Perception

DSC 106: Data Visualization

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UC San Diego

Announcements

Lab 2 due today.

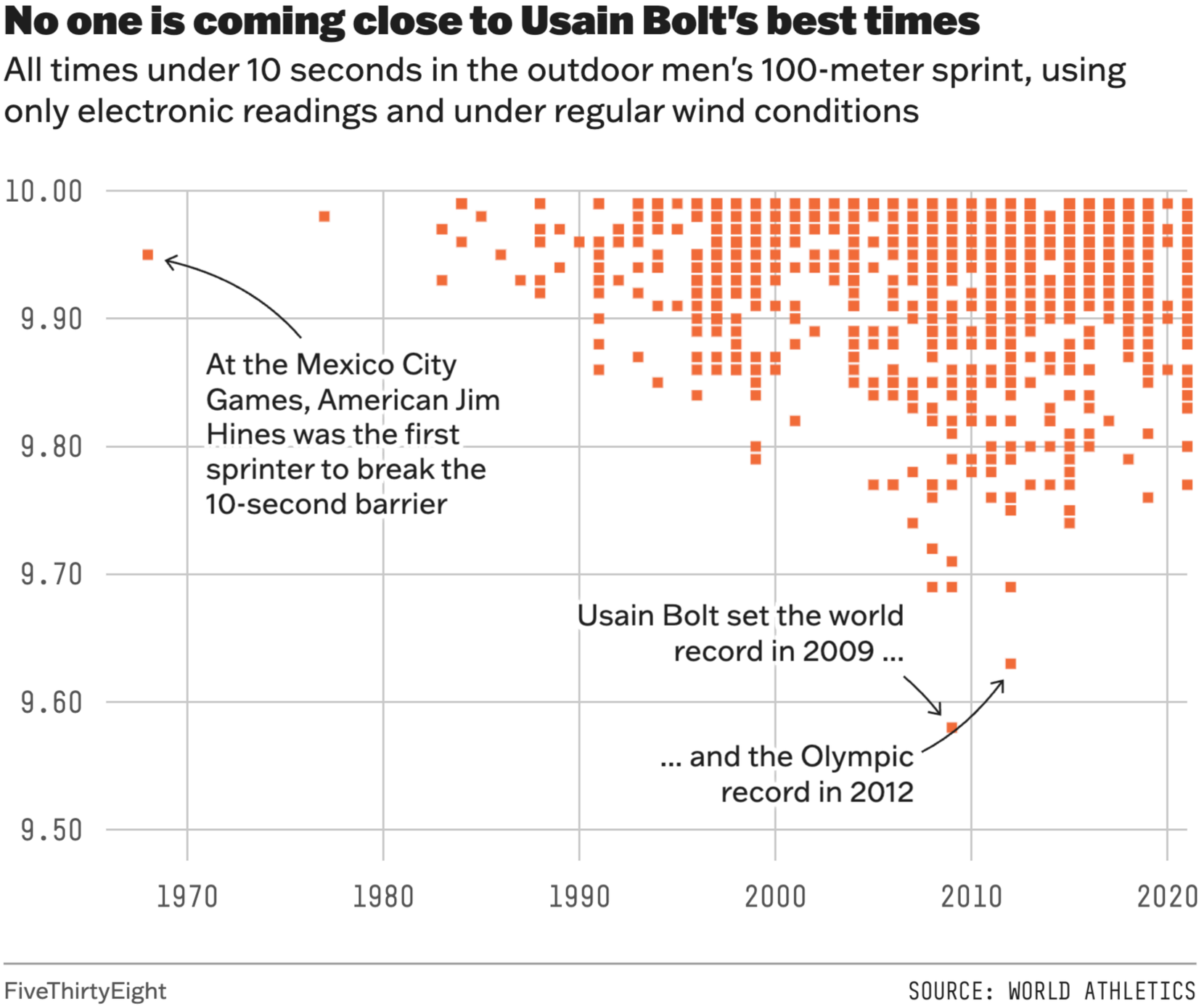
Project 1 due this coming Tuesday.

FAQs:

1. What if I want to customize my website for Lab 2 (and onwards)? Feel free, as long as you can include all required talking points in your video.

More Project 1 Advice

Exemplar: Usain Bolt

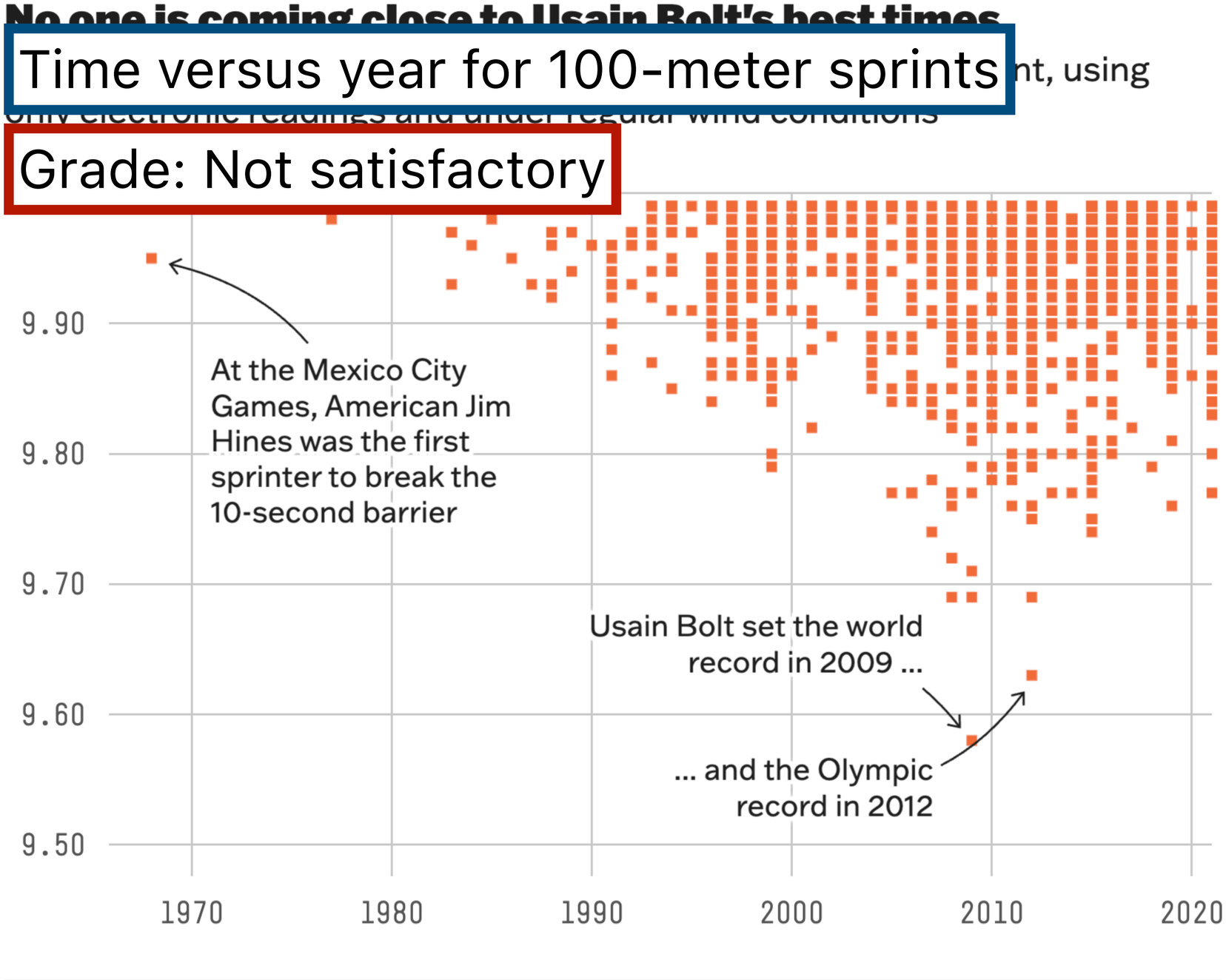


https://fivethirtyeight.com/features/the-fastest-men-in-the-world-are-still-chasing-usain-bolt/

Exemplar: Usain Bolt

Time versus year for 100-meter sprints

Grade: Not satisfactory

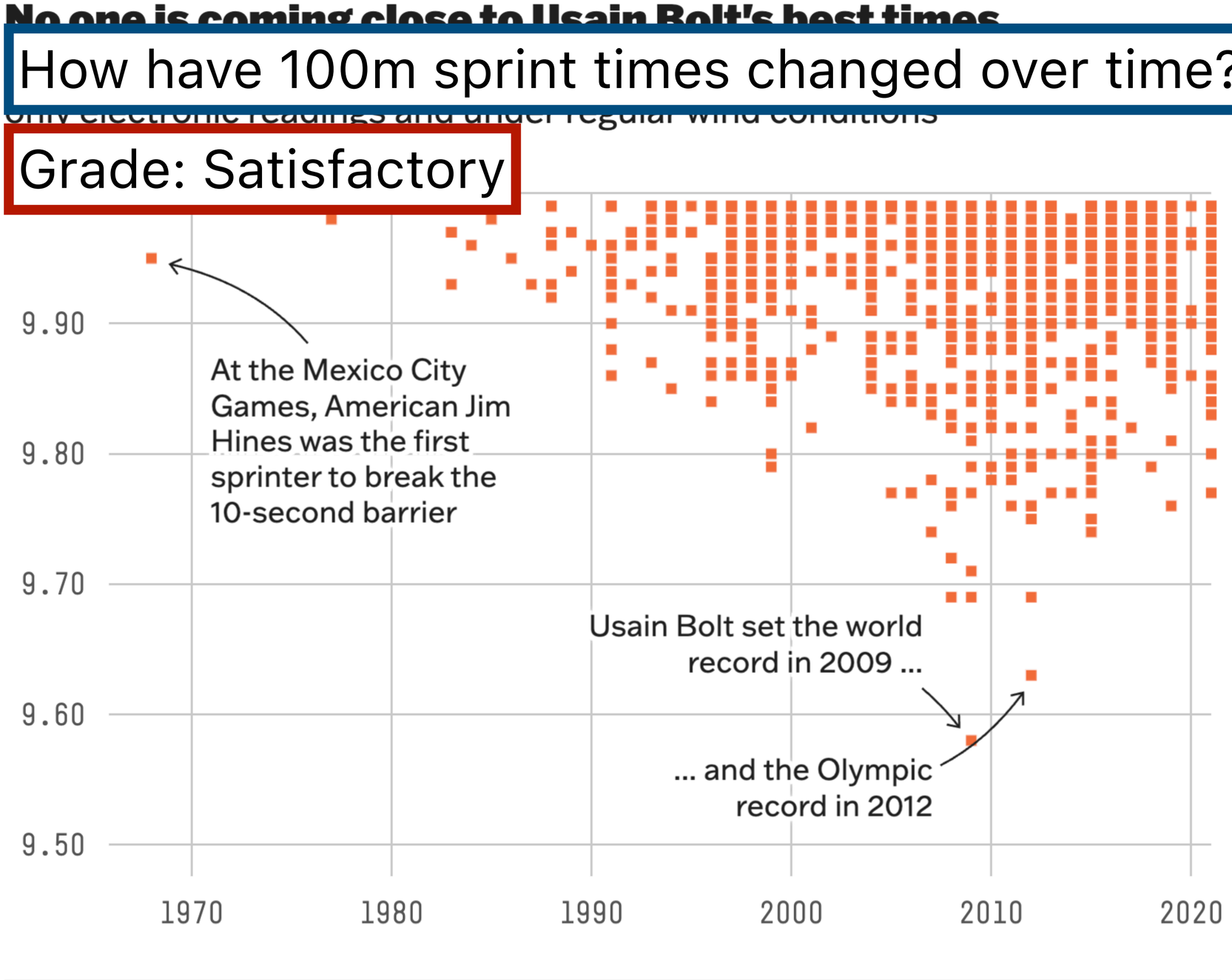


https://fivethirtyeight.com/features/the-fastest-men-in-the-world-are-still-chasing-usain-bolt/

Exemplar: Usain Bolt

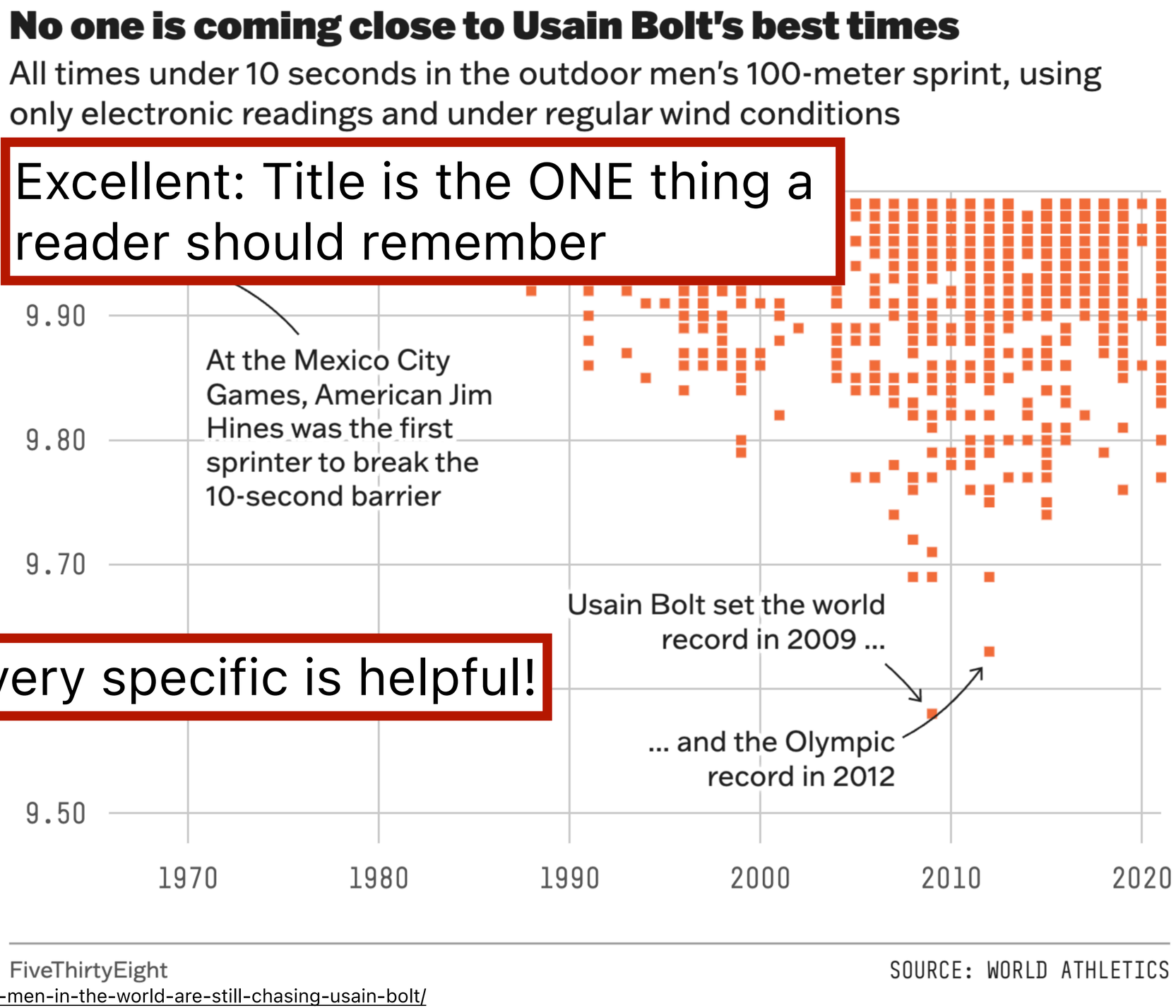
How have 100m sprint times changed over time?

Grade: Satisfactory



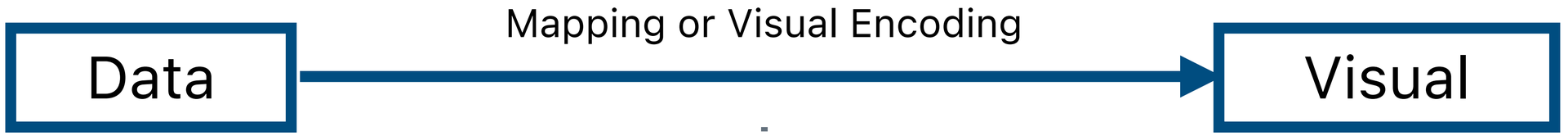
https://fivethirtyeight.com/features/the-fastest-men-in-the-world-are-still-chasing-usain-bolt/

Exemplar: Usain Bolt



Often, being very specific is helpful!

https://fivethirtyeight.com/features/the-fastest-men-in-the-world-are-still-chasing-usain-bolt/



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

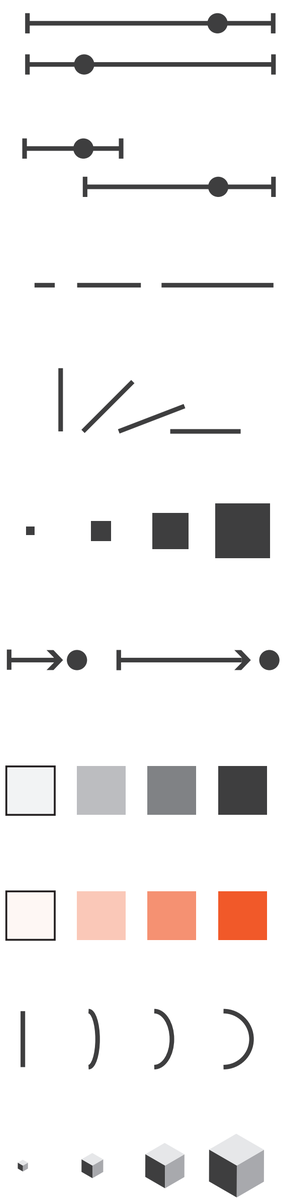
A visualization is more *effective* than another if the information it conveys *is more readily perceived* than the information in the other visualization

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

Magnitude Channels: Ordered 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

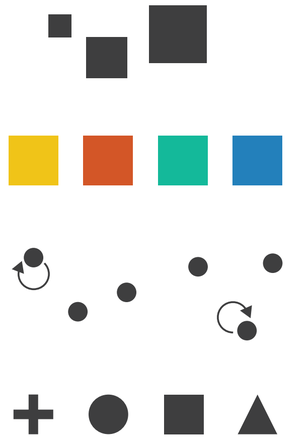
Least

Same

Same

Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

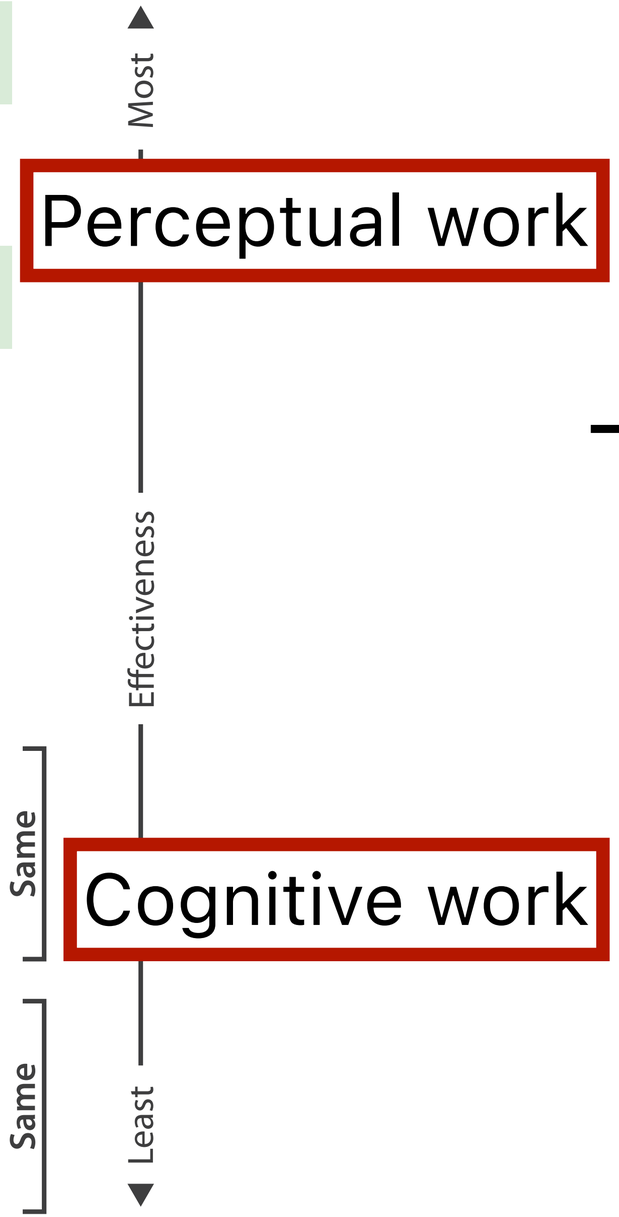


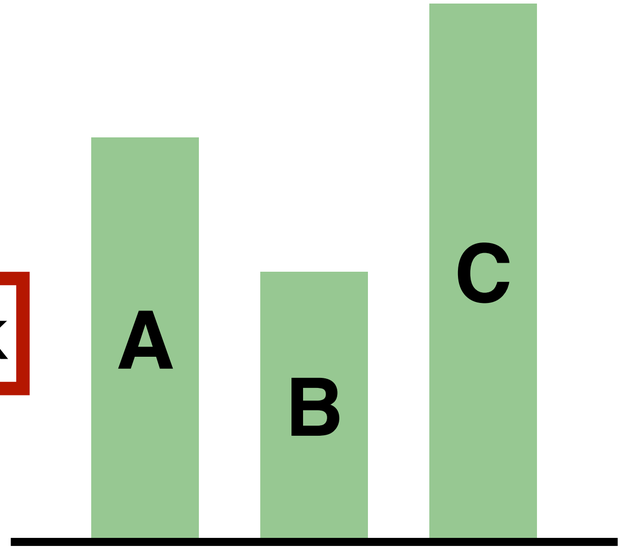
Tamara Munzner, *Visualization Analysis and Design* (2014).

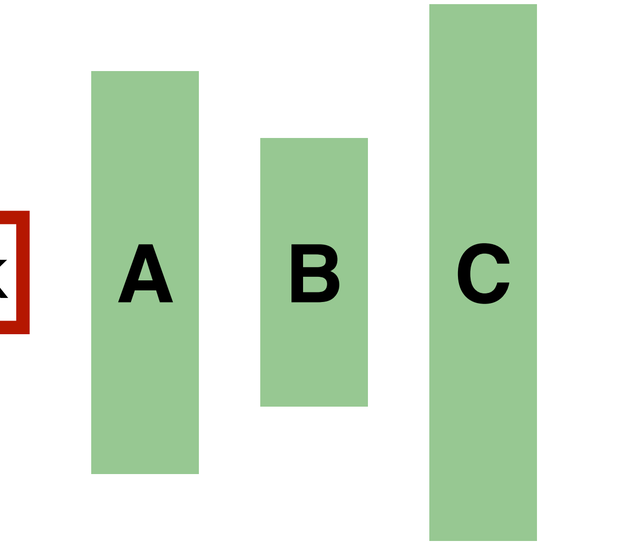
Channels: Expressiveness Types and Effectiveness Ranks

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)







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

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

Magnitude Estimation

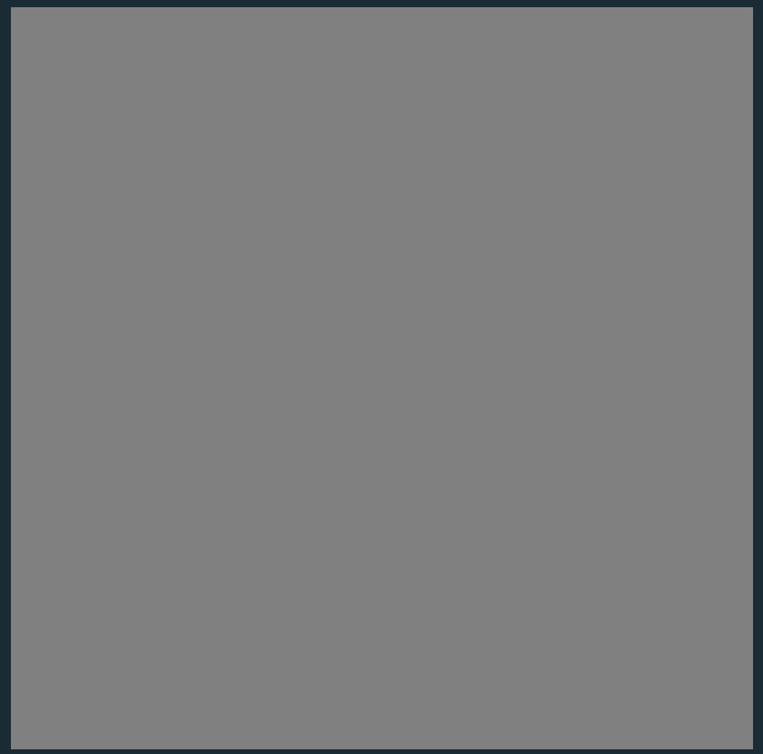
Pre-Attentive Processing

Selective Attention

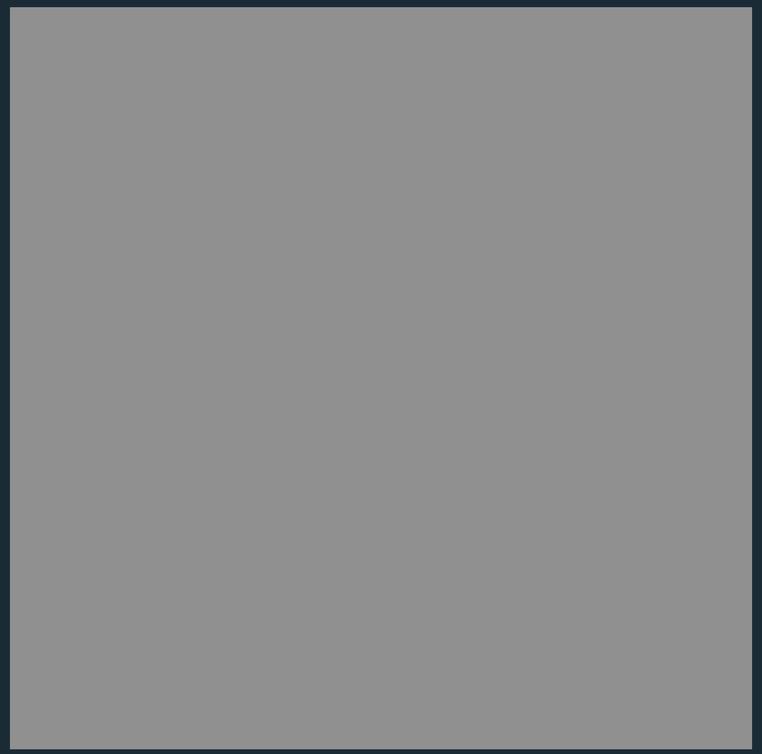
Gestalt Grouping

Which is brighter?

tryclassbuzz.com:
brighter1



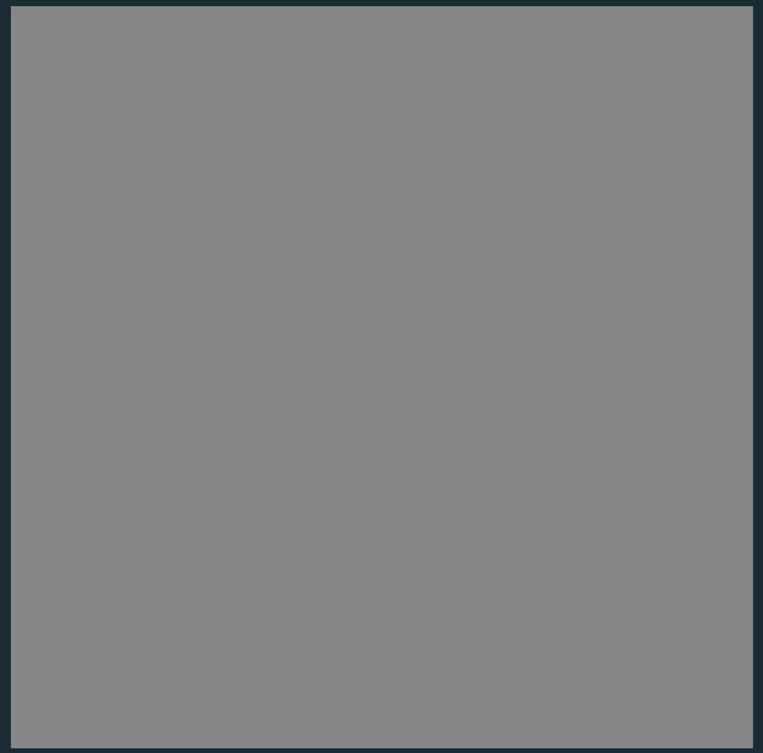
rgb(128, 128, 128)

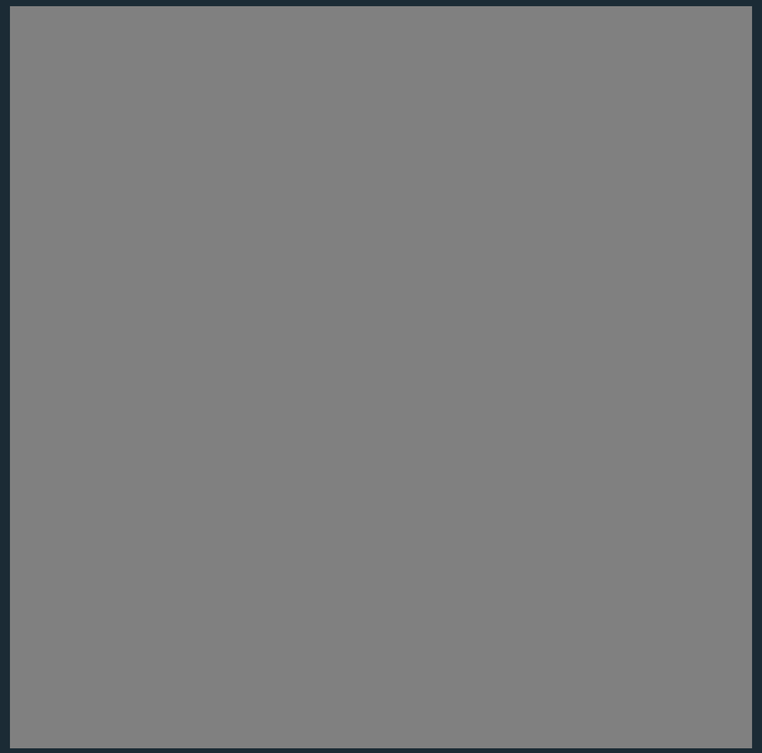


rgb(144, 144, 144)

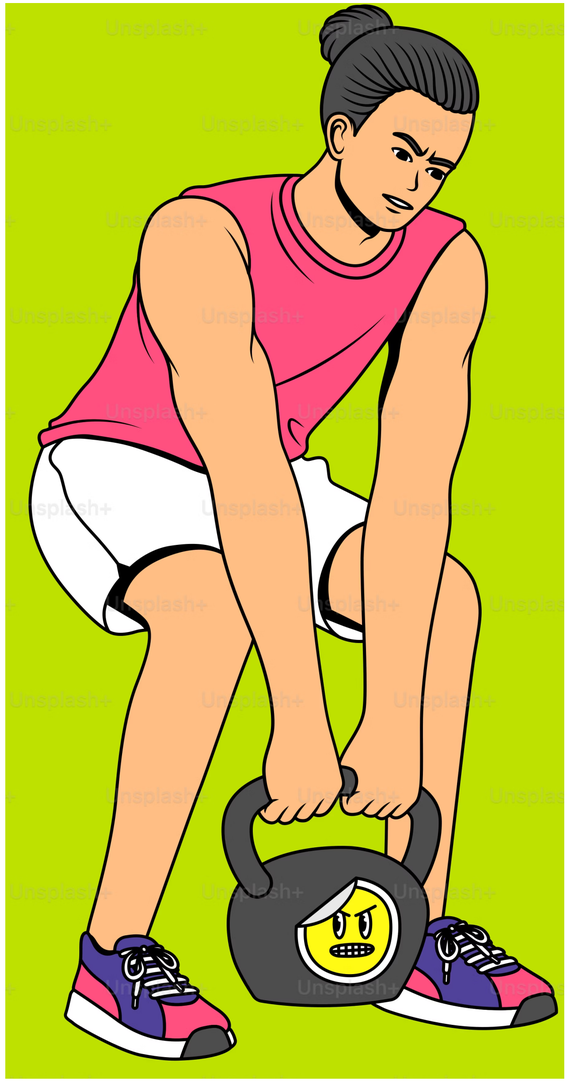
Which is brighter?

tryclassbuzz.com:
brighter2





Just Noticeable Difference (jnd)



Start with 2kg	
add 5g	Don’t notice
add 20g	Notice!

Start with **5kg**	
add 20g	Don’t notice
add 50g	Notice!

Ernst Weber (1795 – 1878) German physician and a founder of experimental psychology.

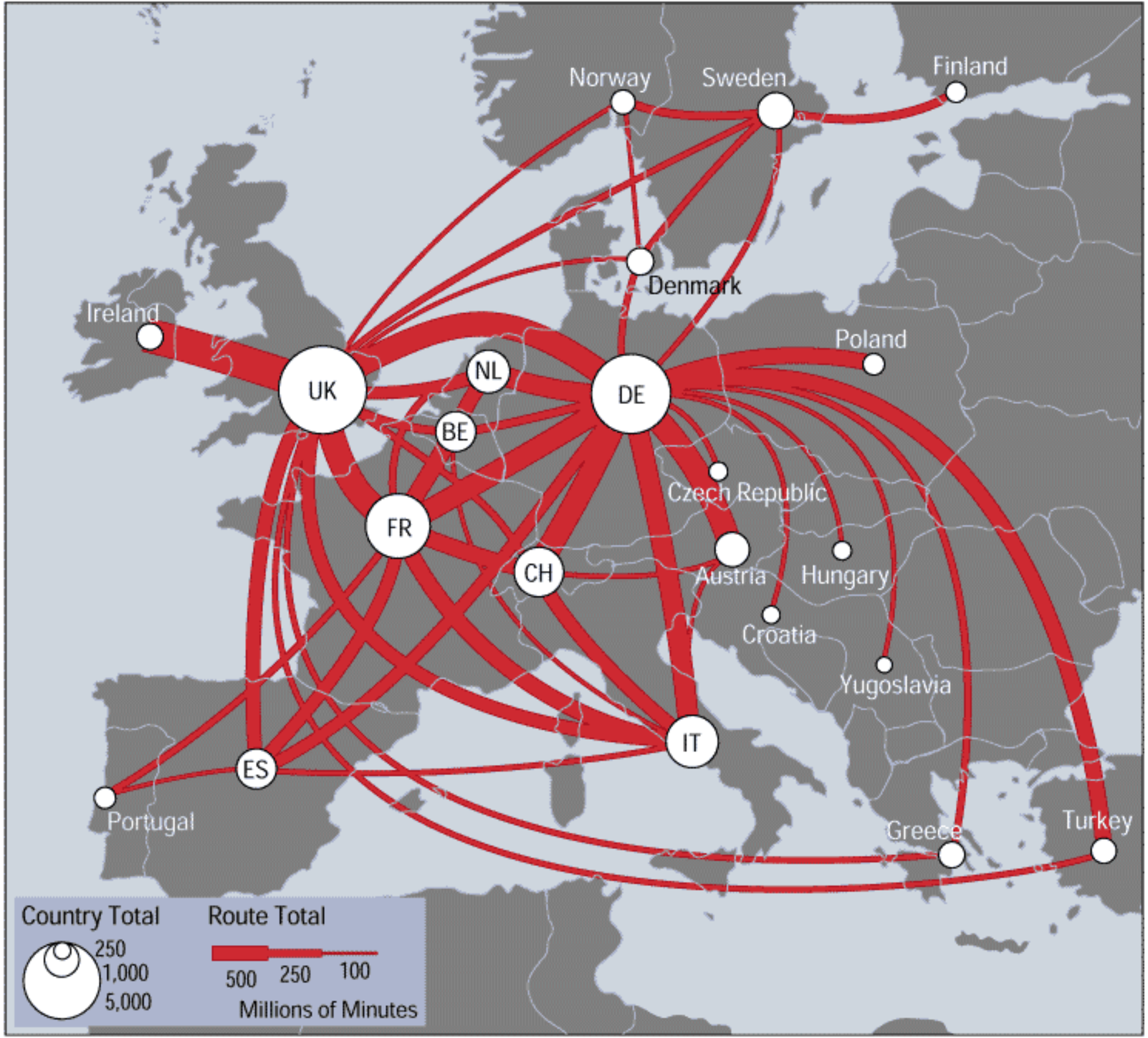
Jnd is proportional to original intensity

Just Noticeable Difference (jnd)

Ernst Weber
(1795 – 1878)
German physician and a founder of experimental psychology.

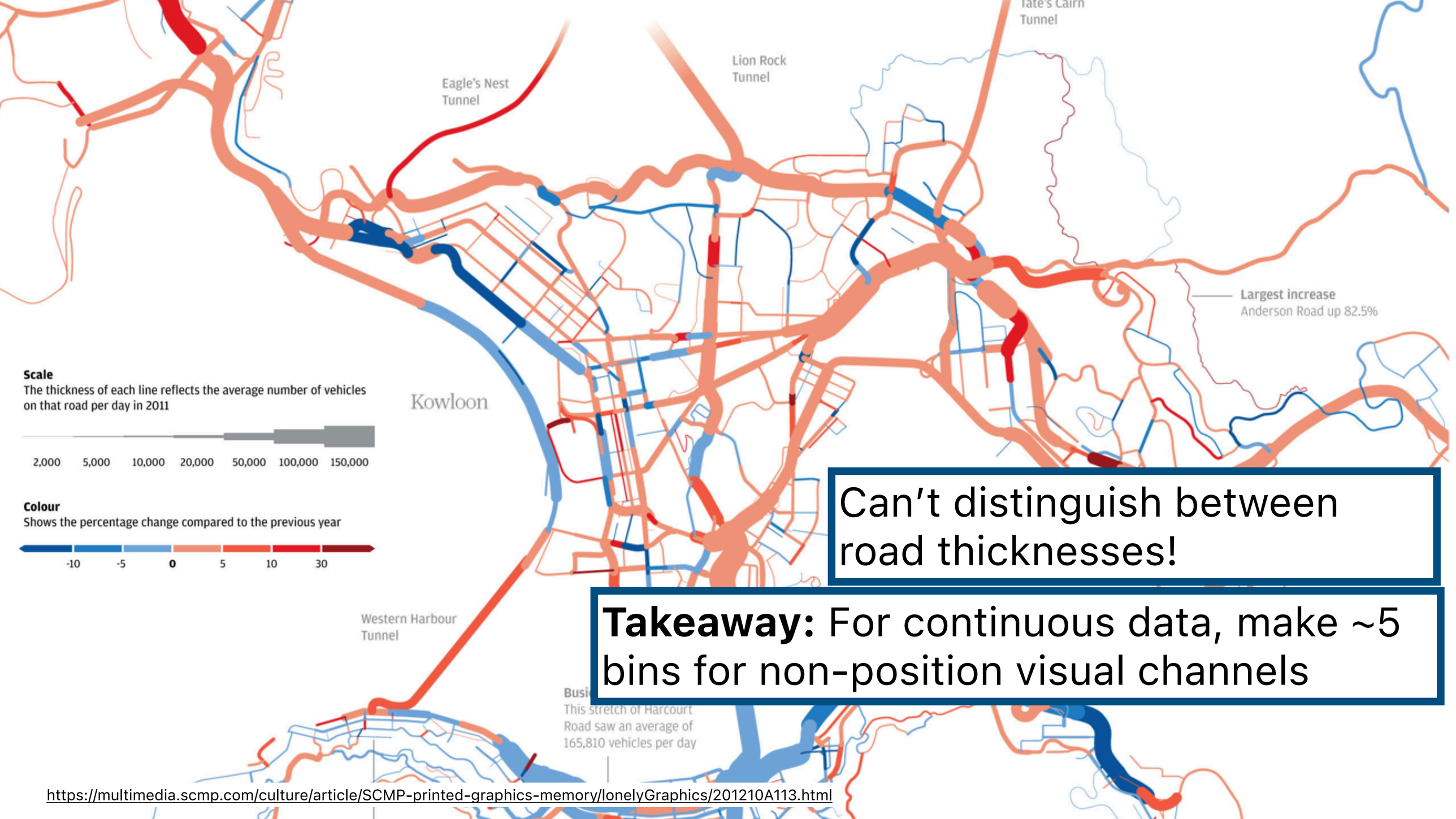
Ratios more important than magnitude

Our brains treat continuous variations like discrete steps



Jnd for line width?

Jnd for circle sizes?



Can't distinguish between road thicknesses!

Takeaway: For continuous data, make ~5 bins for non-position visual channels

https://multimedia.scmp.com/culture/article/SCMP-printed-graphics-memory/lonelyGraphics/201210A113.html

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

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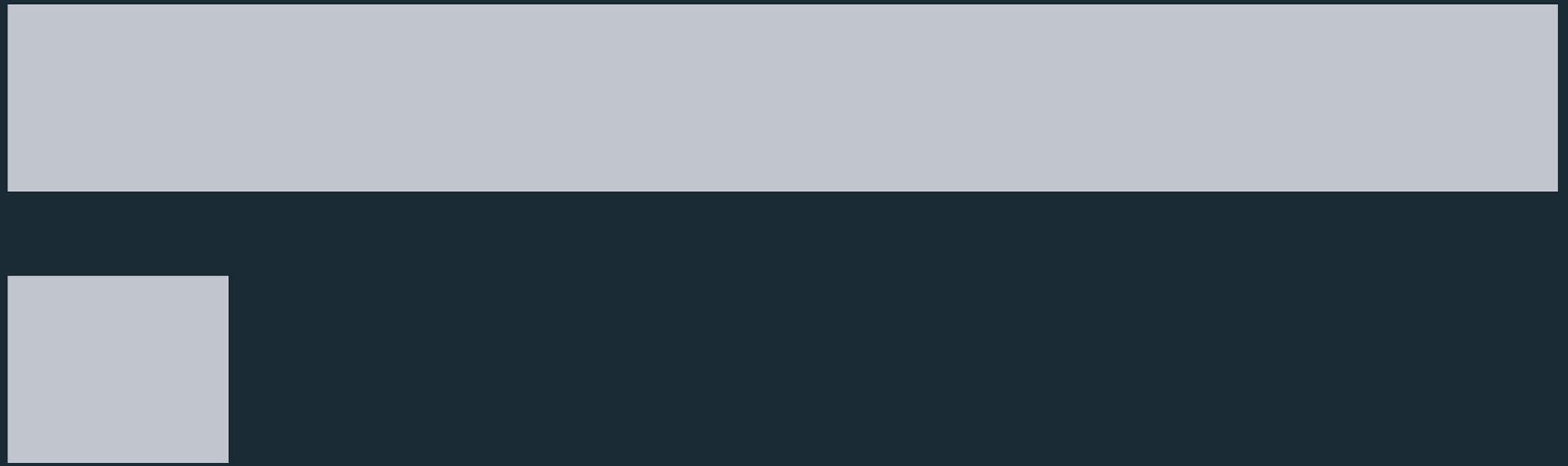
Gestalt Grouping

Accuracy: how correctly can we read off values?

How much larger is the area of the big circle?

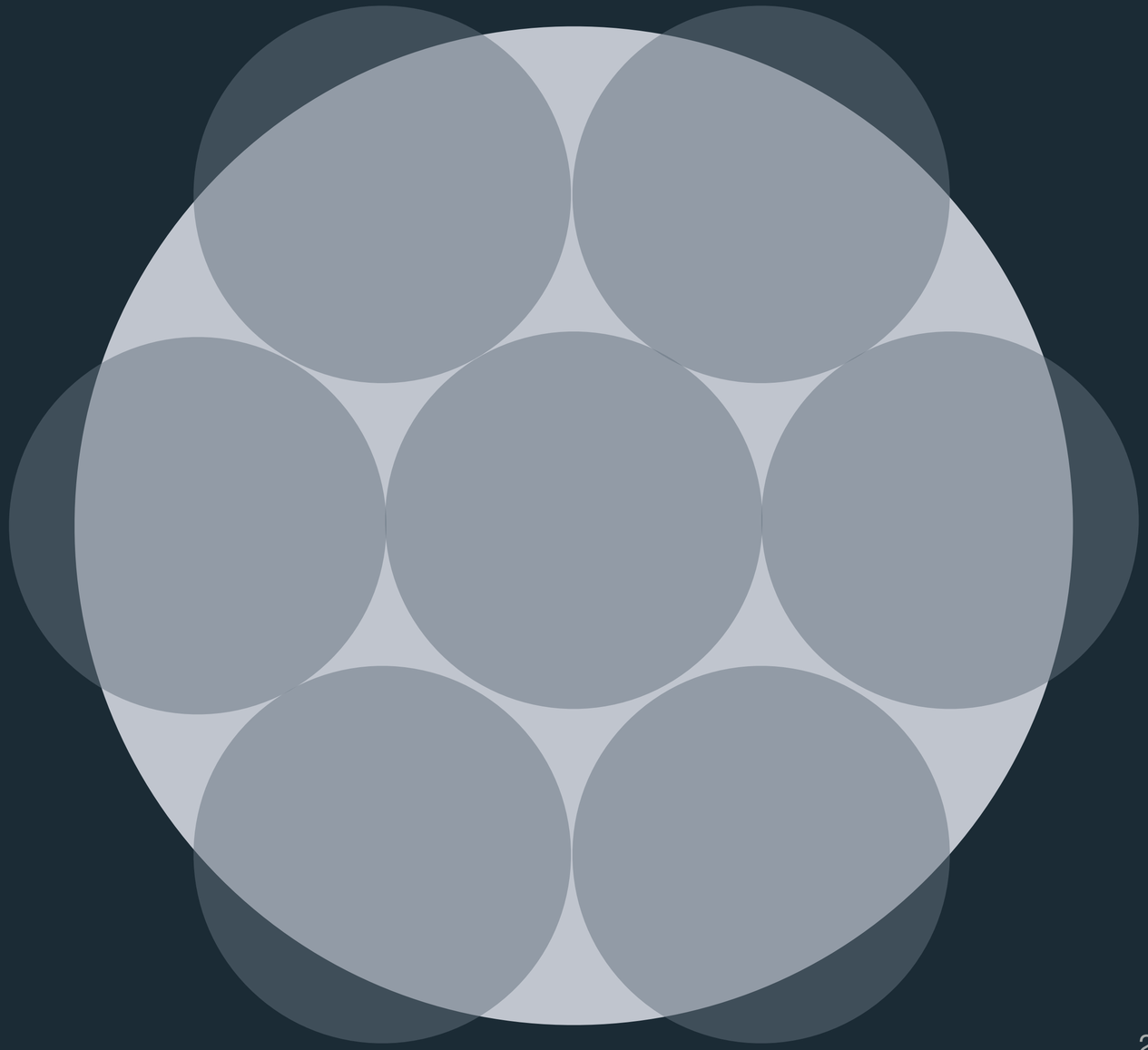
tryclassbuzz.com:
circles

How much longer is the big bar?

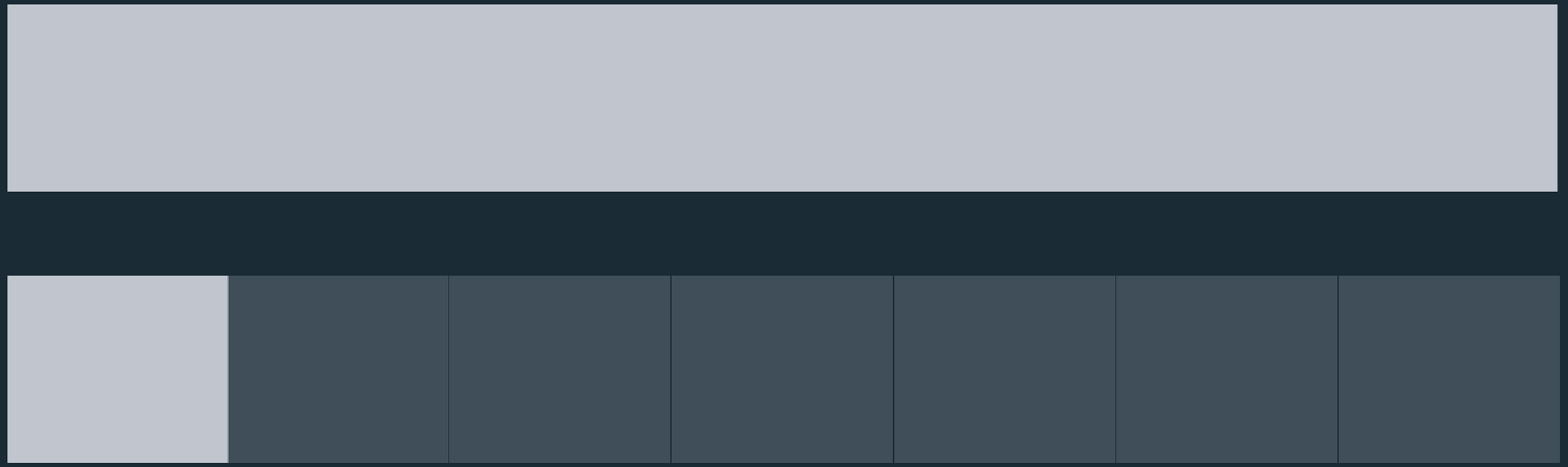


tryclassbuzz.com:
bars

How much larger is the area of the big circle?



How much longer is the big bar?



Graphical Perception Studies

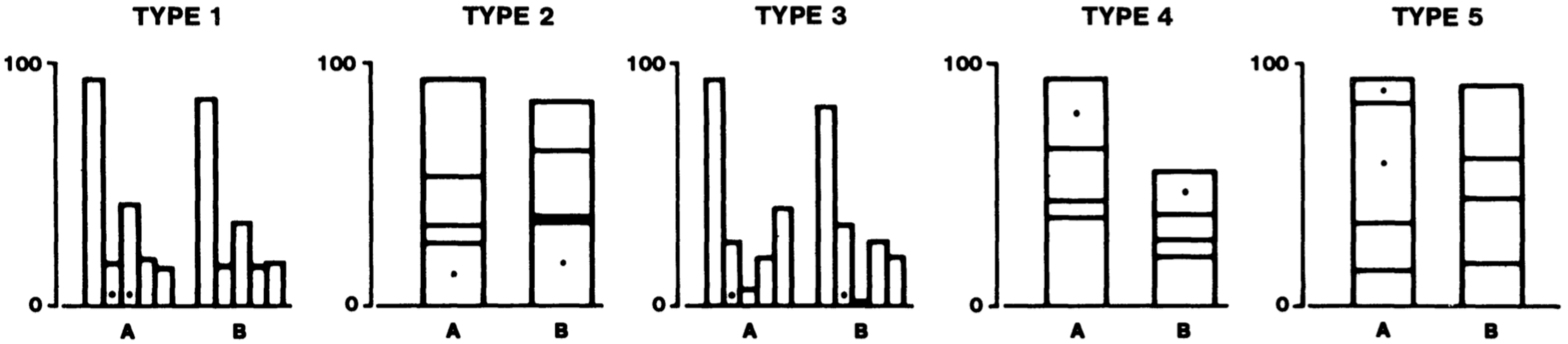


Figure 4. Graphs from position–length experiment.

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

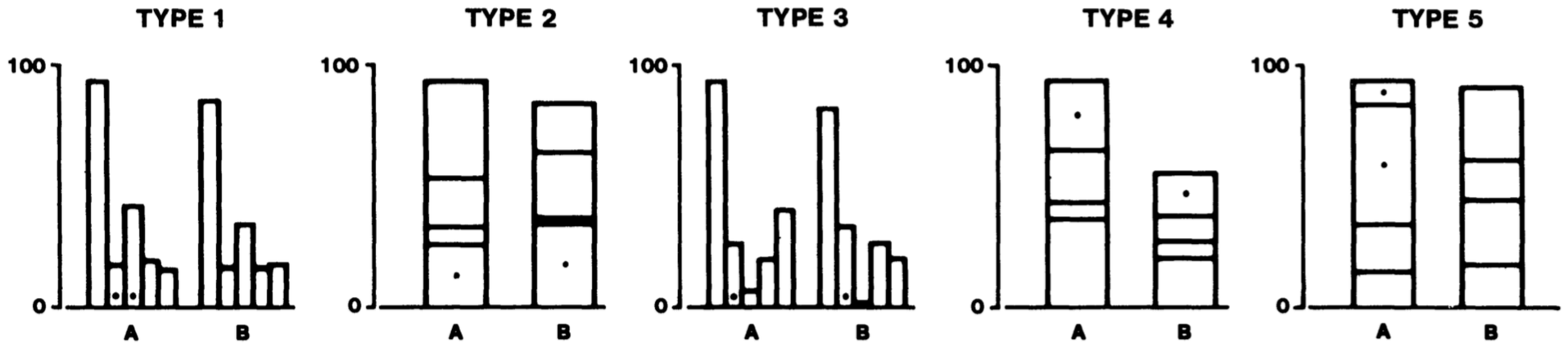
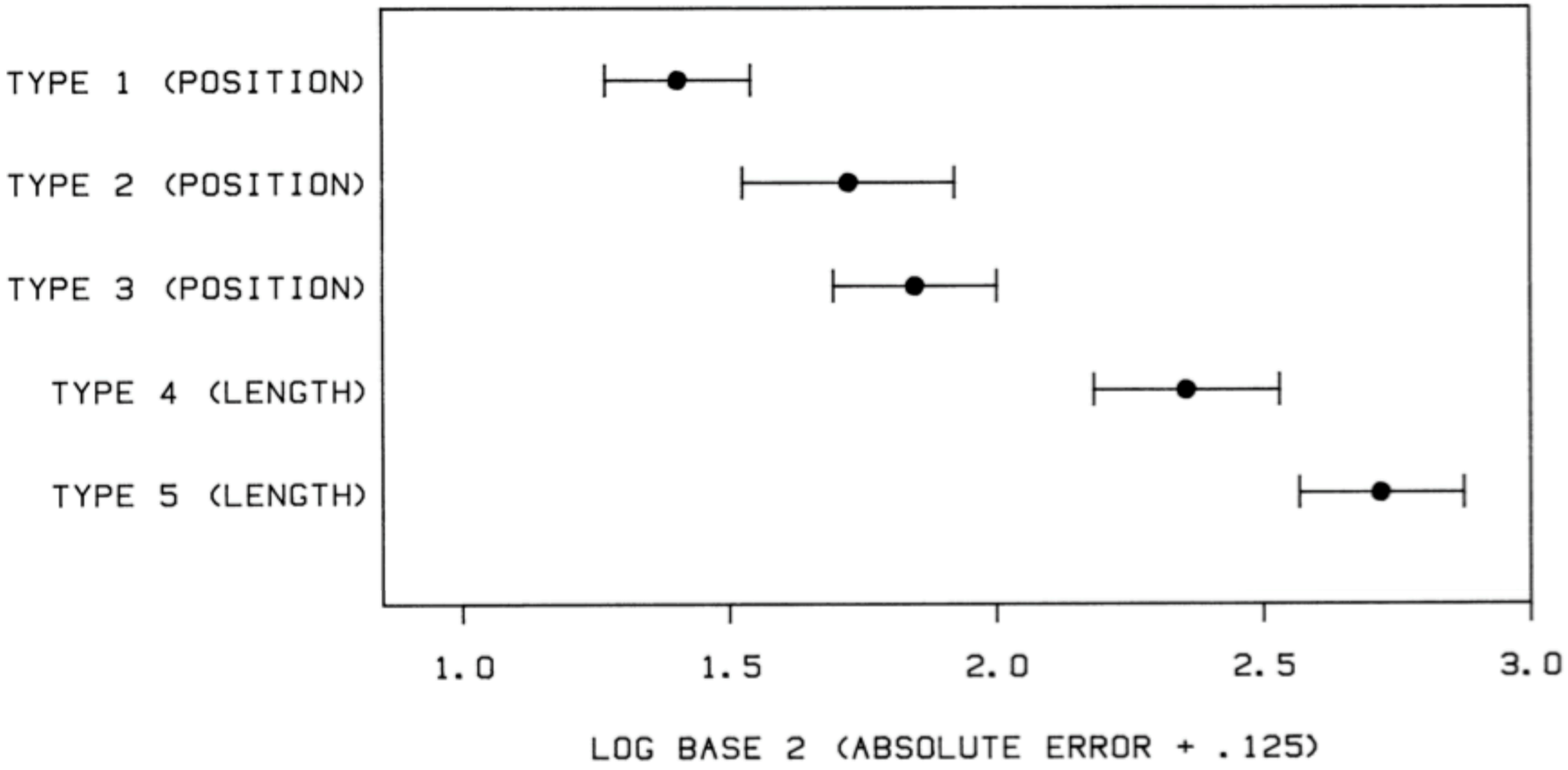
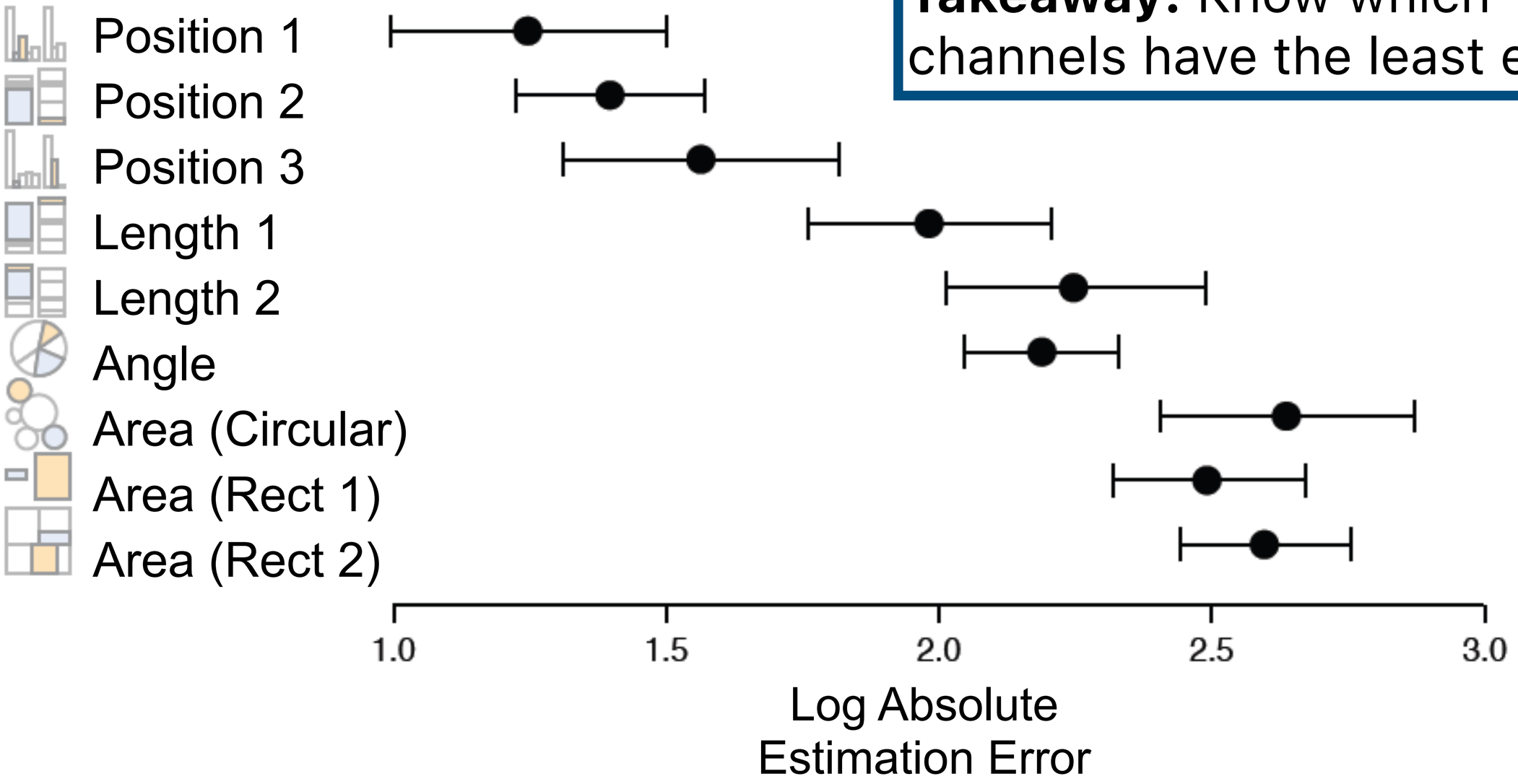


Figure 4. Graphs from position–length experiment.



Takeaway: Know which channels have the least error!



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

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Gestalt Grouping

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

How many 3s?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496 86

[Based on a slide from John Stasko]

How many 3s?

12817687561389765469845069856049828267629809858458224509856458945098450980943585909103020990595959577256467505067890456788457898098216776548763649085609129496 86

[Based on a slide from John Stasko]

Pre-Attentive Processing

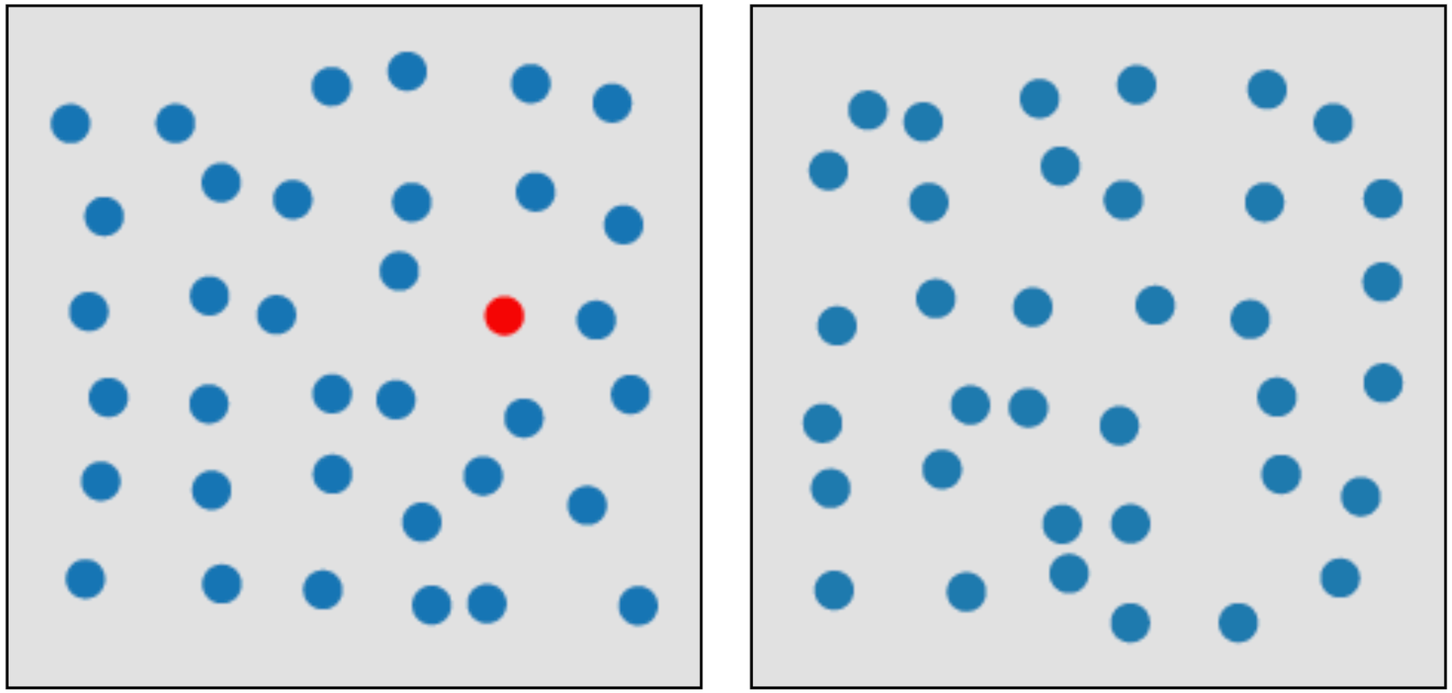
How fast does our visual system perceive differences?

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

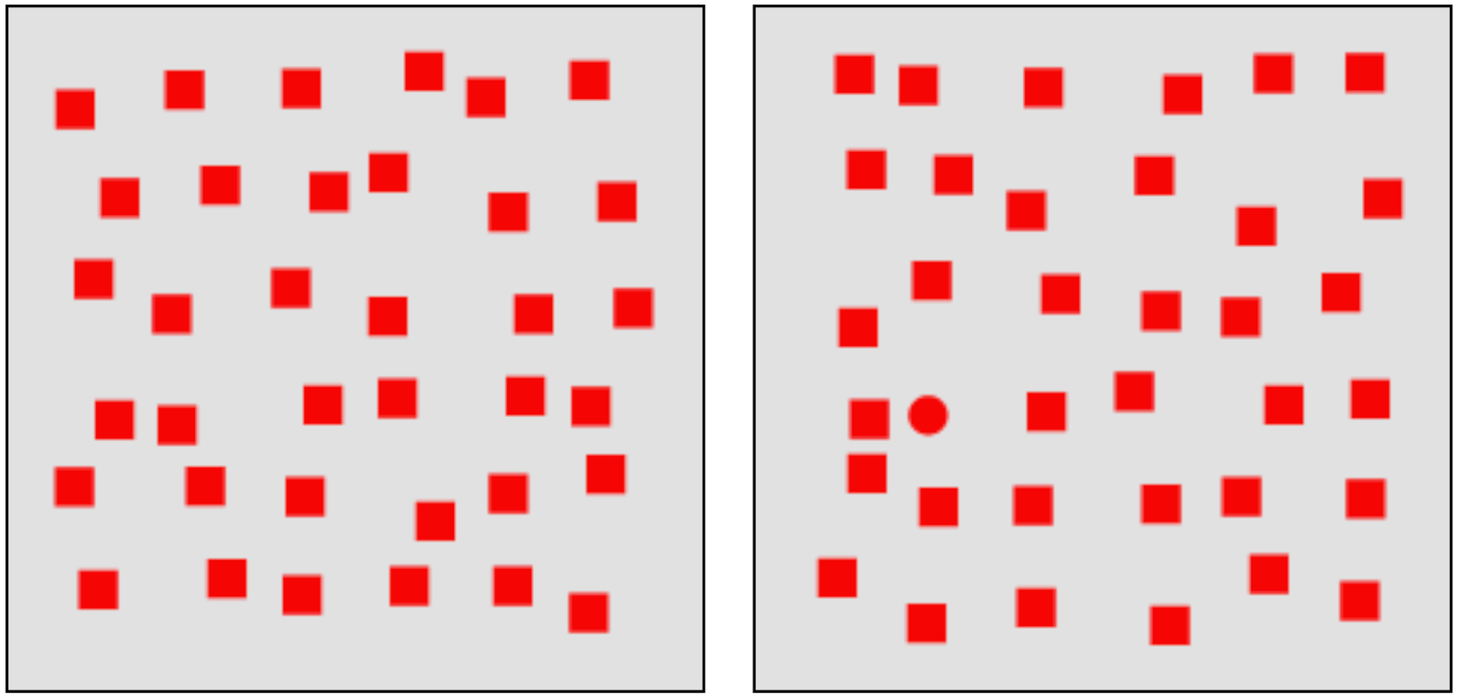
Color is pre-attentive



https://www.csc2.ncsu.edu/faculty/healey/PP/index.html

Pre-Attentive Processing

Shape too

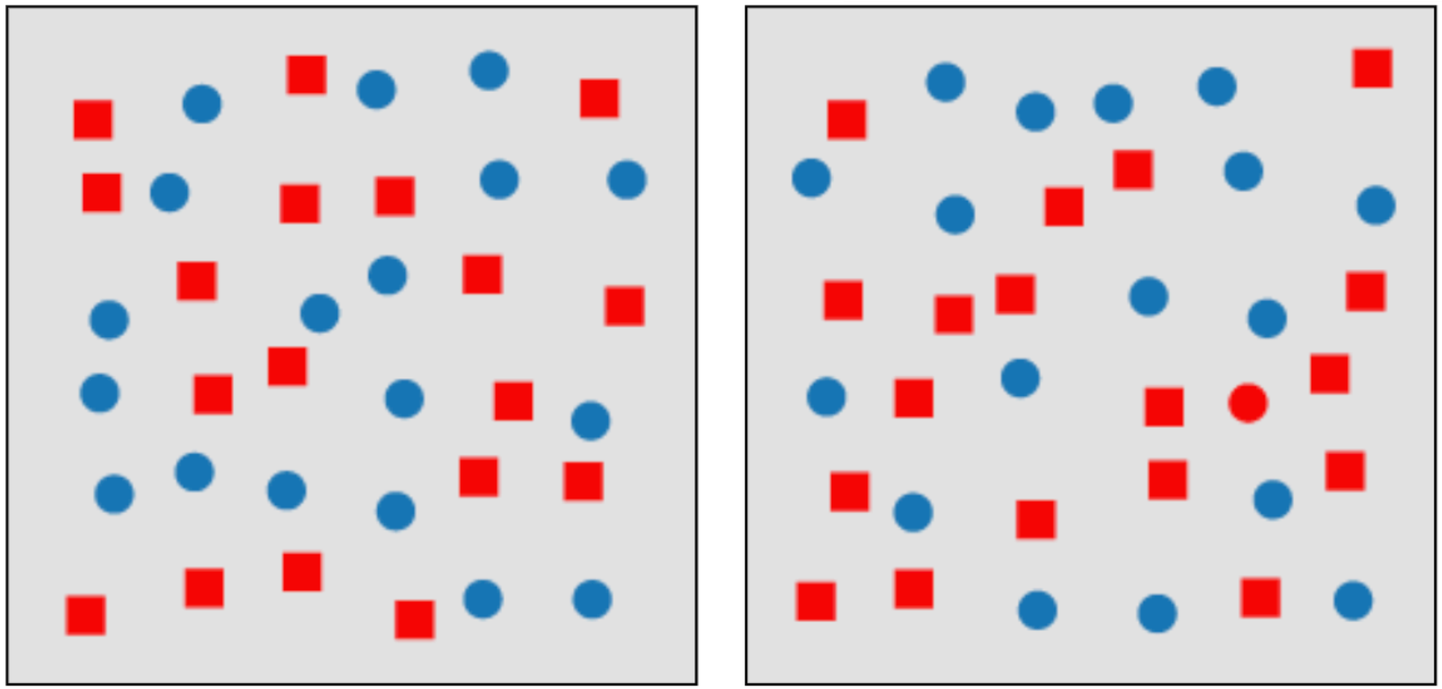


https://www.csc2.ncsu.edu/faculty/healey/PP/index.html

Pre-Attentive Processing

A *conjunction* is a combination of 2+ visual features.

But not a conjunction!



https://www.csc2.ncsu.edu/faculty/healey/PP/index.html

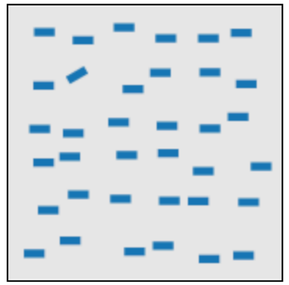
Pre-Attentive Processing

Many spatial features are pre-attentive

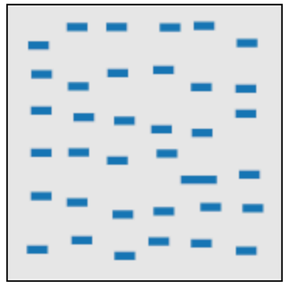
Many spatial *conjunctions* are also pre-attentive

But most other conjunctions are **NOT pre-attentive**

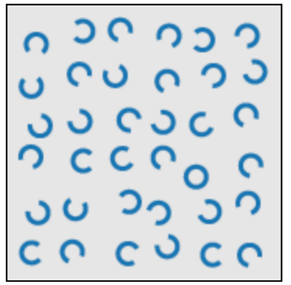
A few more pre-attentive features:



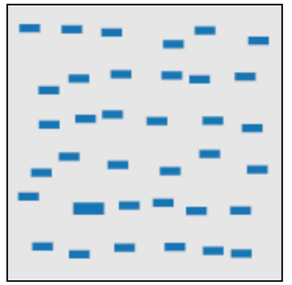
line (blob) orientation
Julész & Bergen 83; Sagi & Julész 85a, Wolfe et al. 92; Weigle et al. 2000



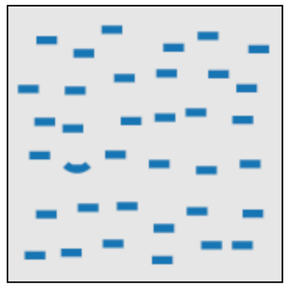
length, width
Sagi & Julész 85b; Treisman & Gormican 88



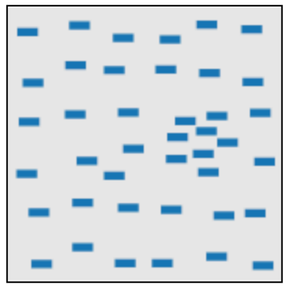
closure
Julész & Bergen 83



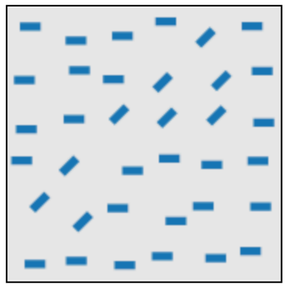
size
Treisman & Gelade 80; Healey & Enns 98; Healey & Enns 99



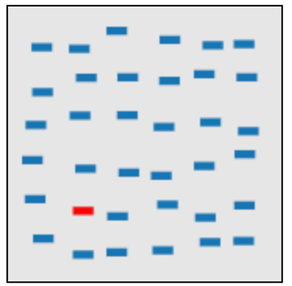
curvature
Treisman & Gormican 88



density, contrast
Healey & Enns 98; Healey & Enns 99



number, estimation
Sagi & Julész 85b; Healey et al. 93; Trick & Pylyshyn 94



colour (hue)
Nagy & Sanchez 90; Nagy et al. 90; D'Zmura 91; Kawai et al. 95; Bauer et al. 96; Healey 96; Bauer et al. 98; Healey & Enns 99

intensity, binocular lustre
Beck et al. 83; Treisman & Gormican 88; Wolfe & Franzel 88

intersection
Julész & Bergen 83

terminators
Julész & Bergen 83

3D depth cues
Enns 90b; Nakayama & Silverman 86

Takeaway: Use pre-attentive features when you want reader to notice a difference

https://www.csc2.ncsu.edu/faculty/healey/PP/index.html

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

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

Signal Detection

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Gestalt Grouping

Separability: how much interaction occurs between attributes?

One-dimensional: brightness

Name the color

White

White

Black

White

Black

White

Black

Black

White

White

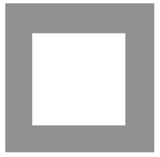
One-dimensional: shape

Name the shape

Square

Circle

Circle



Square

Circle

Circle

Circle

Square

Circle

Circle

Redundant: brightness and shape

Same information in 2+ visual channels

Name the color

Name the shape

White

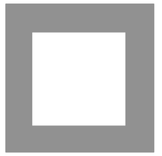
Black

Black

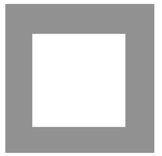
White

Black

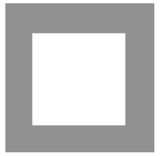
Circle



Square



Square

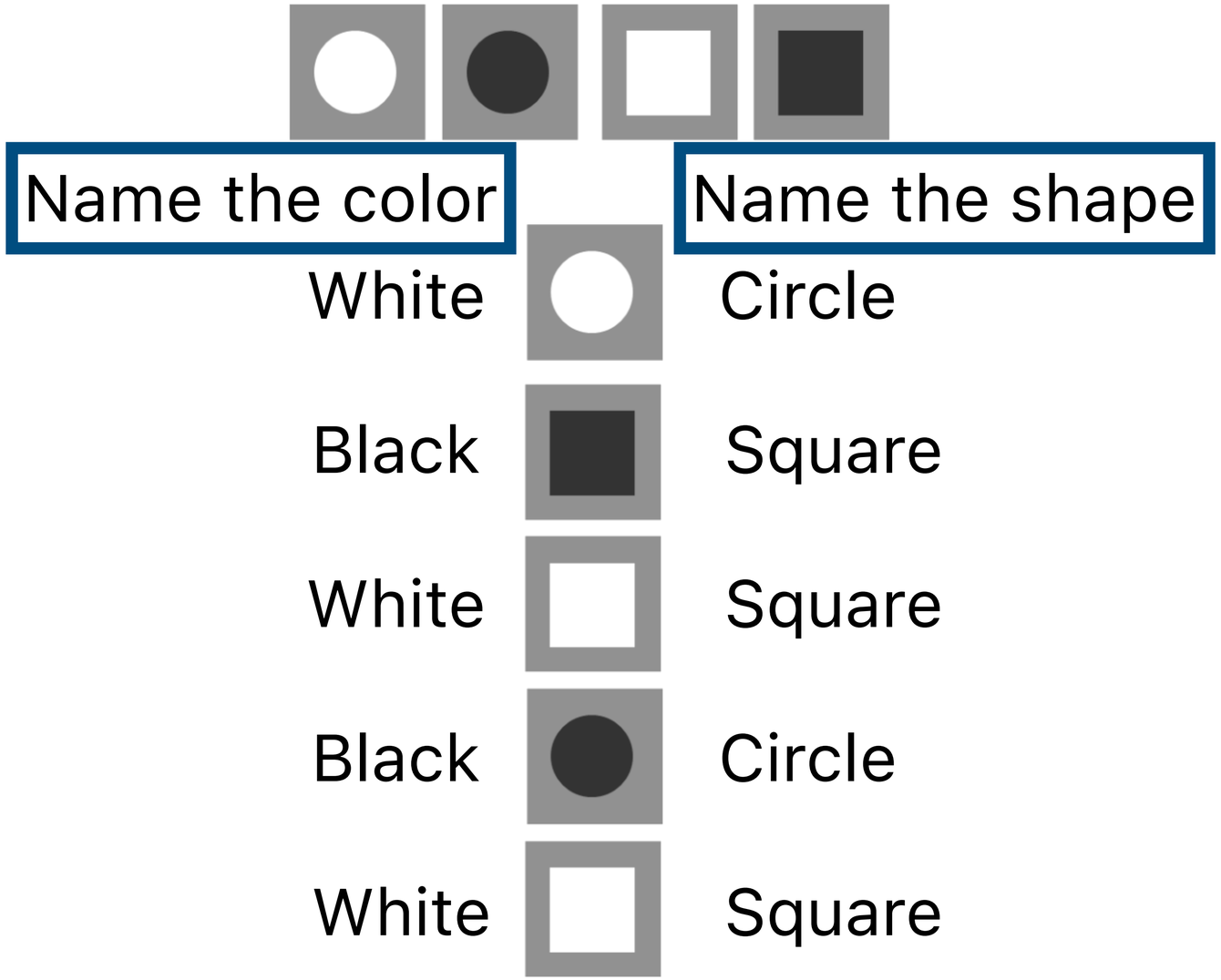


Square

Circle

Orthogonal: brightness and shape

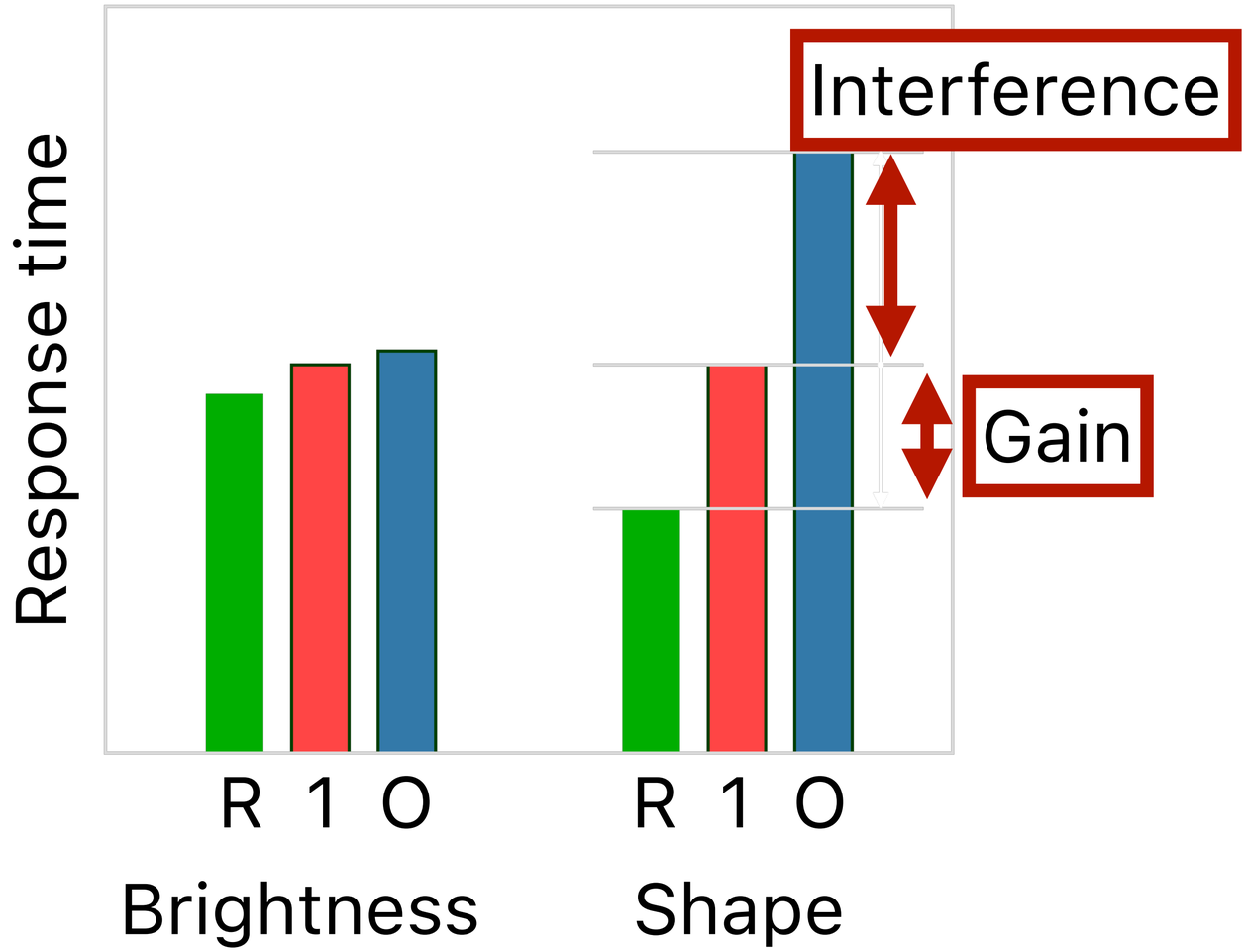
Different information in 2+ visual channels



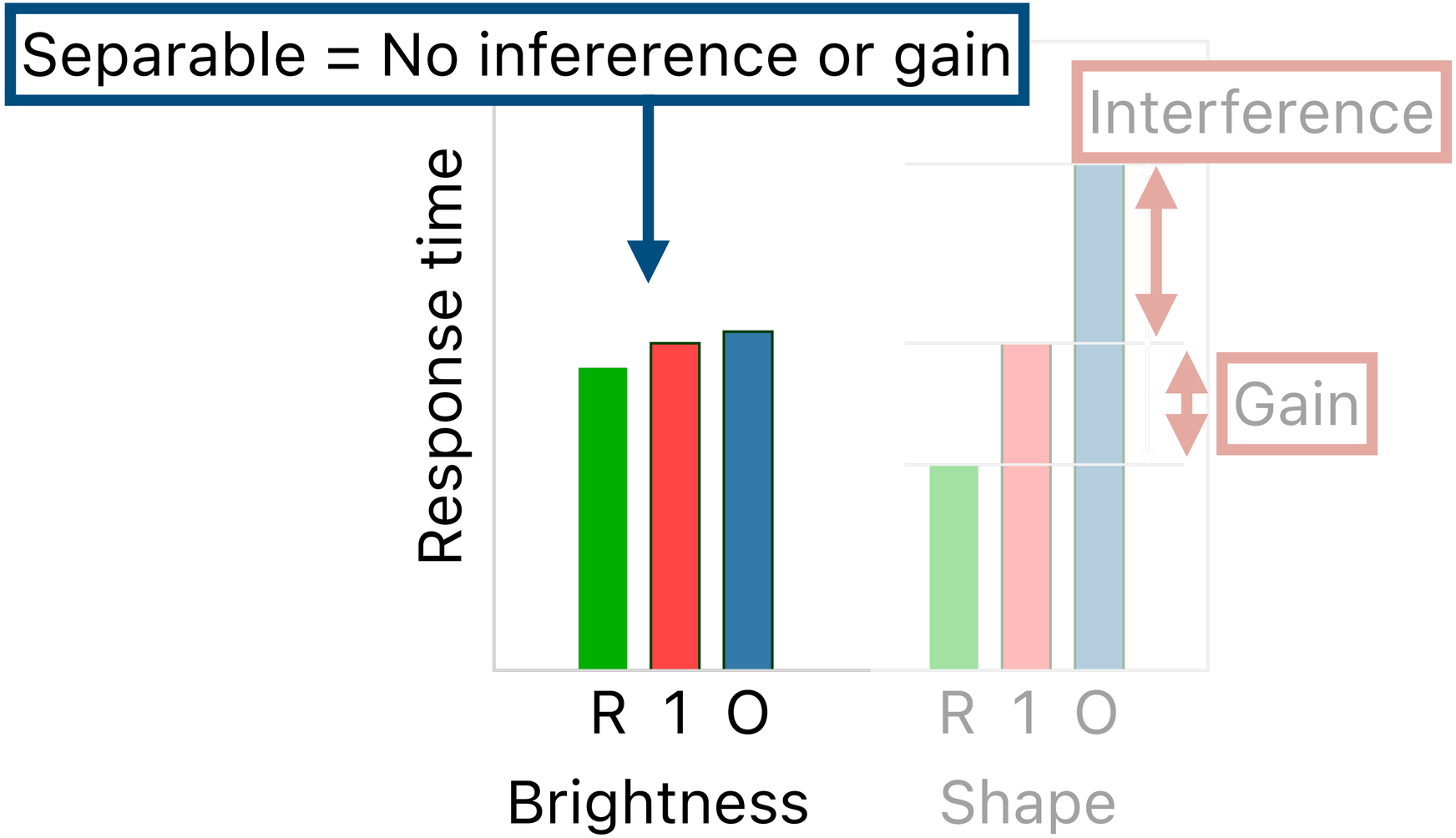
Conjunction principles

Redundancy Gain
Improved performance when both dimensions provide the same information.

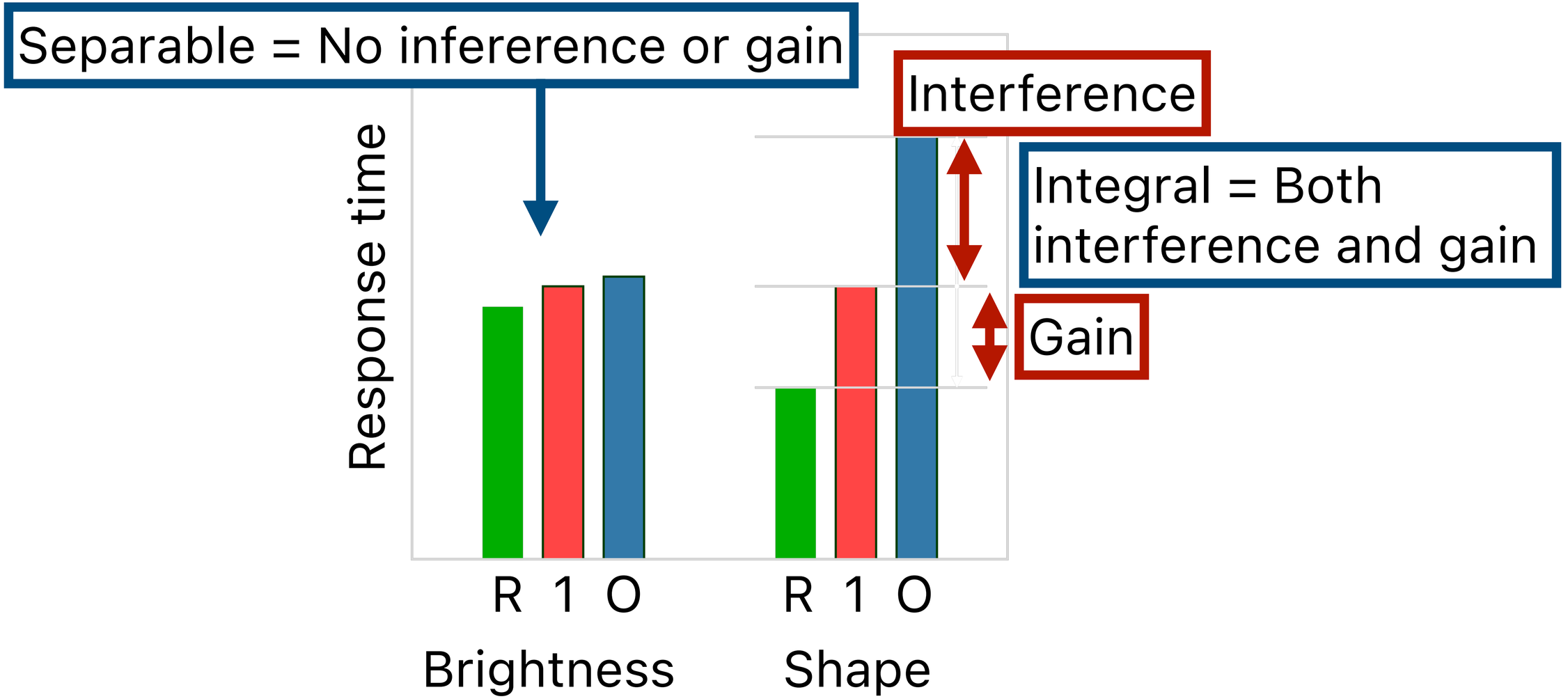
Filtering Interference
Difficulty in ignoring one dimension while attending to another.



Conjunction principles



Conjunction principles



Example: Position and Hue

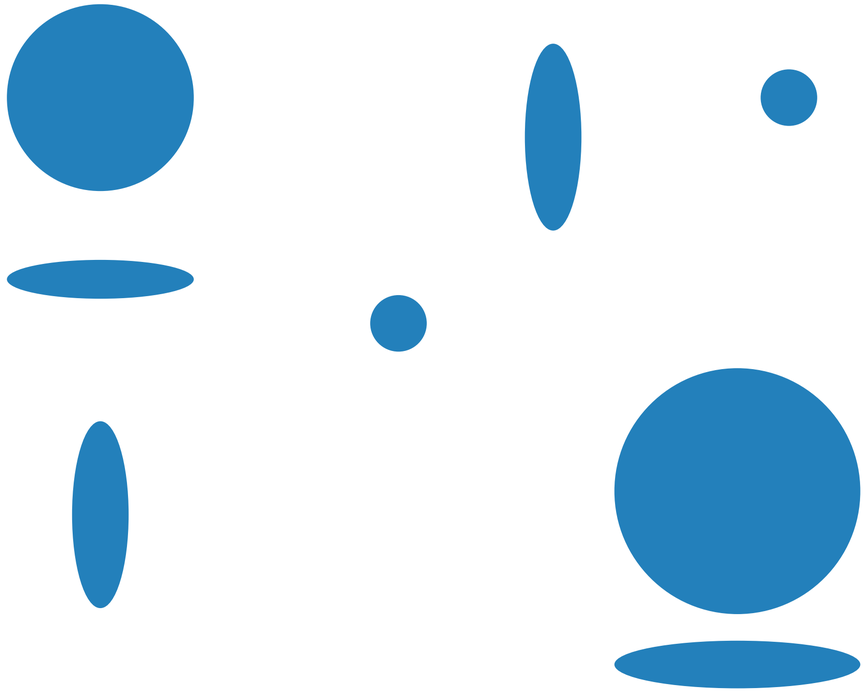
Separable:
No interference or gain

Munzner, Tamara. Visualization analysis and design. CRC press, 2014.

Example: Width and Height

Separable:
No interference or gain

Integral:
Both interference and gain



Munzner, Tamara. Visualization analysis and design. CRC press, 2014.

Example: Thickness and color

Separable:
No interference or gain

Integral:
Both interference and gain

Scale
The thickness of each line reflects the average number of vehicles on that road per day in 2011

2,000 5,000 10,000 20,000 50,000 100,000 150,000

Colour
Shows the percentage change compared to the previous year

-10 -5 0 5 10 30

https://multimedia.scmp.com/culture/article/SCMP-printed-graphics-memory/lonelyGraphics/201210A113.html

Example: Shape and Size?

Separable:
No interference or gain

Integral:
Both interference and gain

Configural:
Only interference, no gain

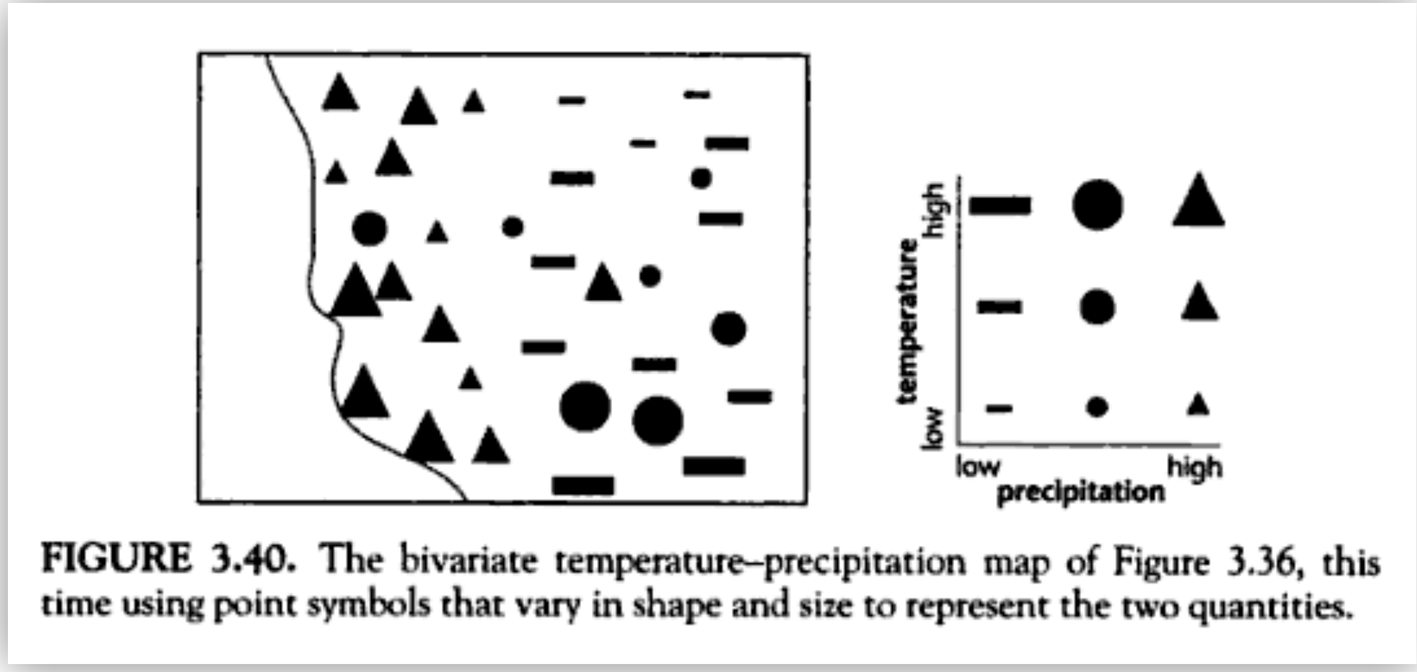


FIGURE 3.40. The bivariate temperature–precipitation map of Figure 3.36, this time using point symbols that vary in shape and size to represent the two quantities.

[MacEachren 1995]

Example: Stroop Effect

Separable:
No interference or gain

Integral:
Both interference and gain

Configural:
Only interference, no gain

blue

yellow

red

green

orange

purple

Example: Stroop Effect

Separable:
No interference or gain

Integral:
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Example: Stroop Effect

Separable:
No interference or gain

Integral:
Both interference and gain

Configural:
Only interference, no gain

Asymmetric:
One dimension separable but not the other

blue

yellow

red

green

orange

purple

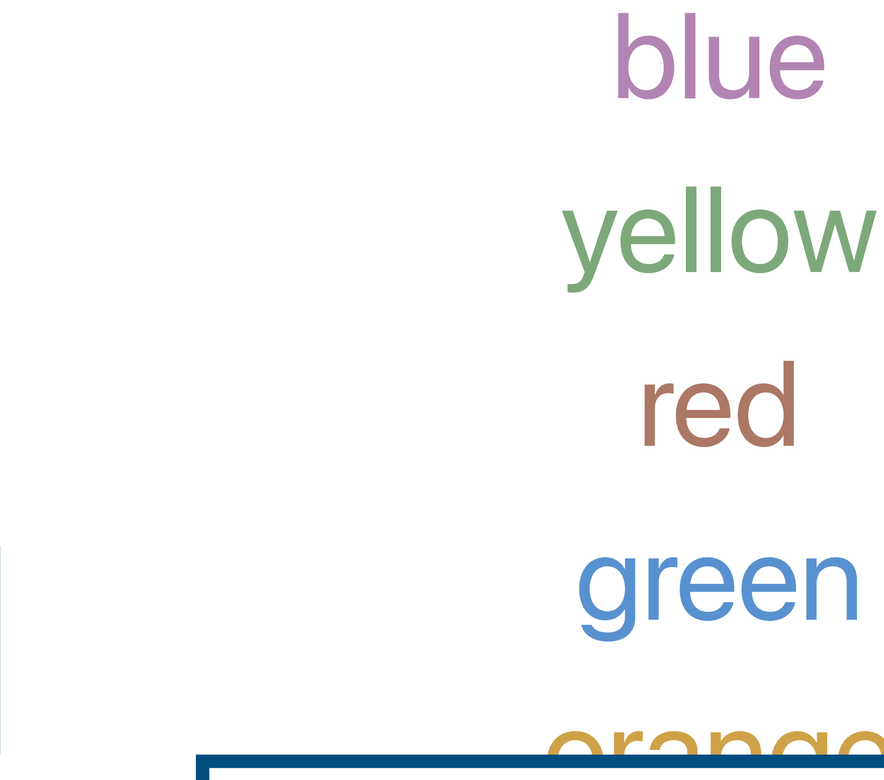
Example: Stroop Effect

Separable:
No interference or gain

Integral:
Both interference and gain

Configural:
Only interference, no gain

Asymmetric:
One dimension separable but not the other



Takeaway: take care when combining visual features, and make use of redundant encodings!

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Separability: how much interaction occurs between attributes?

Signal Detection

Magnitude Estimation

Pre-Attentive Processing

Selective Attention

Gestalt Grouping

Organization: how do we group visual elements?

Gestalt Principles

Figure / Ground

Proximity

Similarity

Symmetry

Connectedness

Continuity

Closure

Common Fate

Will highlight most relevant ones for vis, not all of them

https://en.wikipedia.org/wiki/Principles_of_grouping

Gestalt Principles

What's in the foreground?

Figure / Ground

Proximity

Similarity

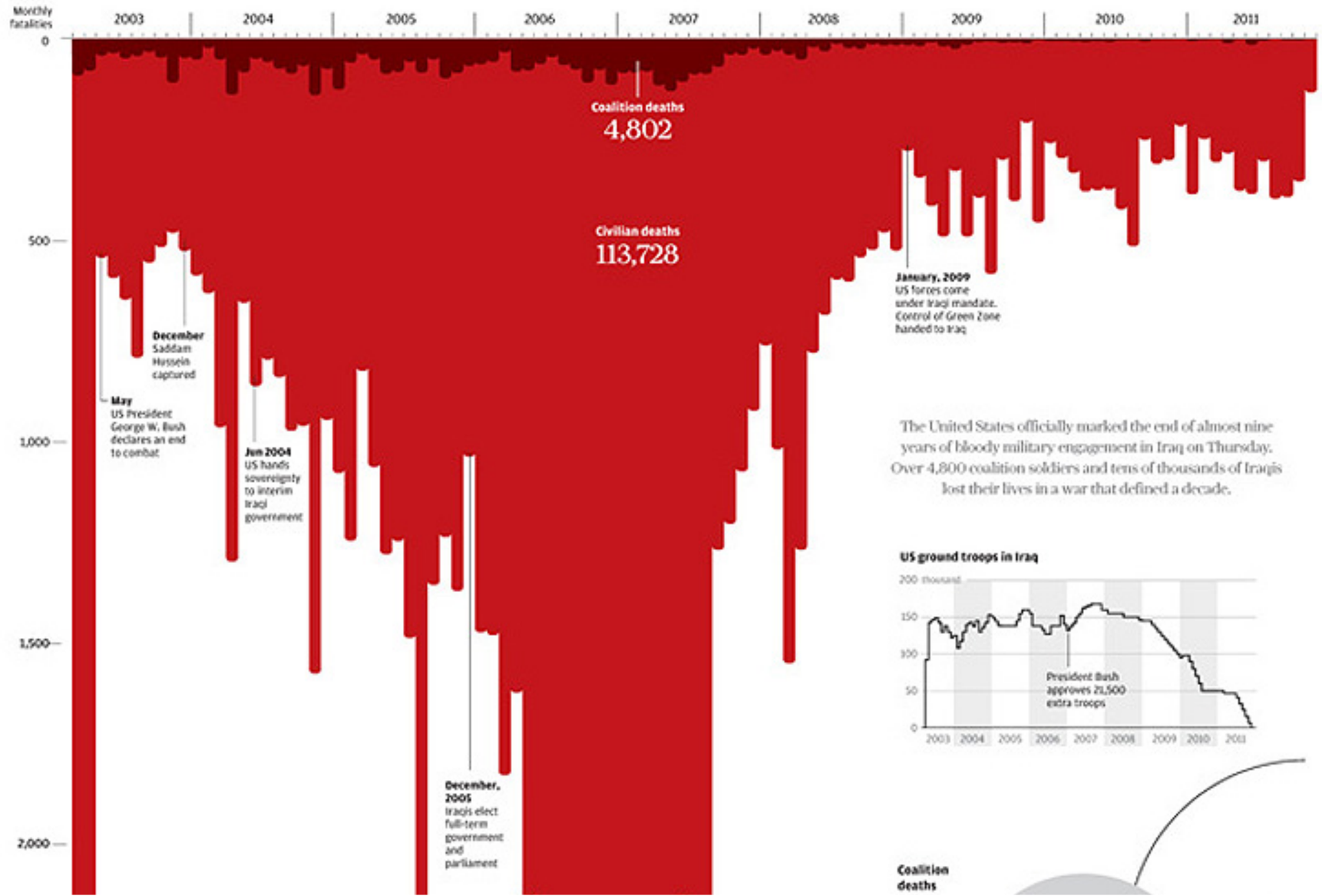
Symmetry

Connectedness

Continuity

Closure

Common Fate



https://www.simonscarr.com/iraqs-bloody-toll

Gestalt Principles

What's in the foreground?

Figure / Ground

Proximity

Similarity

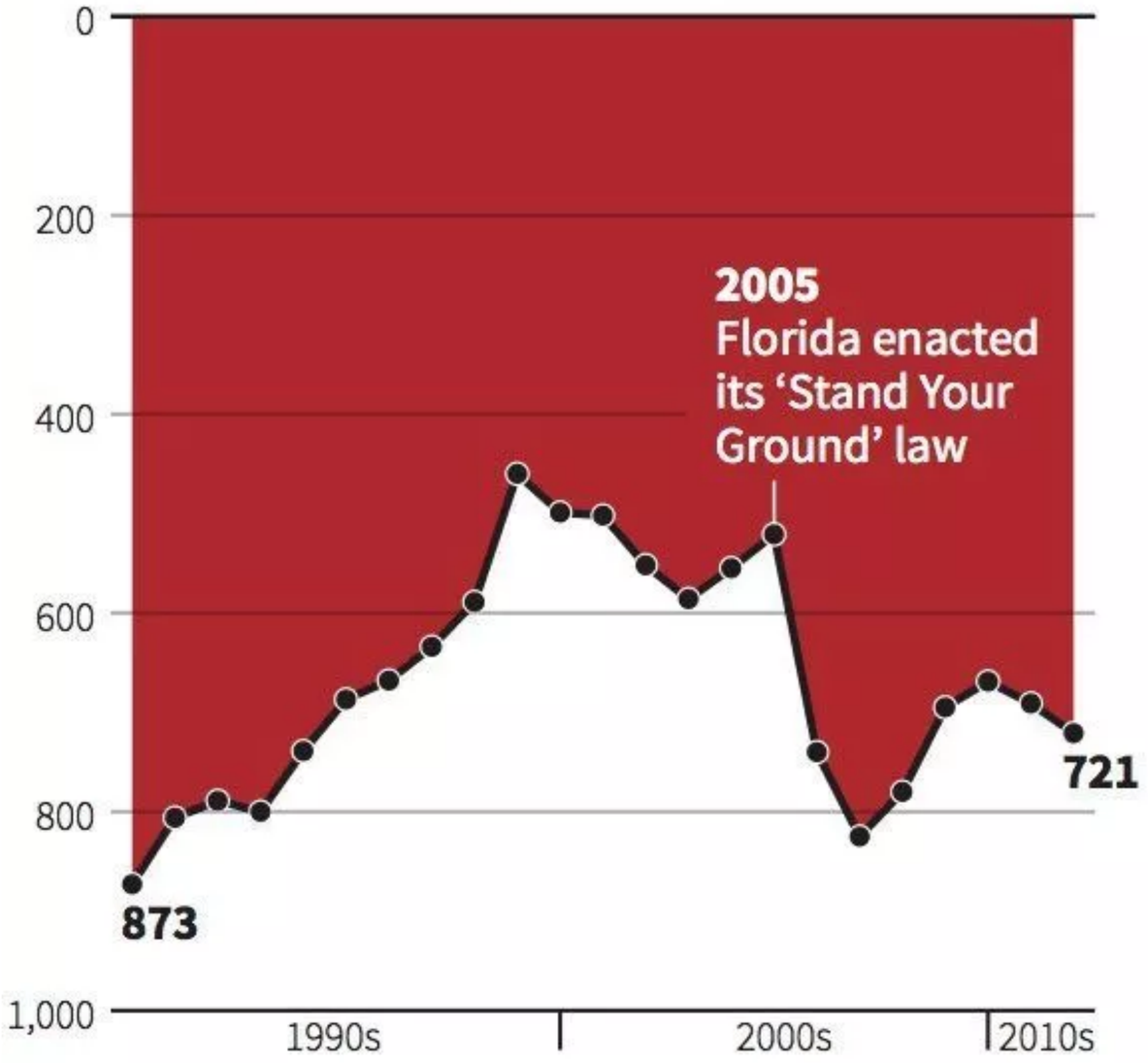
Symmetry

Connectedness

Continuity

Closure

Common Fate



https://www.livescience.com/45083-misleading-gun-death-chart.html

Gestalt Principles

Figure / Ground

Proximity

Similarity

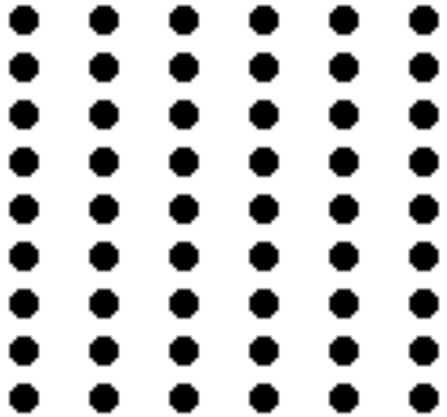
Symmetry

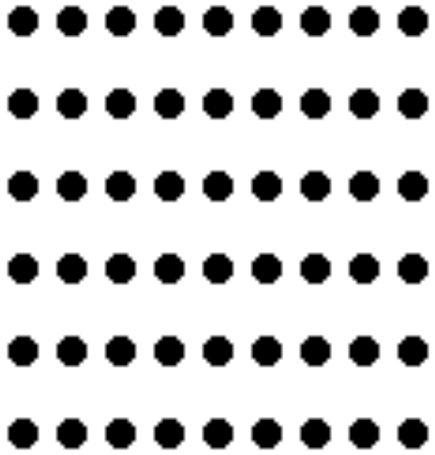
Connectedness

Continuity

Closure

Common Fate





https://www.livescience.com/45083-misleading-gun-death-chart.html

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

METRICS

HANNAH FAIRFIELD

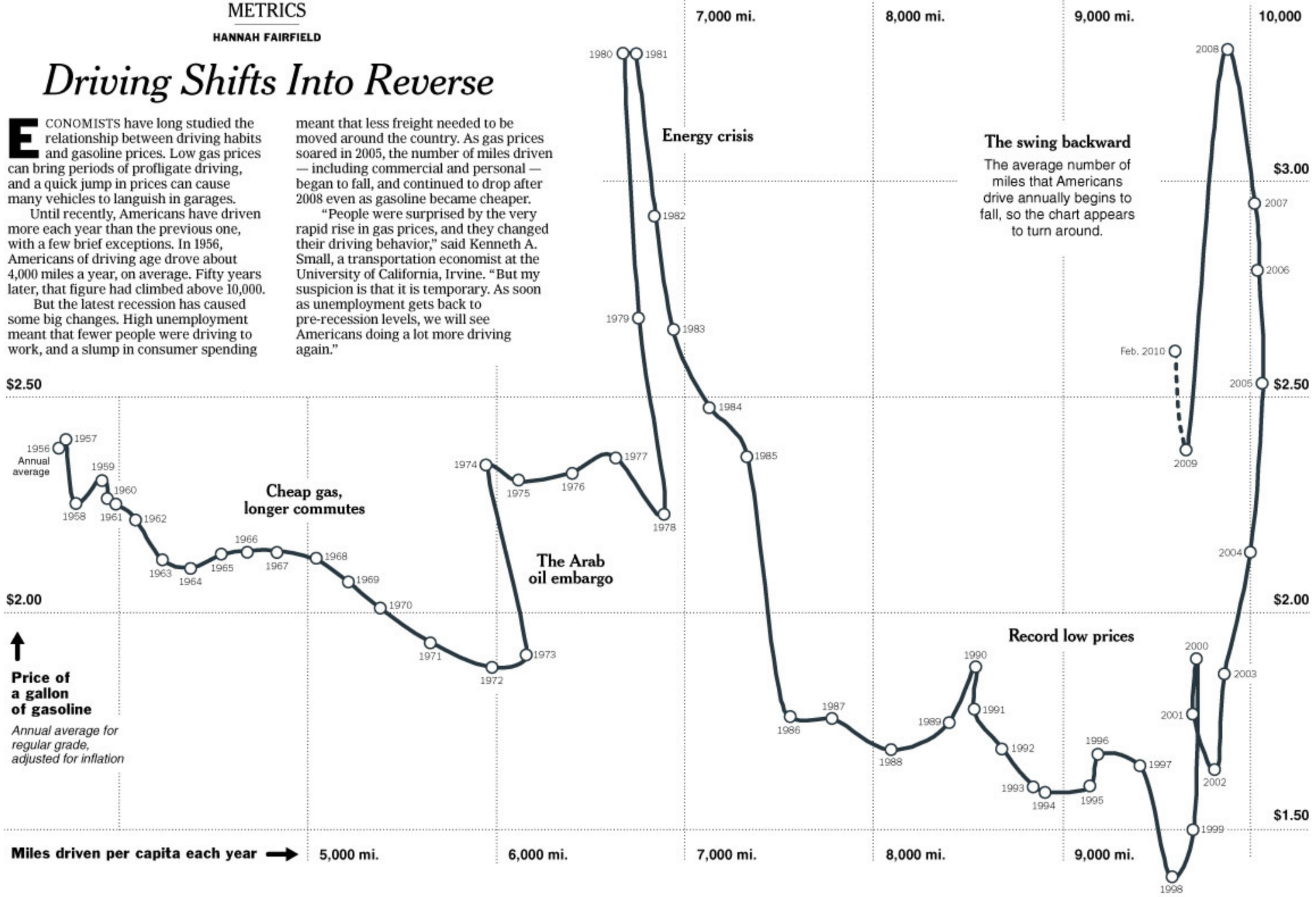
Driving Shifts Into Reverse

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

Figure / Ground

Proximity

Similarity

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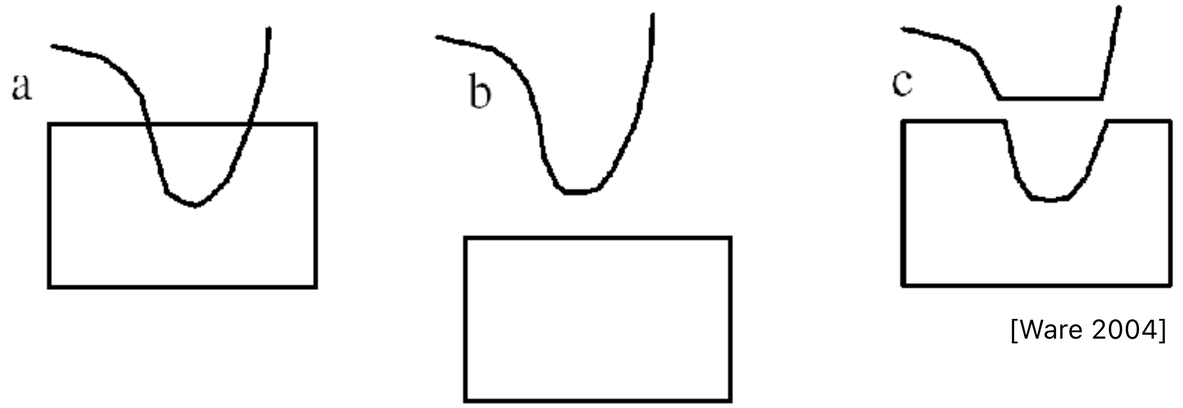
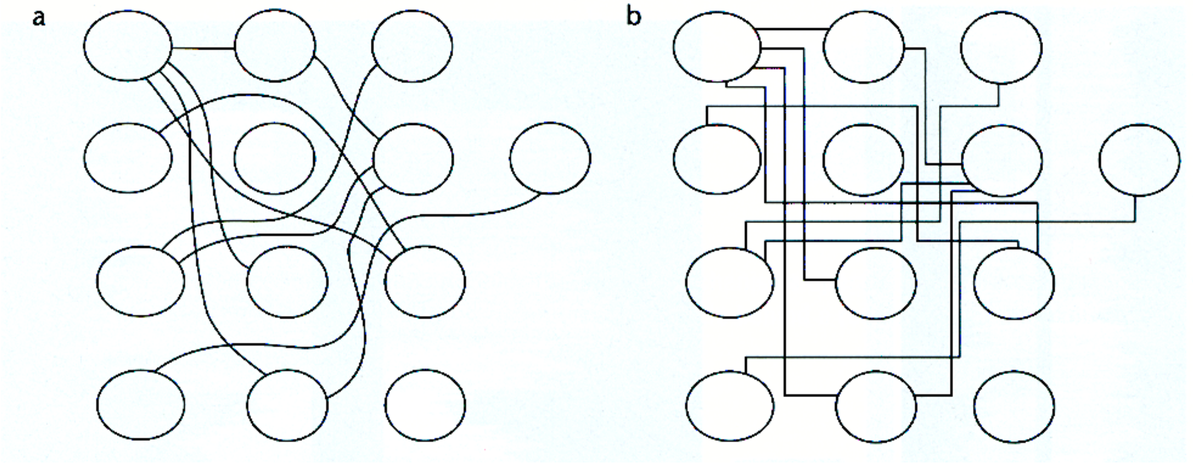
Common Fate



[Ware 2004]

We prefer smooth, not abrupt, changes.



Connections are clearer with smooth contours.

Gestalt Principles

Figure / Ground

Proximity

Similarity

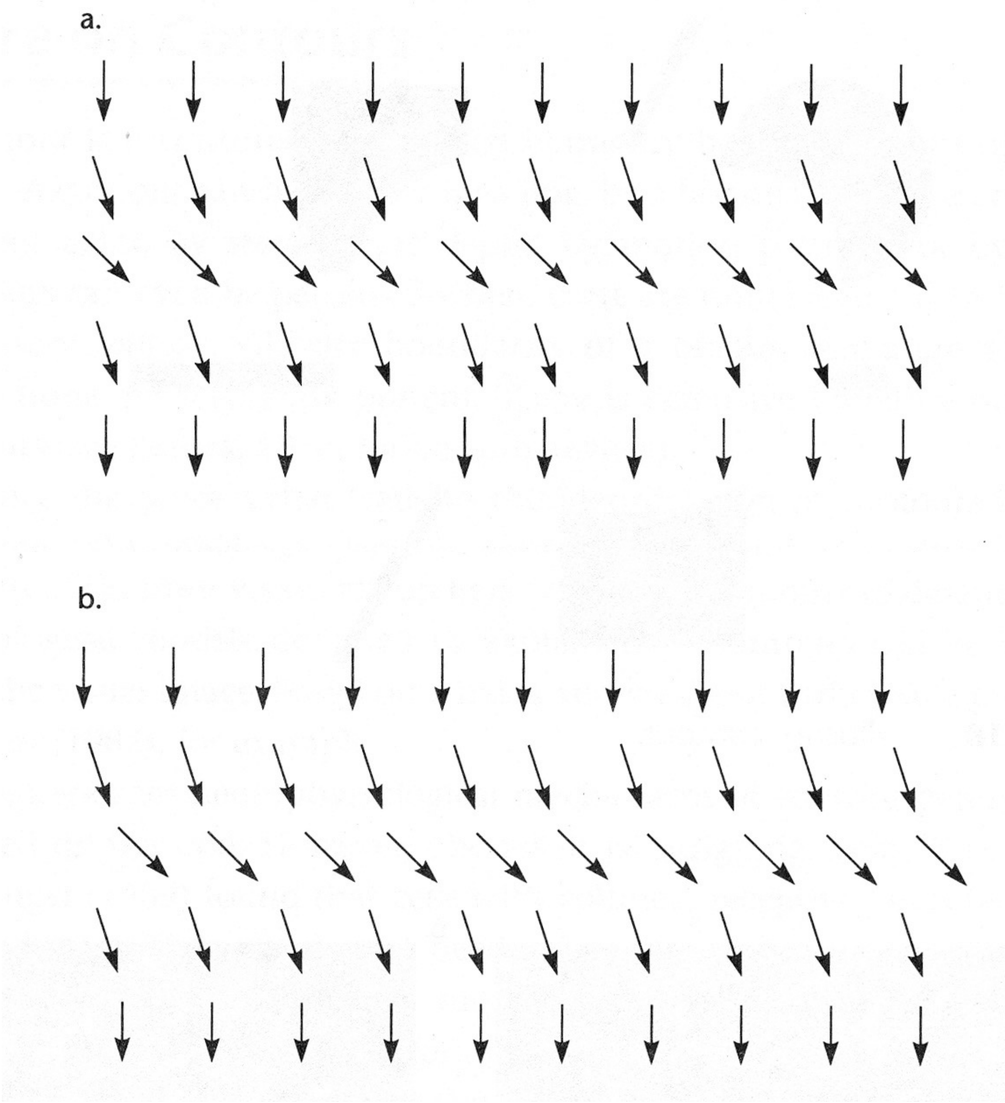
Symmetry

Connectedness

Continuity

Closure

Common Fate



Prefer field that shows smooth continuous contours

Gestalt Principles

Figure / Ground

Proximity

Similarity

Symmetry

Connectedness

Continuity

Closure

Common Fate

Dots moving together are grouped.

Gestalt Principles

Figure / Ground

Proximity

Similarity

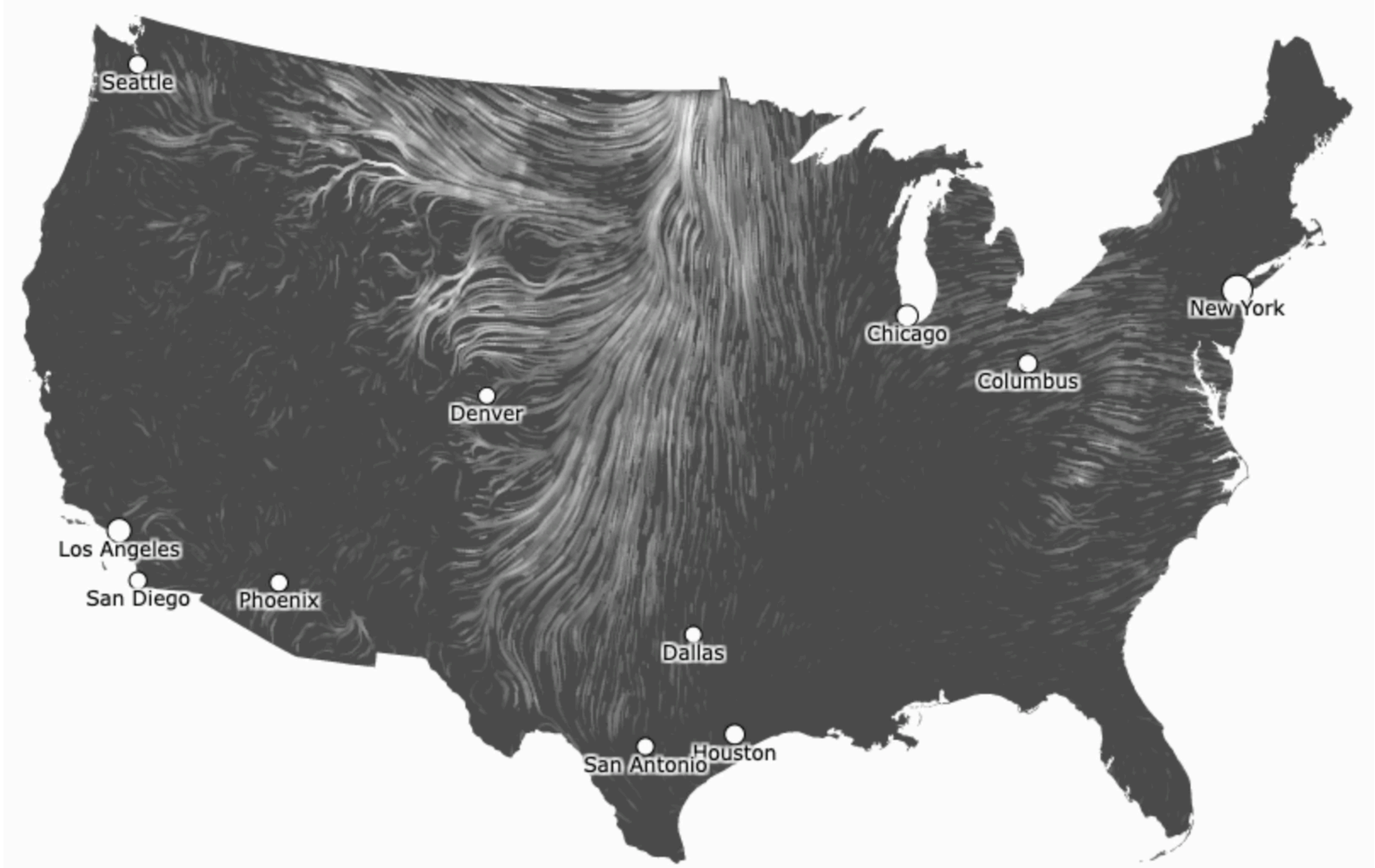
Symmetry

Connectedness

Continuity

Closure

Common Fate



http://hint.fm/wind/

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. position, color.

Selective Attention

...but be careful with combinations of channels!

Gestalt Grouping

Use these to improve annotations, coloring, animations.