The University of Nottingham
UNITED KINGDOM · CHINA · MALAYSIA

G53FIV: Fundamentals of Information Visualization

Lecture 8: Visualization Tools and Visual Perception

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https://moodle.nottingham.ac.uk/course/view.php?id=68644

Overview

- Visualization Tools
- Visual Perception

Visualization Tools

Dr. Ke Zhou (http://www.cs.nott.ac.uk/~pszkz/)

Visualization Tools

Chart Typologies
Excel, Many Eyes, Google Charts

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Component Architectures
Prefuse, Flare, Improvise, VTK

Graphics APIs
Processing, OpenGL, Java2D

Visualization Tools

Chart Typologies
Excel, Many Eyes, Google Charts

Charting Tools

Visual Analysis Grammars
VizQL, ggplot2

Visualization Grammars
Protovis, D3.js

Declarative Languages

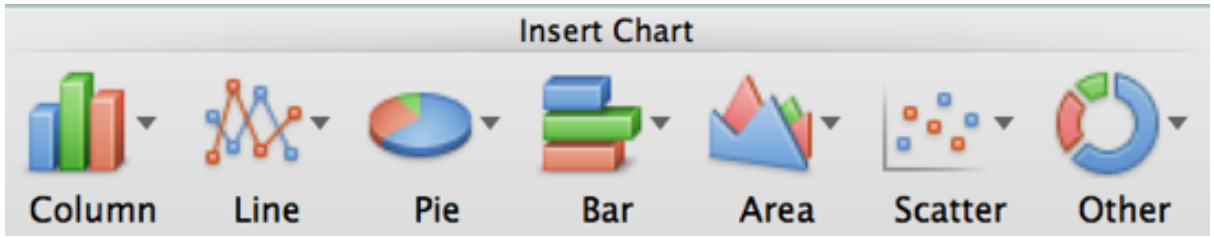
Component Architectures
Prefuse, Flare, Improvise, VTK

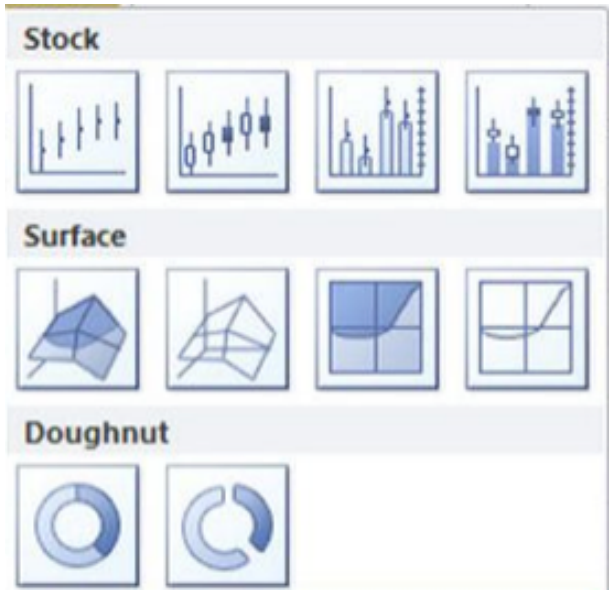
Graphics APIs
Processing, OpenGL, Java2D

Programming Toolkits

Chart Typology (Charting Tools)

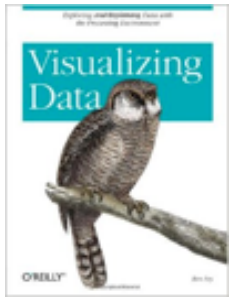
- Pick from a stock of templates
- Easy-to-use but limited expressiveness
- Prohibits novel designs, new data types

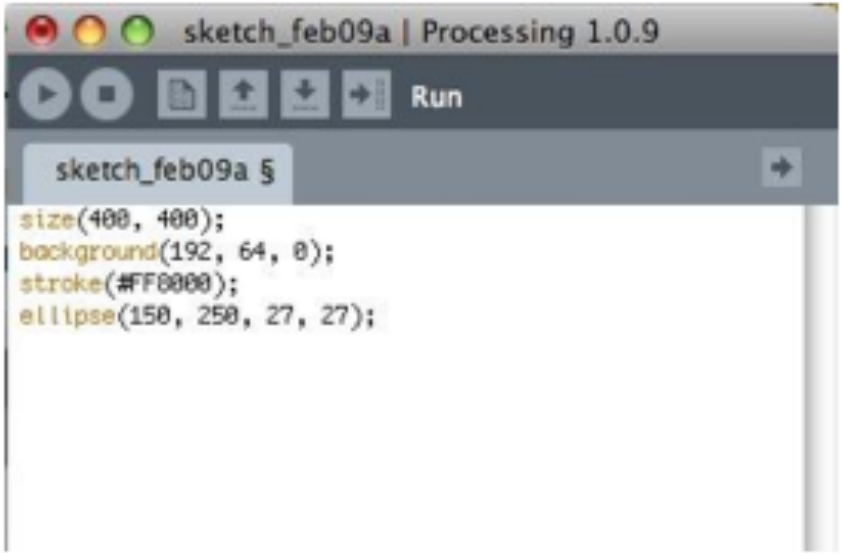


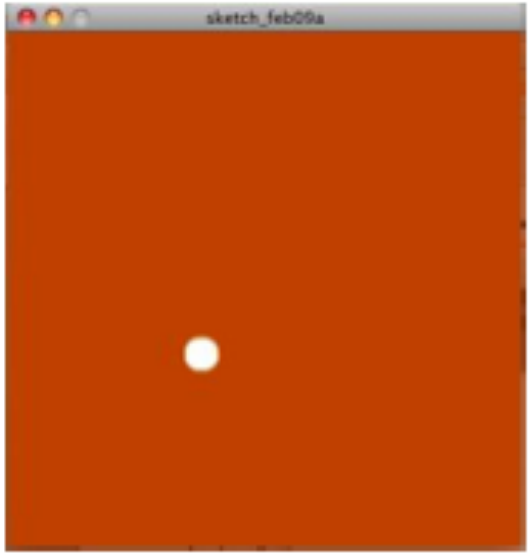


Graphics APIs (Programming Toolkits)

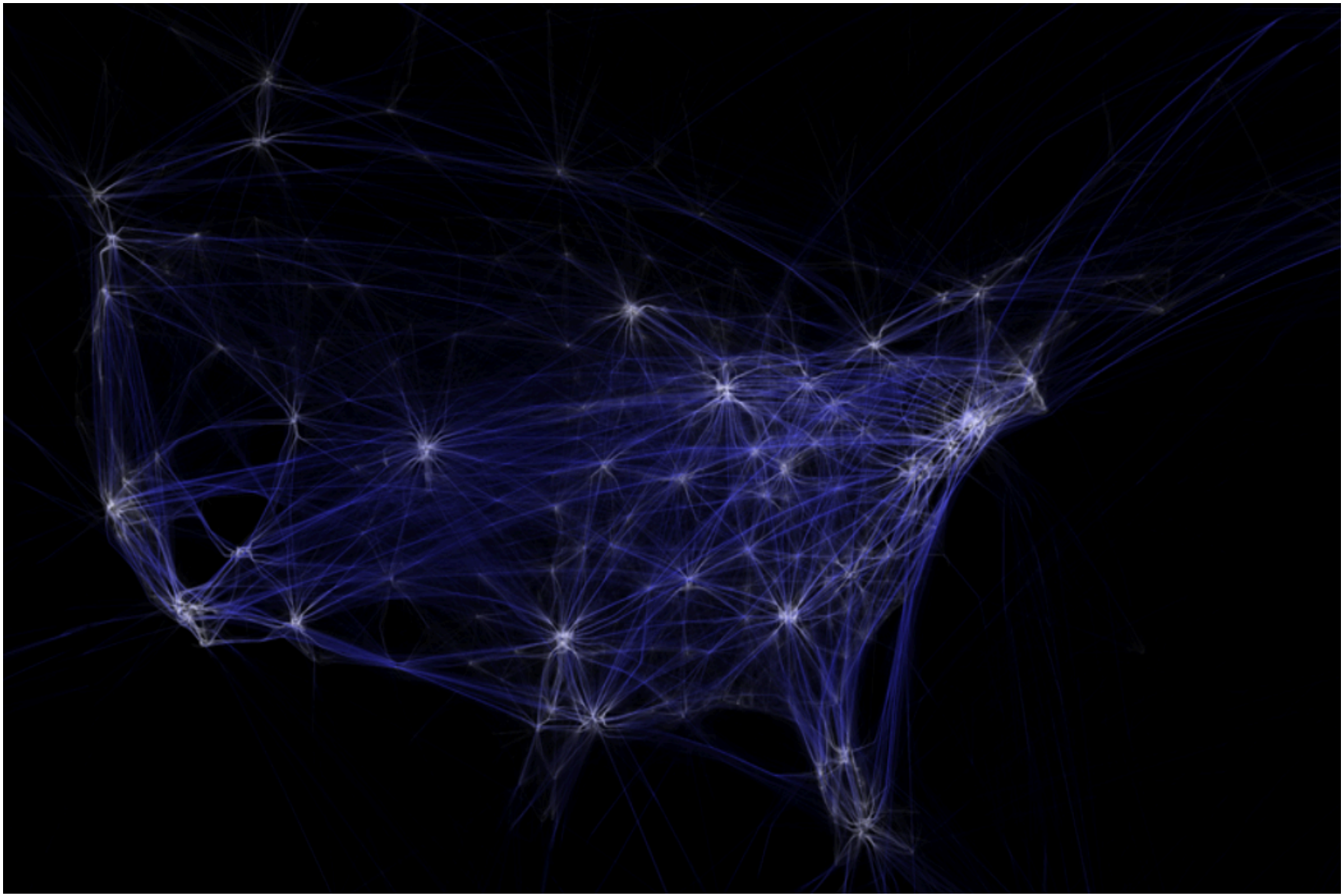
- Processing.org
  - Java based
  - not specifically designed for InfoVis
  - Well documented, lots of tutorials (even books)







Graphics APIs can be very powerful



US Air Traffic Visualization

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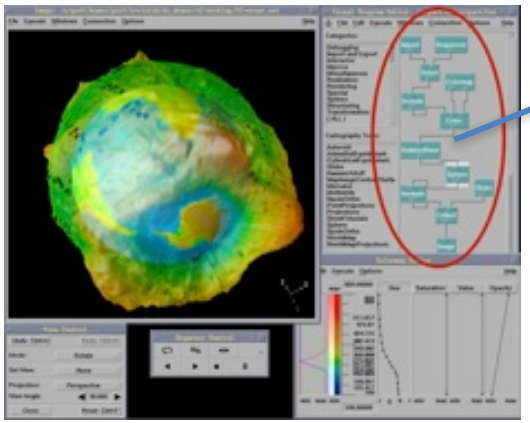
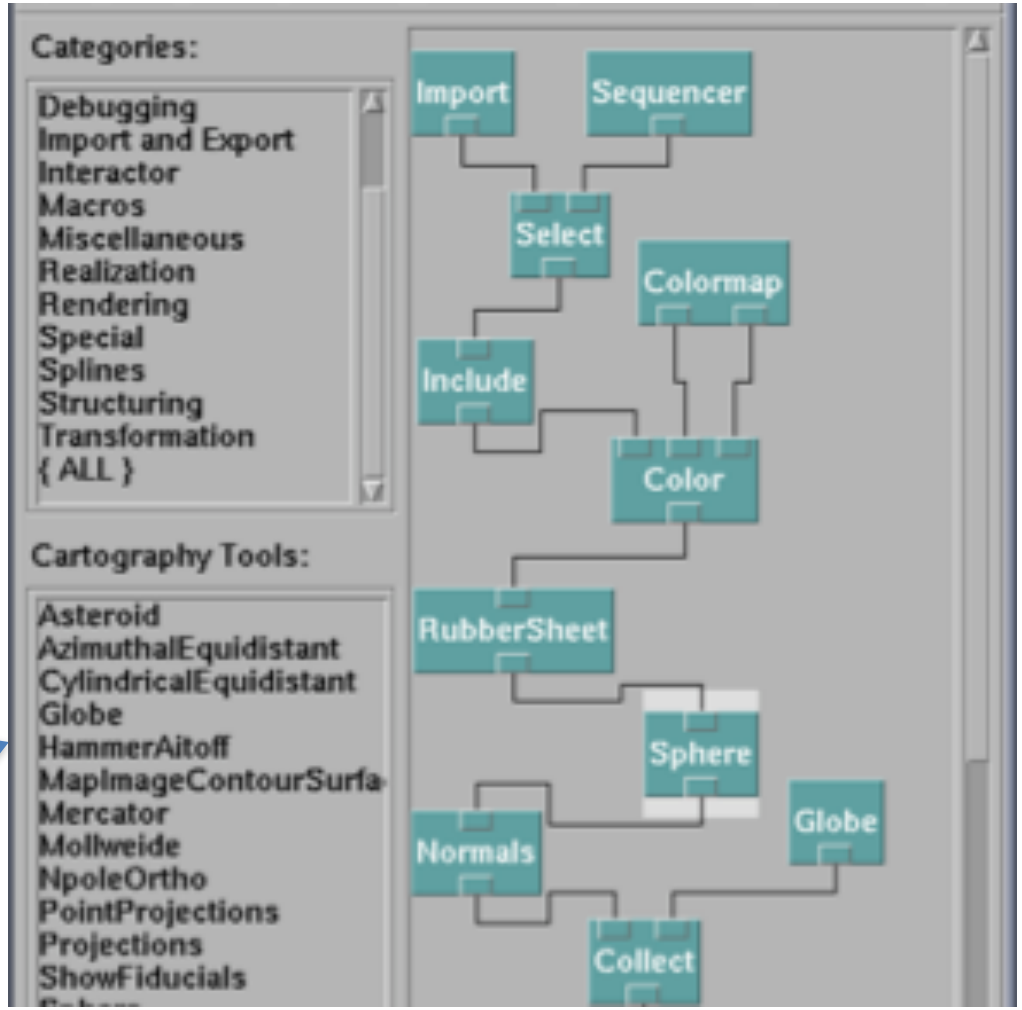
Component Architectures (Programming Toolkits)

- Permits more combinatorial possibilities
- Novel views require new operators, which requires software engineering.

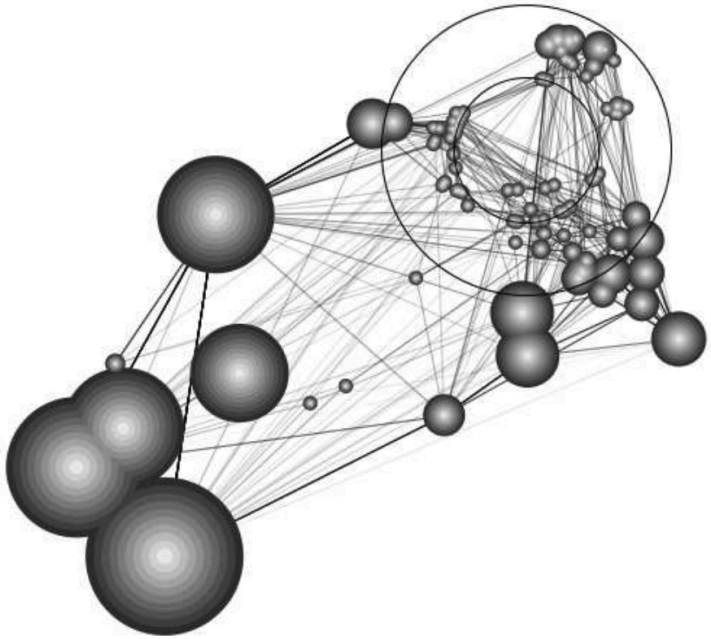




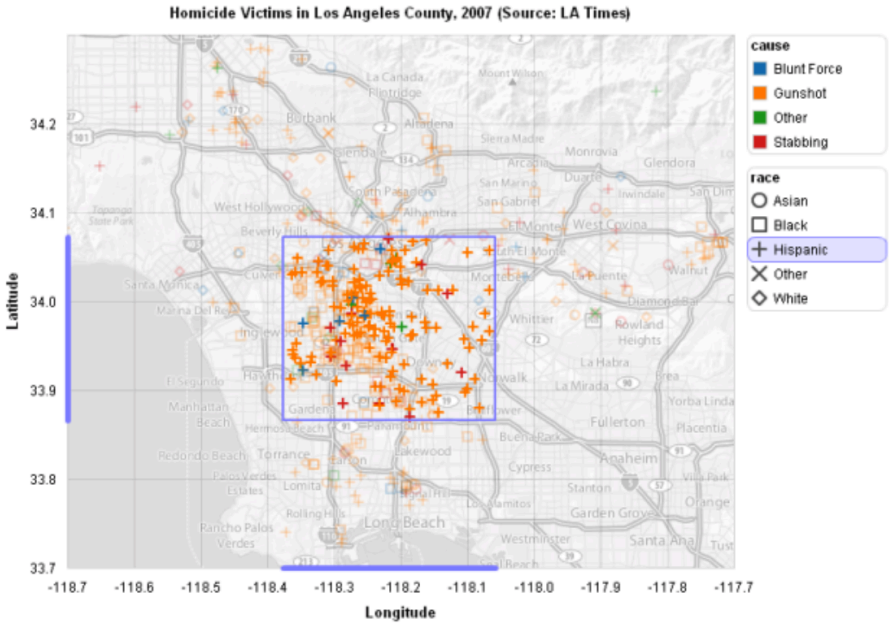
Dr. Ke Zhou (http://www.cs.nott.ac.uk/~pszkz/)

Prefuse & Flare

- Operator-based toolkits for visualization design
  Vis = (Input Data -> Visual Objects) + Operators



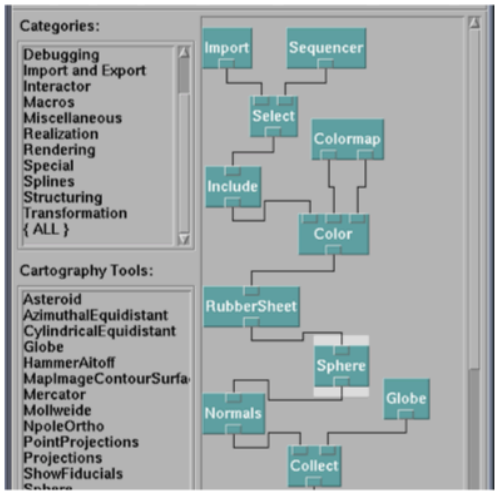
Prefuse (http://prefuse.org)



Flare (http://flare.prefuse.org)

Dr. Ke Zhou (http://www.cs.nott.ac.uk/~pszkz/)

Comparison



- **Chart Typology**
  - Pick from a stock of templates
  - Easy-to-use but limited expressiveness
  - Prohibits novel designs, new data types
- **Component Architecture**
  - Permits more combinatorial possibilities
  - Novel views require new operators, which requires software engineering.

The Grammar of Graphics (Declarative Languages)

- Programming by describing what, not how
- Separate specification (what you want) from execution (how it should be computed)
- In contrast to imperative programming, where you must give explicit steps.

```
d3.selectAll("rect")
  .data(my_data)
 .enter().append("rect")
  .attr("x", function(d) { return xscale(d.foo); })
  .attr("y", function(d) { return yscale(d.bar); })
```

Building a Plot in ggplot2

data to visualize (a data frame)

map variables to ***aes***thetic attributes

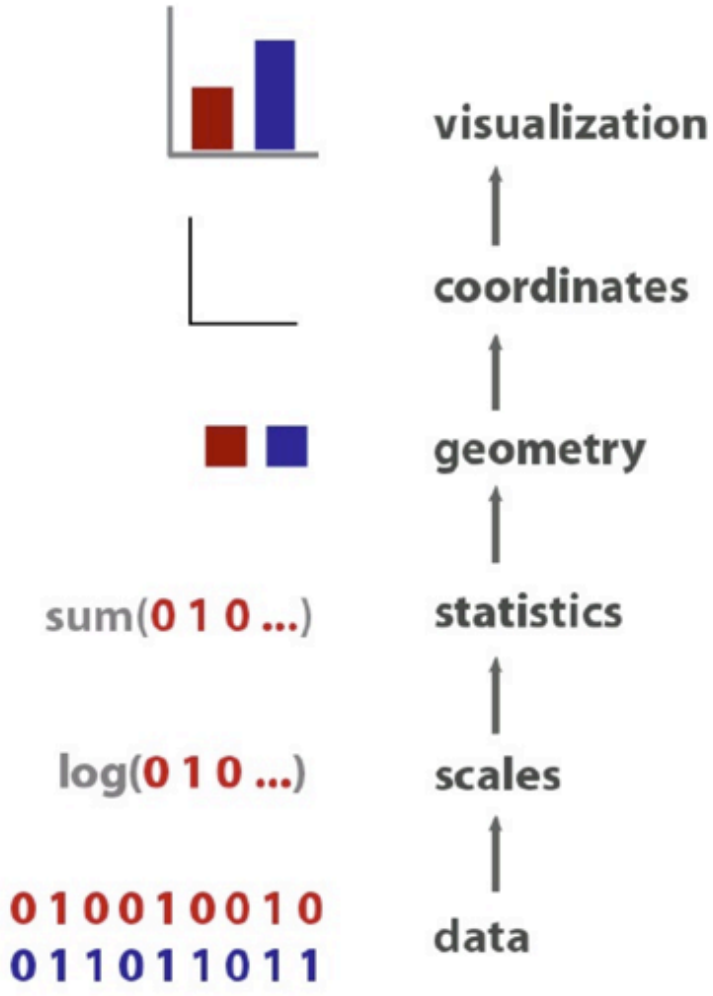
geometric objects – what you see (points, bars, etc)

scales map values from data to aesthetic space

faceting subsets the data to show multiple plots

statistical transformations – summarize data

coordinate systems put data on plane of graphic



Wickham 2009

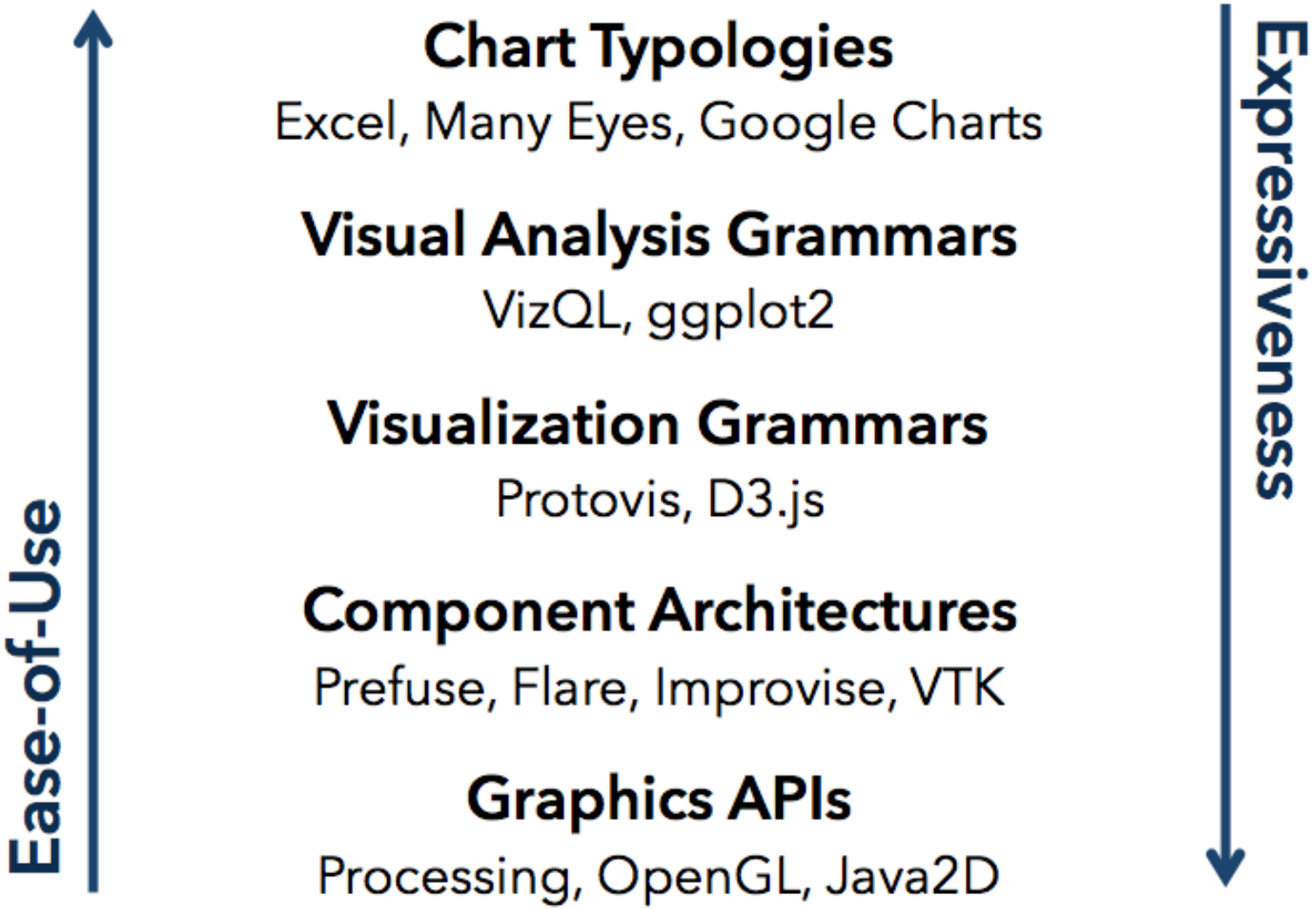
The Advantages of Declarative Languages

- **Faster iteration**. Less code. Larger user base.
- **Better visualization**. Smart defaults.
- **Reuse**. Write-once, then re-apply.
- **Performance**. Optimization, scalability.
- **Portability**. Multiple devices, renderers, inputs.
- **Programmatic generation**. Write programs which output visualizations. Automated search & recommendation.

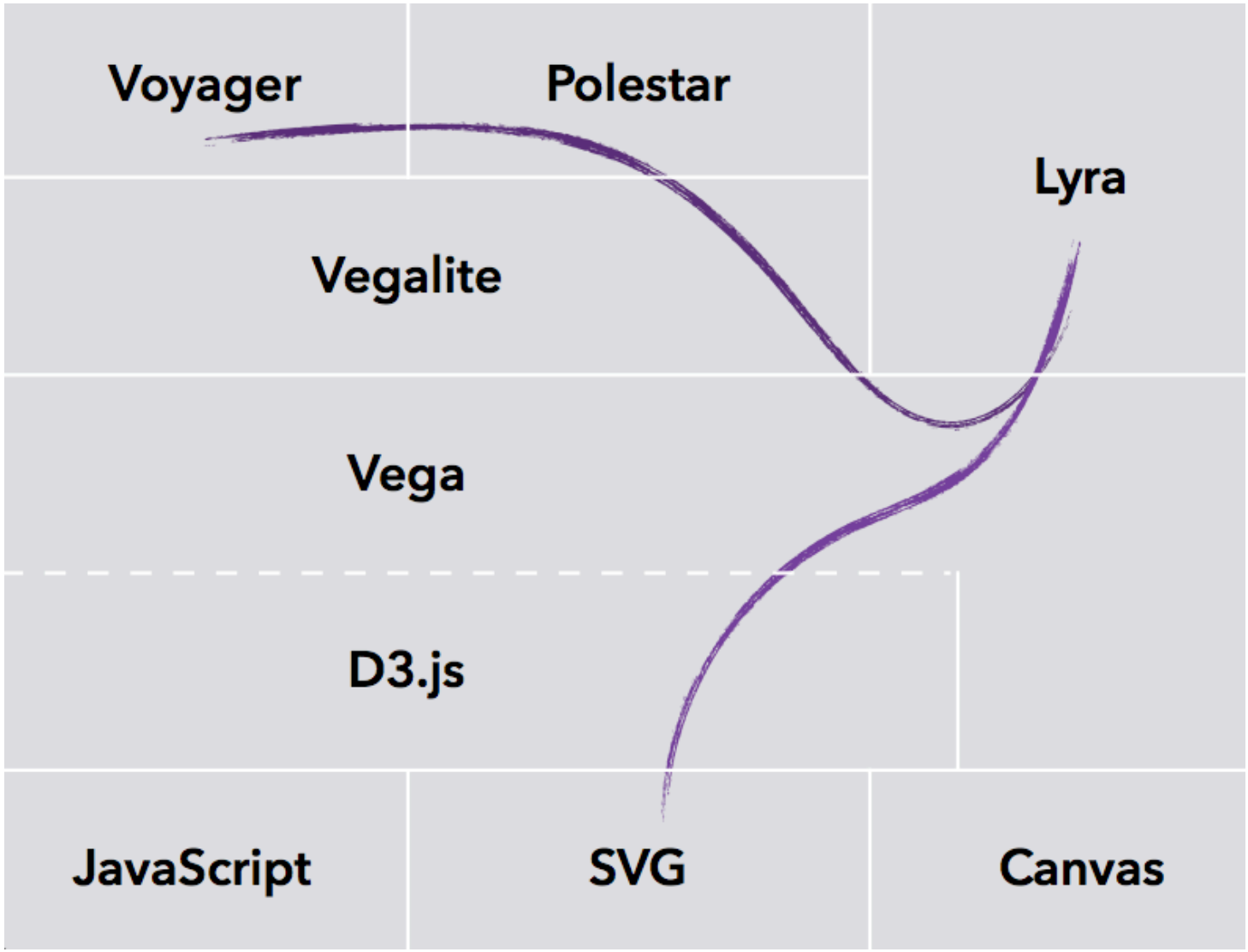
Tools Tradeoffs

- InfoVis-focused
  - Many fundamental techniques built-in
  - Can be faster to get something going
  - Often more difficult to implement something "different"
  - Documentation?
- Generic Graphics
  - More flexible
  - Can customize better
  - Big learning curve
  - Doc is often better
  - Can take a long time to (re)implement basic techniques

Visualization Tools



Many Tools Developed by Prof. Jeffrey Heer, University of Washington



This is just a reference point.
You should try those information visualization tools out
(optional for those who don't take G53IVP)!

(Optional) Resources

- D3 tutorial: https://uwdata.github.io/d3-tutorials/
- Vega tutorial: https://github.com/vega/vega/wiki/Tutorial
- Please start working on the course work using R.

Visual Perception

The ability of viewers to interpret visual encodings of information and thereby decode information in graphs.

Dr. Ke Zhou (http://www.cs.nott.ac.uk/~pszkz/)

Related Disciplines

- Psychophysics
  - Applying methods of physics to measuring human perceptual systems
    - How fast must light flicker until we perceive it as constant?
    - What change in brightness can we perceive?
- Cognitive psychology
  - Understanding how people think, here, how it relates to perception

Effectiveness Ranking

Dr. Ke Zhou (http://www.cs.nott.ac.uk/~pszkz/)

Detecting Brightness

Which one is brighter?

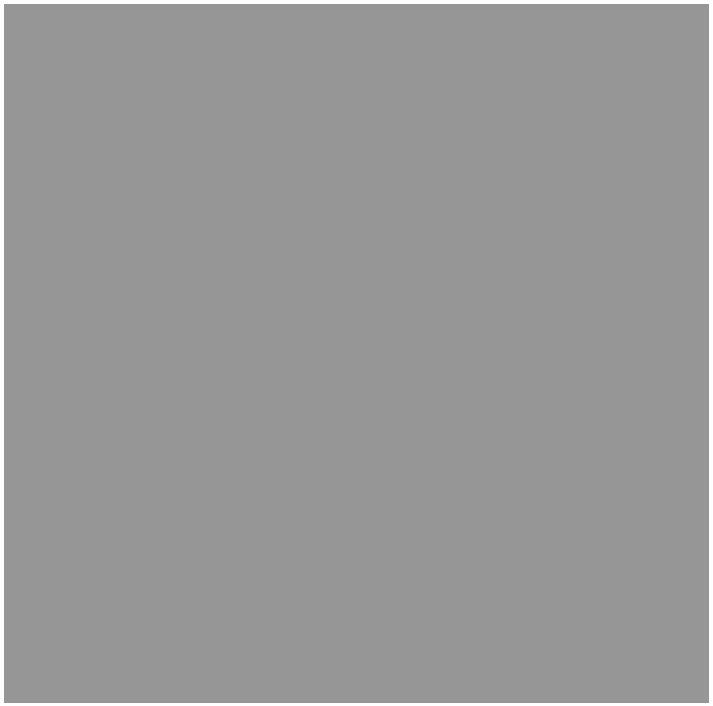
Detecting Brightness

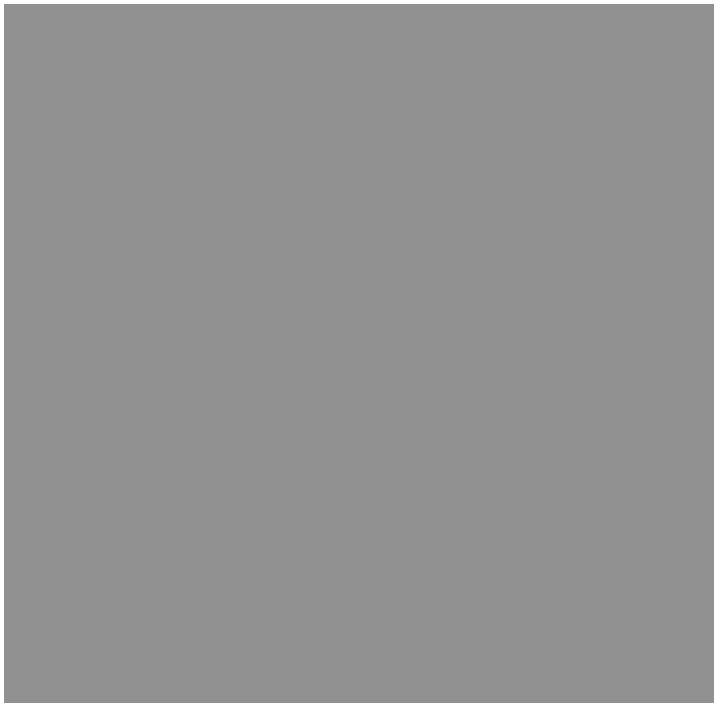
(128,128,128)

(144,144,144)

Which one is brighter?

Detecting Brightness

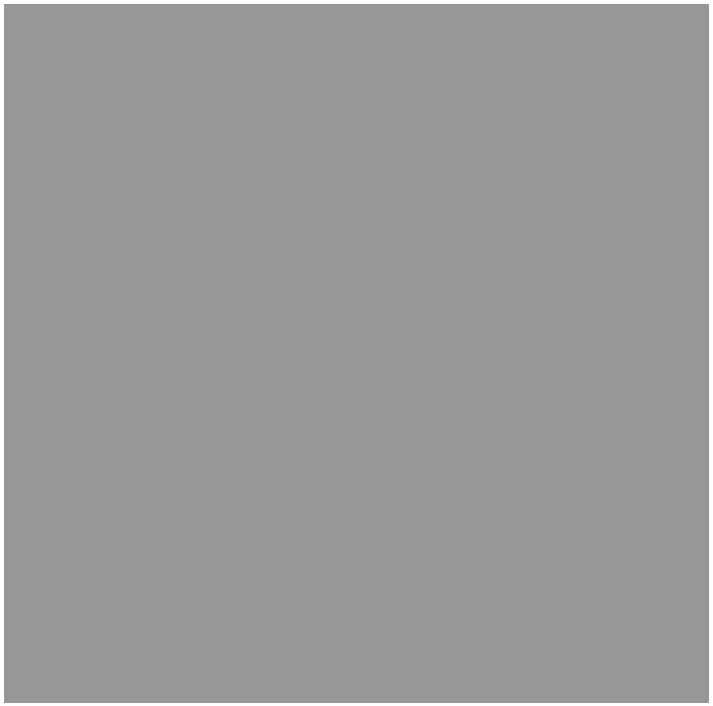




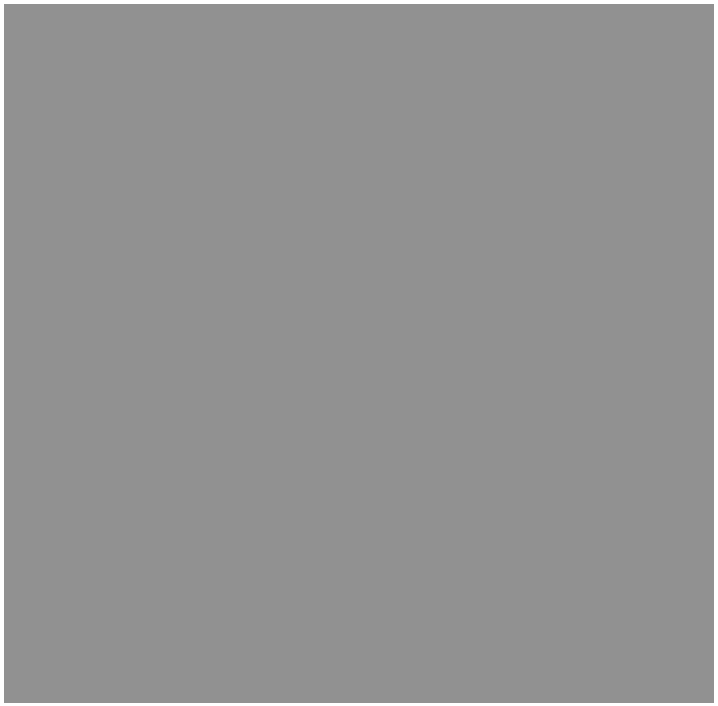
Which one is brighter?

Detecting Brightness

(134,134,134)



(128,128,128)



- Ratios more important than magnitude
- Most continuous variation in stimuli are perceived in discrete steps

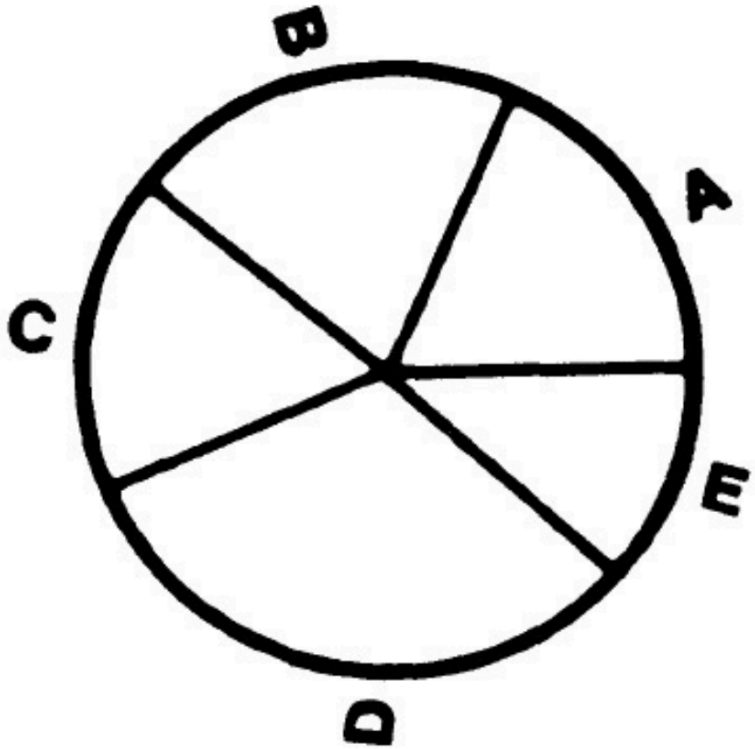
Estimating Magnitude

Compare length of bars

Estimating Magnitude

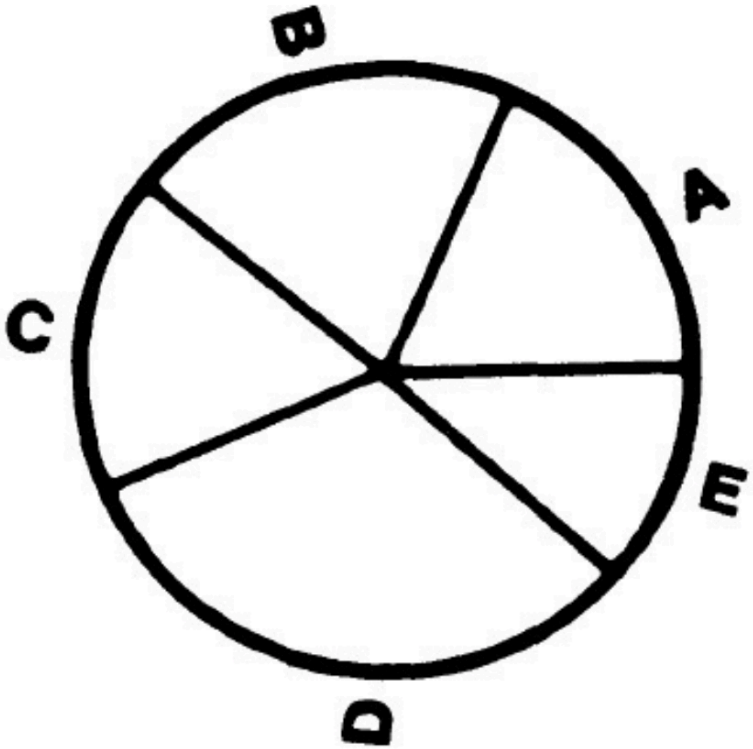
Compare length of bars

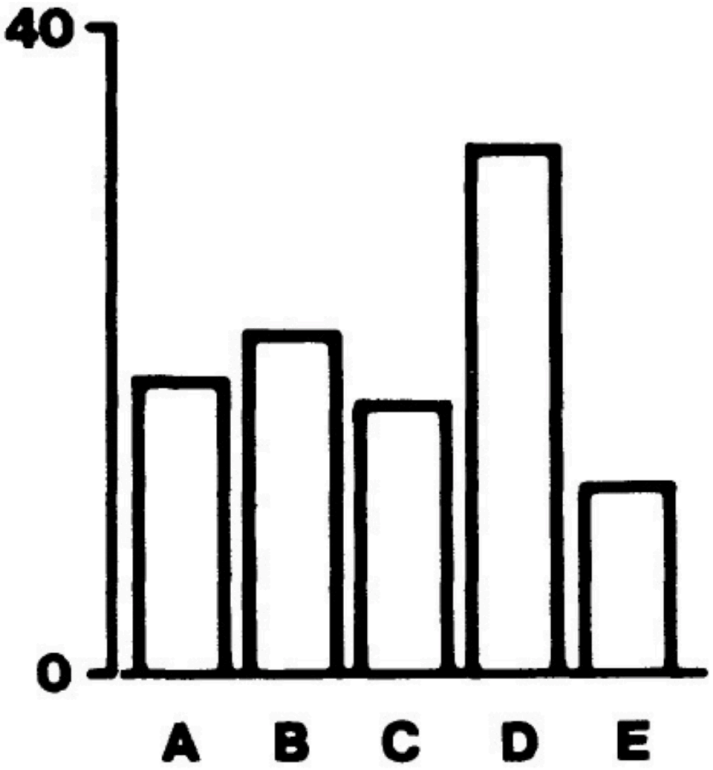
Estimating Magnitude



Which section is bigger? A or C?

Estimating Magnitude

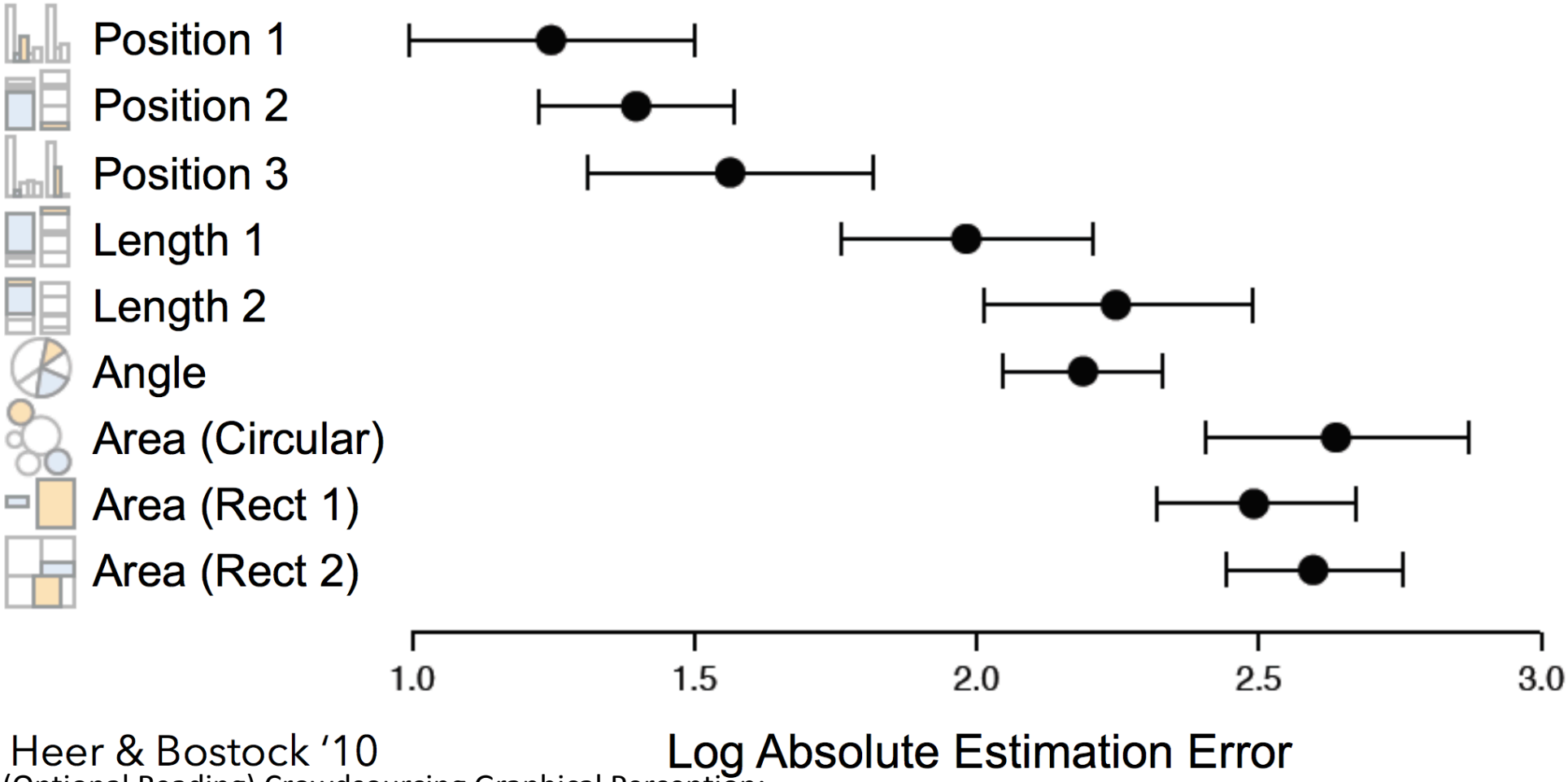




Which section is bigger? A or C?

Graphical Perception Experiments

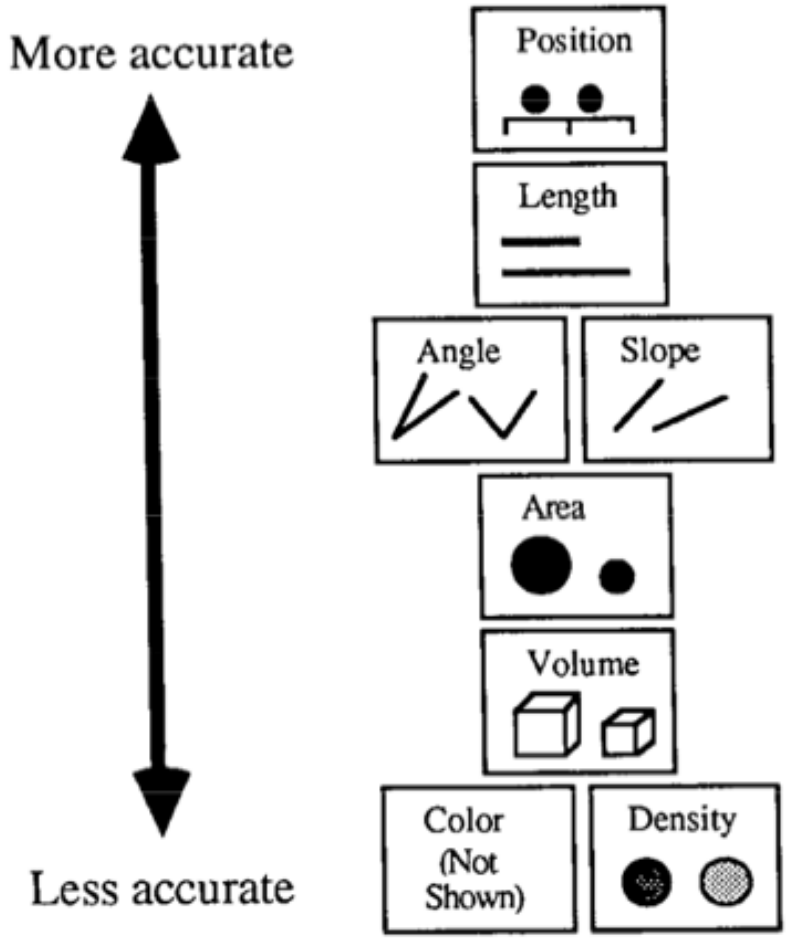
- Empirical estimates of encoding effectiveness



Heer & Bostock '10

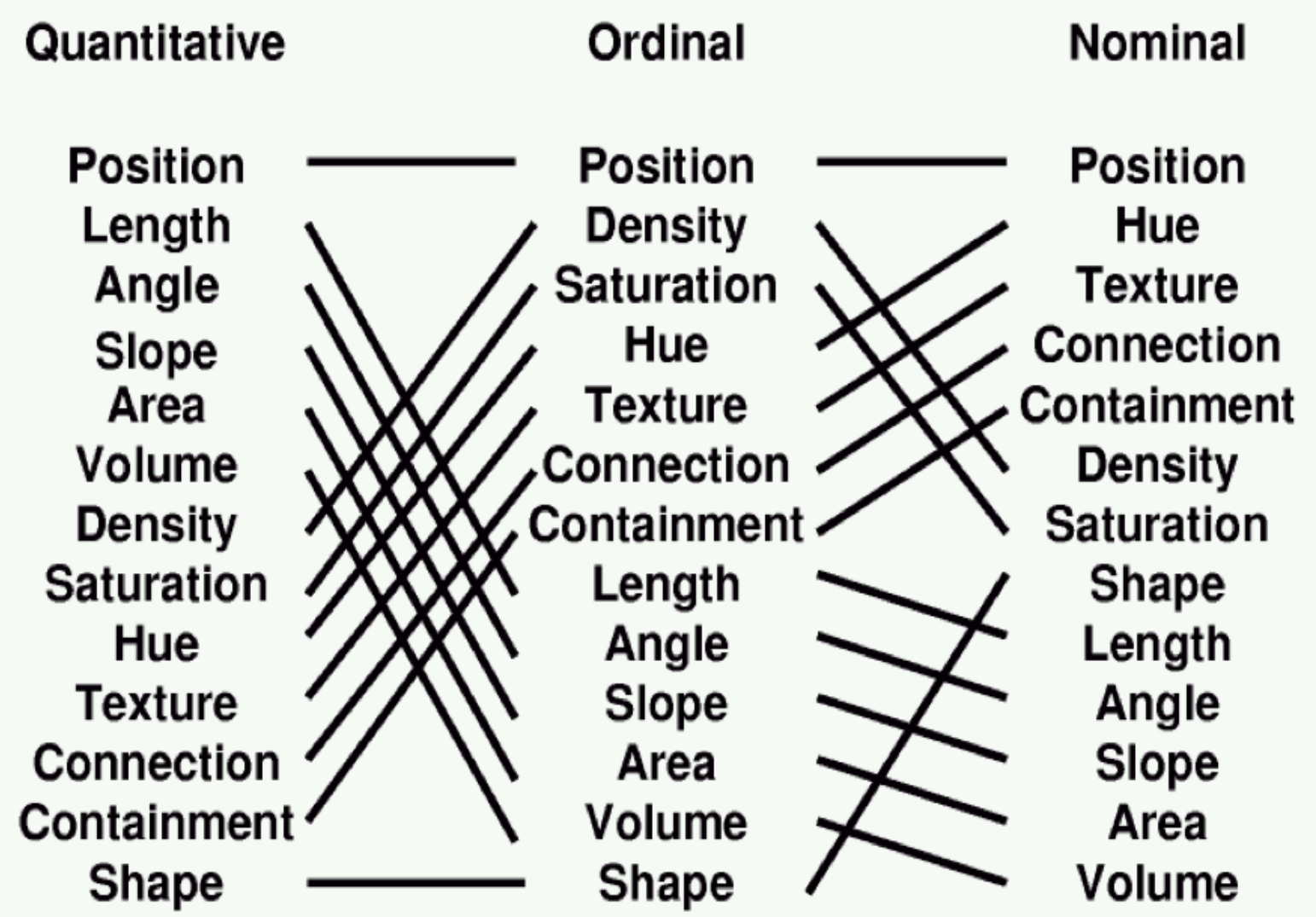
(Optional Reading) Crowdsourcing Graphical Perception: Using Mechanical Turk to Assess Visualization Design

Effectiveness: Accuracy Ranking



Mackinlay, Automating the design of graphical presentations of relational information, 1986.

Conjectured Effectiveness of Encodings by Data Type



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Perceptual Processing

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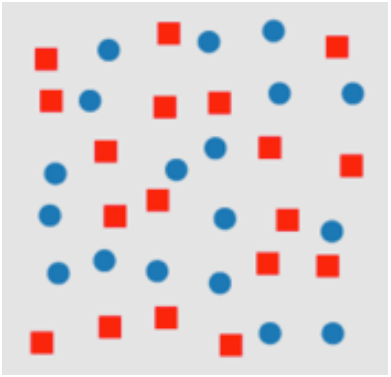
Perceptual Processing Model

- Two stage process
  - Parallel extraction of low-level properties of scene
  - Sequential goal-directed processing



Stage 1

Early, parallel detection of color, texture, shape, spatial attributes

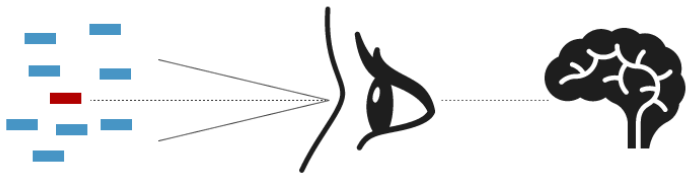
Stage 2

Serial processing of object identification (using memory) and spatial layout, action

Information visualization: Perception for Design (3rd Edition), Colin Ware

Stage 1: Pre-attentive Processing - Low-level, Parallel

- Neurons in eye & brain responsible for different kinds of information
  - Orientation, color, texture, movement, etc.
- Arrays of neurons work in parallel, occurs "automatically" and rapidly
  - Generally less than 200-250 msecs
- Information is transitory, briefly held in iconic store
- Bottom-up data-driven model of processing
- Often called "pre-attentive" processing, i.e. without the need for focused attention

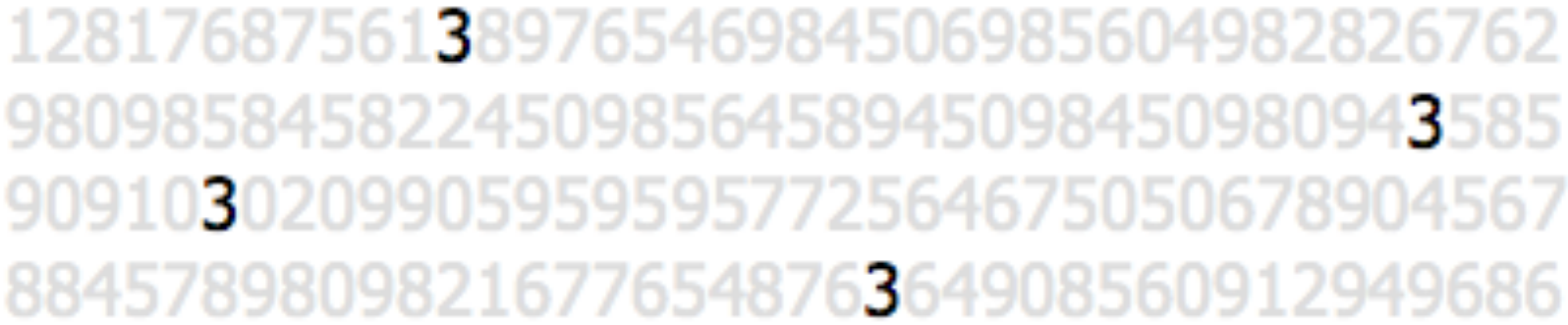


Stage 2 - Sequential, Goal-Directed

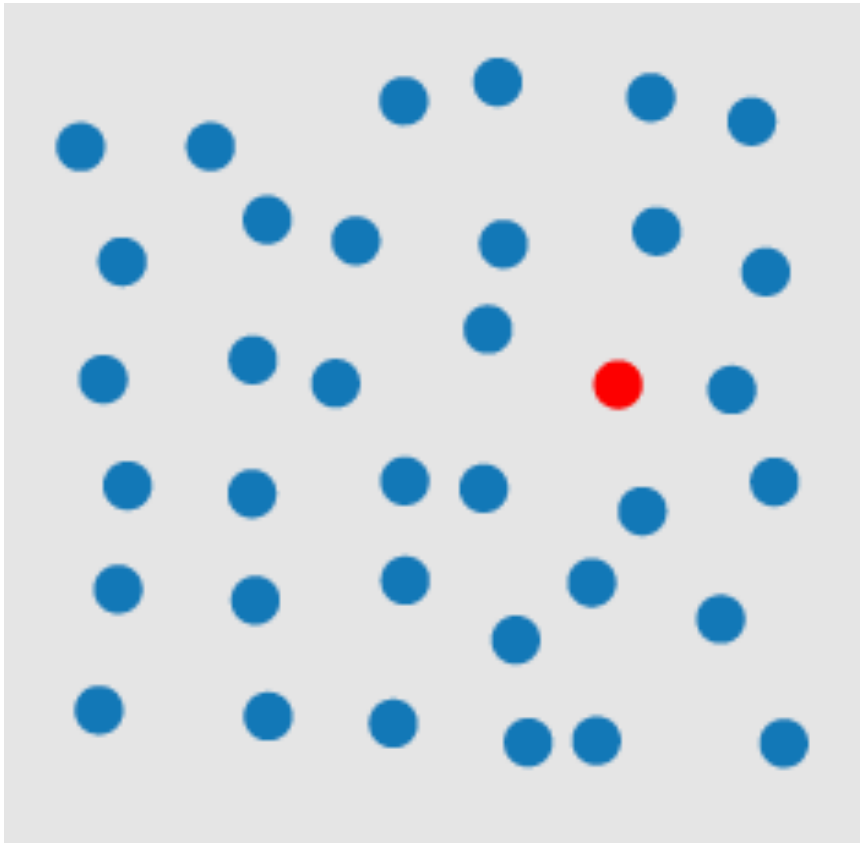
- Splits into subsystems for object recognition and for interacting with environment
- Increasing evidence supports independence of systems for symbolic object manipulation and for locomotion & action
- First subsystem then interfaces to verbal linguistic portion of brain, second interfaces to motor systems that control muscle movements
- Slow serial processing
- Involves working and long-term memory

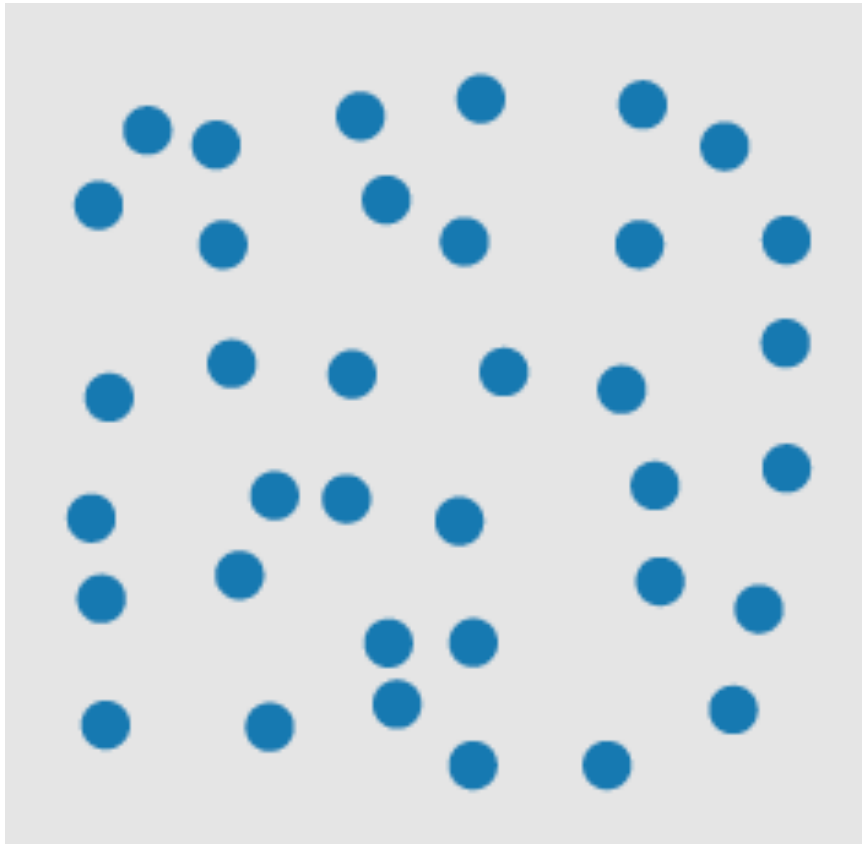
Pre-attentive Processing

How many 3's?



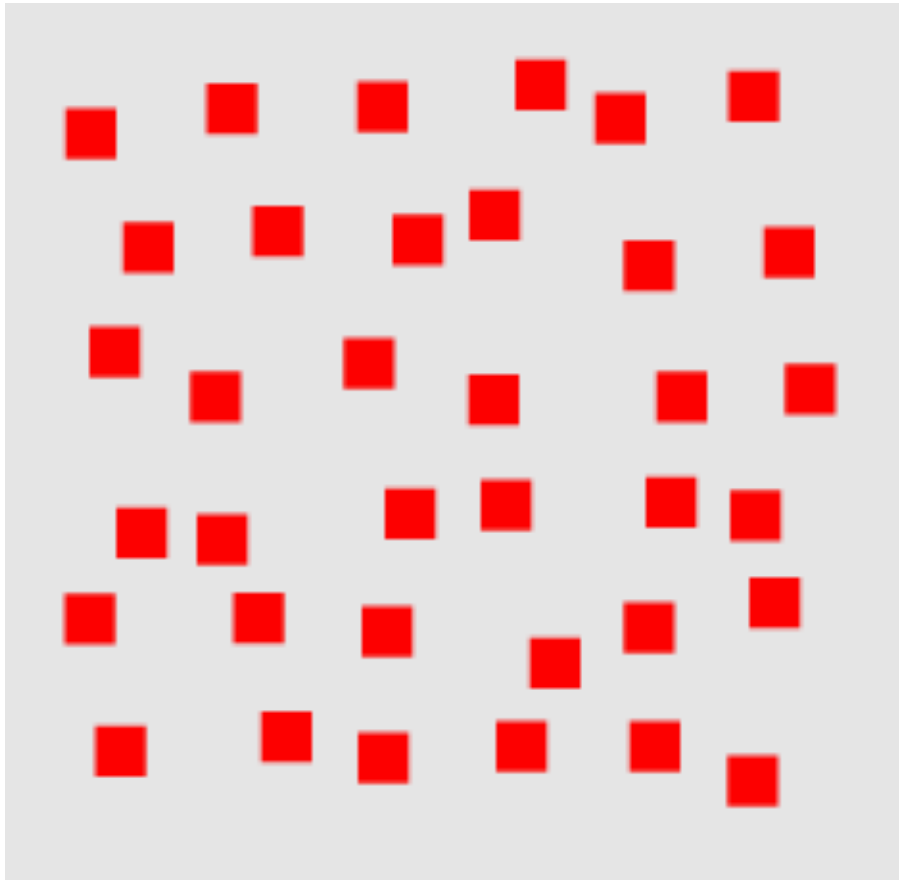
Visual Pop-Out: Color (Hue)

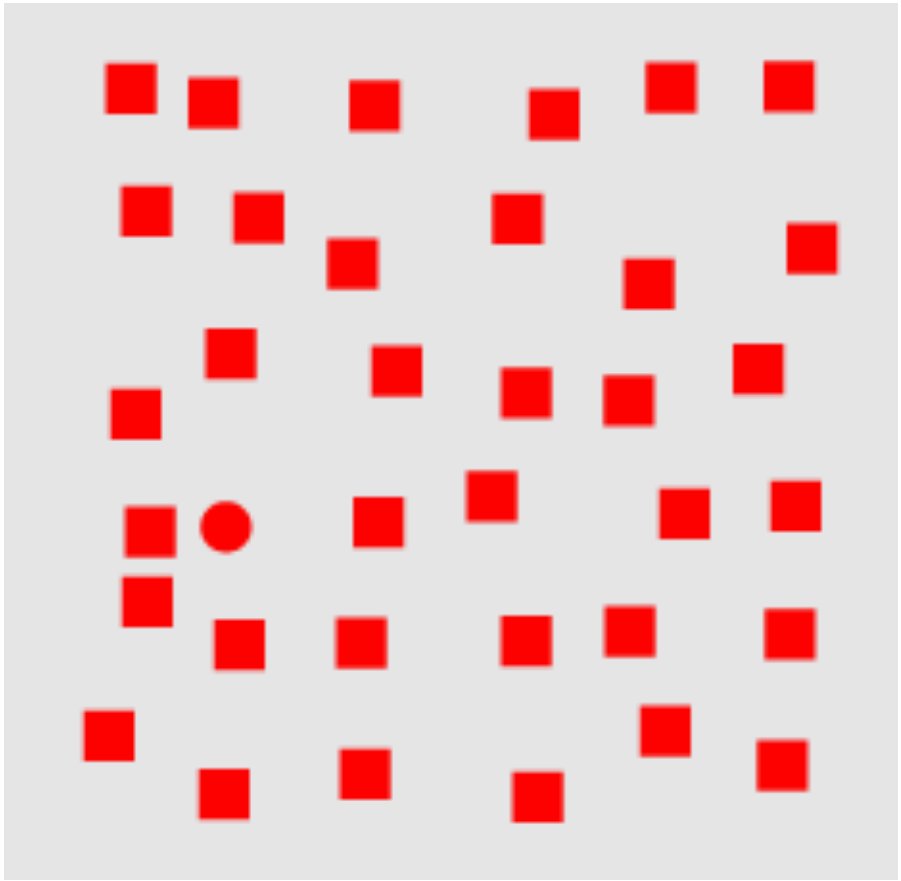




Can be done rapidly (preattentively) by people
Surrounding objects called “distractors”

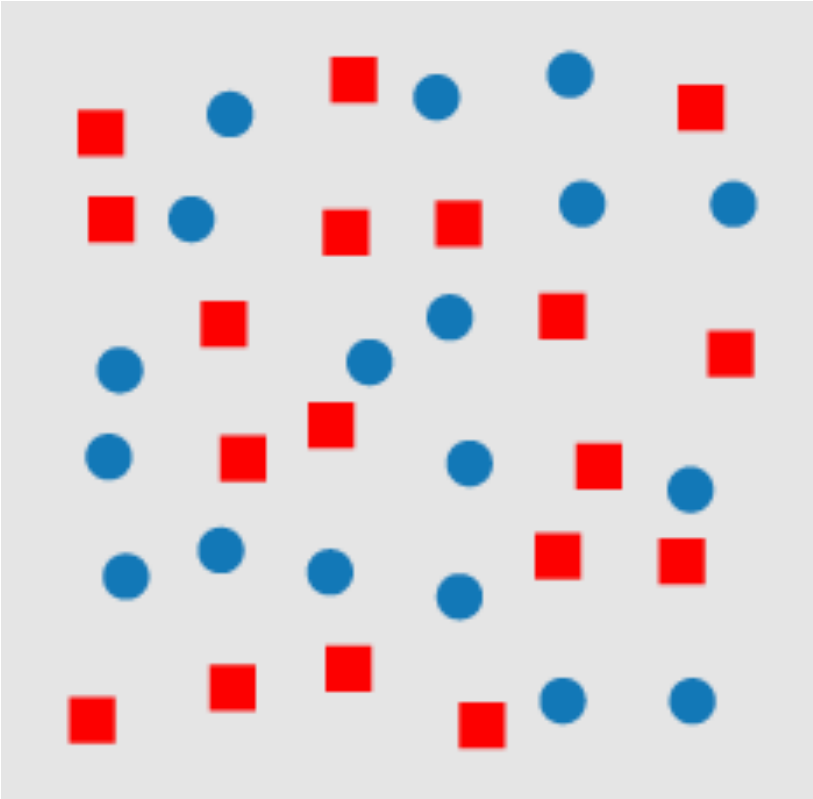
Visual Pop-Out: Shape

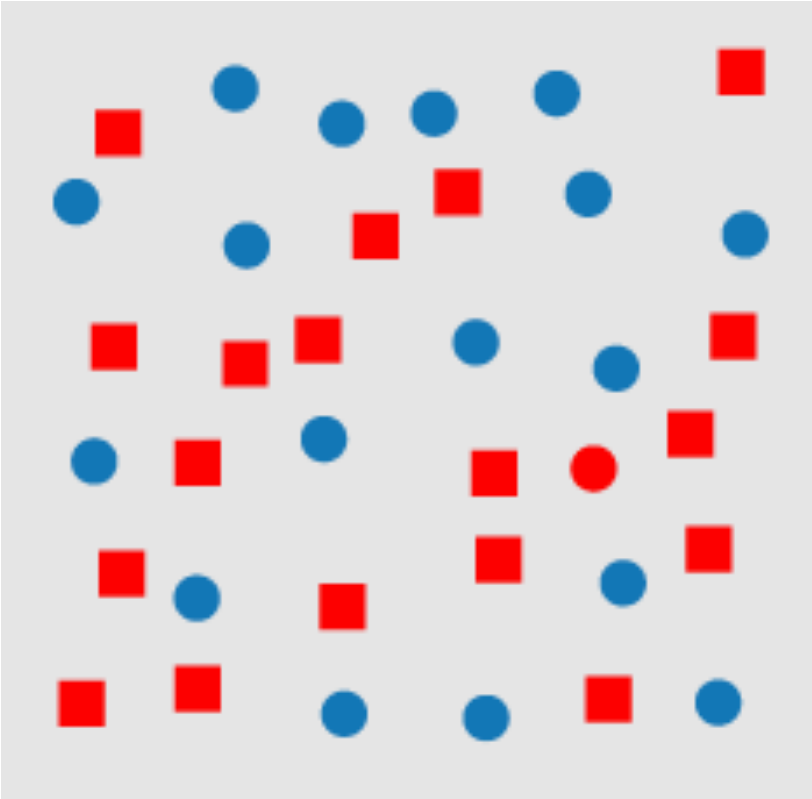




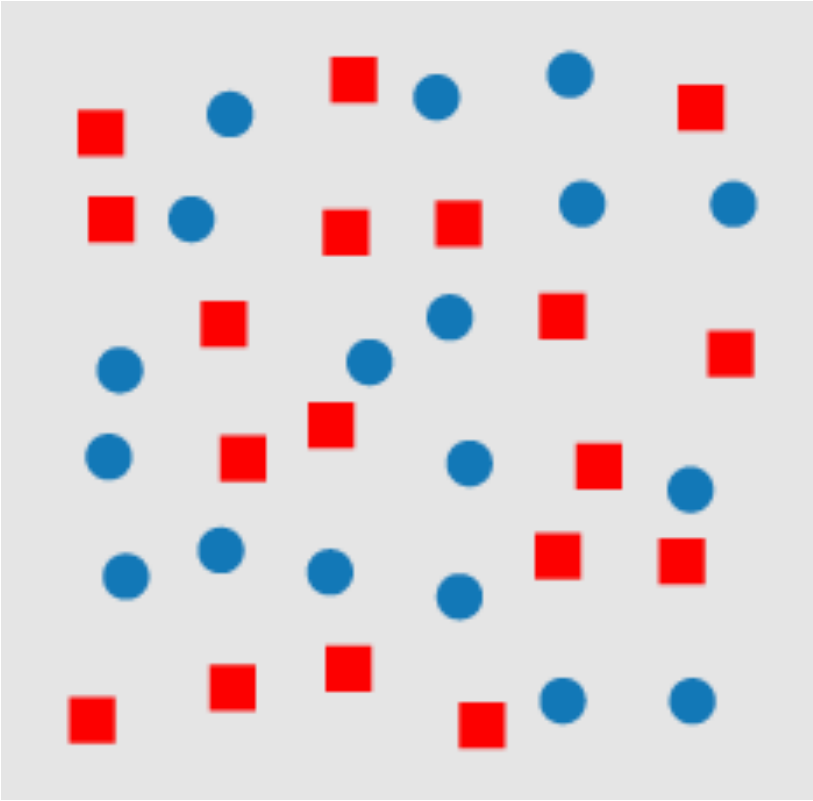
Can be done preattentively by people

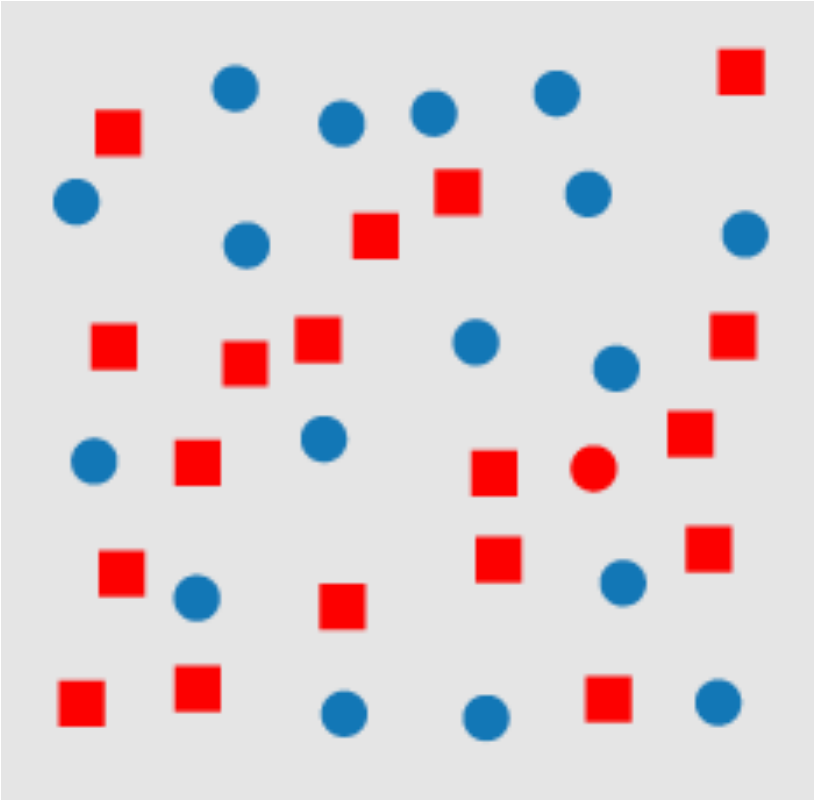
Feature Conjunctions: Color and Shape





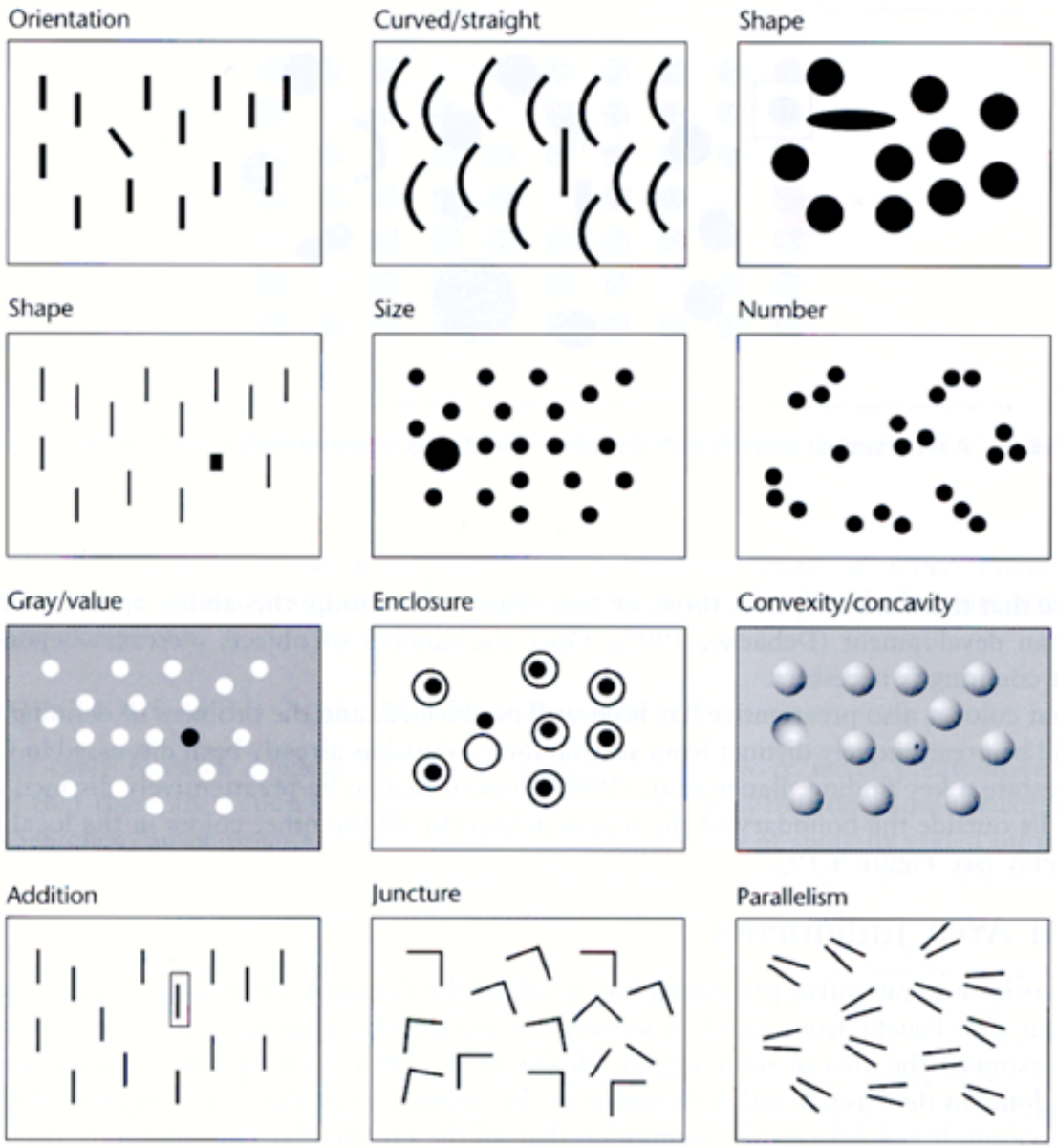
Feature Conjunctions: Color and Shape





- Cannot be done preattentively
- Must perform a sequential search
- Conjuction of features (shape and hue) causes it

Pre-Attentive Features



- length
- width
- size
- curvature
- number
- terminators
- intersection
- closure
- hue
- intensity
- flicker
- direction of motion
- binocular lustre
- stereoscopic depth
- 3-D depth cues
- lighting direction

Information visualization: Perception for Design (3rd Edition), Colin Ware

Pre-Attentive Feature Conjunctions

- Spatial conjunctions are often pre-attentive
- Motion and 3D disparity
- Motion and color
- Motion and shape
- 3D disparity and color
- 3D disparity and shape

- Most conjunctions are not pre-attentive

Gestalt Grouping Principles

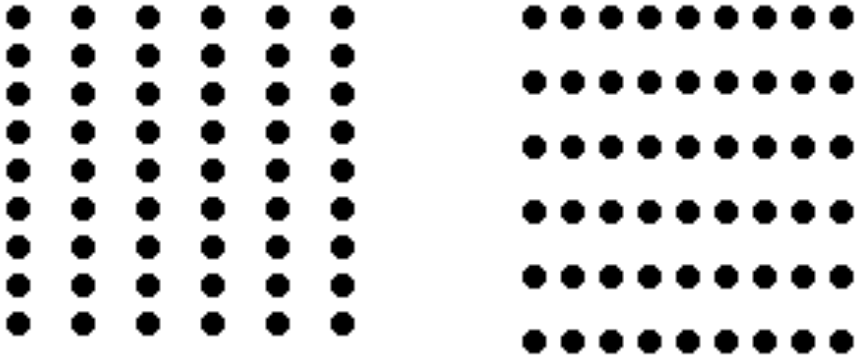
"All else being equal, elements that are related by X tend to be grouped perceptually into higher-order units."

— Stephen Palmer

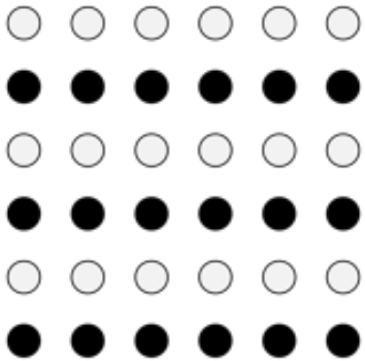
- Proximity
- Similarity
- Connectedness
- Continuity
- Symmetry
- Closure
- Figure/Ground
- Common Fate

Gestalt Grouping Principles

- Proximity
  - Things close together are perceptually grouped together



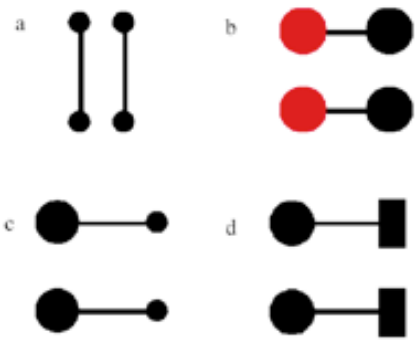
- Similarity
  - Similar elements get grouped together



Rows dominate due to similarity

Gestalt Grouping Principles

- Connectedness
  - Connecting different objects by lines unifies them

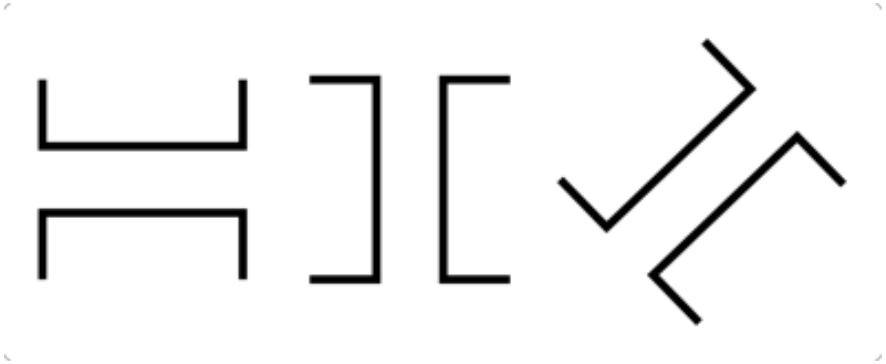


Connectedness overrules proximity, size, color shape

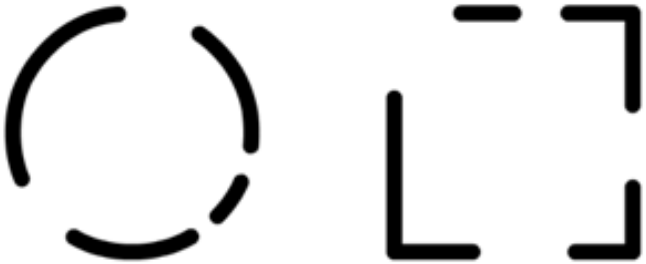
- Continuity
  - More likely to construct visual entities out of smooth, continuous visual elements

Gestalt Grouping Principles

- Symmetry
  - Symmetrical patterns are perceived more as a whole

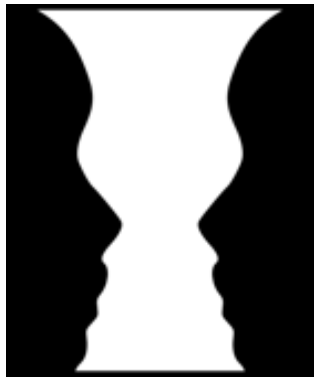


- Closure
  - A closed contour is seen as an object

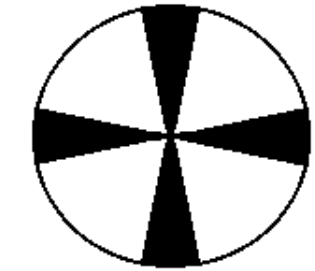


Gestalt Grouping Principles

- Figure/Ground
  - Figure is foreground, ground is behind



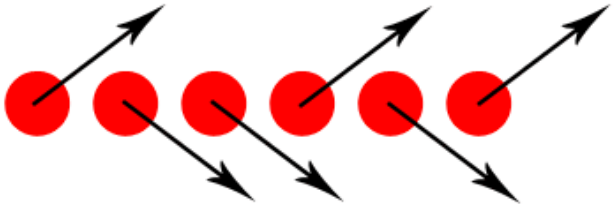
ambiguous



Relative size

surroundedness

- Common Fate (Synchrony)
  - Elements that move in the same direction are perceived as more related



Change Blindness

- We don't always see everything that is there!
- Is the viewer able to perceive changes between two scenes?
  - If so, may be distracting
  - Can do things to minimize noticing changes

- Video: http://www.simonslab.com/videos.html

Next Lecture

- Topic:
  - Interaction
- Next Monday (25 Feb)
  - 12:00 - 14:00
  - A25, Business South, Jubilee Campus