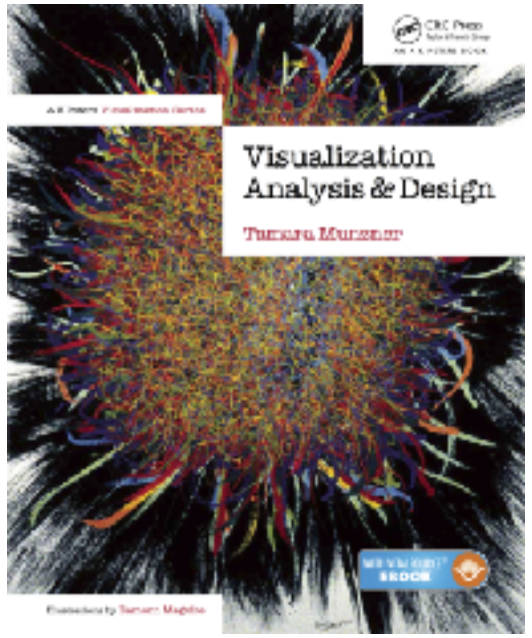
Visualization Analysis & Design

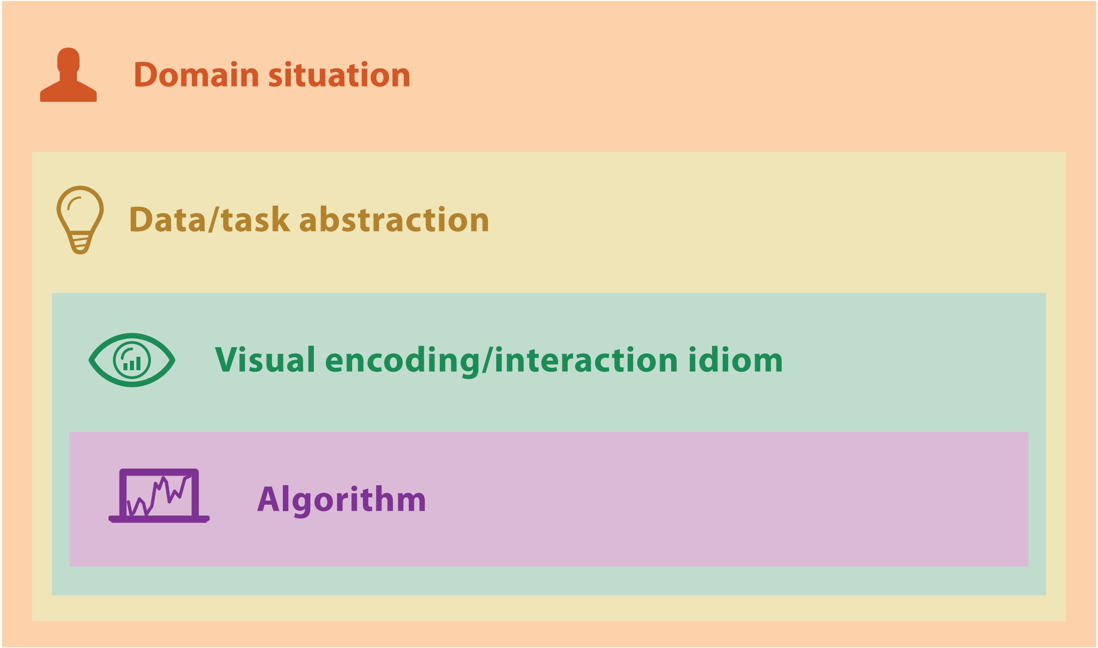
Marks & Channels (Ch 5) I



Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

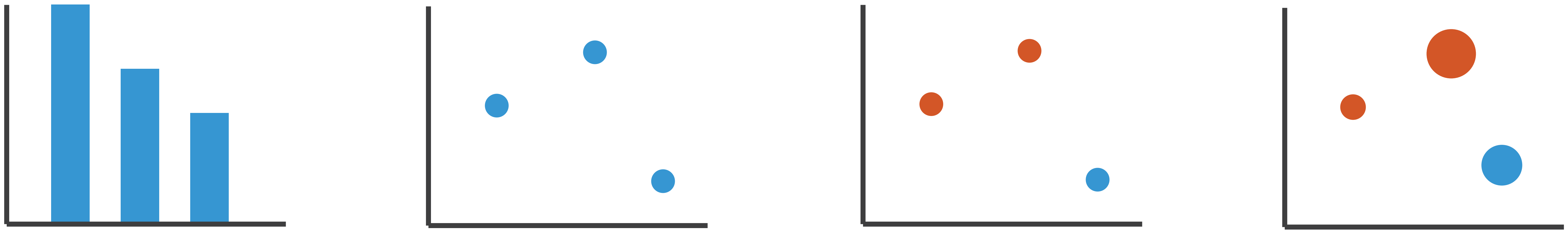
Visual encoding

- how to systematically analyze idiom structure?



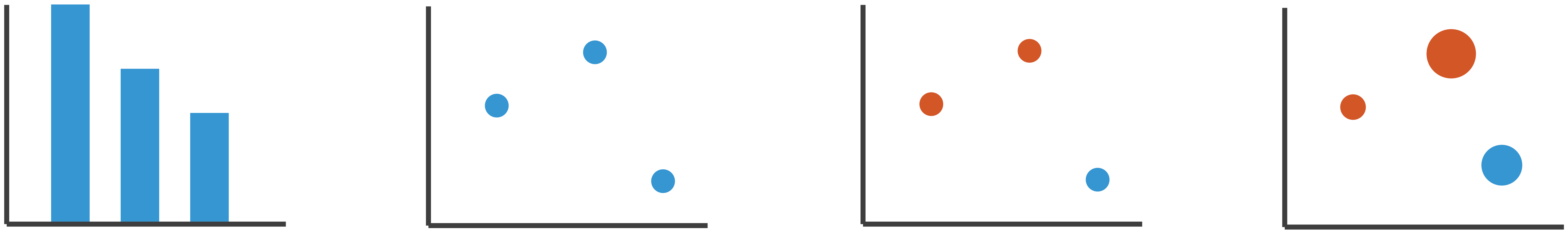
Visual encoding

- how to systematically analyze idiom structure?



Visual encoding

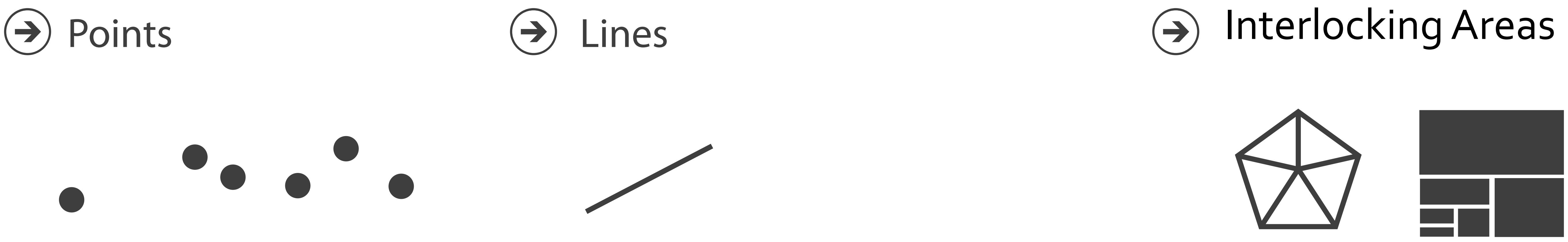
- how to systematically analyze idiom structure?



- marks & channels
  - –marks: represent items or links
  - –channels: change appearance of marks based on attributes

Marks for items

- basic geometric elements

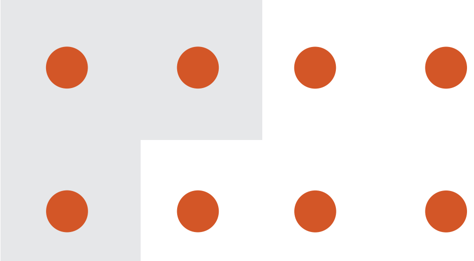


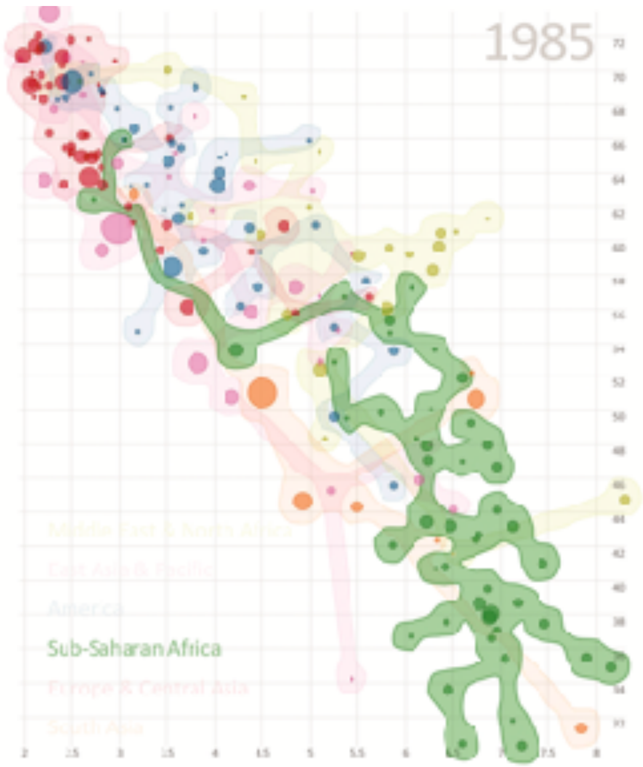
0D 1D 2D

- 3D mark: volume, rarely used

Marks for links

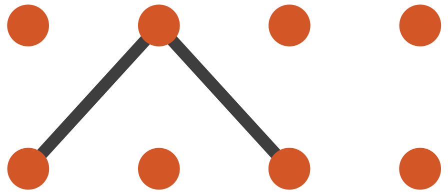
➔ Containment





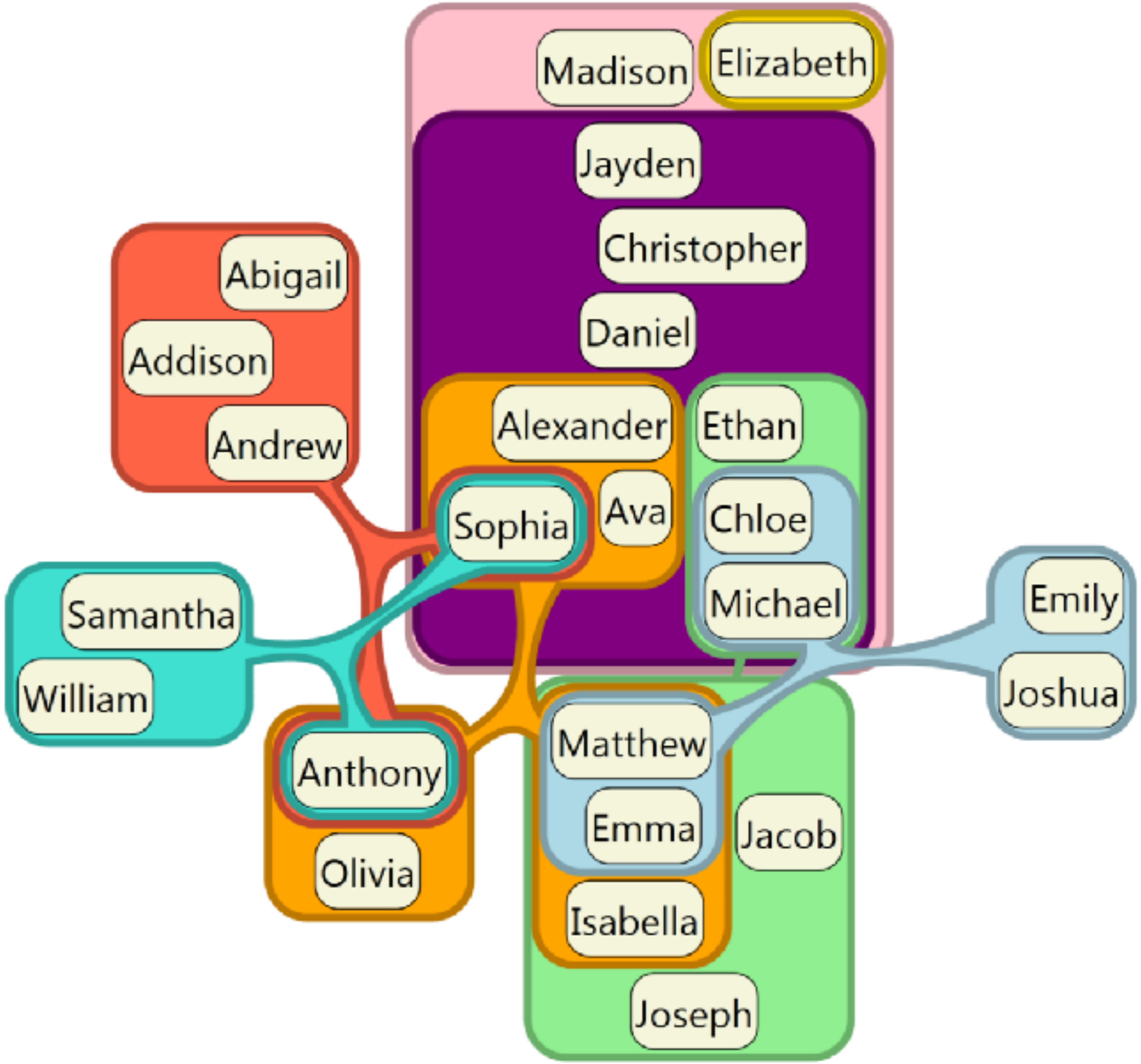
vialab.science.uoit.ca/portfolio/bubblesets

➔ Connection



https://observablehq.com/@d3/force-directed-graph

Containment can be nested

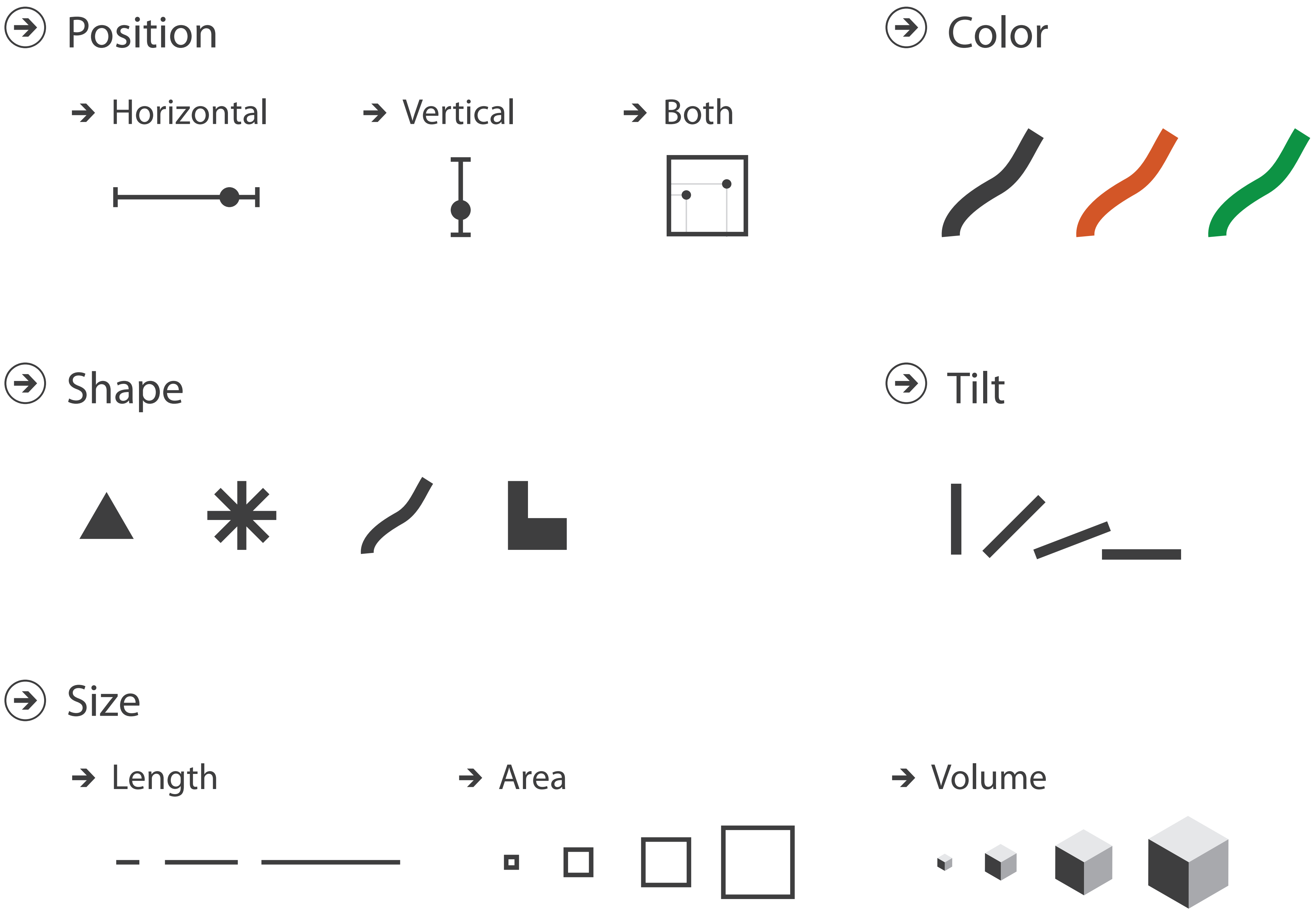


[Untangling Euler Diagrams, Riche and Dwyer, 2010]

Channels

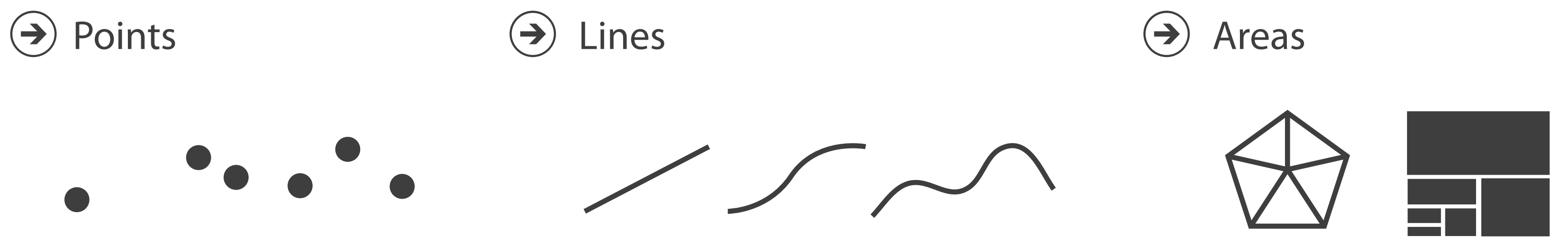
- control appearance of marks
  - proportional to or based on attributes

- many names
  - **visual channels**
  - visual variables
  - retinal channels
  - visual dimensions
  - ...



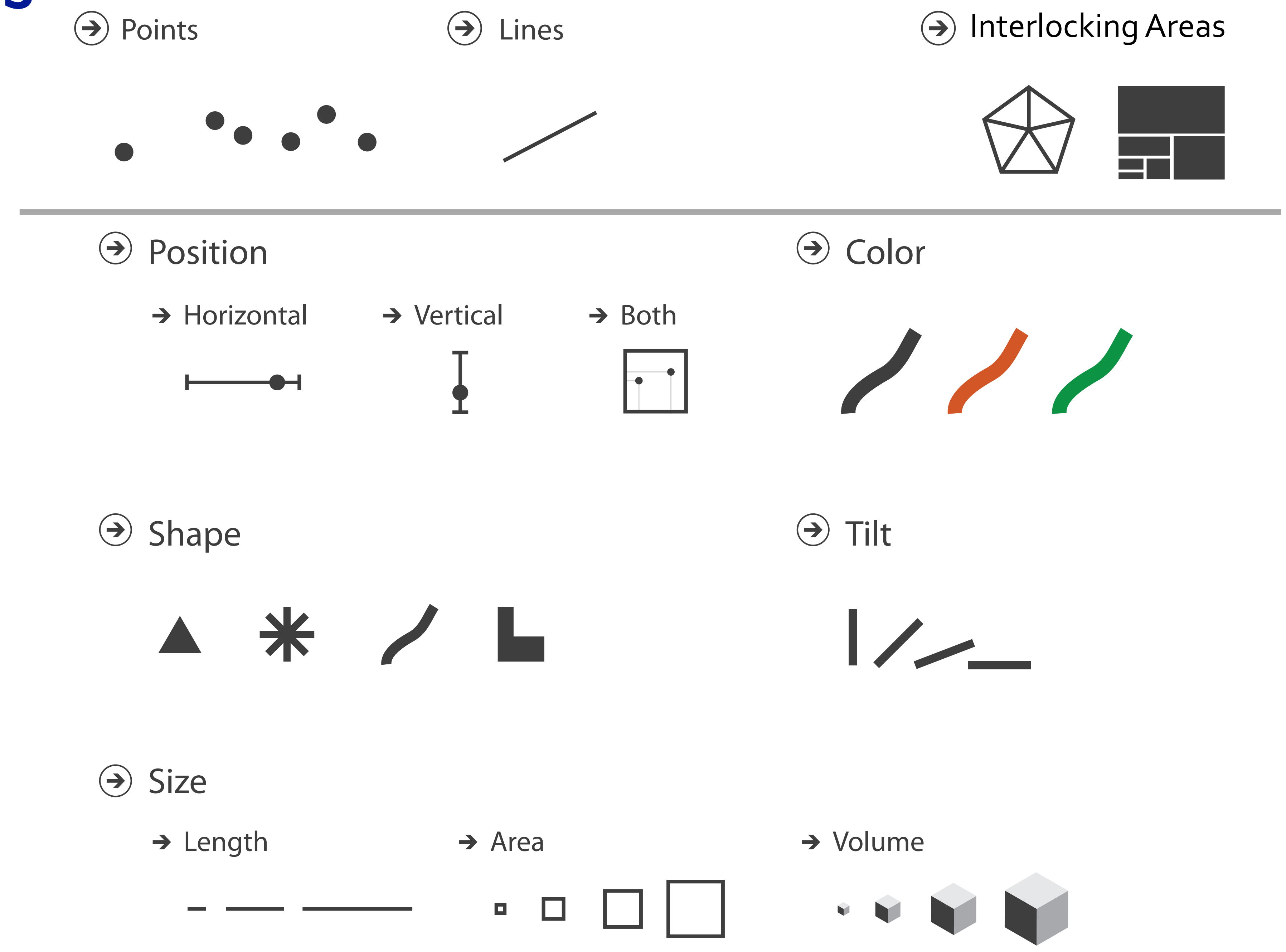
Definitions: Marks and channels

- marks
  - geometric primitives



Definitions: Marks and channels

- marks
  - geometric primitives
- channels
  - control appearance of marks

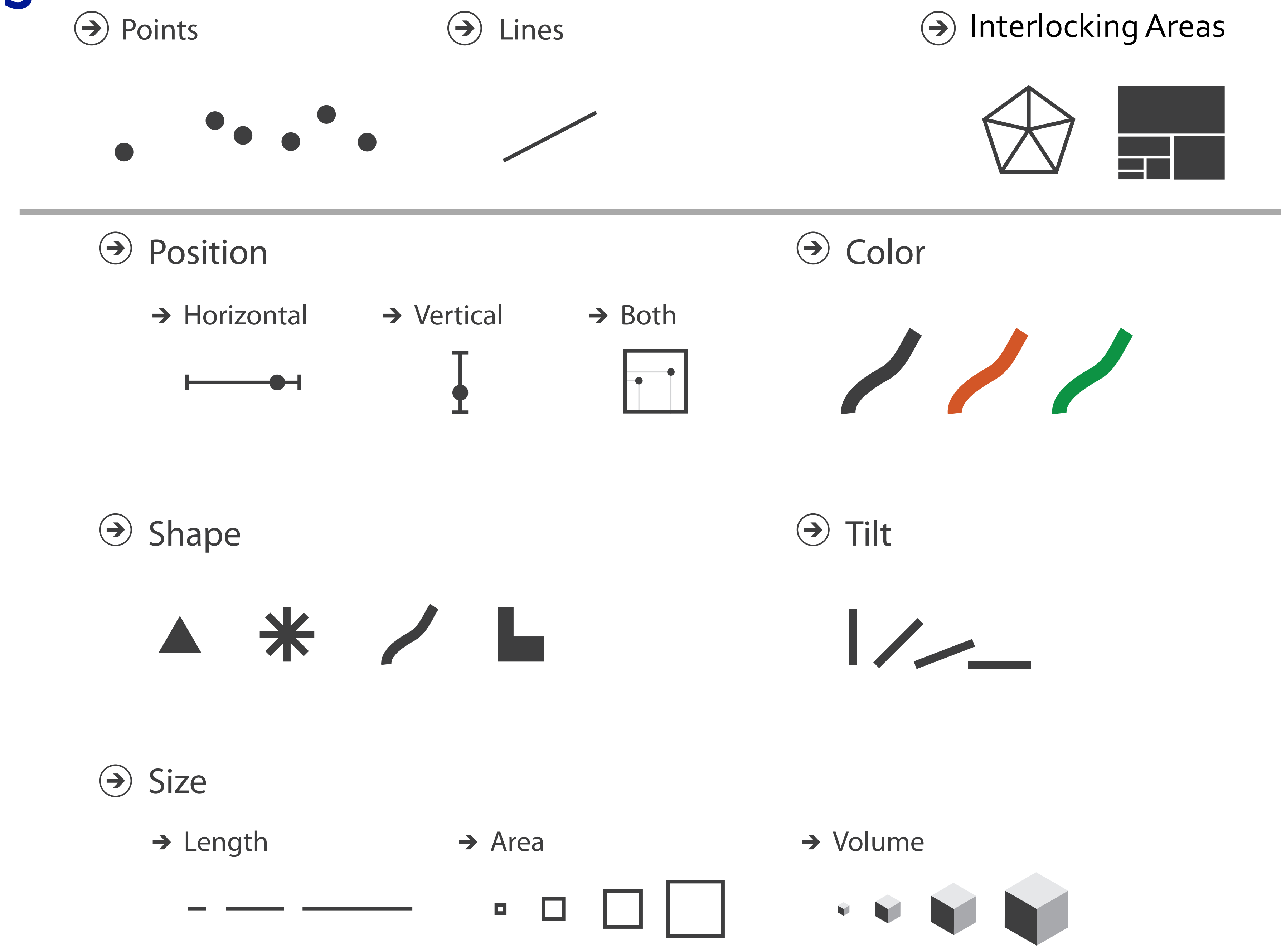


Definitions: Marks and channels

- marks
  - geometric primitives

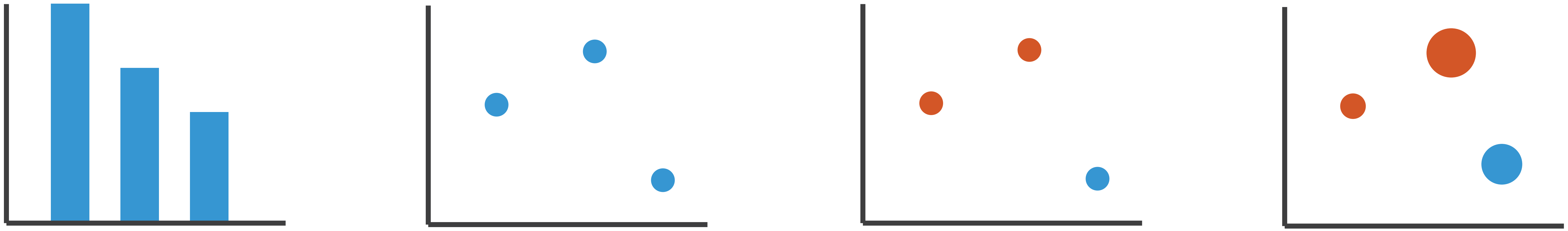
- channels
  - control appearance of marks

- channel properties differ
  - type & amount of information that can be conveyed to human perceptual system



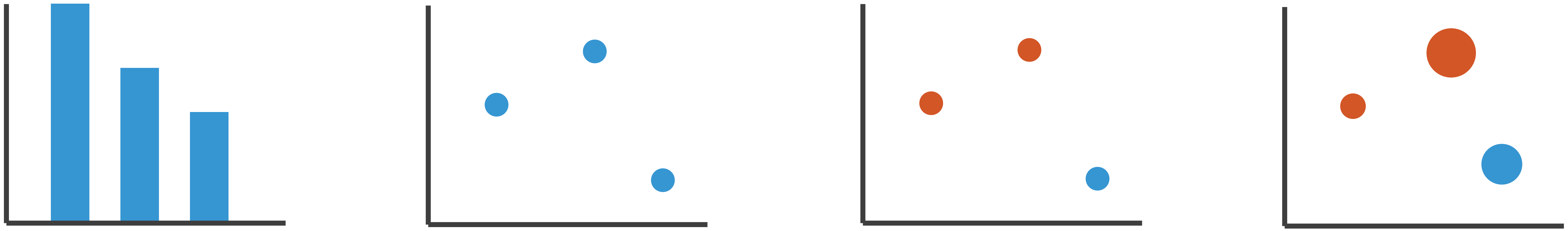
Visual encoding

- analyze idiom structure as combination of marks and channels



Visual encoding

- analyze idiom structure as combination of marks and channels

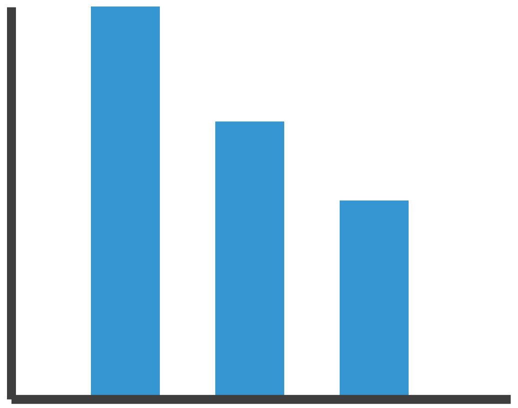


1:
vertical position

mark: line

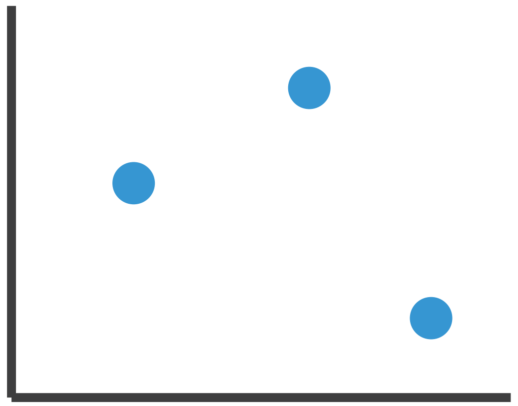
Visual encoding

- analyze idiom structure as combination of marks and channels



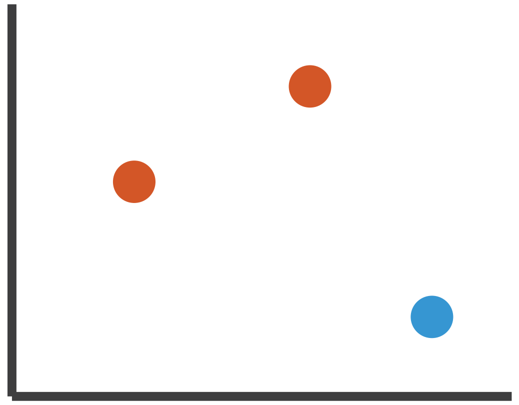
1:
vertical position

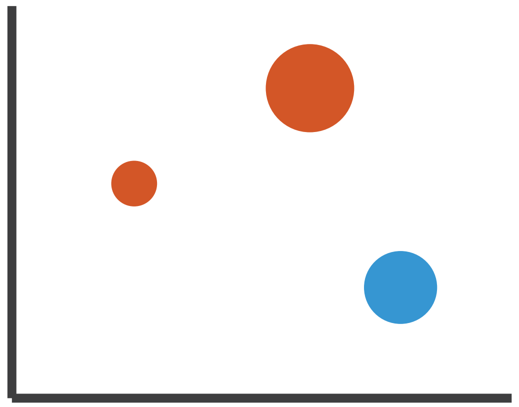
mark: line



2:
vertical position
horizontal position

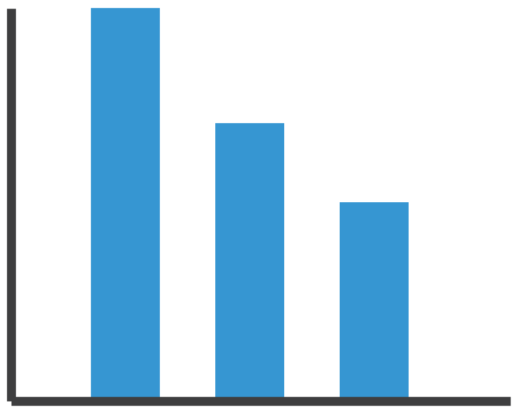
mark: point





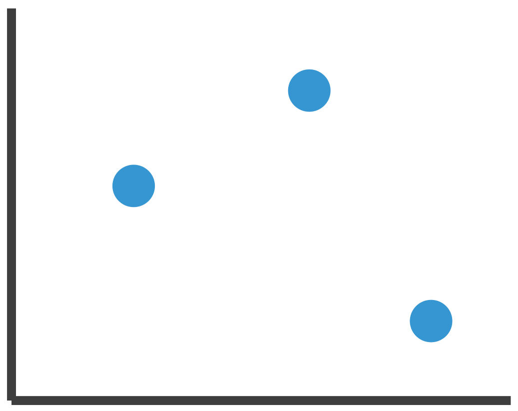
Visual encoding

- analyze idiom structure as combination of marks and channels



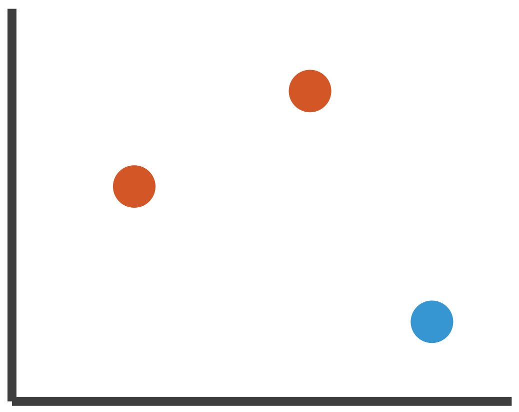
1:
vertical position

mark: line



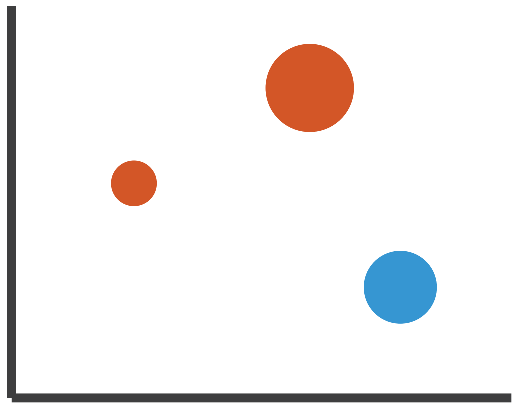
2:
vertical position
horizontal position

mark: point



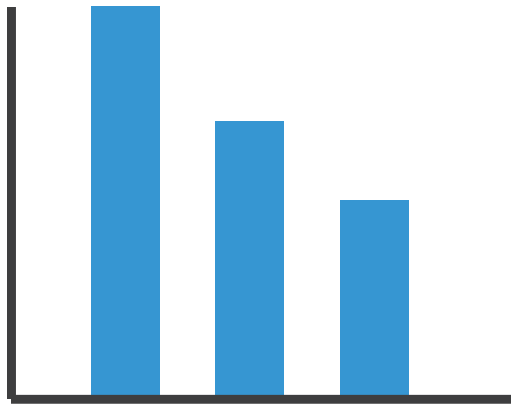
3:
vertical position
horizontal position
color hue

mark: point



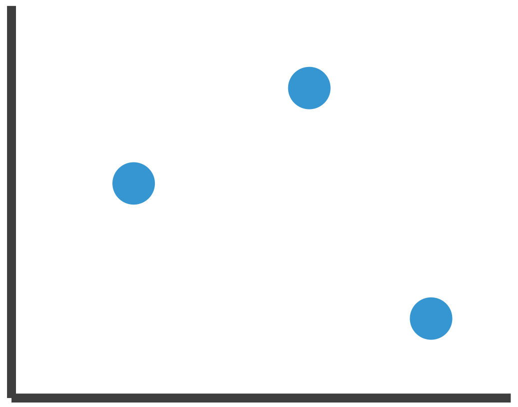
Visual encoding

- analyze idiom structure as combination of marks and channels



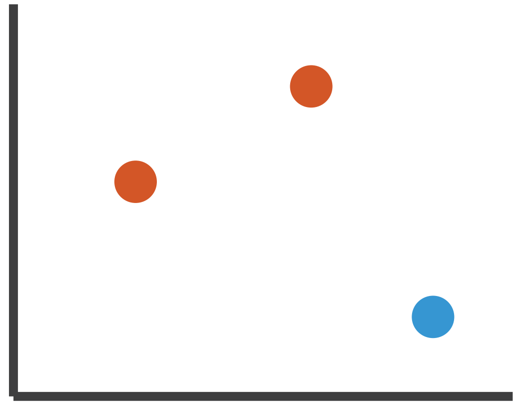
1:
vertical position

mark: line



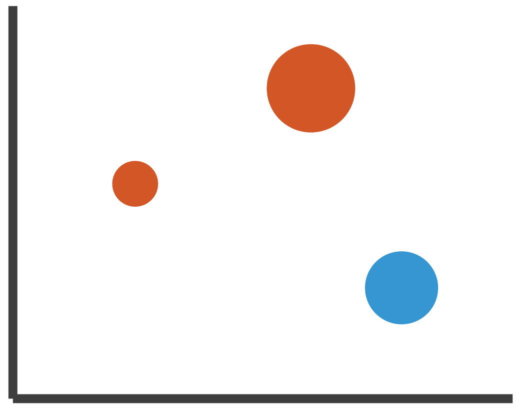
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point

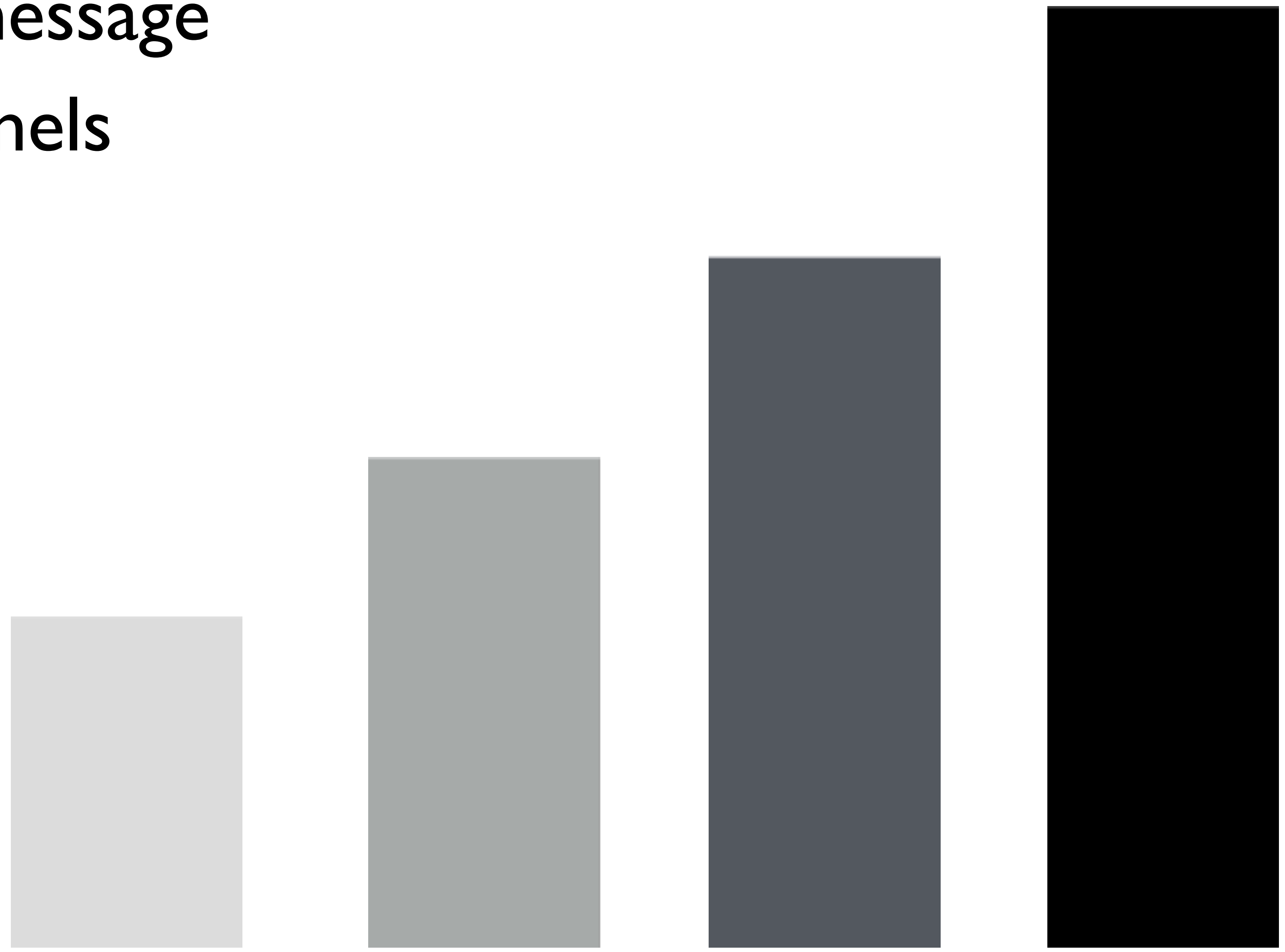


4:
vertical position
horizontal position
color hue
size (area)

mark: point

Redundant encoding

- multiple channels
  - sends stronger message
  - but uses up channels



Length and Luminance

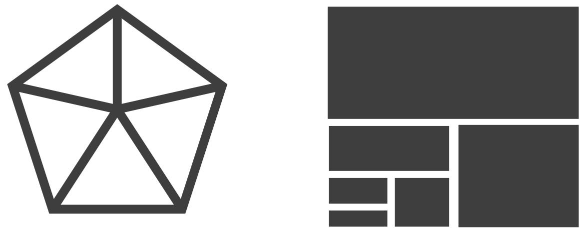
Marks as constraints

- math view: geometric primitives have dimensions

➔ Points 0D

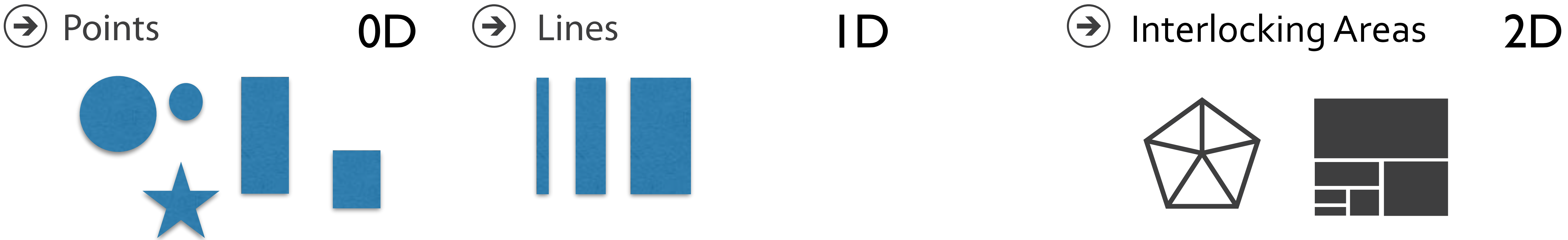
➔ Lines 1D

➔ Interlocking Areas 2D



Marks as constraints

- math view: geometric primitives have dimensions



- constraint view: mark type constrains what else can be encoded
  – points: 0 constraints on size, can encode more attributes w/ size & shape
  – lines: 1 constraint on size (length), can still size code other way (width)
  – interlocking areas: 2 constraints on size (length/width), cannot size or shape code
    - interlocking: size, shape, position

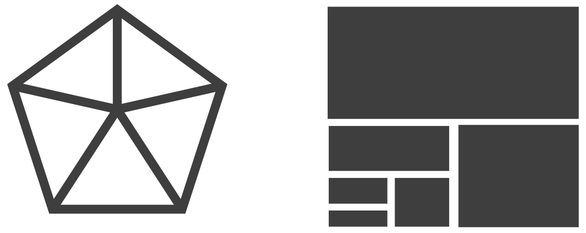
Marks as constraints

- math view: geometric primitives have dimensions

➔ Points 0D

➔ Lines 1D

➔ Interlocking Areas 2D



- constraint view: mark type constrains what else can be encoded
  - points: 0 constraints on size, can encode more attributes w/ size & shape
  - lines: 1 constraint on size (length), can still size code other way (width)
  - interlocking areas: 2 constraints on size (length/width), cannot size or shape code
    - interlocking: size, shape, position
- quick check: can you size-code another attribute
  - or is size/shape in use?

Scope of analysis

- simplifying assumptions: one mark per item, single view

- later on
  - multiple views
  - multiple marks in a region (glyph)
  - some items not represented by marks (aggregation and filtering)

When to use which channel?

expressiveness

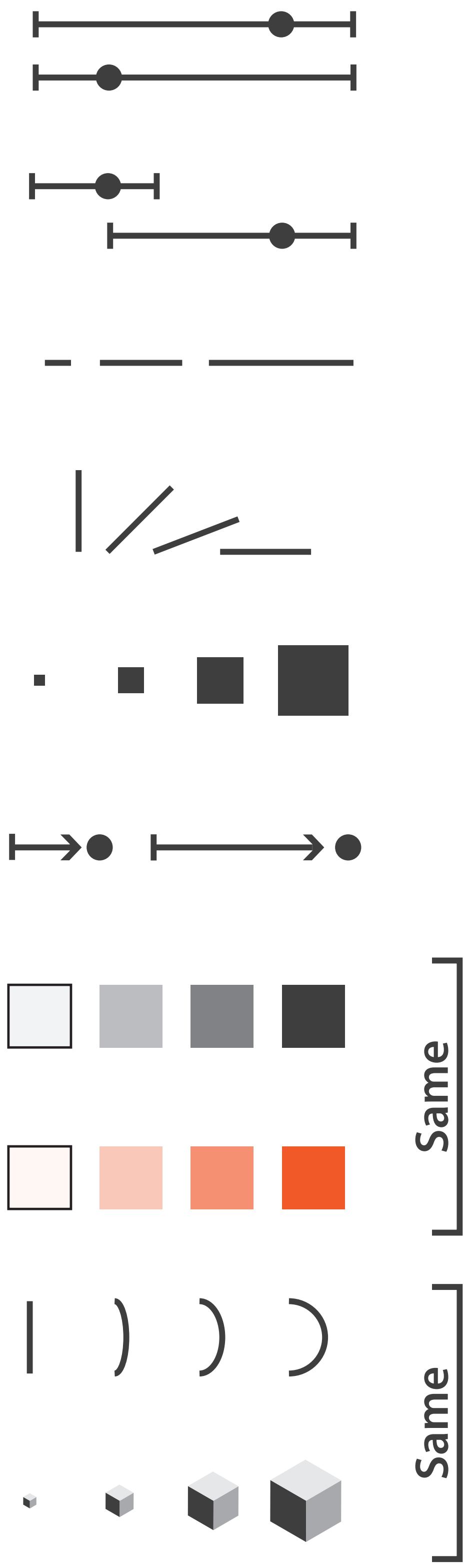
match channel type to data type

effectiveness

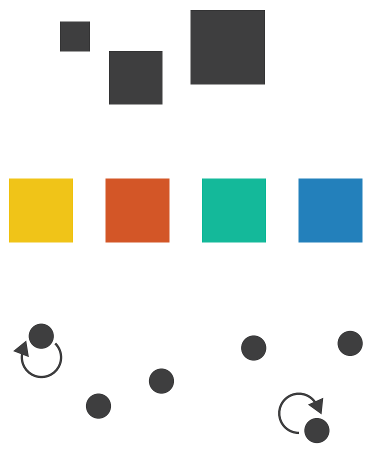
some channels are better than others

Channels: Rankings

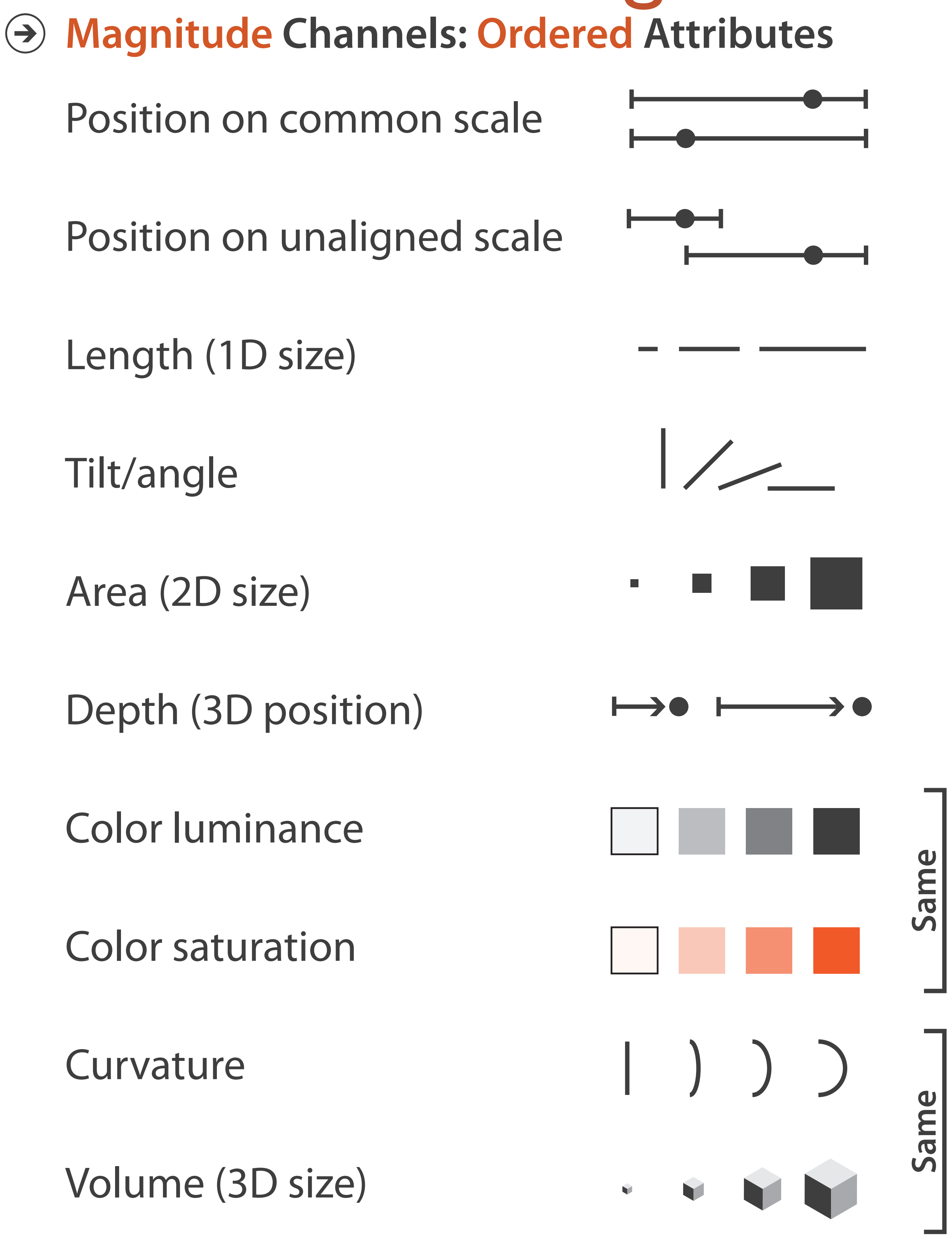
- Position on common scale
- Position on unaligned scale
- Length (1D size)
- Tilt/angle
- Area (2D size)
- Depth (3D position)
- Color luminance
- Color saturation
- Curvature
- Volume (3D size)

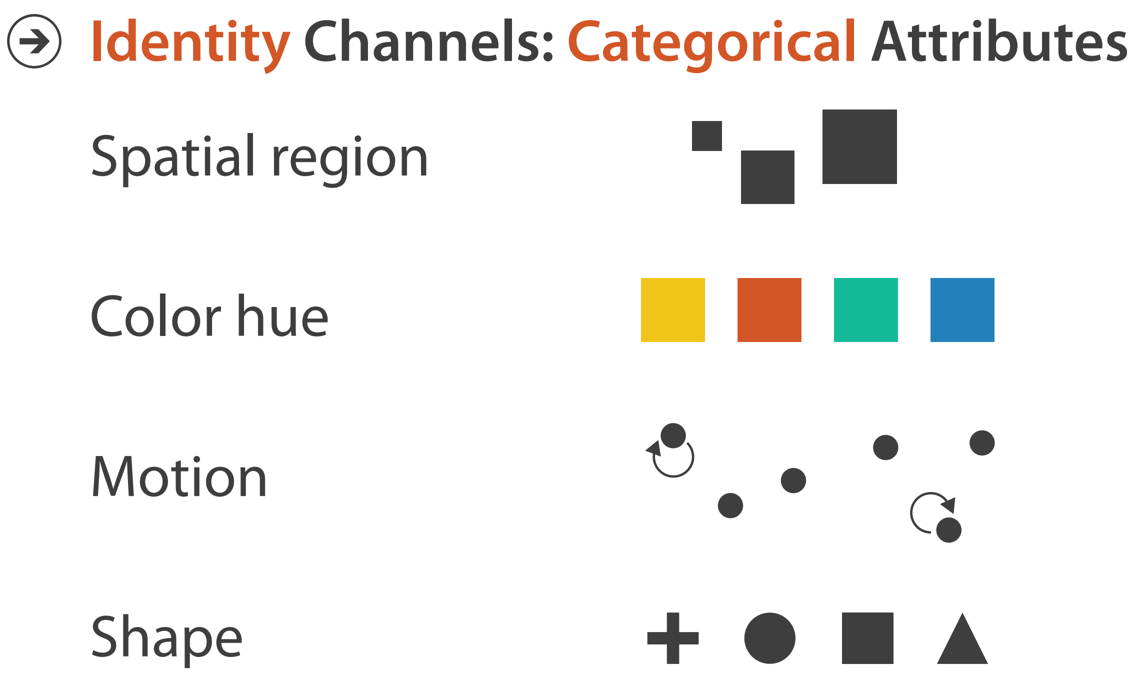


- Spatial region
- Color hue
- Motion
- Shape



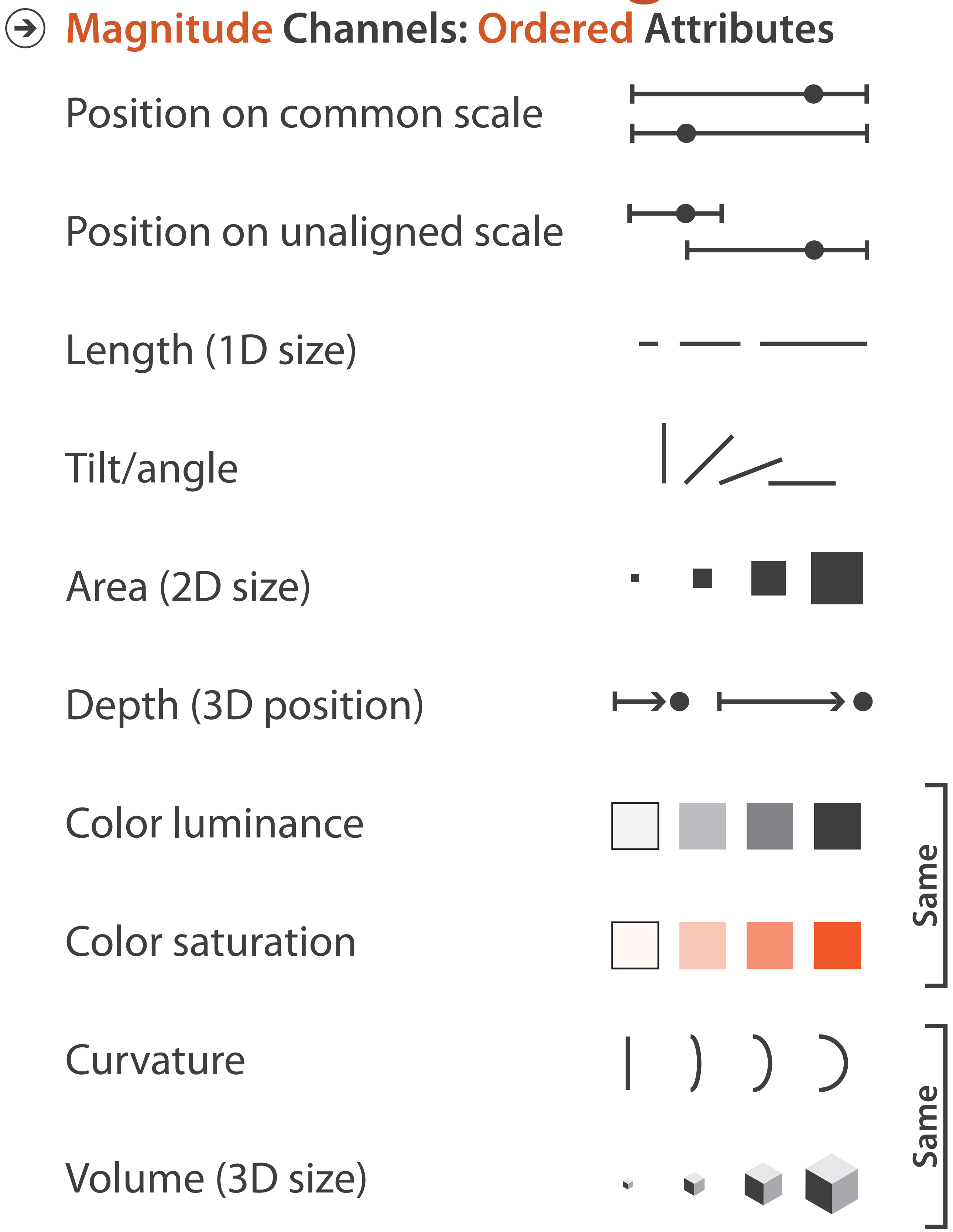
Channels: Rankings

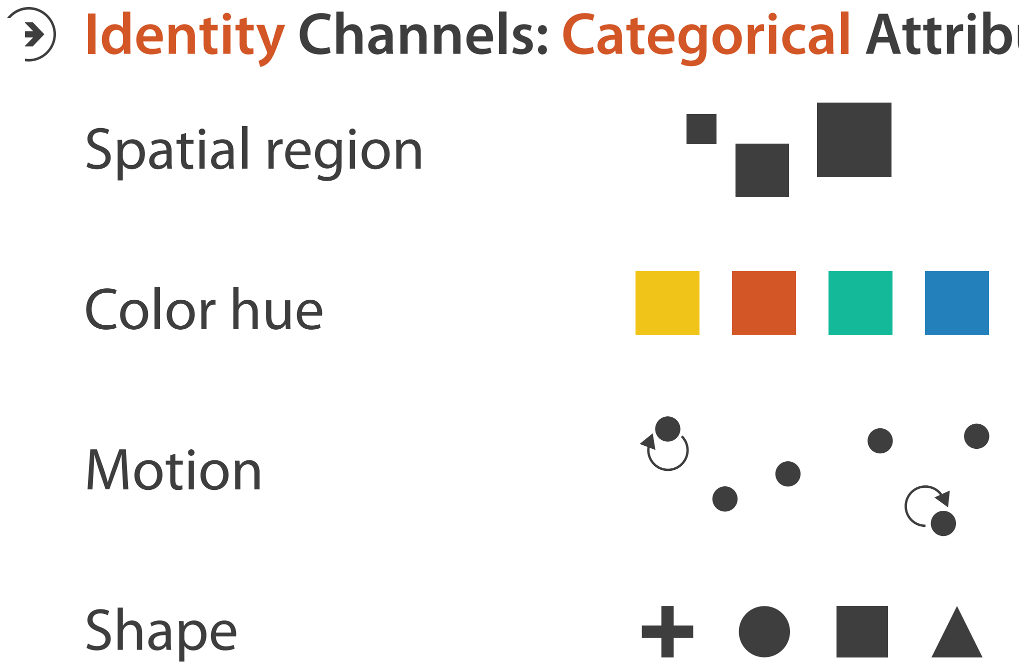


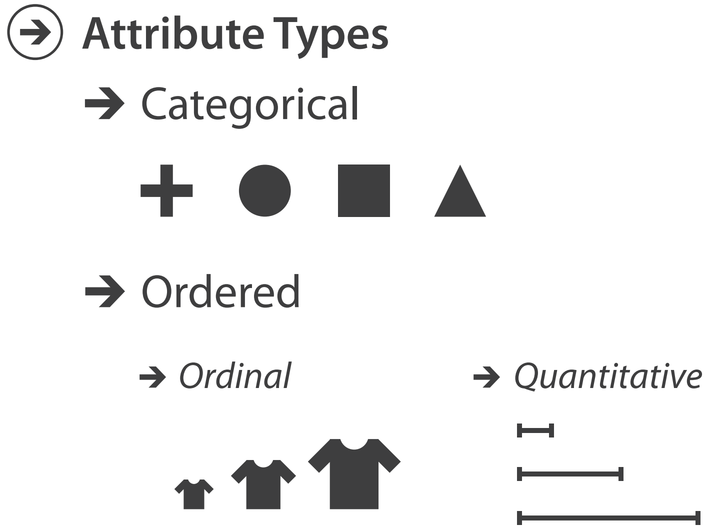


- expressiveness
  - match channel and data characteristics

Channels: Rankings

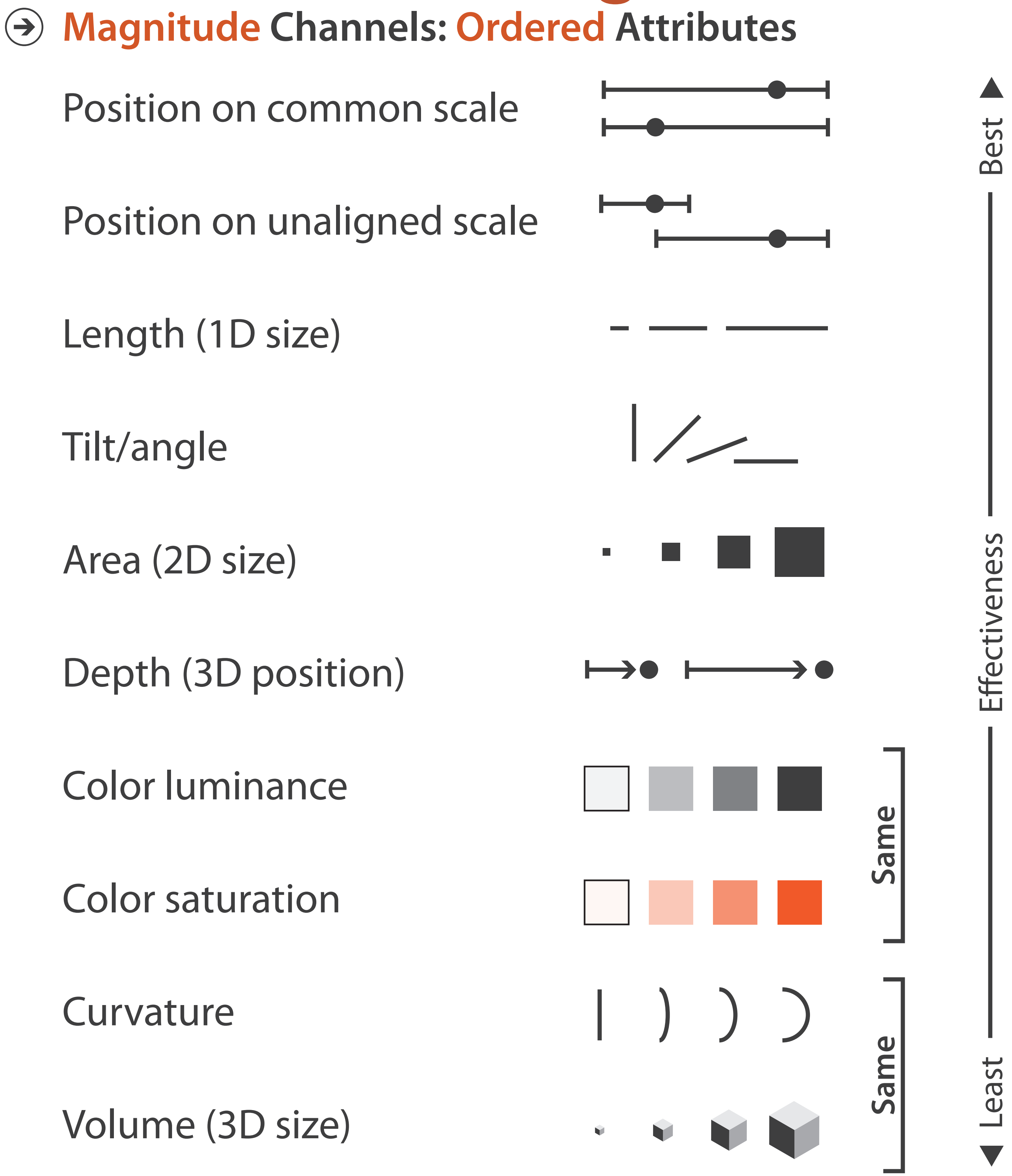


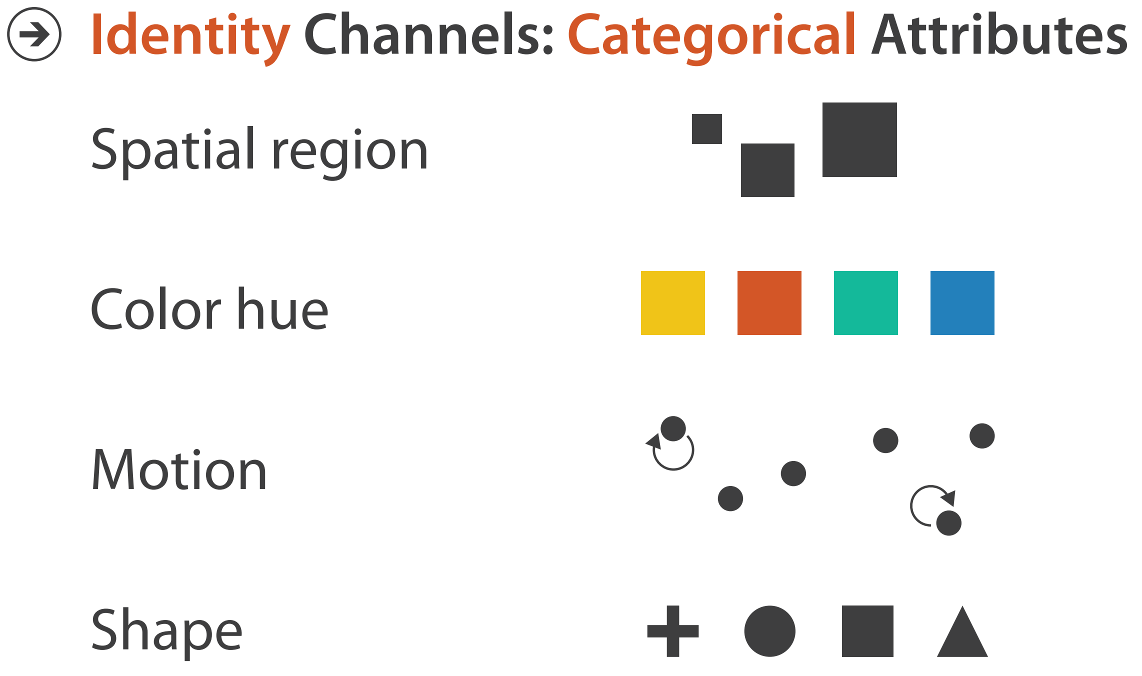




- expressiveness
  - match channel and data characteristics
  - magnitude for ordered
    - how much? which rank?
  - identity for categorical
    - what?

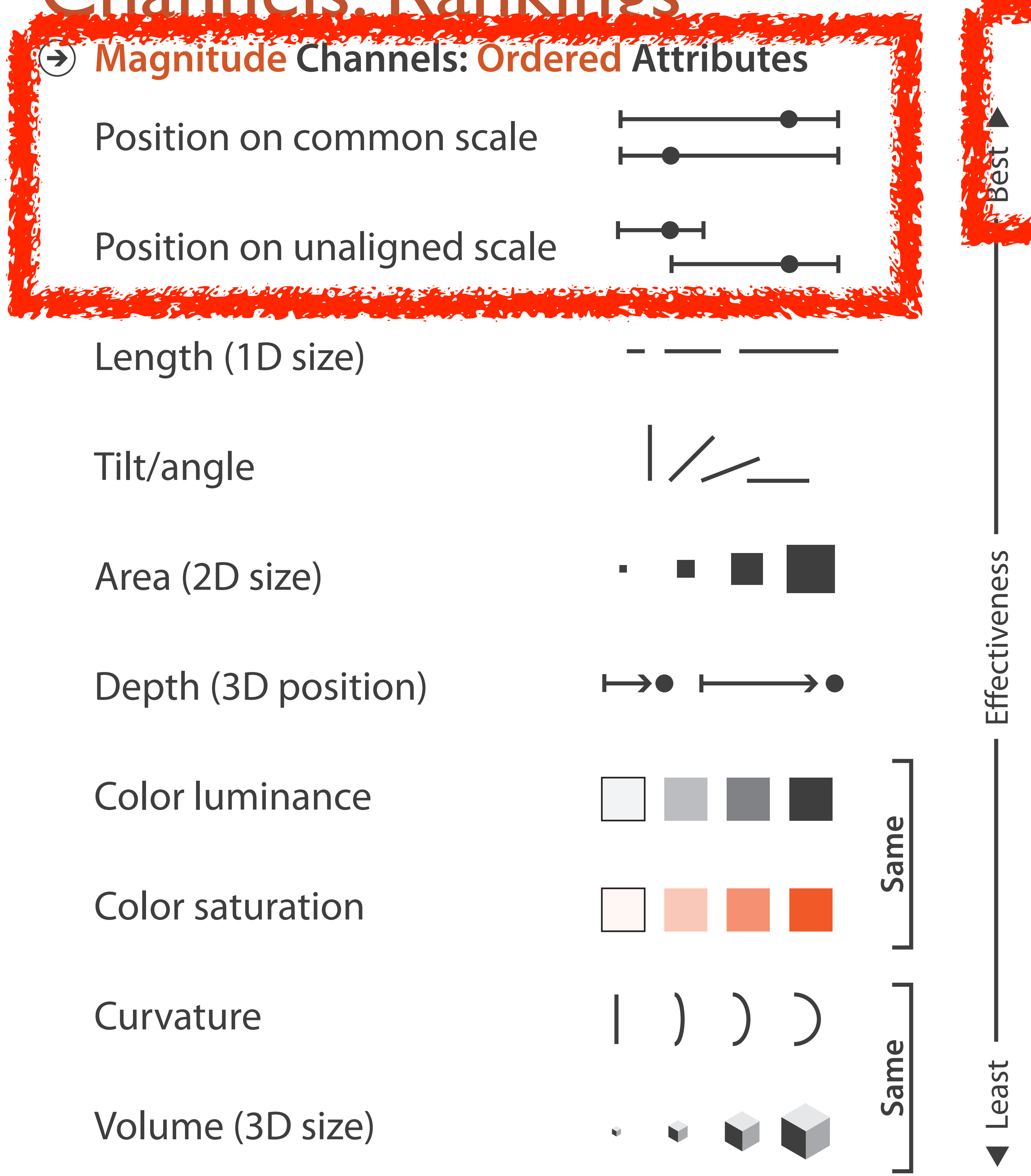
Channels: Rankings

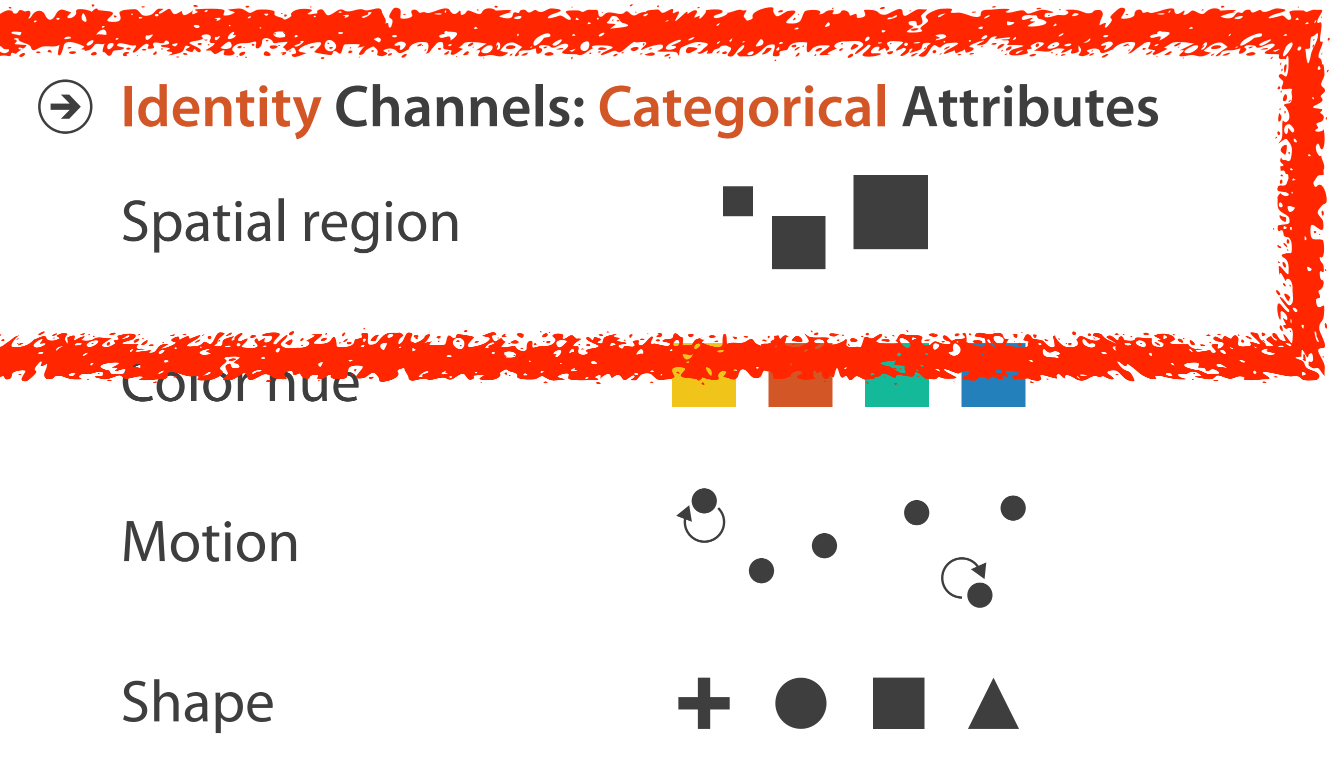




- expressiveness
  - match channel and data characteristics
- effectiveness
  - channels differ in accuracy of perception

Channels: Rankings





- expressiveness
  - match channel and data characteristics
- effectiveness
  - channels differ in accuracy of perception
  - spatial position ranks high for both

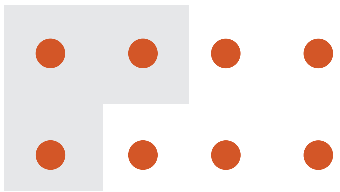
Grouping

- containment
- connection

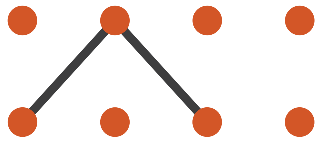
- proximity
  – same spatial region
- similarity
  – same values as other categorical channels

Marks as Links

Containment



Connection



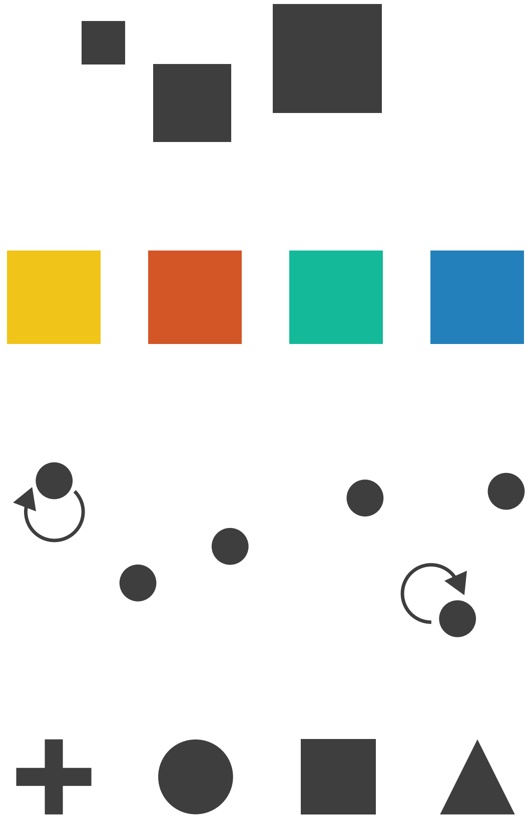
Identity Channels: Categorical Attributes

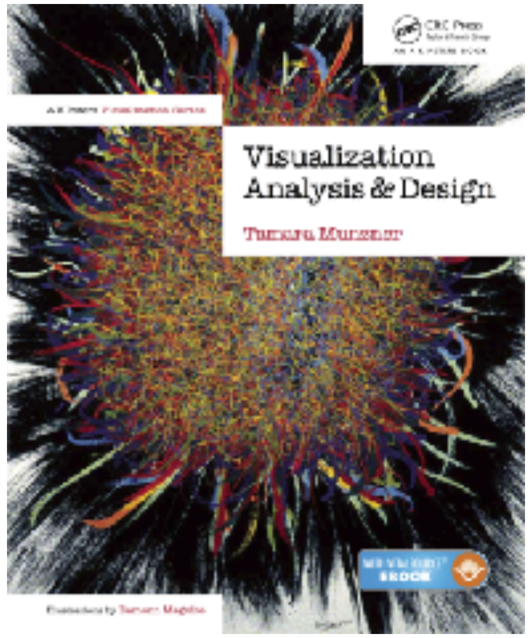
Spatial region

Color hue

Motion

Shape





Visualization Analysis & Design

Marks & Channels (Ch 5) II

Tamara Munzner
Department of Computer Science
University of British Columbia
@tamaramunzner

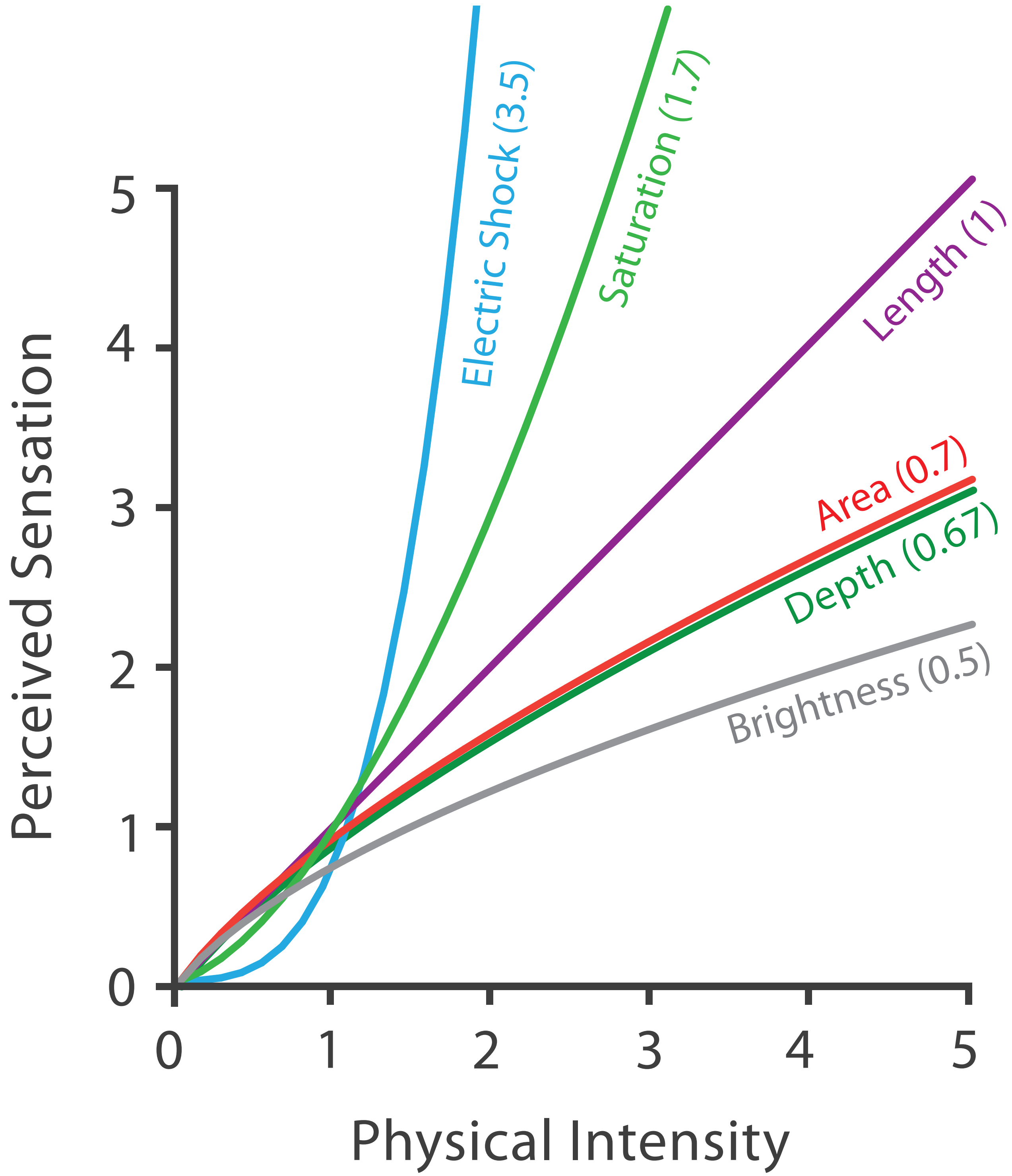
Channel effectiveness

- accuracy: how precisely can we tell the difference between encoded items?
- discriminability: how many unique steps can we perceive?
- separability: is our ability to use this channel affected by another one?
- popout: can things jump out using this channel?

Accuracy: Fundamental theory

- length is accurate: linear
- others magnified or compressed
  - –exponent characterizes

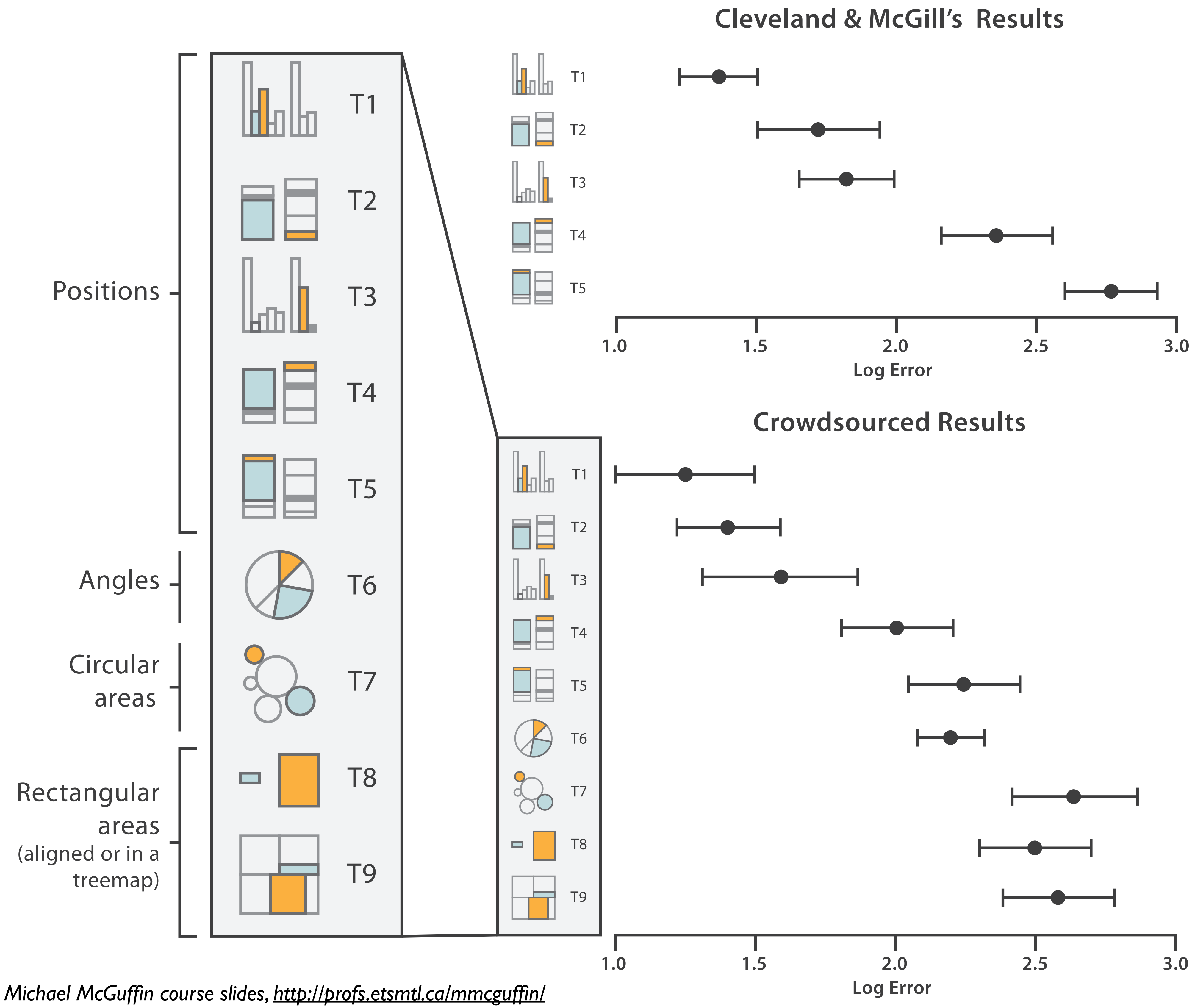
Steven's Psychophysical Power Law: $S= I^N$



S = sensation

I = intensity

Accuracy: Vis experiments

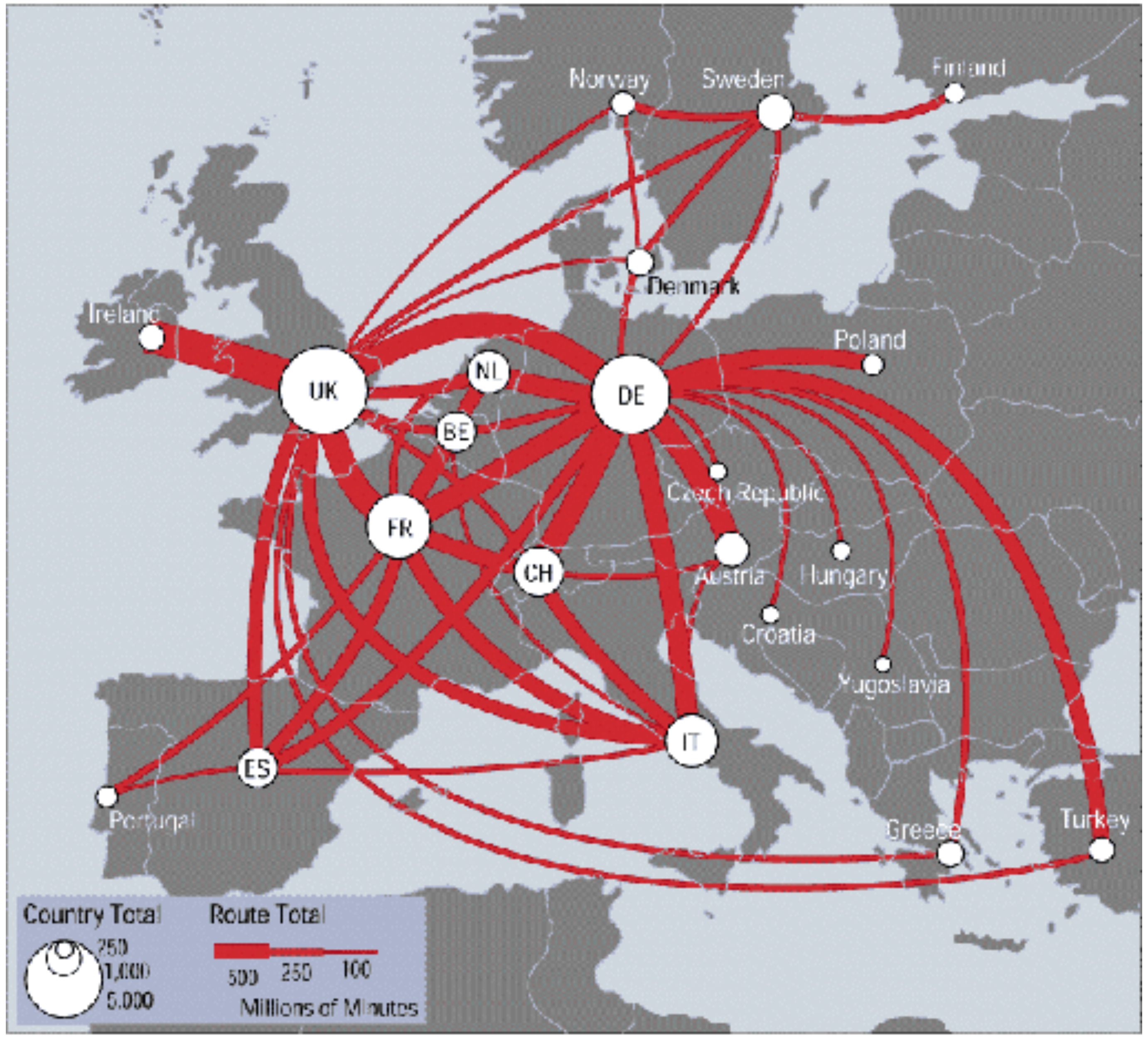


[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

after Michael McGuffin course slides, http://profs.etsmtl.ca/mmcguffin/

Discriminability: How many usable steps?

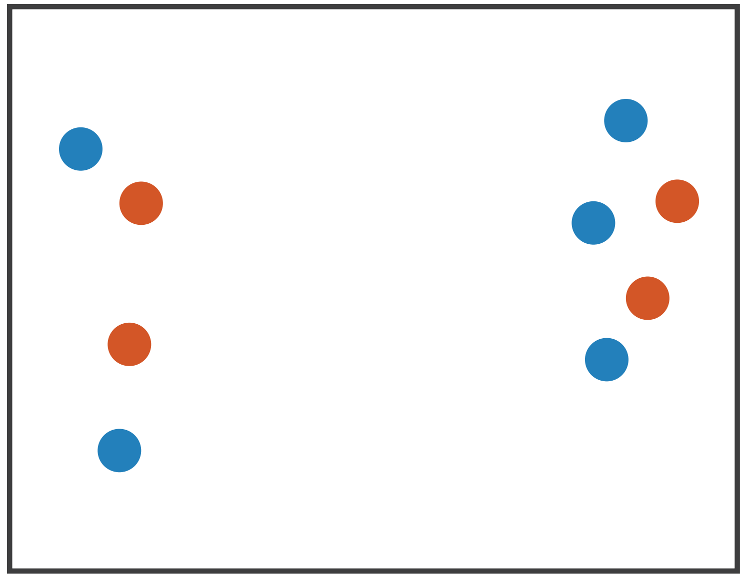
- must be sufficient for number of attribute levels to show
  - linewidth: few bins



[mappa.mundi.net/maps/maps 014/telegeography.html]

Separability vs. Integrality

Position
+ Hue (Color)

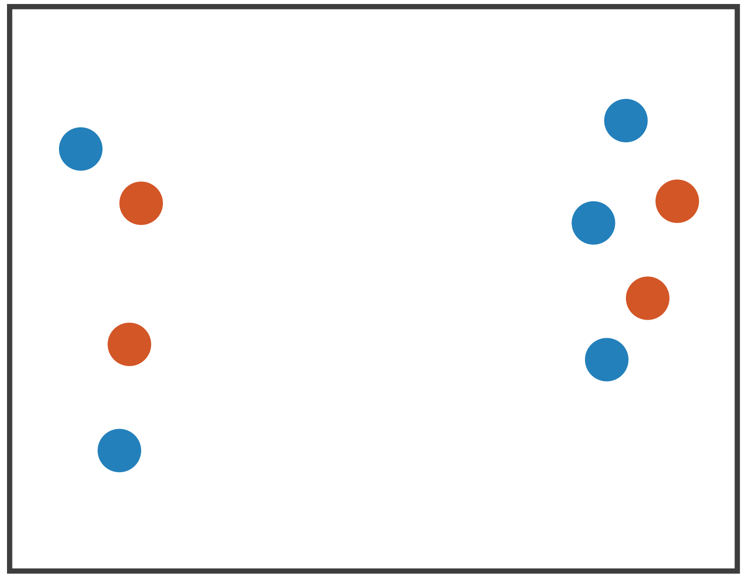


Fully separable

2 groups each

Separability vs. Integrality

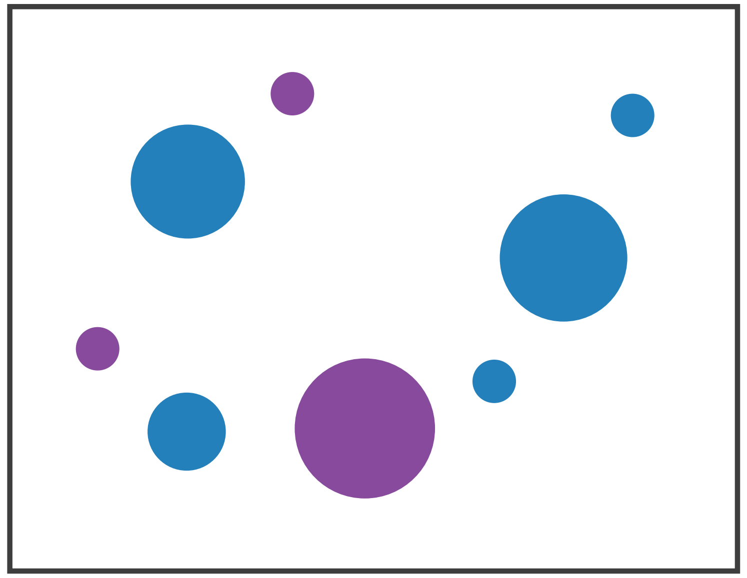
Position
+ Hue (Color)



Fully separable

2 groups each

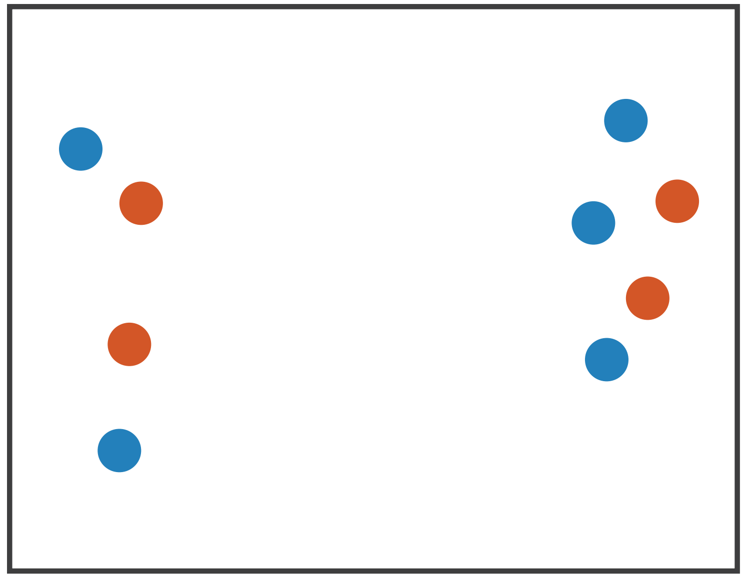
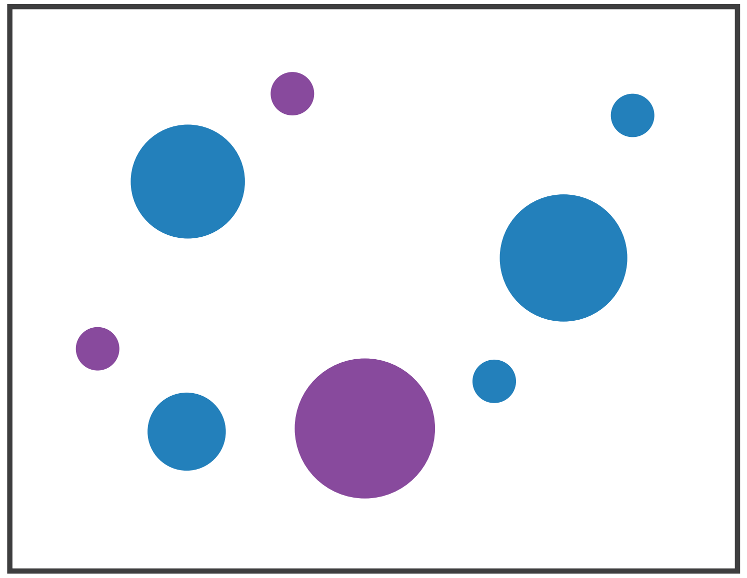
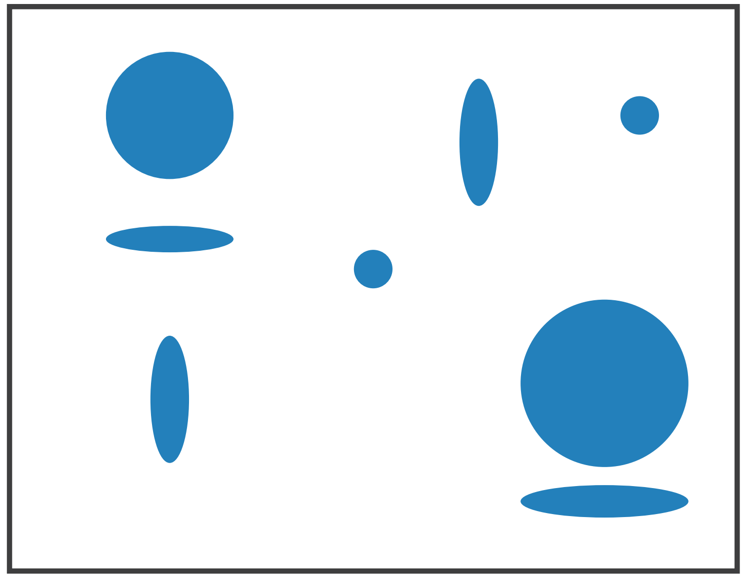
Size
+ Hue (Color)



Some interference

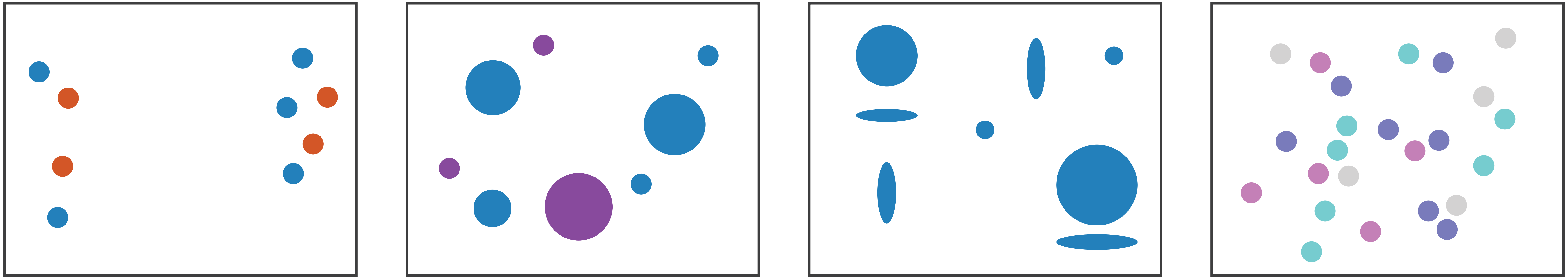
2 groups each

Separability vs. Integrality

Position + Hue (Color)	Size + Hue (Color)	Width + Height
		
Fully separable	Some interference	Some/significant interference
2 groups each	2 groups each	3 groups total: integral area

Separability vs. Integrality

Position + Hue (Color)	Size + Hue (Color)	Width + Height	Red + Green



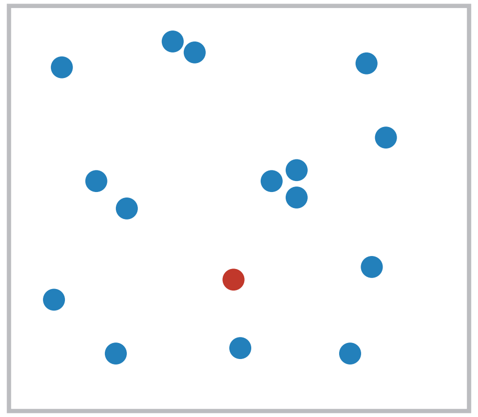
Fully separable	Some interference	Some/significant interference	Major interference
2 groups each	2 groups each	3 groups total: integral area	4 groups total: integral hue

Popout

- find the red dot
  - how long does it take?

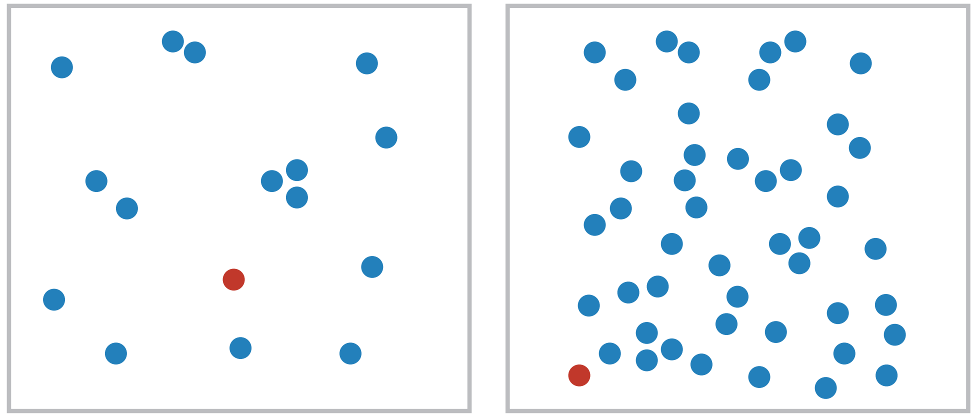
Popout

- find the red dot
  - how long does it take?



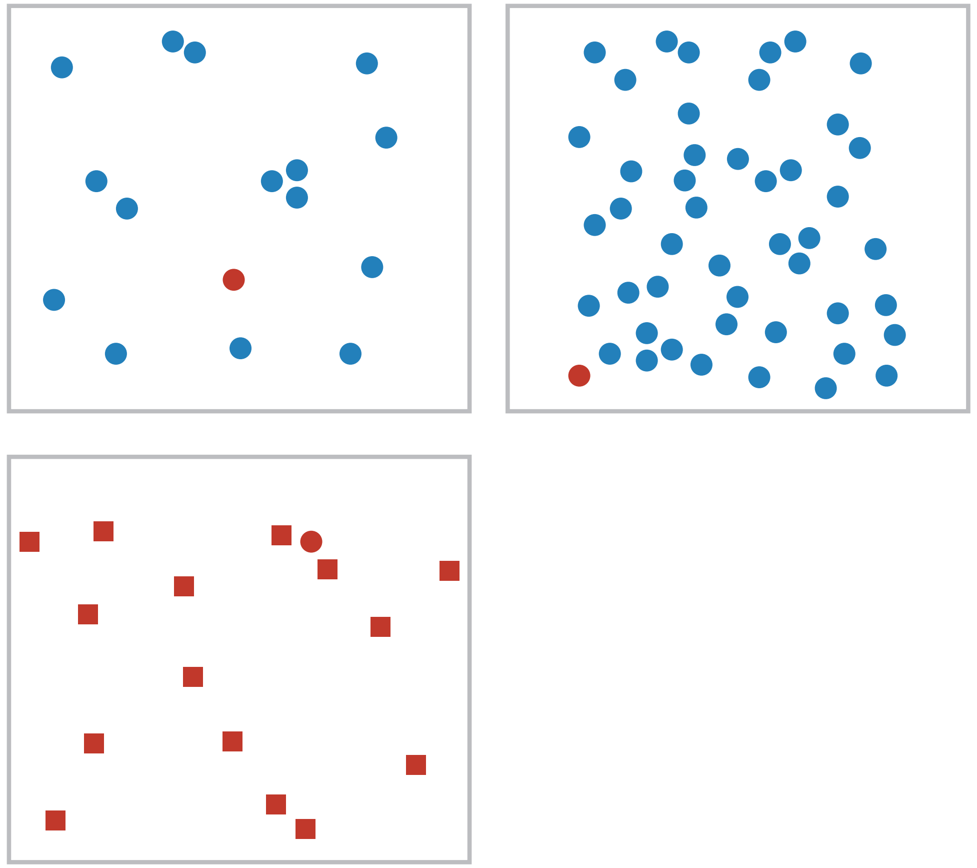
Popout

- find the red dot
  - how long does it take?



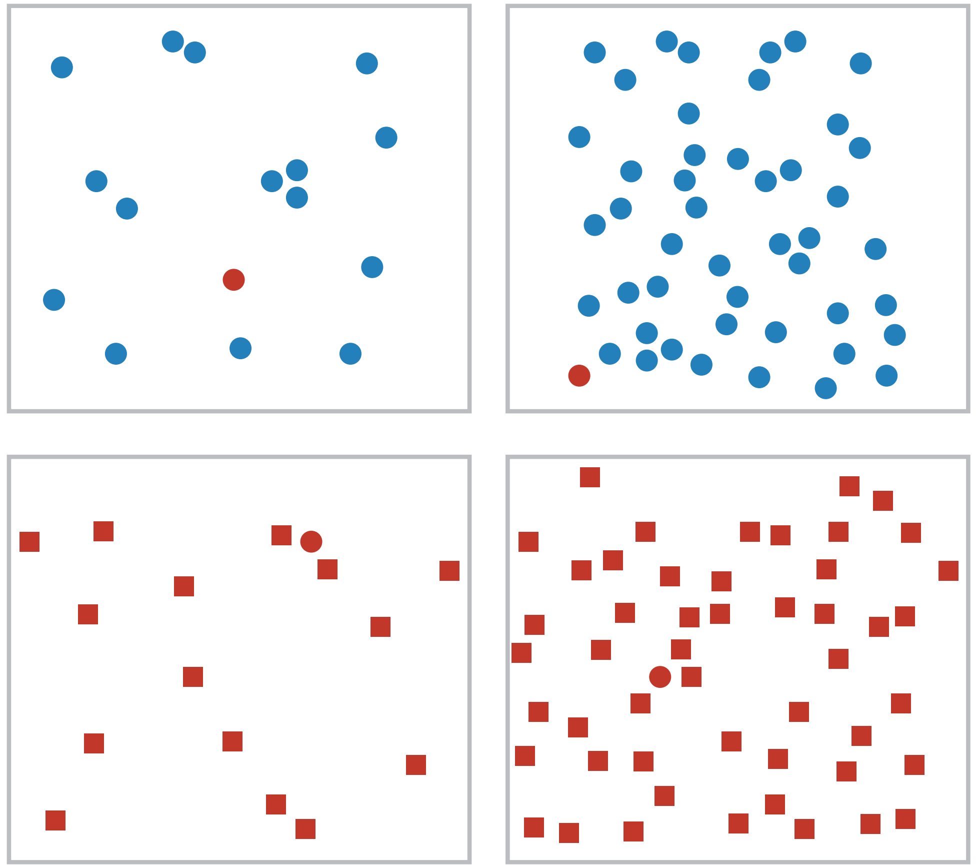
Popout

- find the red dot
  - how long does it take?



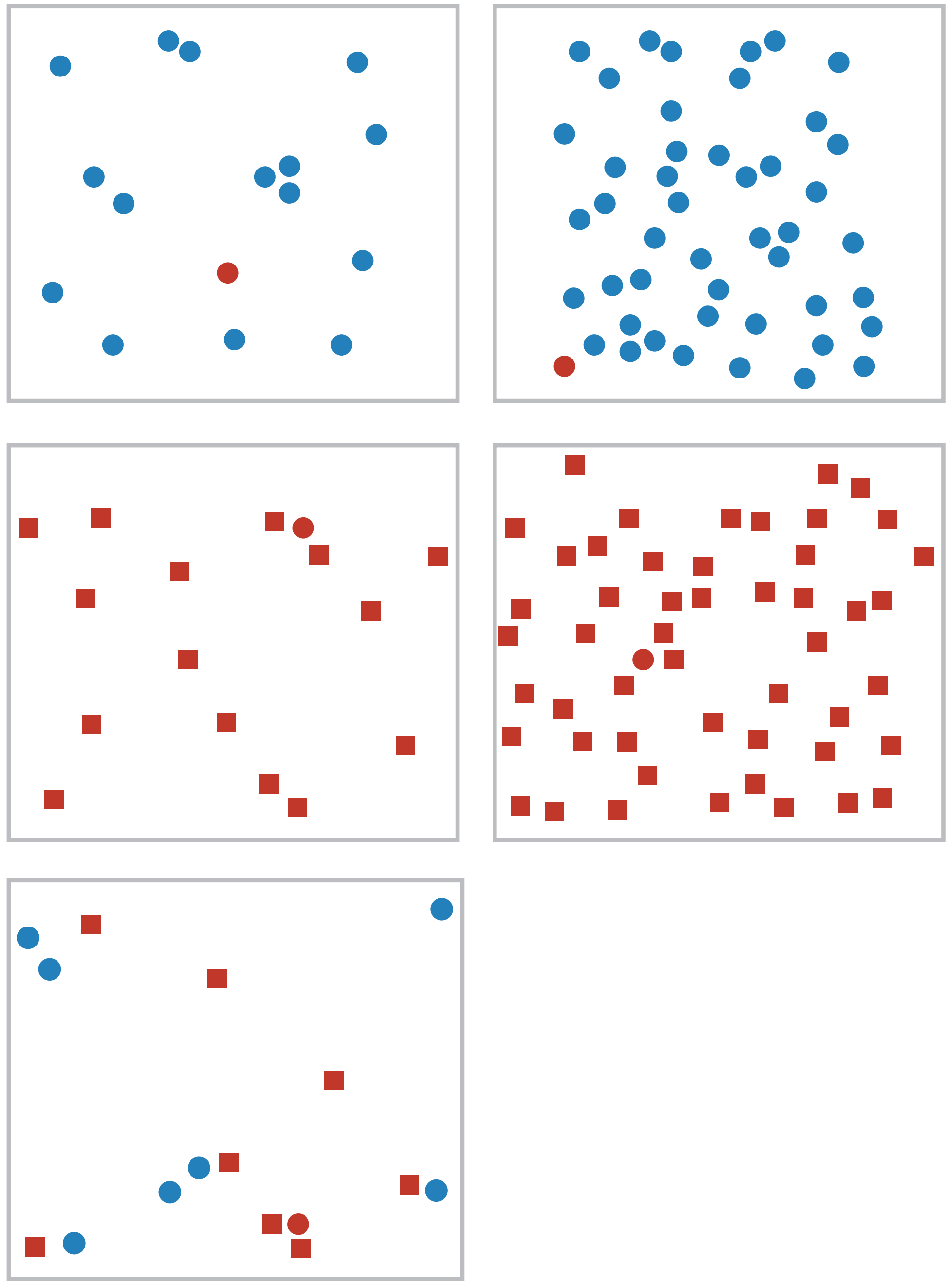
Popout

- find the red dot
  - how long does it take?



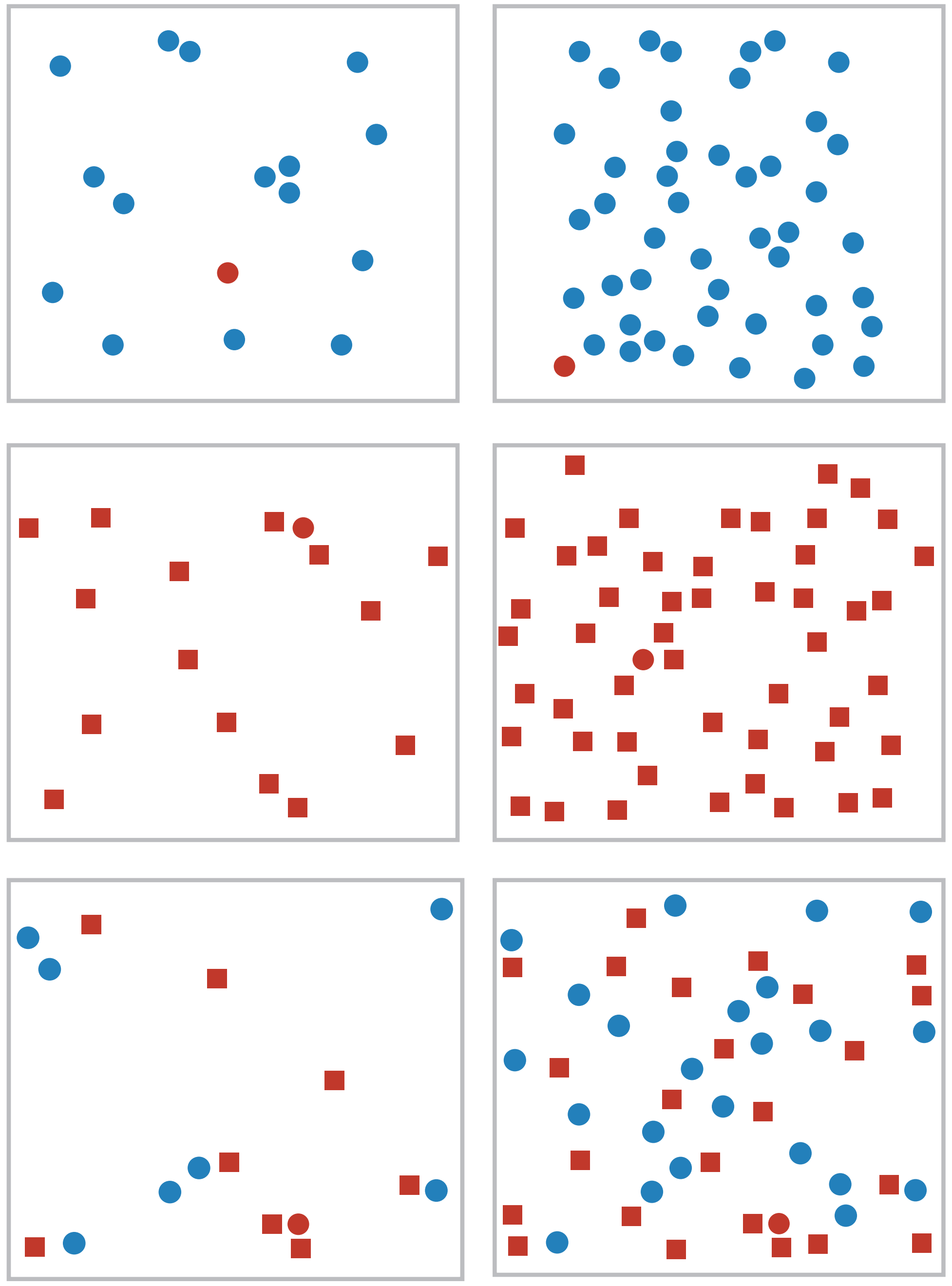
Popout

- find the red dot
  - how long does it take?



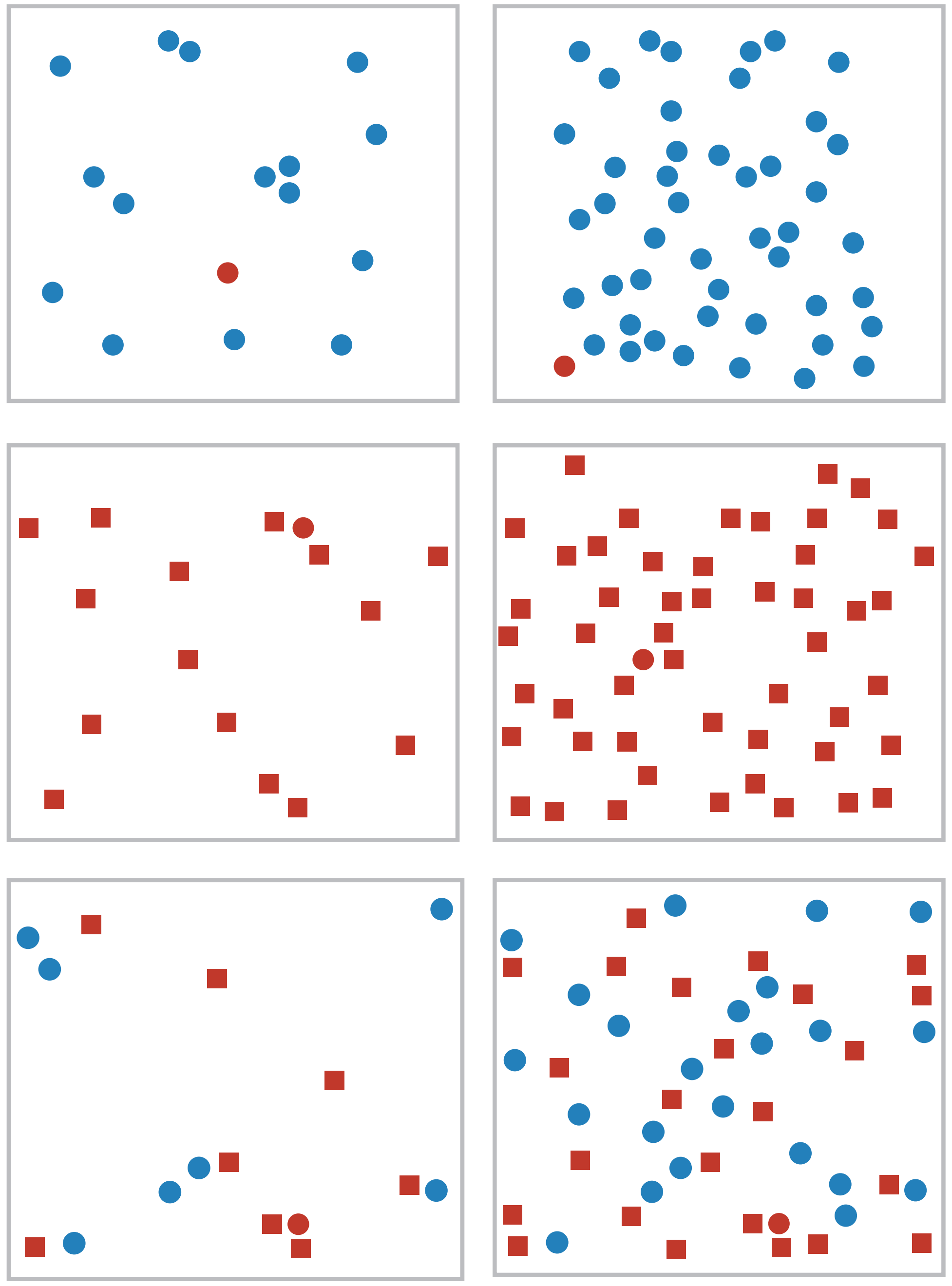
Popout

- find the red dot
  - how long does it take?

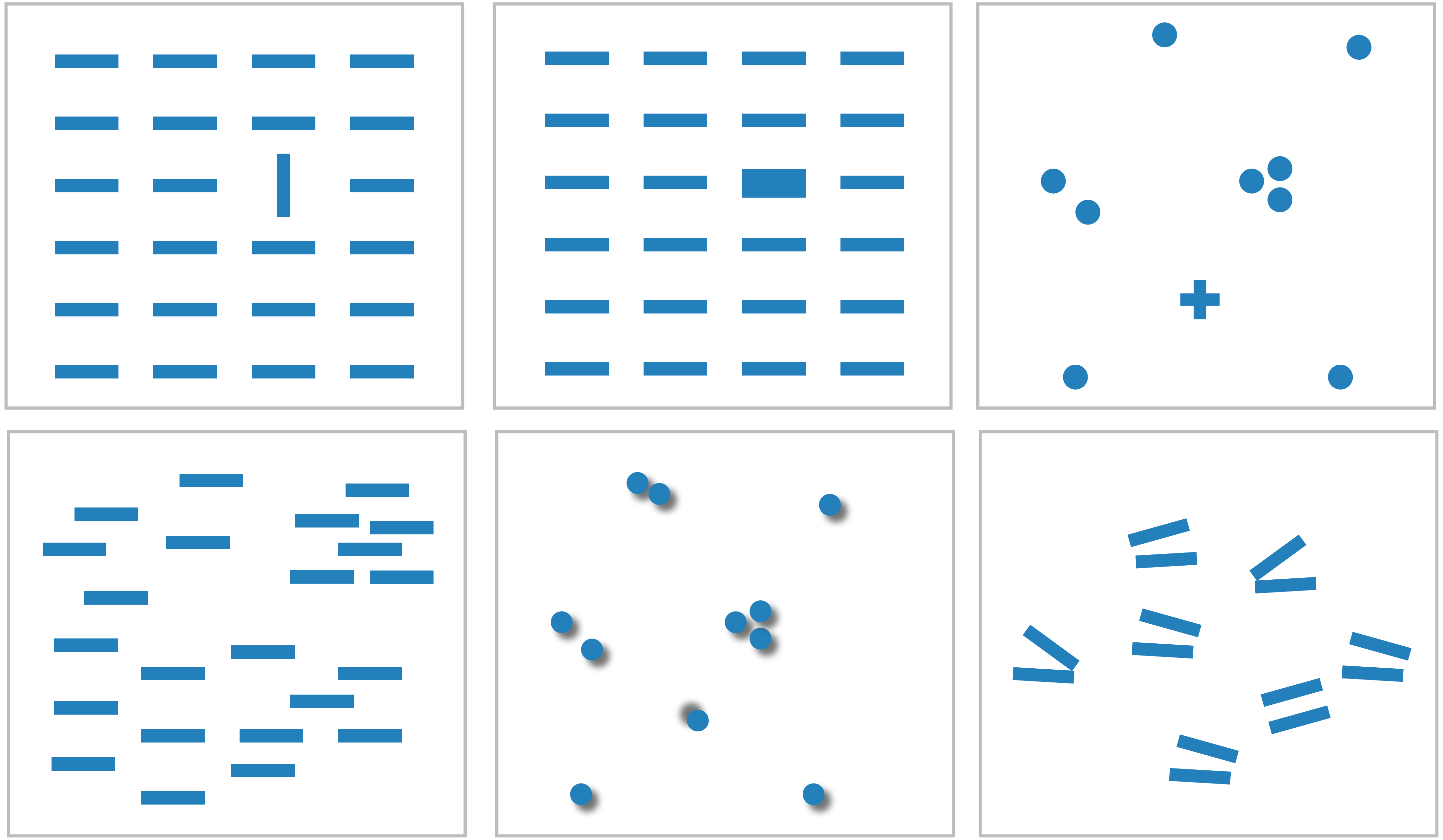


Popout

- find the red dot
  - how long does it take?
- parallel processing on many individual channels
  - speed independent of distractor count
  - speed depends on channel and amount of difference from distractors
- serial search for (almost all) combinations
  - speed depends on number of distractors

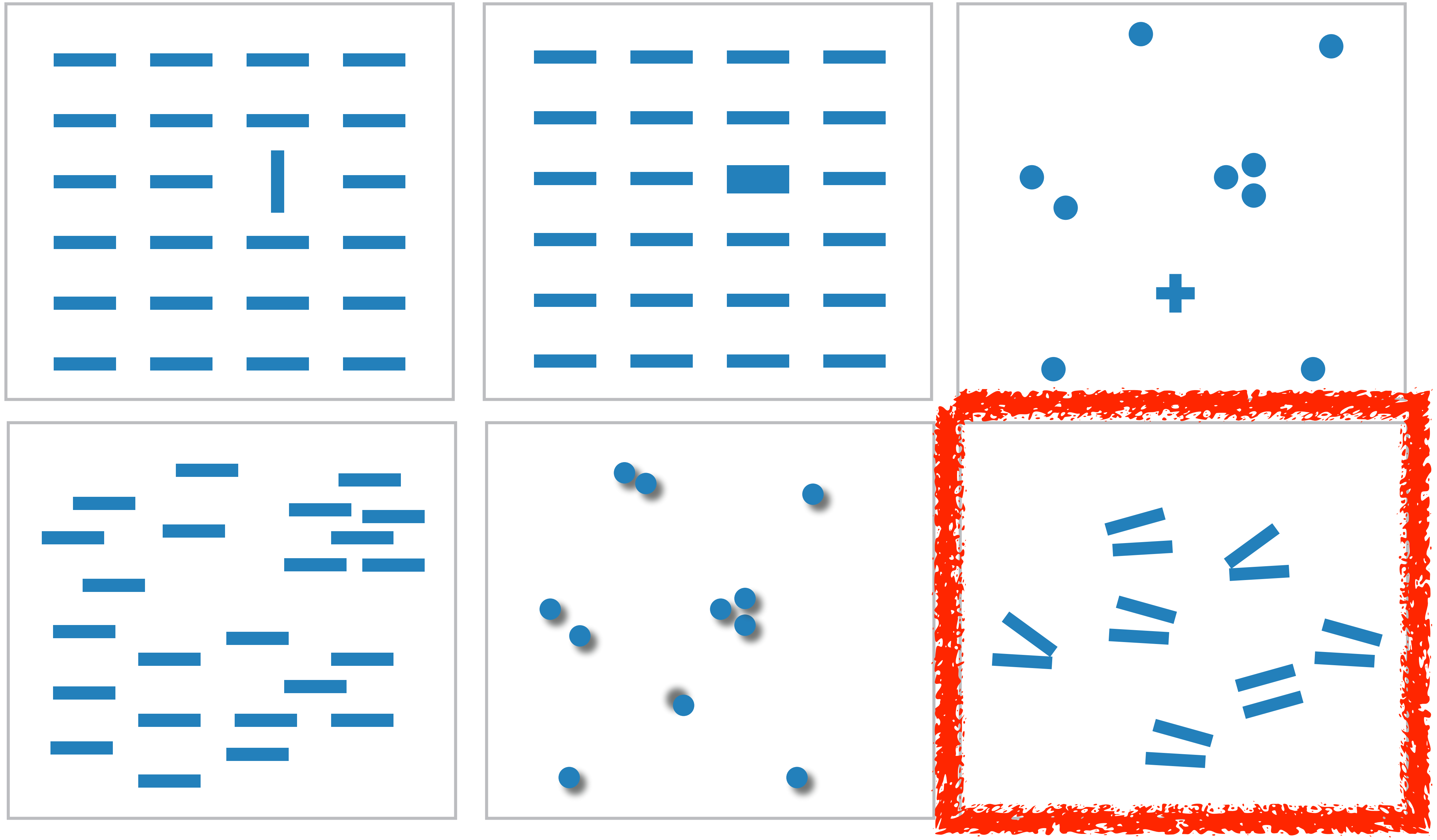


Popout



- many channels
  - tilt, size, shape, proximity, shadow direction, ...

Popout



- many channels
  - tilt, size, shape, proximity, shadow direction, ...
- but not all!
  - parallel line pairs do not pop out from tilted pairs

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale / alignment

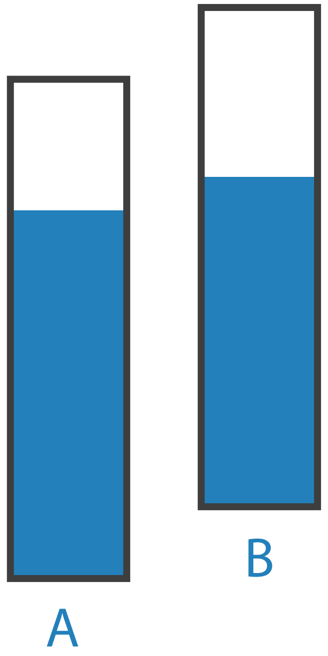
Relative vs. absolute judgements

- perceptual system mostly operates with relative judgements, not absolute

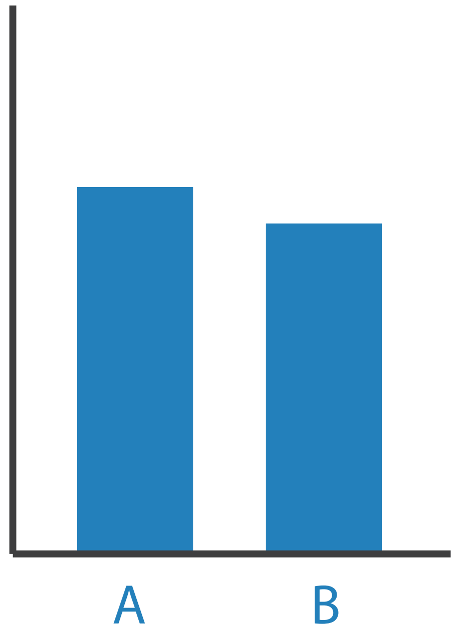
Relative vs. absolute judgements

- perceptual system mostly operates with relative judgements, not absolute
  - that's why accuracy increases with common frame/scale and alignment

length



position along unaligned common scale

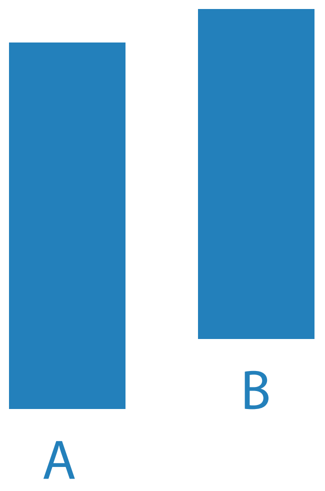


position along aligned scale

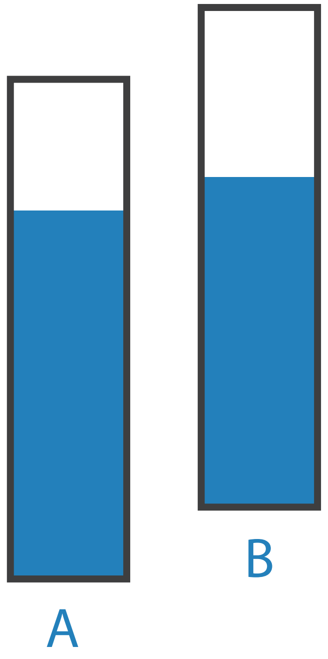
after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Relative vs. absolute judgements

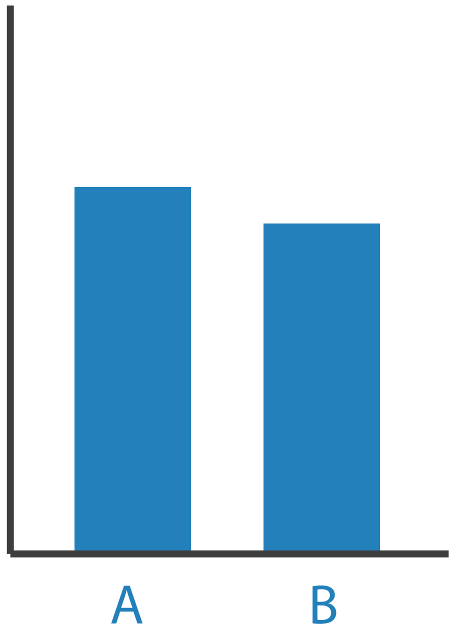
- perceptual system mostly operates with relative judgements, not absolute
  - that's why accuracy increases with common frame/scale and alignment
  - Weber's Law: ratio of increment to background is constant



length



position along unaligned common scale

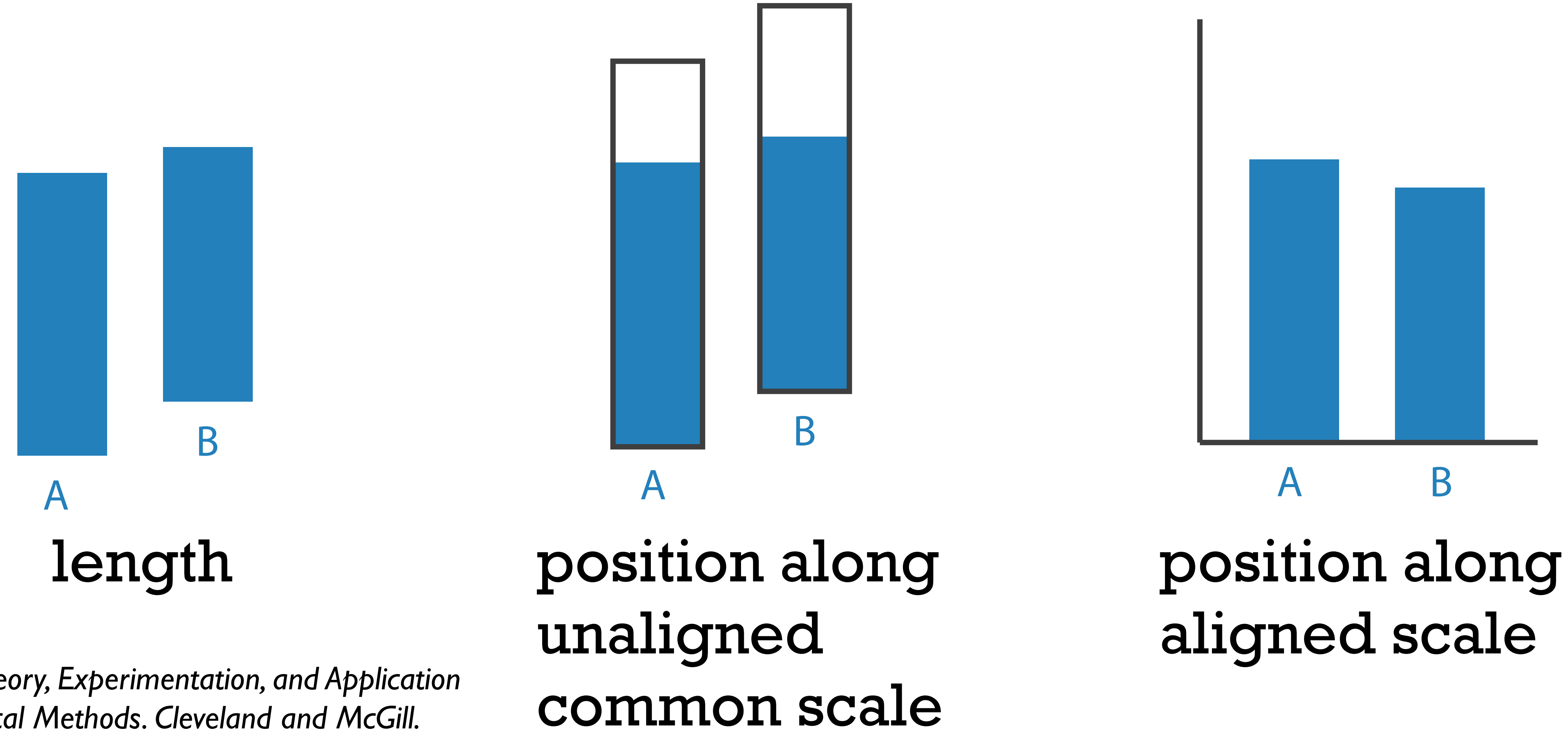


position along aligned scale

after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Relative vs. absolute judgements

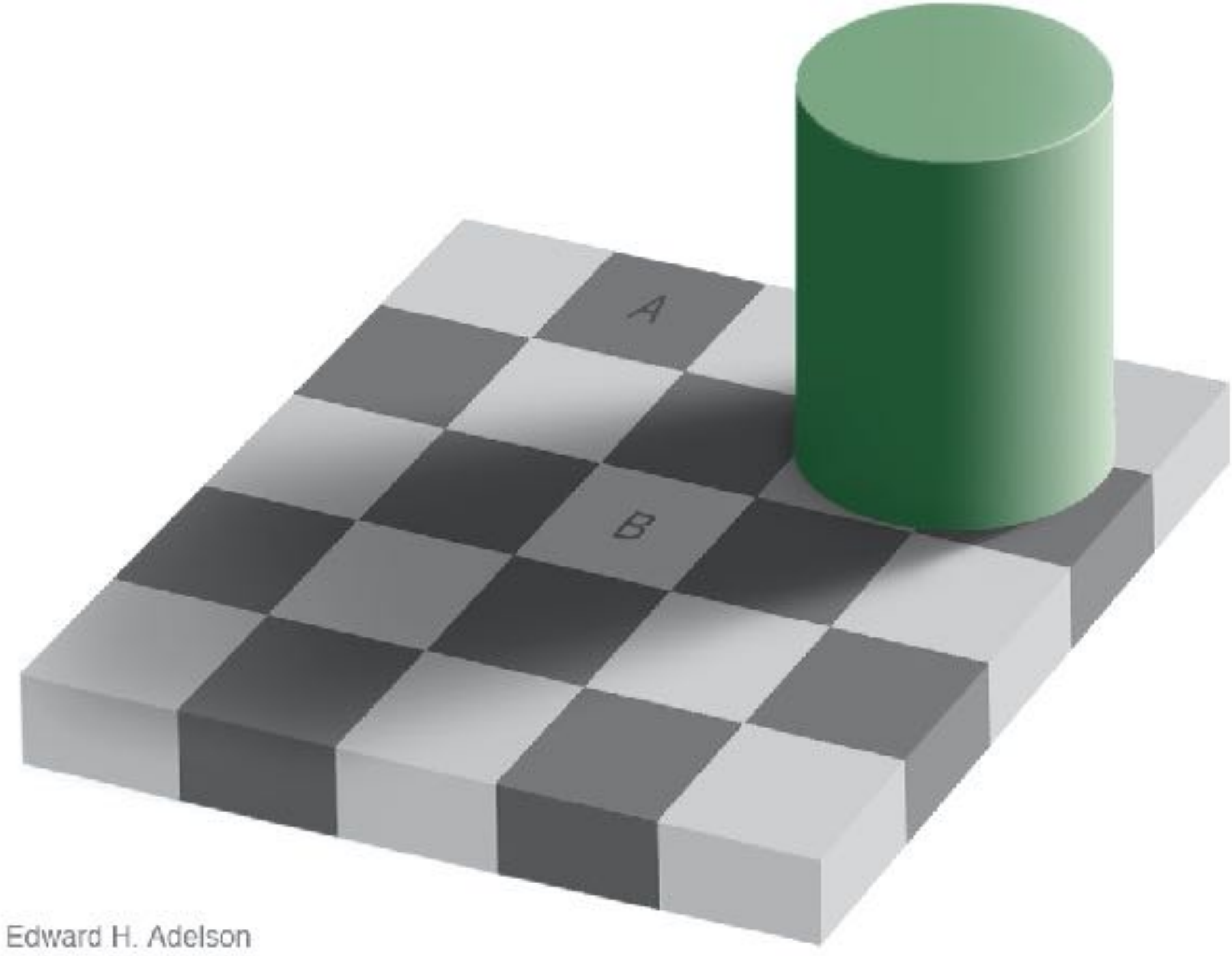
- perceptual system mostly operates with relative judgements, not absolute
  – that's why accuracy increases with common frame/scale and alignment
  – Weber's Law: ratio of increment to background is constant
    - filled rectangles differ in length by 1:9, difficult judgement
    - white rectangles differ in length by 1:2, easy judgement



after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Relative luminance judgements

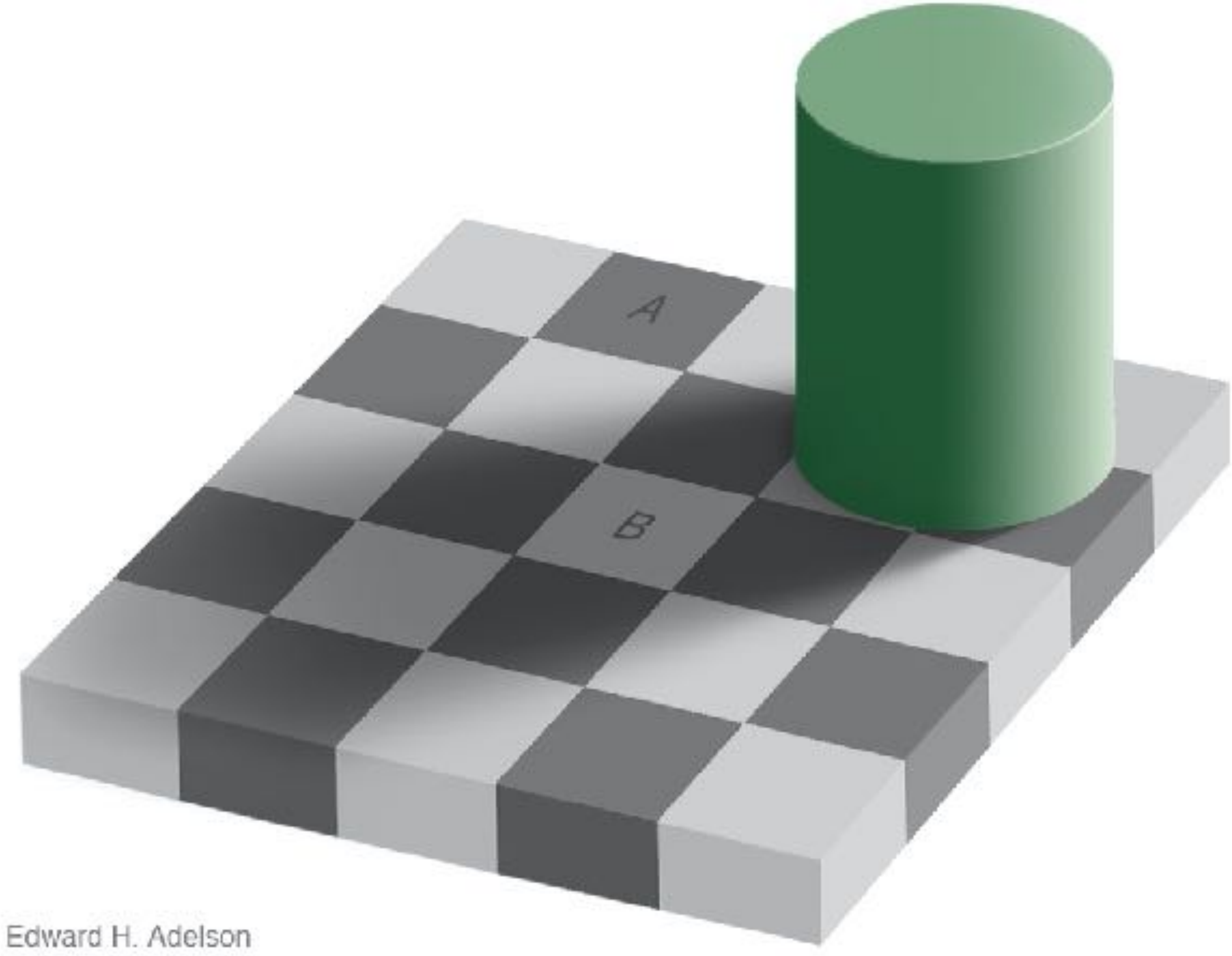
- perception of luminance is contextual based on contrast with surroundings

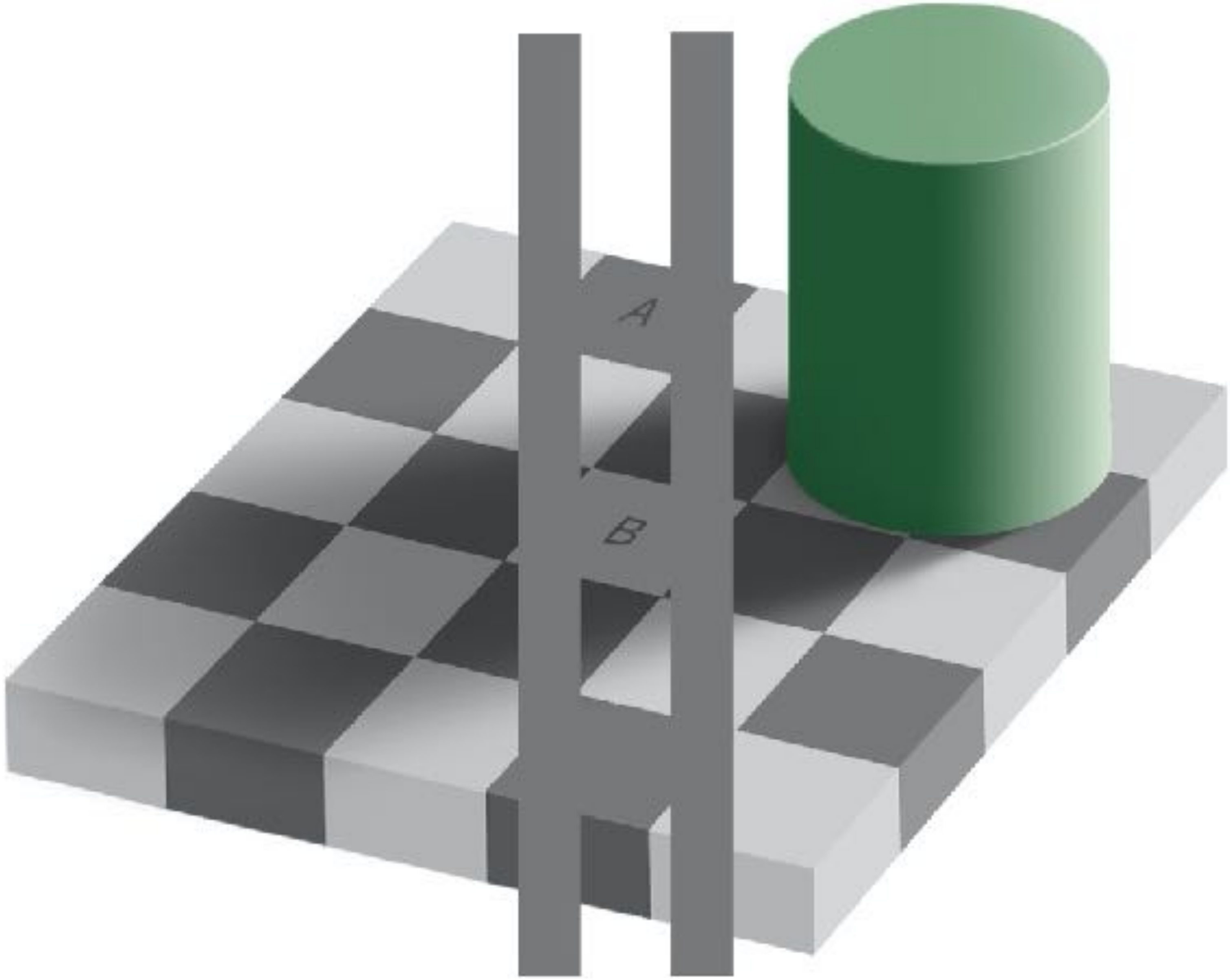


http://persci.mit.edu/gallery/checkershadow

Relative luminance judgements

- perception of luminance is contextual based on contrast with surroundings

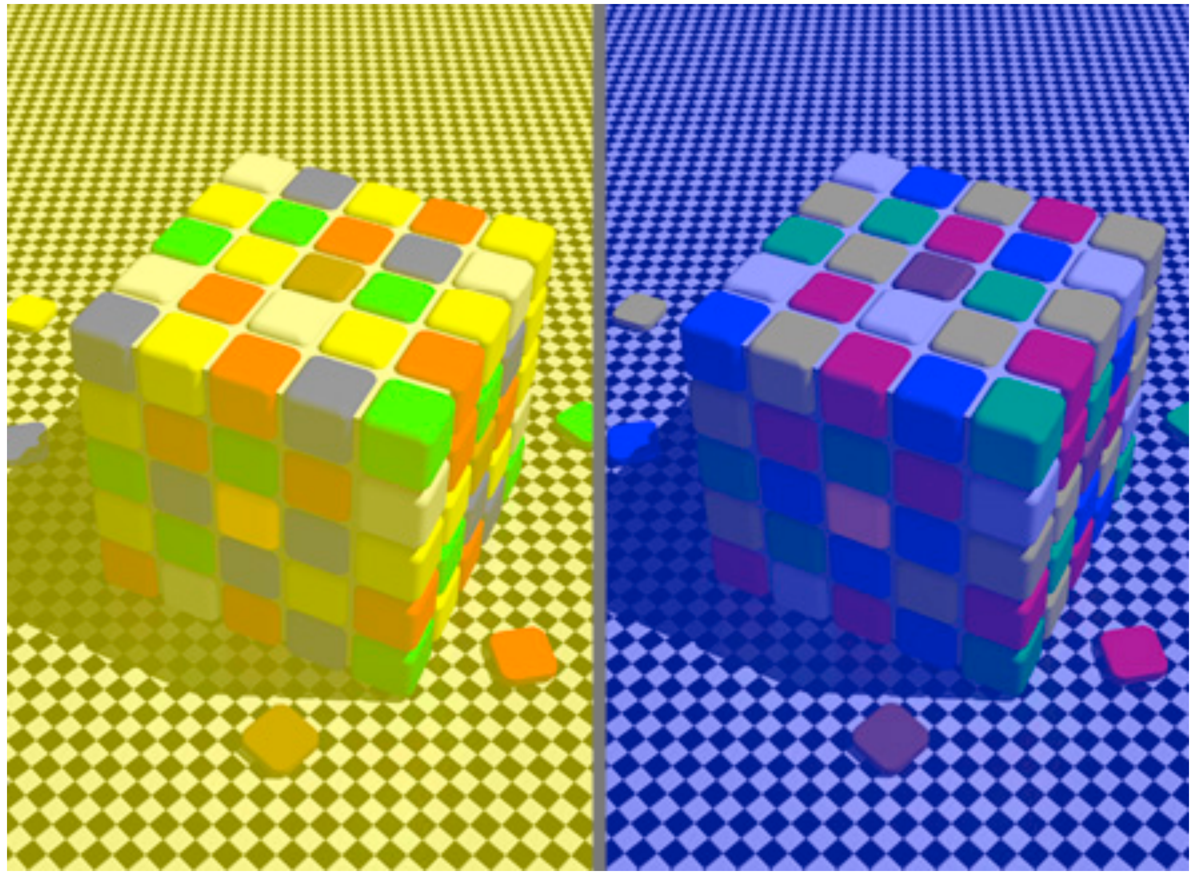




http://persci.mit.edu/gallery/checkershadow

Relative color judgements

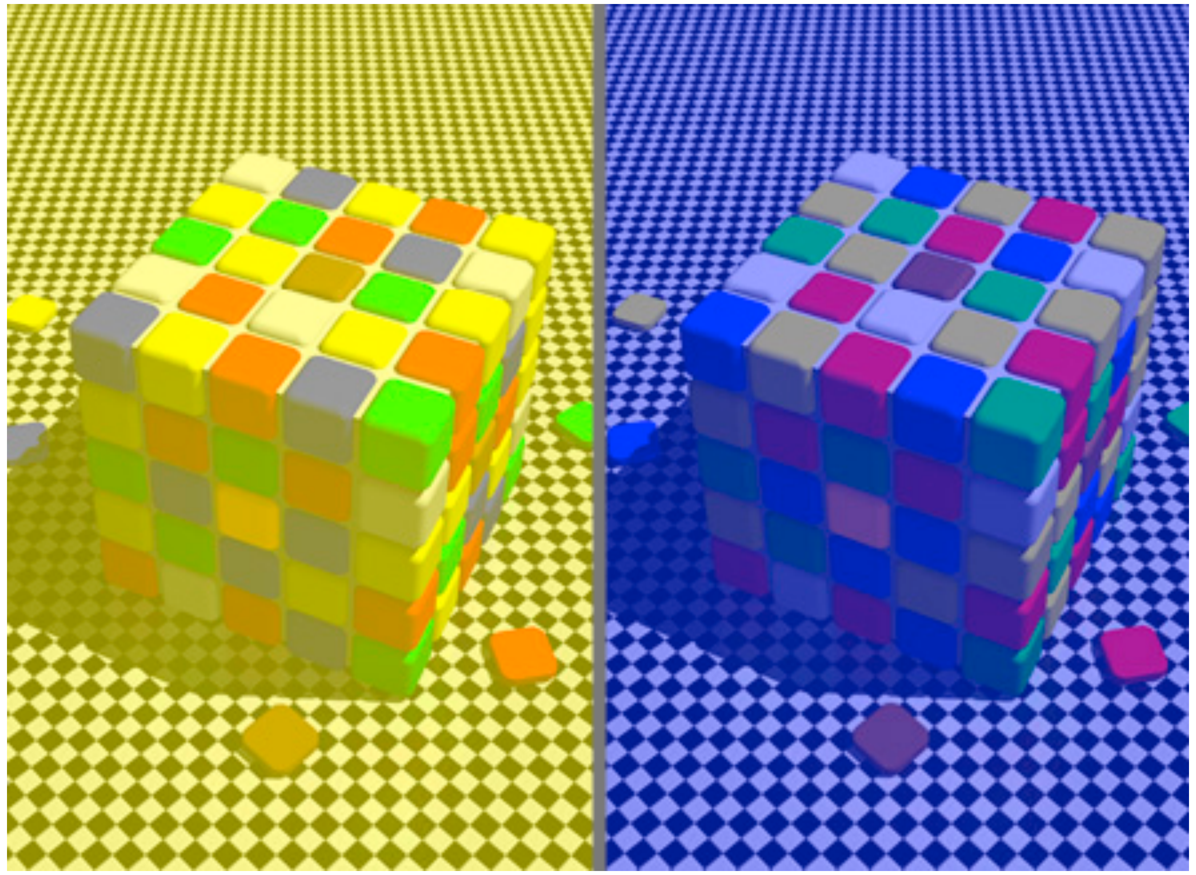
- color constancy across broad range of illumination conditions

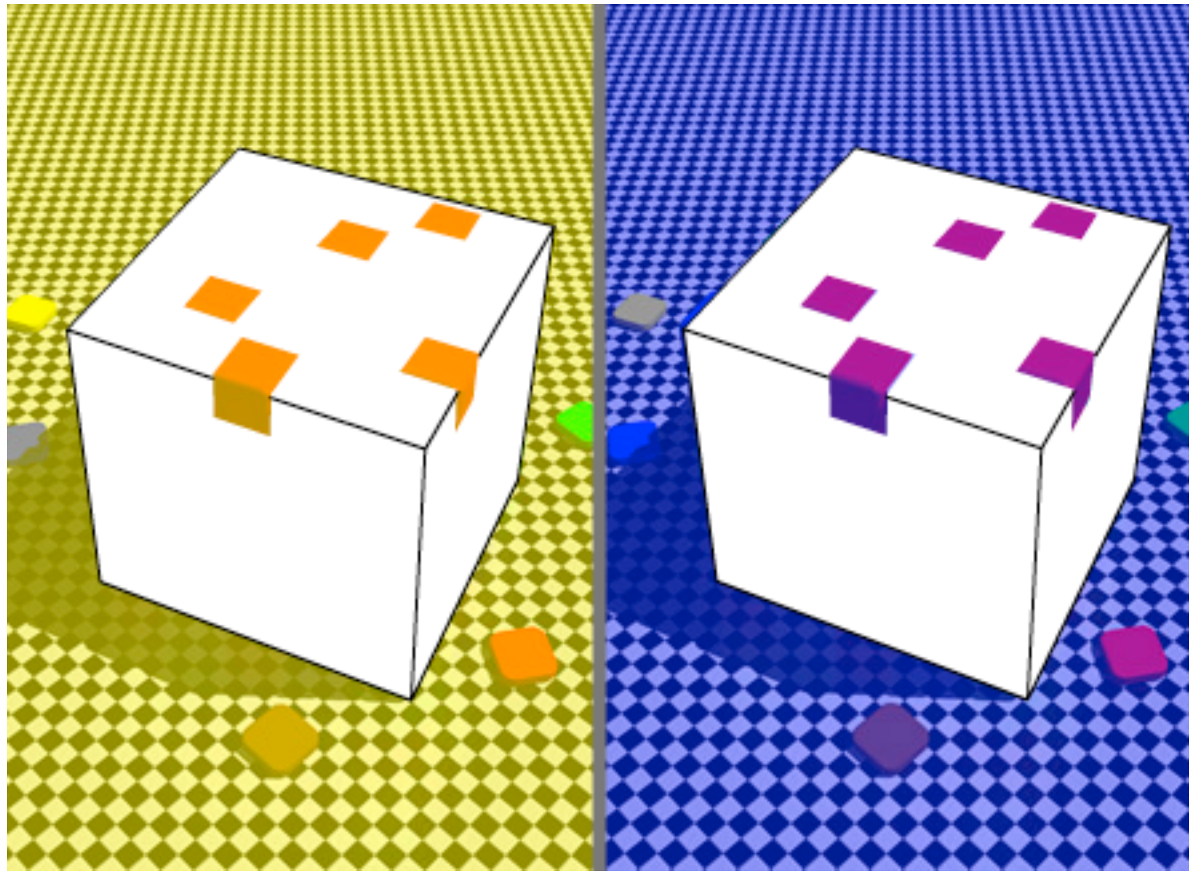


http://www.purveslab.net/seeforyourself/

Relative color judgements

- color constancy across broad range of illumination conditions





http://www.purveslab.net/seeforyourself/