

05: Marks and Channels

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90529 Data Visualization

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<https://2020.aulaweb.unige.it/course/view.php?id=4293>

Credits:

material in these slides is partially taken from

- T. Munzner, University of British Columbia
- A. Lex, University of Utah

other credits in the slides

Definitions: Marks and Channels

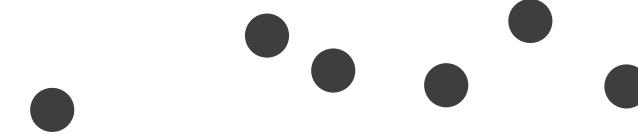
Part of the “How” stage of design

- Marks:
 - graphical elements
 - depict *items / links*
- Channels:
 - control appearance of marks, represent *attributes*
 - correspond to the “What” data classification
 - *Magnitude channels*: ordered data / “how much”
 - *Identity channels*: categorical data / “what-where”
- One mark + one/a few channels → one item + one/a few attributes

Definitions: Marks for Items

- Marks
 - geometric primitives

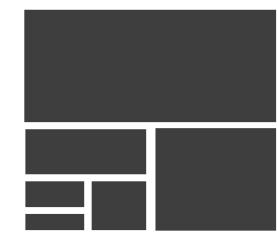
→ Points



→ Lines



→ Areas



0D

1D

2D

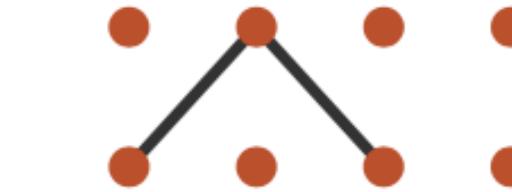
- 3D mark: volume, but rarely used

Definitions: Marks for Links

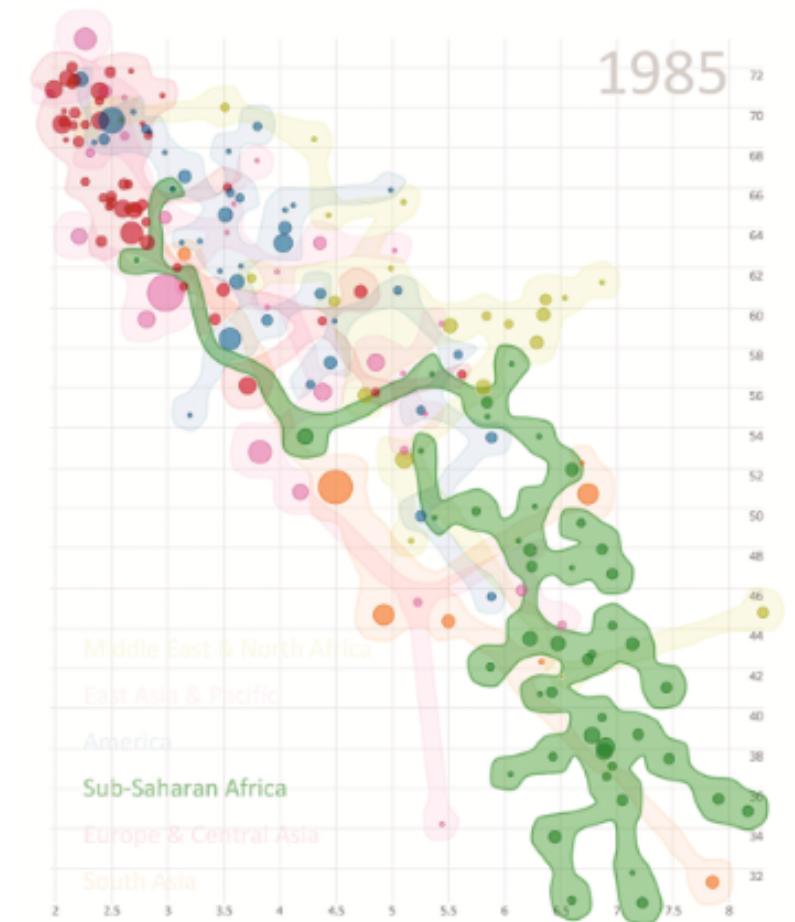
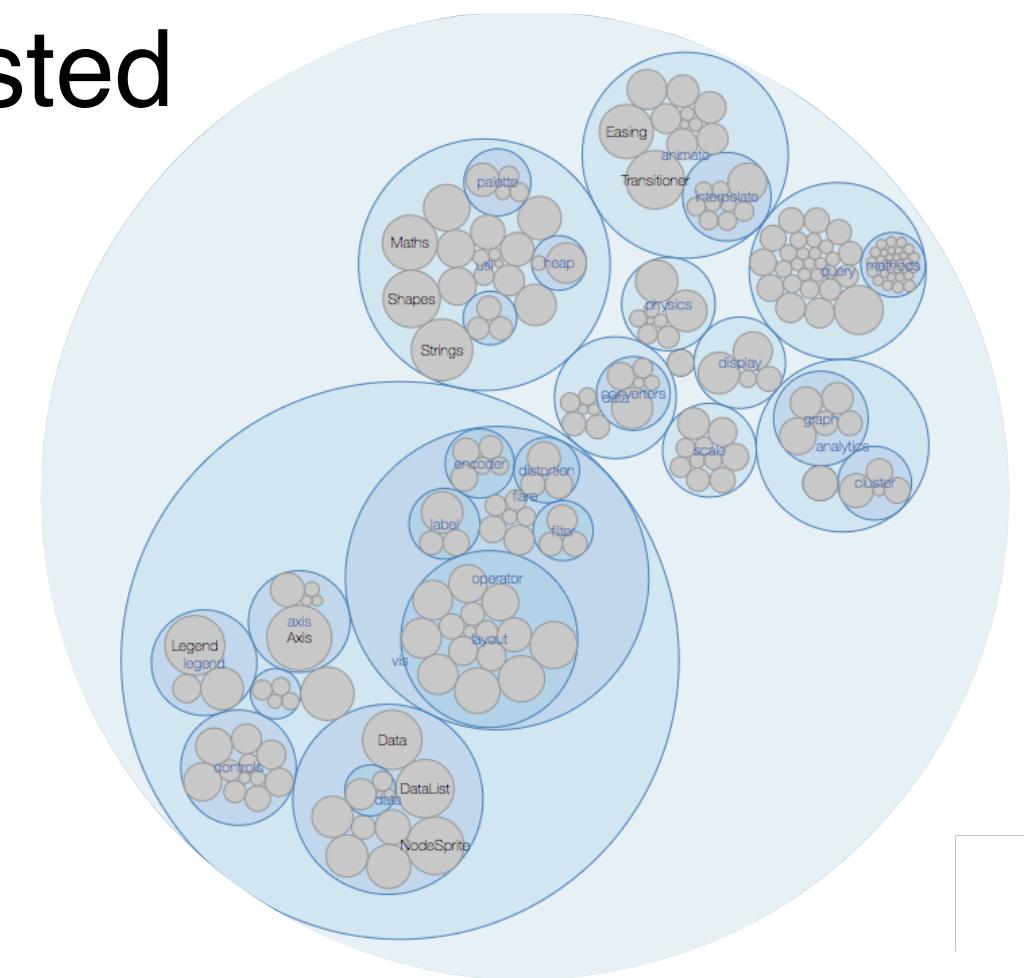
→ **Containment**



→ **Connection**



Containment can be nested



Definitions: Channels

- **Channels**

- graphical/geometrical attributes
- control appearance
- based on attributes

➔ Position

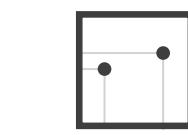
→ Horizontal



→ Vertical



→ Both



➔ Color



➔ Shape



➔ Tilt



➔ Size

→ Length



→ Area



→ Volume



Types of channels

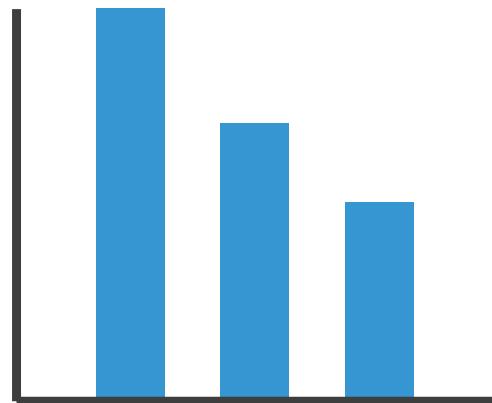
- Magnitude channels
 - How much?
 - At which position? (in an order)
 - spatial position
 - length
 - luminance, saturation
 - tilt
 - area
 - volume
- Identity channels
 - What?
 - Where?
 - shape
 - color (hue)
 - geometry (spatial region)

Ordinal and Quantitative data

Categorical data

Encoding visually with marks and channels

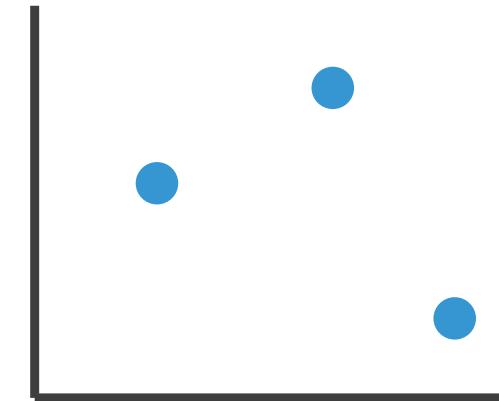
- analyze idiom structure
 - as combination of marks and channels



1 attribute

mark: line

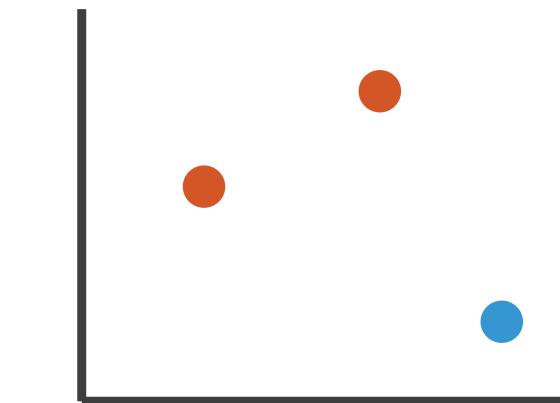
channel:
vertical position



2 attributes/keys

mark: point

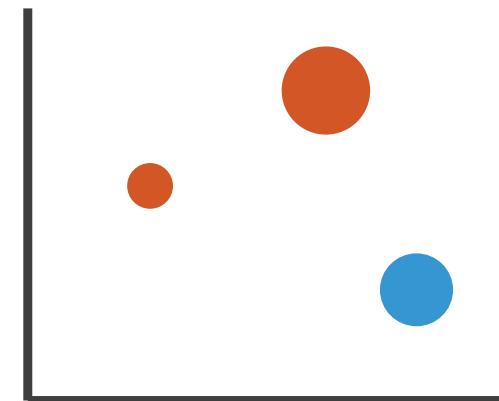
channels:
vertical position
horizontal position



3 attributes

mark: point

channels:
vertical position
horizontal position
color hue



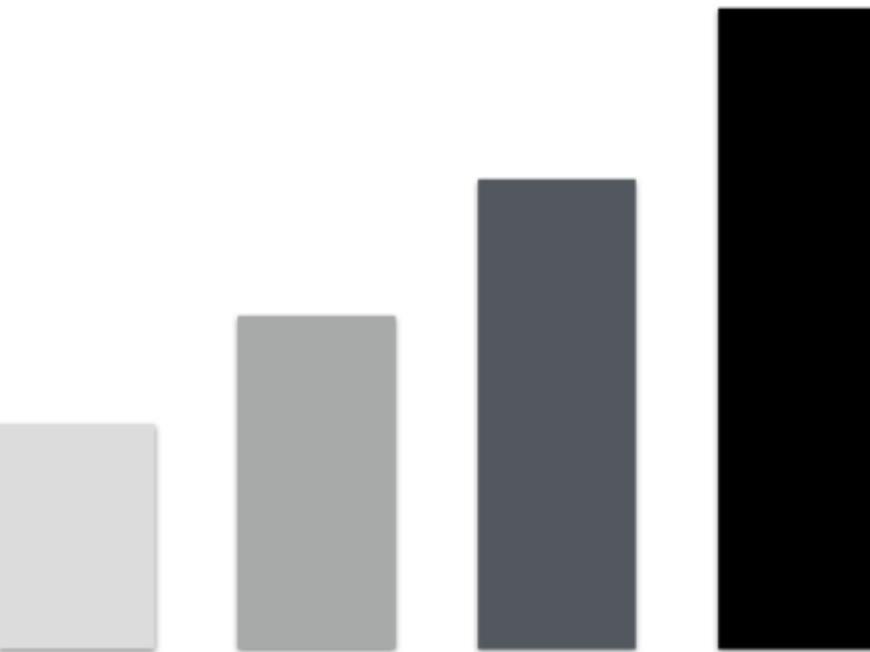
4 attributes

mark: point

channels
vertical position
horizontal position
color hue
size (area)

Channel redundancy

- Possibility to apply *different channels* to the same mark to denote *the same attribute*
- Reinforces expressiveness
- Lessens channels
- Ex: length + position + saturation

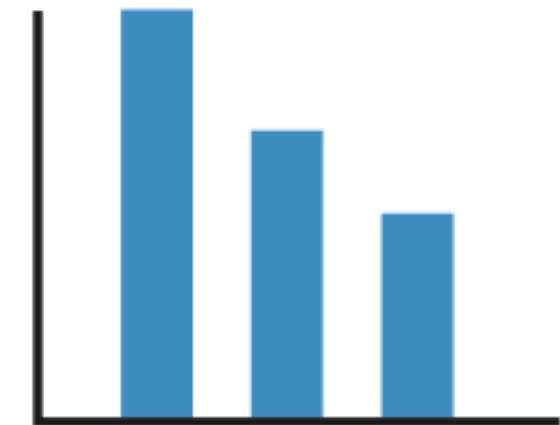


Channel multiplicity

- Possibility to apply *different channels* to the same mark to denote *different attributes* of the same item
 - One mark can be overloaded with 2-3 channels
 - More channels result ineffective
-
- Rule of thumb: use most effective channels for most important attributes
 - Ex: position/length, size, hue/saturation

Scarcity of resources

- Items can be many
 - Attributes per item can be many
 - Few marks and channels can be used together
 - Many different combinations are possible
 - Several views and different idioms can be necessary to show all items and attributes
 - Main challenge in designing a Vis app
- Ex.: a simple barchart can represent:
 - all items, one quantitative attribute per item
 - one item, many quantitative attributes (labeled on one axis)
 - derived data from all items, e.g., number of items for given classes

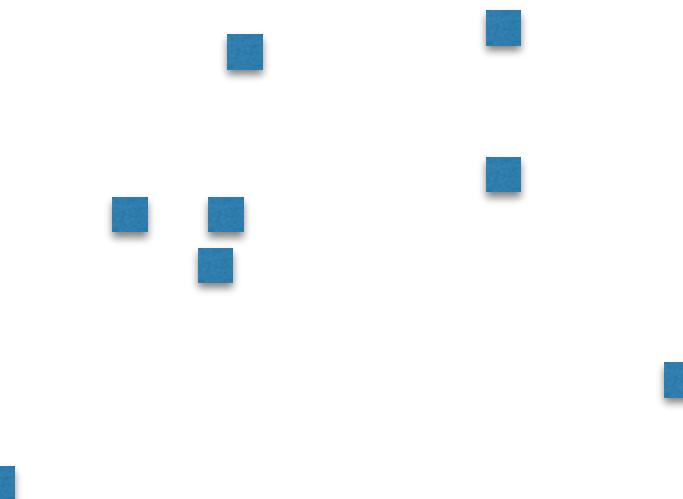


Characteristics of channels

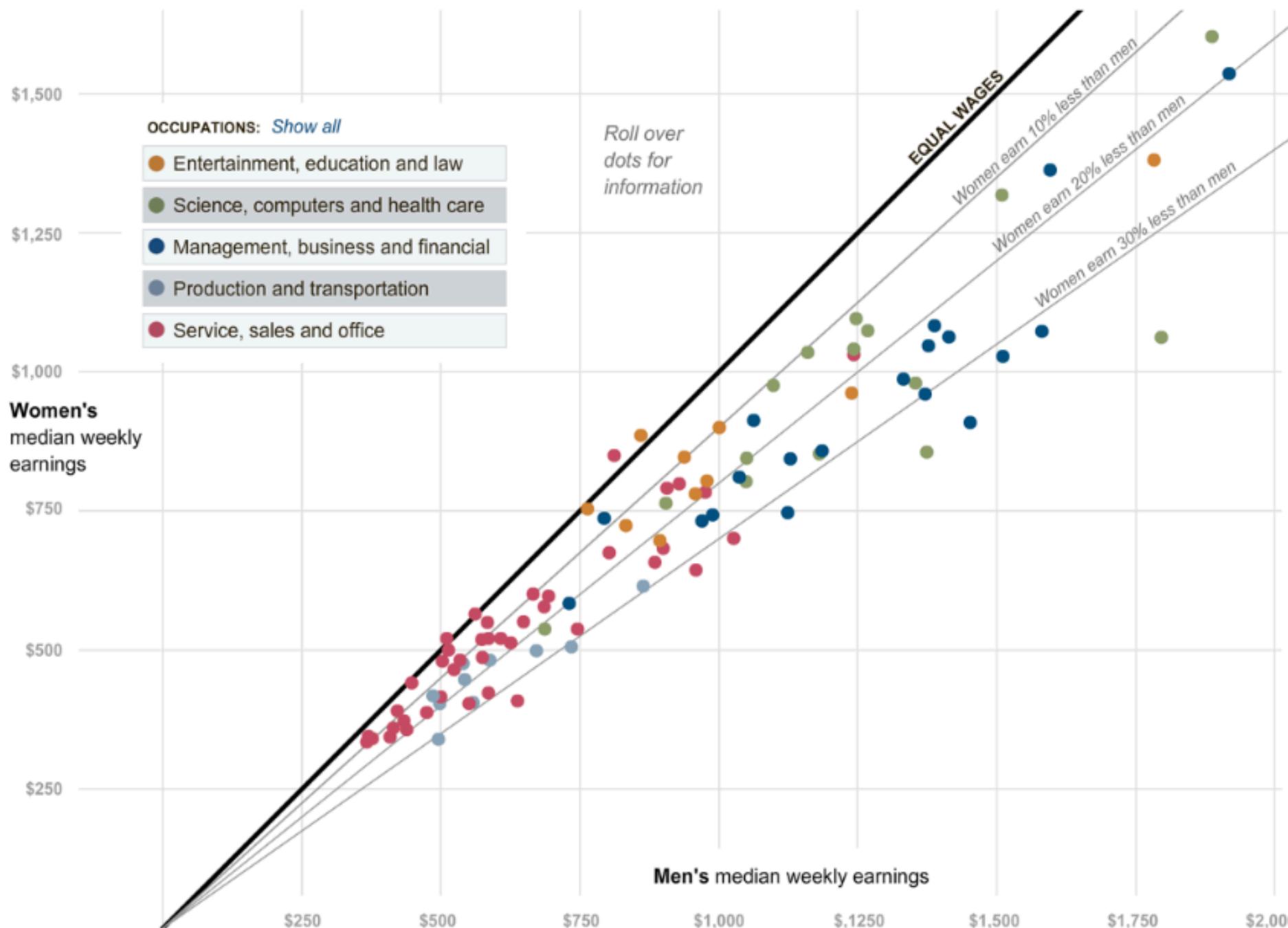
- Selectivity
 - Is a mark distinct from other marks?
 - Can we make out the difference between two marks?
- Associativity
 - Does it support grouping?
- Measurability (Magnitude vs Identity Channels)
 - Can we quantify the difference between two marks?
- Order (Magnitude vs Identity)
 - Can we see a change in order?
- Number of levels
 - How many unique marks can we make?

Position

- Strongest visual variable
- Suitable for all data types
- Issues:
 - Cluttering
 - Available area vs. number of items
 - Distribution of items
 - Sometimes not available (spatial data)
- Selective: yes
- Associative: yes
- Measurable: yes
- Ordered: yes
- # Levels: fairly many

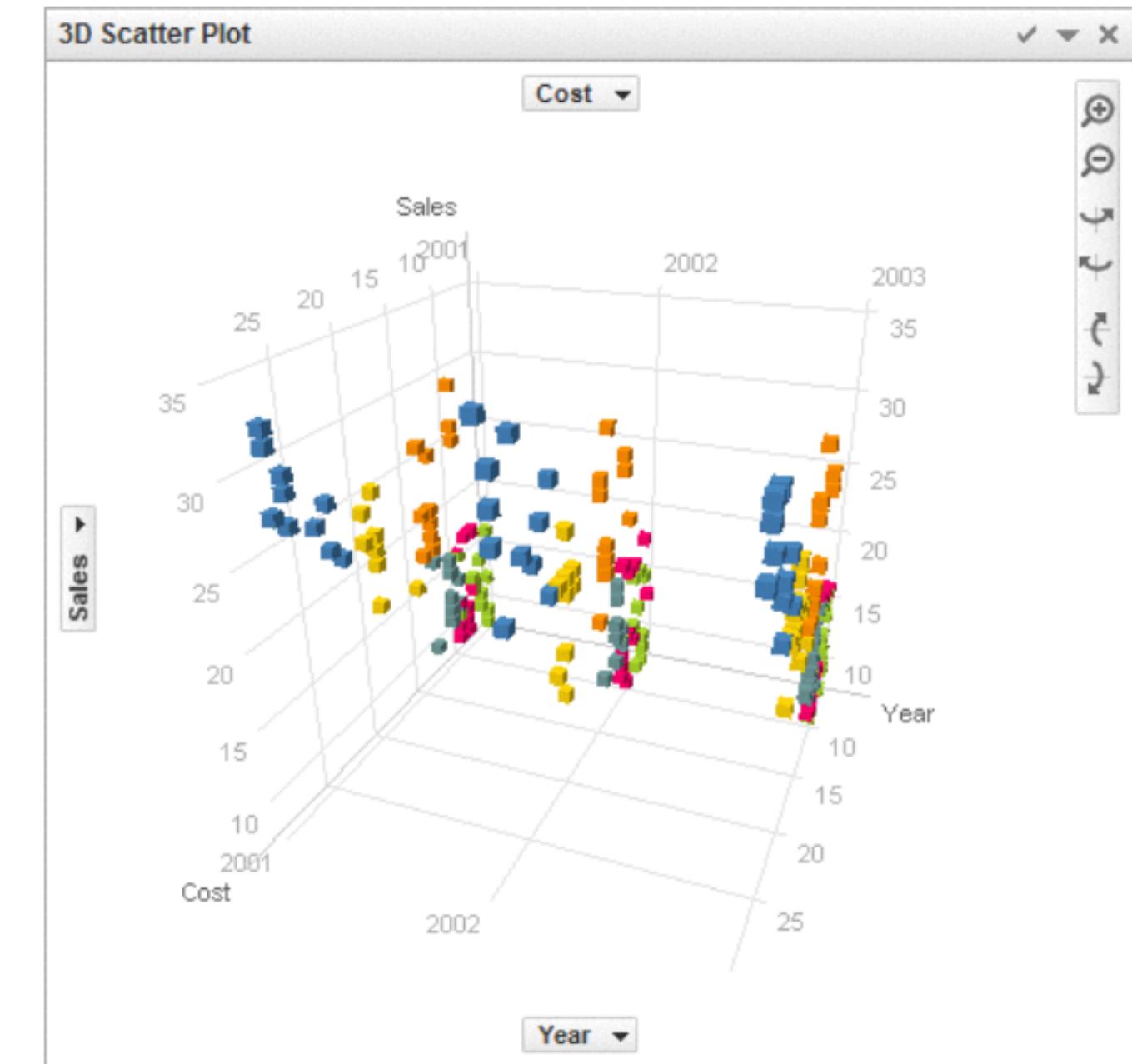


Example: scatterplot



Position in 3D?

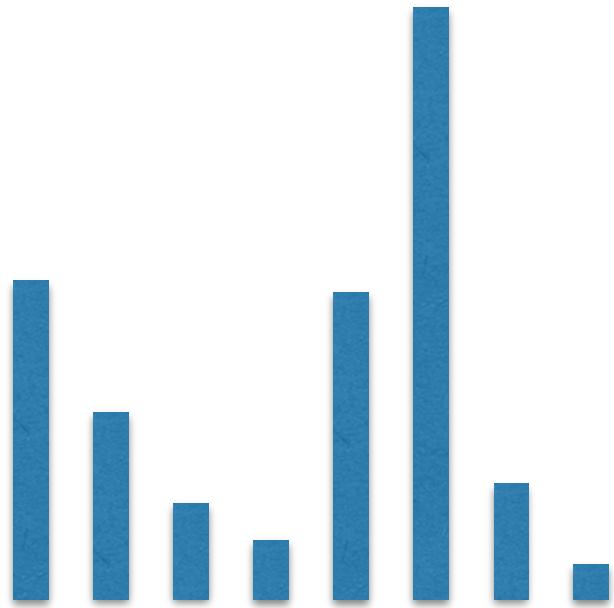
- Hard to read!
 - Occlusion
 - Perspective distortion
 - Misalignment with scales
- Interaction can help
 - variable viewpoint
 - spatial exploration



- Only with exactly three quantitative keys/values on comparable scales
- 2D scatterplot + size/intensity may easily be more effective

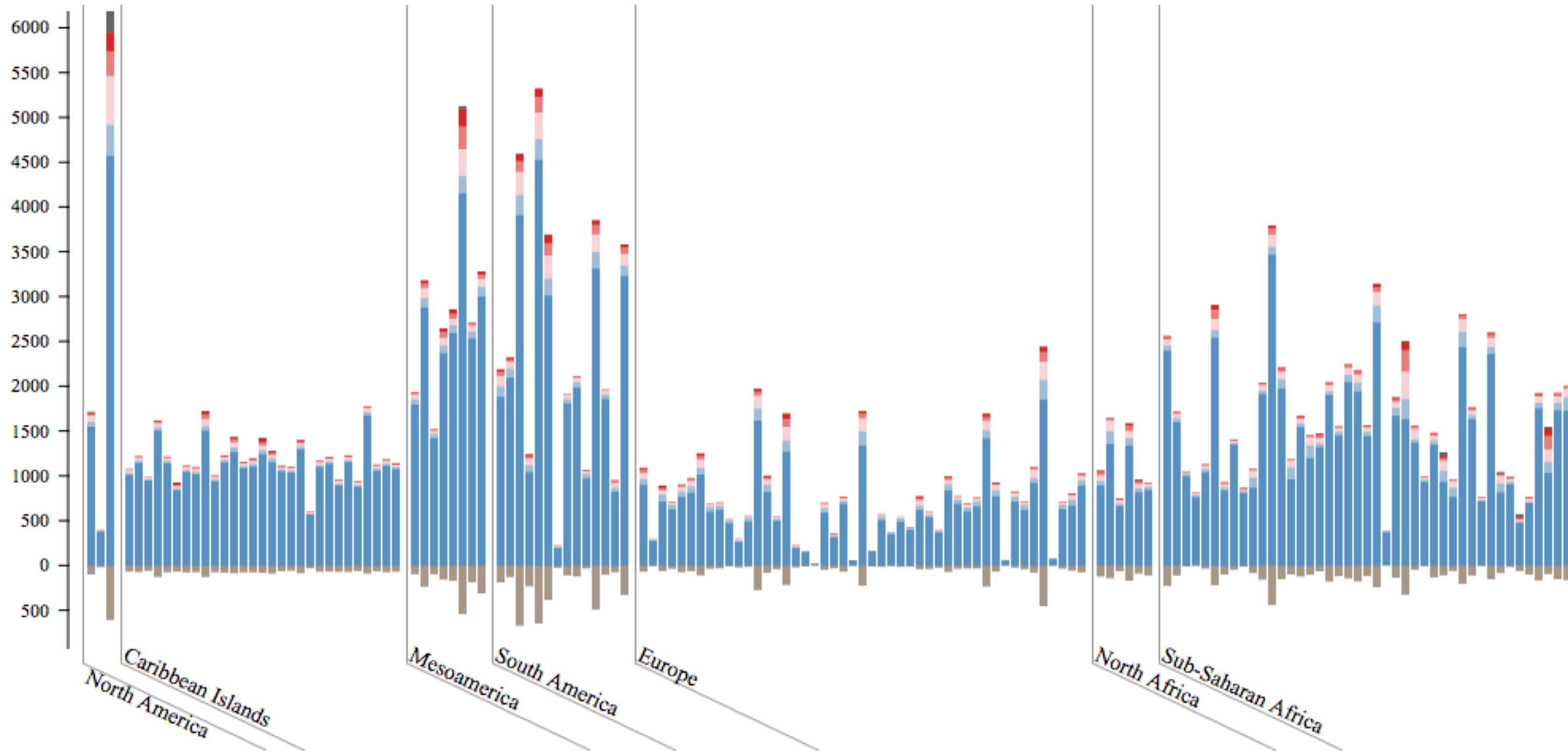
Length

- Strong channel
- Easy to compare



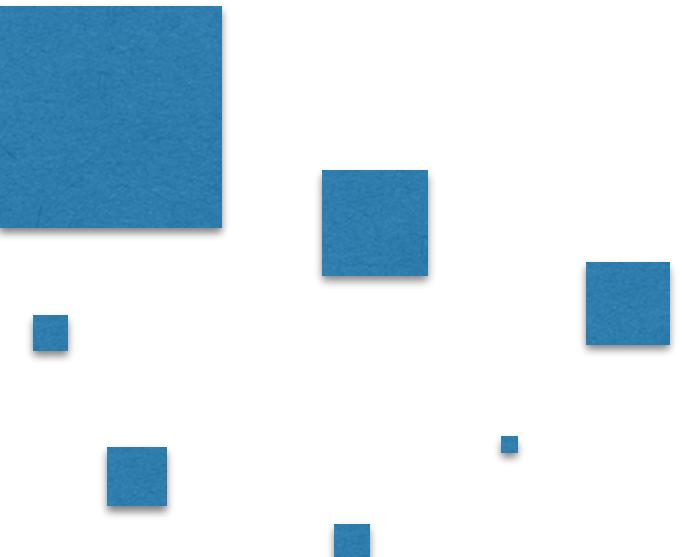
- Selective: yes
- Associative: yes
- Measurable: yes
- Ordered: yes
- # Levels: high

Example: stacked bar chart



Size

- OK in 2D, bad in 3D
- Harder to compare than length

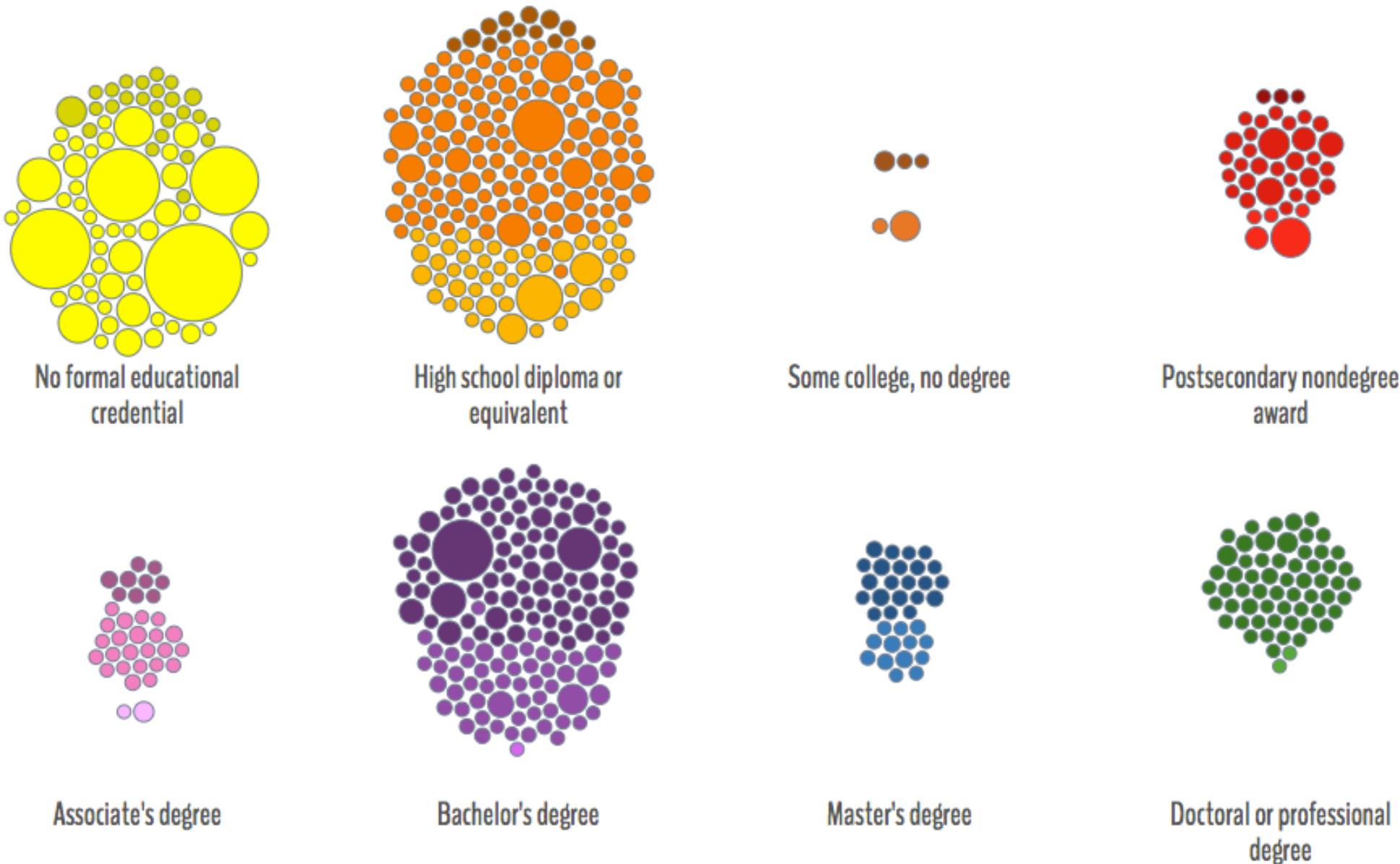


- Issue: consumes space in both directions

- Selective: yes
- Associative: yes
- Measurable: ~
- Ordered: yes
- # Levels: several

Example: bubble chart

Occupations Clustered by Level of Education Typically Required



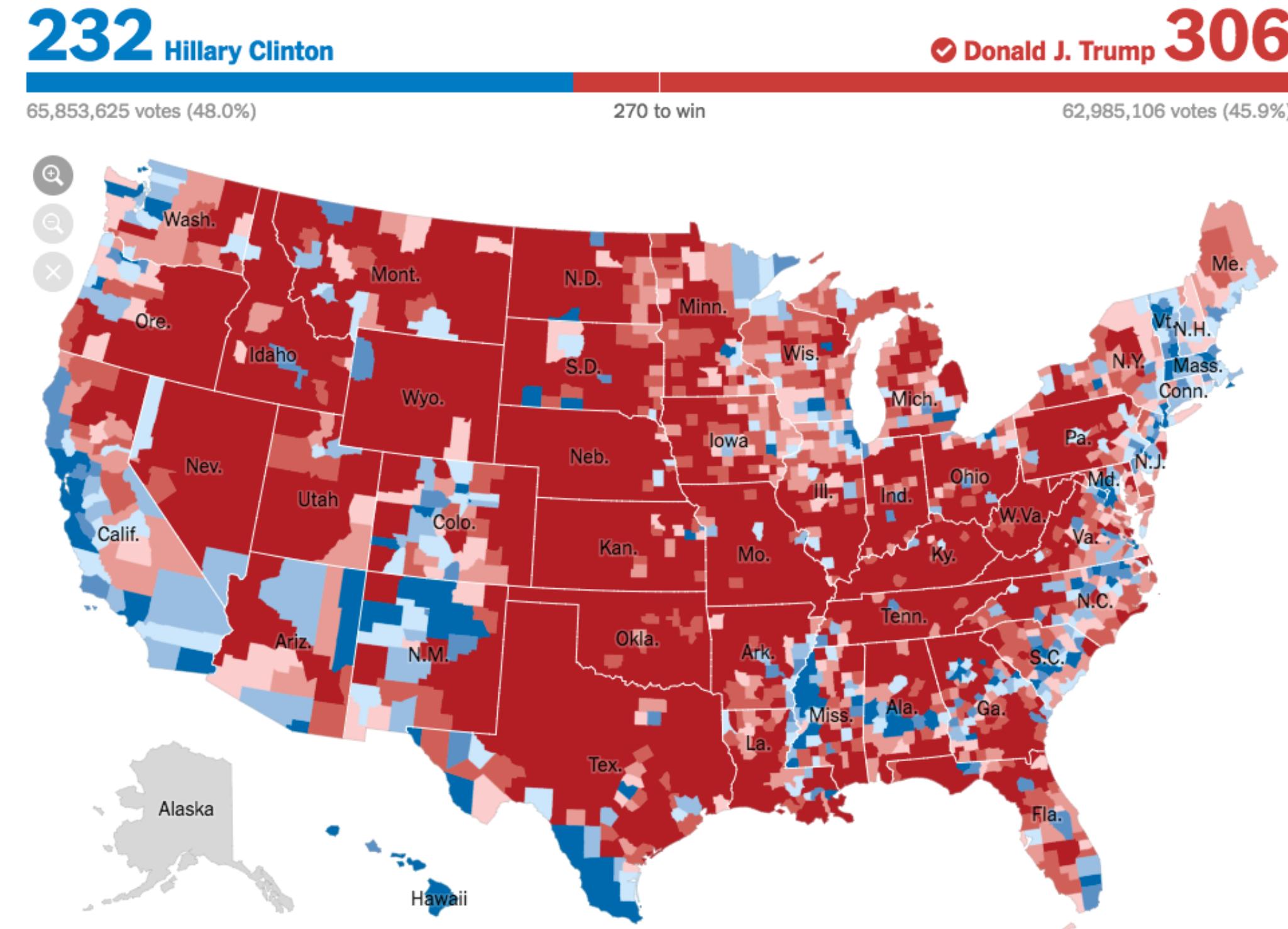
Luminance / Saturation

- OK for quantitative data
 - when length and size already used
 - on maps or other spatially located marks
- Not many shades recognizable



- Selective: yes
- Associative: yes
- Measurable: somewhat
- Ordered: yes
- # Levels: limited

Example: choropleth map with diverging scale



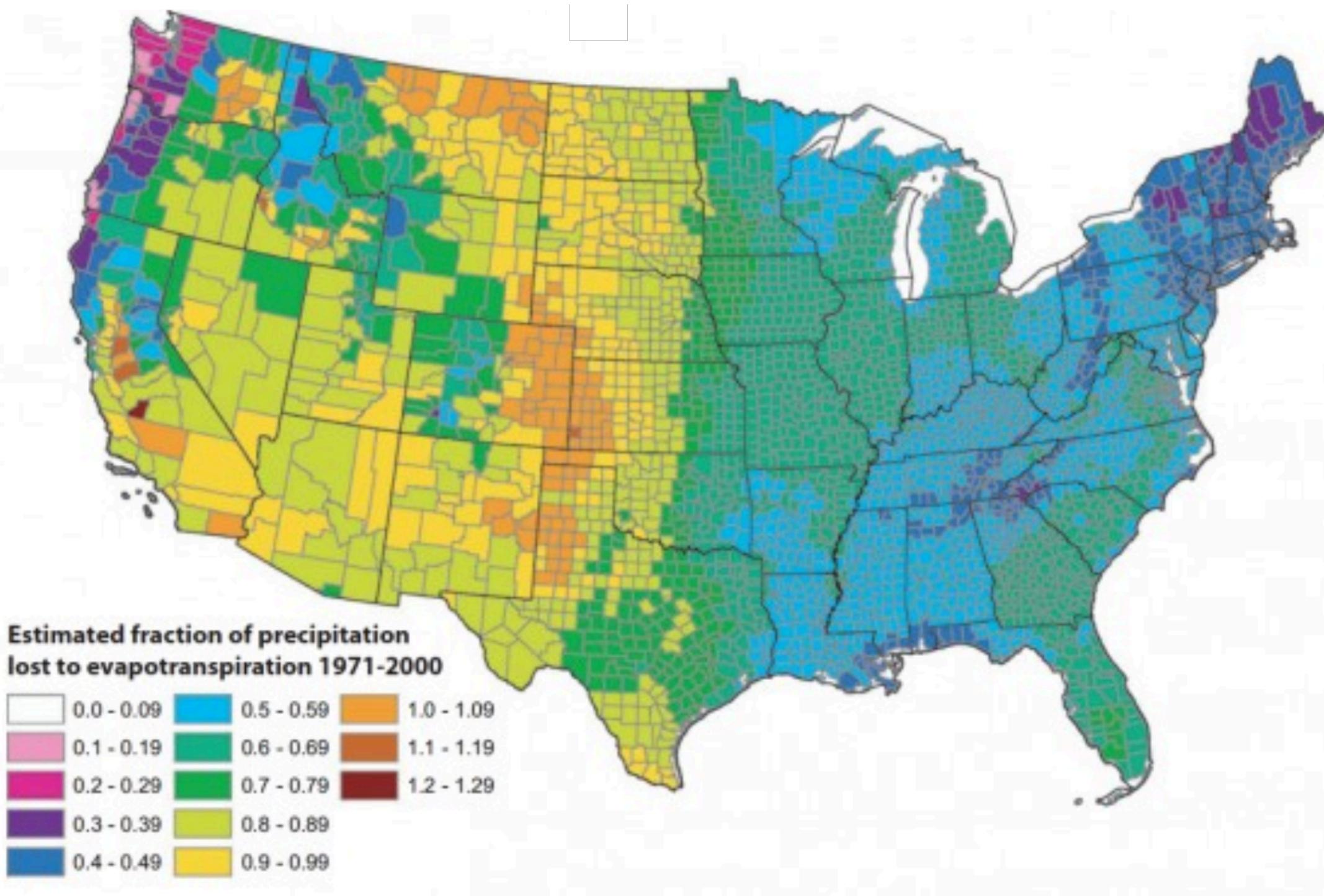
Hue

- Good for categorical data
- Bright colors capture attention
(pre-attentive)



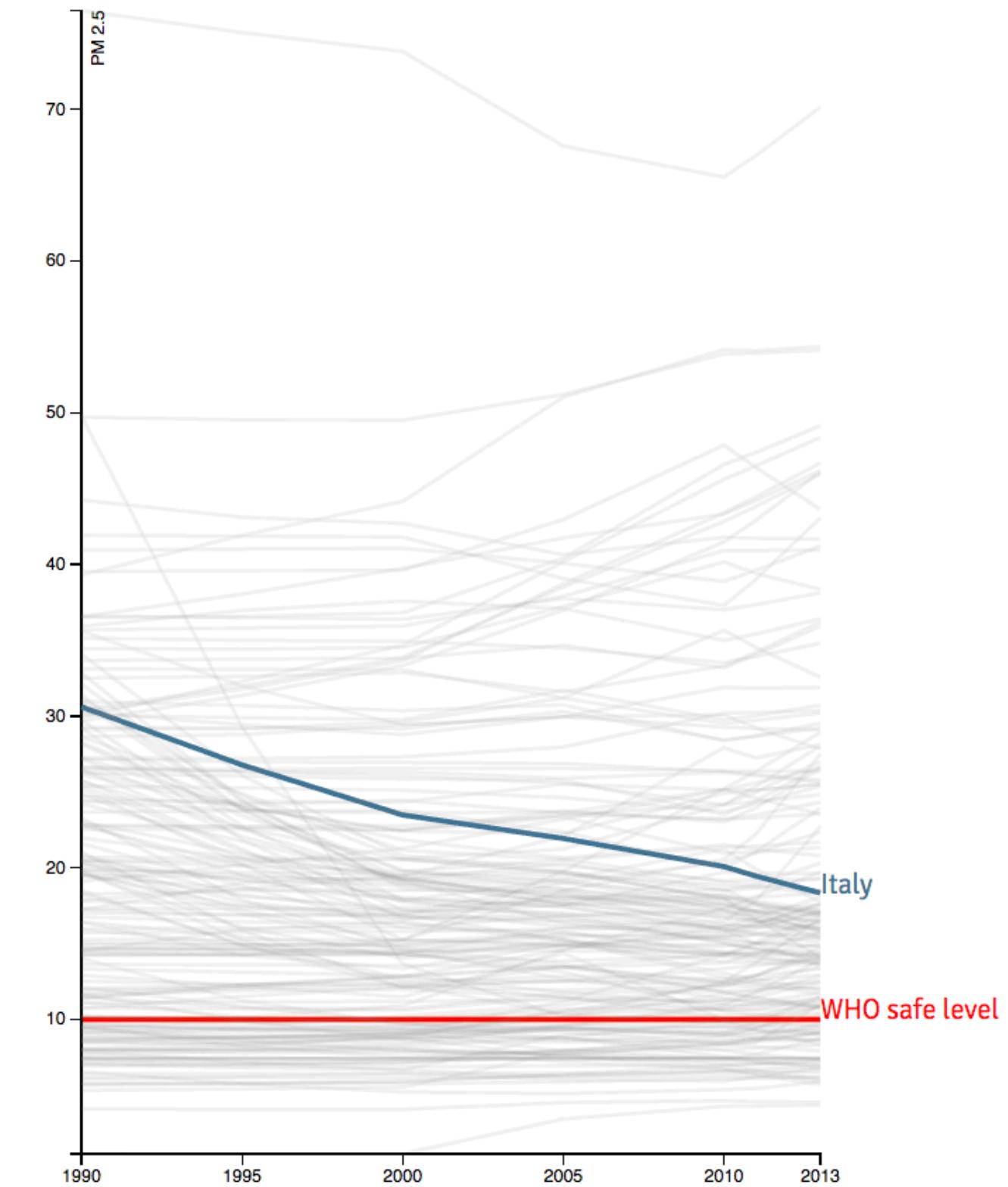
- Limited number of classes
- Lot of pitfalls!
- Selective: yes
- Associative: yes
- Measurable: no
- Ordered: no
- # Levels: limited

Bad example: quantitative use of hue



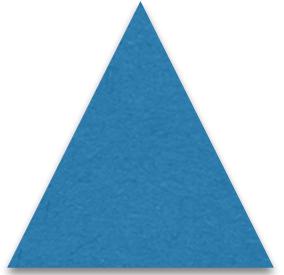
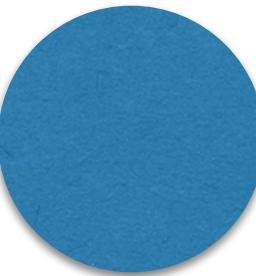
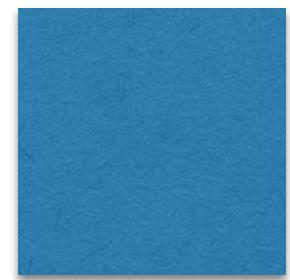
Good example: hue used to highlight

Air pollution: A growing problem around the world



Shape

- Great to recognize many classes



- Selective: yes
- Associative: limited
- Measurable: no
- Ordered: no
- # Levels: vast
- Neither grouping nor ordering

Examples:



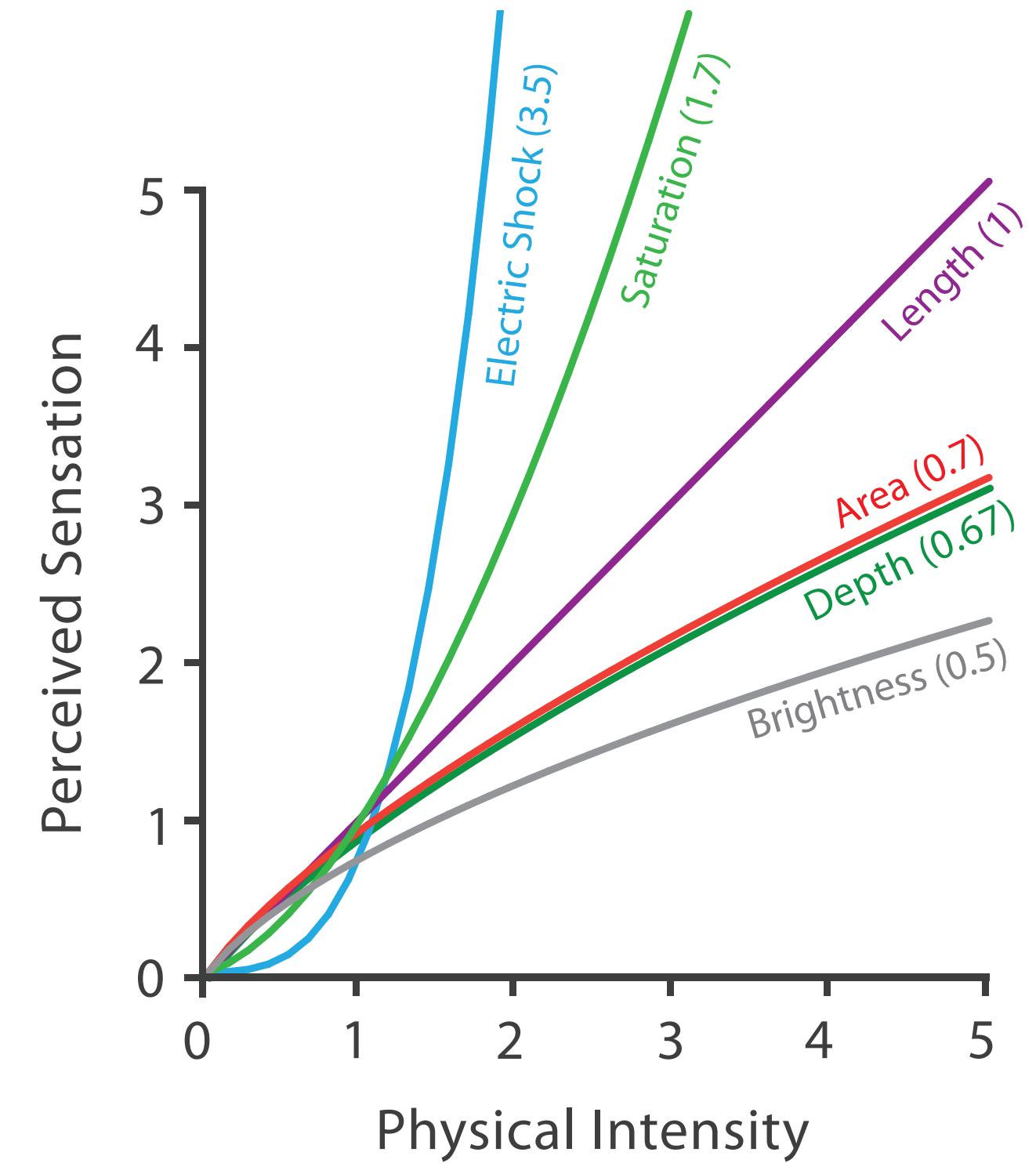
Expressiveness and Effectiveness

- Effectiveness principle
 - marks & channels express all and only the information in the dataset's attributes
 - warrants the correctness of selected idiom
- Expressiveness principle
 - match channel and data characteristics
 - encode most important attributes with highest ranked channels
 - *strategic choice* in selecting idiom

Accuracy: Fundamental Theory

- Accuracy: how close is perception to measurement?

Steven's Psychophysical Power Law: $S = I^N$



Accuracy: examples

- How much longer?



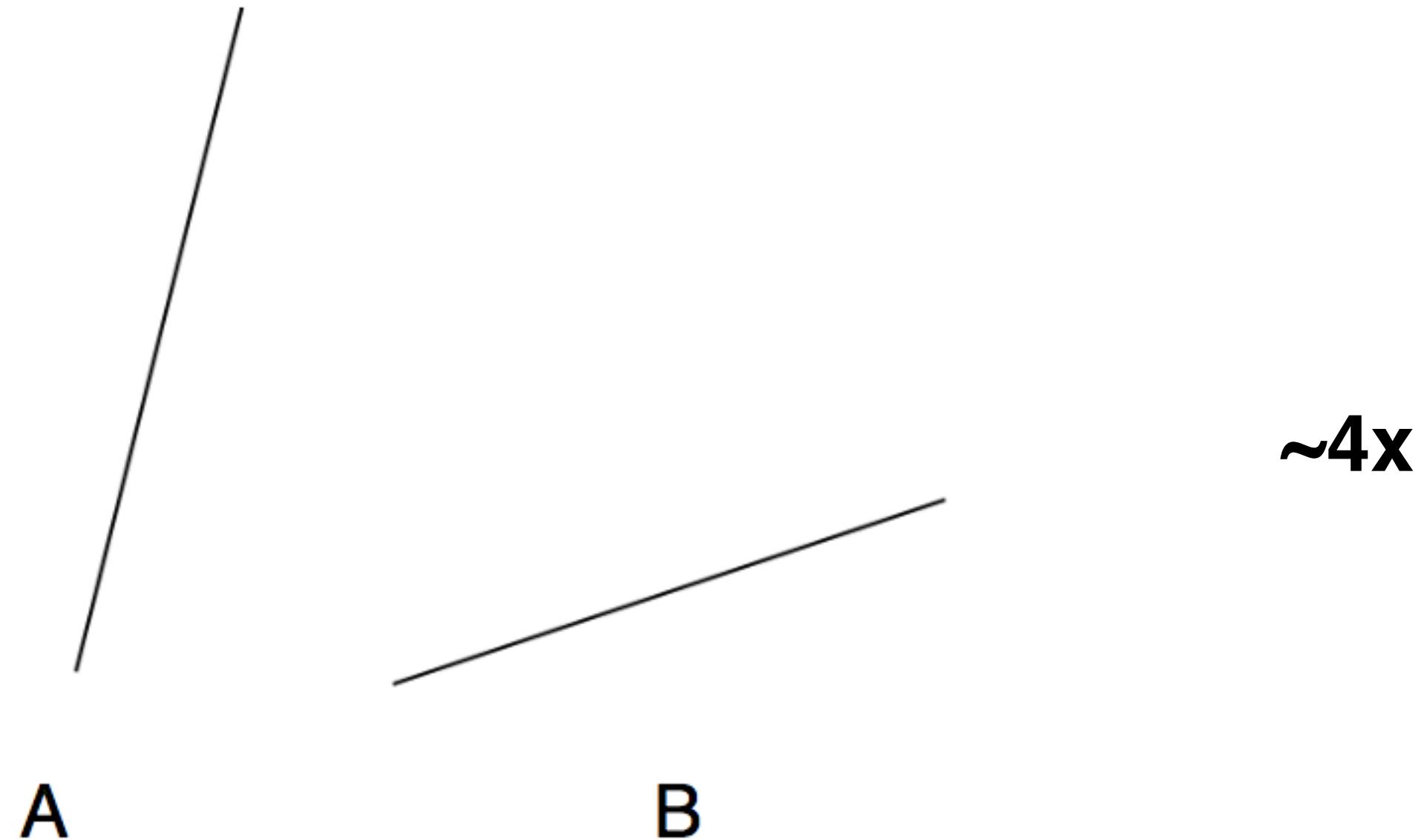
Accuracy: examples

- How much longer?



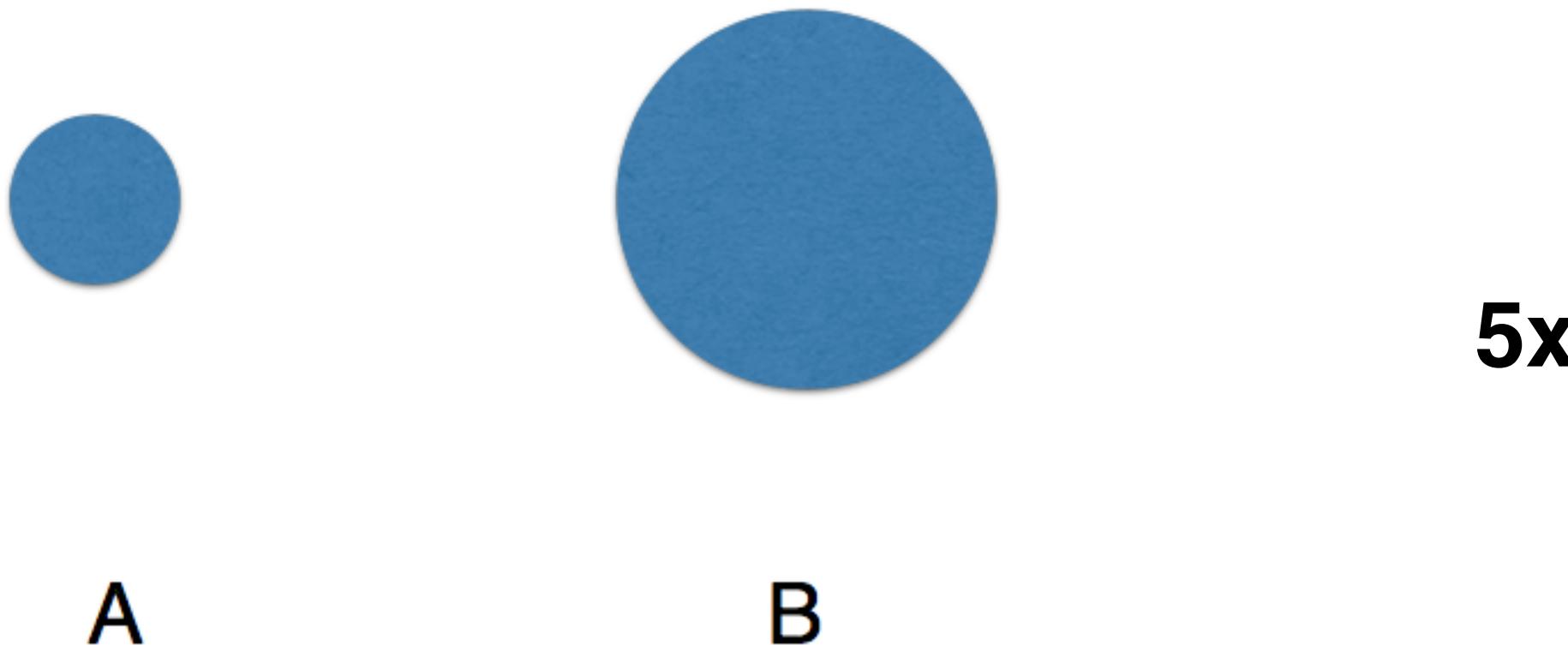
Accuracy: examples

- How much steeper?



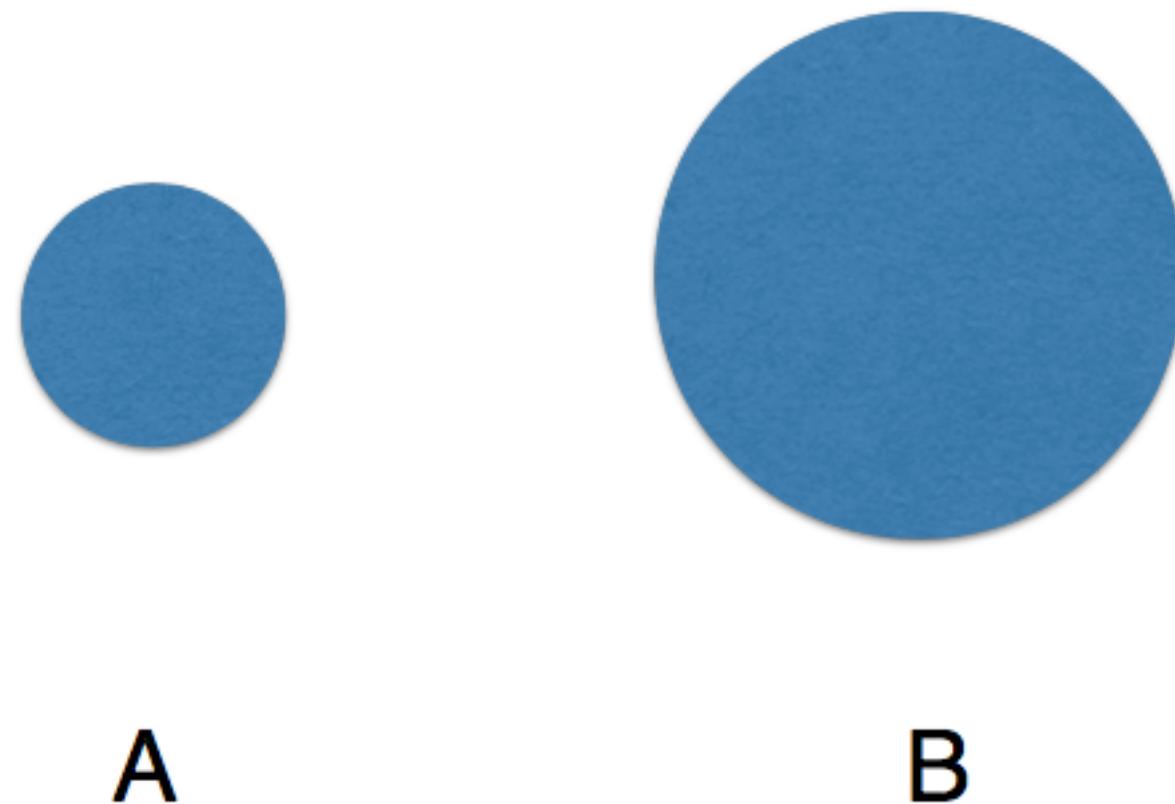
Accuracy: examples

- How much larger?



Accuracy: examples

- How much larger?



2x diameter
4x area
area proportional to
diameter squared

Accuracy: examples

- How much larger (area)?



A

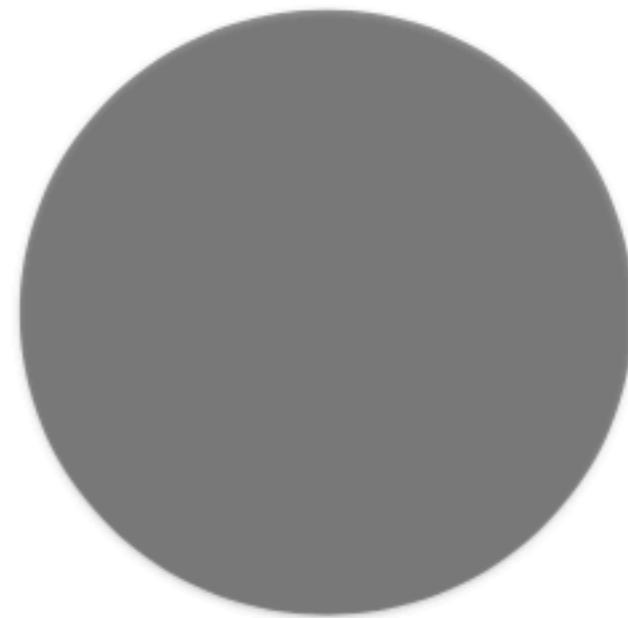
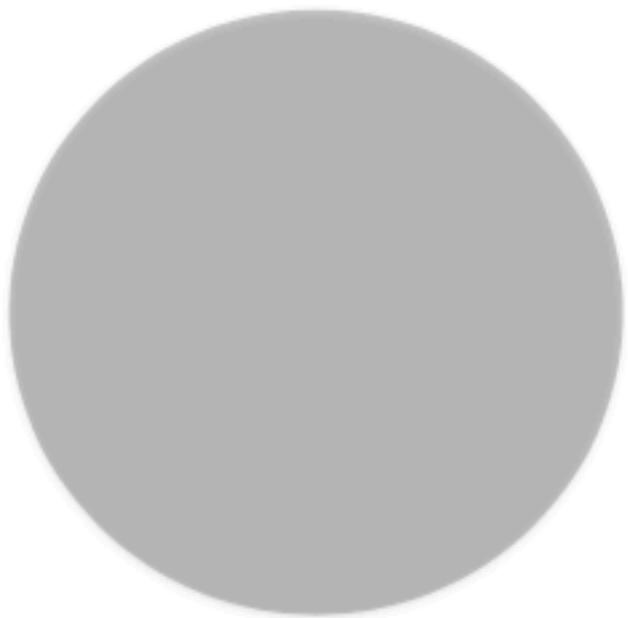


B

3x

Accuracy: examples

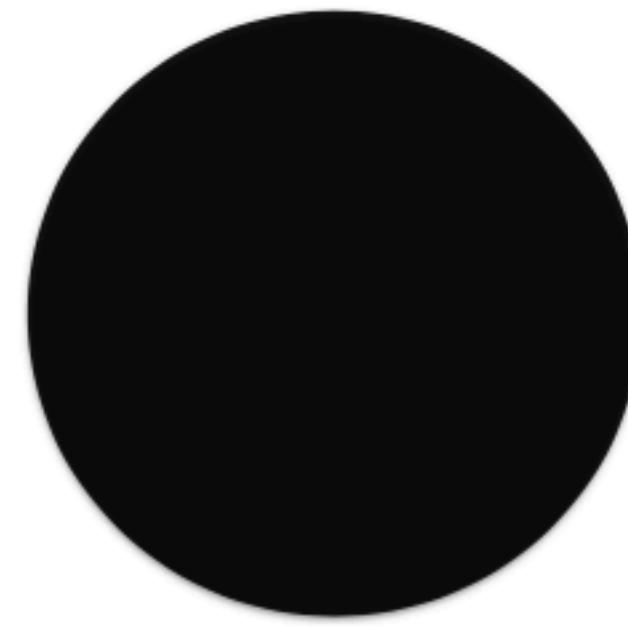
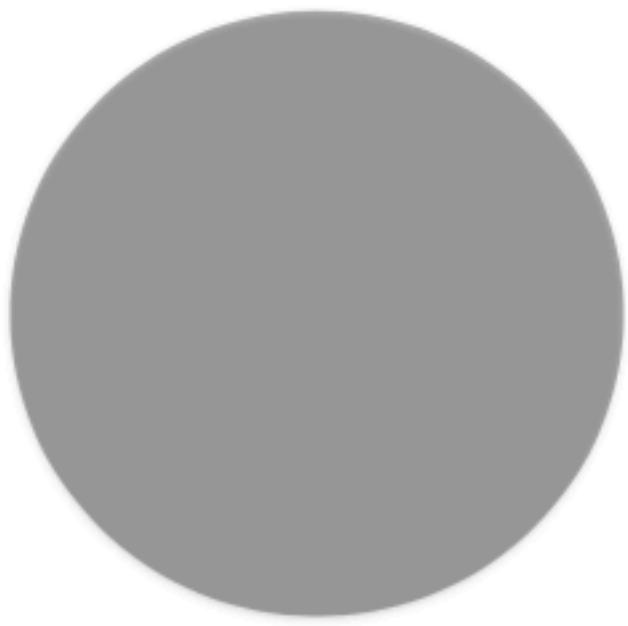
- How much darker?



2x

Accuracy: examples

- How much darker?



3x

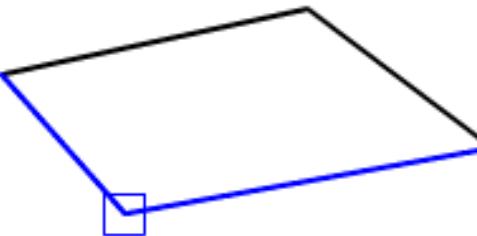
Accuracy: examples

- Try it yourself:

<http://woodgears.ca/eyeball/>

The eyeballing game

Adjust to make a parallelogram



Your inaccuracy by category:

Parallelogram	---	---	---
Midpoint	---	---	---
Bisect angle	---	---	---
Triangle center	---	---	---
Circle center	---	---	---
Right angle	---	---	---
Convergence	---	---	---

Average error: --- (lower is better)

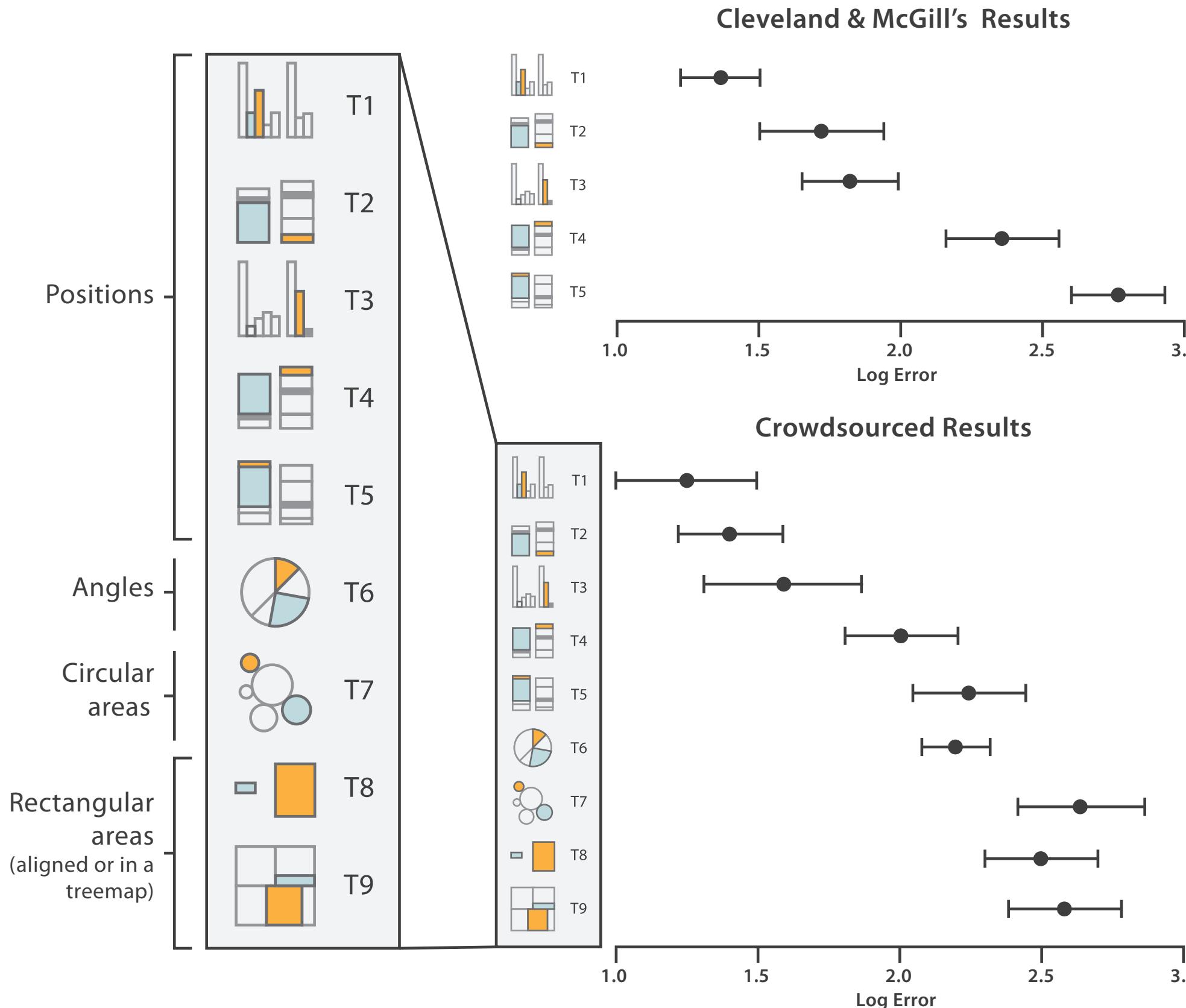
Time taken: 0.0

Best of last 500 score and time: [\(more\)](#)

1.27	72 s	Hawkeye
1.29	287 s	Blir nok skitur idag
1.40	91 s	I want to fuck ur sister±
1.60	235 s	Blir blå sviks i dag
1.92	233 s	1.9(4)(12.914.413.1)395
1.99	145 s	6.6(4)(14.217.510.0)584
2.05	229 s	5.1(2)(14.318.99.9)397
2.30	575 s	sculptorsash
2.30	66 s	My sister has gonorrhea
2.41	211 s	5.1(2)(14.318.99.9)397

Best on this computer score and time:

Accuracy: Vis experiments



[Heer and Bostock. Crowd-sourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. CHI 2010, p. 203–212.]

Channels: Rankings

→ 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)



→ Identity Channels: Categorical Attributes

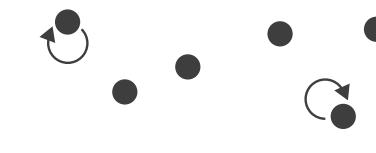
Spatial region



Color hue



Motion



Shape



Best ↑

Effectiveness

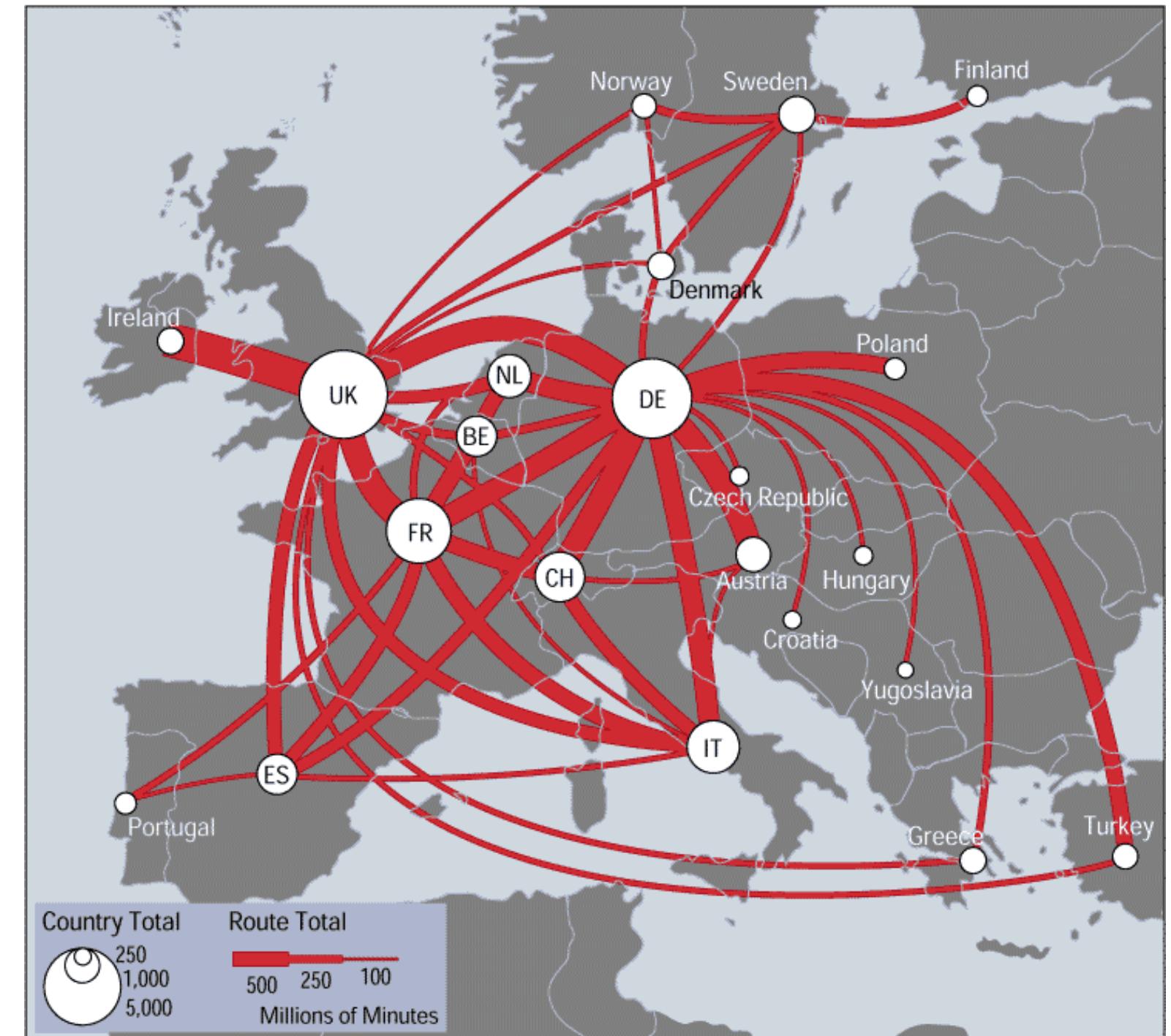
Least ↓

Same]

Same]

Discriminability: How many usable steps?

- must be sufficient for number of attribute levels to show
 - linewidth: few bins
 - area: fairly many bins
 - hue: ~6 bins

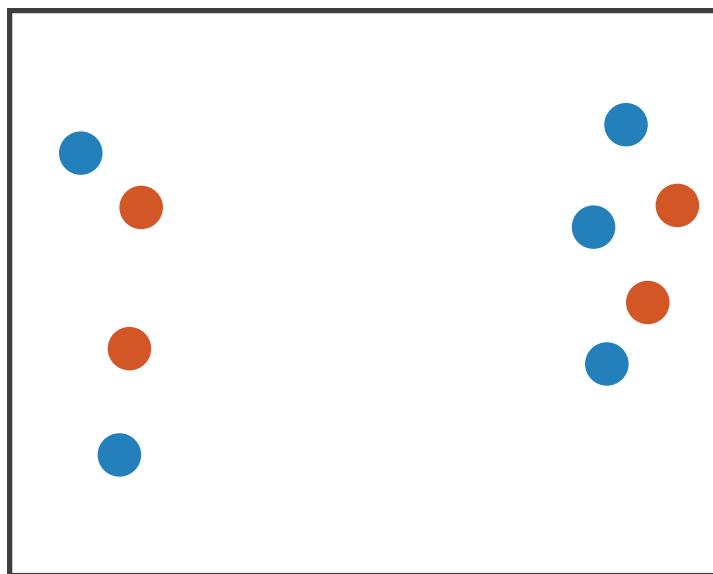


Separability vs. Integrality

- How much can a channel be distinguished from the other channels?

Position

+ Hue (Color)

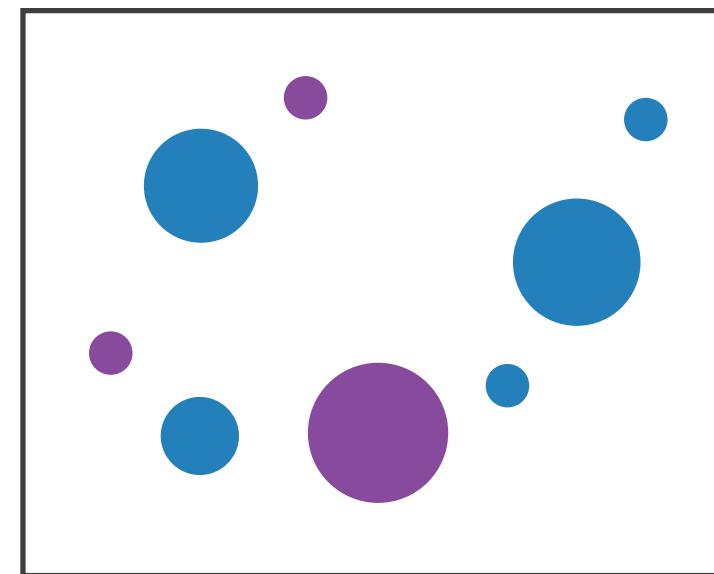


Fully separable

2 groups each

Size

+ Hue (Color)

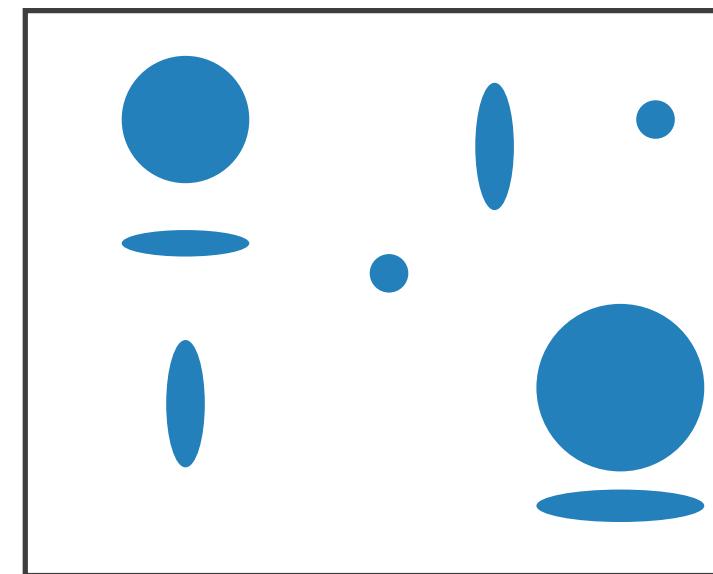


Some interference

2 groups each

Width

+ Height

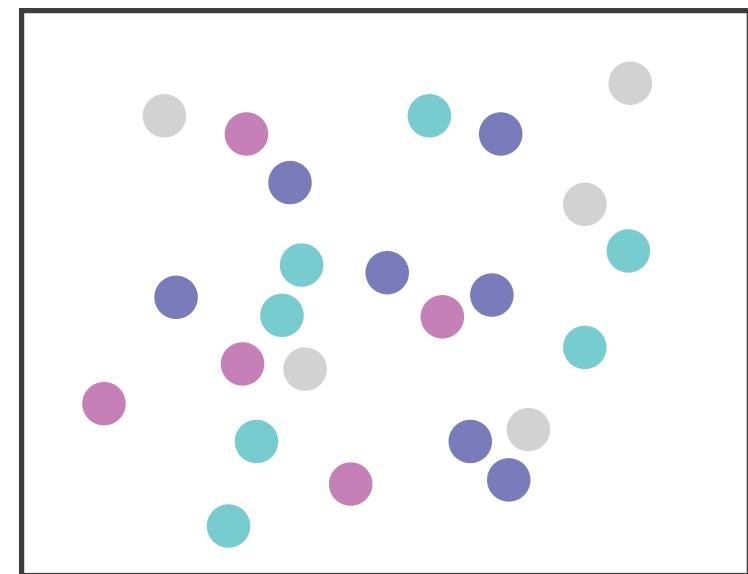


Some/significant
interference

3 groups total:
integral area

Red

+ Green

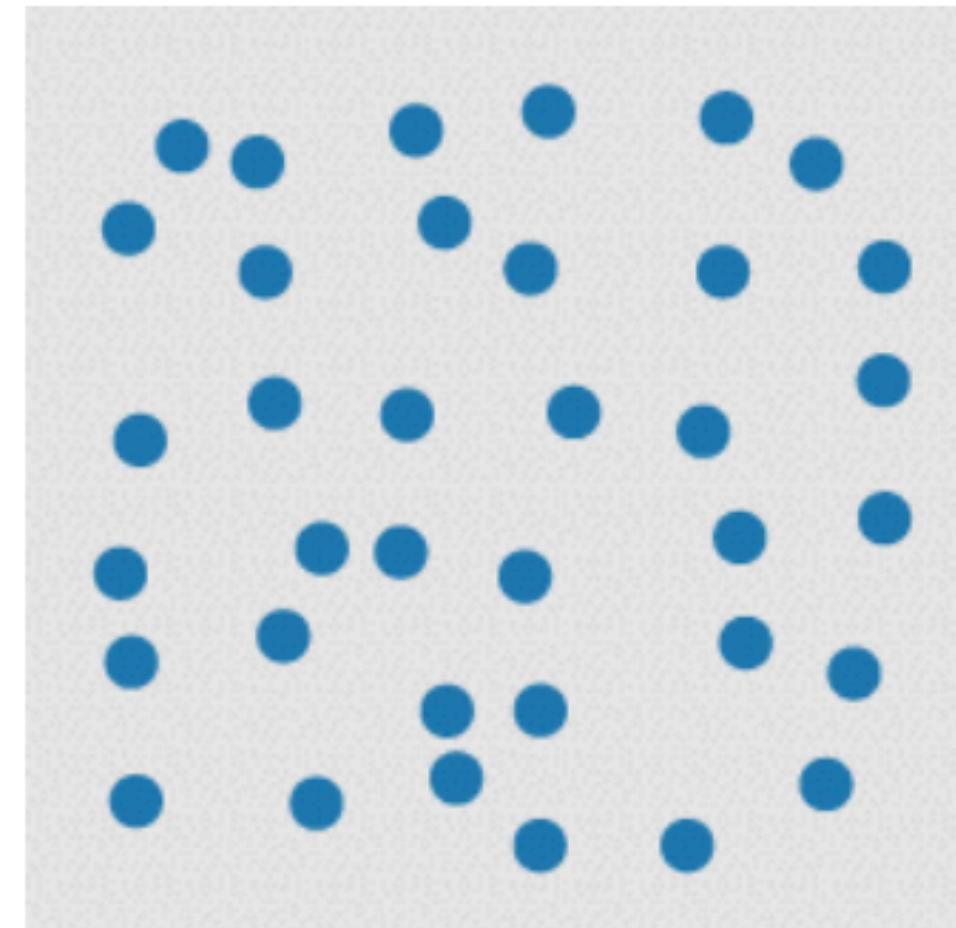
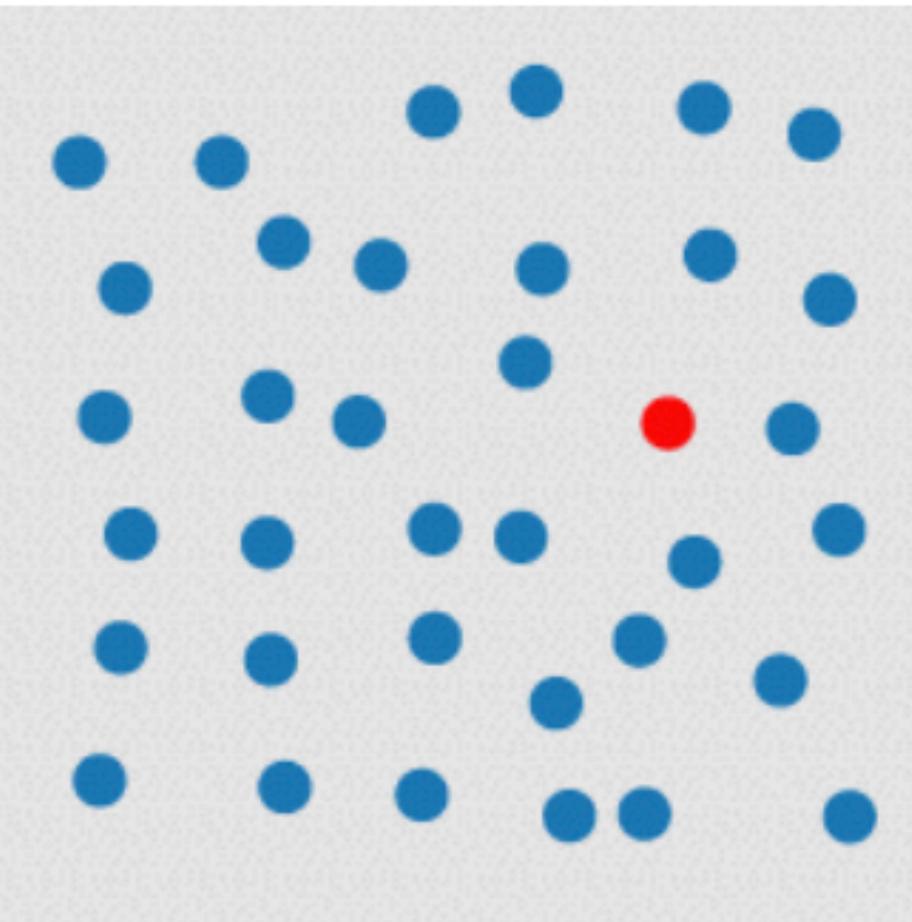


Major interference

4 groups total:
integral hue

Popout

- Some channels are pre-attentive
- Use for a single channel at a time! (see Lecture on perception)

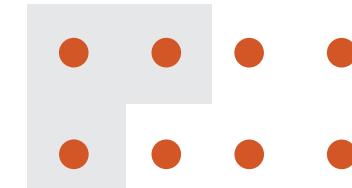


Grouping

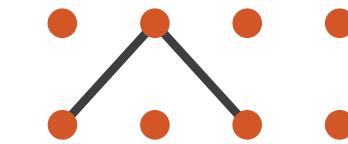
- containment
- connection
- proximity
 - same spatial region
- similarity
 - same values as other categorical channels

Marks as Links

→ Containment



→ Connection



→ Identity Channels: Categorical Attributes

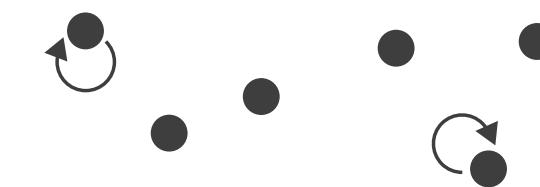
Spatial region



Color hue



Motion



Shape



Grouping

- From links:
 - items that are linked together or in the same container
- From identity channels:
 - items with the same categorical attribute
- From proximity in space:
 - attributes with close spatial positions form *clusters*
- Beware:
 - if spatial position is used to represent one/two channels, proximity cannot be used to group items according to a third *independent* channel
 - grouping based on proximity is valid iff proximity expresses similarity (wrt criterion for grouping)

Next lectures

- tomorrow, to install
 - Apache localhost
- next week, to read
 - VAD Ch. 6: Rules of Thumb