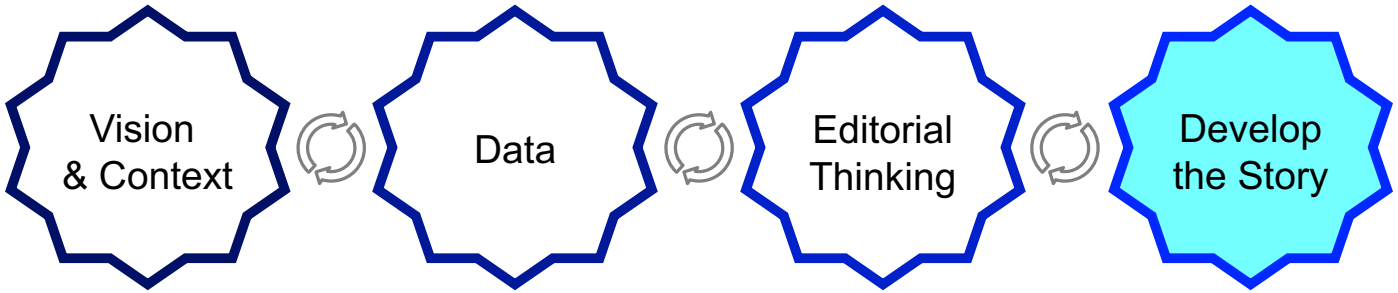
Visualization (Vis)

Storytelling with Interactive Data Visualizations

Lecture 5
–
Visual Encoding

Develop the Story: Visual Encoding



- Visual Encoding and Charts
- Rules of Thumb
- Interactivity and Storytelling
- Annotation, Colour and Composition

Visual Encoding

1. Marks and Channels
2. Ranking of Perceptual Tasks
3. Some More Charts

Visual Encoding, Marks and Attributes

Visual Encoding

Representing Data Visually

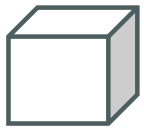
Marks

Visual placeholders representing data items

(Visual Encoding) Channels / Attributes

Variations in the visual appearance of marks

Marks – for Data Items

Points	0-dimensional		Commonly used to represent quantitative values though position (e.g., scatter plot)
Lines	1-dimensional		Commonly used to represent quantitative values through variation in legth (e.g., bar chart)
Areas	2-dimensional		Commonly used to represent quantitative values through size and position (e.g., bubble plot)
Volumes	3-dimensional		Rarely used

(Visual) Channels – Appearance of Marks

- Position
  - Horizontal
  - Vertical
  - Both

- Color

- Shape

- Tilt

- Size
  - Length
  - Area
  - Volume

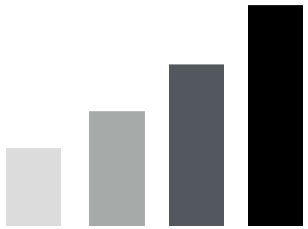
Source: T. Munzner, Visualization Analysis and Design

Using multiple Channels

- Encoding multiple Attributes

  - 2 attributes : vertical position (height) + horizontal position (categories spaced), mark: line
  - 2 attributes: vertical + horizontal position, mark: point
  - 3 attributes: vertical + horizontal position + color (hue), mark: point
  - 4 attributes: vertical + horizontal position + color (hue) + size (area), mark: area

- Redundantly Encoding Attributes
  - Send stronger message
  - But uses up channels



Channels: Length & Color (Luminance)

Source: T. Munzner, Visualization Analysis and Design

Visual Encoding

1. Marks and Channels
2. Ranking of Perceptual Tasks
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When to use which channel: Expressiveness and Effectiveness

Expressiveness: Channel should match data type

1) Show Ordered data in a way that our perceptual system intrinsically senses as ordered
2) Do not show Unordered data in a way that perceptually implies an ordering that does not exist

➔ Violating this principle: common beginner's mistake!

Effectiveness: Some channels are better than others (stay tuned)

- 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?

Expressiveness: Channel should match data type

Attribute Types:

→ Ordered

→ *Ordinal* → *Quantitative*

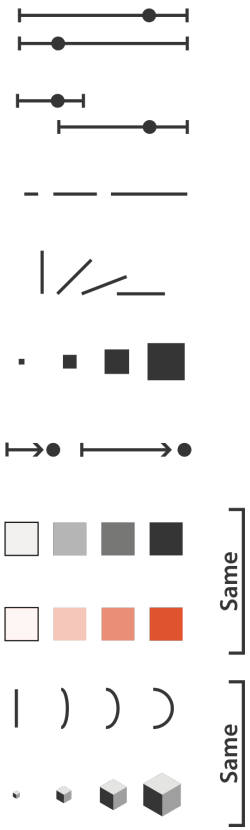
need to perceive magnitude:
how much? which rank?

→ Categorical

need to perceive identity:
what?

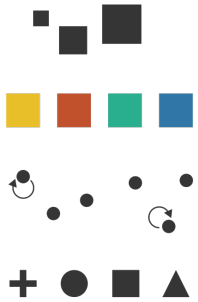
→ **Magnitude Channels: Ordered Attributes**

- 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**

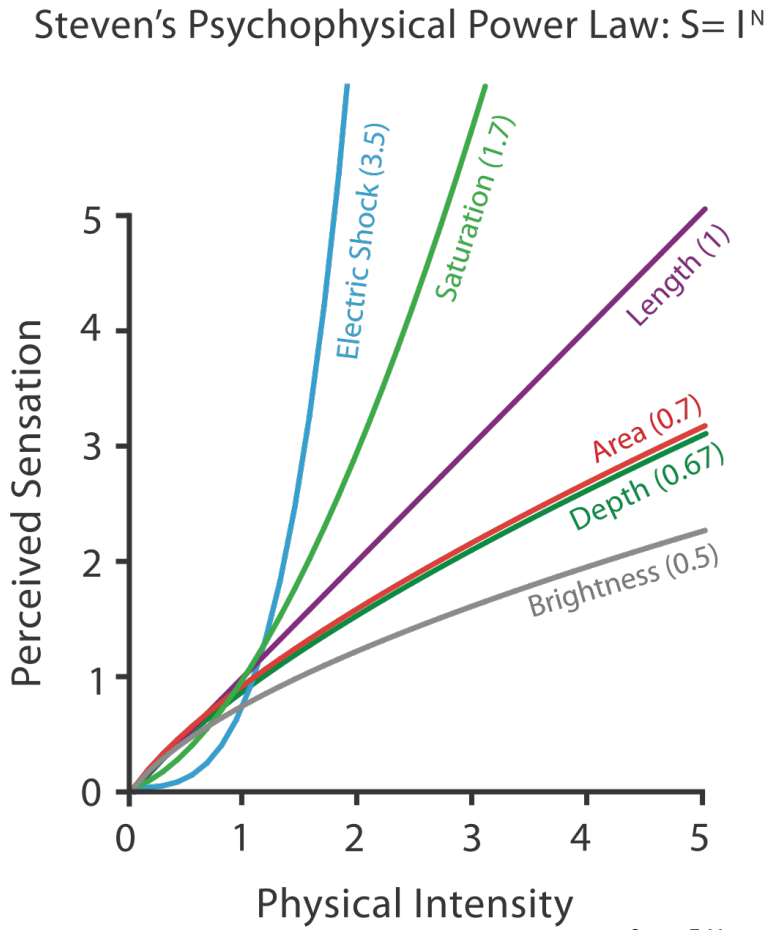
- Spatial region
- Color hue
- Motion
- Shape



Source: T. Munzner, Visualization Analysis and Design

Effectiveness (1) : Accuracy: Fundamental theory

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

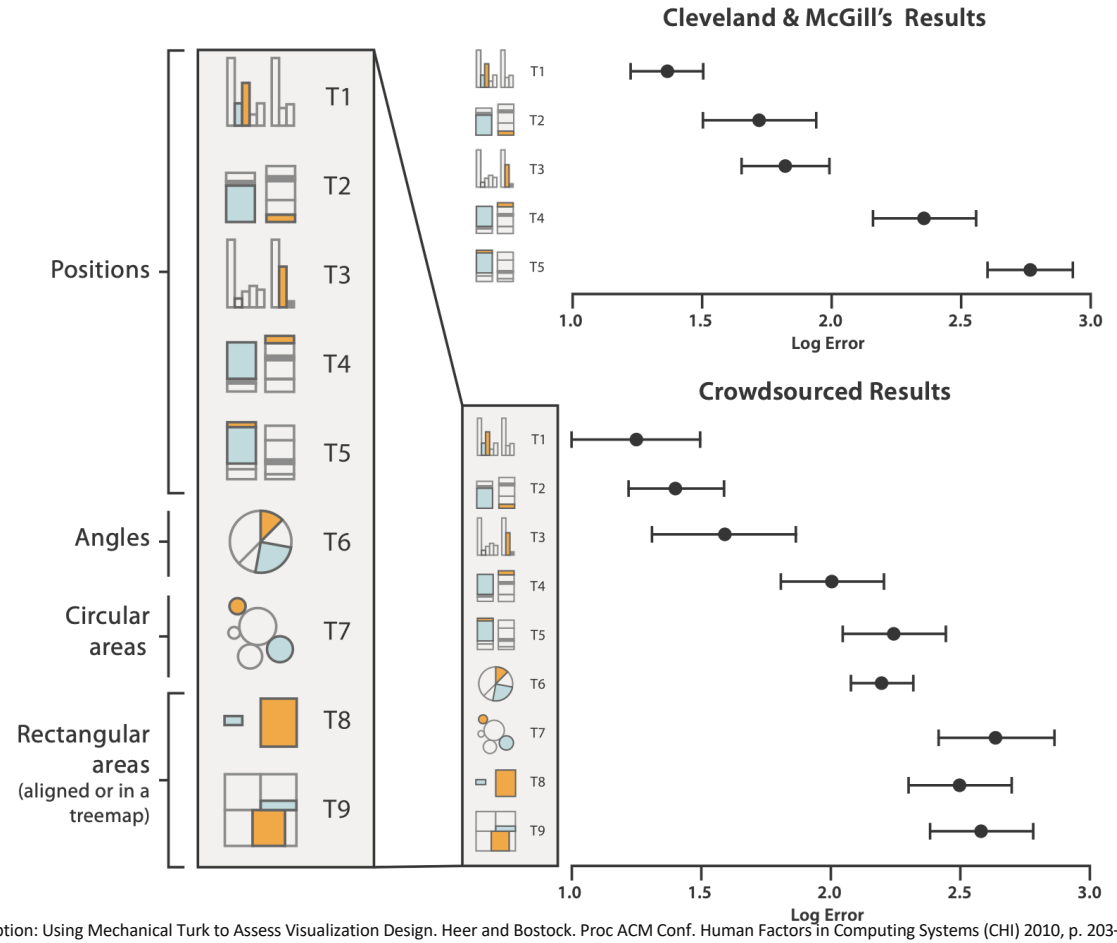


Source: T. Munzner, Visualization Analysis and Design

Effectiveness (1) : Accuracy: Experimental Results

- Controlled Experiments
  - Purpose: Directly map human response to visually encoded abstract information
  - Outcome: Provides explicit rankings of perceptual accuracy for each visual channel

➔ Understand these rankings to choose the most effective visual channels for accurate data representation

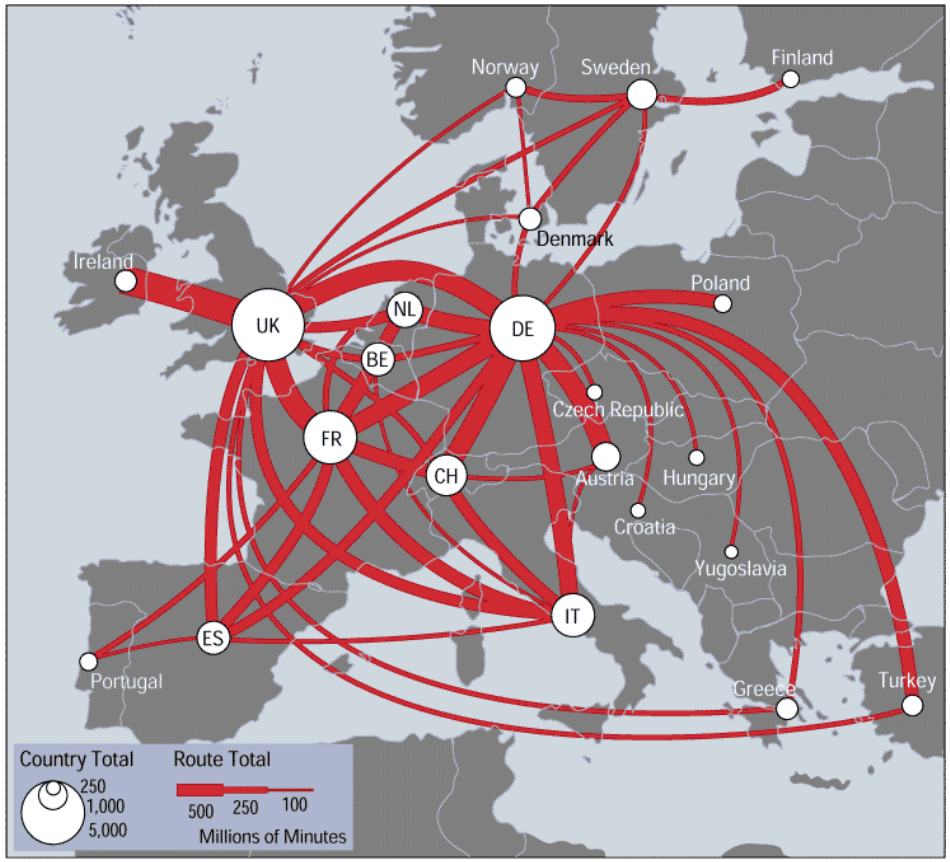


Original Source: Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

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

Effectiveness (2) : Discriminability

- Discriminability: ability to perceive differences between items using a particular channel
  - Ensure that differences are perceptible
  - Bins: distinguishable steps within a channel
- Key Question: How many bins are available for use within a given visual channel?
  - Example: Line Width:
    - Limited Bins: number of perceptible steps (3-4)
    - Beyond a certain point, increased width is perceived as a polygon area, not a line
    - Ineffective for encoding dozens or more values
- Match Ranges: number of values to be shown ≤ number of bins available in the channel.
  - Aggregate the attribute into meaningful bins
  - Alternative: Use different channel if no match



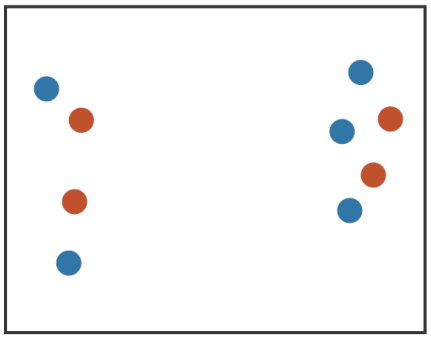
Source: T. Munzner, Visualization Analysis and Design

Effectiveness (3) : Separability

- Interdependencies: Visual channels not always completely independent
- Separable vs. Integral Channels:
  - Separable Channels: Independent and can encode different information easily
  - Integral Channels: Combined and attempts to encode different information will fail, leading to unintended perceptions
  - Continuum of Interactions: from fully independent to inextricably combined
- Obvious: Spatial Position and Planar Proximity
  - Encoding two attributes using vertical and horizontal spatial positions makes it difficult to encode a third attribute using planar proximity: third channel interferes with the first two, preventing clear perception of each attribute
- Less Obvious Interferences:
  - Interchannel Interference: Some interferences between channels are not as apparent
    Example: Encoding color and size might interfere with each other

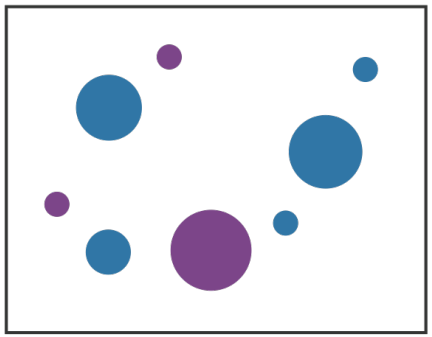
Effectiveness (3) : Separability - Examples

Position
+ Hue (Color)



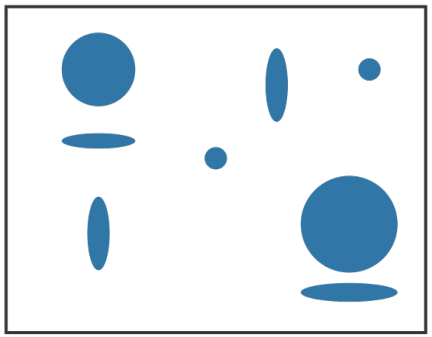
Fully separable

Size
+ Hue (Color)



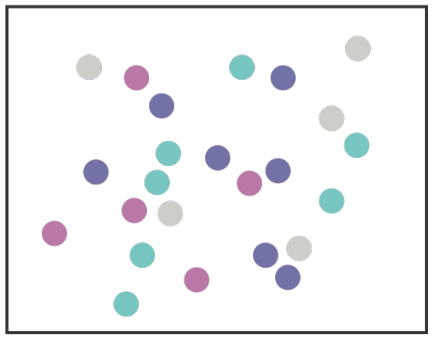
Some interference

Width
+ Height



Some/significant interference

Red
+ Green



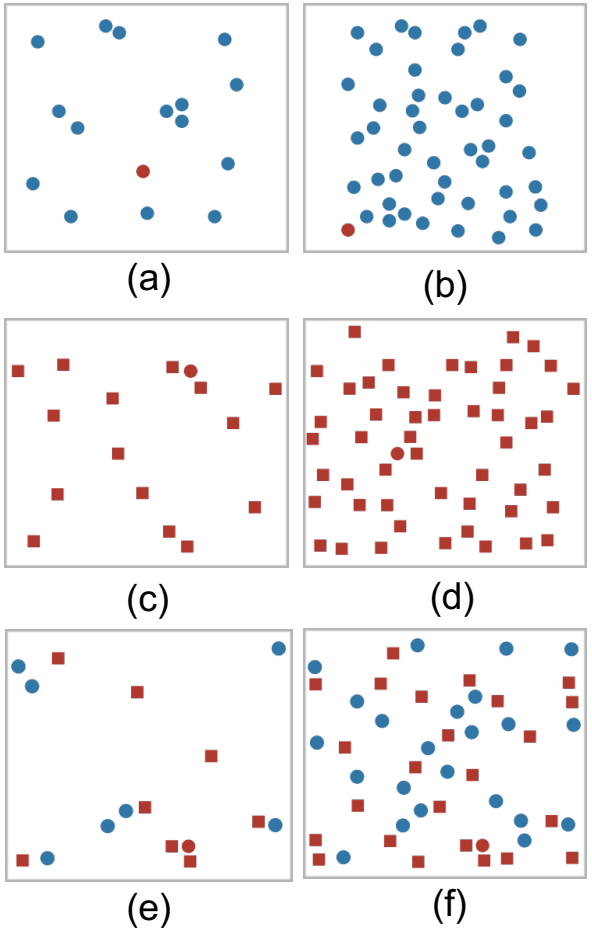
Major interference

Source: T. Munzner, Visualization Analysis and Design

Effectiveness (4) : Popout

- Visual Popout: A distinct item stands out from others immediately
  - Low-Level Visual System: Performs massively parallel processing
  - Time to spot the different item does not depend on number of distractor objects
  - Quick identification without conscious, item-by-item search
  - Speed depends on channel and amount of difference from distractors

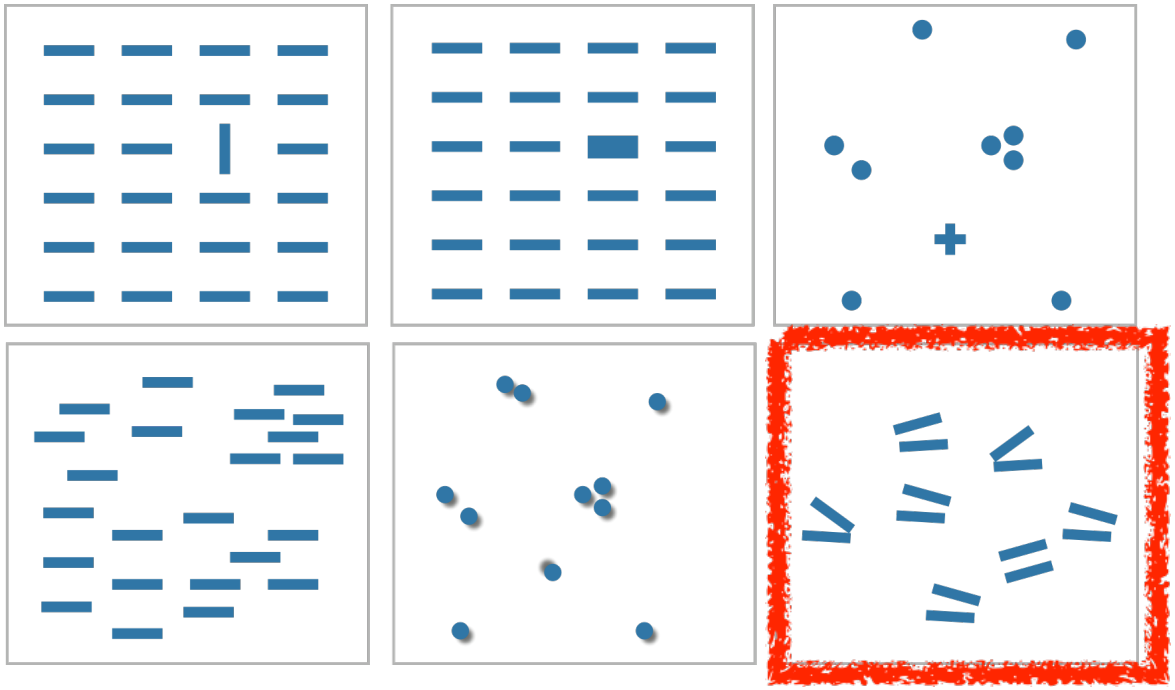
- Examples
  - (a) red circle pops out from a small set of blue circles
  - (b) red circle pops out from a large set of blue circles just as quickly
  - (c) red circle also pops out from a small set of square shapes, although a bit slower than with color
  - (d) red circle also pops out of a large set of red squares
  - (e) red circle does not take long to find from a small set of mixed shapes and colors
  - (f) red circle does not pop out from a large set of red squares and blue circles, and it can only be found by searching one by one through all the objects



Source: T. Munzner, Visualization Analysis and Design; After http://www.csc.ncsu.edu/faculty/healey/PP by Christopher G. Healey.

Effectiveness (4) : Channels and Popout

- many channels support popout
  - tilt, size, shape, proximity, shadow direction, ...
- but not all!
  - parallel line pairs do not pop out from tilted pairs
  - Popout not possible with three or more channels
  - General rule: use popout for a single channel at a time



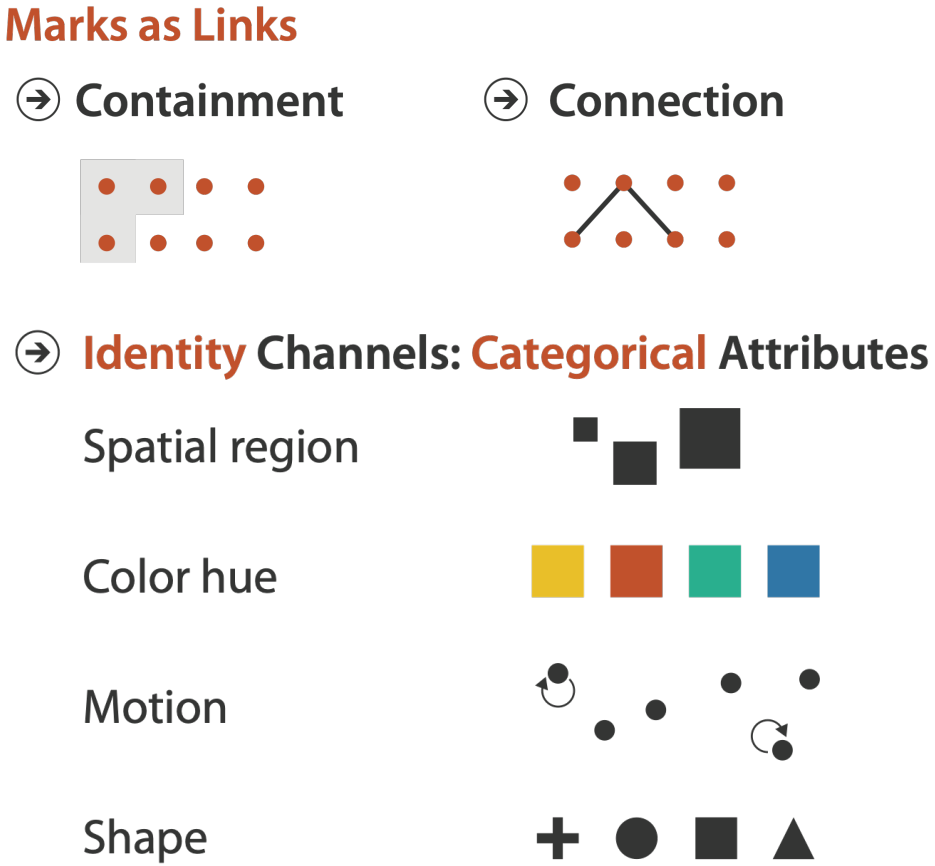
Source: T. Munzner, Visualization Analysis and Design

Grouping

- Perceptual Grouping: effect arises from visual cues that indicate objects form a group
  - visually link related items
- Two options for perceptual grouping

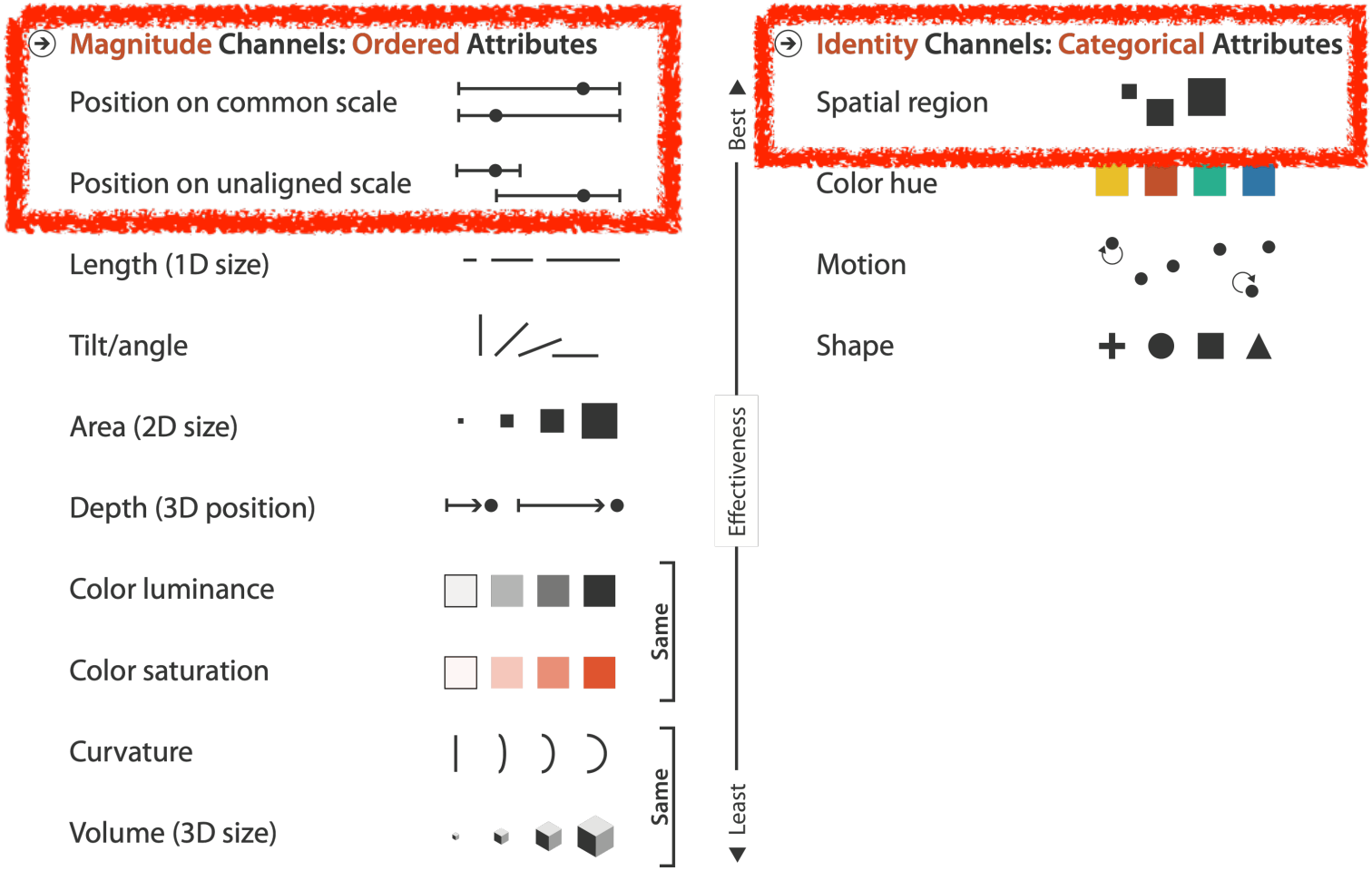
(1) use of link marks
  - Containment
  - Connection

(2) use identity channels to encode categorical attributes
  - Proximity: same spatial region
  - Similarity: same values as other categorical channels



Source: T. Munzner, Visualization Analysis and Design

Effectiveness (5) : Summary: Ranking of Channels

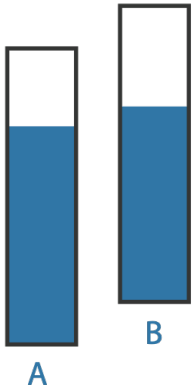


Source: T. Munzner, Visualization Analysis and Design

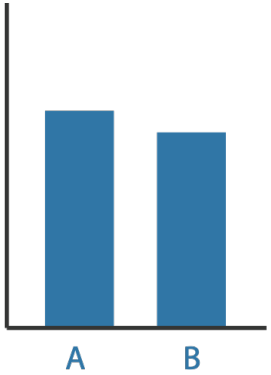
Relative vs. Absolute Judgements

- 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

length



position along unaligned common scale



position along aligned scale

Source: T. Munzner, Visualization Analysis and Design; primary source: [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Visual Encoding

1. Marks and Channels
2. Ranking of Perceptual Tasks
3.  Some More Charts

Charts – Implementations of / Toolbox for the Visual Encoding

- Charts you learned about in the Homework
  - Bar Chart
  - Line Chart
  - Pie Chart
  - Scatterplot
- Charts you will learn about now
  - Parallel Coordinates
  - Stream Graph
  - Treemap
  - Slope Chart
  - Sunburst Chart
  - Strip Plot and Jitter Plot
- All other Charts → use resources from the homework for self study!

Your Turn !

Exercise 1

Charts
Scavenger Hunt

Key Takeaways

- Visual Encoding: Marks and Channels
- When to use which channel
  - Expressiveness:
    Match channel and data type
  - Effectiveness:
    Accuracy
    Discriminability
    Separability
    Popout