Data Visualisation

CMP020L013A

Week 4: Marks & Channels

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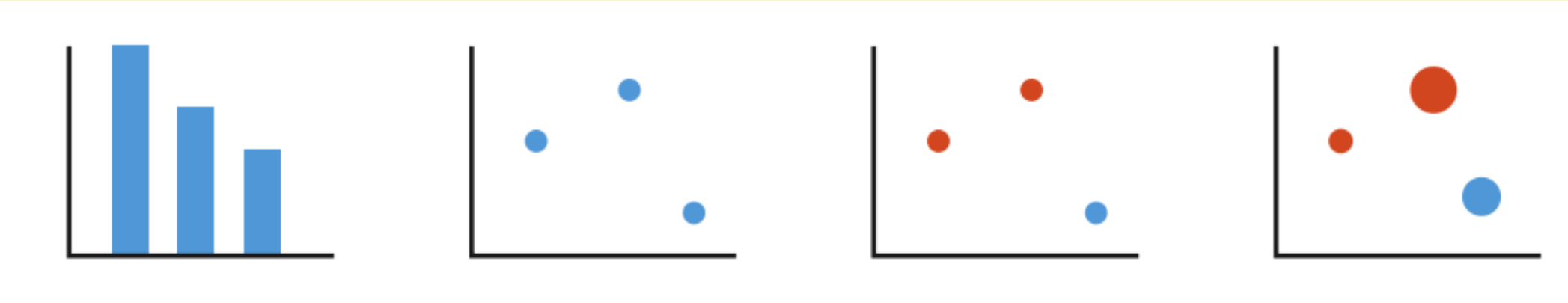
Agenda

- Understand the concepts of marks and channels for visual encoding
- Learn how to choose appropriate marks and channels based on data types for visualisation purposes

The Big Picture

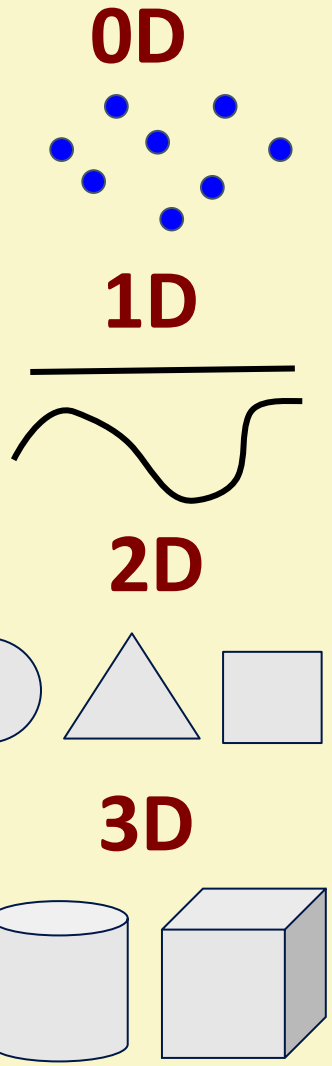
Graphics = Marks + Channels

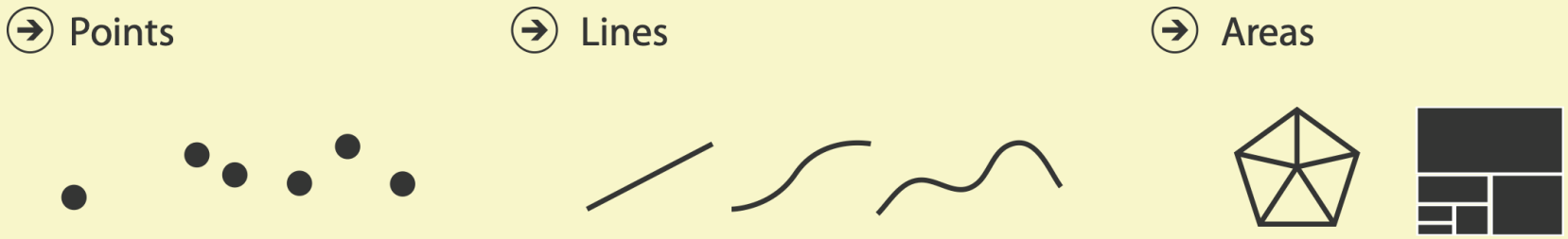
Visualisation = Graphics + (in+formation)



Marks

- A mark is a basic graphical element (primitives) in an image
- Marks are primitive geometric objects classified according to the number of spatial dimensions they are required to encode.
- 0D zero-dimensional mark is a point
- 1D one-dimensional mark is a line
- 2D two-dimensional mark is an area
- 3D three-dimensional mark is a volume (avoid 3D marks)
- Marks represent data items (rows in a dataset)





Channel

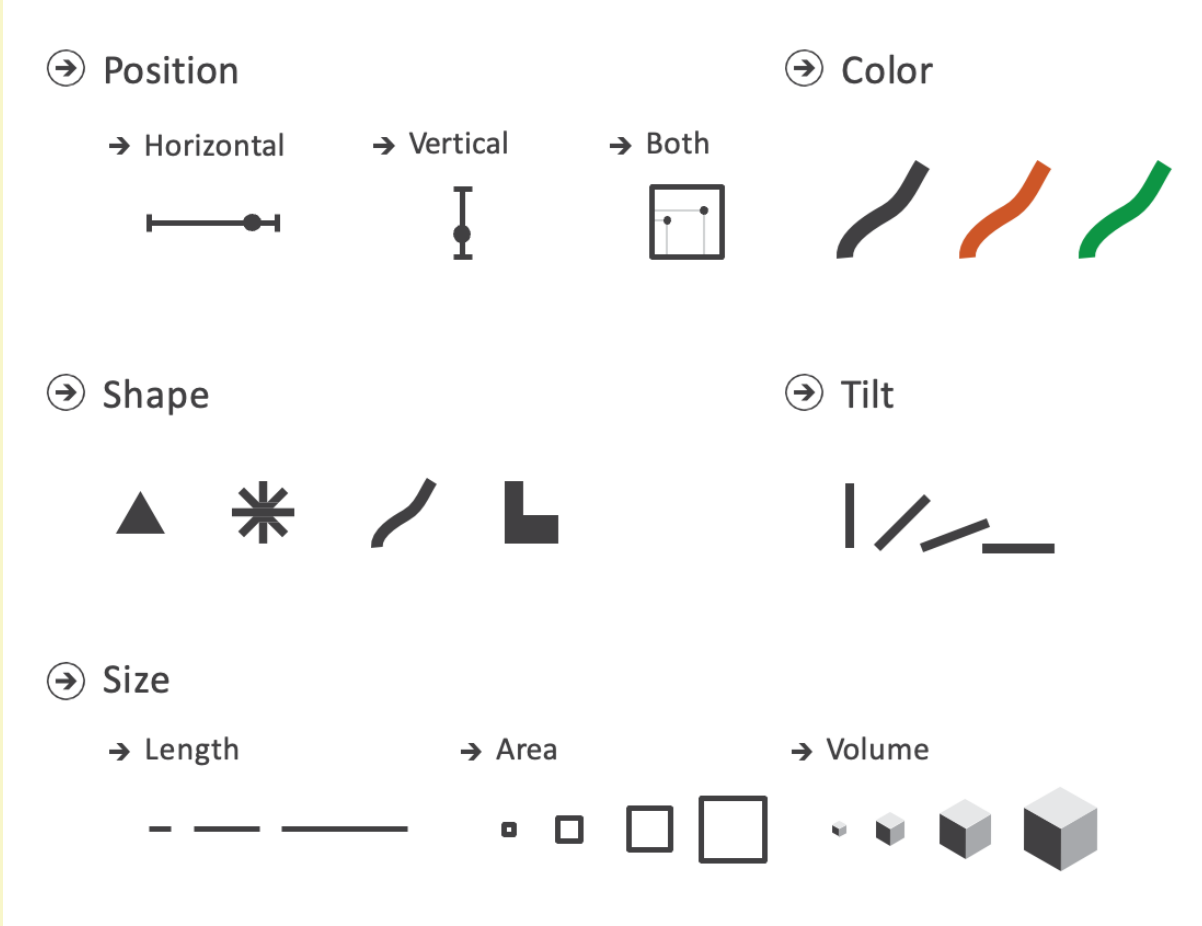
- A visual channel is a way to control the appearance of marks, independent of the dimensionality of the geometric primitive
- Channel represents data attributes (columns in a dataset)
  - Proportional to/based on attributes
- Channel properties differ
    - Type and amount of information that can be conveyed to the human perceptual system
- **visual channels, visual variables**
  - retinal channels, visual dimensions

Marks and Channels

	- Channel - attribute, data type, data element, variable
- Mark - item, data point, values observation	

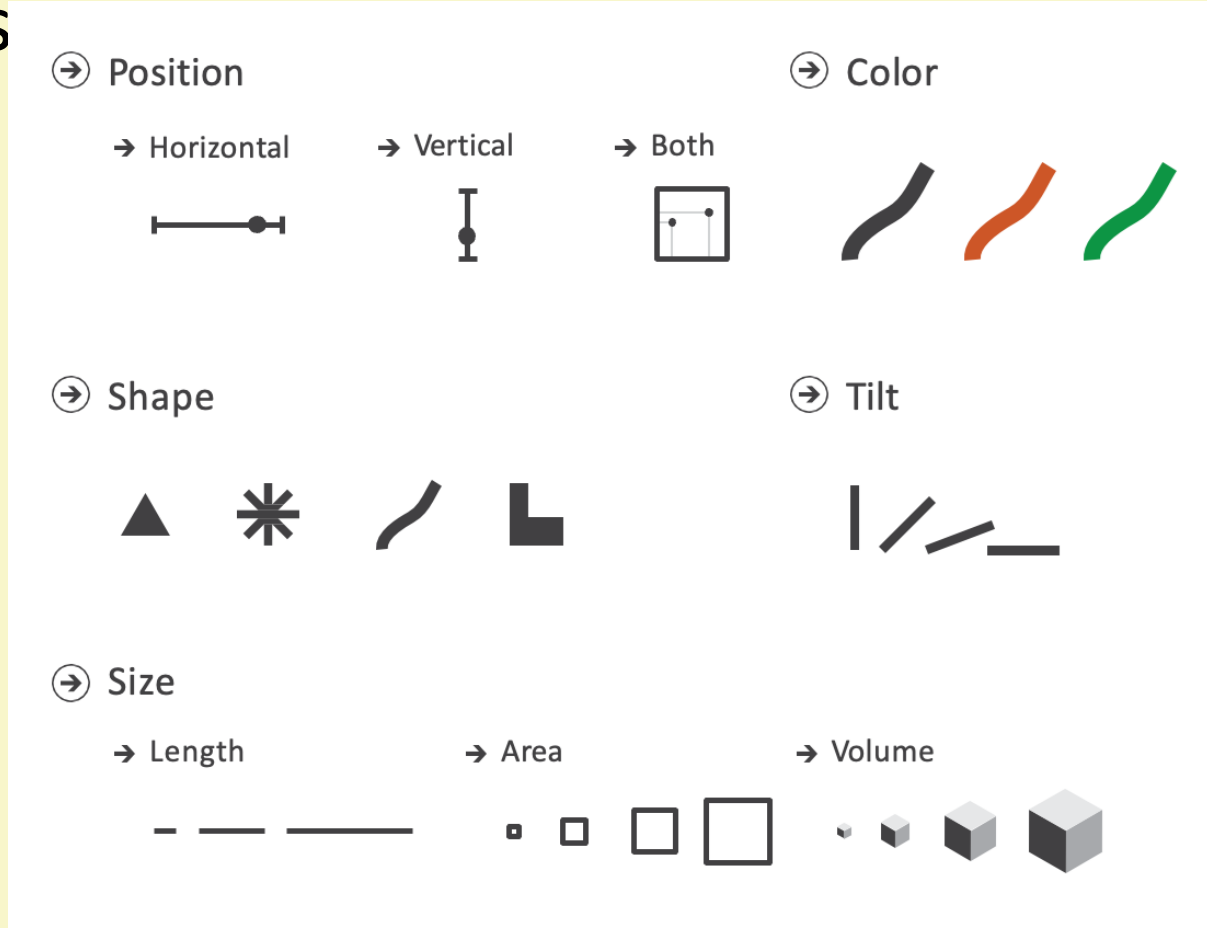
Channel

- Examples visual channels that can encode information as properties of a mark.
- Some pertain to spatial position, including aligned planar position, unaligned planar position, depth (3D position), and spatial region.
- Some pertain to colour, which has three distinct aspects: hue, saturation, and luminance (brightness).



Channel

- There are three size channels, one for each added dimension: length is 1D size, area is 2D size, and volume is 3D size.
- Angle is also a channel, sometimes called tilt.
- Curvature is also a visual channel.
- Shape is a complex phenomenon, but it is treated as a channel in this framework.



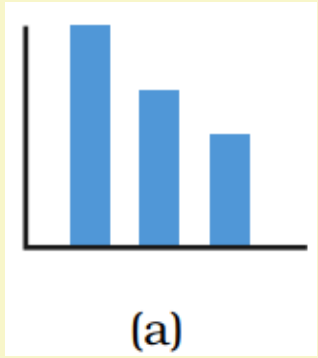
Applying Marks and Channels

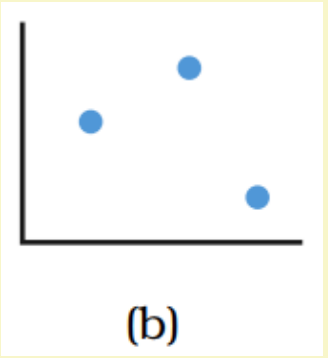
a) Bar chart encodes two attributes using a line mark with the vertical spatial position channel for the quantitative attribute, and the horizontal spatial position channel for the categorical attribute.

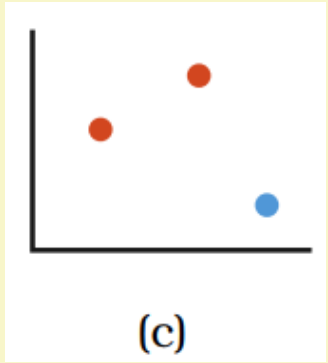
b) Scatterplots encode two quantitative attributes using point marks and both vertical and horizontal spatial position

c) A third categorical attribute is encoded by adding colour to the scatterplot.

d) Adding the visual channel of size encodes a fourth quantitative attribute as well

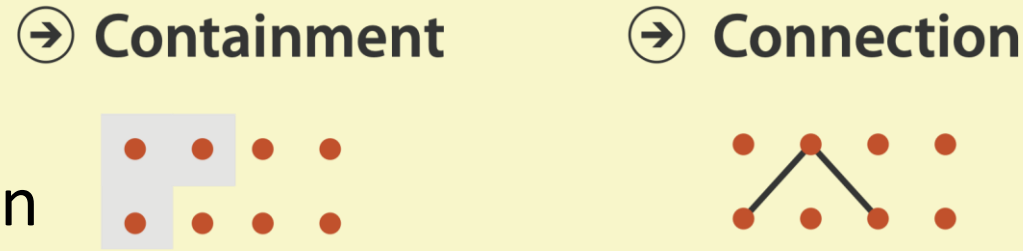


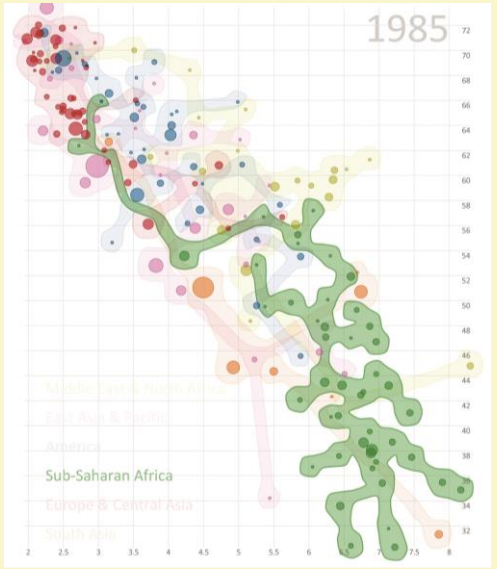


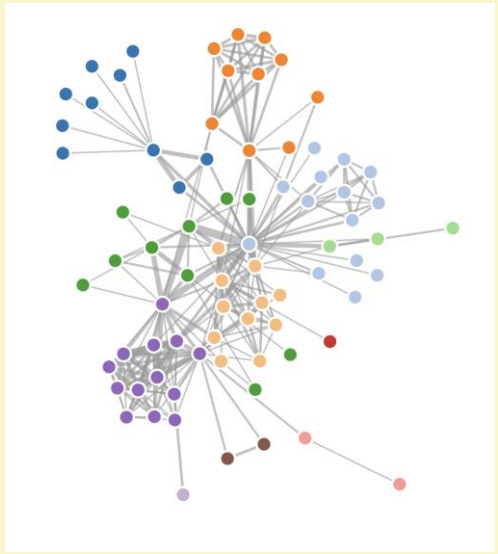


Marks for Links

- For network datasets, a mark might represent an item (node/link).
- Link marks represent a relationship between items.
- The two link mark types are connection and containment.
- A connection mark shows a relationship between two items, using a line.
- A containment mark shows hierarchical relationships using areas, and to do so, connection marks can be nested within each other at multiple levels.

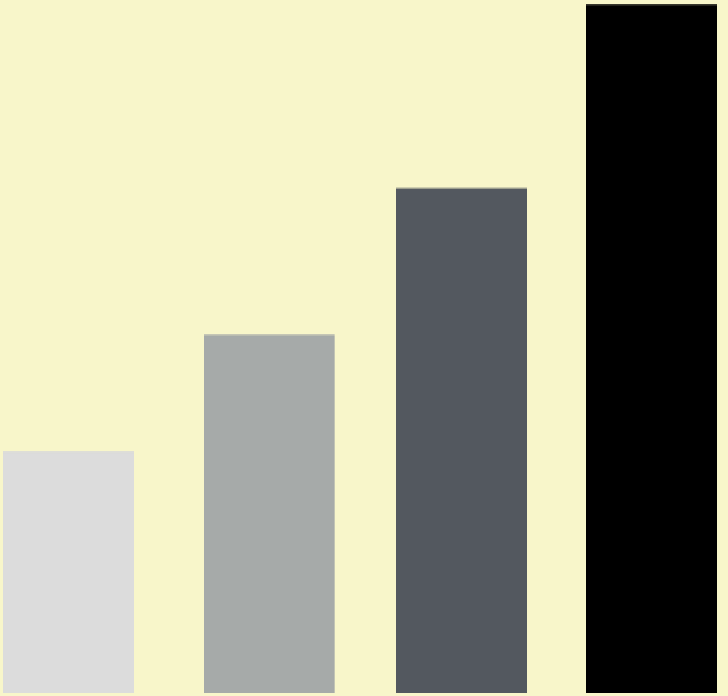






Redundant encoding

- Multiple channels can be combined to redundantly encode the same attribute.
- The limitation of this approach is that more channels are “used up” so that not as many attributes can be encoded in total
- The benefit is that the attributes that are shown will be very easily perceived. multiple channels
  - sends stronger message
  - but uses up channels



Length and Luminance

Expressiveness and Effectiveness

- Two principles guide the use of visual channels in visual encoding:

  expressiveness and effectiveness.

- The expressiveness principle dictates that the visual encoding should express all of, and only, the information in the dataset attributes.
- The most fundamental expression of this principle is that ordered data should be shown in a way that our perceptual system intrinsically senses as ordered.
- Conversely, unordered data should not be shown in a way that perceptually implies an ordering that does not exist.
- Violating this principle is a common beginner's mistake in vis.match channel type to data types, characteristics

Expressiveness and Effectiveness of Channels

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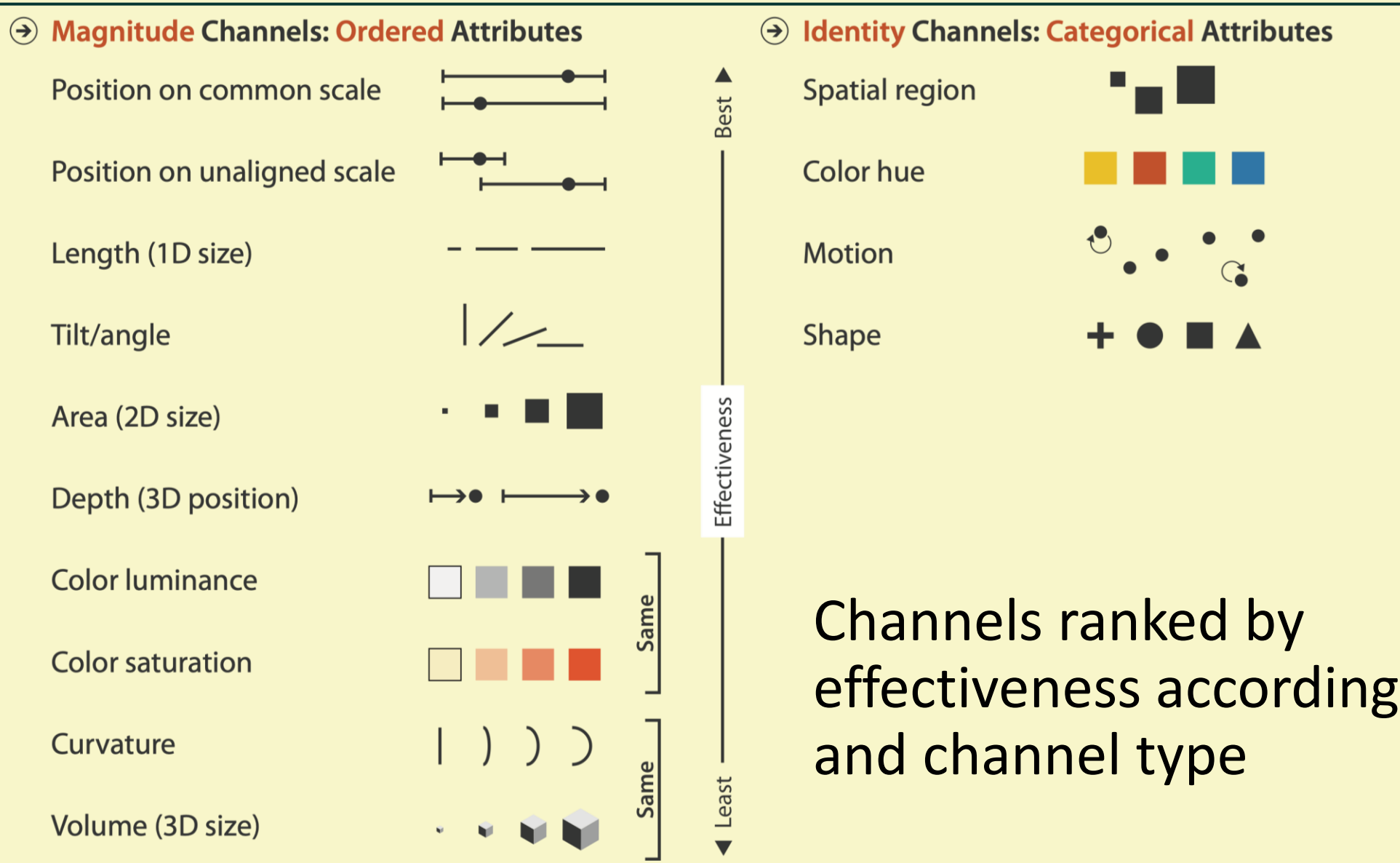
- Violating this principle is a common beginner's mistake in vis.

Expressiveness and Effectiveness of Channels

- The effectiveness principle dictates that the importance of the attribute should match the salience of the channel (noticeability)
- The most important attributes should be encoded with the most effective channels in order to be most noticeable, and then decreasingly important attributes can be matched with less effective channels.

Channels: Rankings

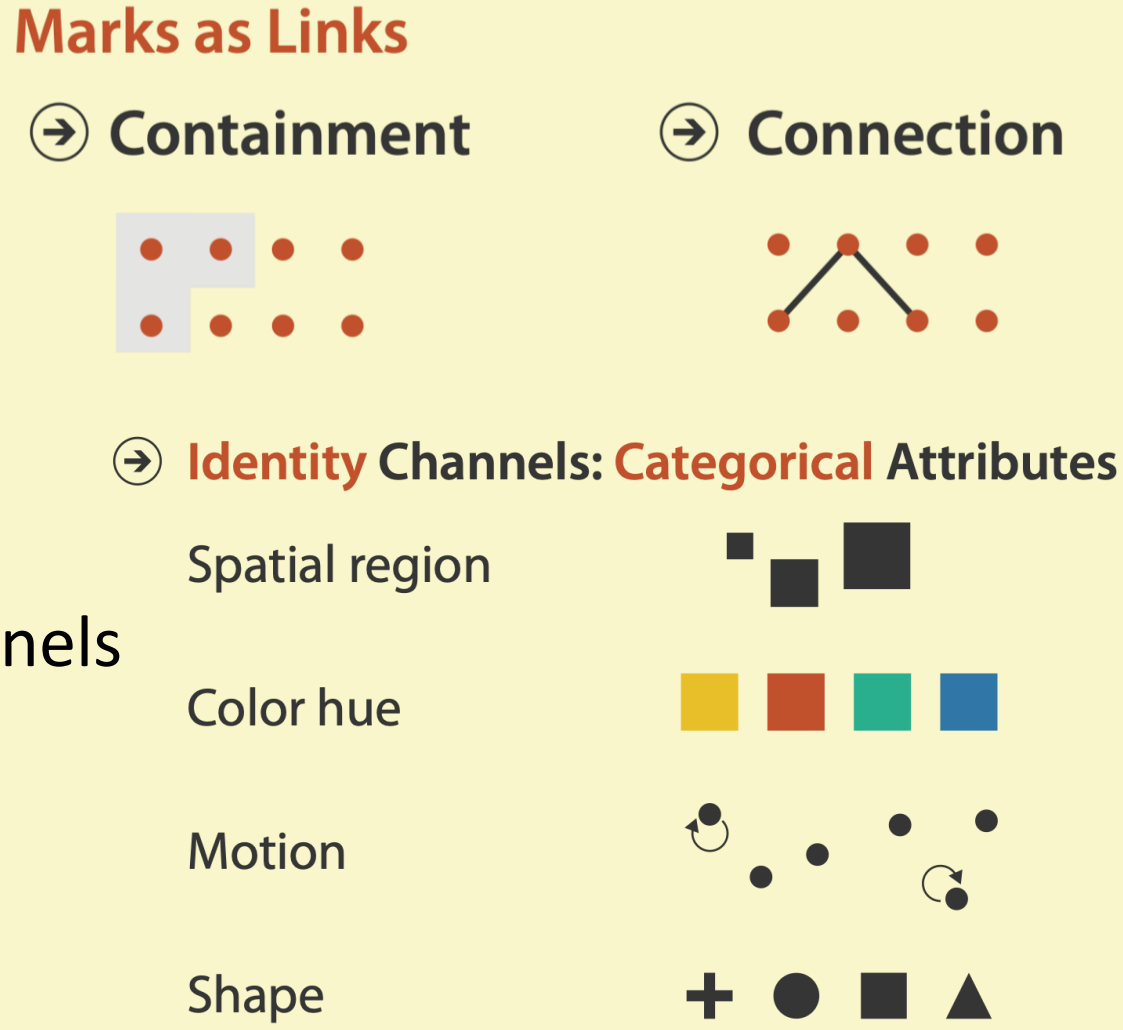


Channels ranked by effectiveness according to data and channel type

Grouping

- Containment
- Connection

- Proximity
  - same spatial region
- Similarity
  - same values as other categorical channels

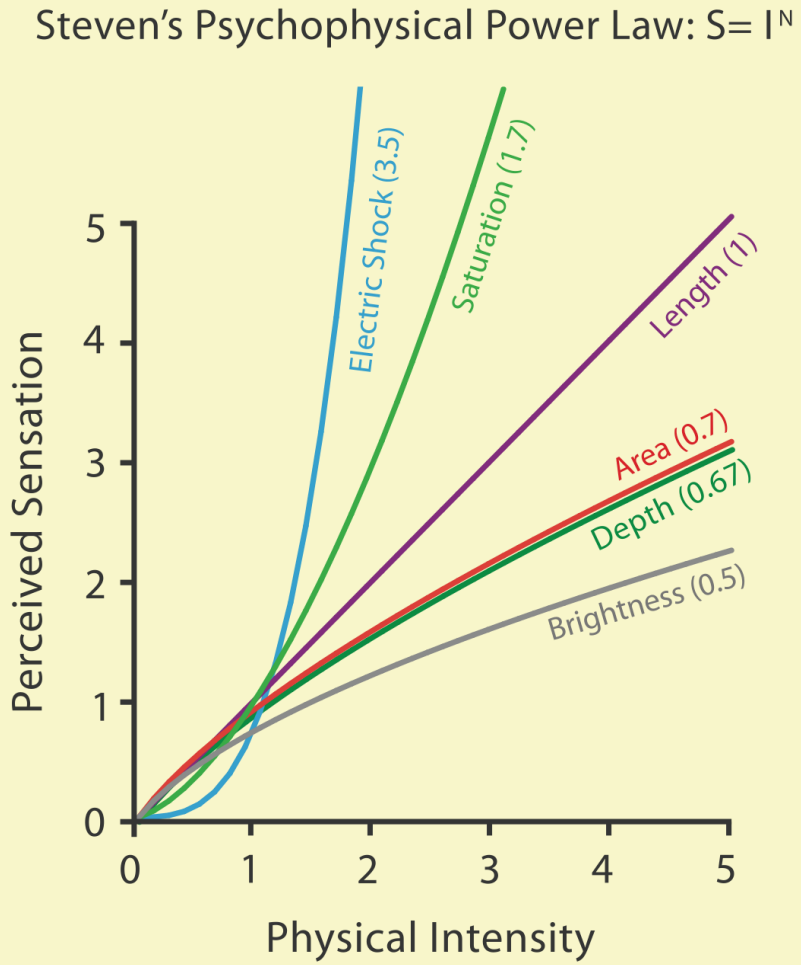


Channel Effectiveness

- 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 (saliency):
  - can things jump out using this channel?

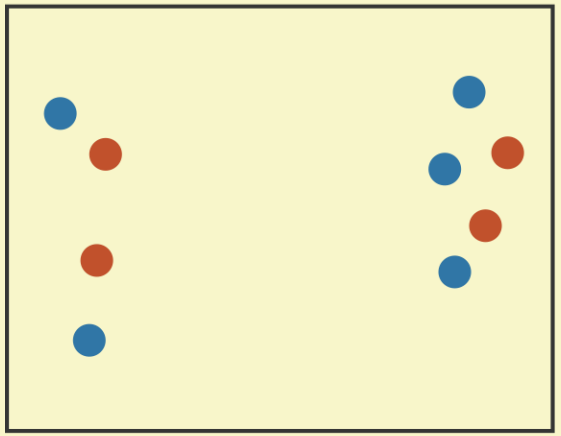
Accuracy: Fundamental theory

- How close is human perceptual judgement to some objective measurement of the stimulus?
- length is accurate: linear
- others magnified or compressed
  - exponent characterizes



Separability vs. Integrality

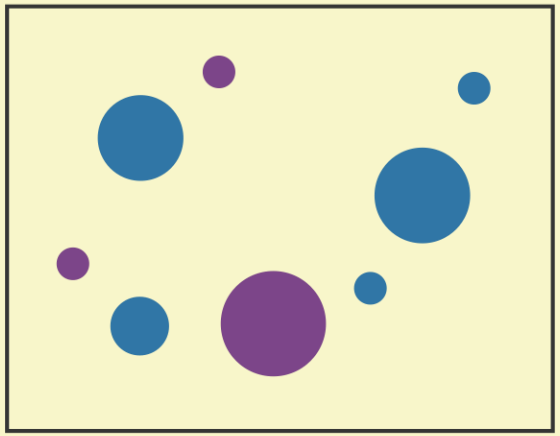
Position
+ Hue (Color)



Fully separable

2 groups each

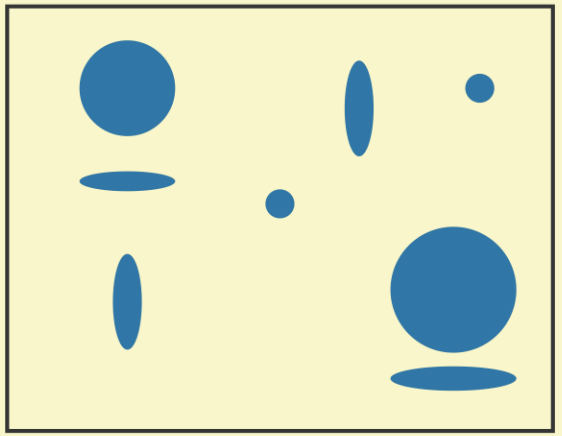
Size
+ Hue (Color)



Some interference

2 groups each

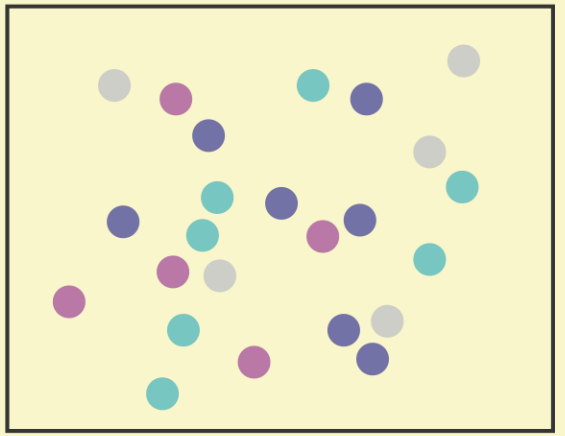
Width
+ Height



Some/significant interference

3 groups total:
integral area

Red
+ Green

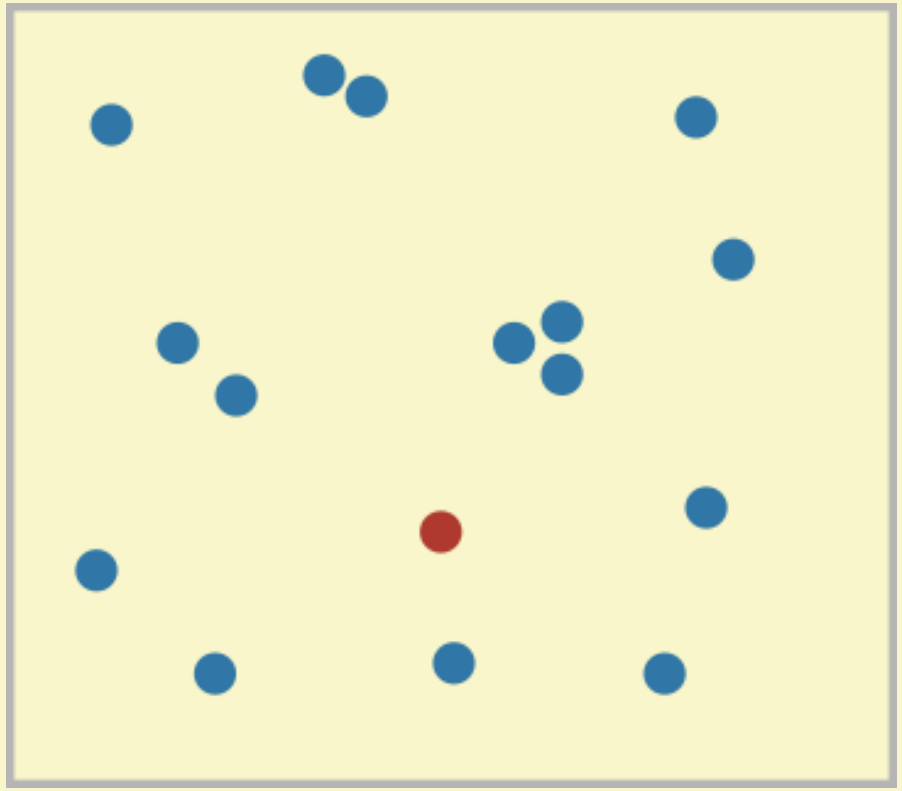


Major interference

4 groups total:
integral hue

Popout (saliency)

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



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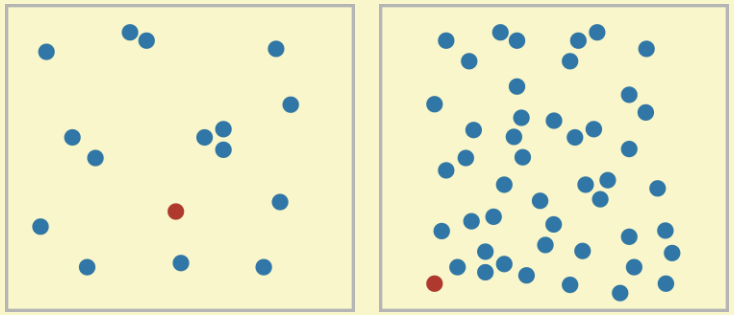

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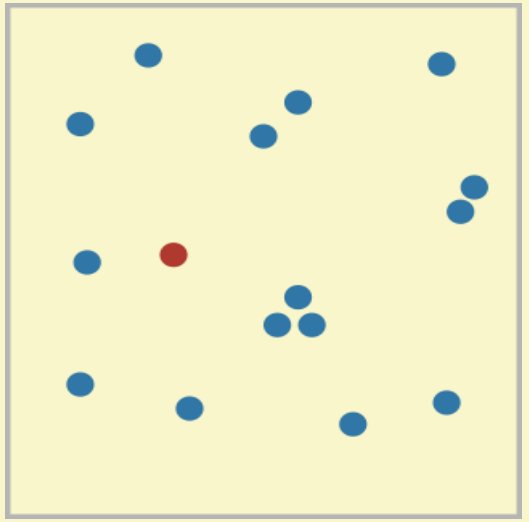

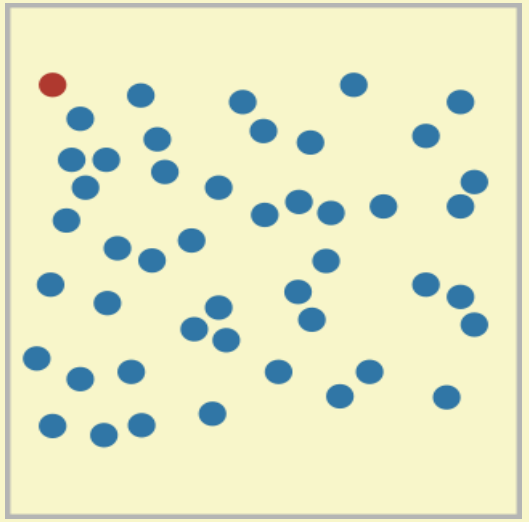

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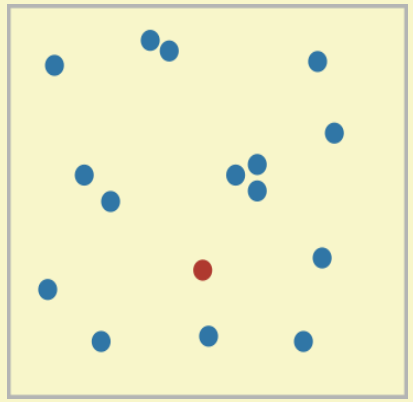

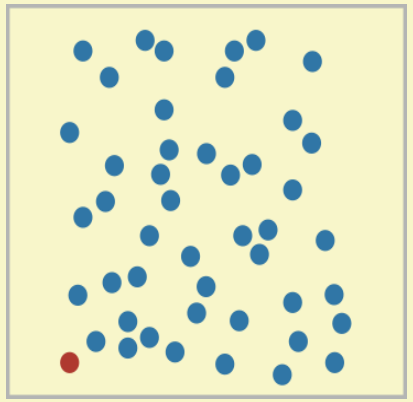

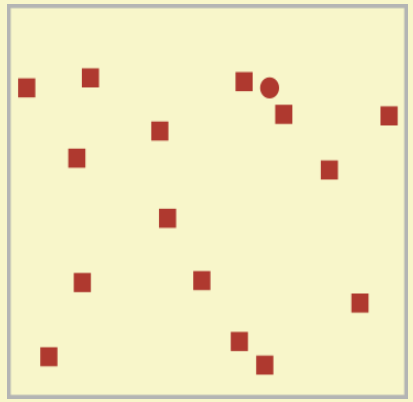

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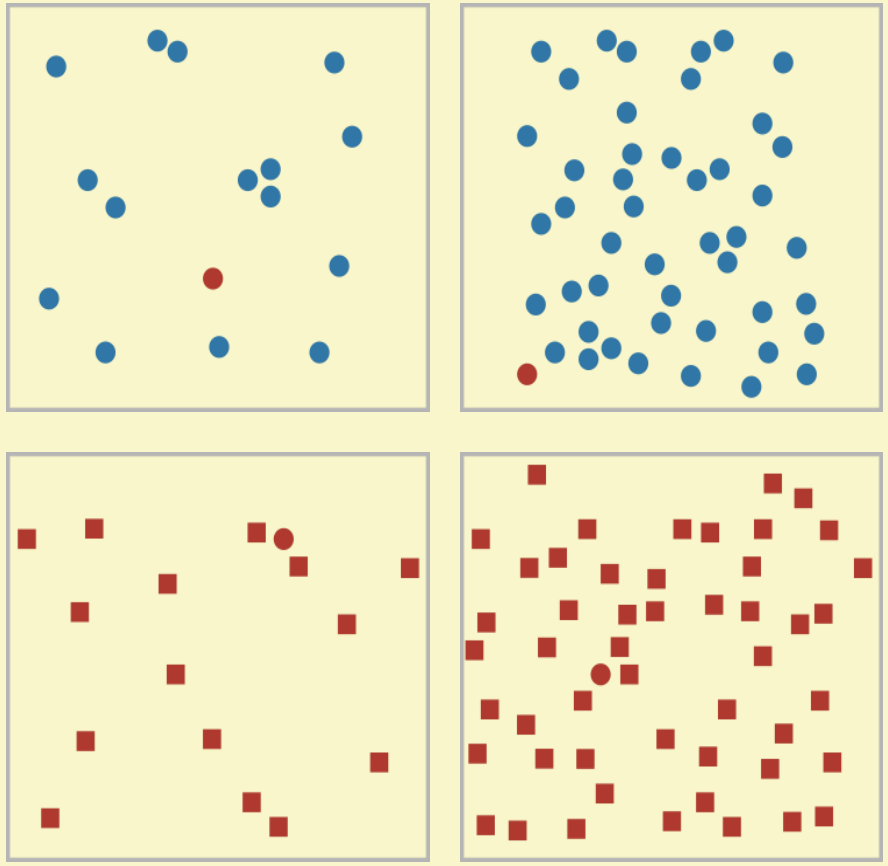

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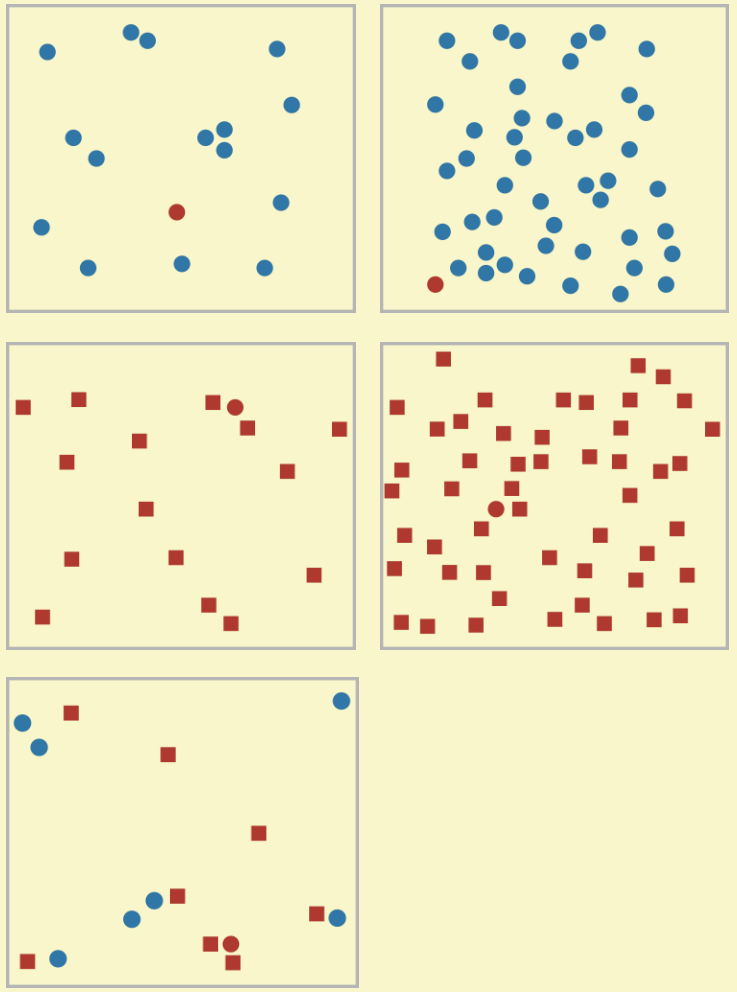

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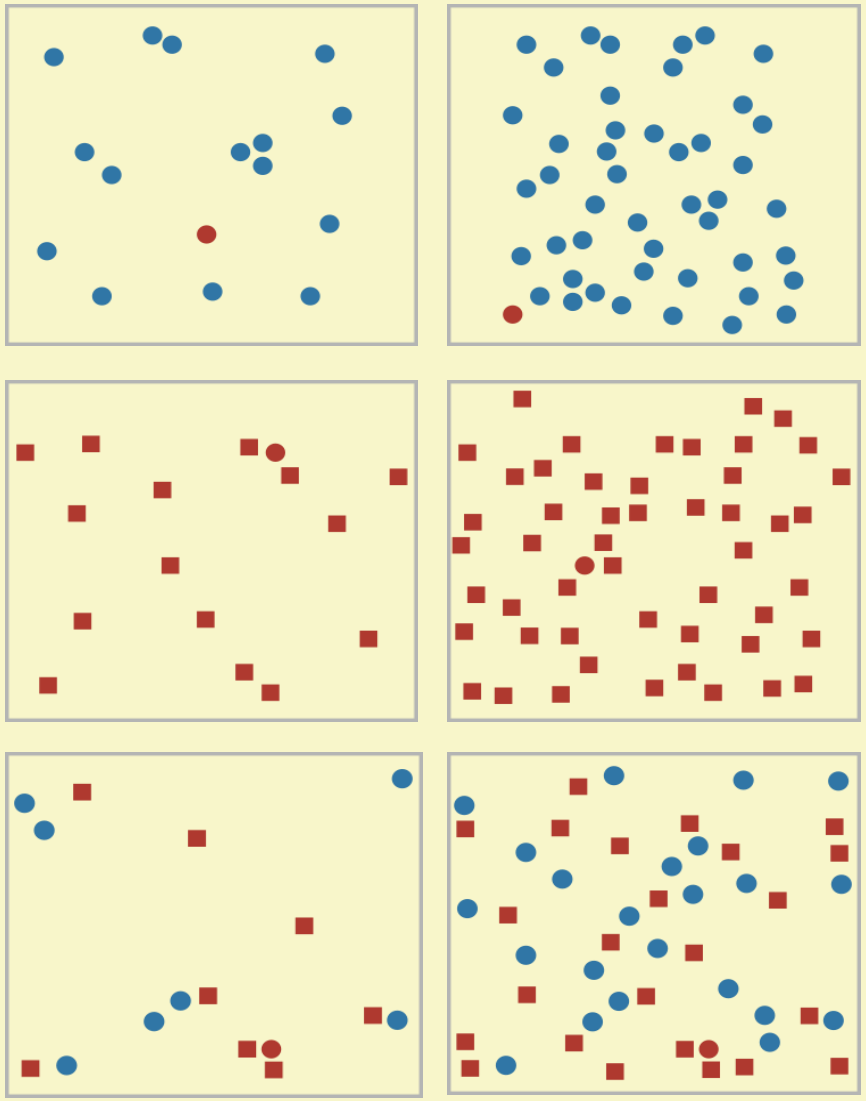
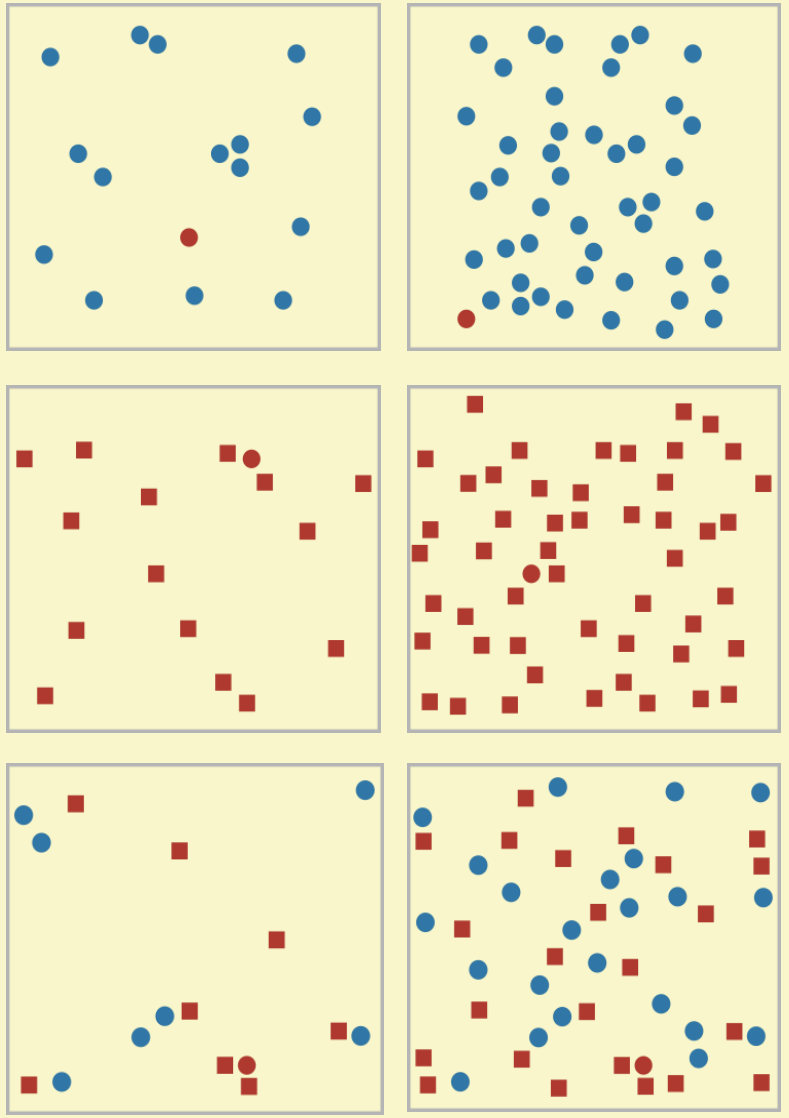


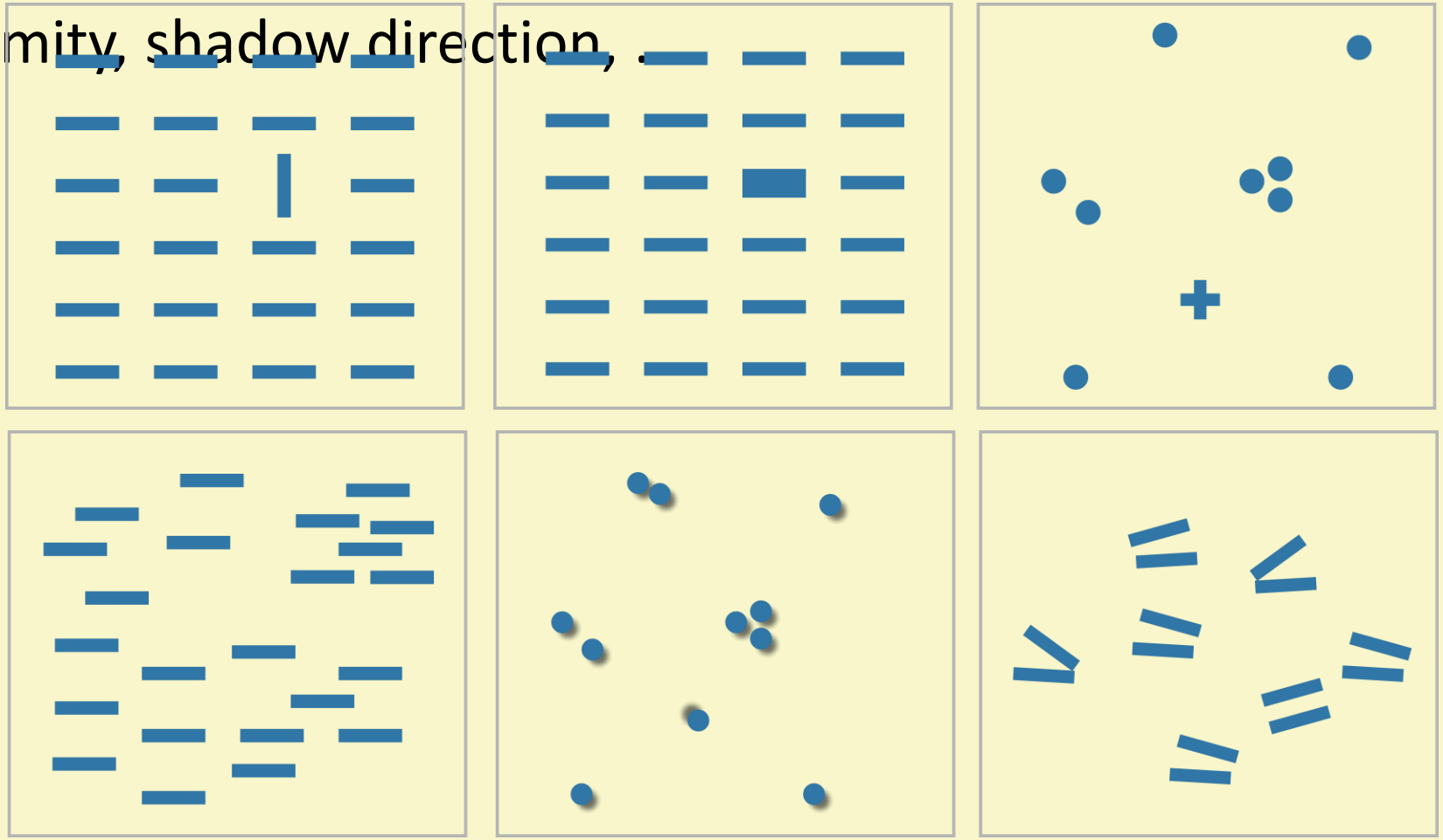
Popout (saliency)

- 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 the number of distractors



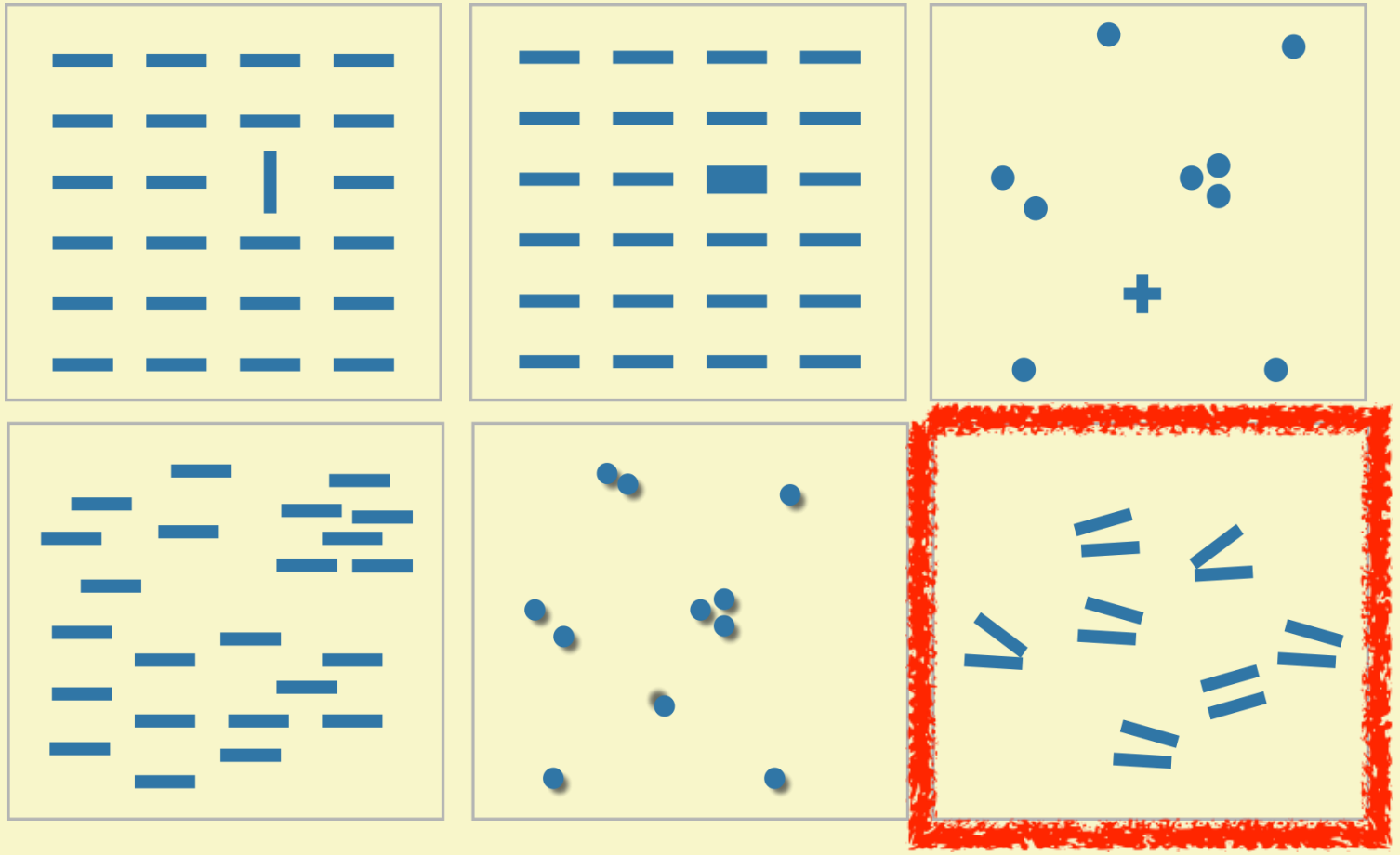
Popout (saliency)

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



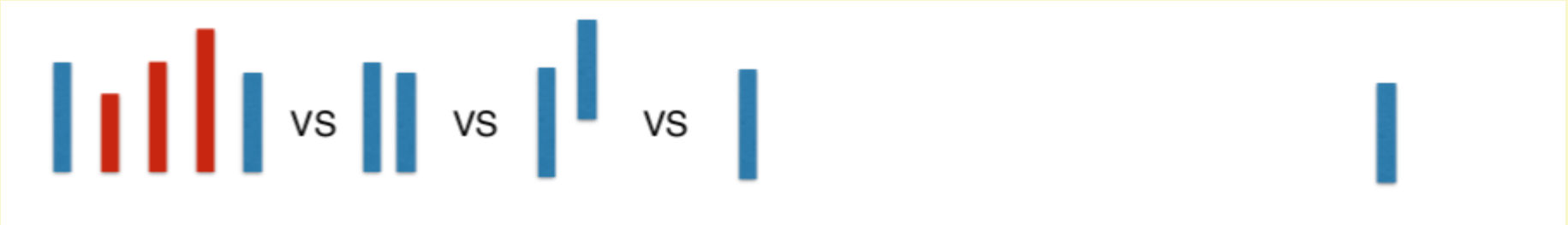
Popout (saliency)

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



Factors affecting accuracy

- alignment
- distractors
- distance
- common scale / alignment



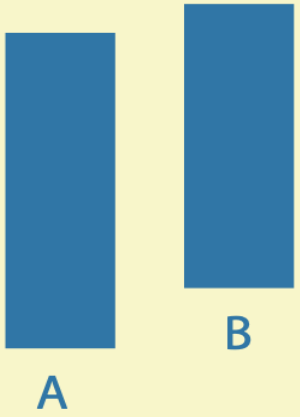
Weber–Fechner Law

- Relative vs Absolute Judgements in human perception
- The human perceptual system is fundamentally based on relative judgements, not absolute ones;
- For instance, the amount of length difference we can detect is a percentage of the object's length (all sensory modalities)
- The fact that our senses work through relative rather than absolute judgements has far-ranging implications.
- When considering questions such as the accuracy and discriminability of our perceptions, we must distinguish between relative and absolute judgments

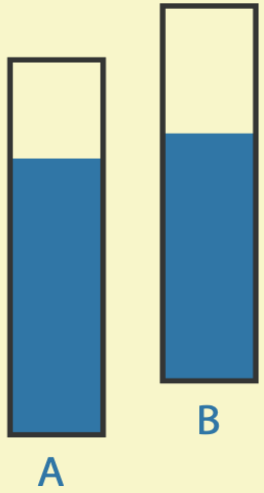
Weber–Fechner Law

- When two objects are directly next to each other and aligned, we can make much more precise judgements than when they are not aligned and when they are separated from many other objects.
- An example based on Weber's Law illuminates why position along a scale can be more accurately perceived than a pure length judgement of position without a scale.

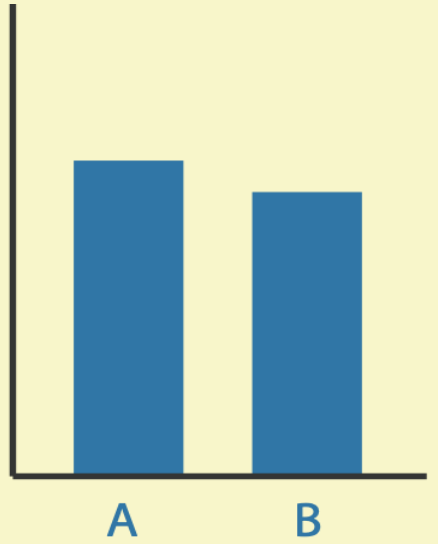
Relative vs. Absolute Judgements



(a) length



(b) position along unaligned common scale

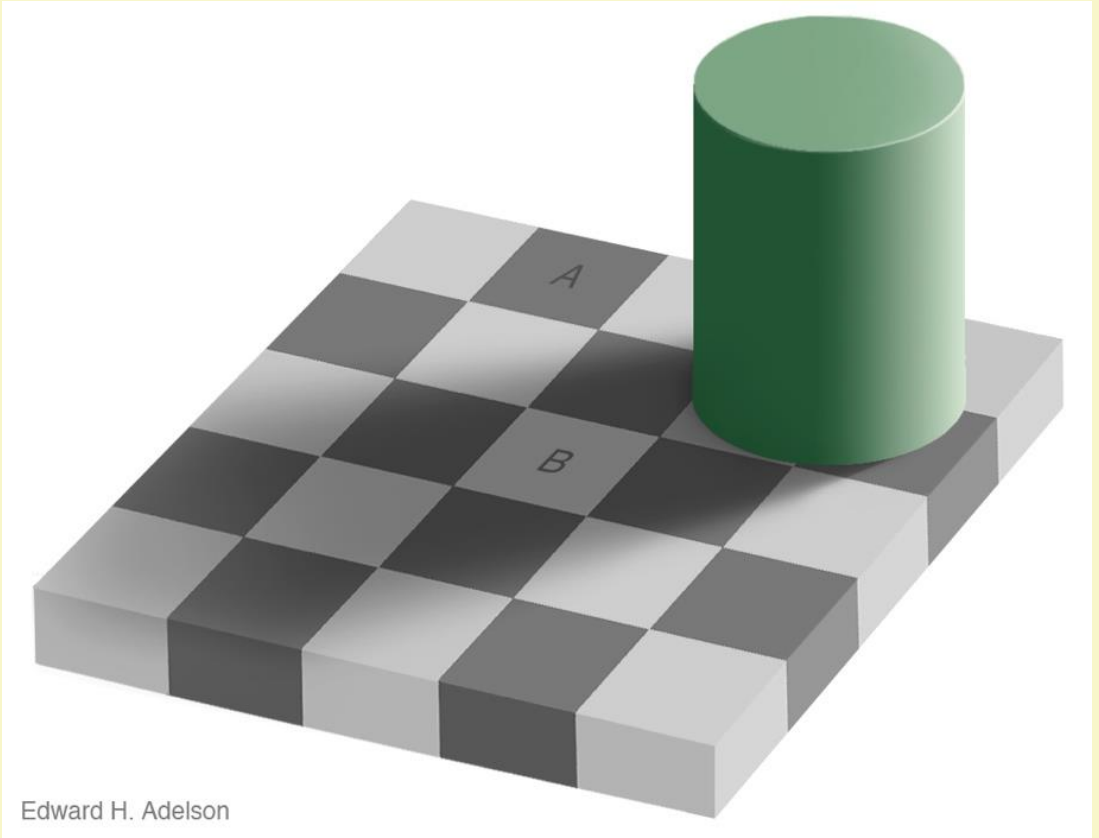


(c) position along aligned scale

- (a) The lengths of unframed, unaligned rectangles of slightly different sizes are hard to compare.
- (b) Adding a frame allows us to compare the very different sizes of the unfilled rectangles between the bar and frame tops.
- (c) Aligning the bars also make the judgement easy

Relative Luminance Judgements

- Perception of luminance is contextual based on contrast with surroundings



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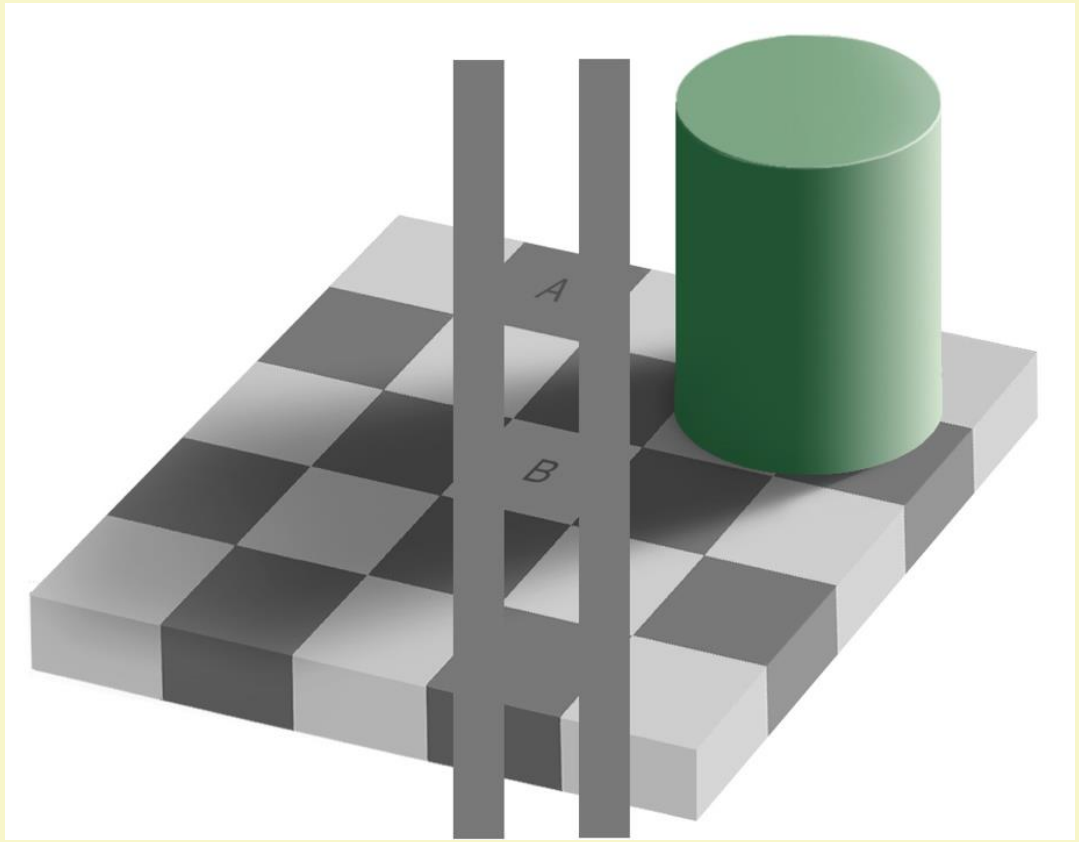
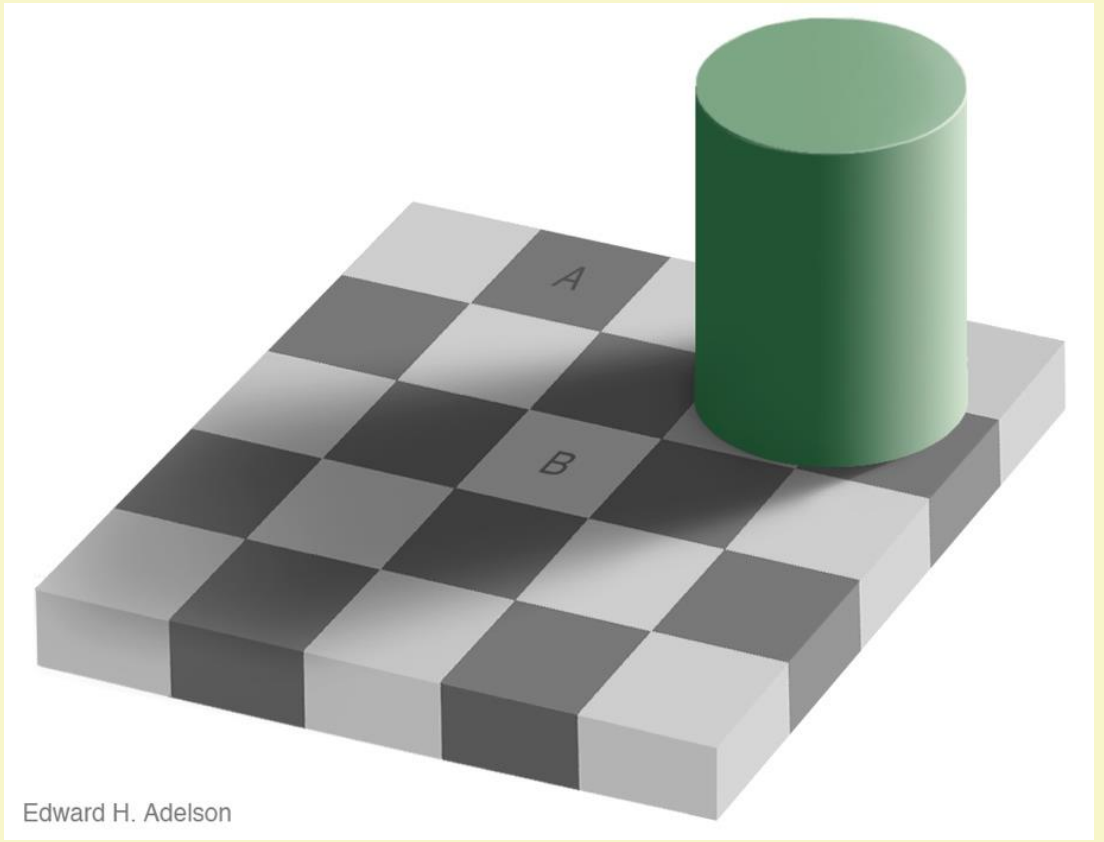
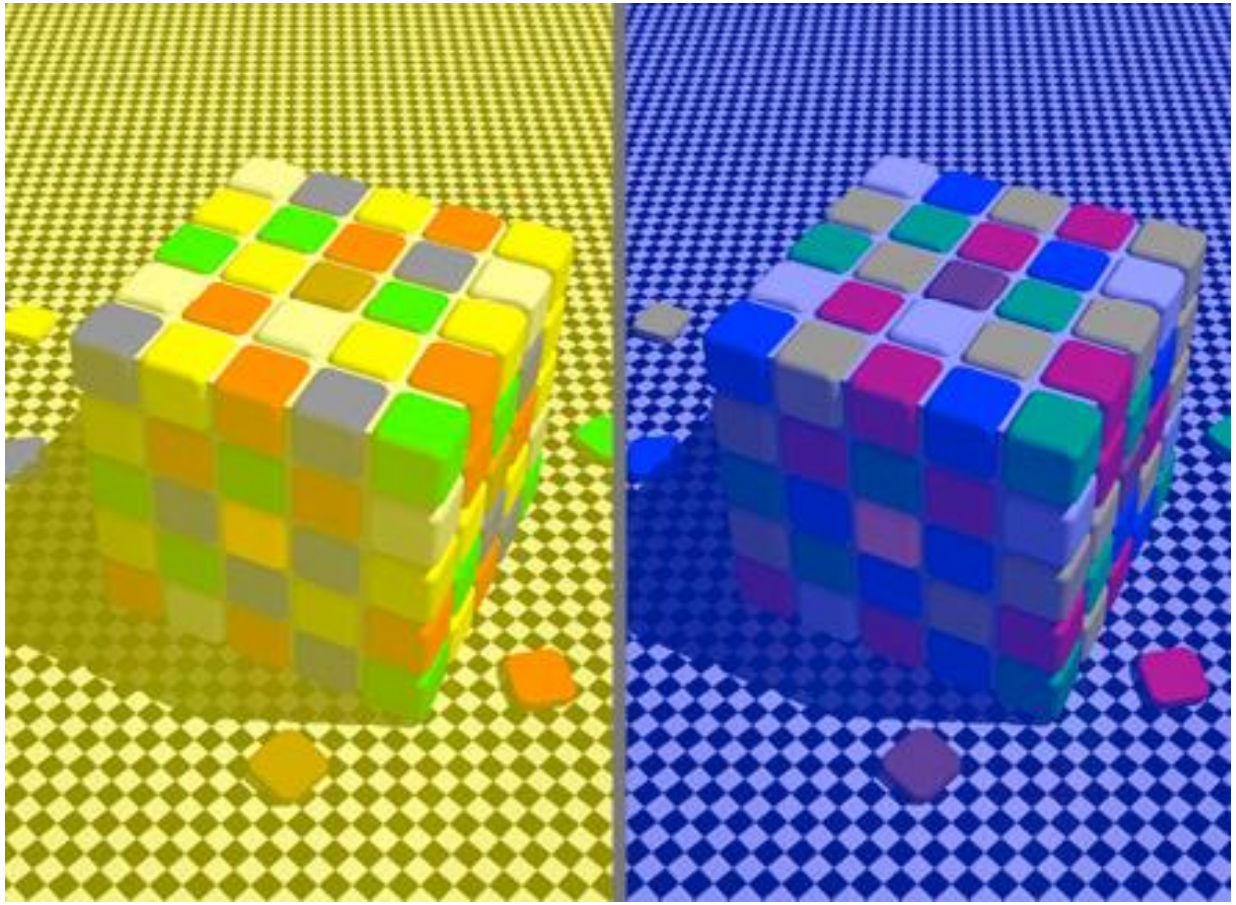




Relative Colour Judgements

- color constancy across broad range of illumination conditions



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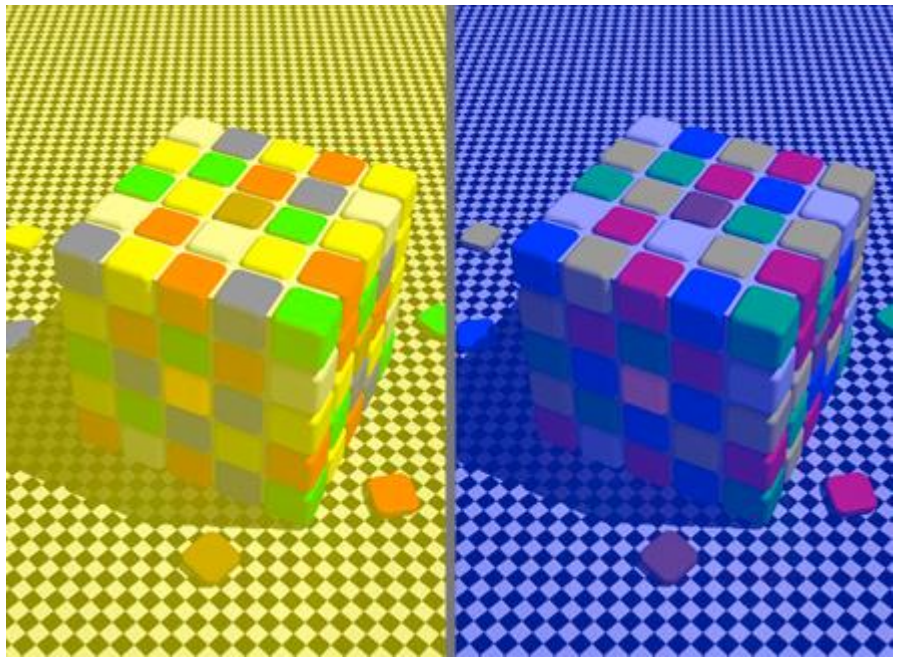

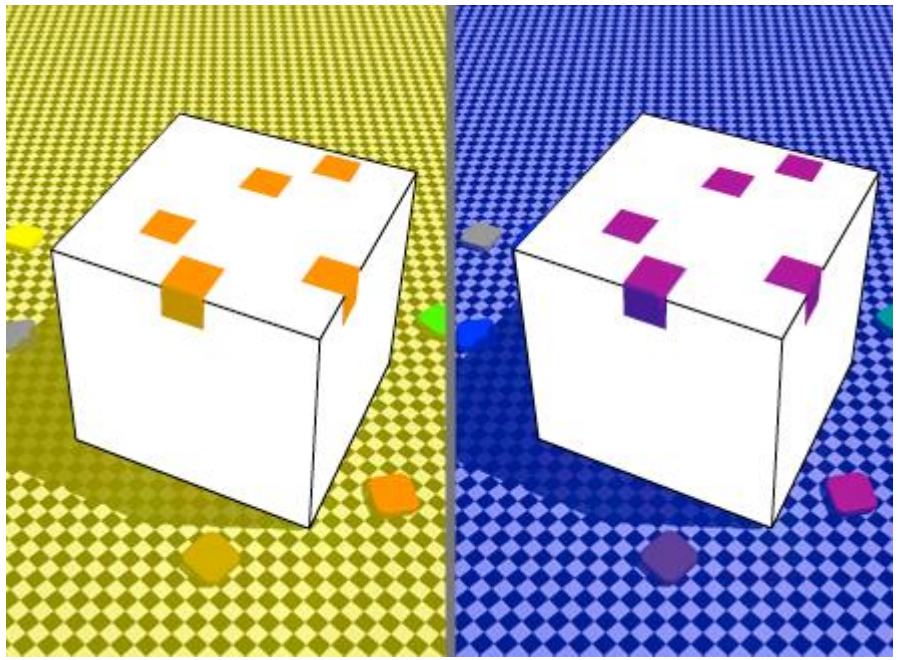

http://www.purveslab.net/seeforyourself/