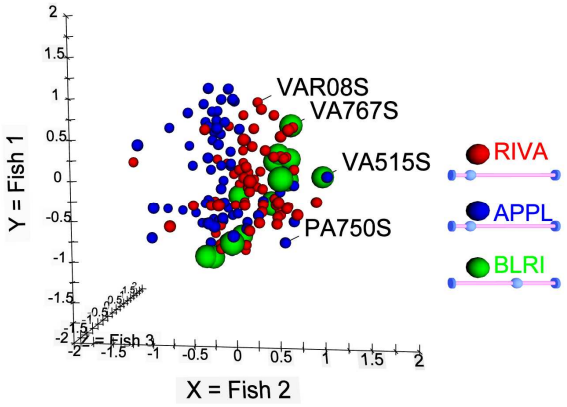
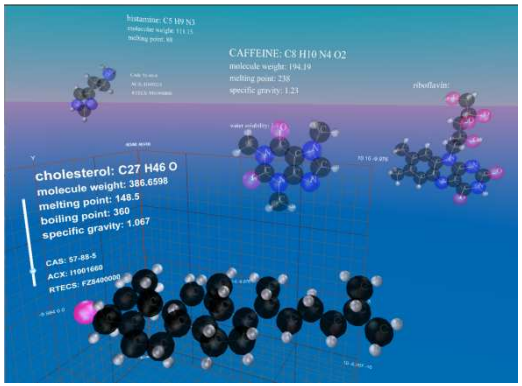
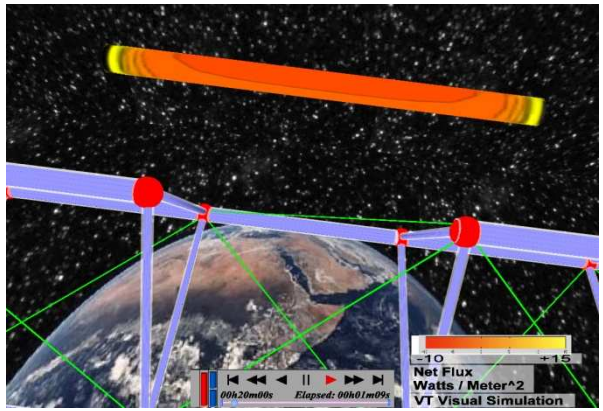
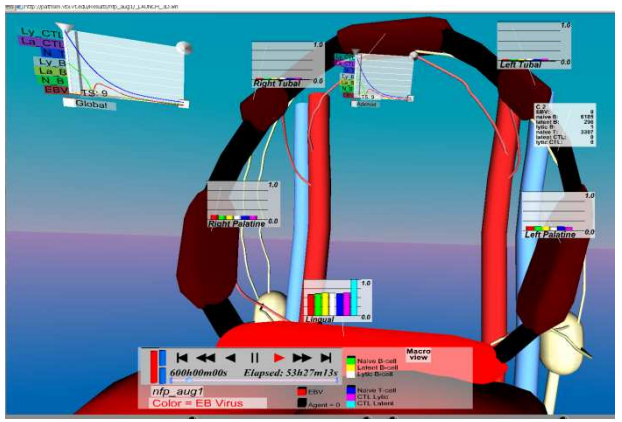




HPC Bootcamp 2010: Visual Computing



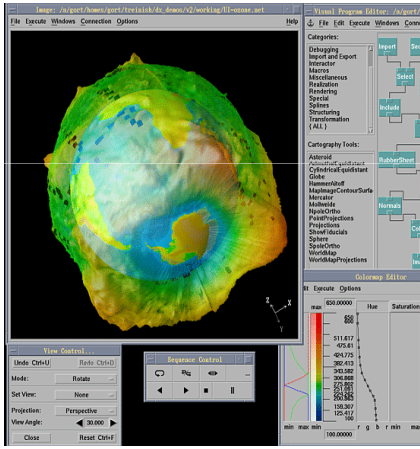
Nicholas F. Polys, Ph.D.
VT Advanced
Research Computing



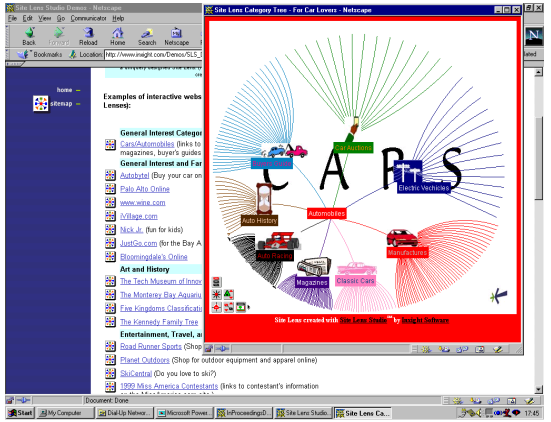
A Definition

- Generally:
  - The use of computer-supported, interactive, visual representations of data to amplify cognition

Card, McKinlay and Schneiderman

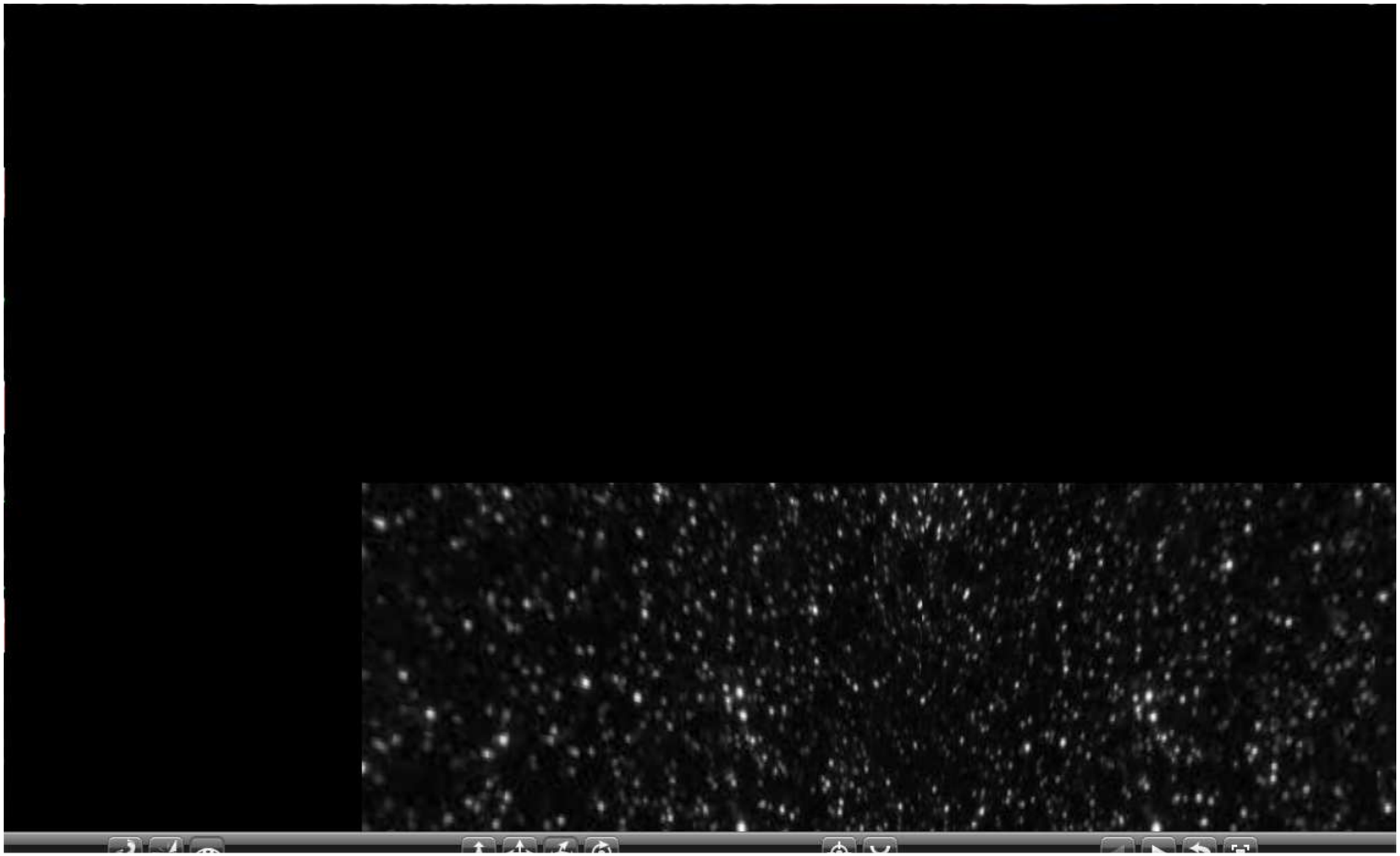


  - Scientific Visualization
  - Information Visualization
  - Virtual Environments



Viewers, Browsers, Players

- Web3D Anywhere!

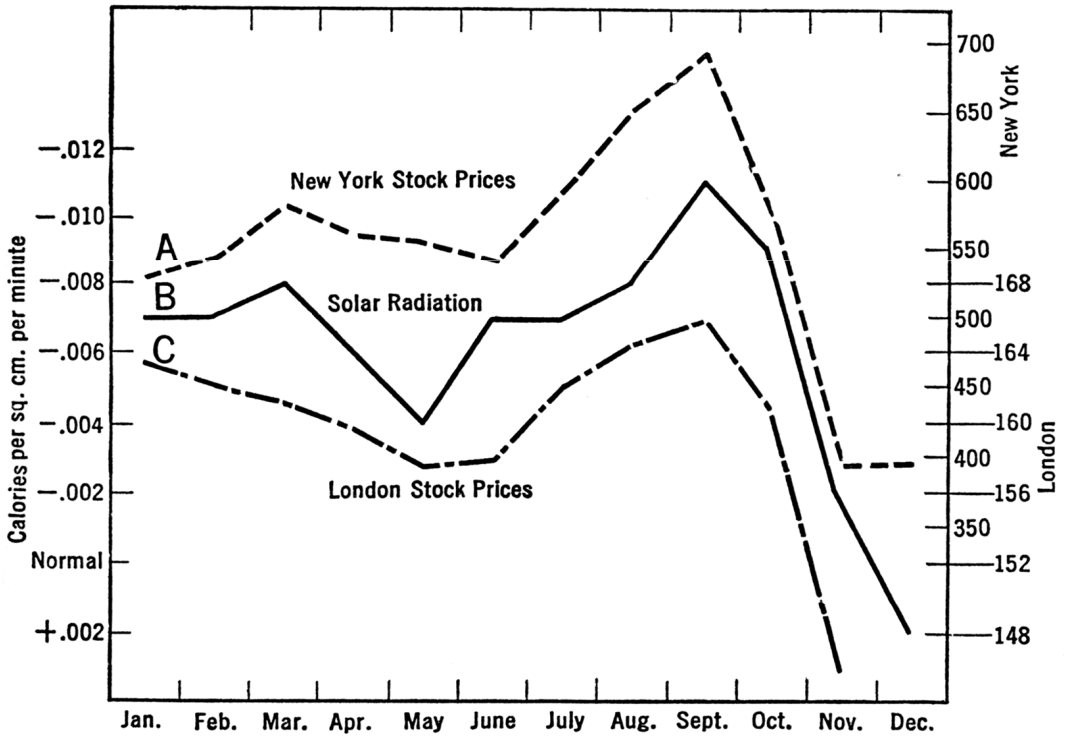


Rewind- to first principles

- The human mind is still the best analyst; how do we:
  - discover trends and relationships
  - communicate concept and results graphically
- How can perception inform design?

Principles of Perception

Of course, statistical graphics, just like statistical calculations, are only as good as what goes into them. An ill-specified or preposterous model or a puny data set cannot be rescued by a graphic (or by calculation), no matter how clever or fancy. A silly theory means a silly graphic:



SOLAR RADIATION AND STOCK PRICES

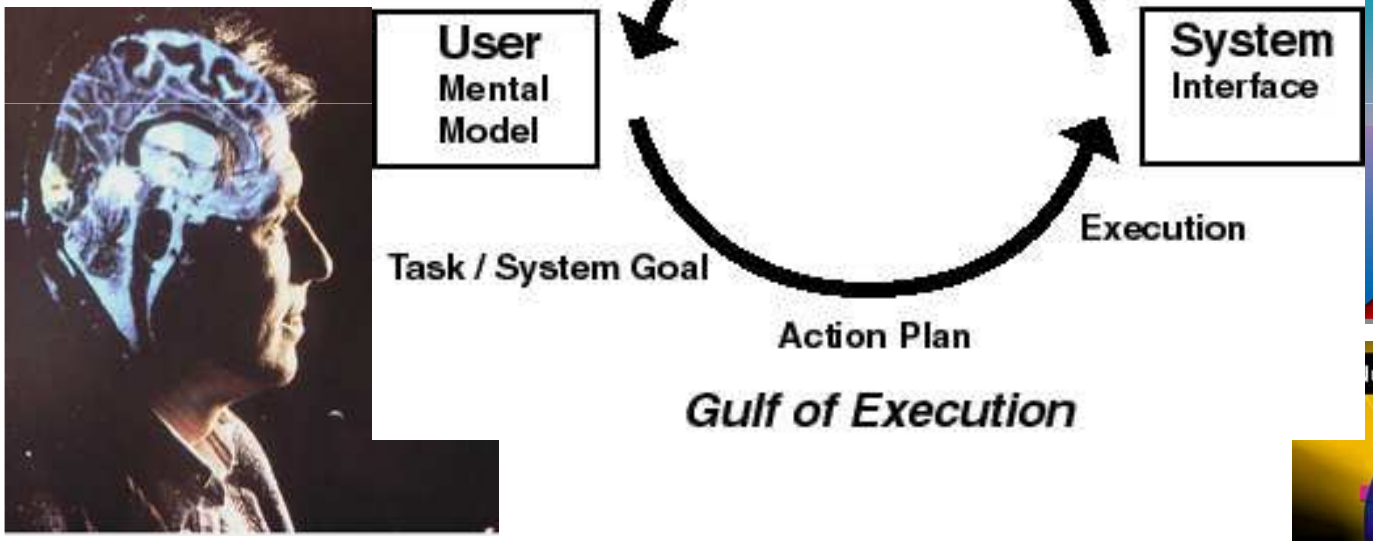
A. New York stock prices (Barron's average). B. Solar Radiation, inverted, and C. London stock prices, all by months, 1929 (after Garcia-Mata and Shaffner).

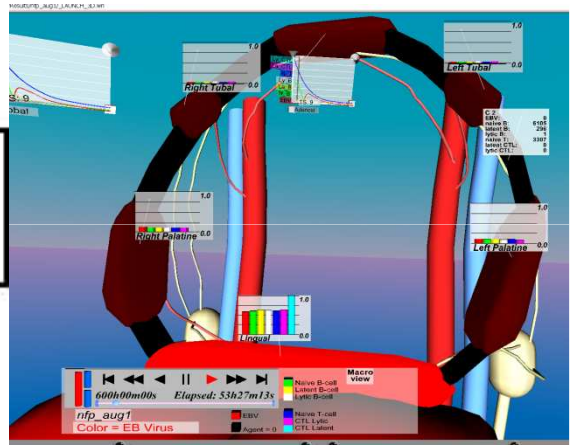
What is HCI?

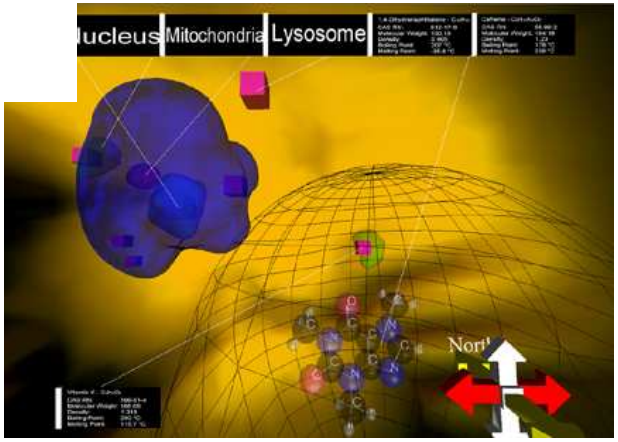
- A multidisciplinary science of the interface: *psychology, design & media, human factors, sociology, computer science*

- Experimental methods to rationalize UI features, design, and software architecture

Norman's Gulfs







Communication Across the Gulfs

User-centered design:

- ***Evaluation*** : Information Design
  - What do I see?
  - What does it mean?

- ***Execution*** : Interaction Design
  - What is my next goal?
  - How do I achieve it?
  - Make it happen!

Information Design

Goal: identify methods for representing and arranging the objects and actions possible in a system in a way that facilitates perception and understanding

Information Design

- Define and arrange the visual (and other modality) elements of a user interface
  - Screen layout, icon design, vocabulary selection
  - But also the “big picture” or overall info model
  - Models of perception, psychology guide this
- Engineering an information design
  - Make sure what people see (hear, etc.) makes sense, and helps them to pursue meaningful goals
  - Depends on *what they are doing*, hence the important role of user interaction scenarios

Good Graphics

- Precision
- Clarity
- Maximize Data-to-ink ratio
  - Data Ink Ratio = (data ink) / (total ink in the plot)
- Minimize Lie factor
  - Lie factor = (size of graphic) / (size of data)

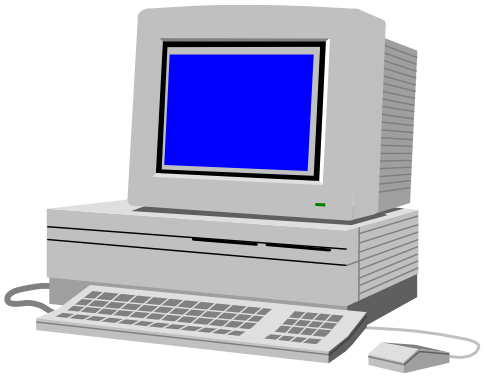
Information Visualization Mantra

(Shneiderman)

- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand
- Overview first, zoom and filter, then details on demand

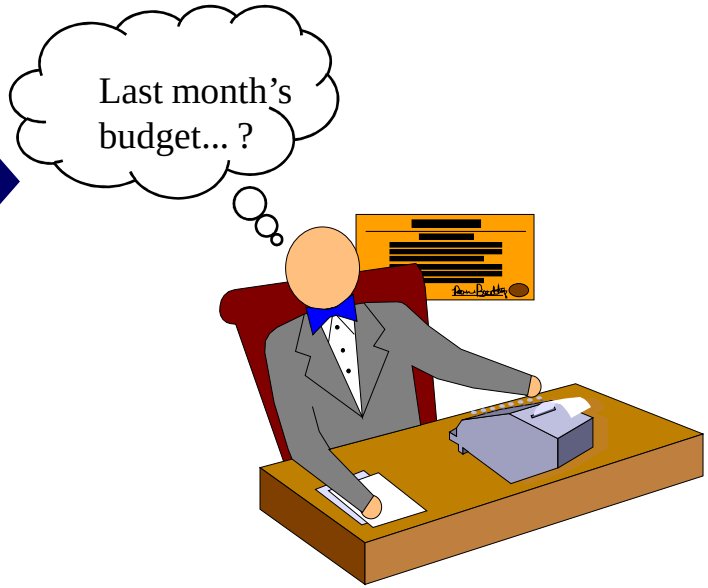
Making Sense of an Information Display

Perception
color, shading, lines
characters, squares,
spatial organization

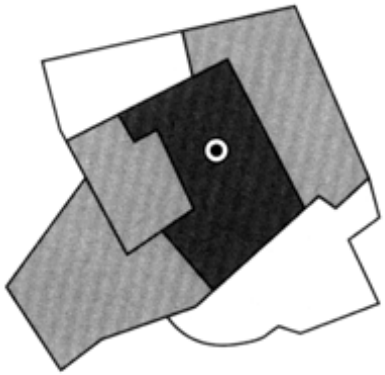


Interpretation
Excel worksheet, a cell
is selected, formula is
displayed at top

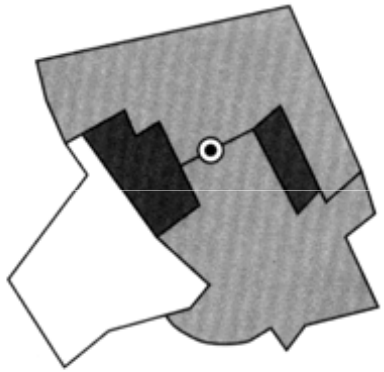
Making Sense
Income worksheet,
Total tax income is being
calculated, the wrong
multipler is being used



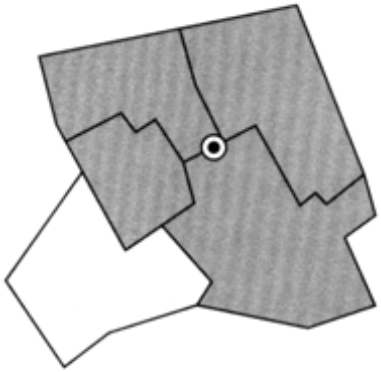
Edward Tufte



In this aggregation of individual deaths into six areas, the greatest number is concentrated at the Broad Street pump.



In this aggregation of the deaths, the two areas with the most deaths do not even include the infected pump!



Using different geographic subdivisions, the cholera numbers are nearly the same in four of the five areas.

[18] Mark Monmonier, *How to Lie with Maps* (Chicago, 1991), pp. 142–143.

Visual Analysis Overview

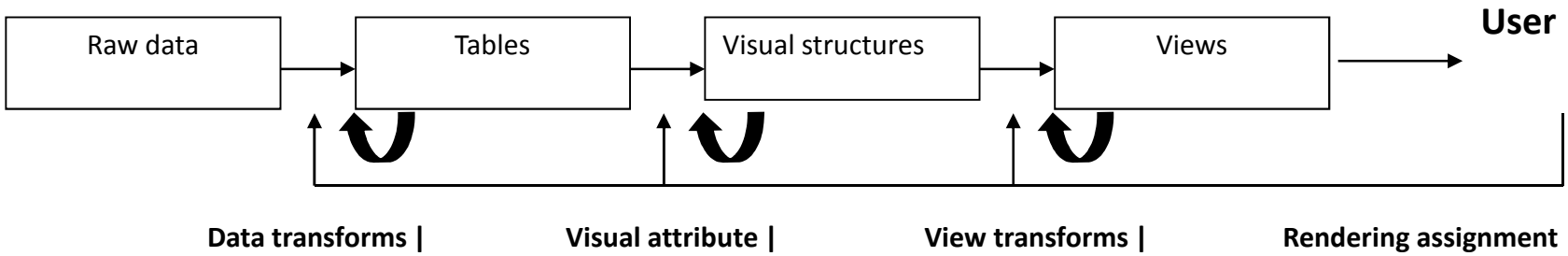


Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)

First Steps

Extract data and Map

- **Data transformation**
  - Raw data -> attributes of interest
  - File formats or scripts are usually employed
- **Visual attributes**
  - Assign attributes -> visual representation
  - Typically use some tool (e.g. Paraview, Excel, Gnuplot)

Second Steps

Publish and Deliver

- **View transformation**
  - ‘Camera’ location and properties
- **Rendering assignment**
  - Print vs. interactive
  - Resolution, size
  - Stereo, immersion

Fundamental Data Types

- Spatial / perceptual data:

  geometry, colors, textures, lighting

- Abstract data / world & object attributes:

  nominal, ordinal, quantitative

- Temporal data / behaviors:

  states, dynamics

Data Transformations

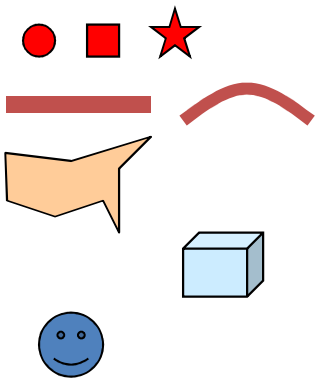
- Data table operations:
  - Selection
  - Projection
  - Aggregation
    - r = f(rows)
    - c = f(cols)
  - Join
  - Transpose
  - Sort
  - …

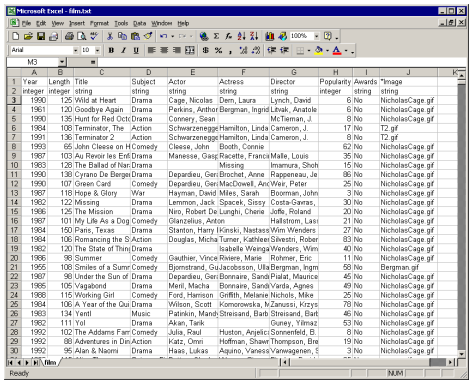
Visual Mapping: Step 1

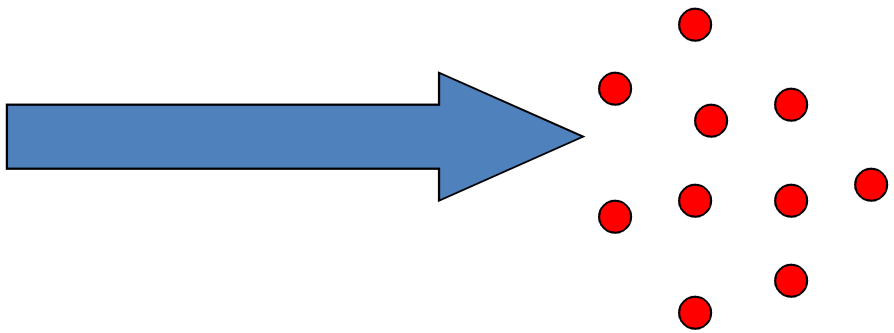
1. Map: data items → visual marks

Visual marks:

- Points
- Lines
- Areas
- Volumes
- Glyphs







Perception for Design

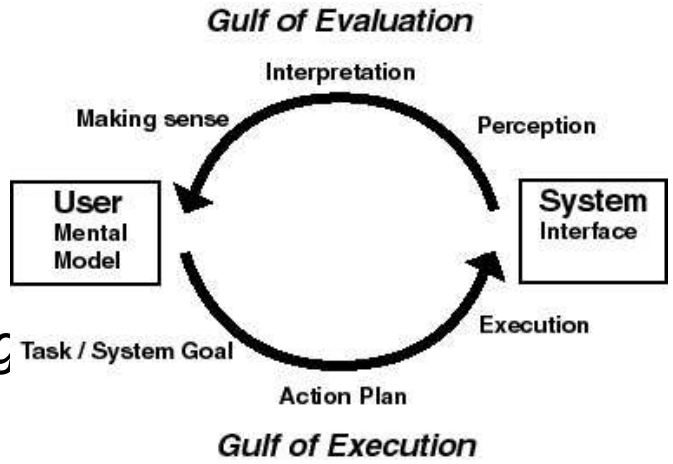
- Using our understanding of the human perceptual systems to guide design
  - Visual system
  - Auditory system
  - Vestibular system
- Leverage pre-attentive facilities
- Reduce cognitive overhead

Perception

- Organize and encode sensory data in the mind
  - Lines, shapes, colors are “extracted”
  - Very fast, generally with no conscious thought
  - May be influenced by expectations, “top-down”
- Low-level units then grouped and organized
  - Perceived as rows, columns, grids, figures
  - Seeing the relationships among different elements
- Design goal: make this perceptual process rapid and accurate

Background:
Information Psychophysics

- Edward Tufte, *Envisioning Information* (1983, 1990)
- Jaques Bertin, *Semiology of Graphics* (1983)
- Donald Norman, *Cognitive Engineering* (1986)
- Joseph Goguen, *Semiotic Morphisms* (2000)
- Colin Ware, *Perception for Design* (2003)



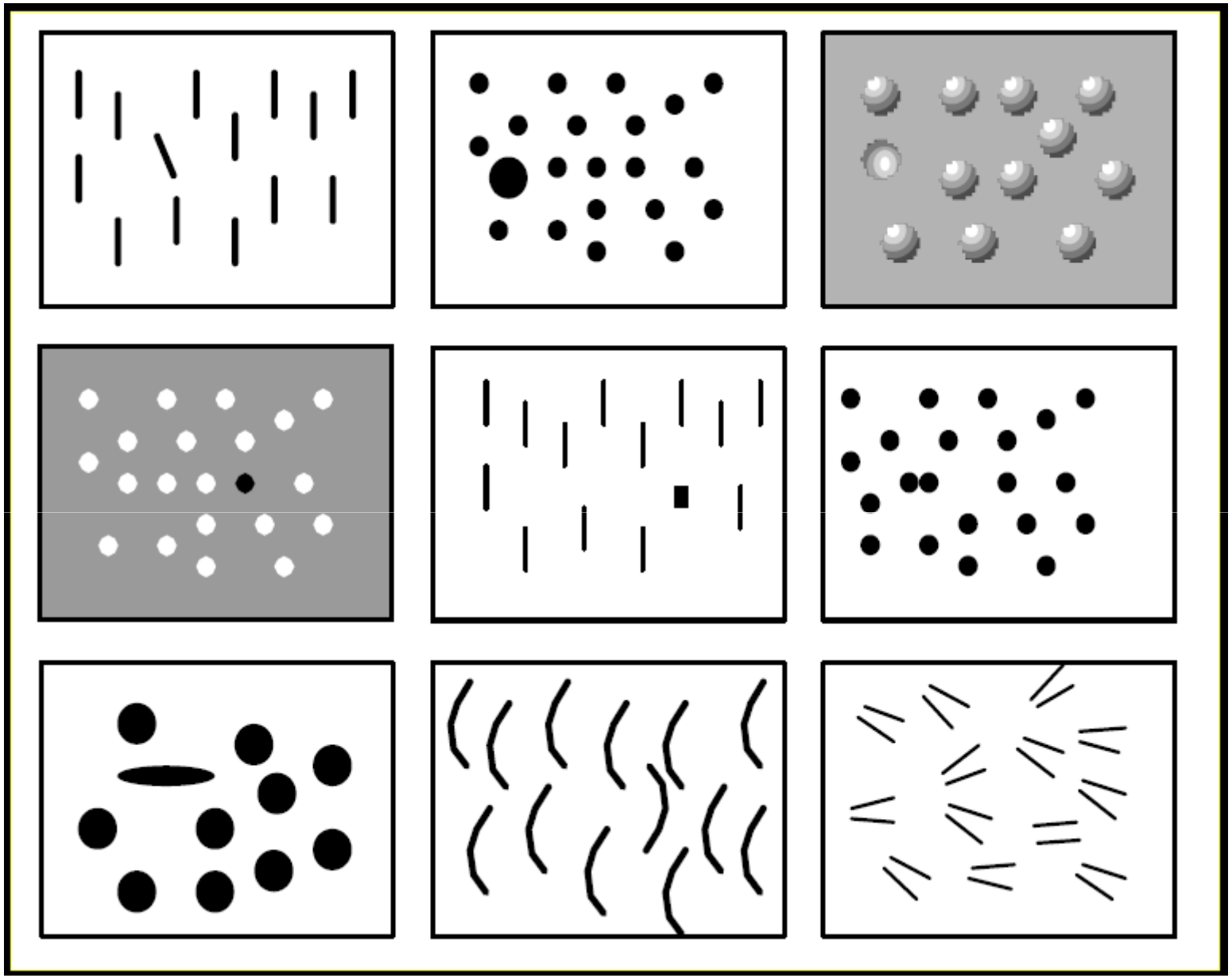
Pre-attentive Processing

- Involuntary, do not require conscious attention
- Parallel
- Efficient
- Resistant to instruction

Attention

- Pop out effects ‘stand out’ in some simple dimension (conjunctions don’t):
  - Rapid visual search
  - Form, color, simple motion/blinking, spatial stereo depth, shading, position

12987621909023748594329
08706548394056024859543
72890098905098746322 34



Frame Rate

- Threshold for perceiving continuity:
  - flicker < 50 Hz
  - > 24 fps looks smooth & plenty interactive
- Flicker & Attention can lead to change blindness (Simmons, 2000)

- Browser.getCurrentFrameRate()
- Implementing X3DPerFrameObserverScript
  - public void prepareEvents (){}

Attention and blindness

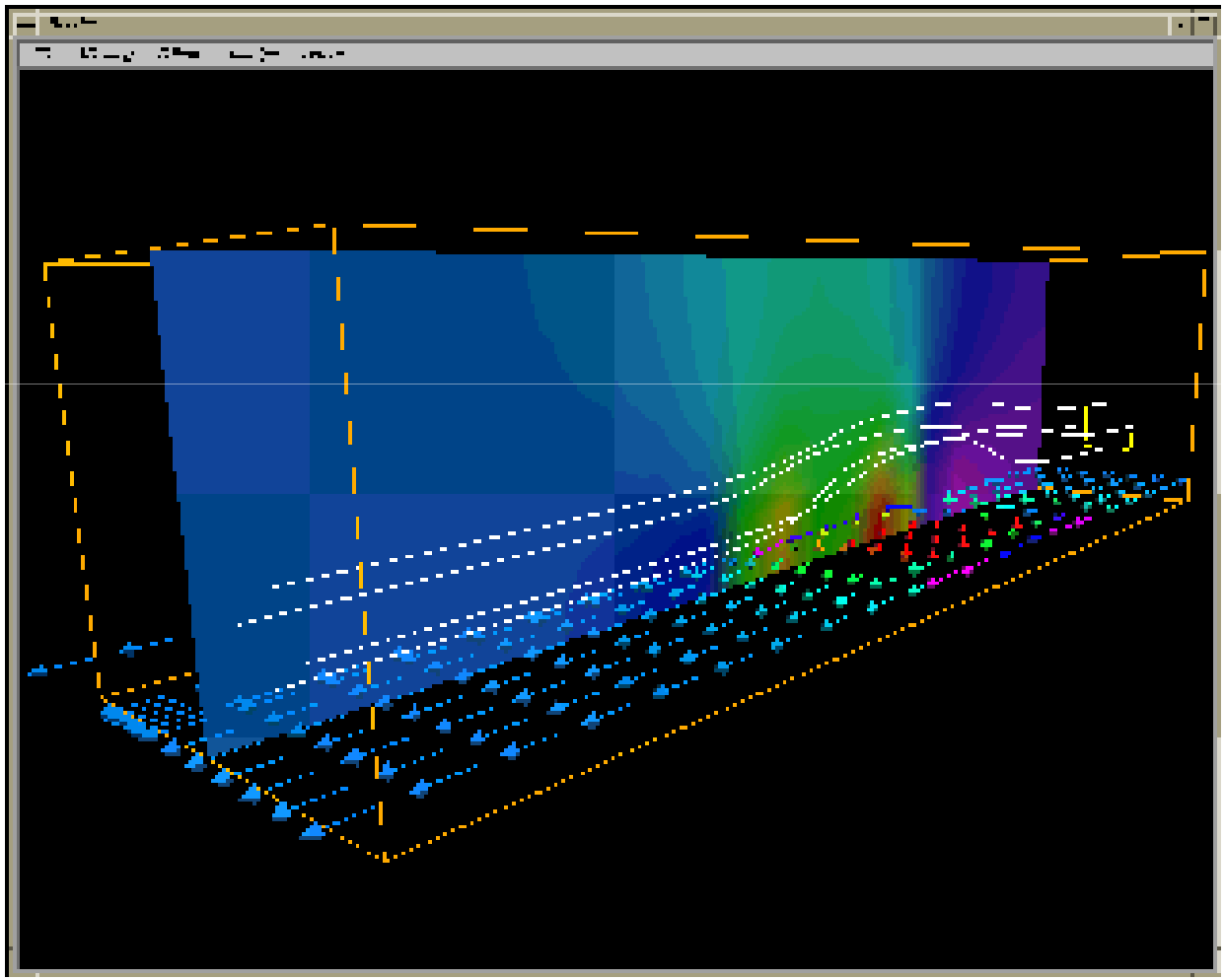
- http://viscog.beckman.uiuc.edu/djs_lab/demos.html
- http://www.psych.ubc.ca/~rensink/flicker/
  - http://www.psych.ubc.ca/~rensink/flicker/download/index.html

Animation Guidelines

- The higher the frame-rate the better
- Beware data assumptions:

  Interpolation versus Sequencing
- Provide user control over time ? (e.g. DVDTimeController)

Representing multiple properties

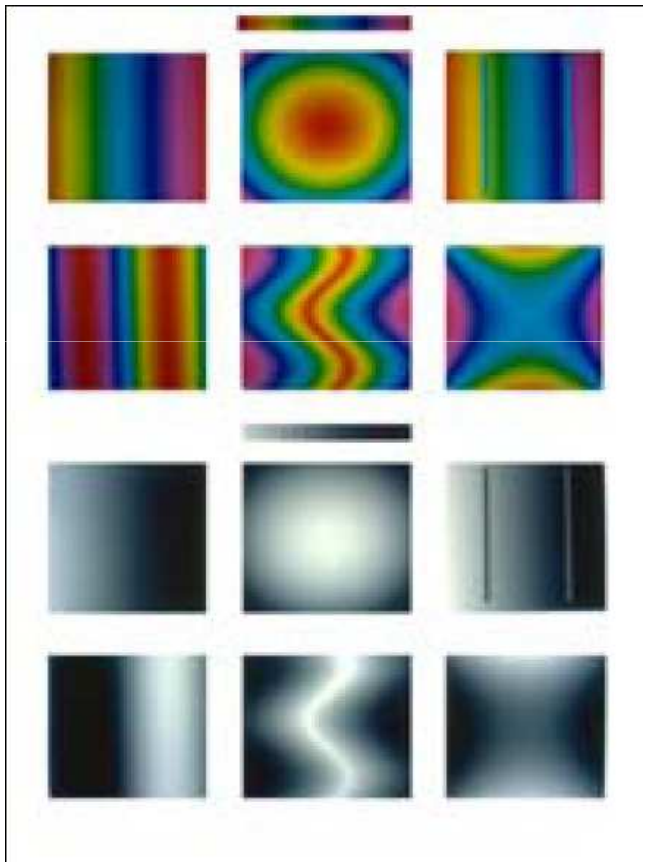


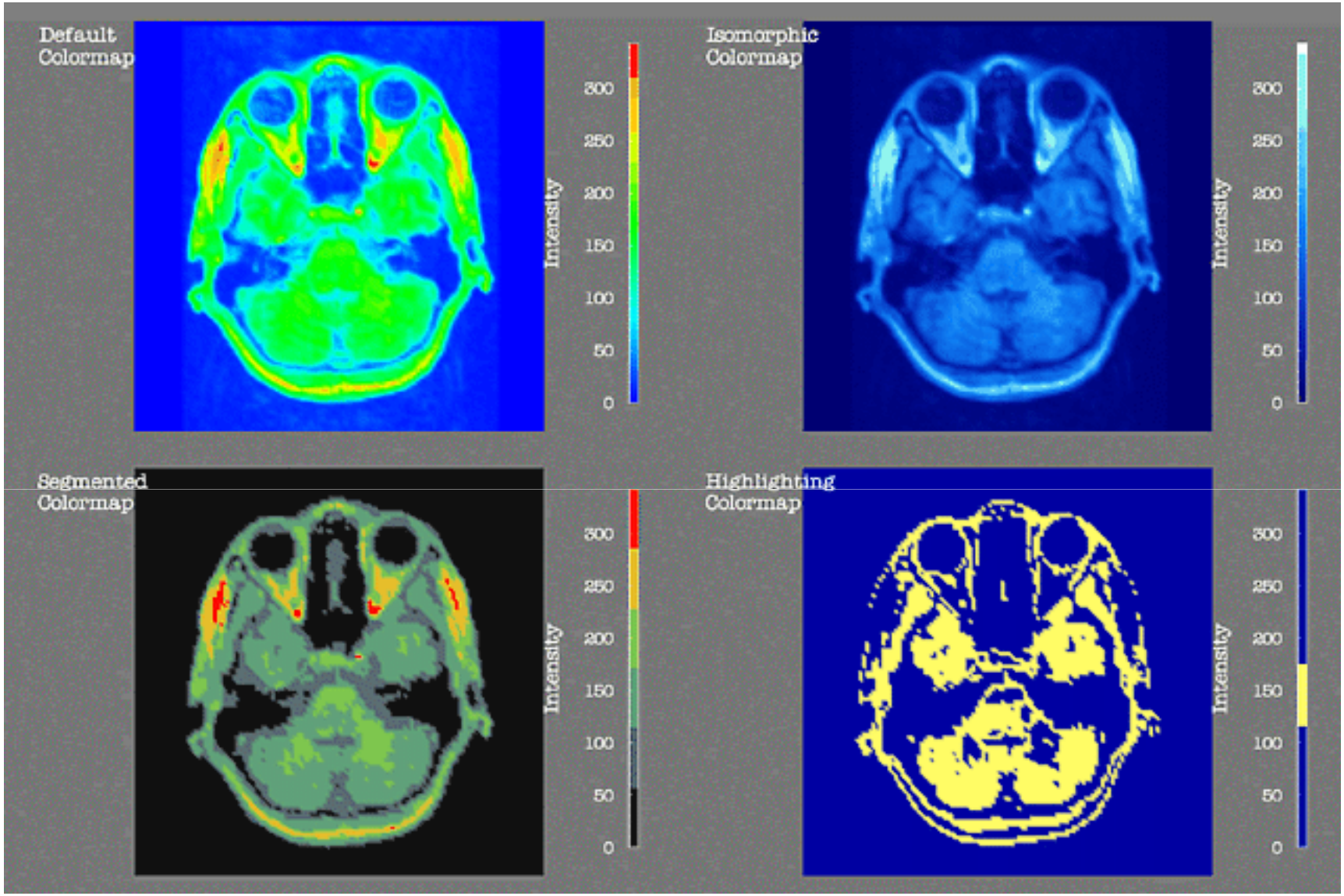
- Flow of air around a car
  - Vectors and particle paths illustrate flow
  - Coloured slice indicates pressure

Features: Color

- Luminance channel
  (3x spatial accuity)
- Red / Green channel
- Yellow / Blue channel

The spectrum is not a perceptually linear sequence (not pre-attentive)!
(Keller 1993; Ware, 2000)




Default
Colormap
Intensity
300
250
200
150
100
50
0
Isomorphic
Colormap
Intensity
300
250
200
150
100
50
0
Segmented
Colormap
Intensity
300
250
200
150
100
50
0
Highlighting
Colormap
Intensity
300
250
200
150
100
50
0

IBM

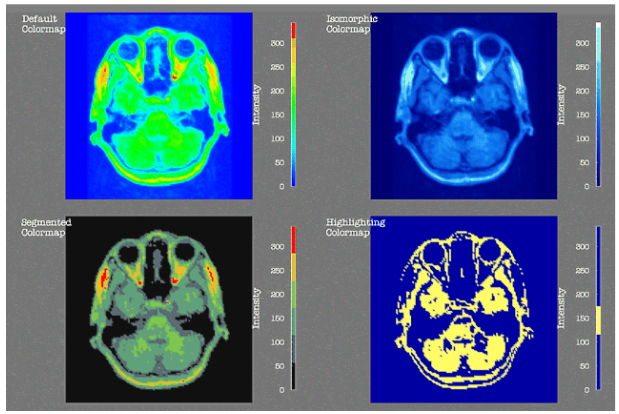
Good Pubs

David Borland, Russell M. Taylor II, "Rainbow Color Map (Still) Considered Harmful," IEEE Computer Graphics and Applications, vol. 27, no. 2, pp. 14-17, Mar./Apr. 2007, doi:10.1109/MCG.2007.46

LIGHT AND P. J.BARTLEIN "The End of the Rainbow? Color Schemes for Improved Data Graphics". Eos, Vol. 85, No. 40, PAGES 385, 391 , 5 October 2004

P. Schulze-Wollgast, C. Tominski, and H. Schumann, "Enhancing Visual Exploration by Appropriate Color Coding," *Proc. 13th Int'l Conf. Central Europe on Computer Graphics, Visualization and Computer Vision,* pp. 203-210, 2005.

Color (again)



- **IBM Research and color maps:**
  http://www.research.ibm.com/dx/proceedings/pravda/truevis.htm

- **Human factors in visualization research**
  Tory, M.; Moller, T.;
  Visualization and Computer Graphics, IEEE Transactions on
  Volume 10, Issue 1, Jan-Feb 2004 Page(s):72 - 84
  http://doi.ieeecomputersociety.org/10.1109/TVCG.2004.1260759

- **Some guidelines for Sci Vis:**

http://www-ugrad.cs.colorado.edu/~csci4576/SciVis/SciVisColor.html#ColorGuidelines

- **More detail about CG color models**

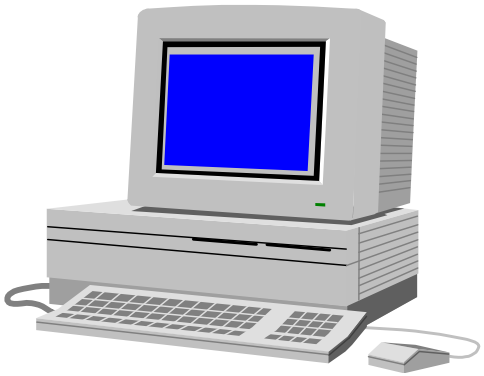
http://www.ncsu.edu/scivis/lessons/colormodels/color_models2.html

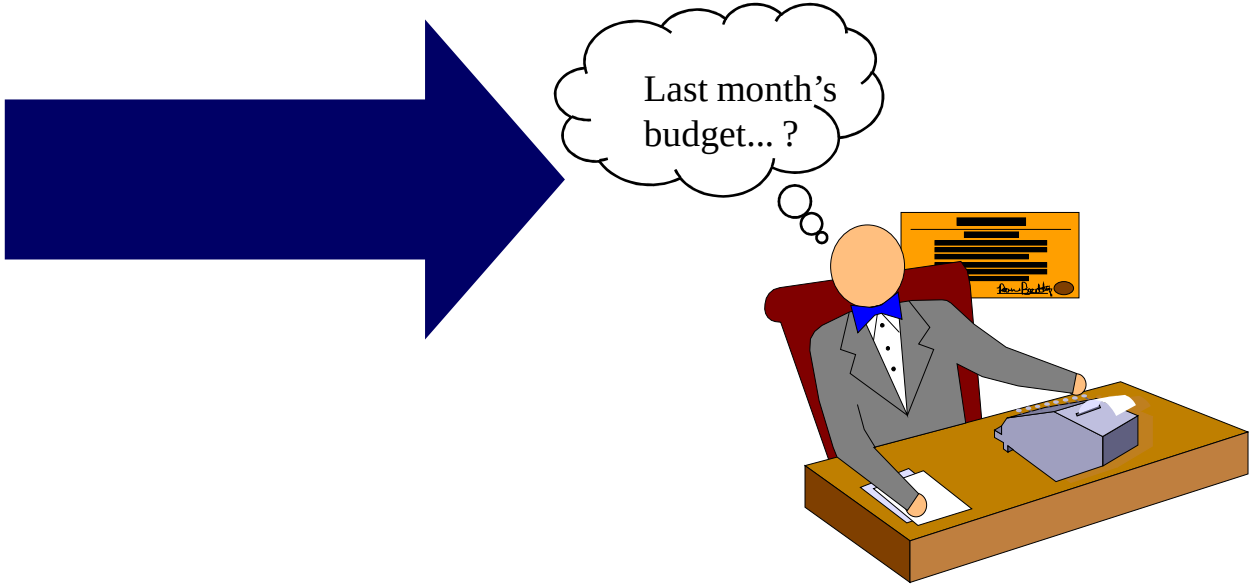
Making Sense of an Information Display

Interpretation
Excel worksheet, a cell is selected, formula is displayed at top

Perception
color, shading, lines characters, squares, spatial organization

Making Sense
Income worksheet, Total tax income is being calculated, the wrong multipler is being used





Interpretation

- Perceiving enables interpretation
  - Perceptual processing identifies major display structures (rectangles, text strings, etc)
  - Users must interpret what these display structures mean in the system
- Designers must anticipate and support user reactions to interface elements
  - Choosing familiar images, symbols, words
  - Refining elements through abstraction
  - Promoting affordances that users can recognize

Depth Cues

Structure the world- locating objects and relationships in space

- Stereoscopy
- Motion parallax
- Relative size / scale
- Fog / atmosphere…

Patterns & Grouping

- Gestalt principles

- Also: continuation, closure, common fate
- Guiding Law of Pragnanz (simplest, most stable configuration)

Gestalt principles

- Palmer & Rock, 1990– review & update principles; grouping based on perceived proximity in 3D space (not 2D proximity on retina)
- Quinlan & Wilton, 1998 – study involving Gestalt conflict; proposed resolution mechanisms

Objects

- Feature Binding – putting the streams together for internal represenation
  - color, form, motion
  - Just in time?
- 2.5 D sketch (Marr, 1982)
- Geons (Biederman, 1993)

Fundamental Data Types

- Spatial / perceptual data:

  geometry, colors, textures, lighting

- Abstract data / world & object attributes:

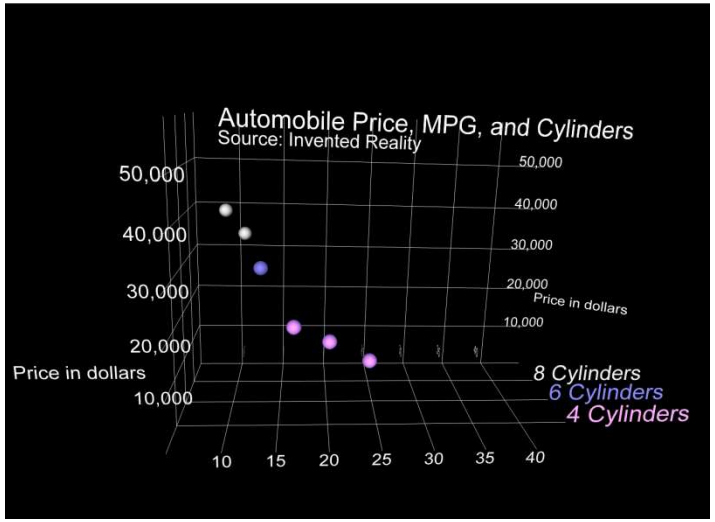
  nominal, ordinal, quantitative

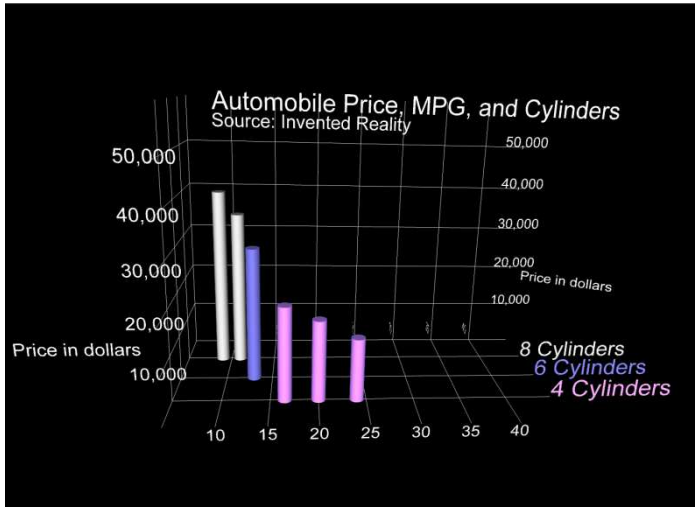
- Temporal data / behaviors:

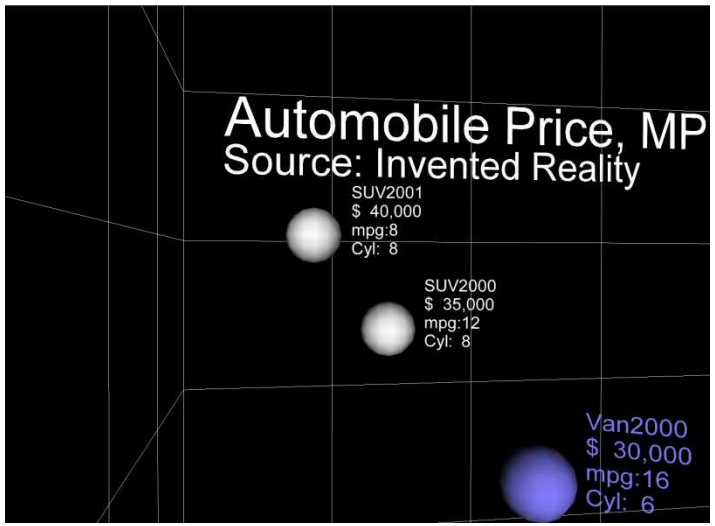
  states, dynamics

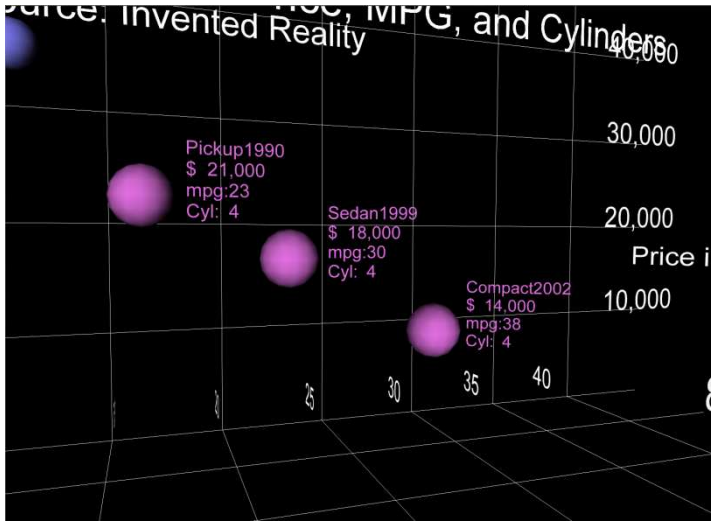
InfoVis: Visual Markers

Data Type	Quantitative	Ordinal	Nominal
Graphical Representation	position length angle / slope area volume color / density (Cleveland and McGill, 1980)	position density color texture connection containment length angle slope area volume (Mackinlay, 1986)	position color texture connection containment density shape length angle slope area volume (Mackinlay, 1986)

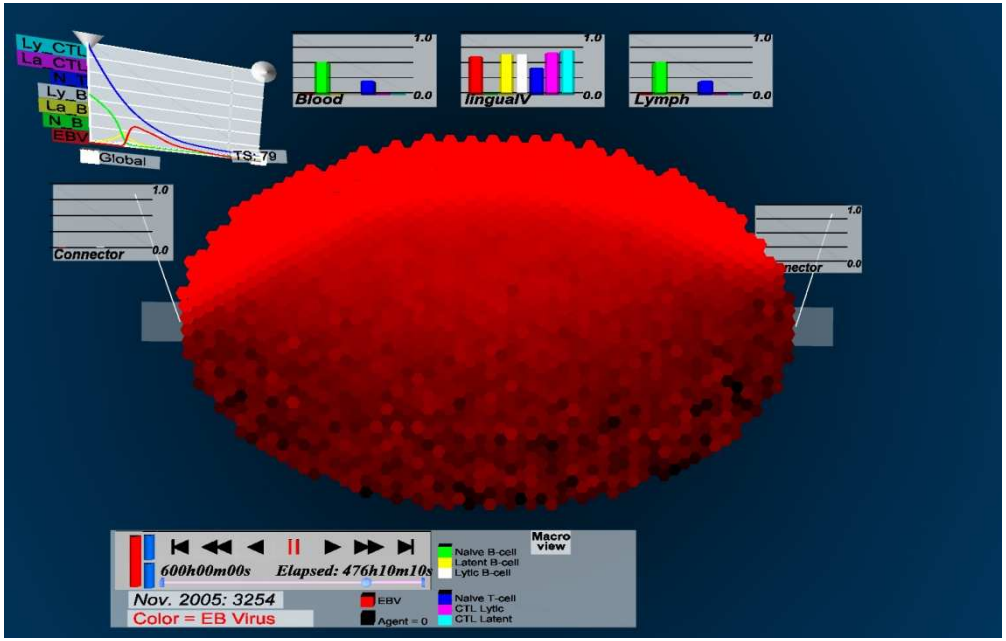

Automobile Price, MPG, and Cylinders
Source: Invented Reality
50,000
40,000
30,000
20,000
10,000
Price in dollars
10 15 20 25 30 35 40
8 Cylinders
6 Cylinders
4 Cylinders

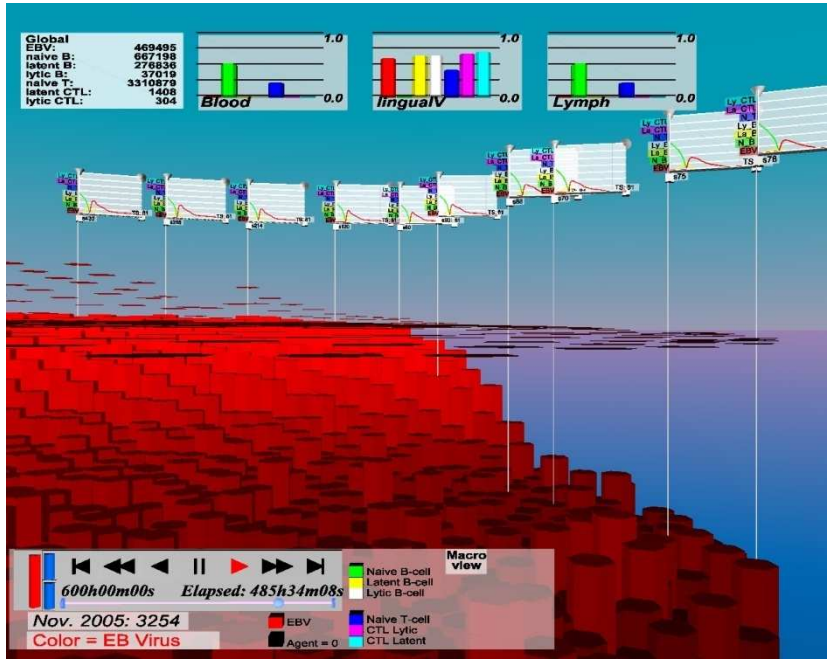

Automobile Price, MPG, and Cylinders
Source: Invented Reality
50,000
40,000
30,000
20,000
10,000
Price in dollars
10 15 20 25 30 35 40
8 Cylinders
6 Cylinders
4 Cylinders


Automobile Price, MP
Source: Invented Reality
SUV2001
$ 40,000
mpg:8
Cyl: 8
SUV2000
$ 35,000
mpg:12
Cyl: 8
Van2000
$ 30,000
mpg:16
Cyl: 6


Pickup1990
$ 21,000
mpg:23
Cyl: 4
Sedan1999
$ 18,000
mpg:30
Cyl: 4
Compact2002
$ 14,000
mpg:38
Cyl: 4
30,000
20,000
10,000
30
35
40

PathSim example



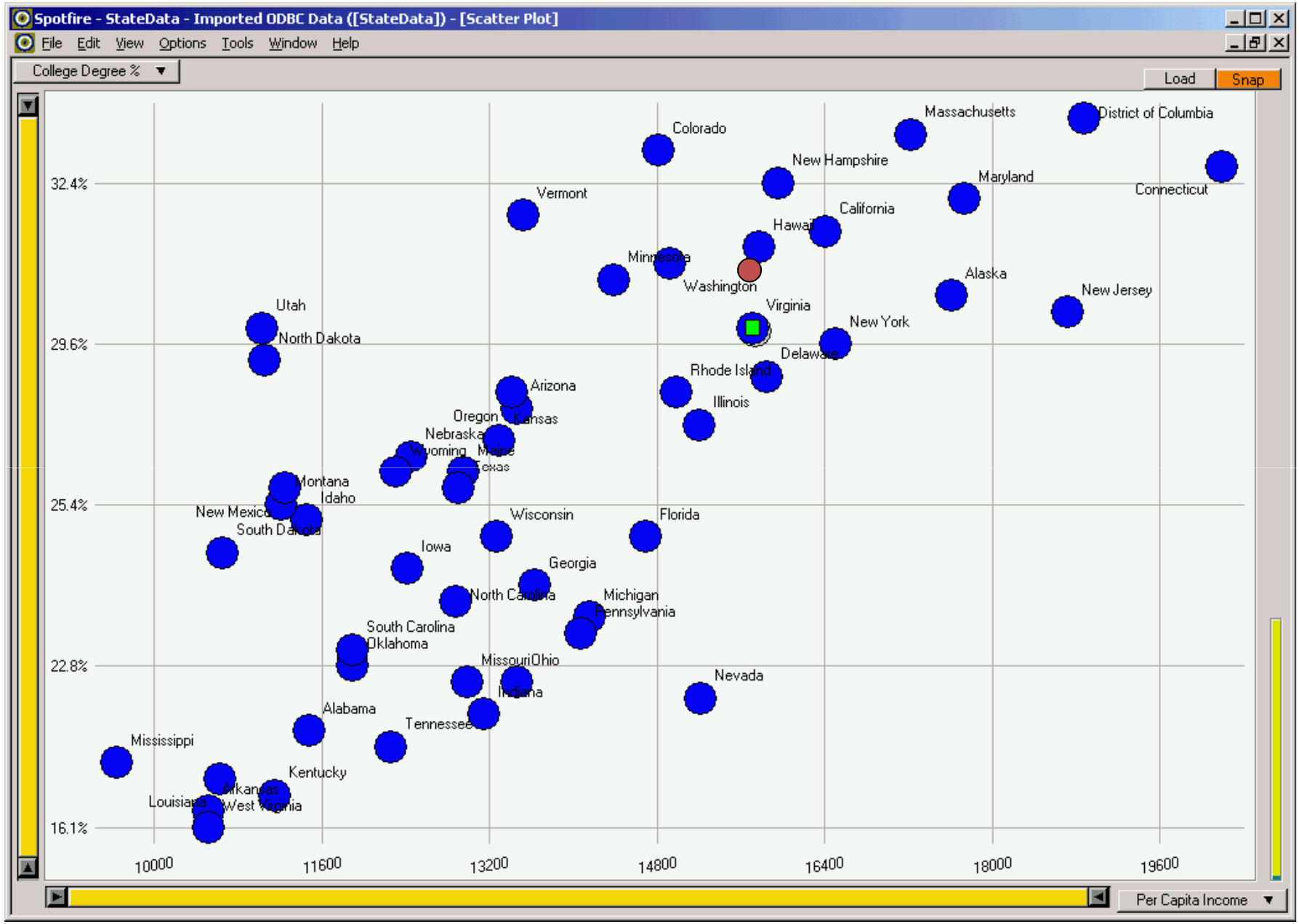


- Which state has highest income?
- Relationship between income and education?
- Outliers?

Table - StateData ()

Load | Snap

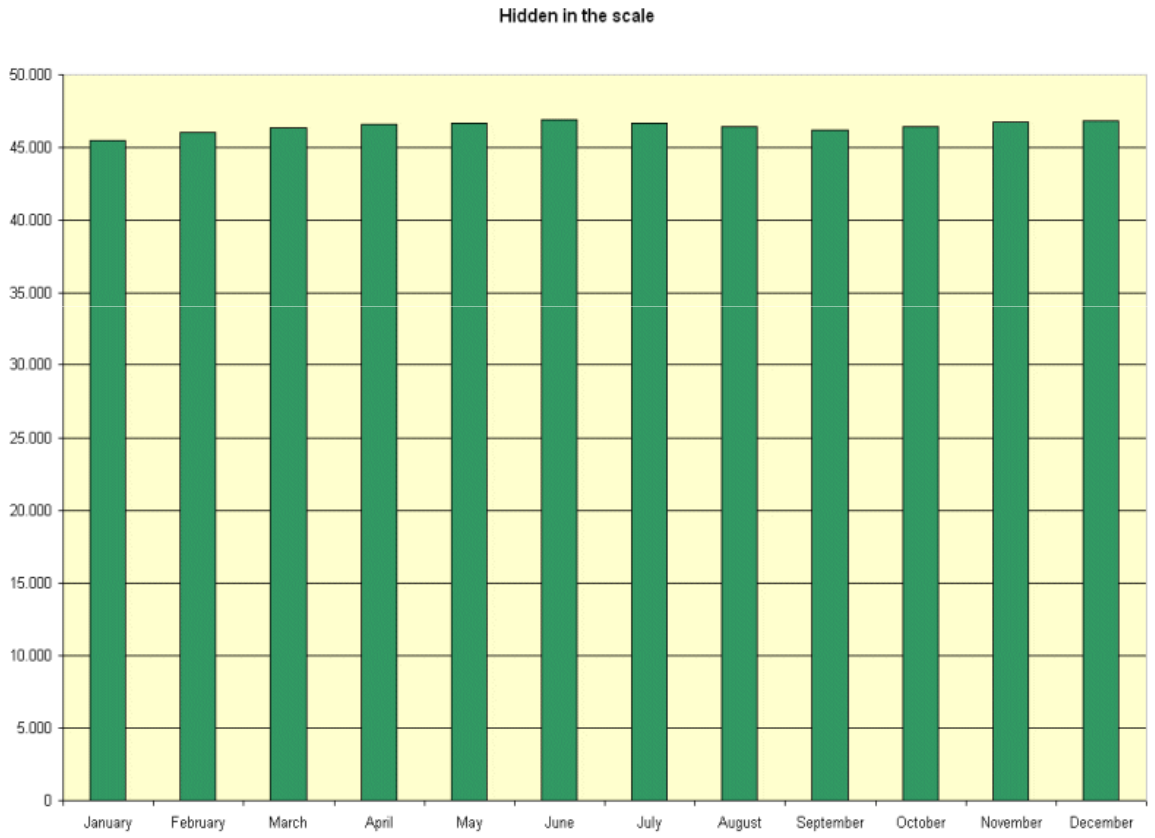
State	College Degree %	Per Capita Income
Alabama	20.6%	11486
Alaska	30.3%	17610
Arizona	27.1%	13461
Arkansas	17.0%	10520
California	31.3%	16409
Colorado	33.9%	14821
Connecticut	33.8%	20189
Delaware	27.9%	15854
District of Columbia	36.4%	18881
Florida	24.9%	14698
Georgia	24.3%	13631
Hawaii	31.2%	15770
Idaho	25.2%	11457
Illinois	26.8%	15201
Indiana	20.9%	13149
Iowa	24.5%	12422
Kansas	26.5%	13300
Kentucky	17.7%	11153
Louisiana	19.4%	10635
Maine	25.7%	12957
Maryland	31.7%	17730
Massachusetts	34.5%	17224
Michigan	24.1%	14154
Minnesota	30.4%	14389
Mississippi	19.9%	9648
Missouri	22.3%	12989
Montana	25.4%	11213
Nebraska	26.0%	12452
Nevada	21.5%	15214
New Hampshire	32.4%	15959
New Jersey	30.1%	18714
New Mexico	25.5%	11246
New York	29.6%	16501
North Carolina	24.2%	12885
North Dakota	28.1%	11051
Ohio	22.3%	13461
Oklahoma	22.8%	11893
Oregon	27.5%	13418
Pennsylvania	23.2%	14068
Rhode Island	27.5%	14981
South Carolina	23.0%	11897
South Dakota	24.6%	10661
Tennessee	20.1%	12255
Texas	25.5%	12904
Utah	30.0%	11029
Vermont	31.5%	13527
Virginia	30.0%	15713
Washington	30.9%	14923
West Virginia	16.1%	10520
Wisconsin	24.9%	13276
Wyoming	25.7%	12311

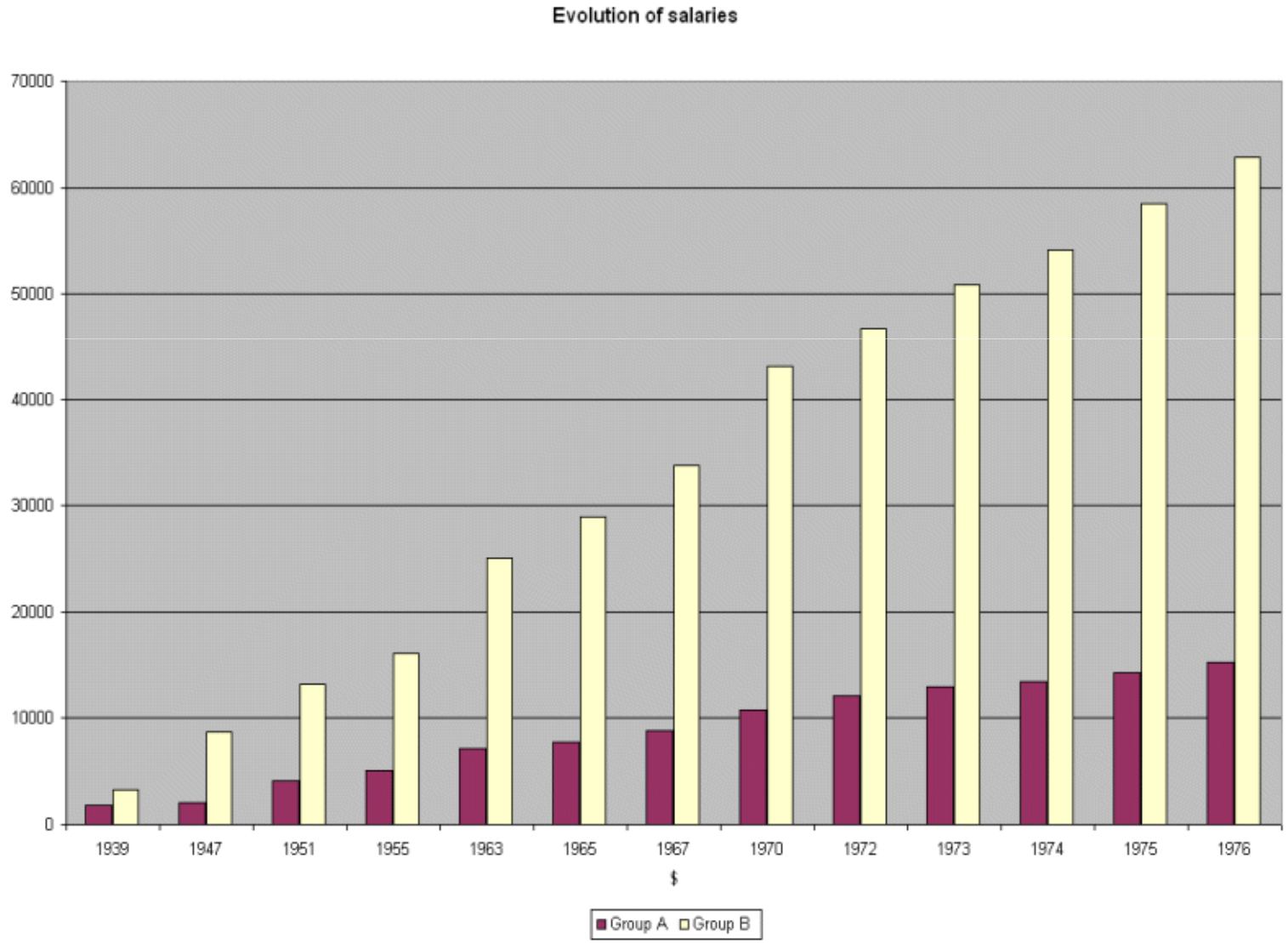


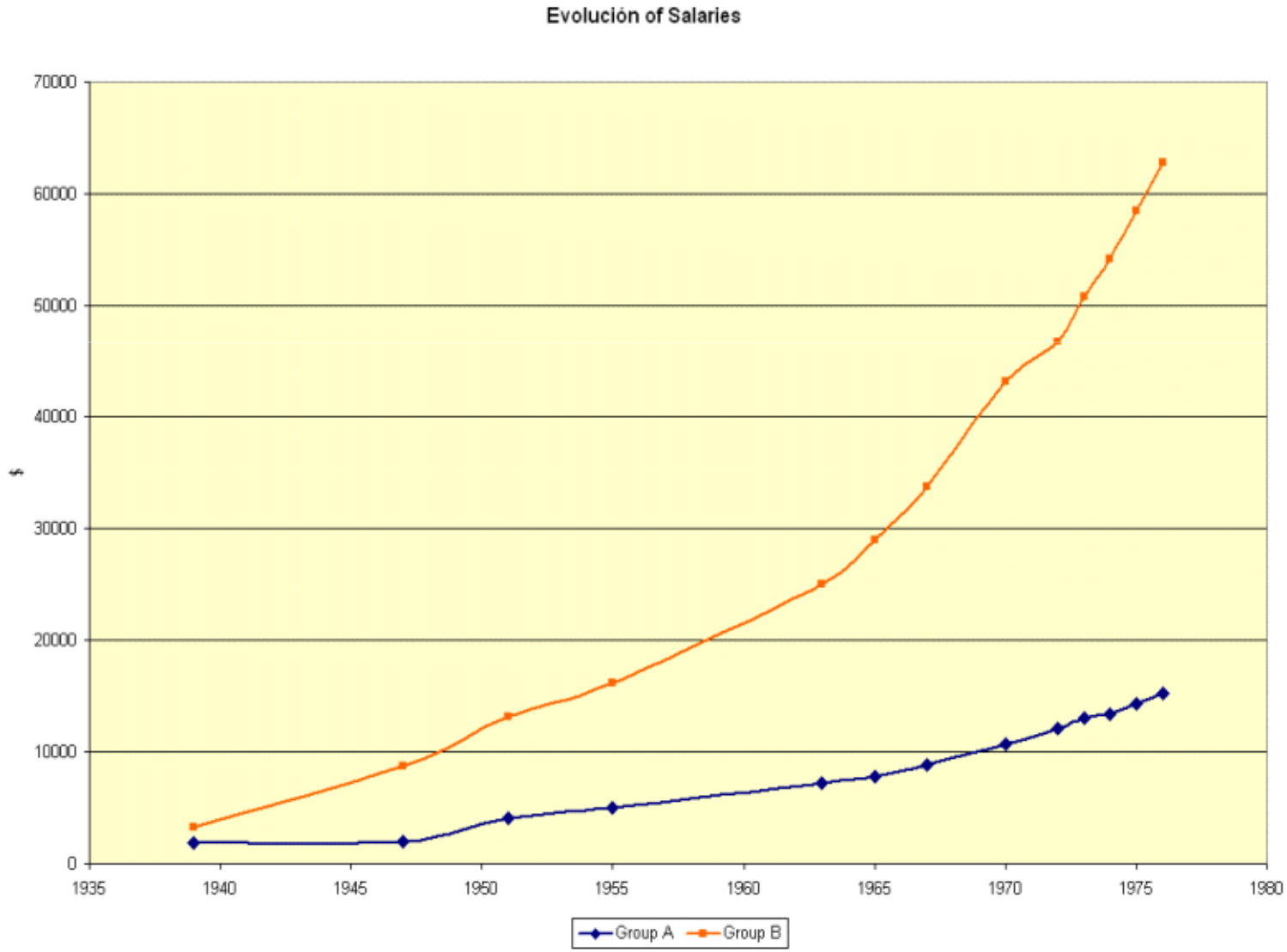
College Degree %

Per Capita Income

Scale

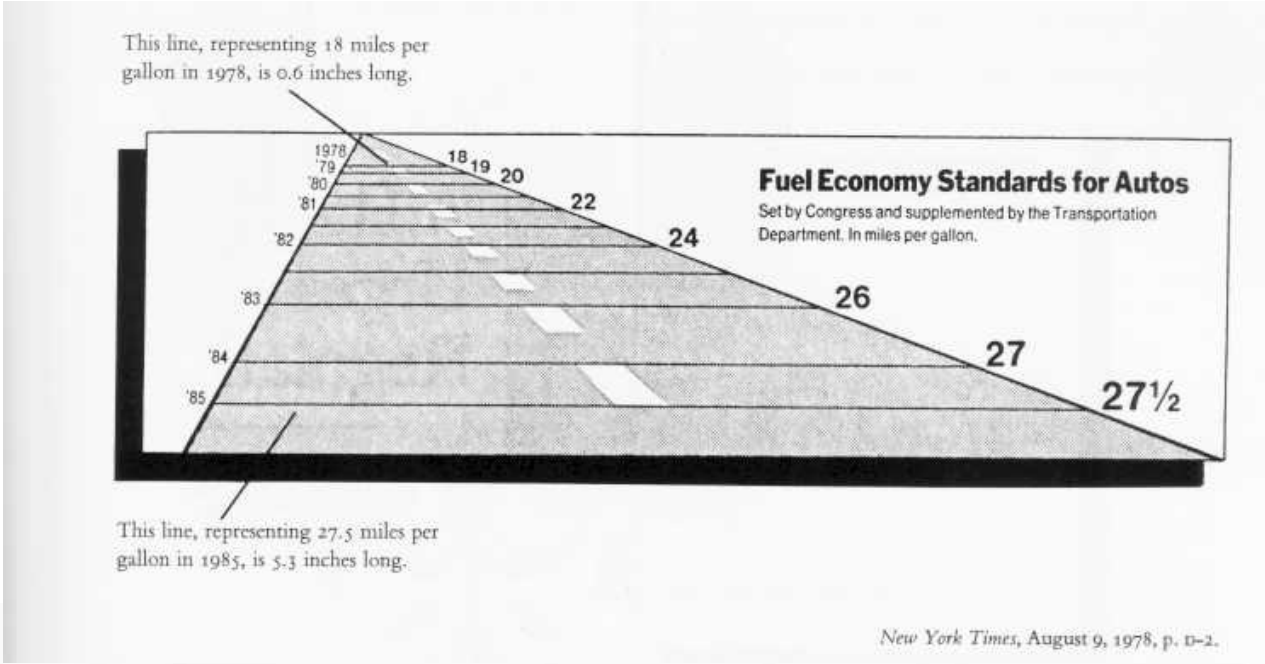

Hidden in the scale
50.000
45.000
40.000
35.000
30.000
25.000
20.000
15.000
10.000
5.000
0
January
February
March
April
May
June
July
August
September
October
November
December


Evolution of salaries
70000
60000
50000
40000
30000
20000
10000
0
1939
1947
1951
1955
1963
1965
1967
1970
1972
1973
1974
1975
1976
$
Group A
Group B

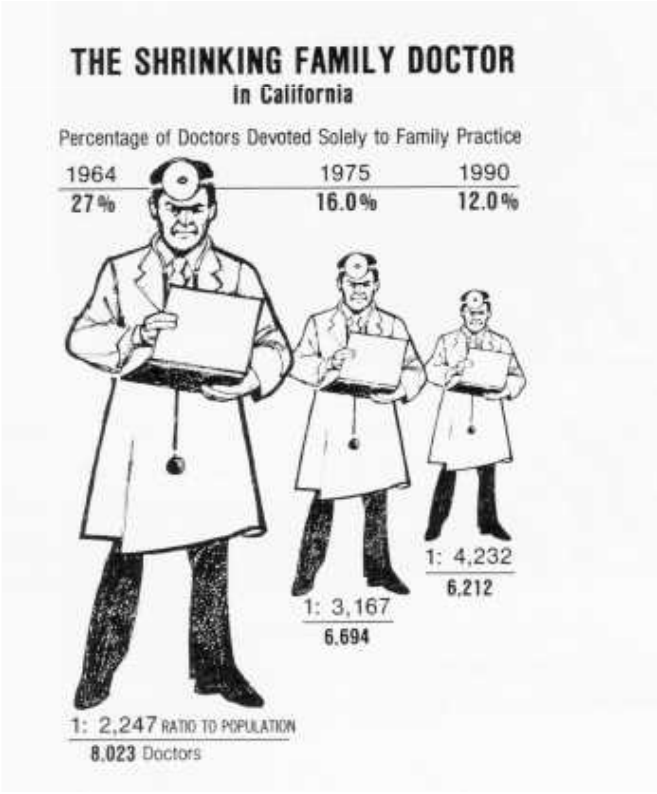

Evolución of Salaries
70000
60000
50000
40000
30000
20000
10000
0
$
1935
1940
1945
1950
1955
1960
1965
1970
1975
1980
Group A
Group B

Lying

From Tufte
1983

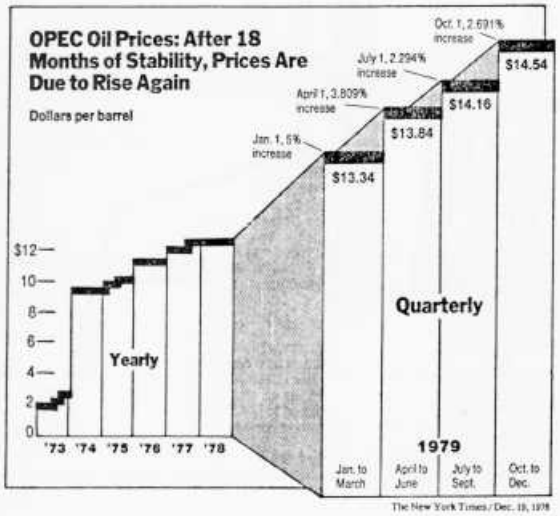


New York Times, August 9, 1978, p. D-2.



Los Angeles Times, August 5, 1979, p. 3.

Design variation corrupts this display:



New York Times, December 19, 1978, p. D-7.

Human Limitations for Short-Term Memory

- Miller's 7 +/- 2 magic number
  - People can recognize 7 +/- 2 chunks of information at a time and hold these chunks in memory for 15-30 seconds
- Chunking
  - Ability to cluster information together
  - Size of chunk depends on knowledge, experience, and familiarity

Chunking Example 1

HEC ATR ANU PTH ETR EET

Chunking Example 2

THE CAT RAN UP THE TREE

Other Chunking Examples

- Image sequences
- Facial recognition
- Word/letter familiarity
- Hierarchies of information
- Others?

Making Sense of an Information Display

Interpretation

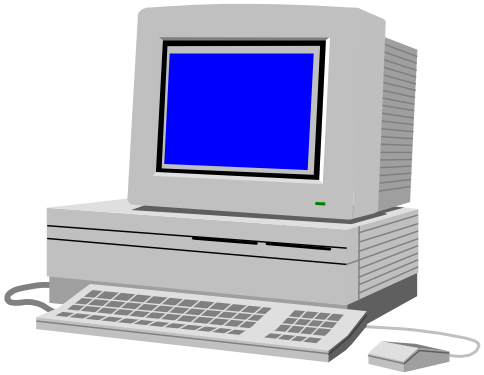
Excel worksheet, a cell is selected, formula is displayed at top

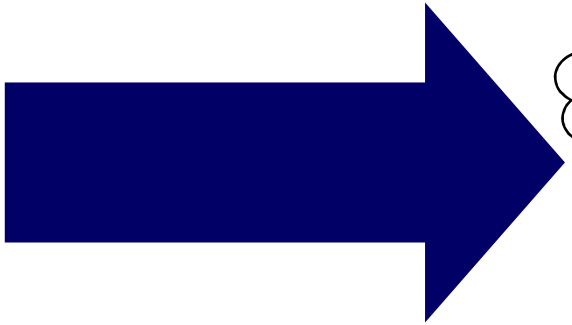
Perception

color, shading, lines characters, squares, spatial organization

Making Sense

Income worksheet, Total tax income is being calculated, the wrong multipler is being used



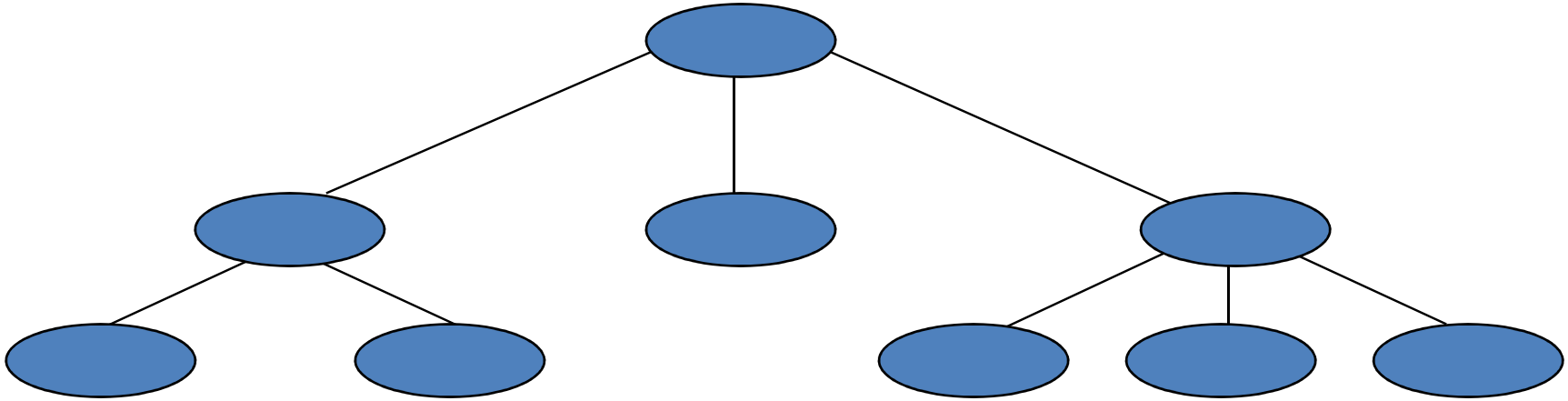


Making Sense

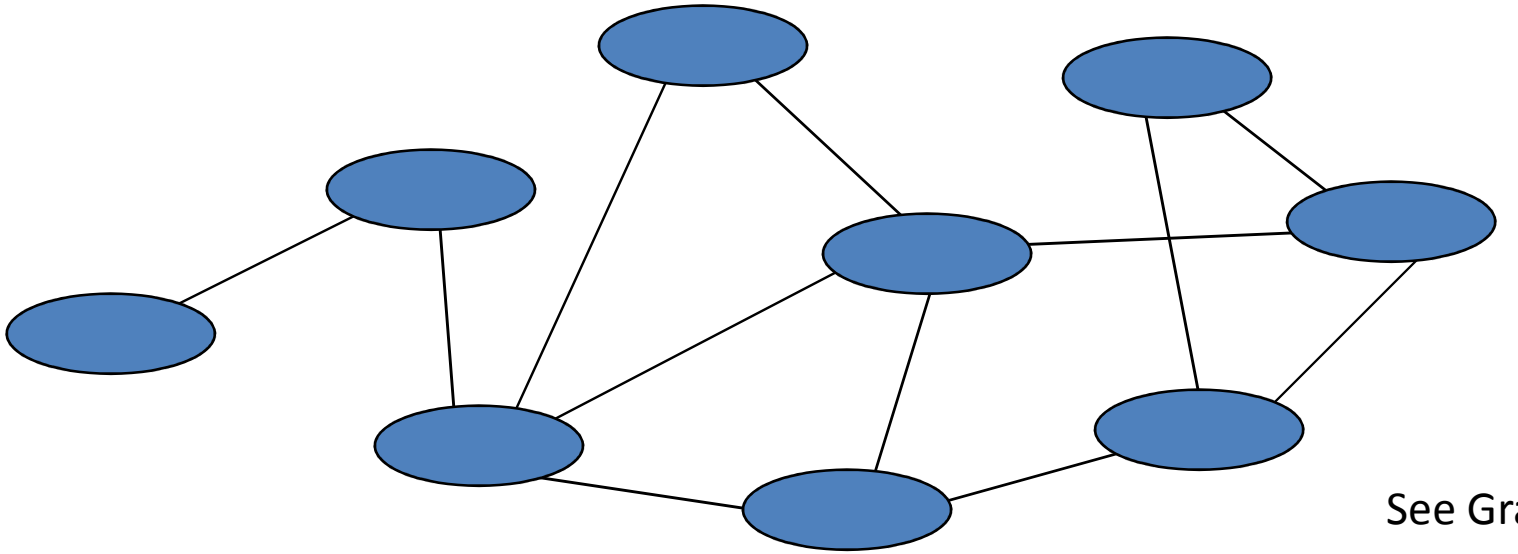
- Last step in crossing the ‘Gulf of Evaluation’
  - Information has been perceived and interpreted
  - Users must “make sense” of information by relating it to their tasks, goals, and interests
- Designers must support people’s abilities to detect patterns and relationships
  - Consistent use of shape, size, color, position
  - Information models (e.g., hierarchies) organize data
  - Dynamic displays cue users to structure

Important Considerations

- Understanding the domain
- Understanding the Research Question
- Understanding the purpose of the Vis
  - User and reader tasks



Which network is easier to understand?

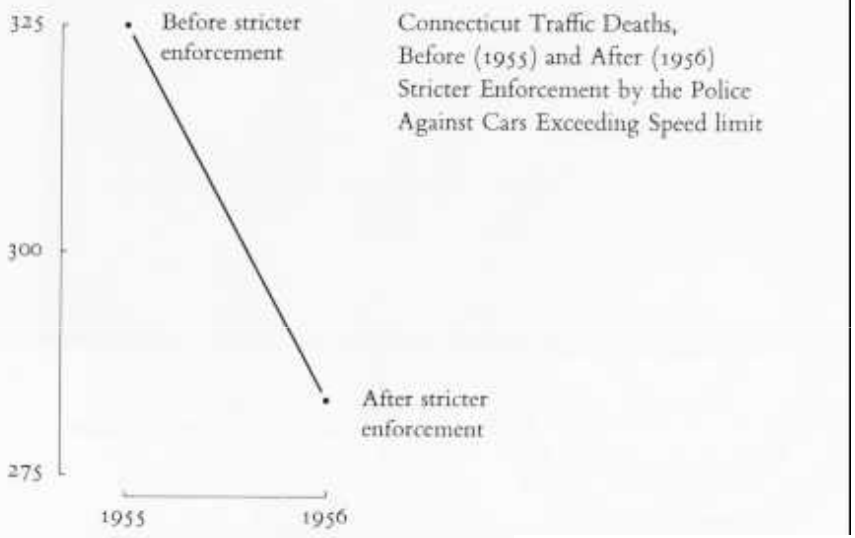


See Graph Vis !

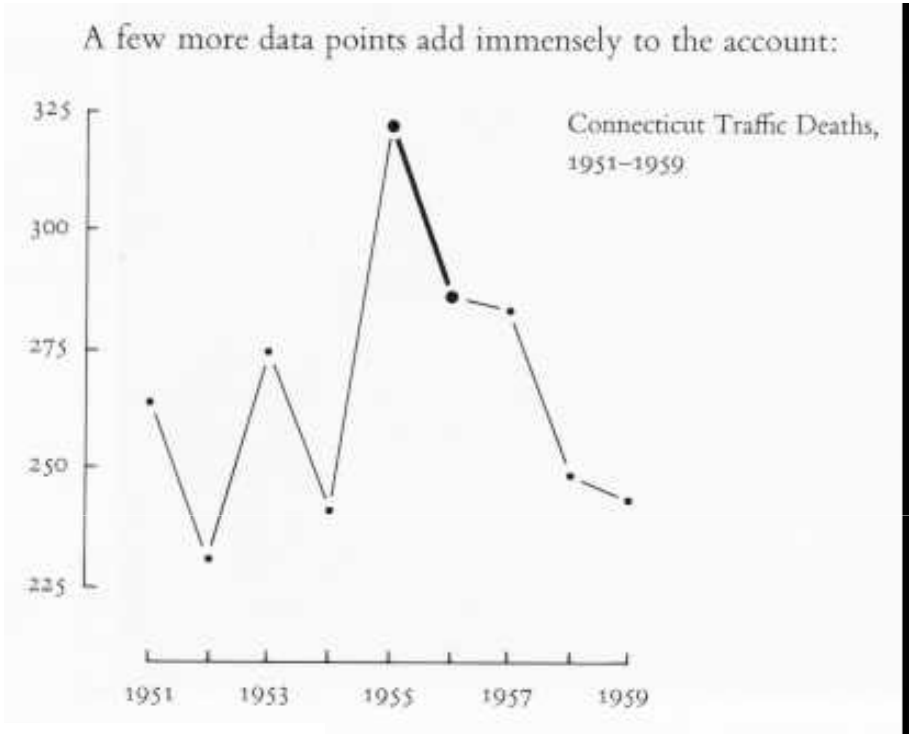
Context Required

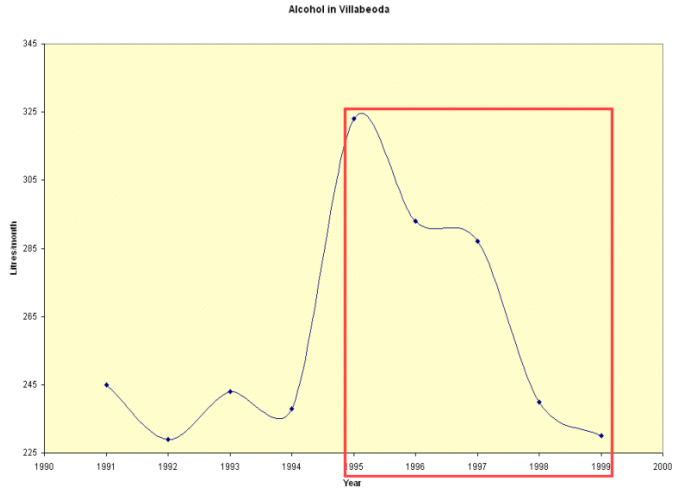
Graphics must not quote data out of context.

Nearly all the important questions are left unanswered by this display:



A few more data points add immensely to the account:





Visual Analysis Overview

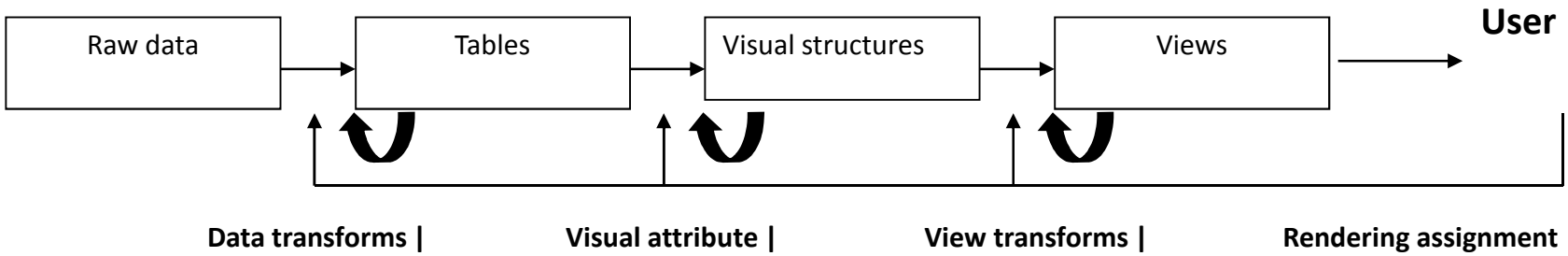
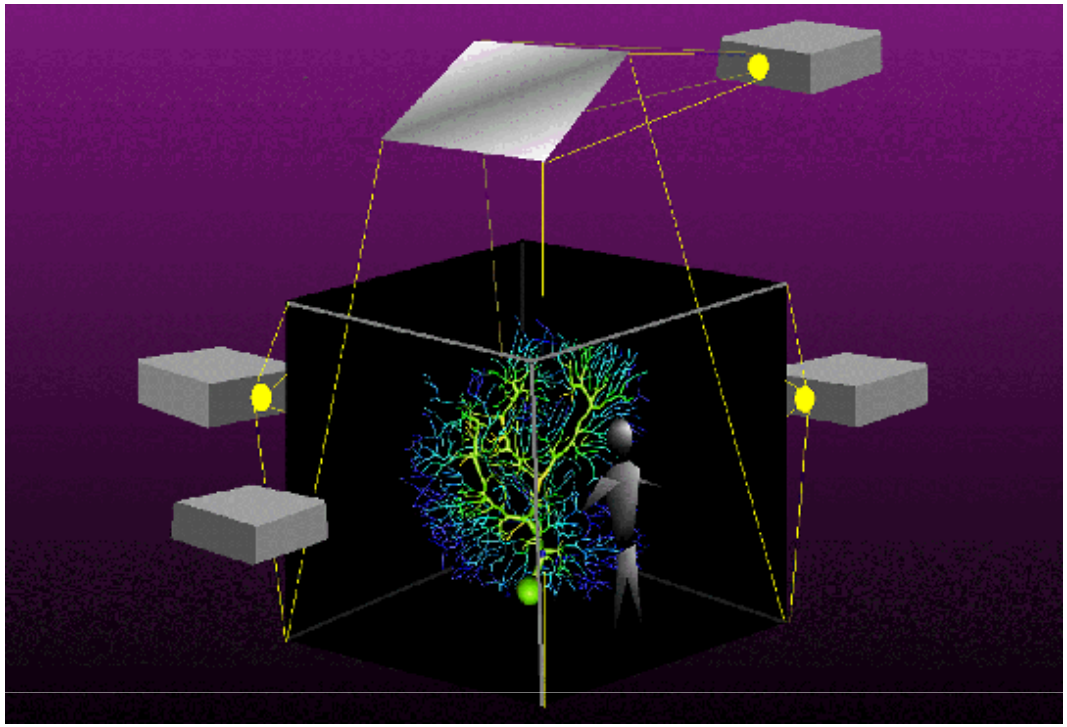
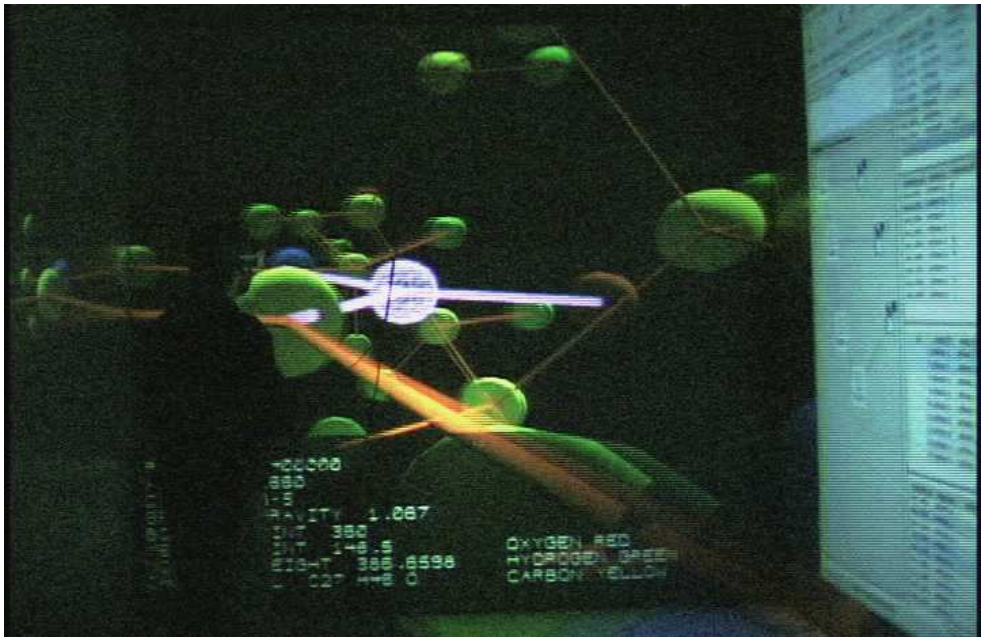


Figure 2.1: Processing in a typical visualization pipeline (from Card et al, 1999)

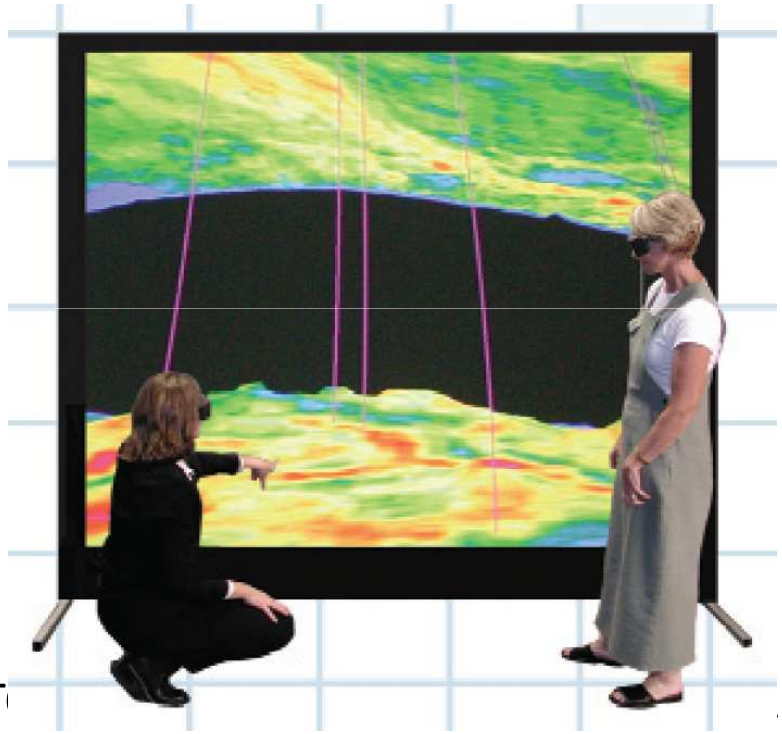
Immersive Virtual Environments

- Leveraging Spatial perception and knowledge
- Embodied interaction
- Examples
- More at last class!




OXYGEN RED
CARBON YELLOW

Stereo Walls



T ndrews (passive)

3-4 additional in labs around campus

ParaView

- Use your knowledge to present the important aspects of the simulation data as:
- An image
- A movie