Ch 4/5/6: Validation, Marks & Channels, Rules of Thumb Paper: Artery Vis

Tamara Munzner
Department of Computer Science
University of British Columbia

CPSC 547, Information Visualization
Week 3: 24 September 2019

http://www.cs.ubc.ca/~tmm/courses/547-19

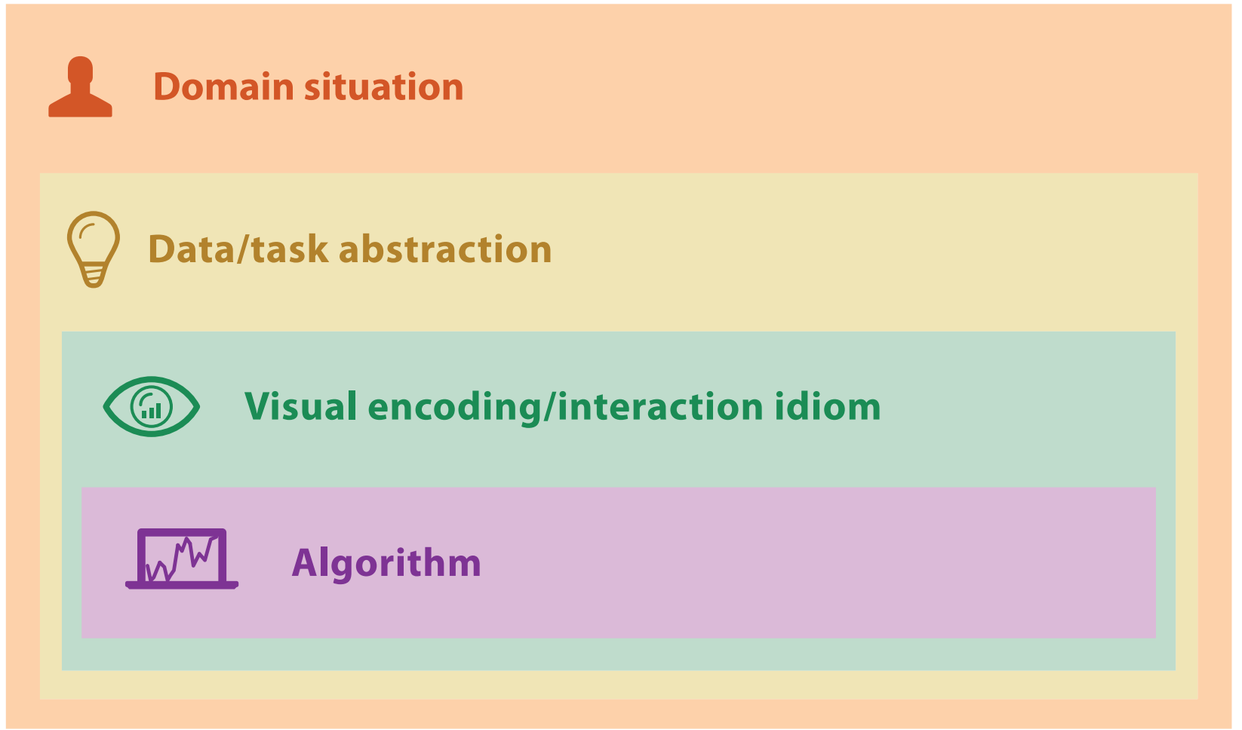
News

- schedule today
  - discussion: readings
  - papers: types and strategies for reading
  - exercise: Decoding

- presentations plan
  - yes, we'll have presentations
  - presentation topic choices will be due Oct 25
  - stay tuned for more on presentation topics

Ch 4: Validation

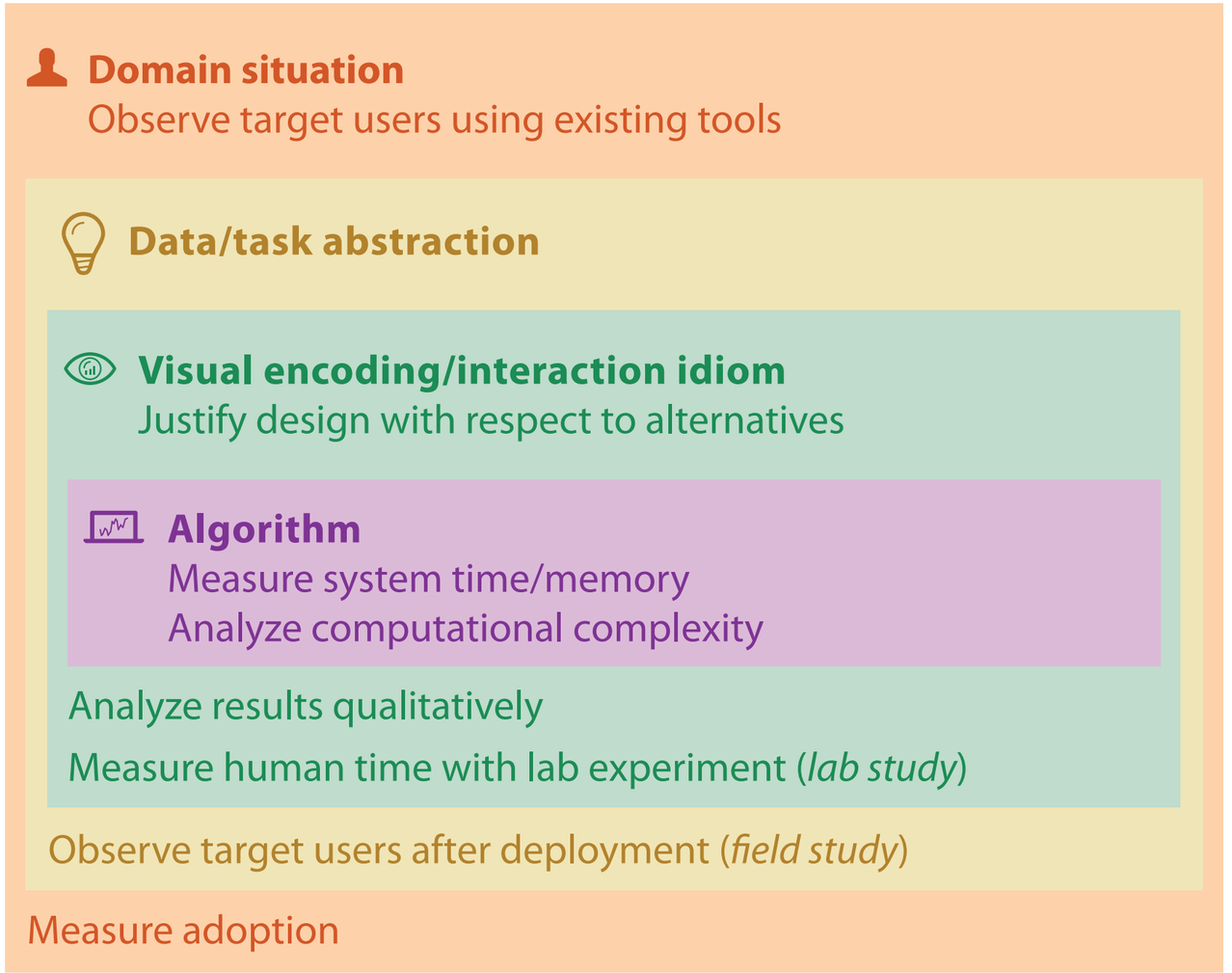
VAD Ch 4: Analysis: Four Levels for Validation



Four levels of design and validation

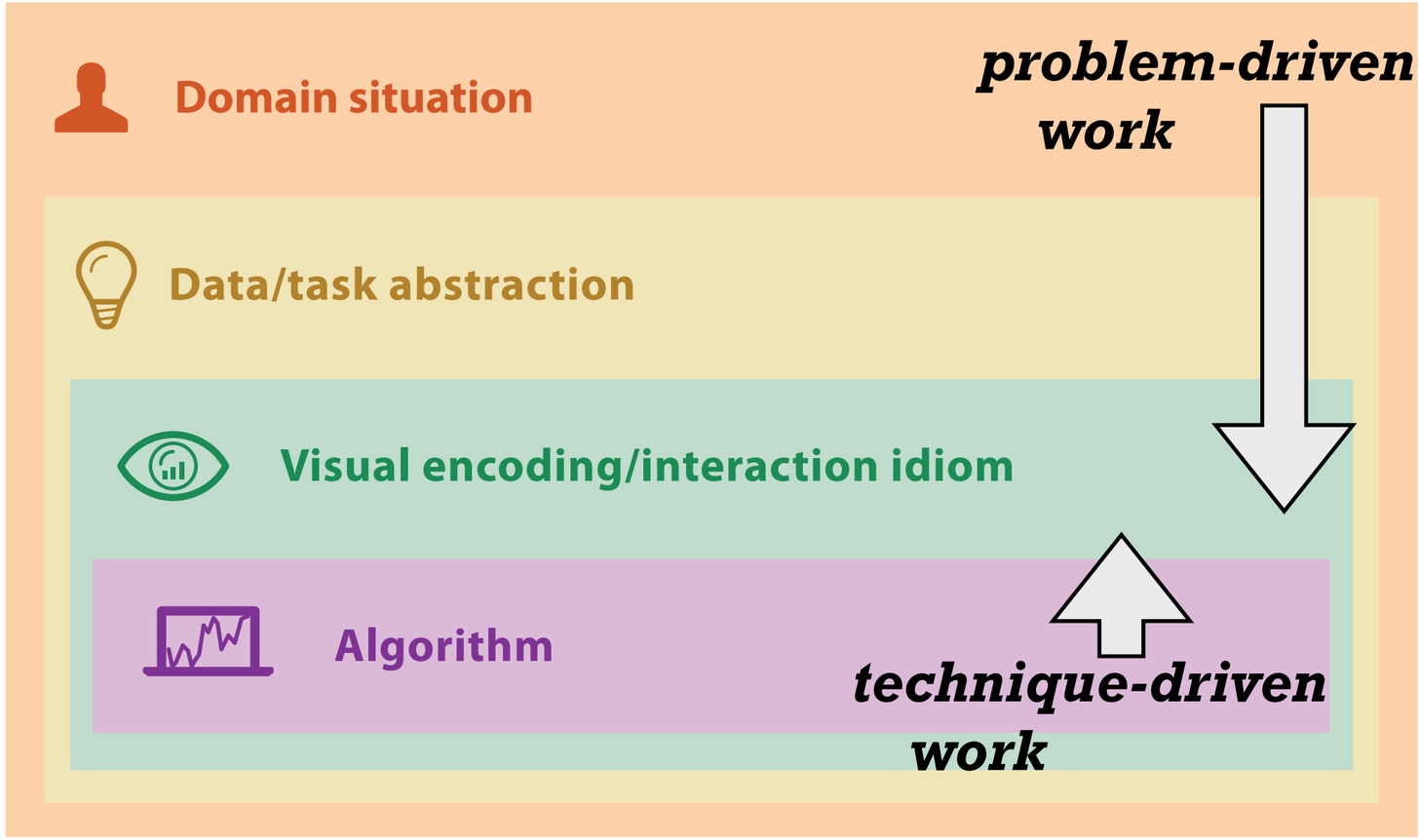
- four levels of design problems
  - different threats to validity at each level

Validation by level



- mismatch: cannot show idiom good with system timings
- mismatch: cannot show abstraction good with lab study

Directionality & scope



Ch 5: Marks & Channels

Definitions: Marks and channels

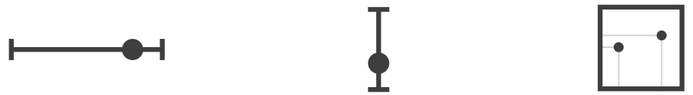
- marks
  - geometric primitives

Points Lines Areas

- channels
  - control appearance of marks

Position

Horizontal Vertical Both



Color

Shape

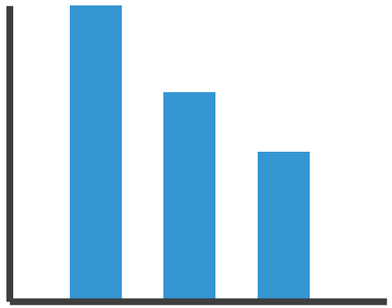
Tilt

Size

Length Area Volume

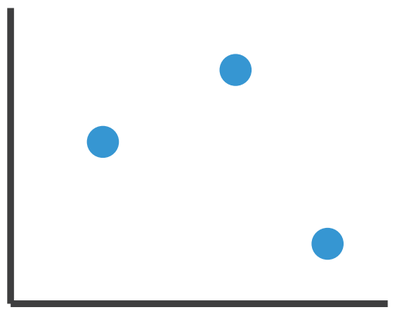
Encoding visually with marks and channels

- analyze idiom structure
  - as combination of marks and channels



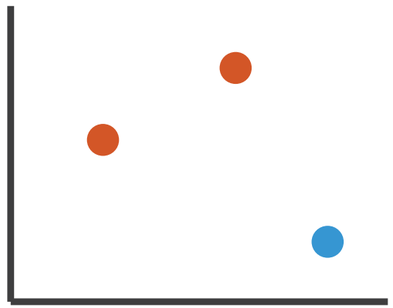
1:
vertical position

mark: line



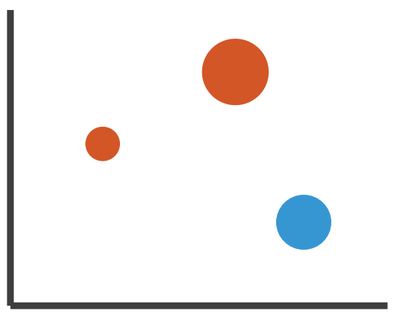
2:
vertical position
horizontal position

mark: point



3:
vertical position
horizontal position
color hue

mark: point



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

mark: point

Channels

Position on common scale

Position on unaligned scale

Length (1D size)

Tilt/angle

Area (2D size)

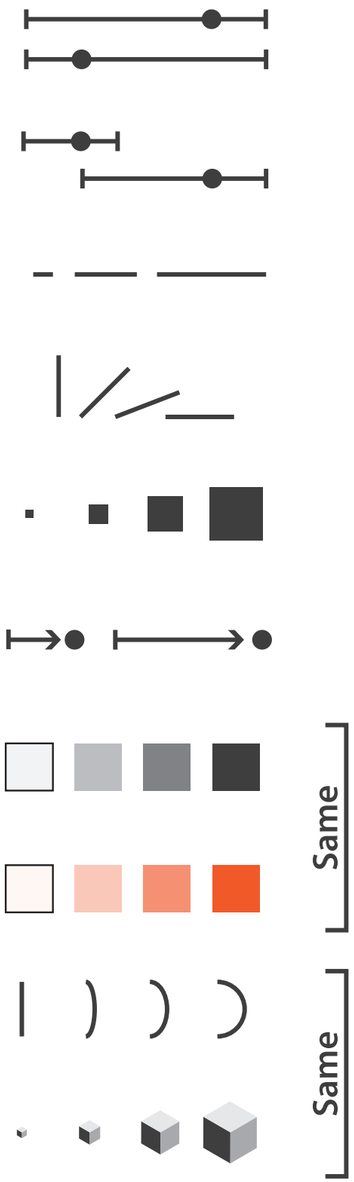
Depth (3D position)

Color luminance

Color saturation

Curvature

Volume (3D size)

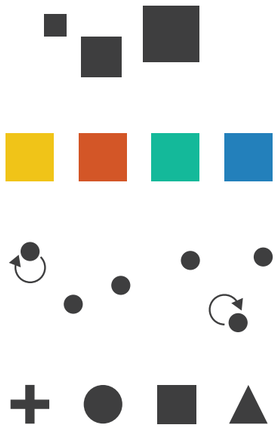


Spatial region

Color hue

Motion

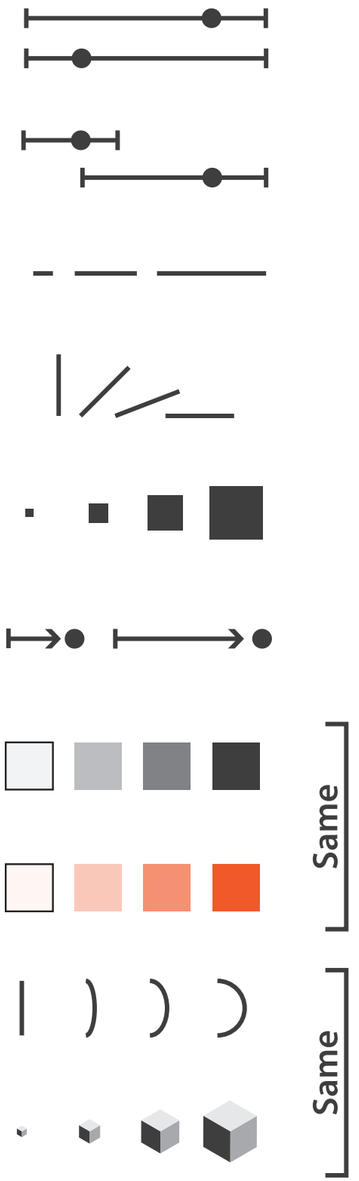
Shape



Channels: 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)



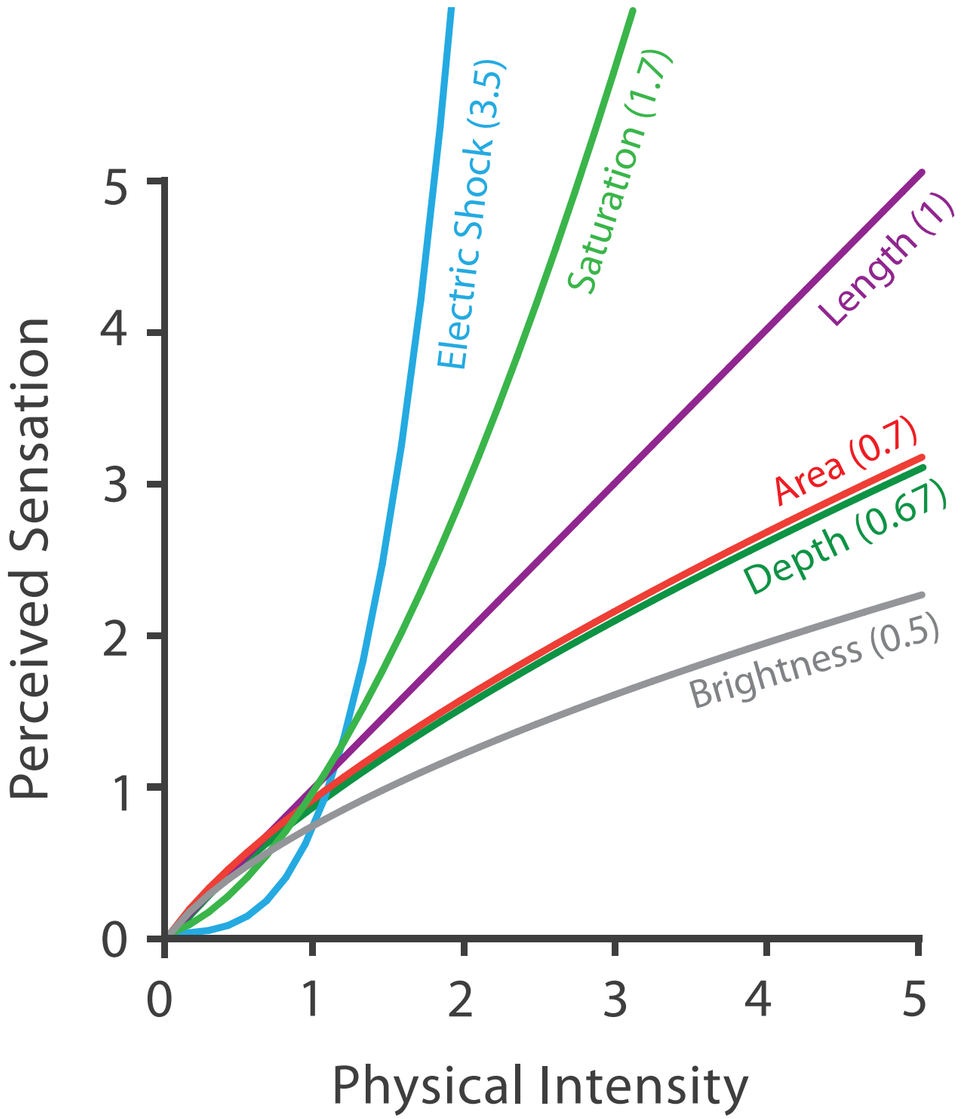
Identity Channels: Categorical Attributes

- Spatial region
- Color hue
- Motion
- Shape

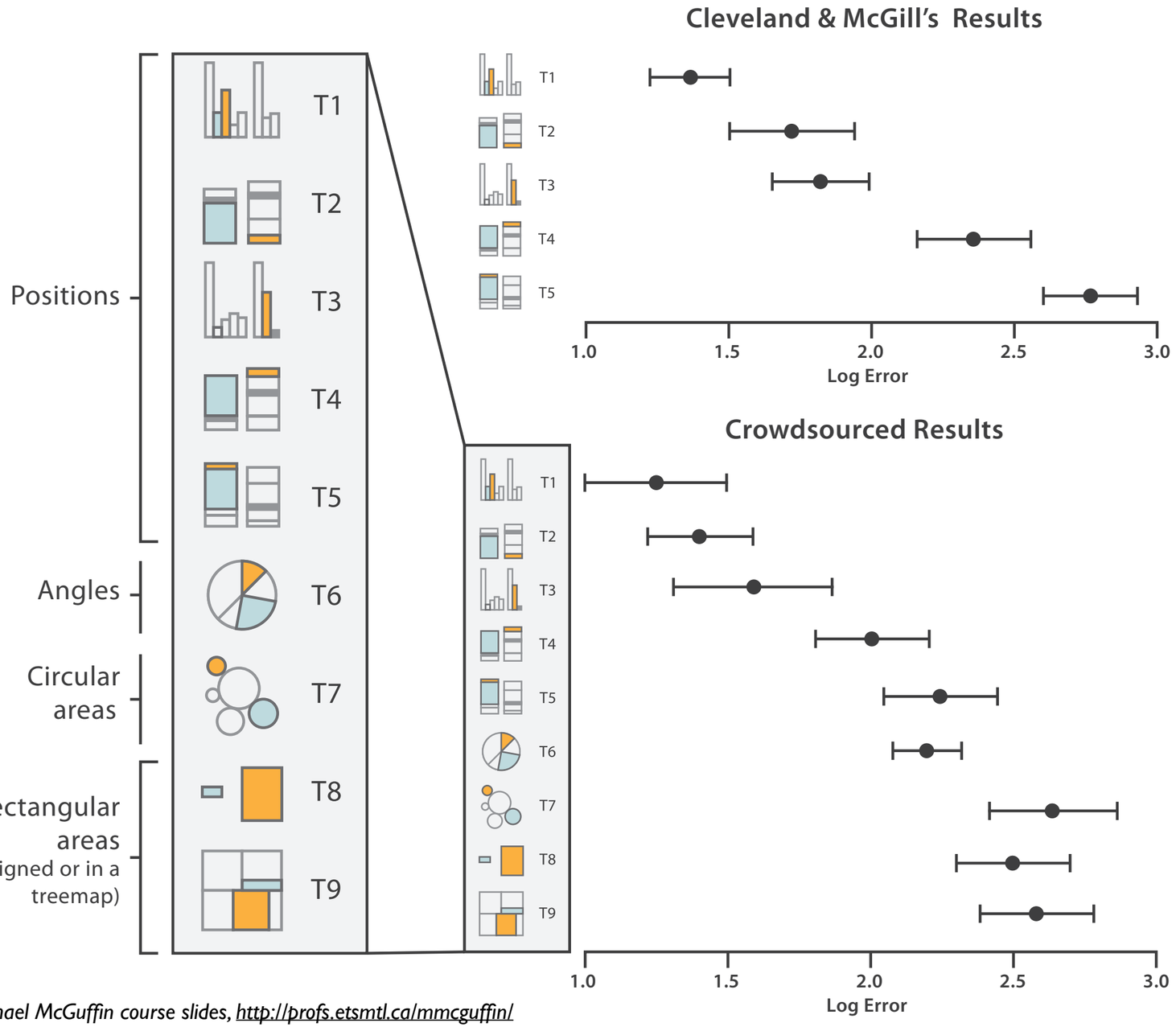
- effectiveness principle
  - encode most important attributes with highest ranked channels
- expressiveness principle
  - match channel and data characteristics

Accuracy: Fundamental Theory

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



Accuracy: Vis experiments

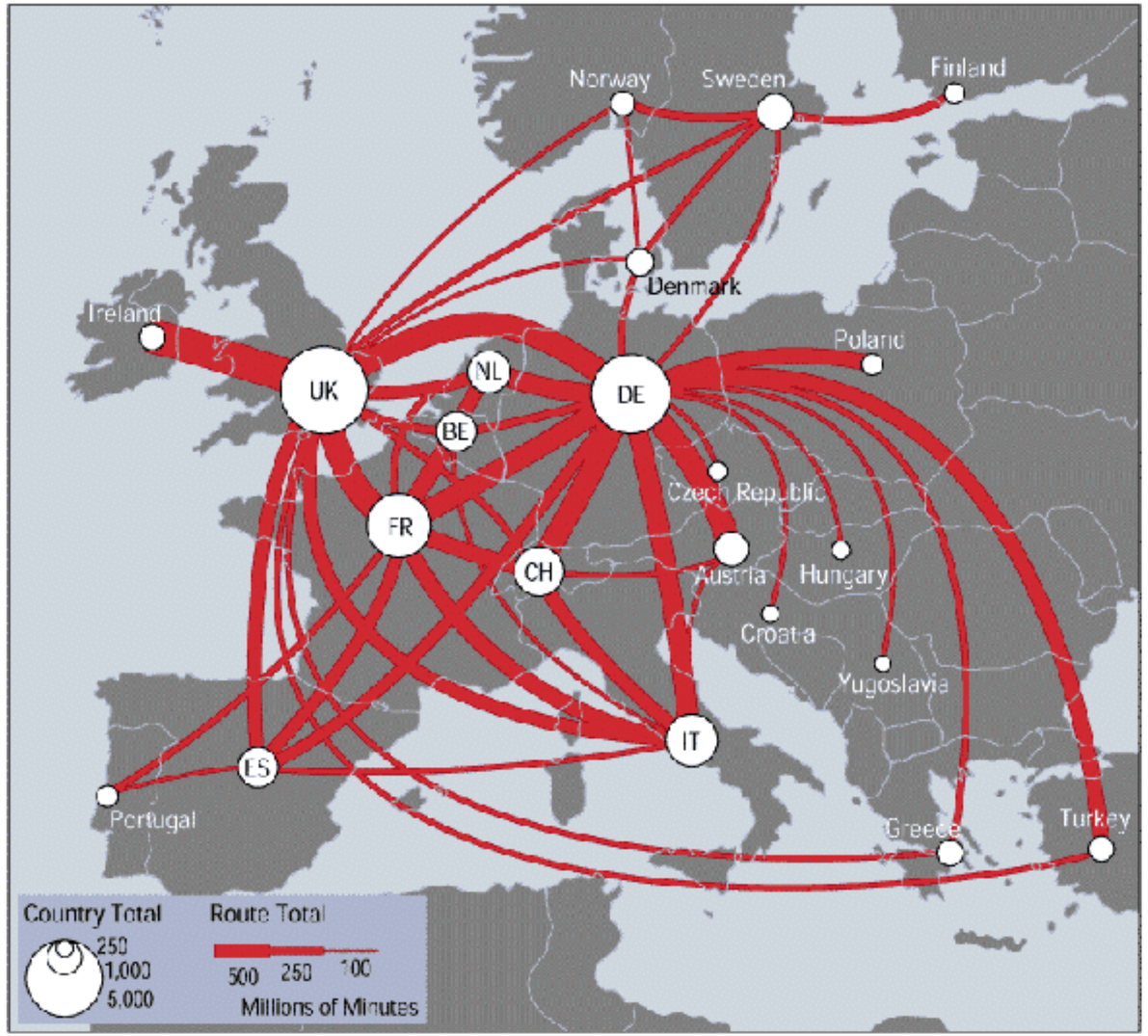


[Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design. Heer and Bostock. Proc ACM Conf. Human Factors in Computing Systems (CHI) 2010, p. 203–212.]

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

Discriminability: How many usable steps?

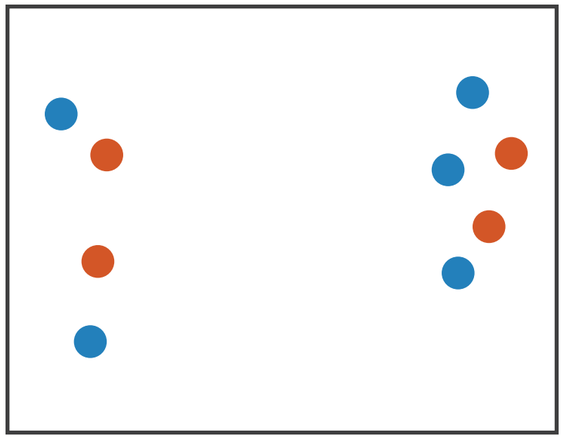
- must be sufficient for number of attribute levels to show
  - linewidth: few bins



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

Separability vs. Integrality

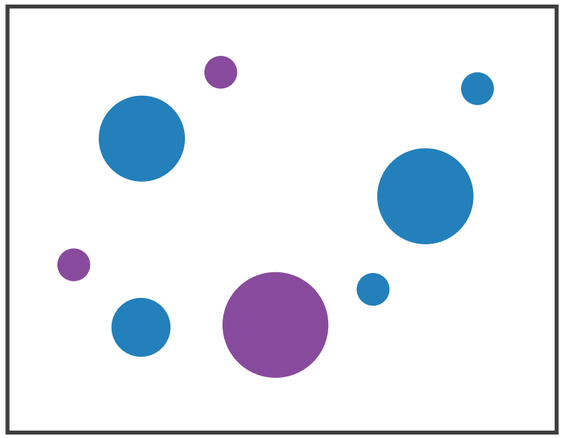
Position
+ Hue (Color)



Fully separable

2 groups each

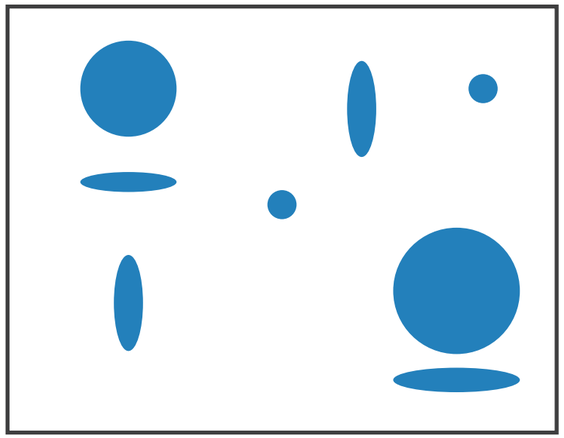
Size
+ Hue (Color)



Some interference

2 groups each

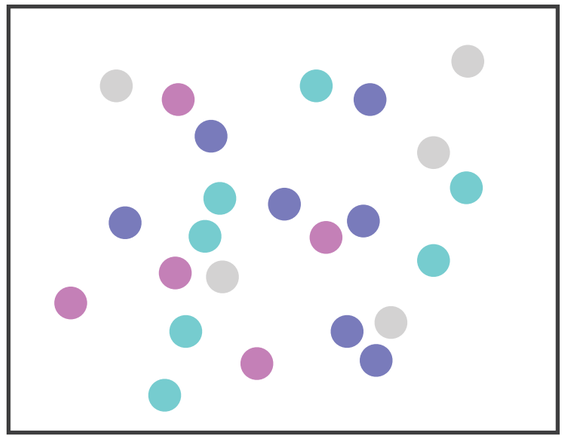
Width
+ Height



Some/significant interference

3 groups total: integral area

Red
+ Green

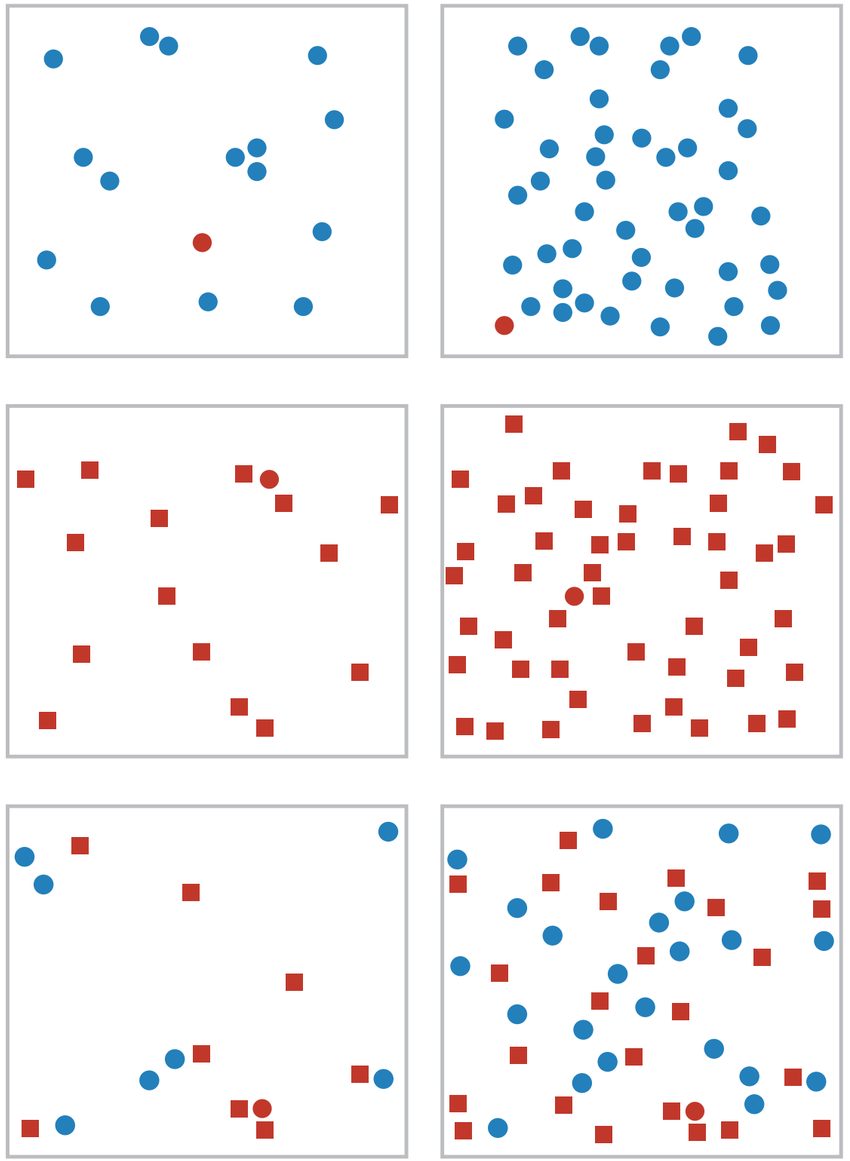


Major interference

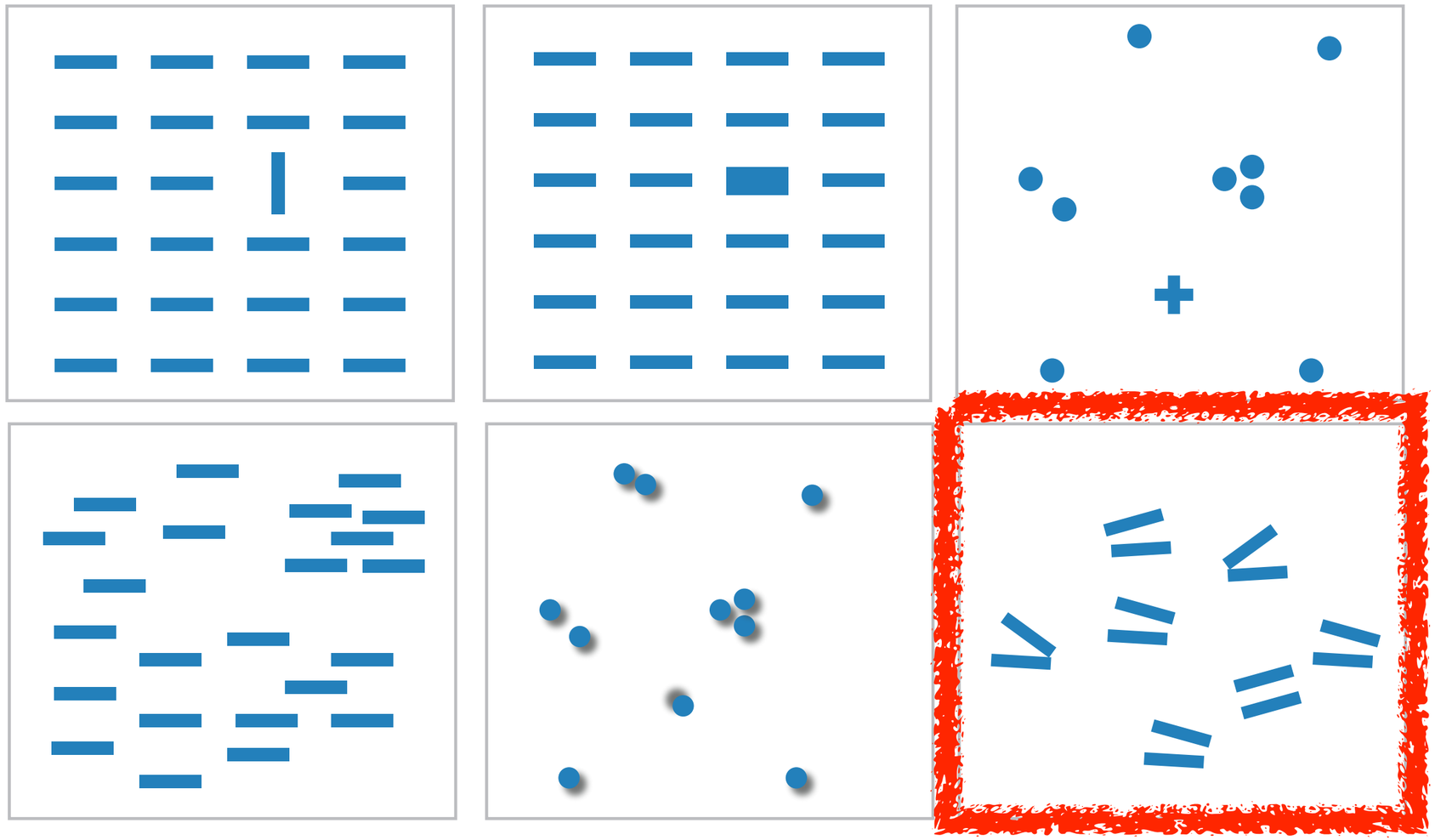
4 groups total: integral hue

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

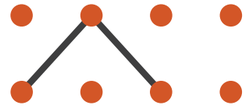
- containment
- connection

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

Marks as Links

Containment

Connection

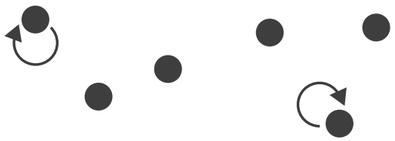


Identity Channels: Categorical Attributes

Spatial region

Color hue

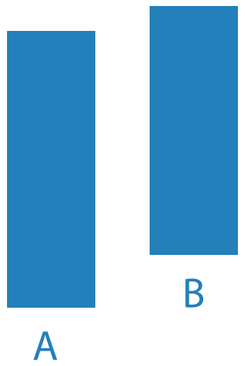
Motion



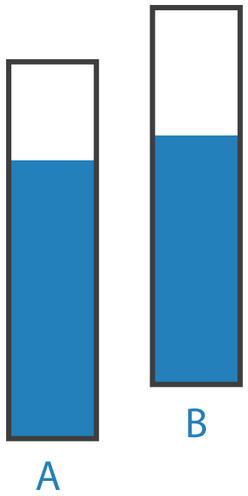
Shape

Relative vs. absolute judgements

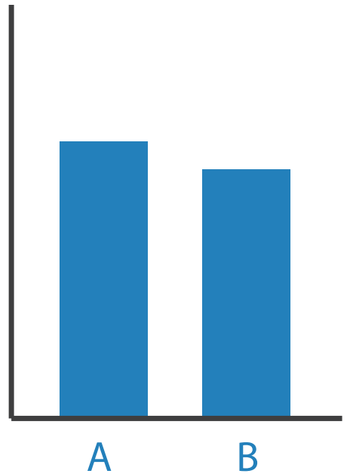
- perceptual system mostly operates with relative judgements, not absolute
  - that's why accuracy increases with common frame/scale and alignment
  - Weber's Law: ratio of increment to background is constant
    - filled rectangles differ in length by 1:9, difficult judgement
    - white rectangles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



length



position along unaligned common scale

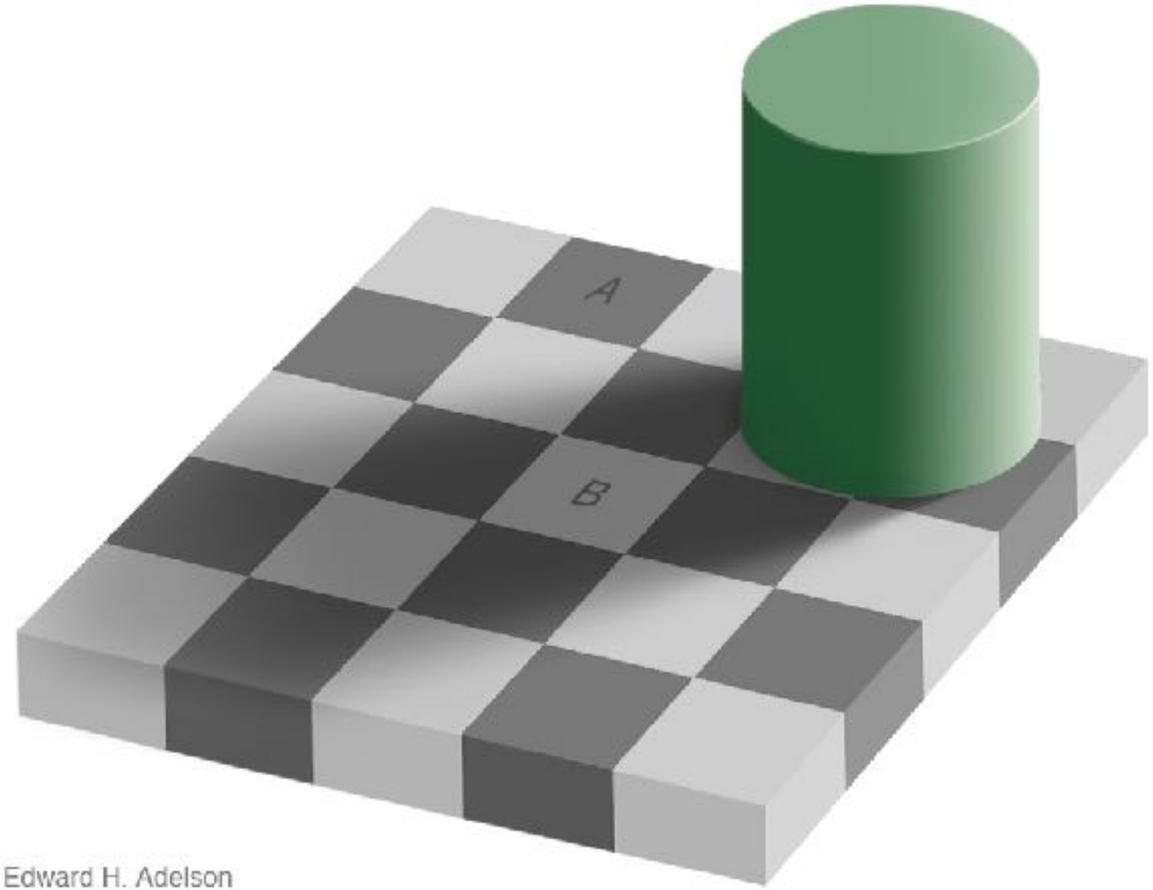


position along aligned scale

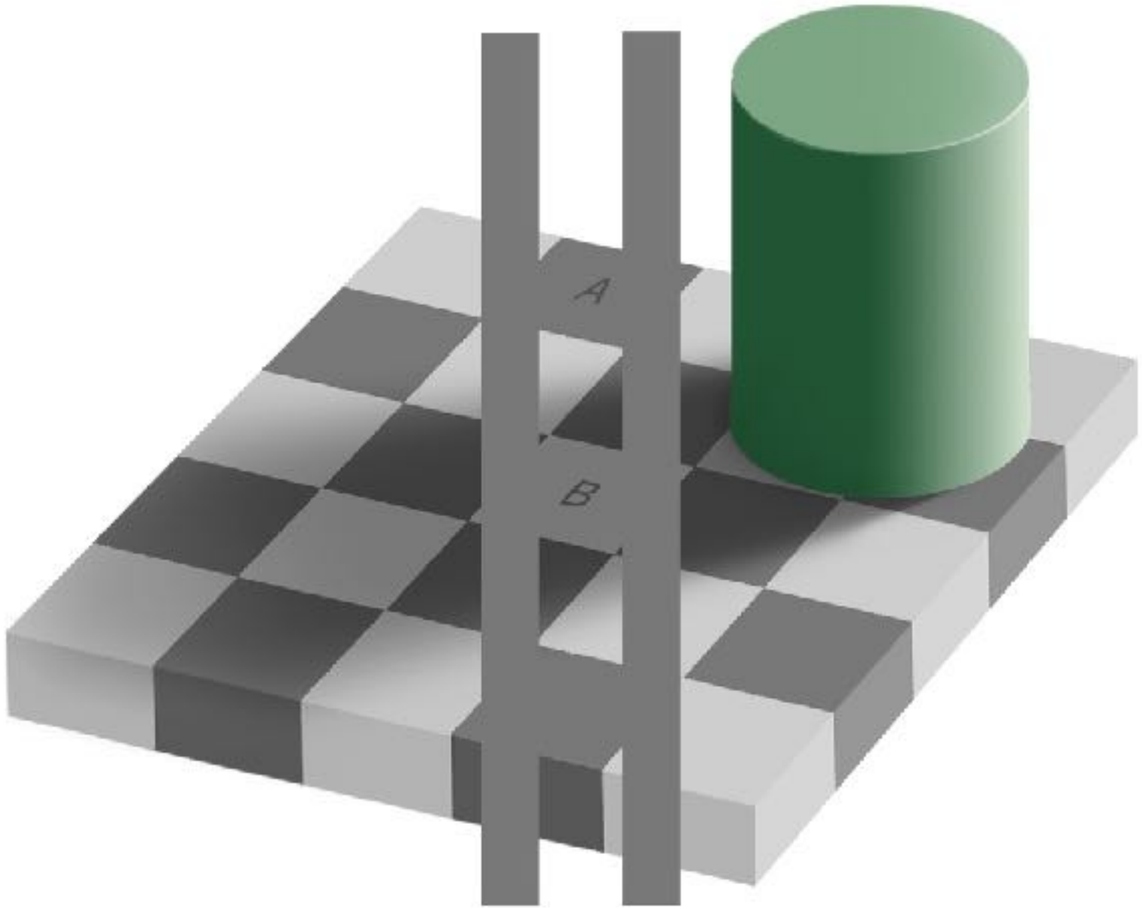
after [Graphical Perception: Theory, Experimentation, and Application to the Development of Graphical Methods. Cleveland and McGill. Journ. American Statistical Association 79:387 (1984), 531–554.]

Relative luminance judgements

- perception of luminance is contextual based on contrast with surroundings



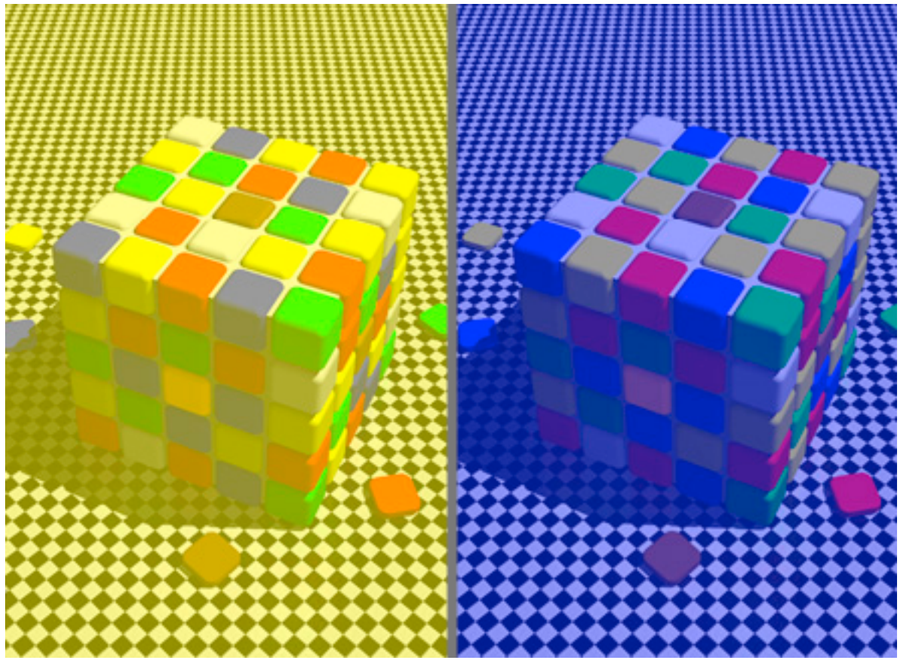
Edward H. Adelson

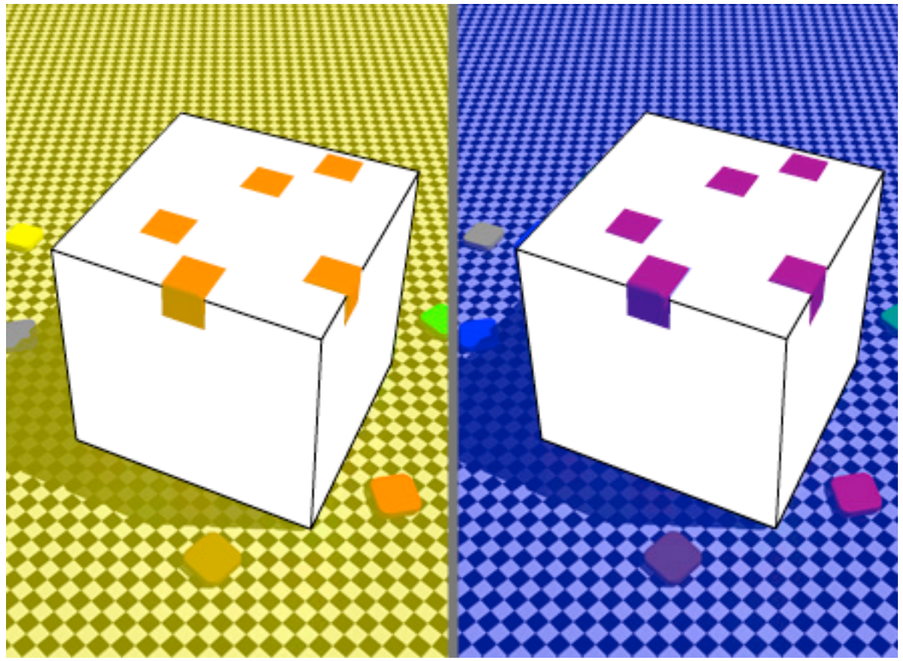


http://persci.mit.edu/gallery/checkershadow

Relative color judgements

- color constancy across broad range of illumination conditions





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

Ch 6: Rules of Thumb

VAD Ch 6: Rules of Thumb

- No unjustified 3D
  - Power of the plane, dangers of depth
  - Occlusion hides information
  - Perspective distortion loses information
  - Tilted text isn't legible
- No unjustified 2D
- Eyes beat memory
- Resolution over immersion
- Overview first, zoom and filter, details on demand
- Function first, form next

- (Get it right in black and white)

No unjustified 3D: Power of the plane

- high-ranked spatial position channels: **planar** spatial position
  - not depth!

➔ **Magnitude Channels: Ordered Attributes**

Position on common scale

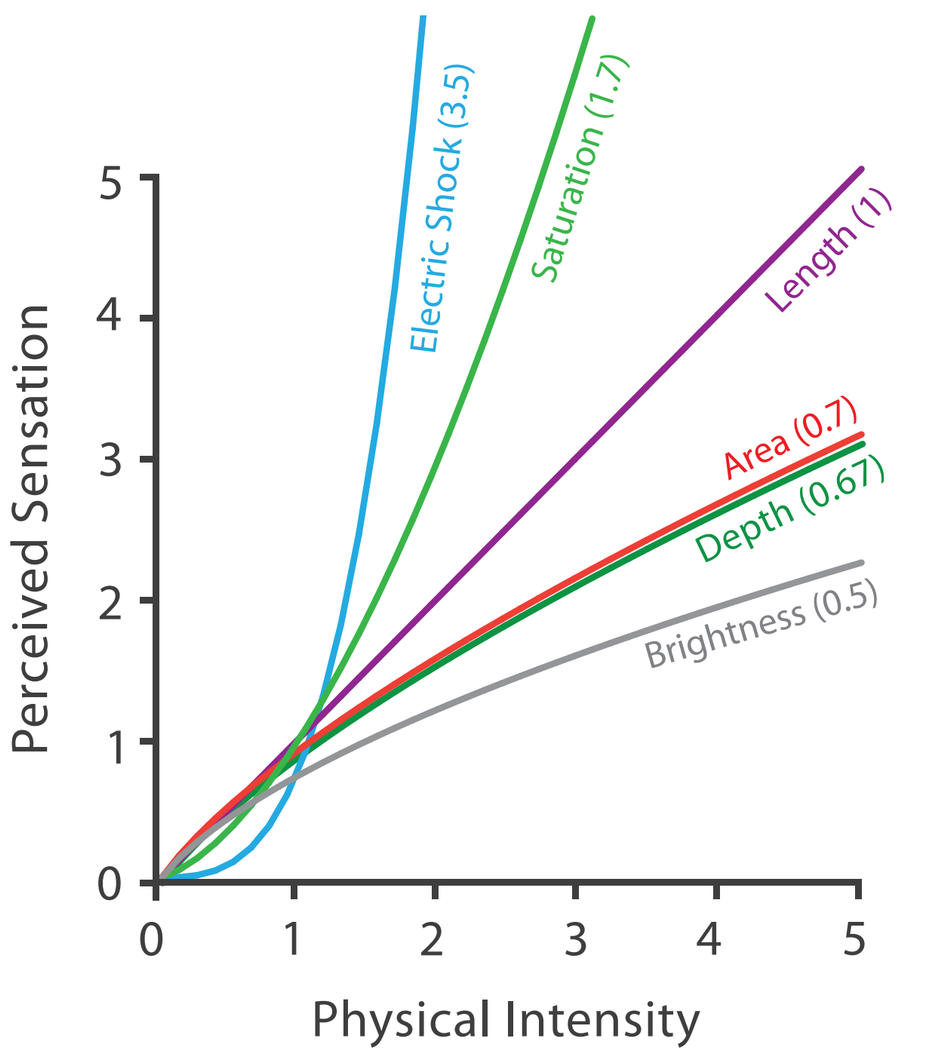
Position on unaligned scale

Length (1D size)

Tilt/angle

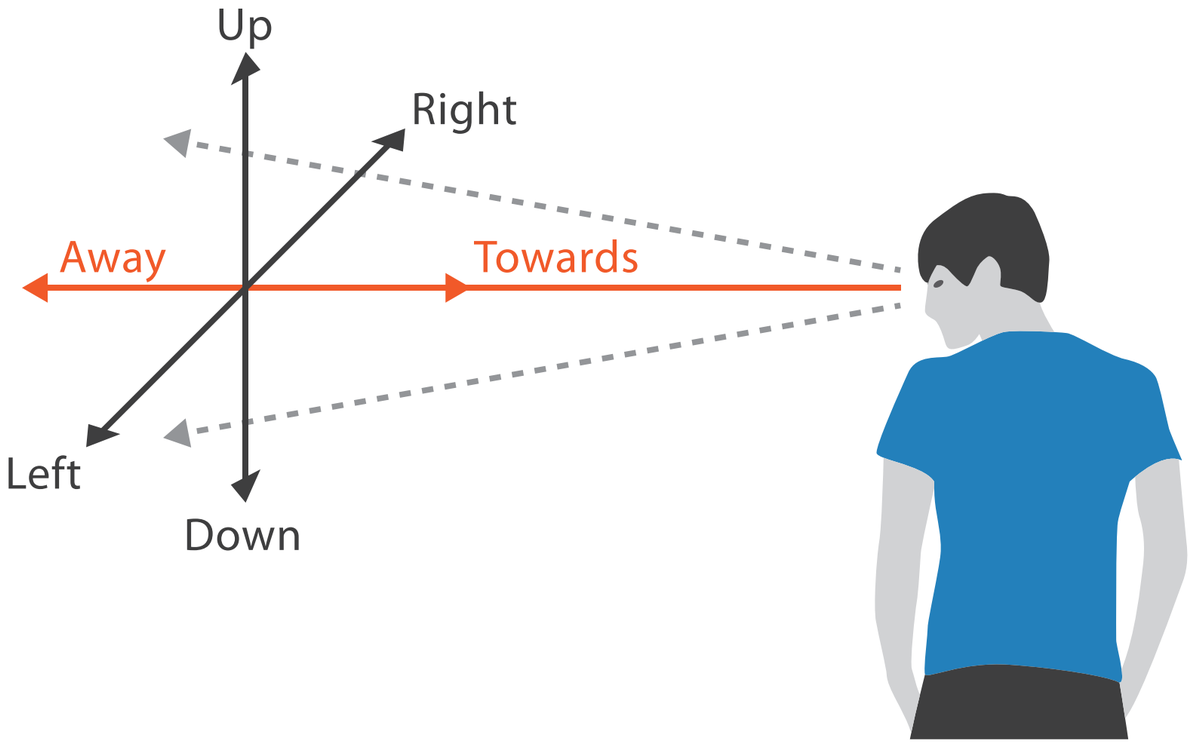
Area (2D size)

Depth (3D position)

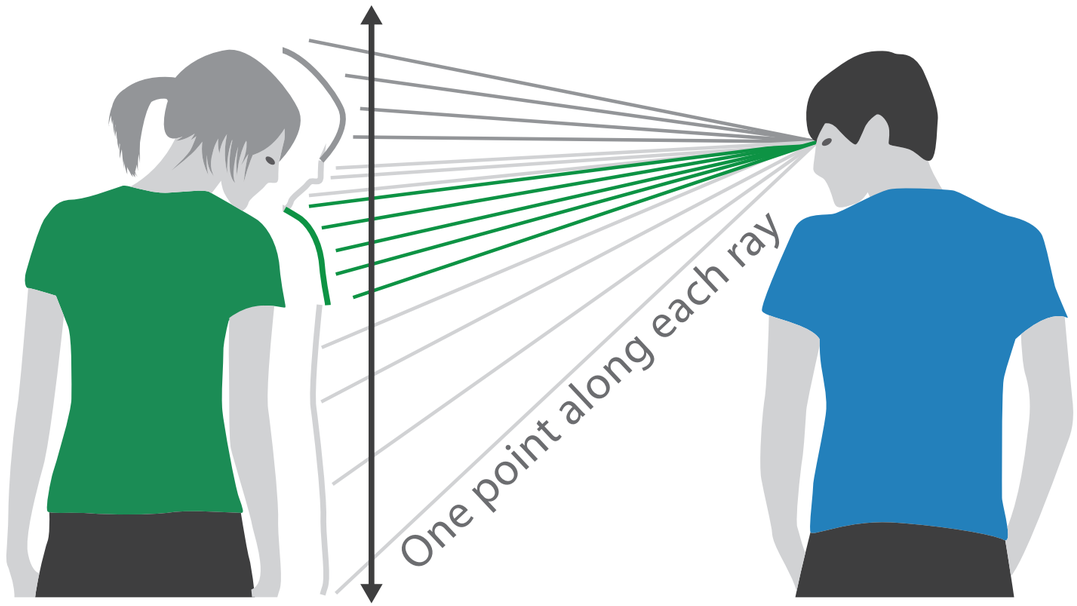


No unjustified 3D: Danger of depth

- we don't really live in 3D: we ***see*** in 2.05D
  - acquire more info on image plane quickly from eye movements
  - acquire more info for depth slower, from head/body motion



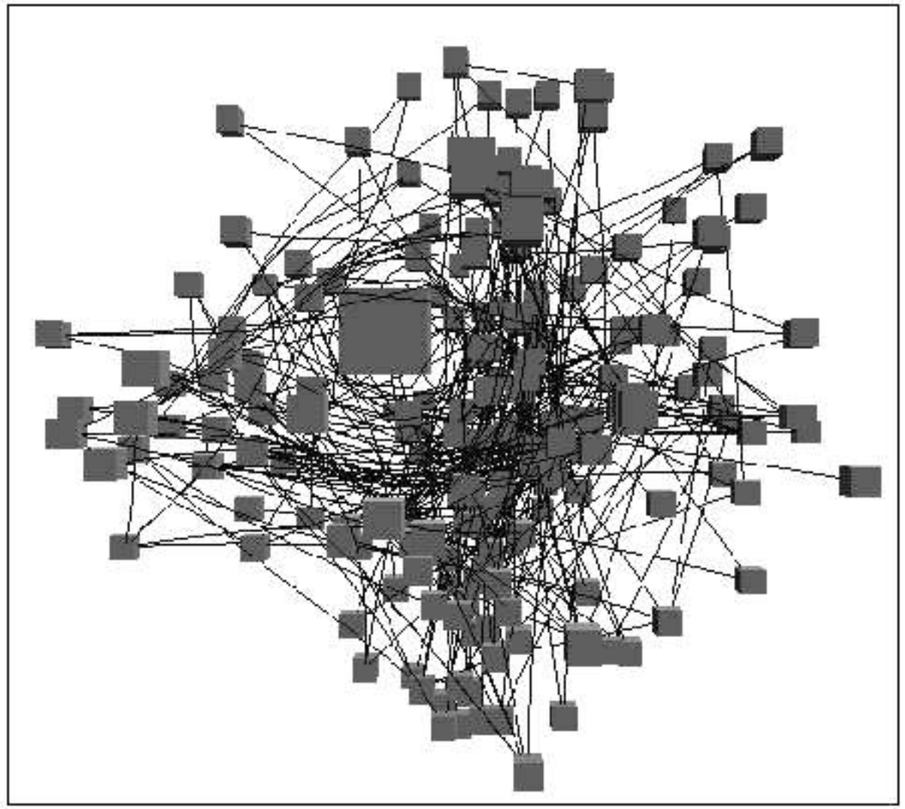
Thousands of points up/down and left/right



We can only see the outside shell of the world

Occlusion hides information

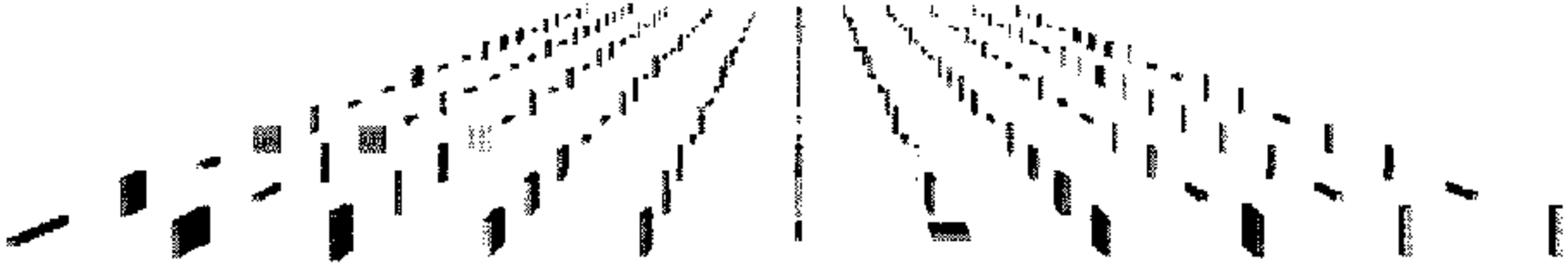
- occlusion
- interaction complexity



[Distortion Viewing Techniques for 3D Data. Carpendale et al. InfoVis1996.]

Perspective distortion loses information

- perspective distortion
  - interferes with all size channel encodings
  - power of the plane is lost!



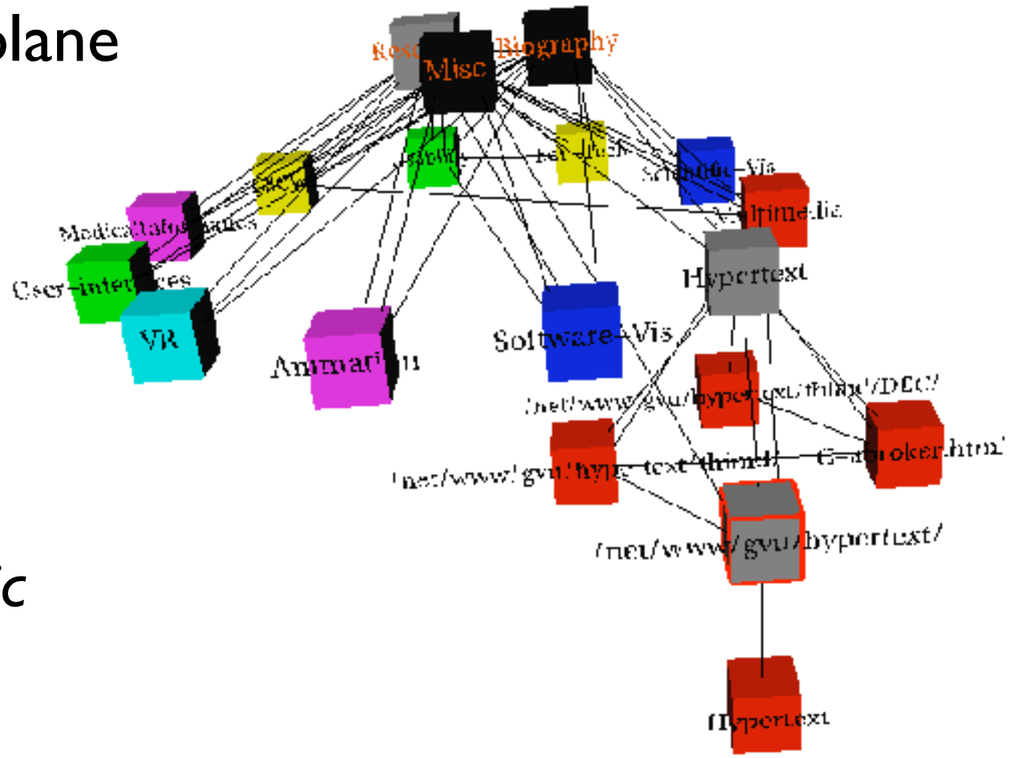
[Visualizing the Results of Multimedia Web Search Engines. Mukherjea, Hirata, and Hara. InfoVis 96]

Tilted text isn't legible

- text legibility
  - –far worse when tilted from image plane

- further reading

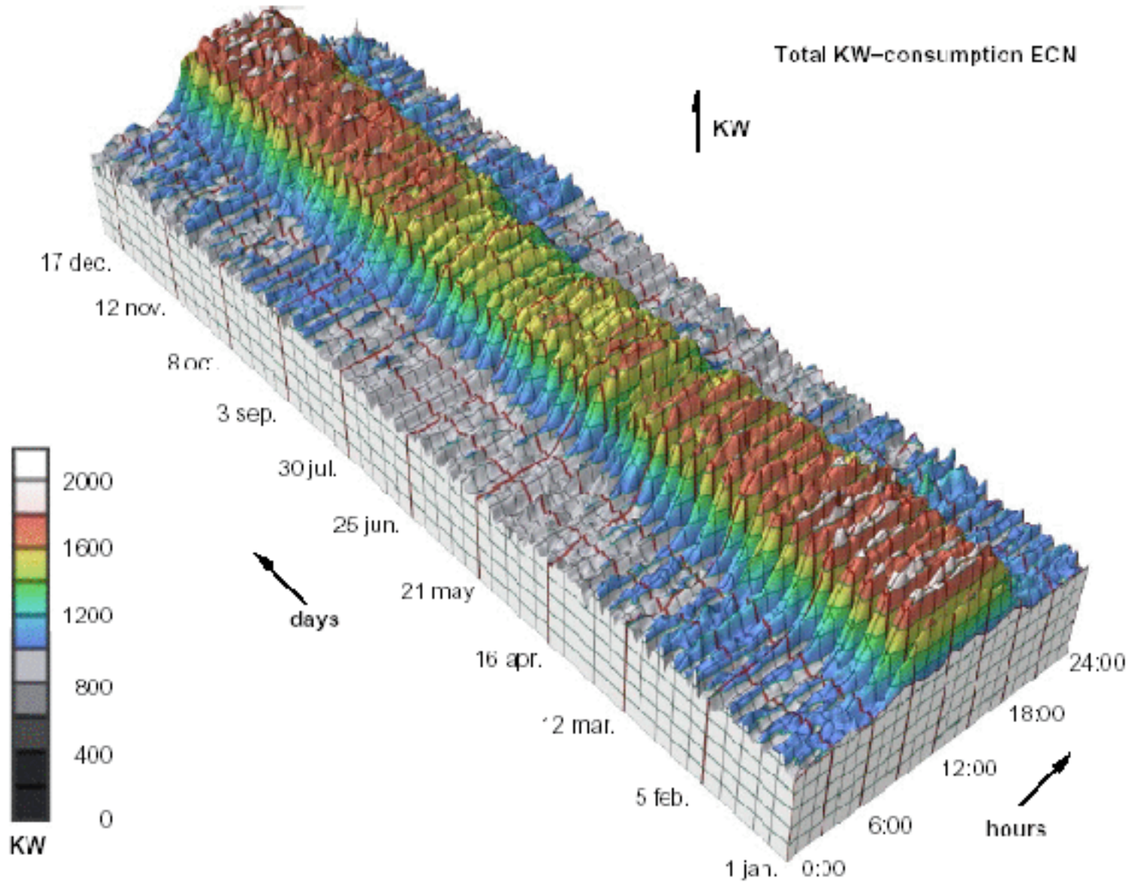
  [Exploring and Reducing the Effects of Orientation on Text Readability in Volumetric Displays.
  Grossman et al. CHI 2007]



[*Visualizing the World-Wide Web with the Navigational View Builder. Mukherjea and Foley. Computer Networks and ISDN Systems, 1995.]*

No unjustified 3D example: Time-series data

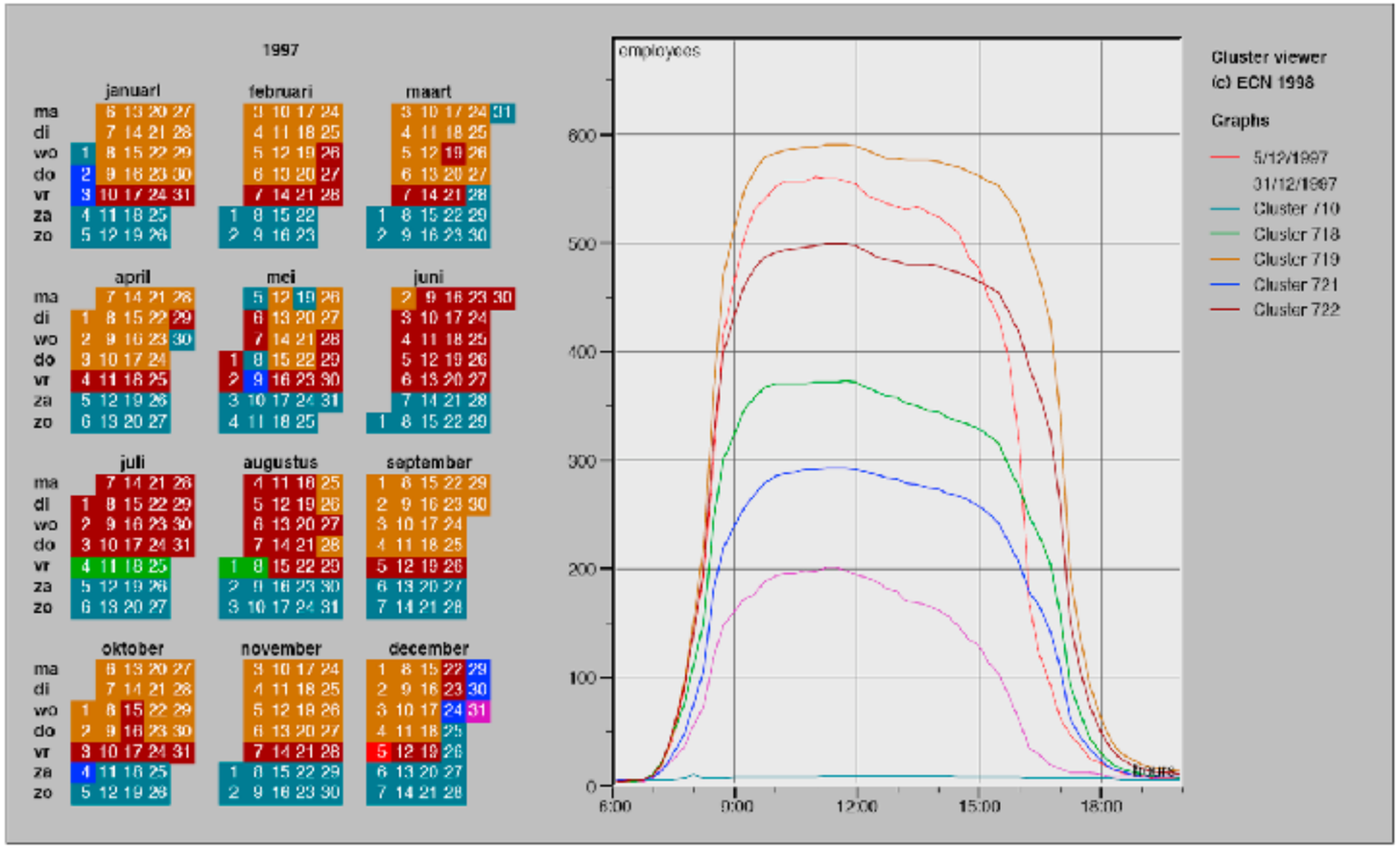
- extruded curves: detailed comparisons impossible



[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

No unjustified 3D example: Transform for new data abstraction

- derived data: cluster hierarchy
- juxtapose multiple views: calendar, superimposed 2D curves



[Cluster and Calendar based Visualization of Time Series Data. van Wijk and van Selow, Proc. InfoVis 99.]

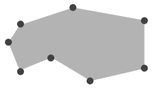
Justified 3D: shape perception

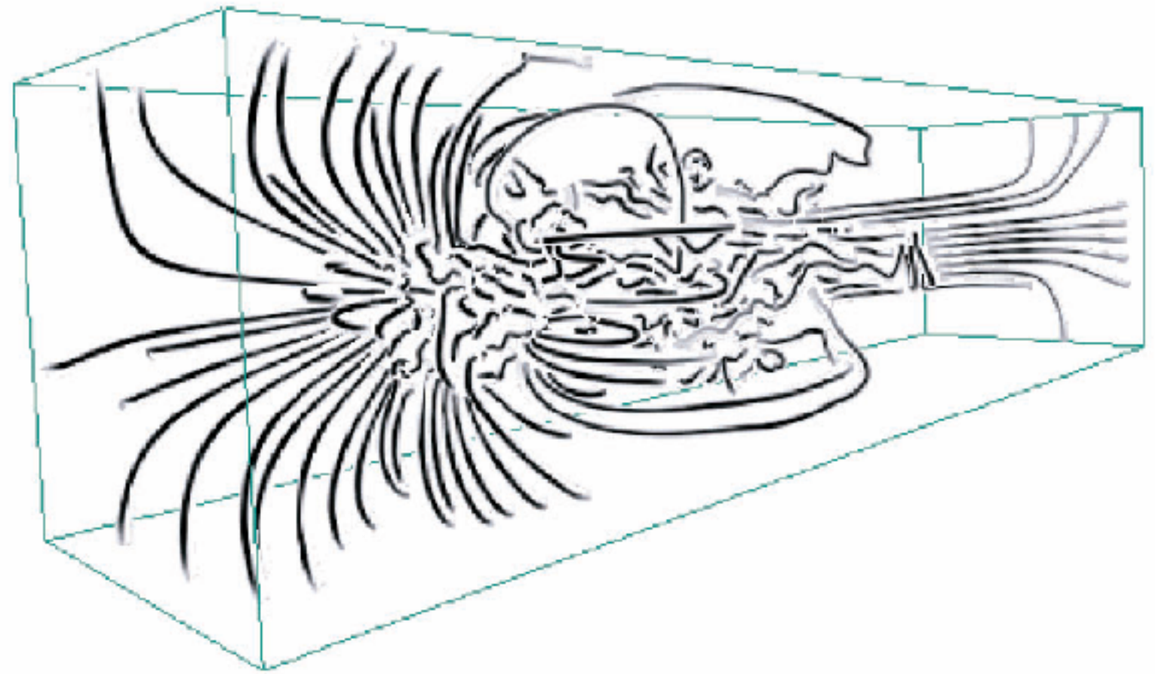
- benefits outweigh costs when task is shape perception for 3D spatial data
  - interactive navigation supports synthesis across many viewpoints

Targets

Spatial Data

→ Shape

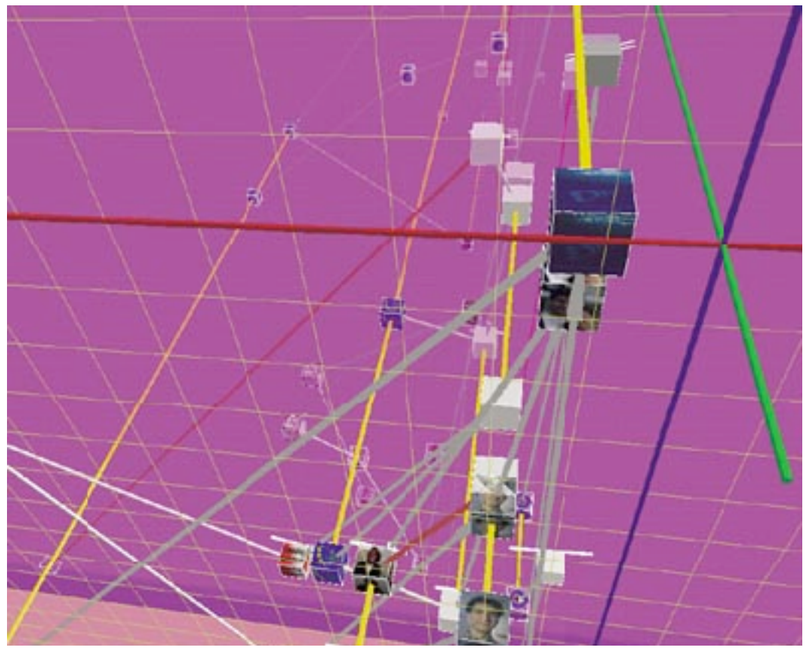




[Image-Based Streamline Generation and Rendering. Li and Shen. IEEE Trans. Visualization and Computer Graphics (TVCG) 13:3 (2007), 630–640.]

No unjustified 3D

- 3D legitimate for true 3D spatial data
- 3D needs very careful justification for abstract data
  - enthusiasm in 1990s, but now skepticism
  - be especially careful with 3D for point clouds or networks



[WEBPATH-a three dimensional Web history. Frecon and Smith. Proc. InfoVis 1999]

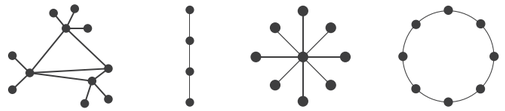
No unjustified 2D

- consider whether network data requires 2D spatial layout
  - especially if reading text is central to task!
  - arranging as network means lower information density and harder label lookup compared to text lists
- benefits outweigh costs when topological structure/context important for task
  - be especially careful for search results, document collections, ontologies

Targets

Network Data

→ Topology



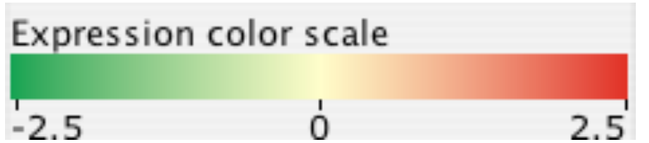
→ *Paths*

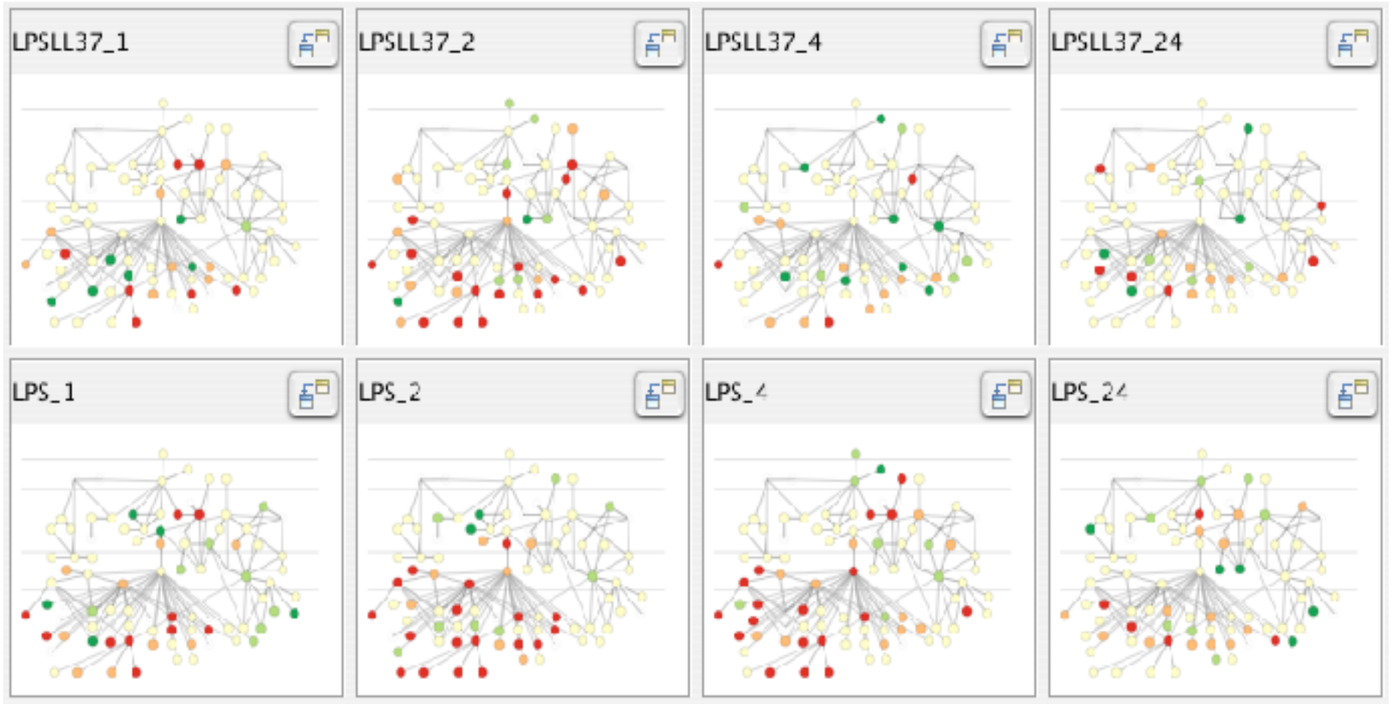
Eyes beat memory

- principle: external cognition vs. internal memory
  - easy to compare by moving eyes between side-by-side views
  - harder to compare visible item to memory of what you saw
- implications for animation
  - great for choreographed storytelling
  - great for transitions between two states
  - poor for many states with changes everywhere
    - consider small multiples instead

Eyes beat memory example: Cerebral

- small multiples: one graph instance per experimental condition
  - same spatial layout
  - color differently, by condition

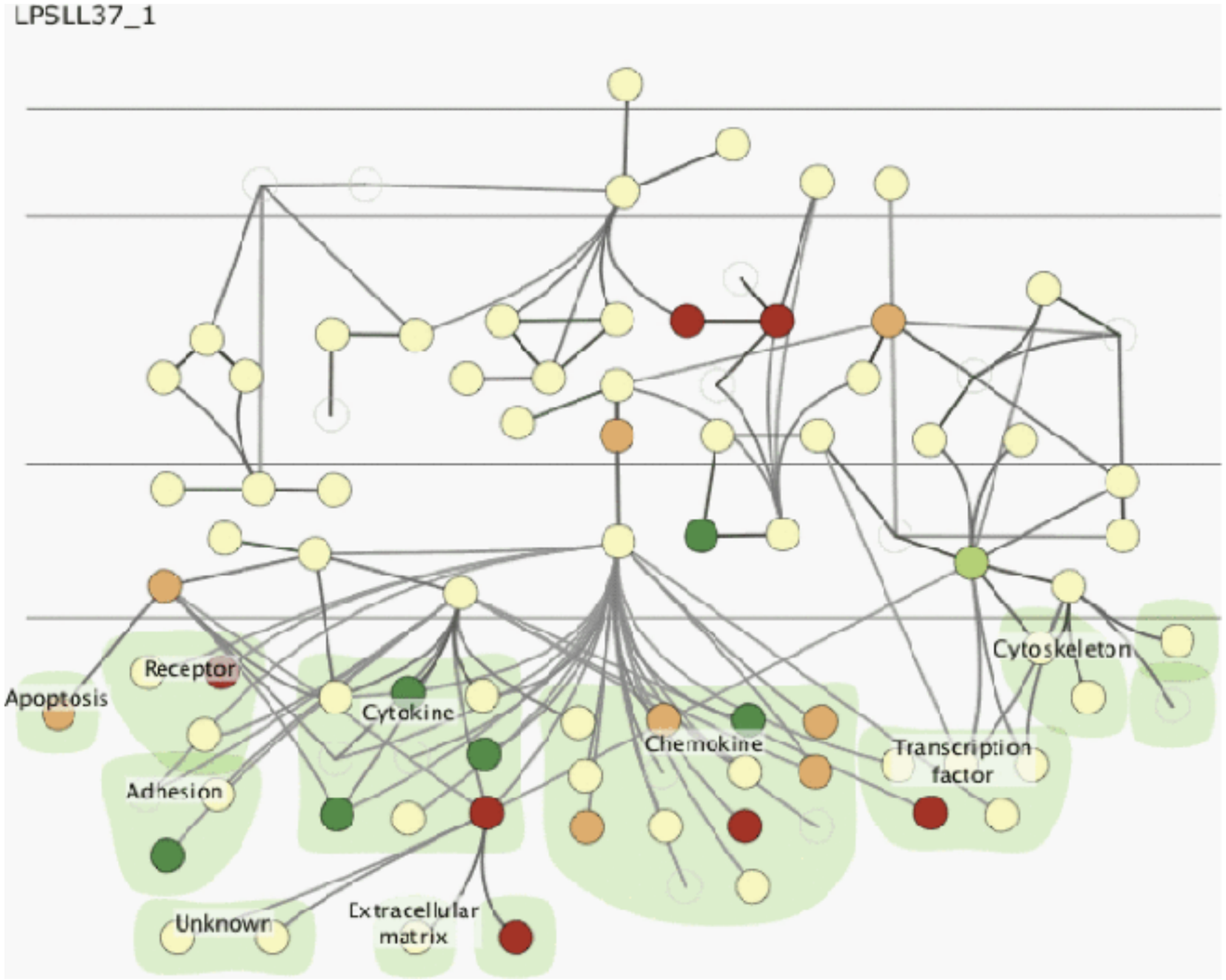




[Cerebral: Visualizing Multiple Experimental Conditions on a Graph with Biological Context. Barsky, Munzner, Gardy, and Kincaid. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2008) 14:6 (2008), 1253–1260.]

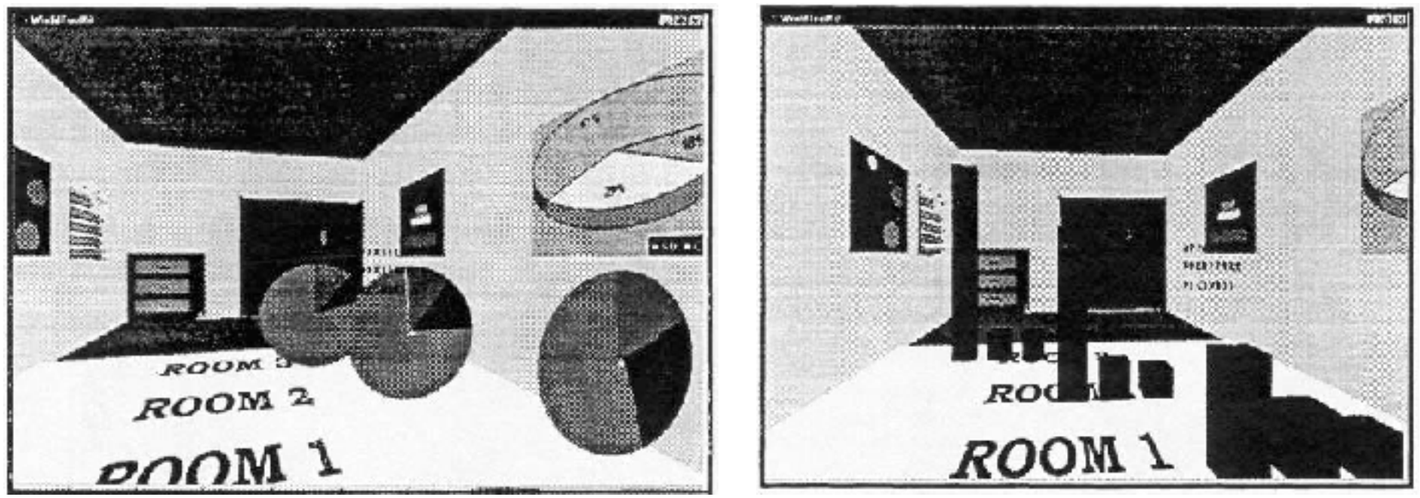
Why not animation?

- disparate frames and regions: comparison difficult
  - vs contiguous frames
  - vs small region
  - vs coherent motion of group
- change blindness
  - even major changes difficult to notice if mental buffer wiped
- safe special case
  - animated transitions



Resolution beats immersion

- immersion typically not helpful for abstract data
  - do not need sense of presence or stereoscopic 3D
- resolution much more important
  - pixels are the scarcest resource
  - desktop also better for workflow integration
- virtual reality for abstract data very difficult to justify



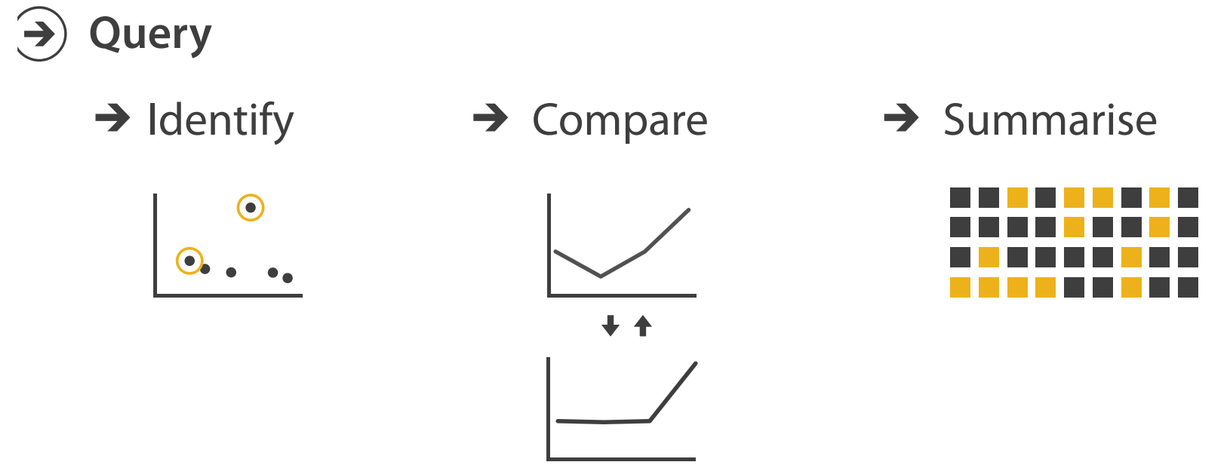
[Development of an information visualization tool using virtual reality. Kirner and Martins. Proc. Symp. Applied Computing 2000]

Overview first, zoom and filter, details on demand

- influential mantra from Shneiderman

[The Eyes Have It: A Task by Data Type Taxonomy for Information Visualizations. Shneiderman. Proc. IEEE Visual Languages, pp. 336–343, 1996.]

- overview = summary
  - microcosm of full vis design problem



- nuances
  - beyond just two levels: multi-scale structure
  - difficult when scale huge: give up on overview and browse local neighborhoods?

[Search, Show Context, Expand on Demand: Supporting Large Graph Exploration with Degree-of-Interest. van Ham and Perer. IEEE Trans. Visualization and Computer Graphics (Proc. InfoVis 2009) 15:6 (2009), 953–960.]

Function first, form next

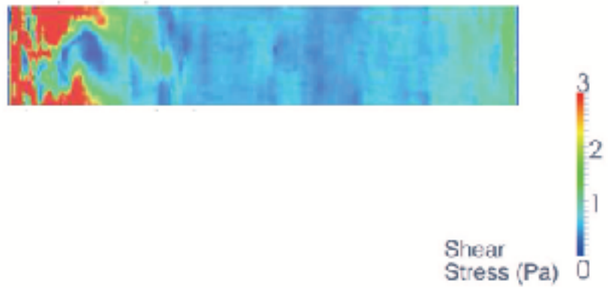
- start with focus on functionality
  - straightforward to improve aesthetics later on, as refinement
  - if no expertise in-house, find good graphic designer to work with

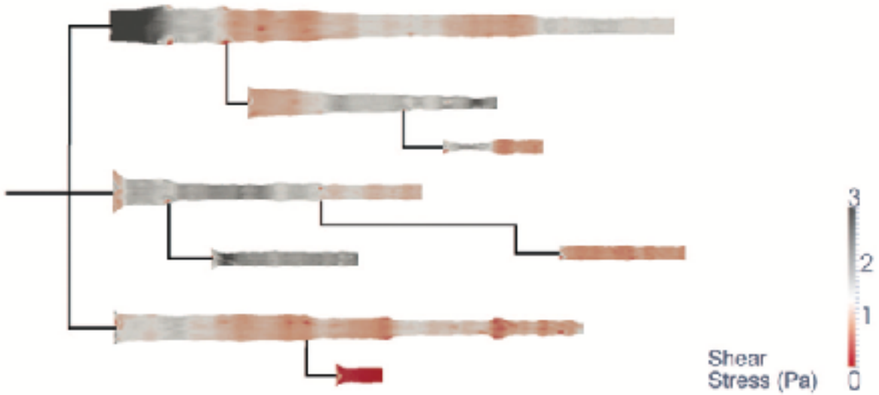
- dangerous to start with aesthetics
  - usually impossible to add function retroactively

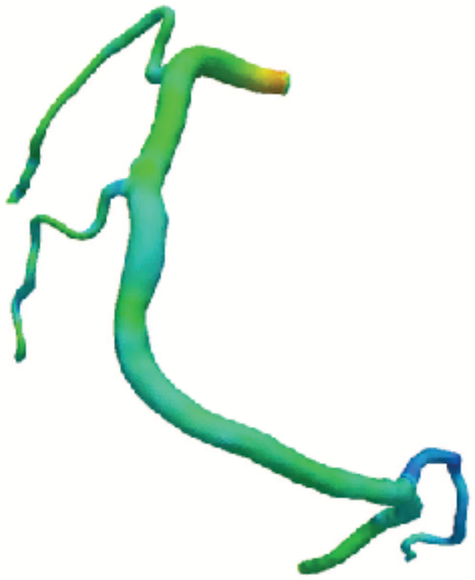
Artery Visualizations for Heart Disease Diagnosis

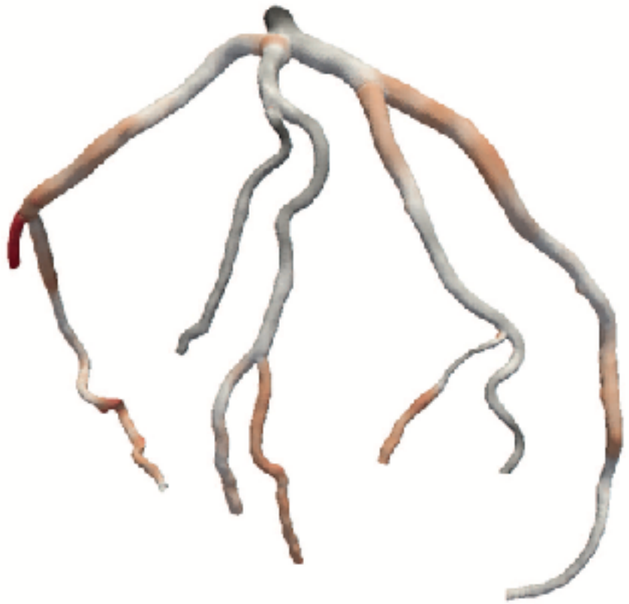
HemoViz: Design study + evaluation

- formative study with experts
  - task taxonomy
- HemoViz design
- deploy attempt fails
  - experts balk: demand 3D and rainbows
- quantitative user study
  - med students, real data
  - 91% with 2D/diverging vs 39% with 3D/rainbows
  - experts willing to use



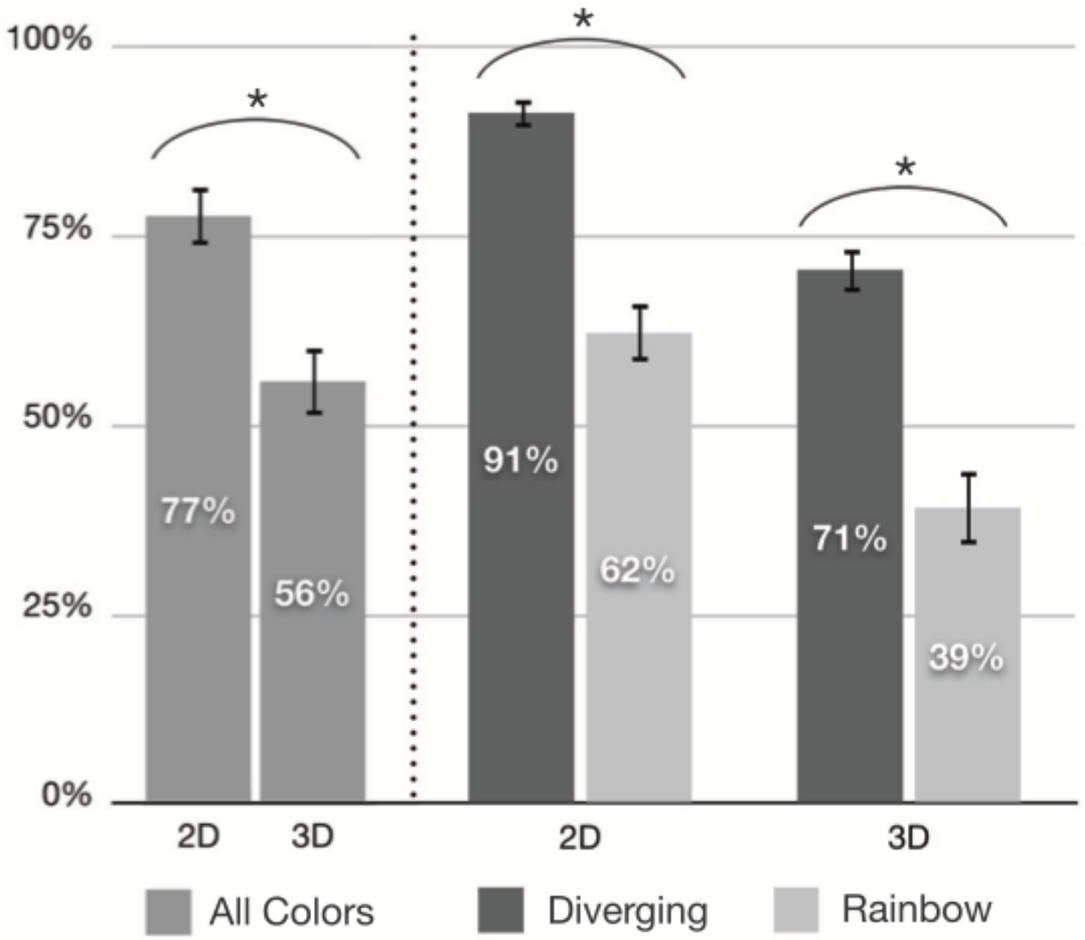


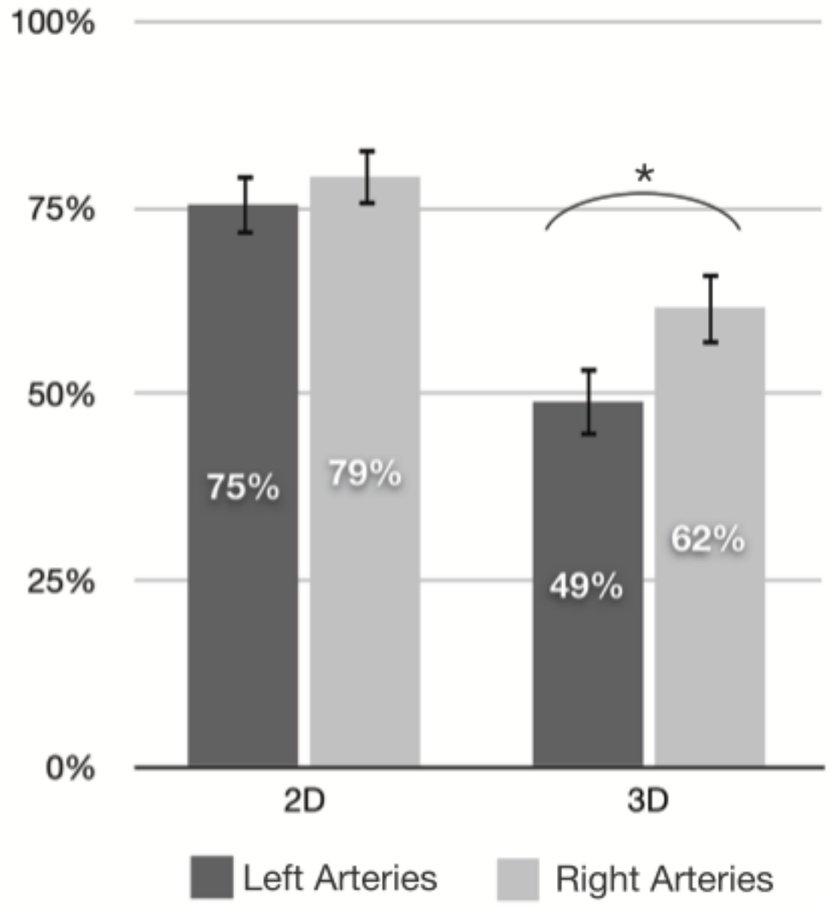




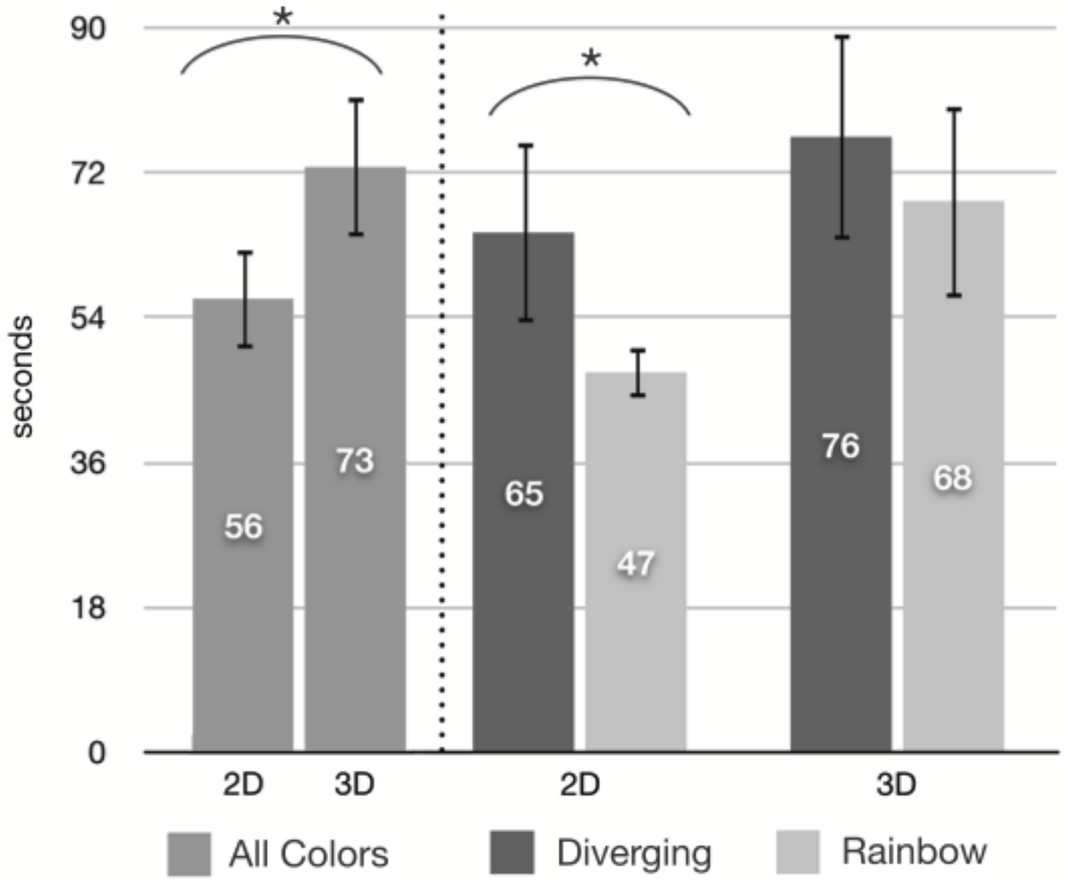
[Fig 1. Borkin et al. Artery Visualizations for Heart Disease Diagnosis. Proc InfoVis 2011.]]

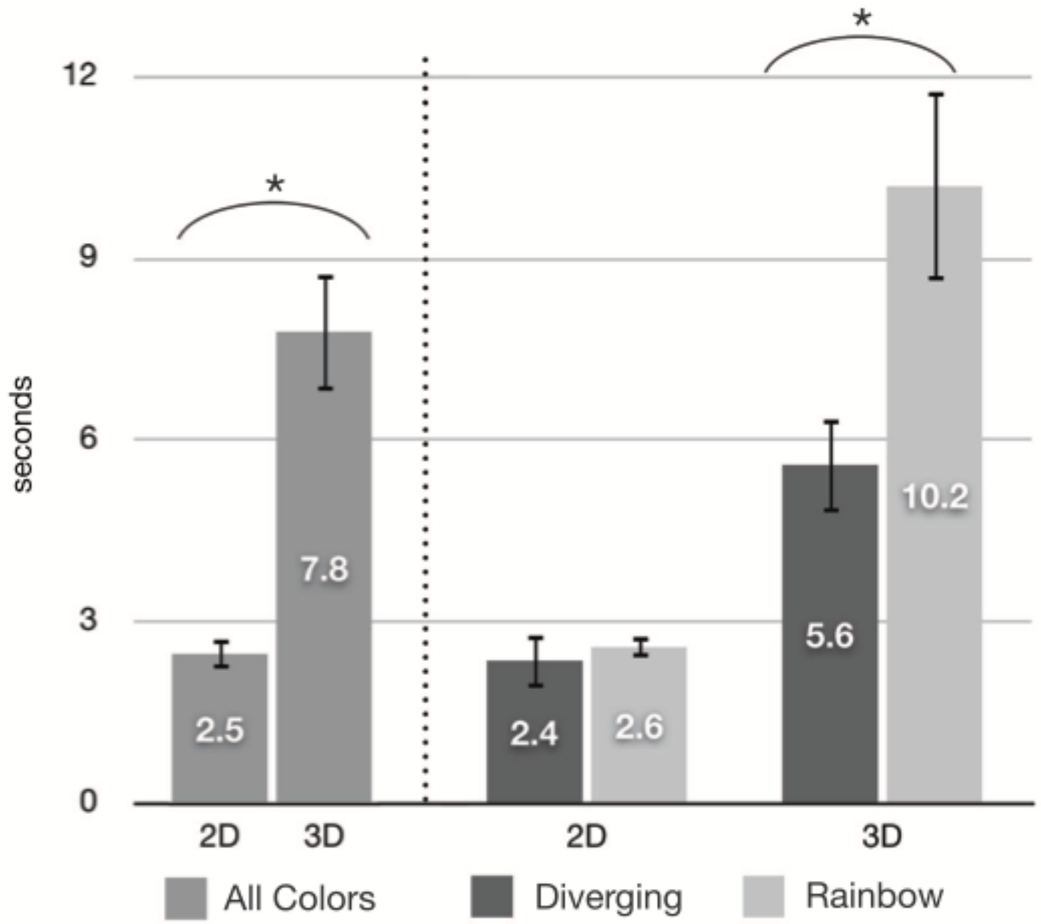
Study results: Error





Study results: Time





Critique

- many strengths
  - careful and well justified design, convincing human-subjects experiment
    - bringing visualization best practices to medical domain
- limitation
  - paper does not clearly communicate why colormap is diverging not sequential
    - answer by email
    - doctors care about extremely high and extremely low ESS (scalar) values
      - high values (top of scale, dark grey): extreme blood flow patterns may relate to heart malfunctions - but not imminently life threatening and don't indicate plaque locations
      - low values (bottom of scale, dark red): very diseased regions with lots of plaque, docs care a lot!
      - much debate from doctors on where is boundary between "normal" and "low" ESS values
        - » most think below 3 Pa are indicative of disease but many argue other values in the 2-4 range
        - » all docs agree that values below 2 Pa are increasingly dangerous disease levels
        - » thus map has transition at 3 Pa for the diverging point and truly red below 2 Pa
    - why continuous not segmented?
      - doctors gain tremendous insight by seeing the subtle patterning of the ESS values
      - particularly varying values in red region - patterns help them understand disease progression and severity
        - » especially useful for deciding what types of interventions to prescribe for the patient

Papers: Types, Reading Strategies

Paper types

- each has different contributions, validation methods, structure
  - design studies
  - technique/algorithm
  - evaluation
  - model/taxonomy
  - system

http://ieeevis.org/year/2019/info/call-participation/infovis-paper-types

Paper types: Validation

- design studies
  - qualitative discussion of result images/videos
  - abstraction & idiom validation: case studies, field studies, design justification
- technique/algorithm
  - qualitative discussion of result images/videos
  - algorithm validation for algorithm papers: computational benchmarks
  - idiom validation for technique papers: controlled experiments
- evaluation
  - (controlled experiment as primary contribution)
- theory/model/taxonomy
  - *show power: descriptive, generative, evaluative, (predictive)*
- system
  - *show power for developer using system*

Paper structures

- typical research paper vs expectations for this course final report
  - more on implementation
  - novel research contribution not required

http://www.cs.ubc.ca/~tmm/courses/547-19/projectdesc.html#outlines

Reading visualization papers

- one strategy: multiple passes
  - title
  - abstract, authors/affiliation
  - flip through, glance at figures, notice structure from section titles
  - skim intro, results/discussion (maybe conclusion)
  - fast read to get big ideas
    - if you don't get something, just keep going
  - second pass to work through details
    - later parts may cast light on earlier parts for badly structured papers
  - third pass to dig deep
    - if it's highly relevant, or you're presenting it to class
- literature search
  - decide when to stop reading: is this relevant to my current concerns?

Literature search

- this course: I will give you seed papers during our 1on1 meetings
- forwards vs backwards search
  - Google Scholar forward citations!
  - only a subset of forwards & backwards citations will be what you need
- building up landscape
  - authors/affiliations will have more signal as you develop expertise

In-Class Exercise: Decoding

Reading for Next Time

- VAD book Ch 7: Arrange Tables
- VAD book Ch 10: Map Color and Other Channels
- paper: D3 (Data-Driven Documents)
  - [type: system]