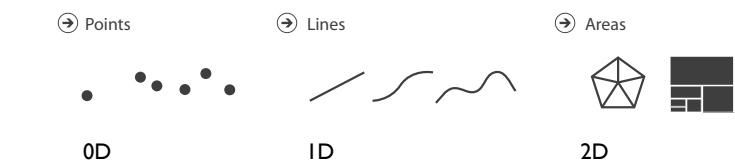# Information Visualization
Marks & Channels

Tamara Munzner
Department of Computer Science
University of British Columbia

Lect 4/5, 16/21 Jan 2020

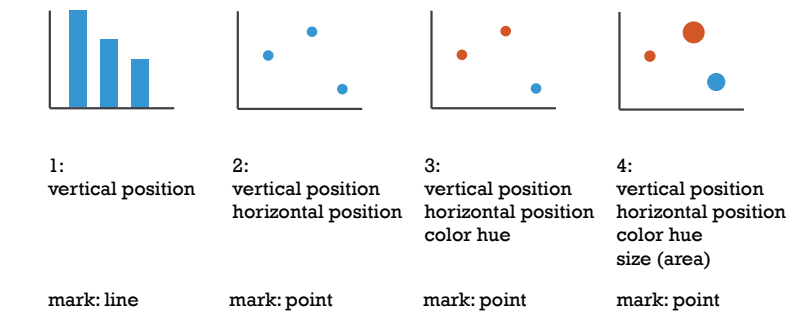https://www.cs.ubc.ca/~tmm/courses/436V-20

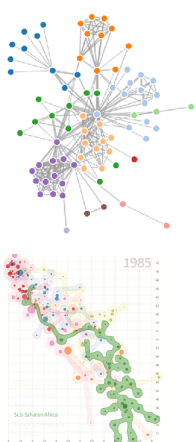## Exercise: Two numbers

9 and 26

- How can you visually represent these two numbers?
  - Solo: quickly sketch 3 ideas
  - Pair: compare with your neighbor
    - Q: how many matched?
  - Together: sketch 2 more different ones
- Keep pix for Foundations 2
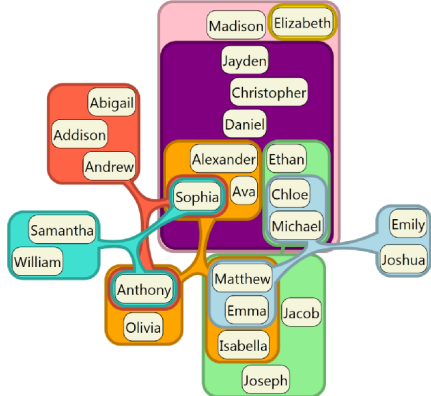 - (snap a picture so each of you has it)
- Many possibilities!
  https://visual.ly/blog/45-ways-to-communicate-two-quantities/

Marks and Channels

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

- Points — 0D
- Lines — 1D
- Areas — 2D

- 3D mark: volume, rarely used

Marks for links

- Containment
- Connection

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
  - ...

- Position — Horizontal, Vertical, Both
- Color
- Shape
- Tilt
- Size — Length, Area, Volume

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)
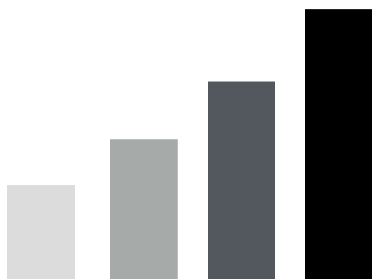mark: point

---

Redundant encoding

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

Length, Position, and Value

What is wrong with this picture?

- should use channel proportional to data!

https://twitter.com/ChaseThomason/status/1118478036507164672?s=19

When to use which channel?

expressiveness
match channel type to data type

effectiveness
some channels are better than others

Channels

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: Matching Types

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
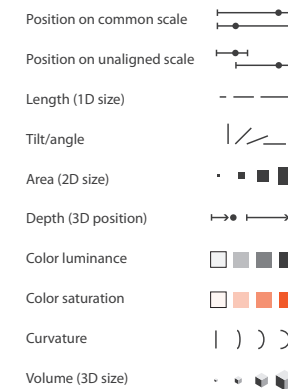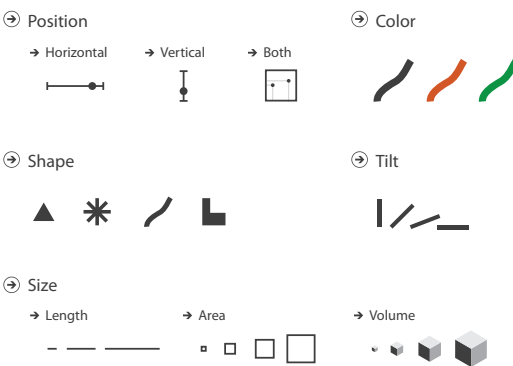- Color hue
- Motion
- Shape

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

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

- expressiveness principle
  - match channel and data characteristics
- effectiveness principle
  - encode most important attributes with highest ranked channels

---

Channels: Expressiveness types and effectiveness 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

- expressiveness principle
  - match channel and data characteristics
- effectiveness principle
  - encode most important attributes with highest ranked channels
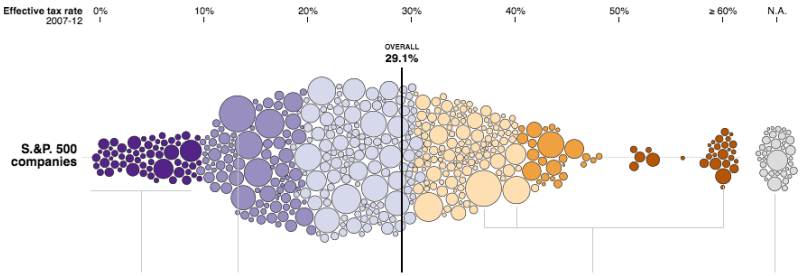 - spatial position ranks high for both

Quiz: Name those channels
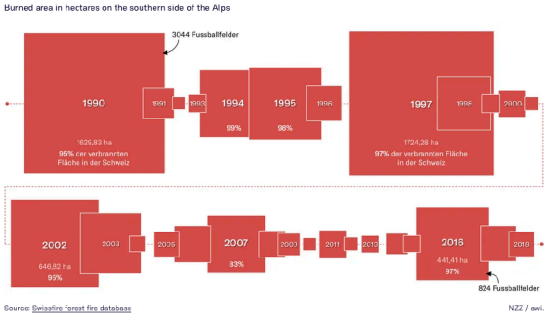- A: Inconvenient Truth

17
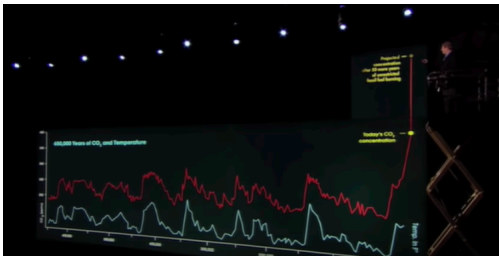
Quiz: Name those channels
- B: Tax Rates

18

Quiz: Name those channels
- C: Alpen Forest Fires

19

Quiz: Name those channels
- D: More Alpen Forest Fires

20
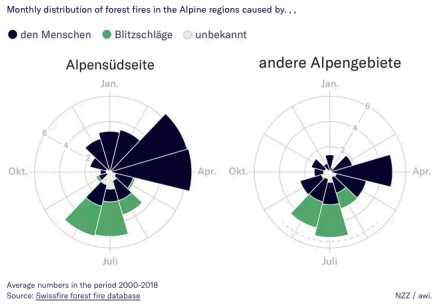
Quiz: Name those channels
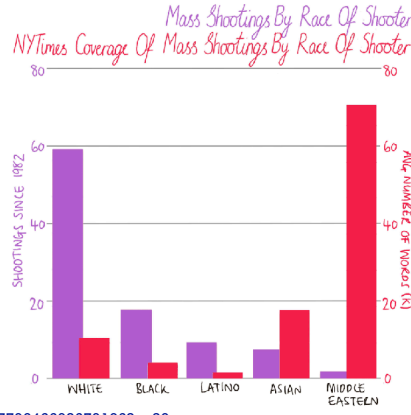- E: Netherlands Commuters

21
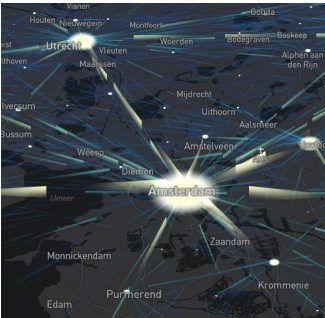
Reminder: Marks and channels
- marks
  – basic geometric elements

- channels
  – control appearance of marks

22
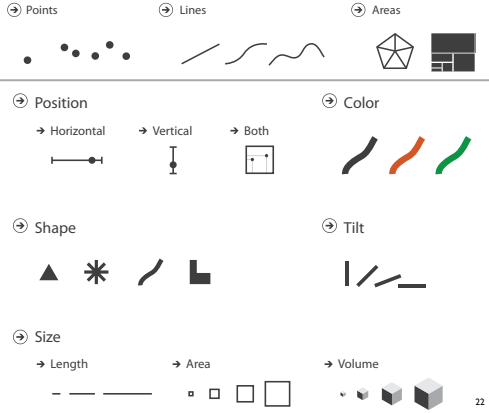
Quiz: Name that mark
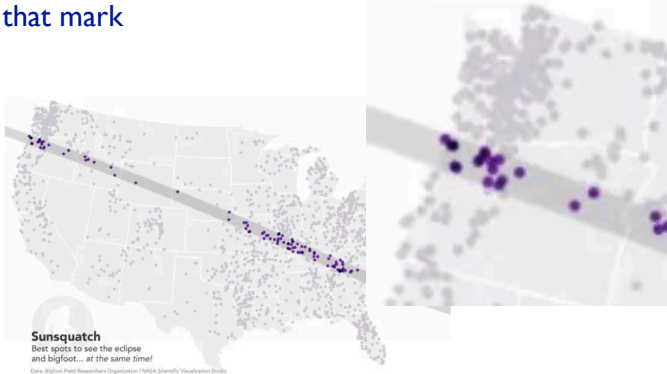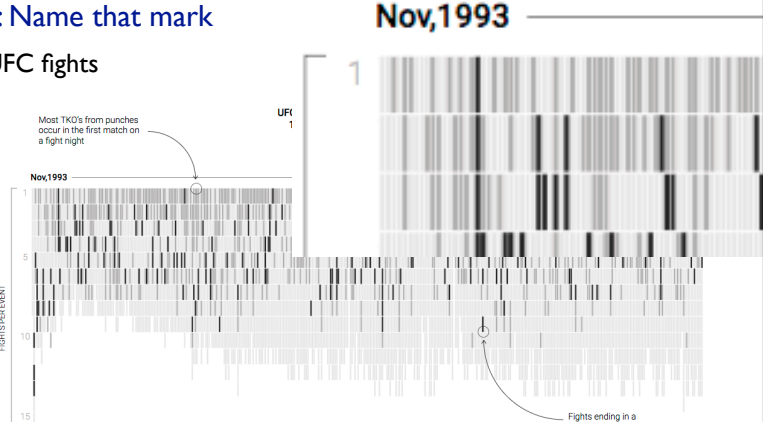- A: Shooting Media Coverage

23

Quiz: Name that mark
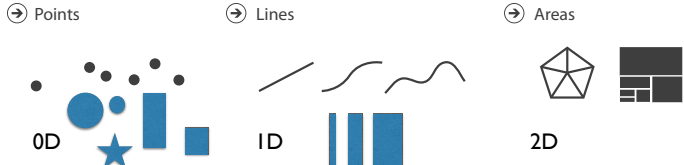- B: Sunsqatch

24

Quiz: Name that mark
- C: UFC fights

25

Marks: Constrained vs encodable
- 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)
  – areas: 2 constraints on size (length/width), cannot size code or shape code

- quick check: can you size-code another attribute, or is size/shape in use?
26

Analyzing marks
- what type of mark?
  – line?
    - no, not length coded
  – point mark with rectangular shape?
    - yes!
  – area?
    - no, area/shape does not convey meaning
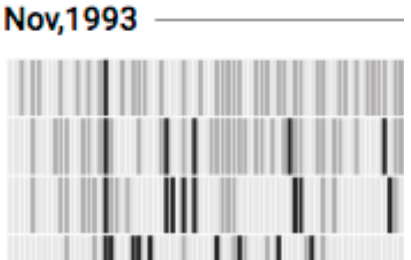
Quiz: Name that mark
- D: Yet More Alpen Forest Fires

28
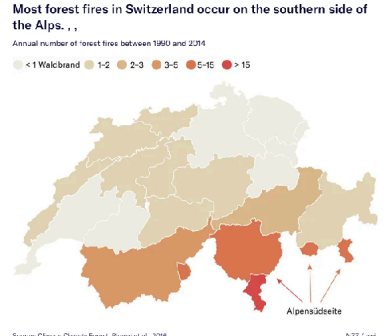
Quiz: Name that mark
- E: Tax Rates

29
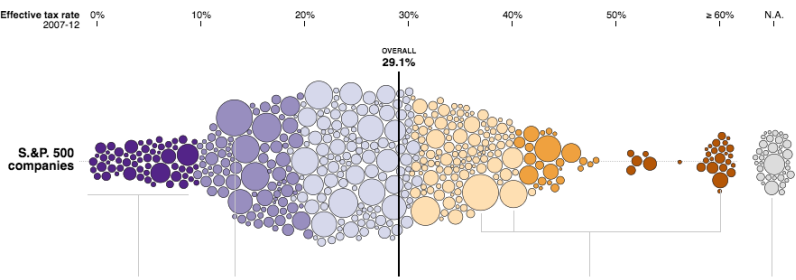
Quiz: Name that mark
- F: Alpen Forest Fires

30
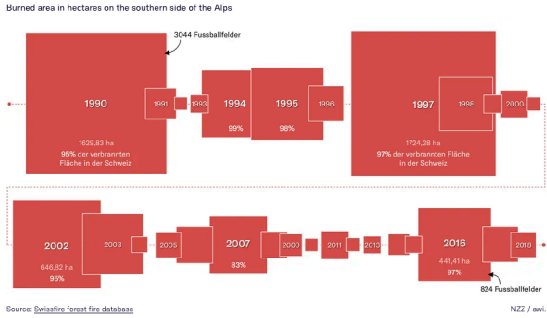
Quiz: Name that mark
- G: More Alpen Forest Fires

31
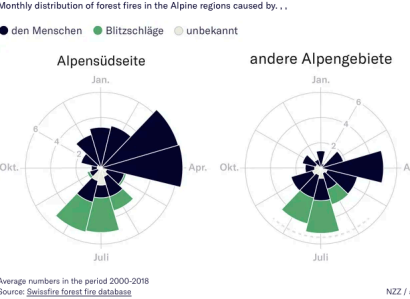
Scope of analysis
- simplifying assumptions: one mark per item, single view

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

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

Electric Shock (3.5)
Saturation (1.7)
Length (1)
Area (0.7)
Depth (0.67)
Brightness (0.5)

Perceived Sensation (y-axis)
Physical Intensity (x-axis)

Accuracy: Vis experiments

Cleveland & McGill's Results
Crowdsourced Results

Positions, Angles, Circular areas, Rectangular areas (aligned or in a treemap)

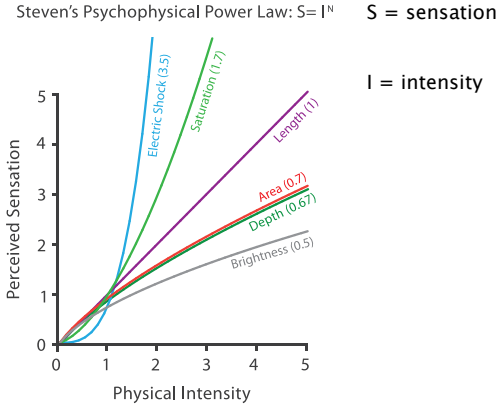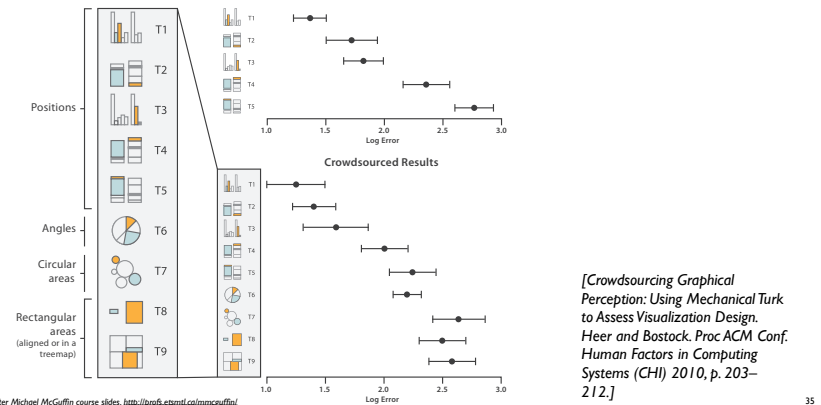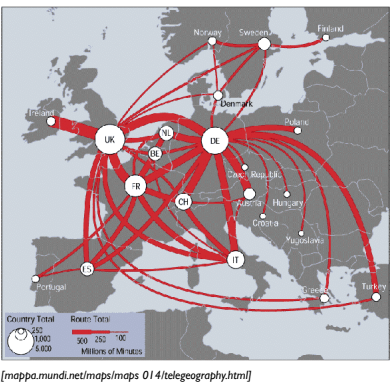[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

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

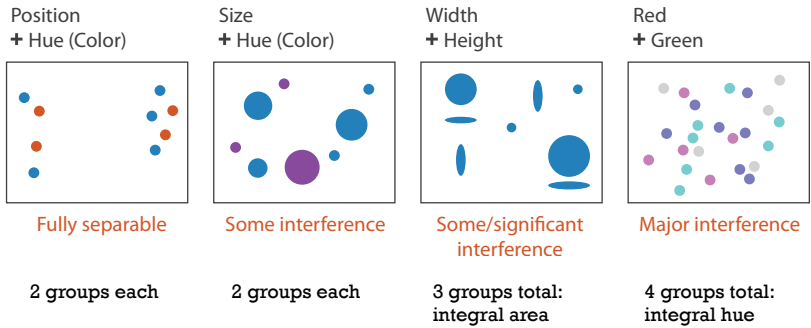## Discriminability: How many usable steps?

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

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

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
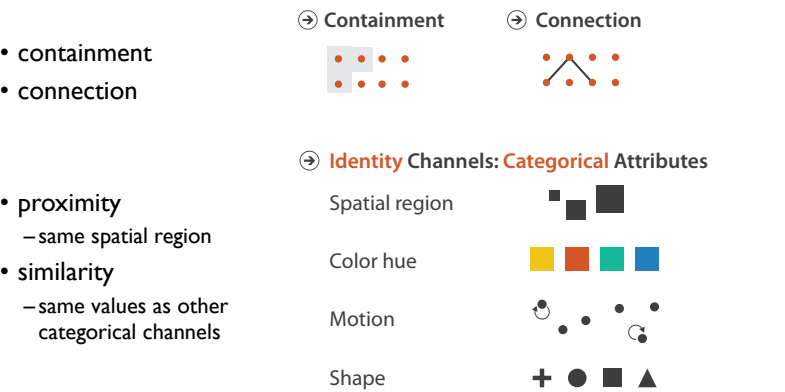

Popout

- 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
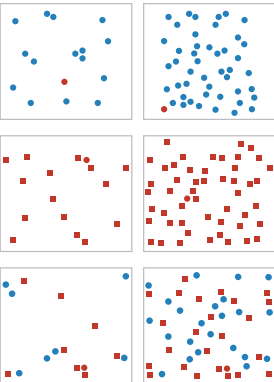
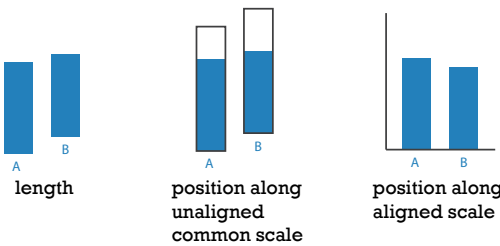
Popout

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

---

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

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

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.]

Factors affecting accuracy

- alignment
- distractors
- distance
- common scale

vs vs vs

Relative luminance judgements

- perception of luminance is contextual based on contrast with surroundings

Edward H. Adelson

http://persci.mit.edu/gallery/checkershadow
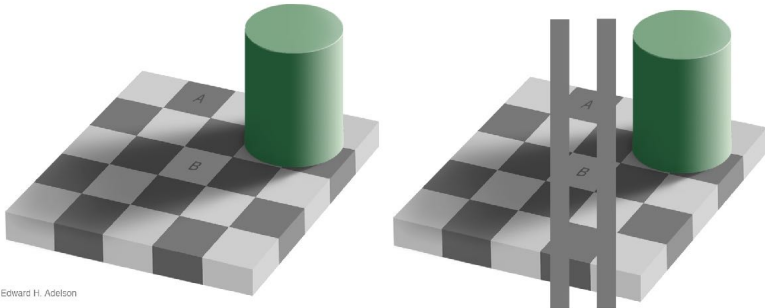
Relative color judgements

- color constancy across broad range of illumination conditions

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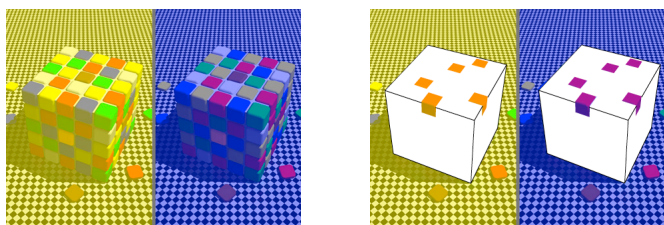
Upcoming

- D3 videos to watch, week 3
  - Making a Bar Chart with D3 and SVG [30 min]
- Quiz 2, due by Fri Jan 17, 8am
- labs start this week!
  - Fri 9-10, 11-12, 4-5
  - strongly recommended but optional: we do not track attendance
  - TA office hours for individual consultation and help
    - TAs will typically alternate weeks
  - if you can't register, try attending the one you want
    - seats for registered students first, but may be room
- Foundations Exercise 2 out, due Wed Jan 22
- Programming Exercise 1 out, due Wed Jan 29

Credits

- Visualization Analysis and Design (Ch 5)
- Alex Lex & Miriah Meyer, http://dataviscourse.net/