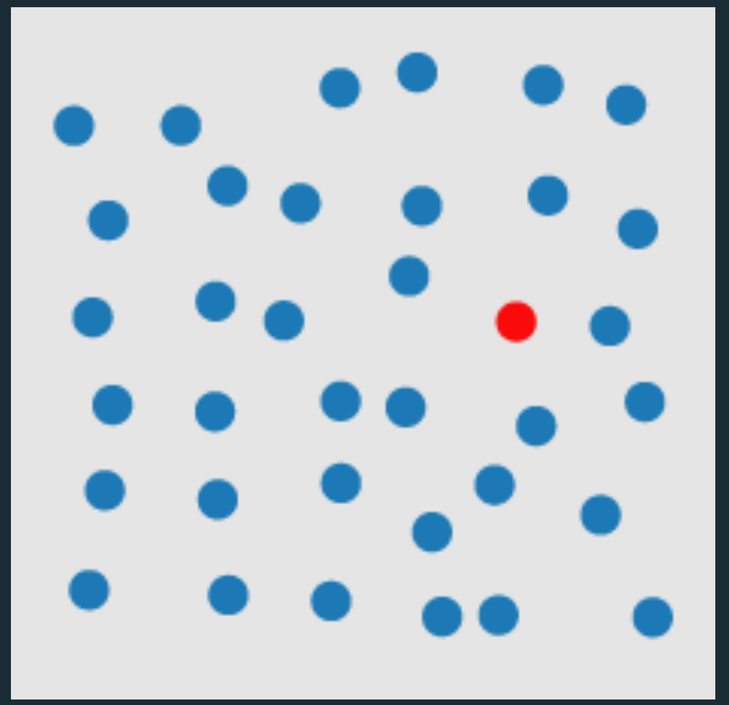
Visual Pop-Out: Color





[Healey & Enns 2012]

Pre-Attentive Processing

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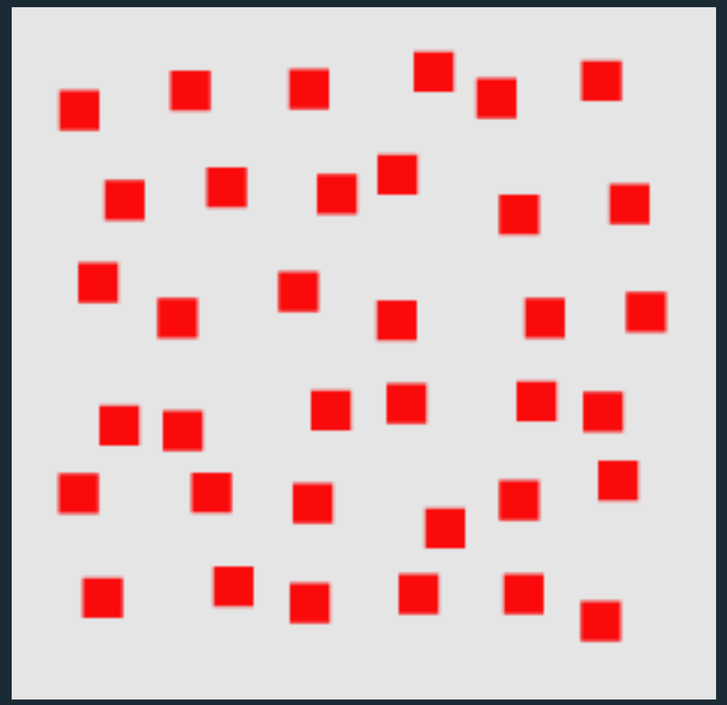
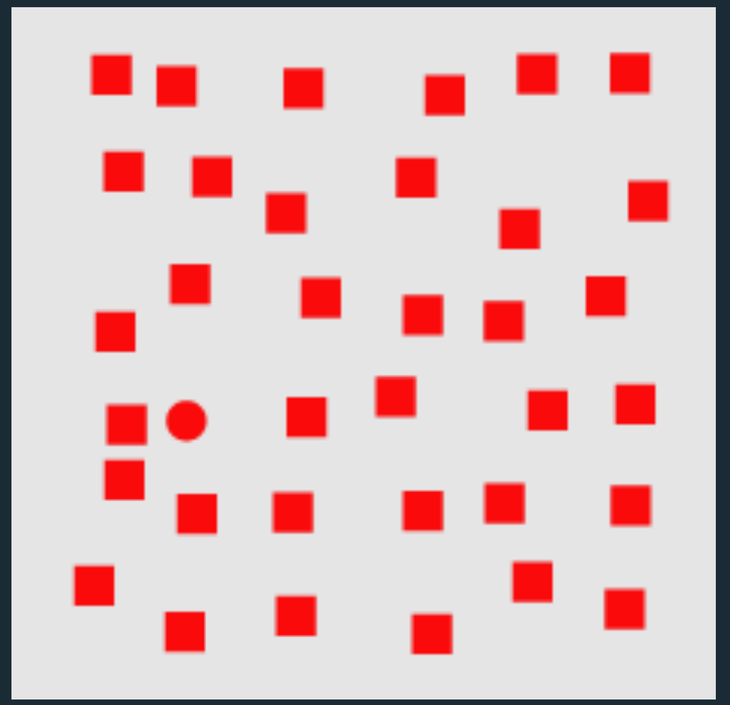
Visual Pop-Out: Color

Visual Pop-Out: Shape





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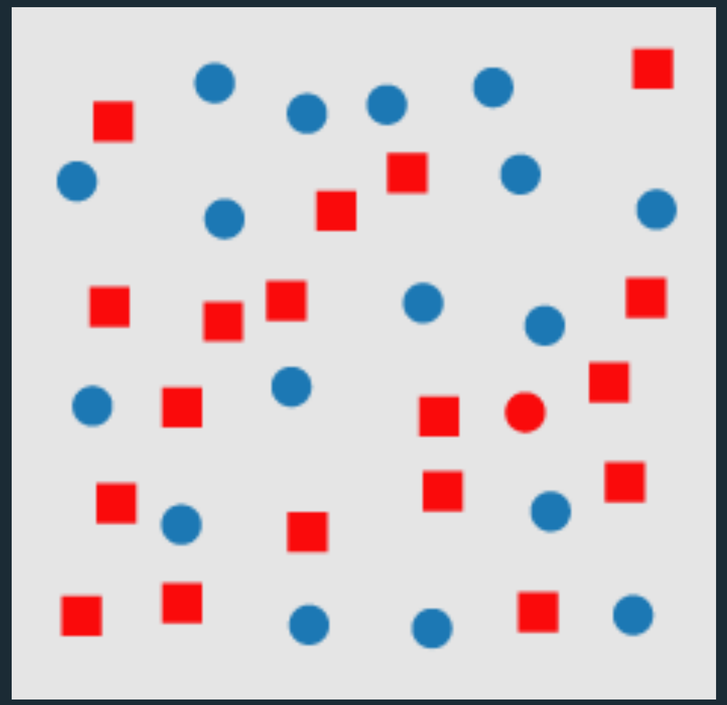
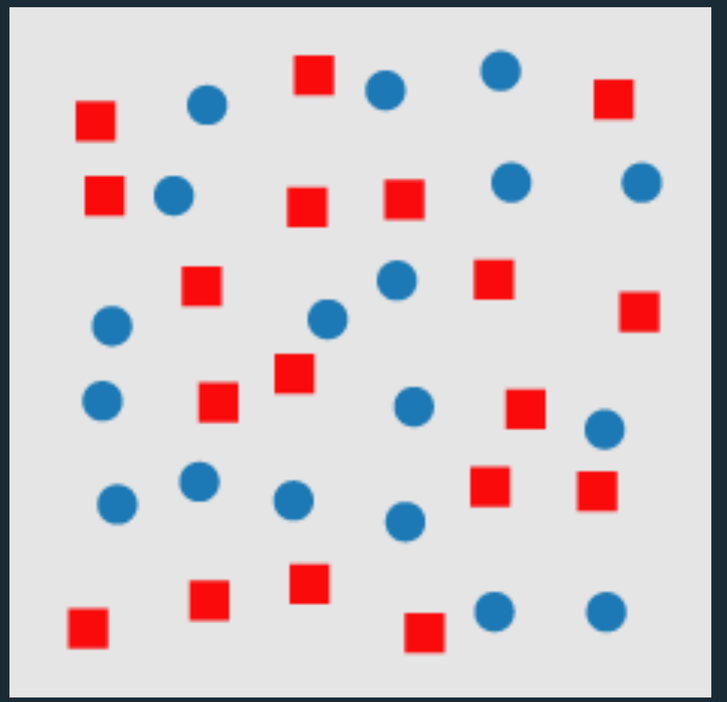
Visual Pop-Out: Color

Visual Pop-Out: Shape

Feature Conjunctions





[Healey & Enns 2012]

Pre-Attentive Processing

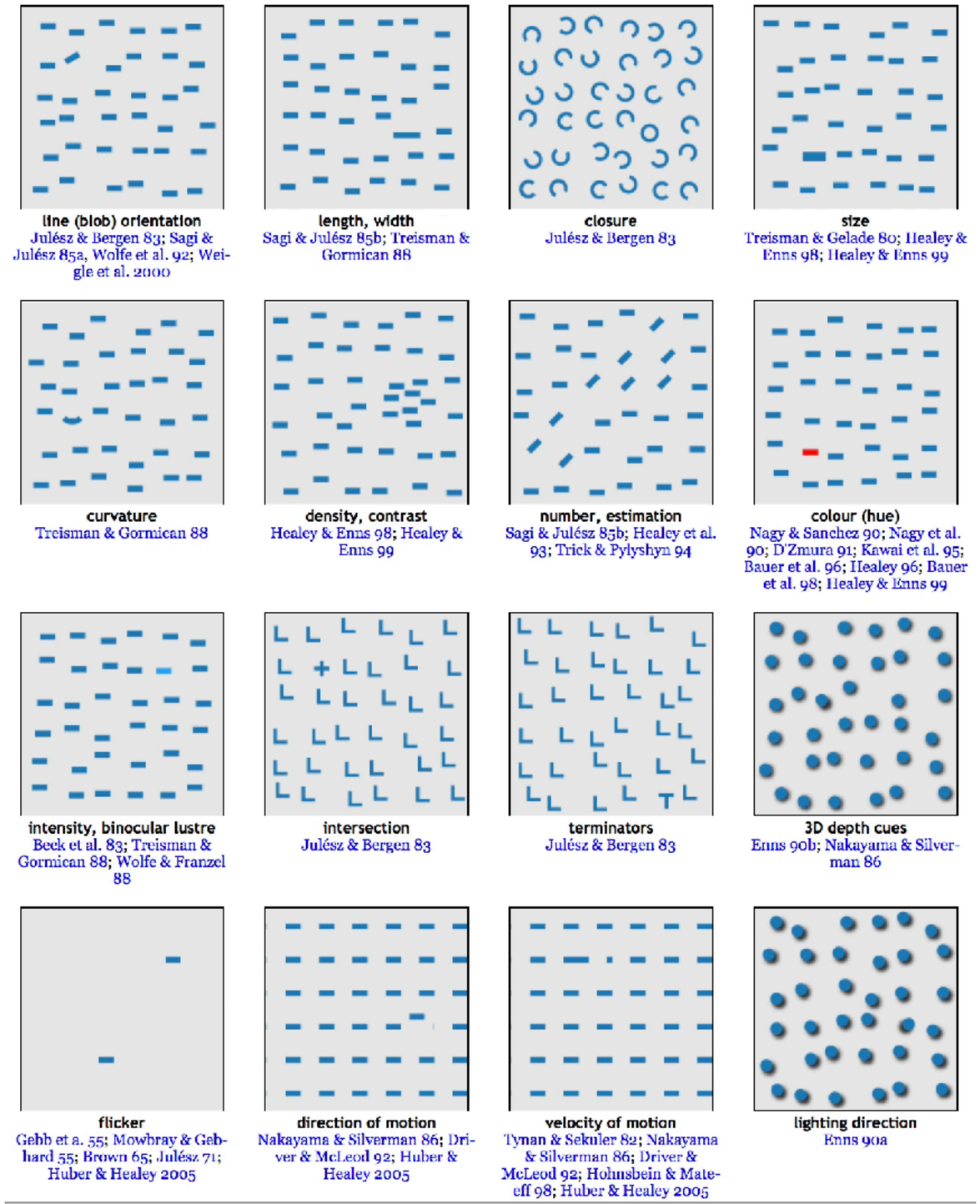
Visual Pop-Out: Color

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



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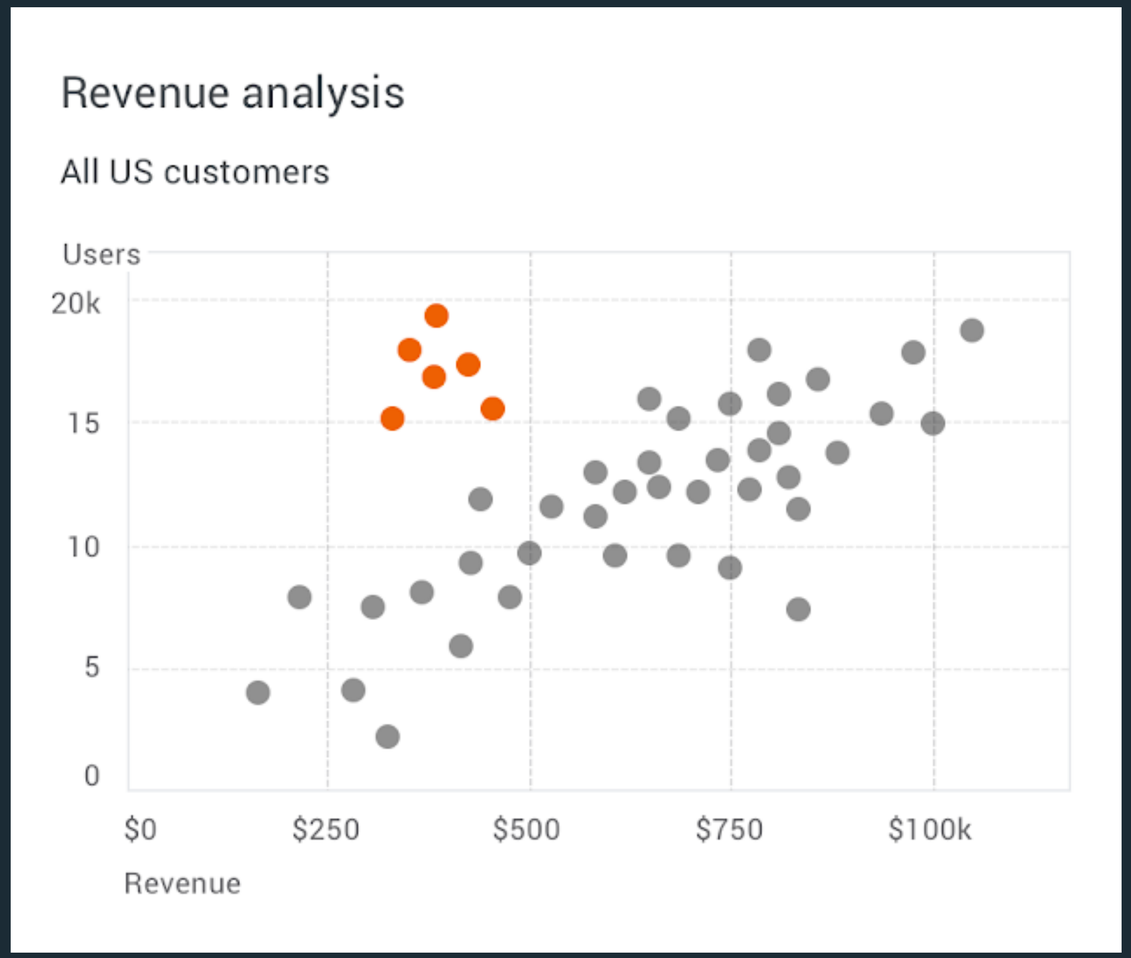

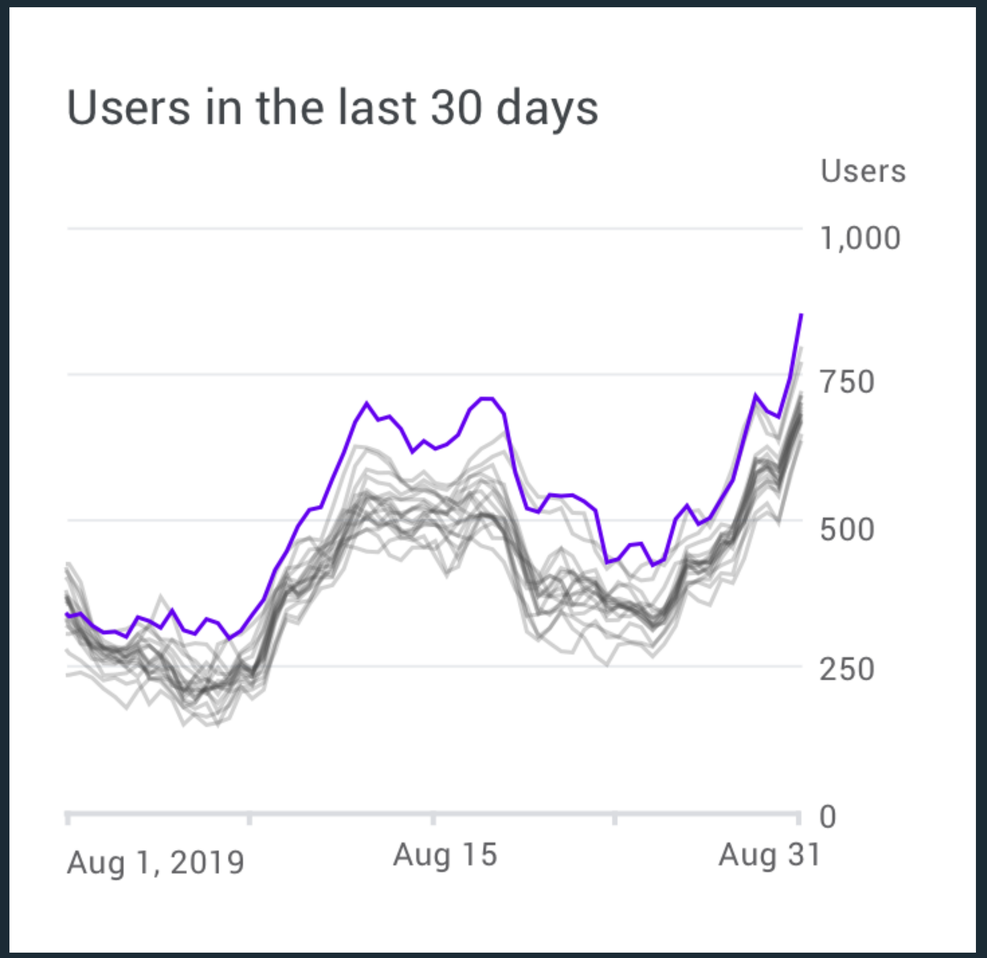

[Google Material Design]

Signal Detection

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Selective Attention

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Selective Attention

Separability: how much interaction occurs between attributes?

Gestalt Grouping

One-Dimensional: Lightness

White

White

Black

White

Black

White

Black

Black

White

White

One-Dimensional: Shape

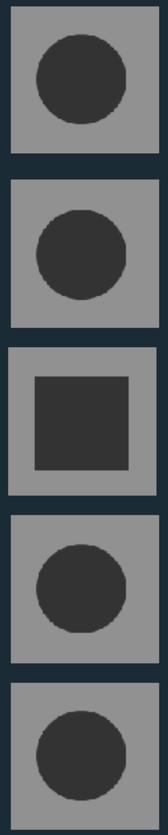
Square

Circle

Circle

Square

Circle



Circle

Circle

Square

Circle

Circle

Redundant: Shape & Lightness

White

Black

Black

White

Black

Circle

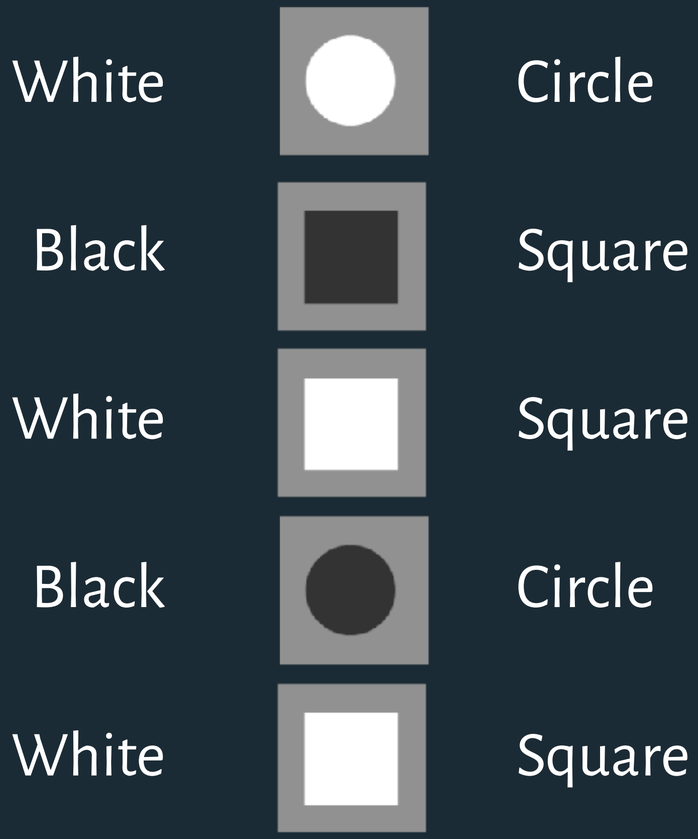
Square

Square

Square

Circle

Orthogonal: Shape & Lightness



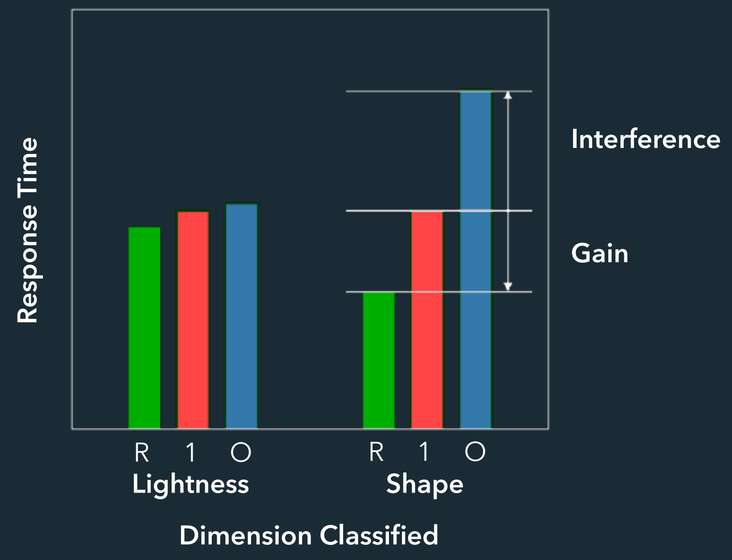
Principles

Redundancy Gain

Improved performance when both dimensions provide the same information.

Filtering Interference

Difficulty in ignoring one dimension while attending to another.



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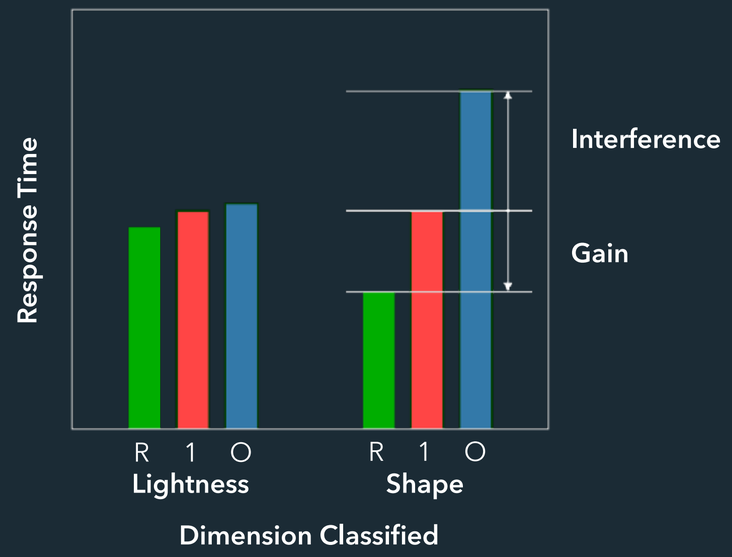

Types of Dimensions

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.

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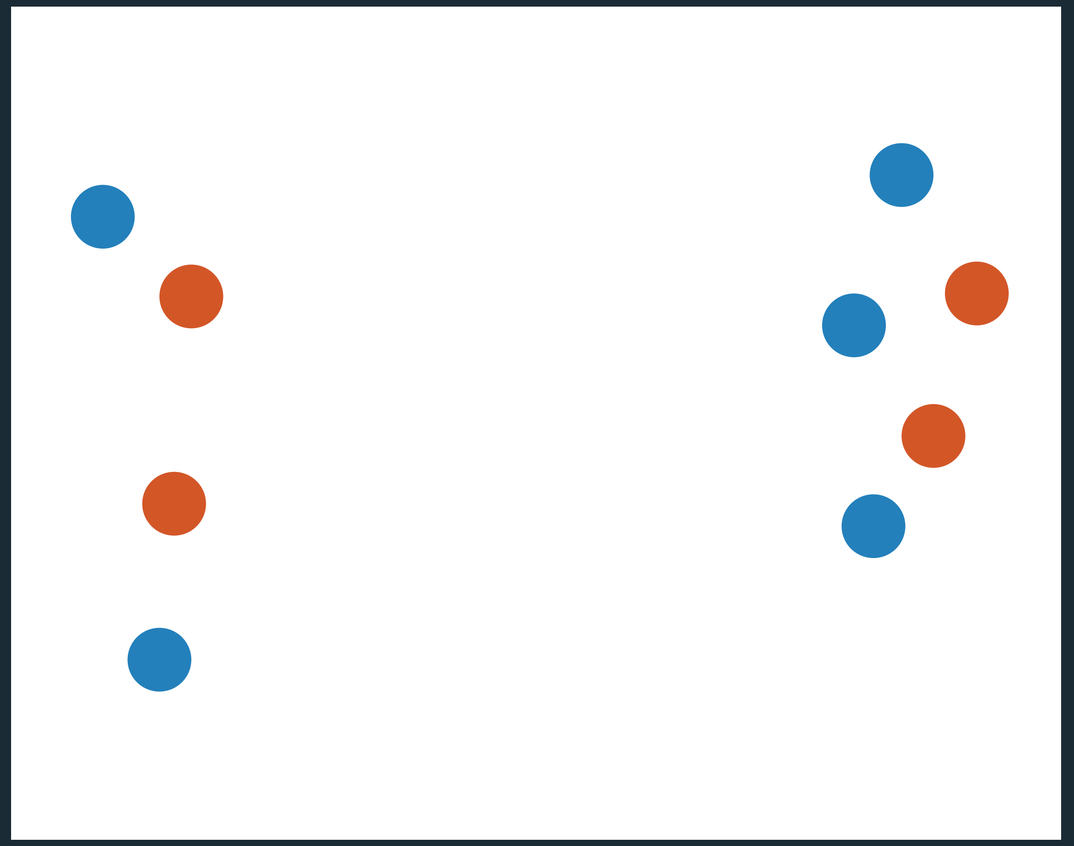
One dimension is separable from the other, but not vice versa.

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?

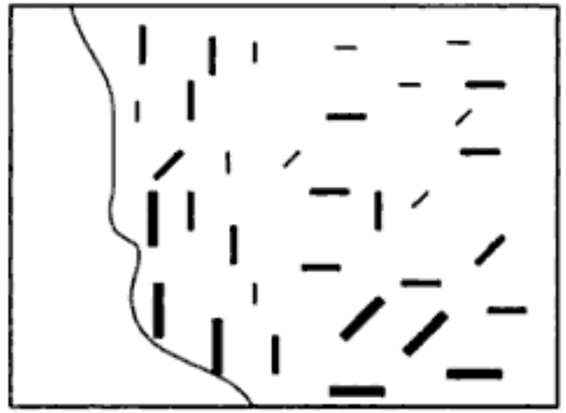


FIGURE 3.36. A map of temperature and precipitation using symbol size and orientation to represent data values on the two variables.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

Filtering interference and redundancy gain.

Configural

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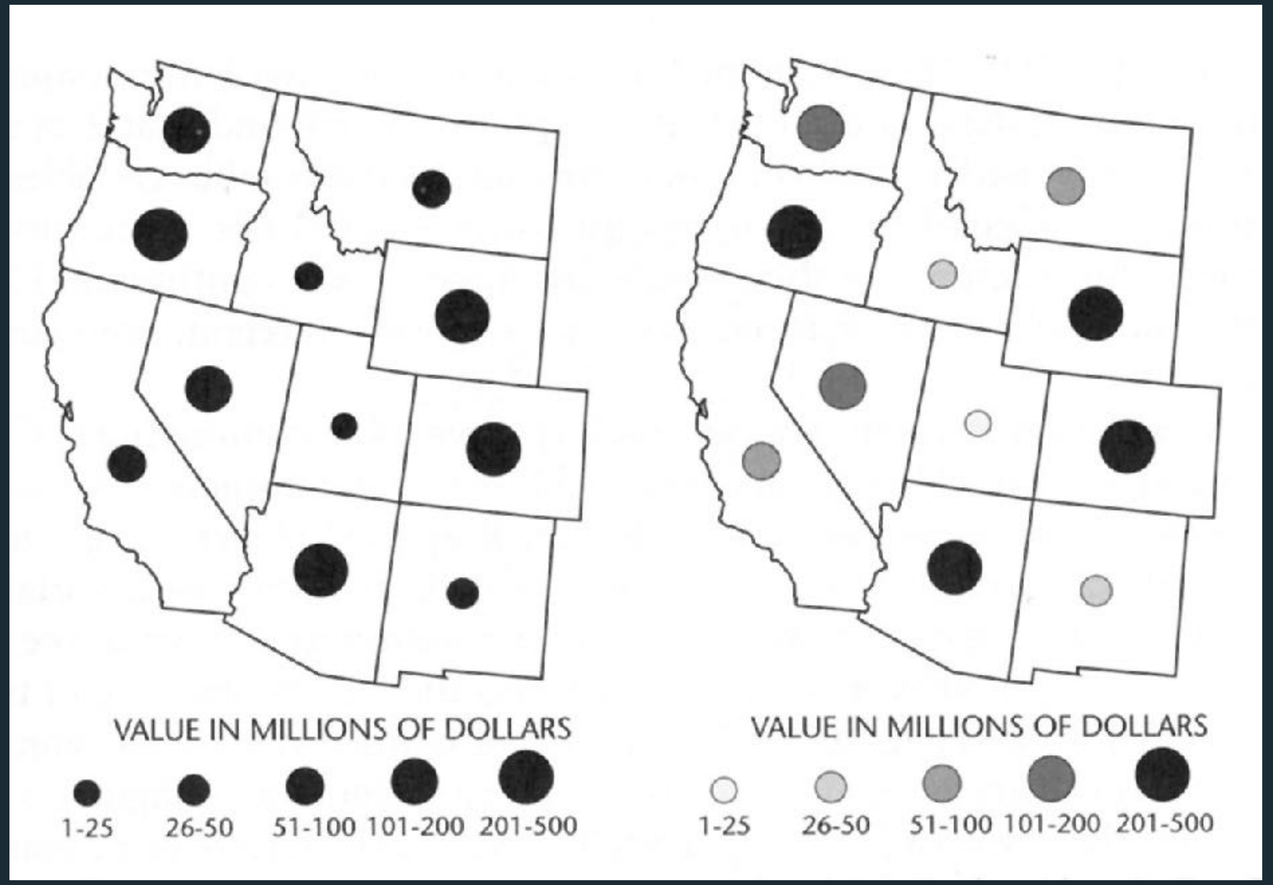
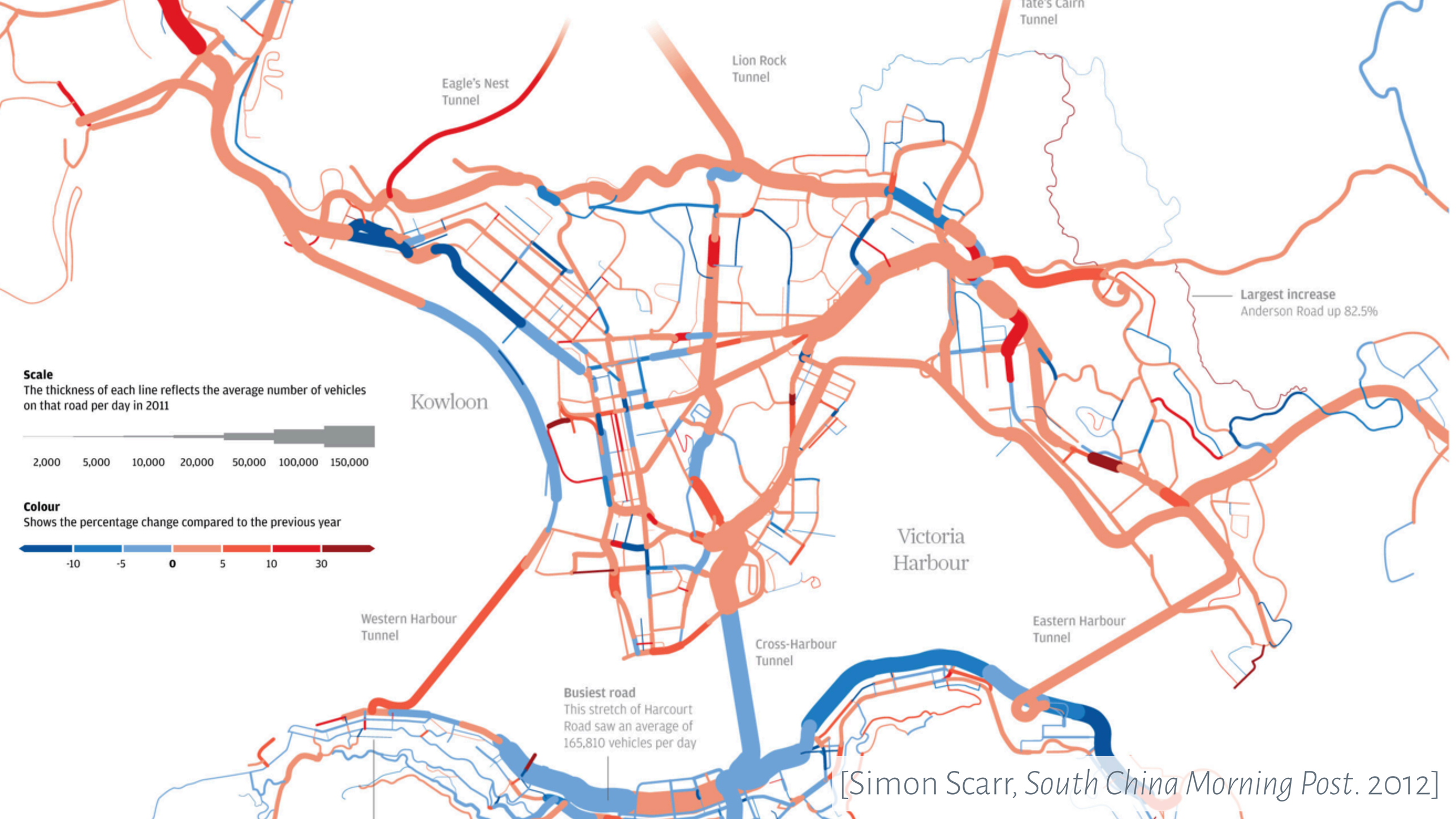
Asymmetric

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

Size & Lightness?



[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.

Width & Height?

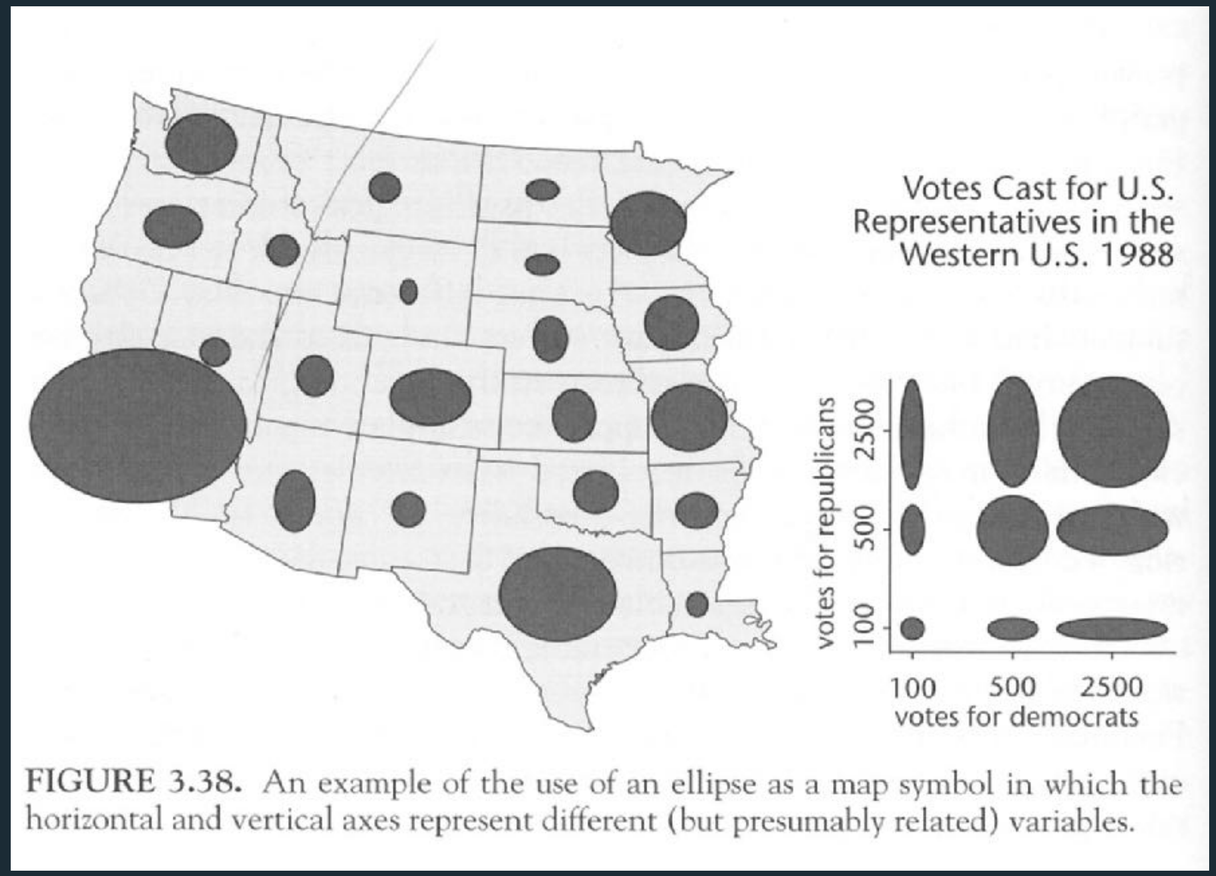


FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 1995]

Types of Dimensions

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No interference or redundancy gain.

Integral

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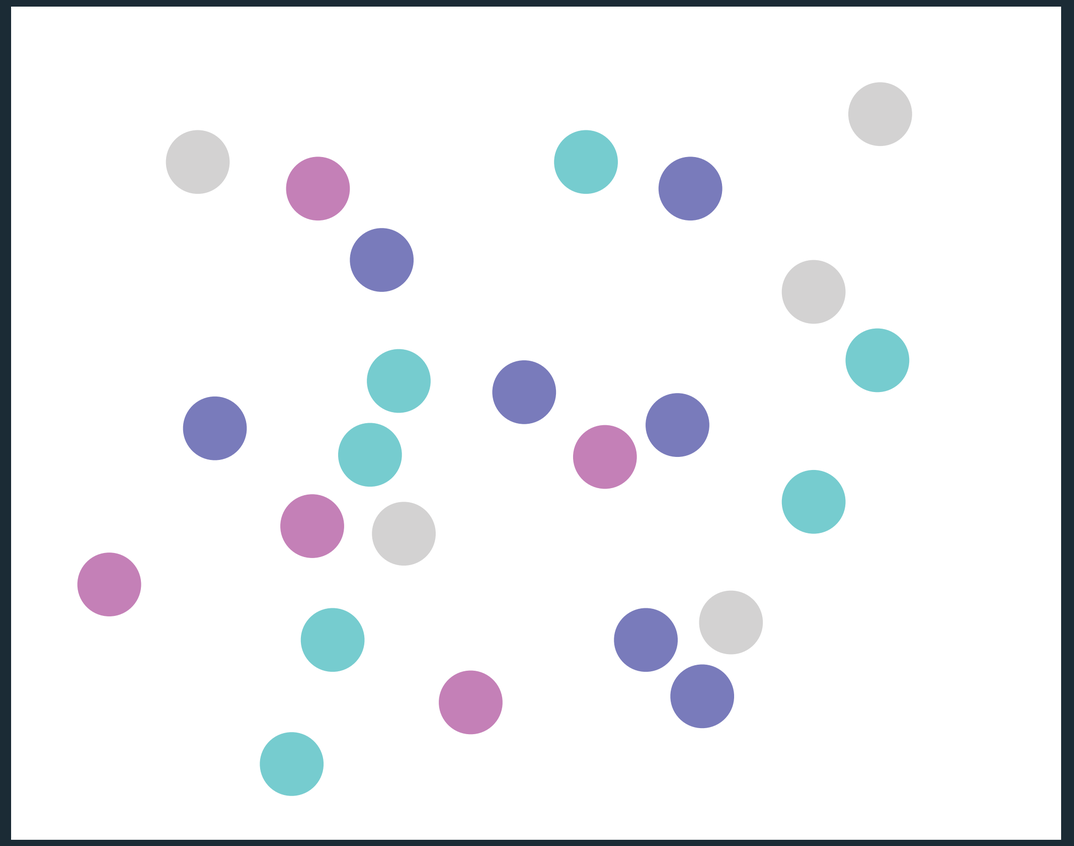
Configural

Only interference. No redundancy gain.

Asymmetric

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

Red & Green?



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

Types of Dimensions

Separable

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Integral

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Configural

Only interference. No redundancy gain.

Asymmetric

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Shape & Size?

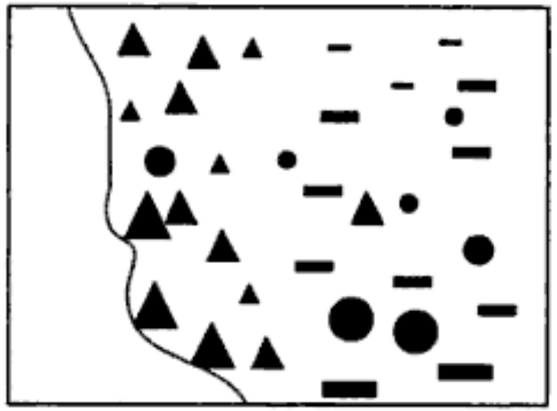

FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

[MacEachren 1995]

Types of Dimensions

Separable

No interference or redundancy gain.

Integral

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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

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Configural

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Asymmetric

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purple

Signal Detection

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

Magnitude Estimation

Accuracy: how correctly can we read off values?

Pre-Attentive Processing

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

Selective Attention

Separability: how much interaction occurs between attributes?

Gestalt Grouping

Signal Detection

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

Magnitude Estimation

Accuracy: how correctly can we read off values?

Pre-Attentive Processing

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

Selective Attention

Separability: how much interaction occurs between attributes?

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

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Ambiguous – vase or faces?

Unambiguous (?)

http://visual-memory.co.uk/daniel/Modules/FM21820/vispero7.html

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pragnänz: we favor the simplest and most stable interpretations

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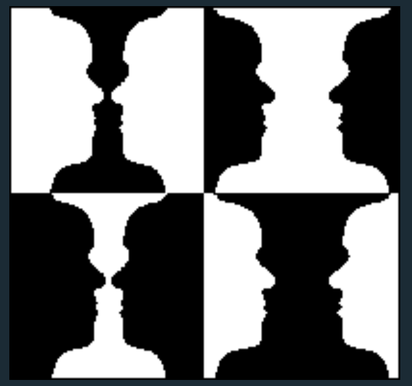
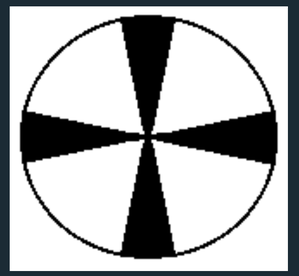
Ambiguous – vase or faces?



Unambiguous (?)

Principle of *surroundedness*.

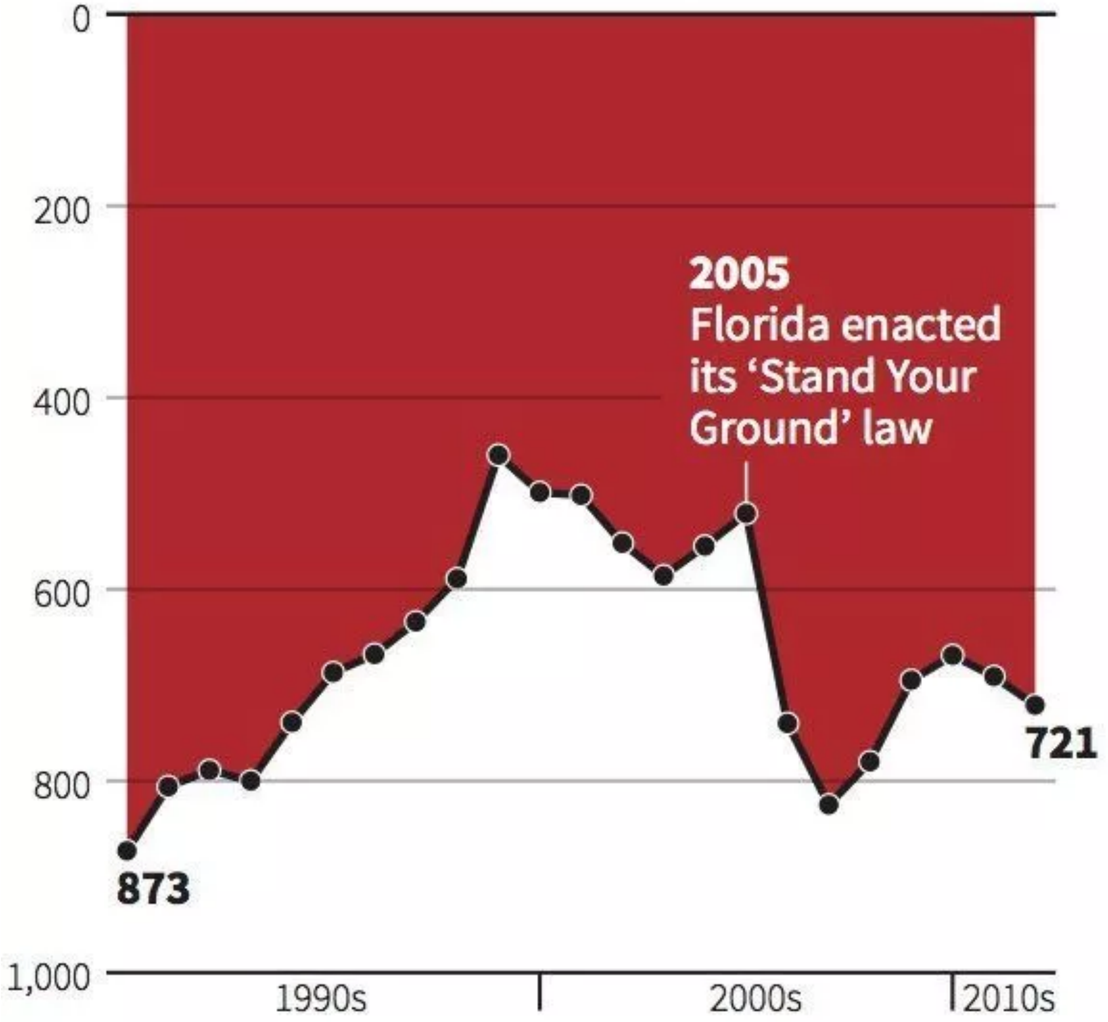


Principle of *relative size*.

http://visual-memory.co.uk/daniel/Modules/FM21820/vispero7.html

Gun deaths in Florida

Number of murders committed using firearms



Source: Florida Department of Law Enforcement

C. Chan 16/02/2014

REUTERS

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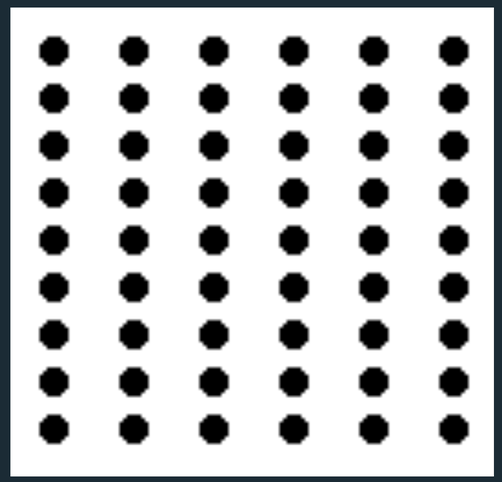
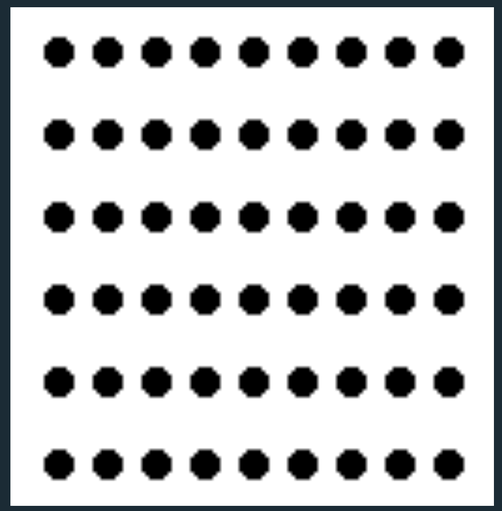




http://visual-memory.co.uk/daniel/Modules/FM21820/vispero7.html

METRICS

HANNAH FAIRFIELD

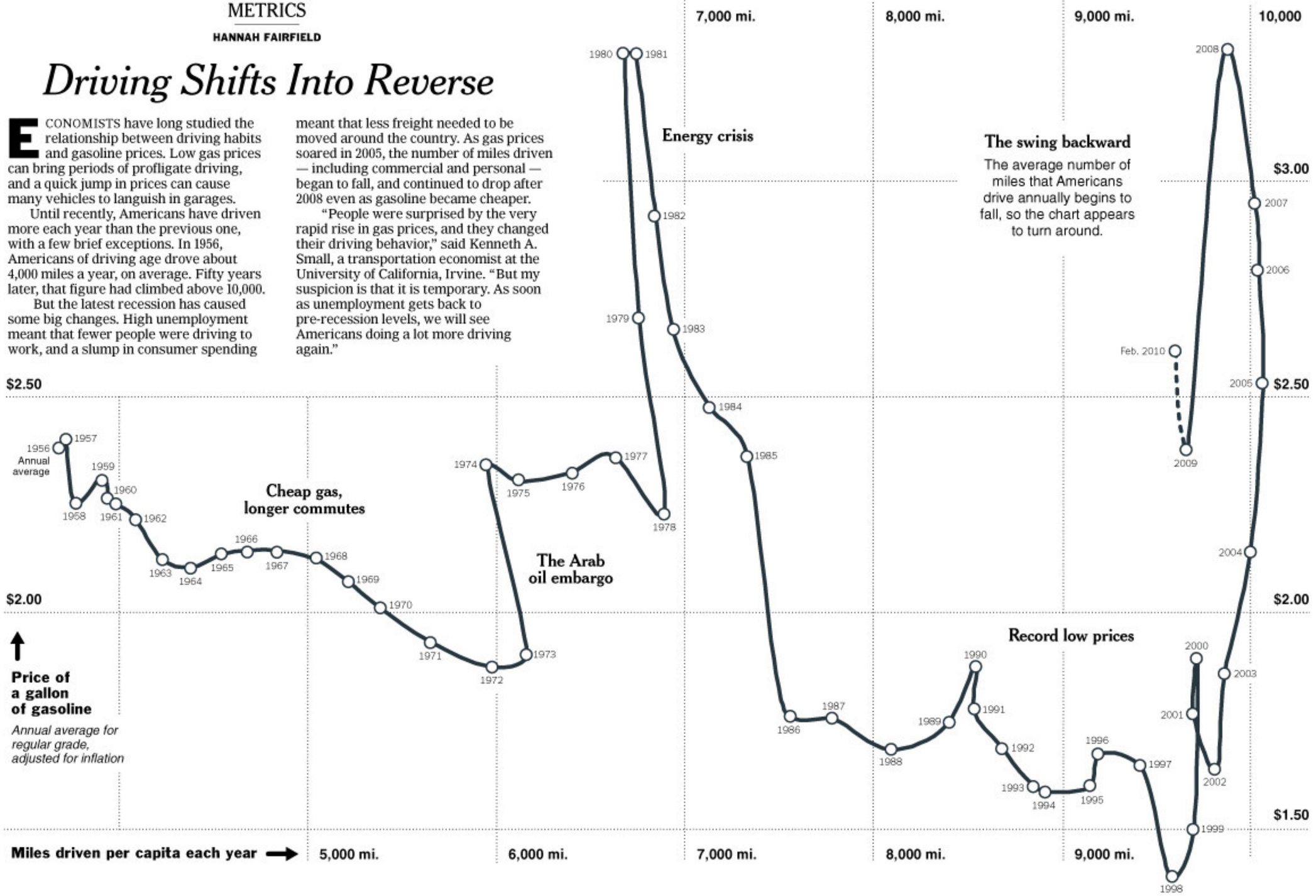
Driving Shifts Into Reverse

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

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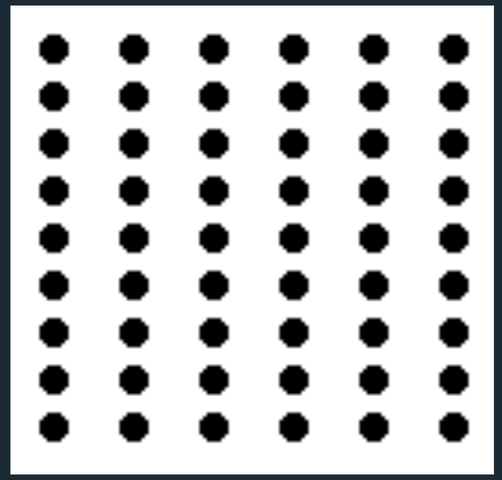
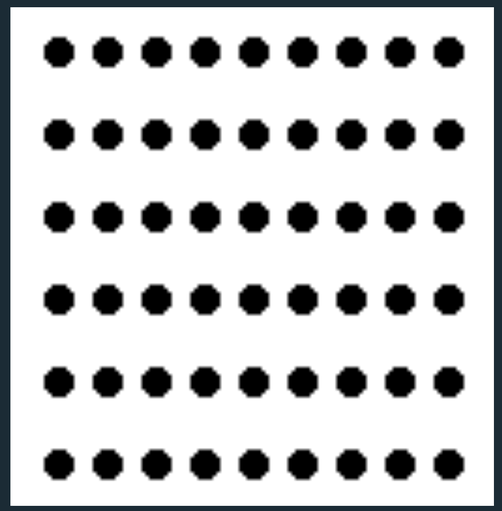
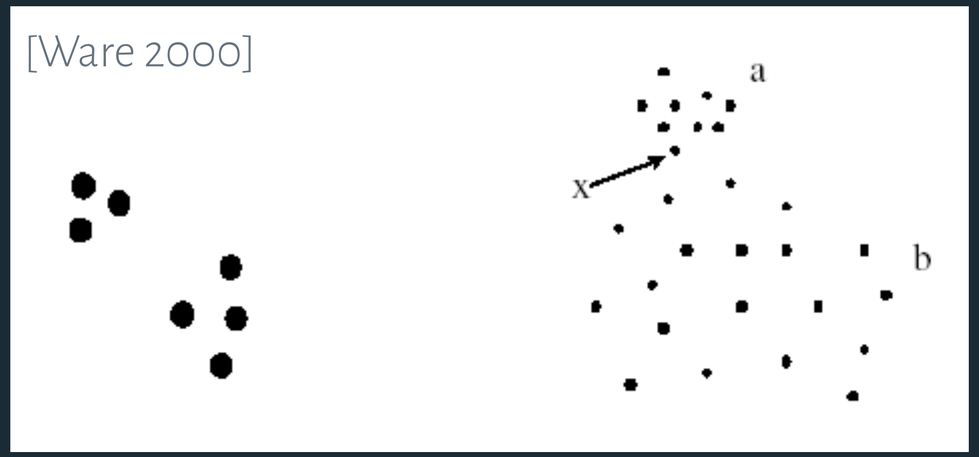




[Ware 2000]



Principle of *concentration*.

http://visual-memory.co.uk/daniel/Modules/FM21820/vispero7.html

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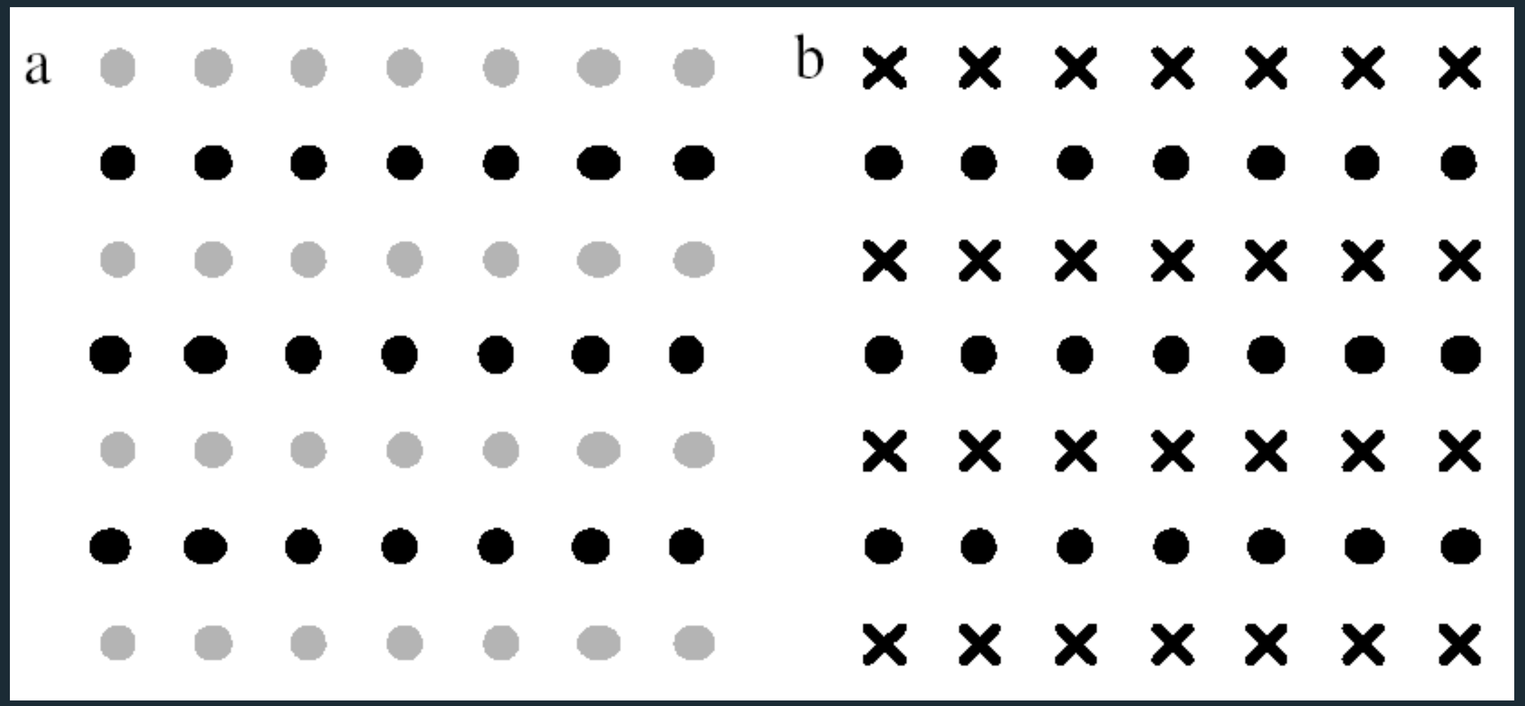

Rows dominate due to similarity. [Ware 2004]

Gestalt Principles

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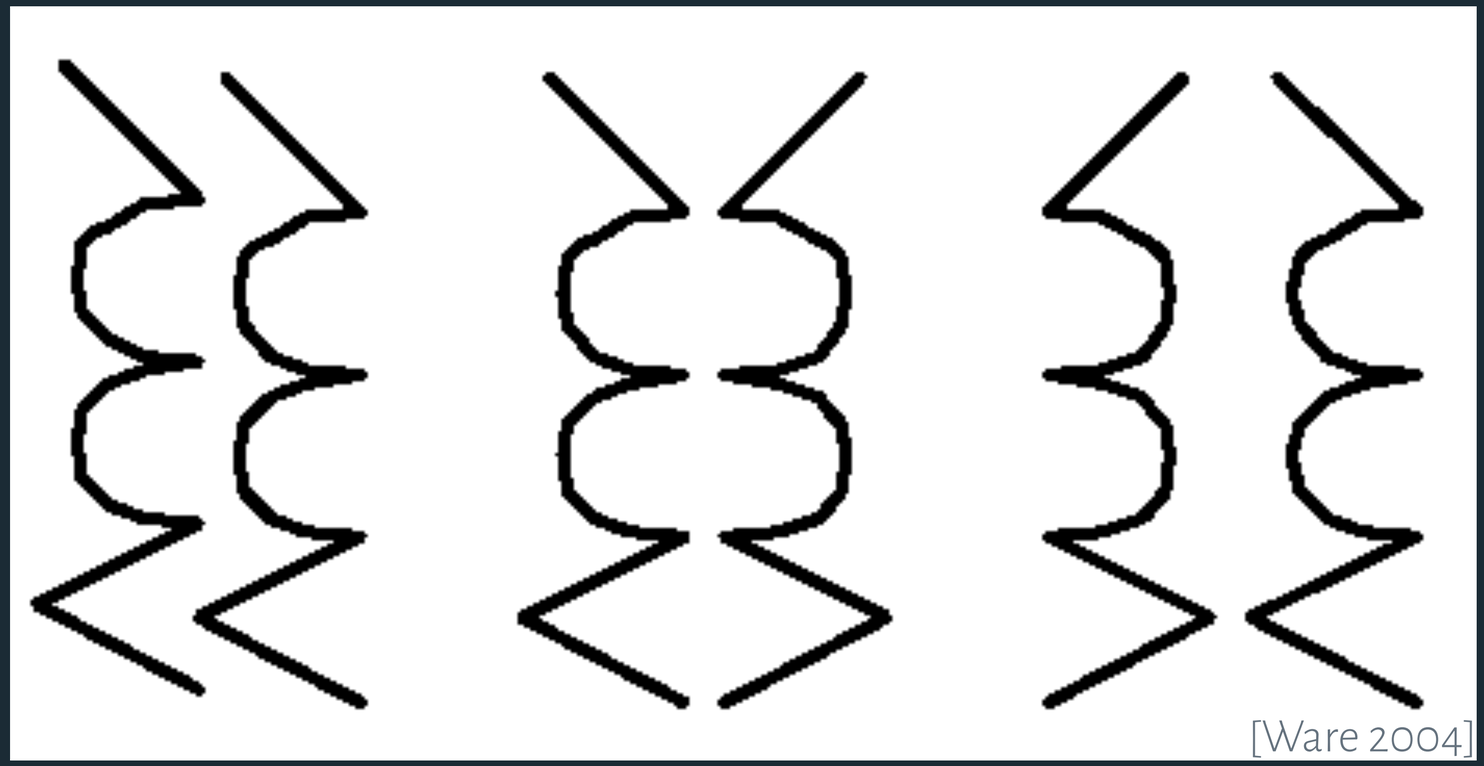

Bilateral symmetry gives the strong sense of a figure.

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

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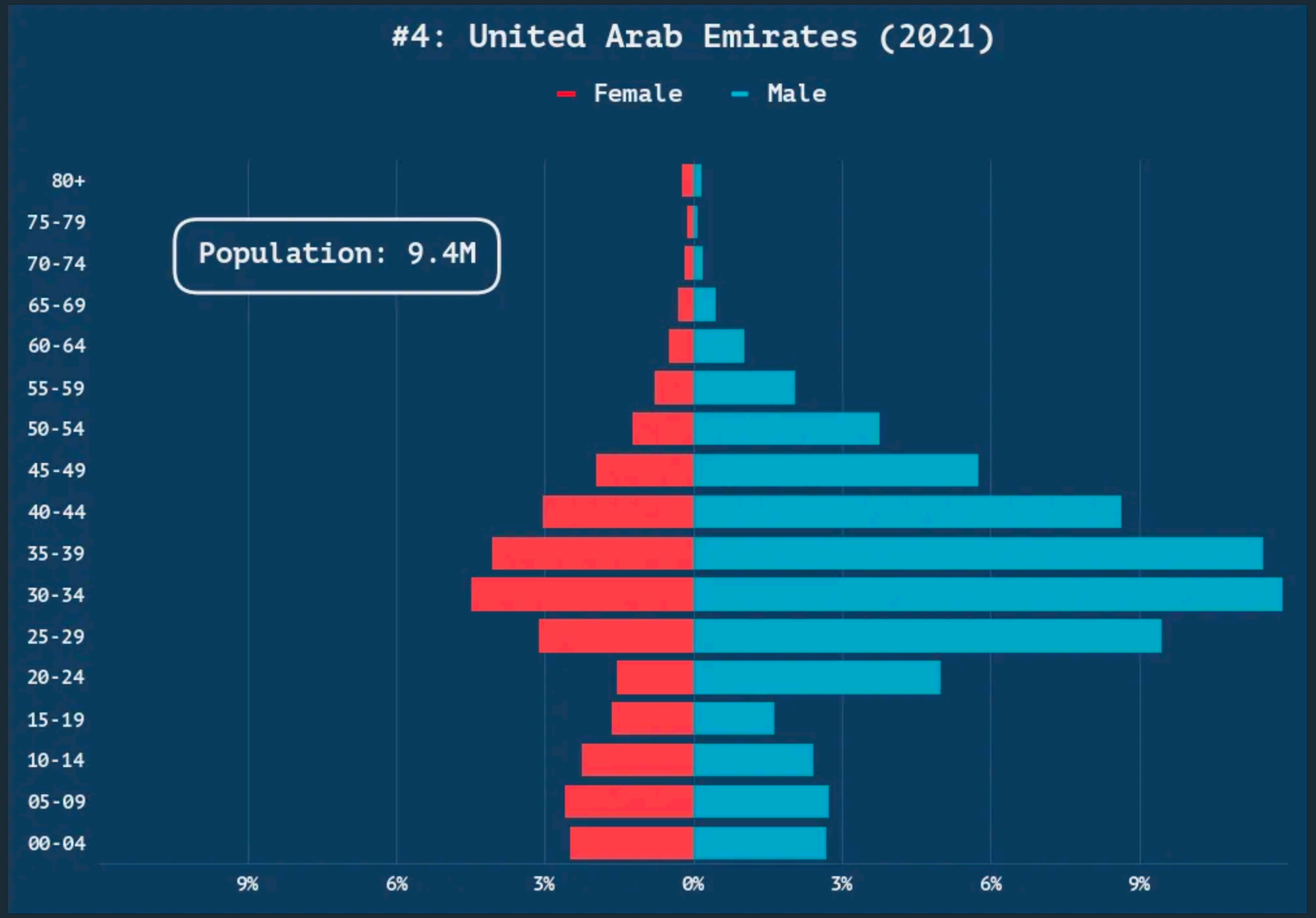
Common Fate



[Oscar Leo, 2023]

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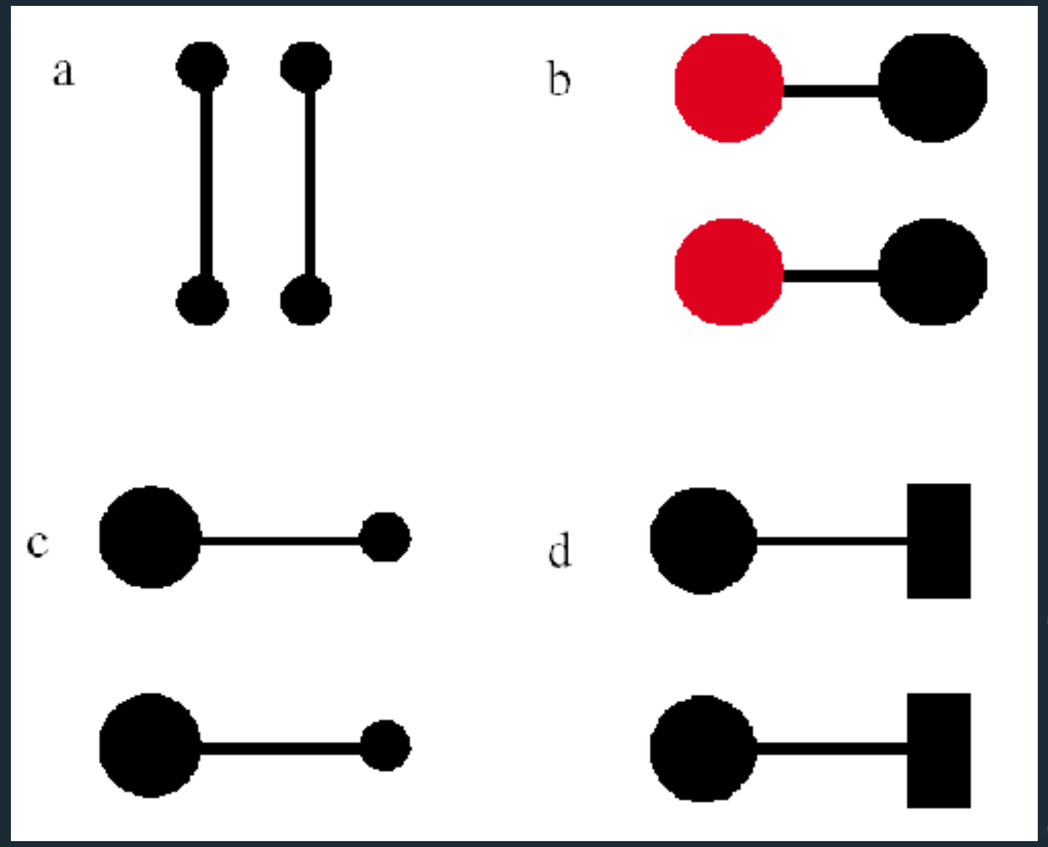

[Ware 2004]

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

Gestalt Principles

pragnänz: we favor the simplest and most stable interpretations

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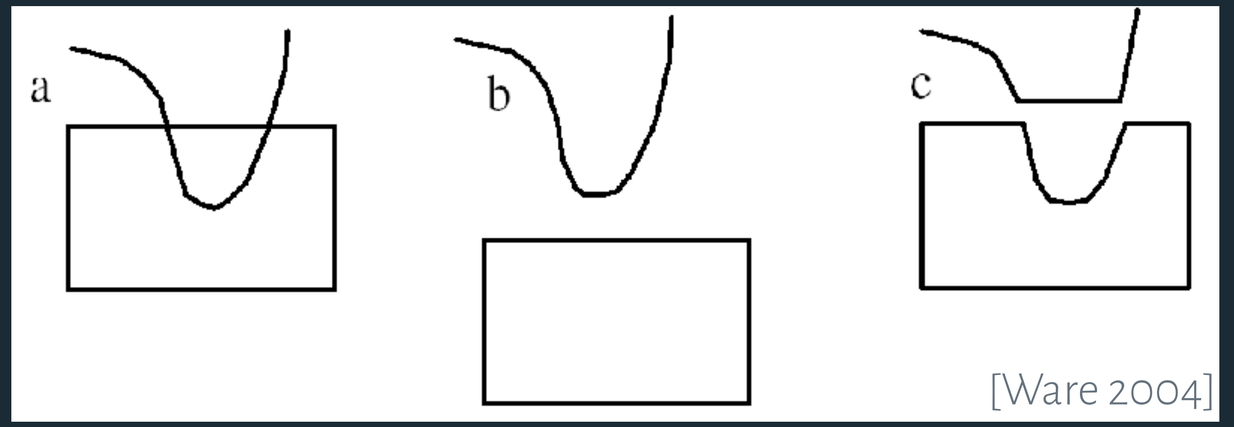
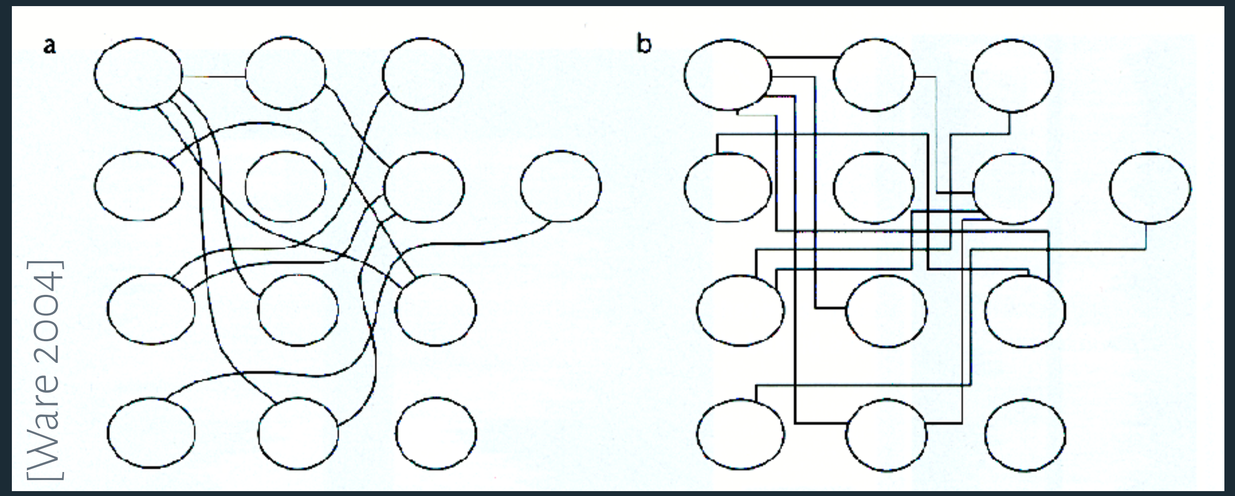
Common Fate



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

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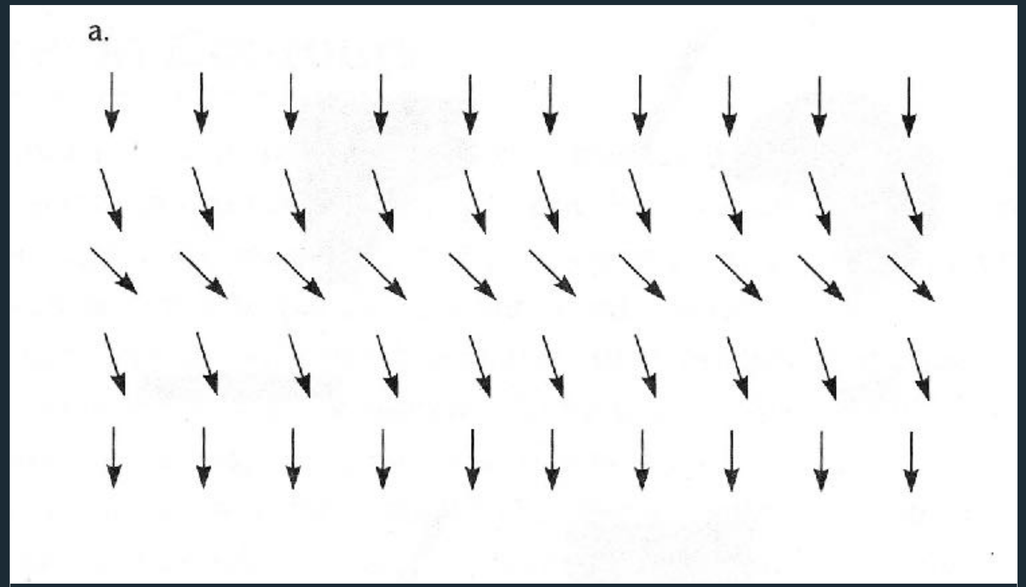
Common Fate



Prefer field that shows smooth continuous contours

[Ware 2004]

Gestalt Principles

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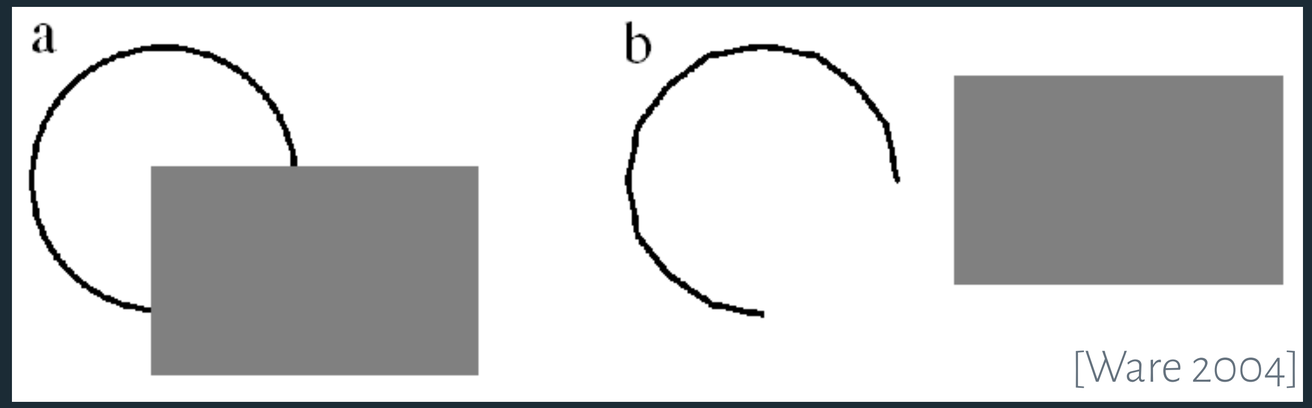
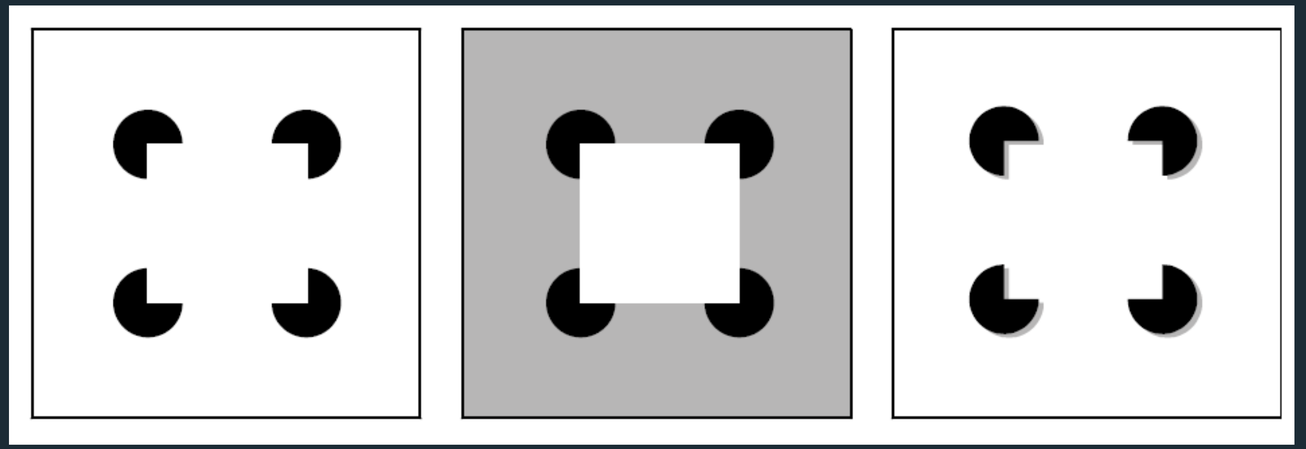


[Ware 2004]

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

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Common Fate

Dots moving together are grouped.