CS 185 -- Human Computer Interaction

4/10 Intro to Visualization

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Overview

- Visualization for Exploring and Understanding Data
- Visual Variables
- Visual Design
- Visualizing Algorithms
- Geospatial Visualization
- High Dimensional Data

Exploit Human Perception

Highest bandwidth sense

Fast, parallel

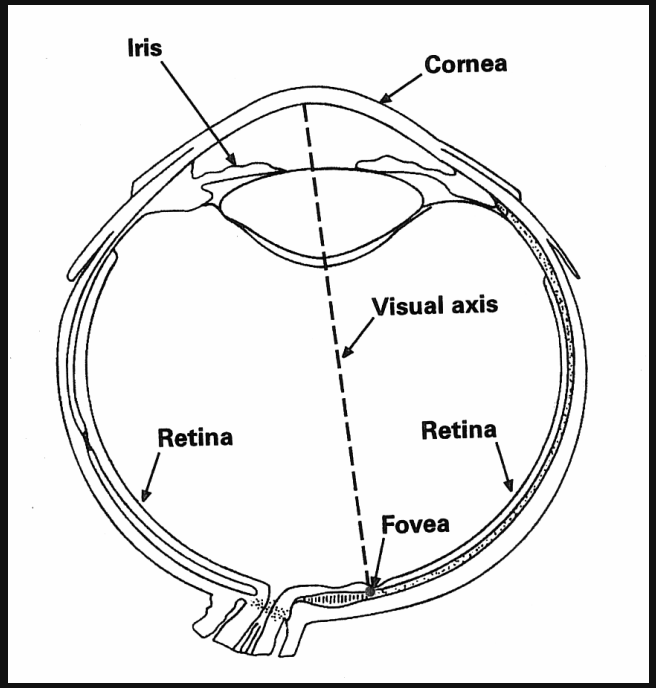
Pattern recognition

Pre-attentive

Extends memory and cognitive capacity

People think visually

Impressive. Lets use it!



Types of data

Entities – objects of interest

Relationships

- form structures that relate entities
- many kinds of relationships

Attributes of entities or relationships

- if they cannot be thought of independently

Operations (cf Colin Ware)

- Operations (actions) can also be considered as data

What is visualization?

Understanding and seeing

We talk about trying to make our thoughts clear, to bring them into focus

"To visualize" – really means "to construct a visual image in the mind" – but now also refers to "a graphical representation of data or concepts"

Defn of Visualization: The use of computer-supported, visual representation of data to amplify cognition

The purpose of visualization is insight, not pictures

Visualizations can be said to be natural or visually efficient

How Visualization Amplifies Cognition

Different ways that visualizations *could* help amplify cognition:

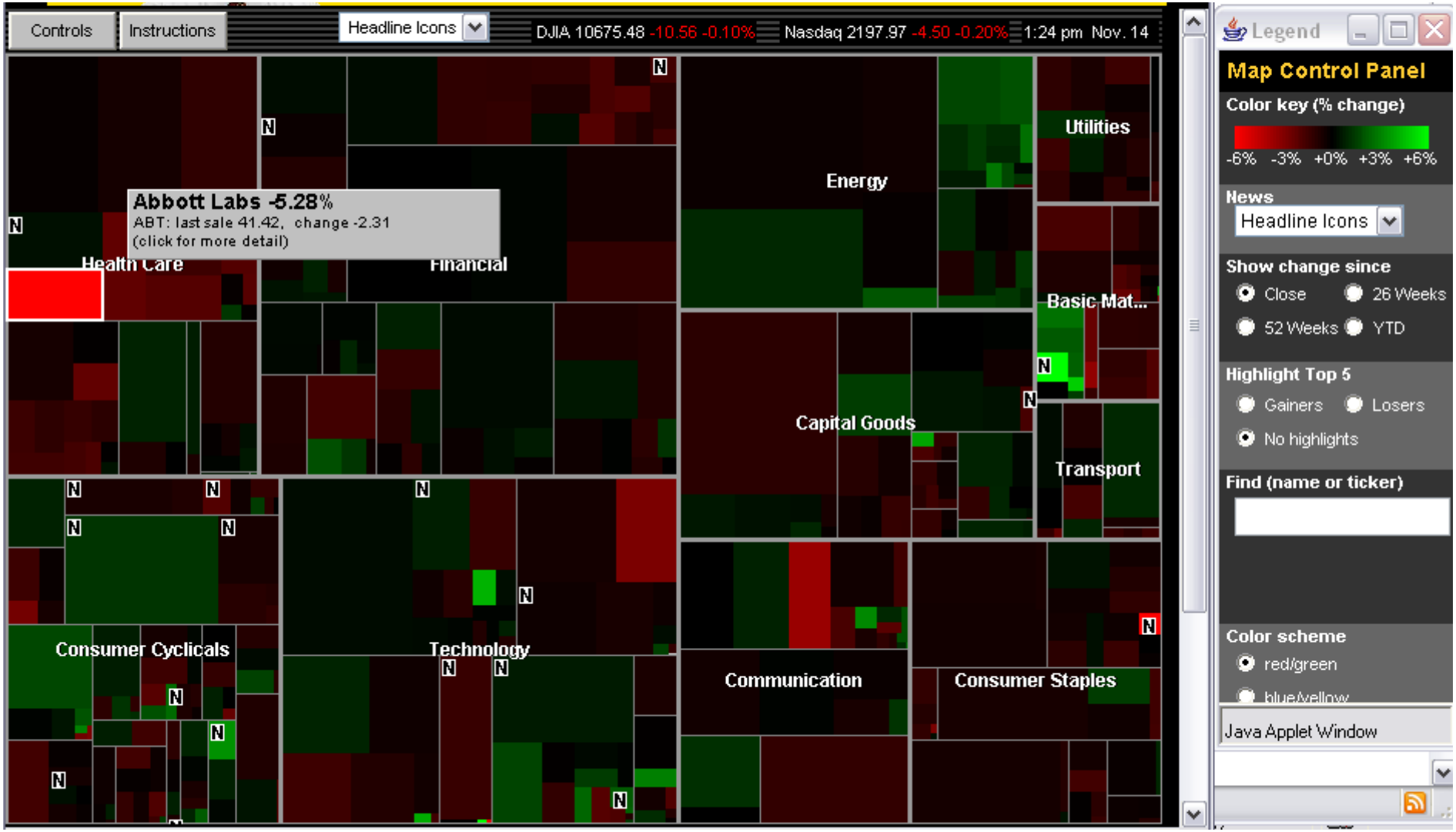
1. **By increasing memory and processing resources available**
2. **By reducing the amount of time to search**
3. **Enhancing the detections of patterns and enabling perceptual inference operations**
4. **Aid perceptual monitoring**
5. **By encoding information in a manipulable medium**

Mapping Data to Visual Form

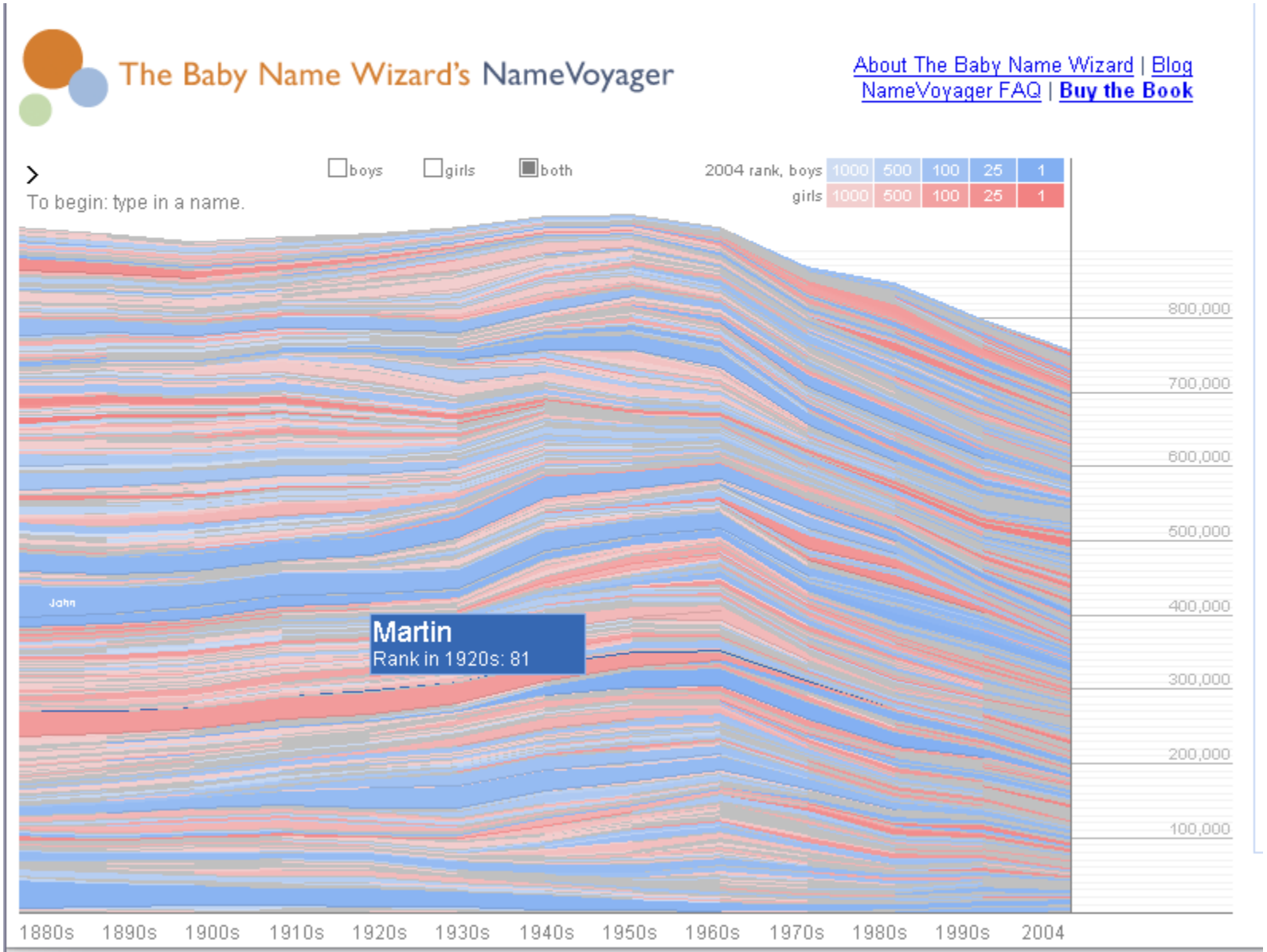
Different forms of data:

- Data tables
- Meta data (descriptive data about data)
- Hierarchies, heterarchies

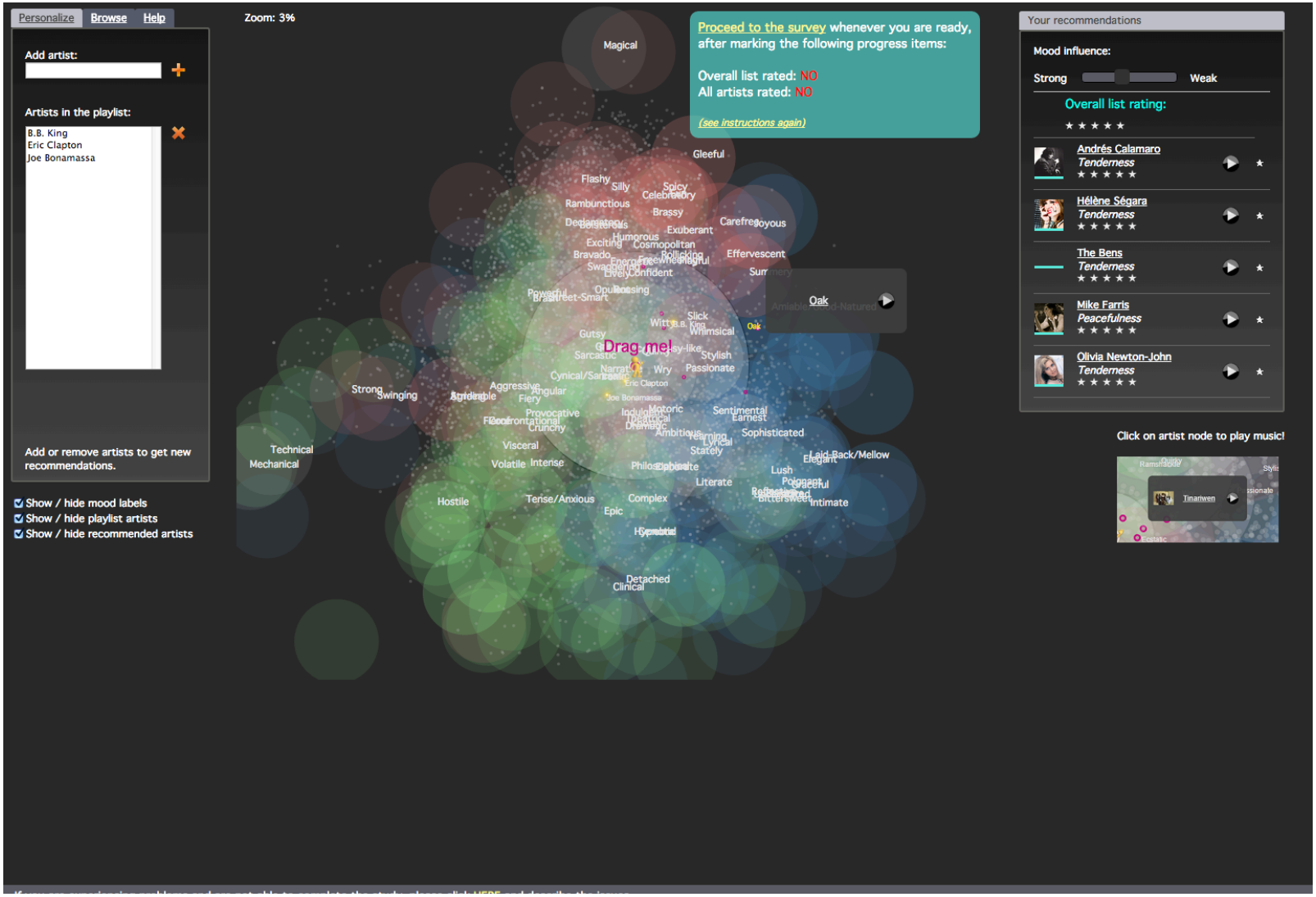
SmartMoney (TreeMap)



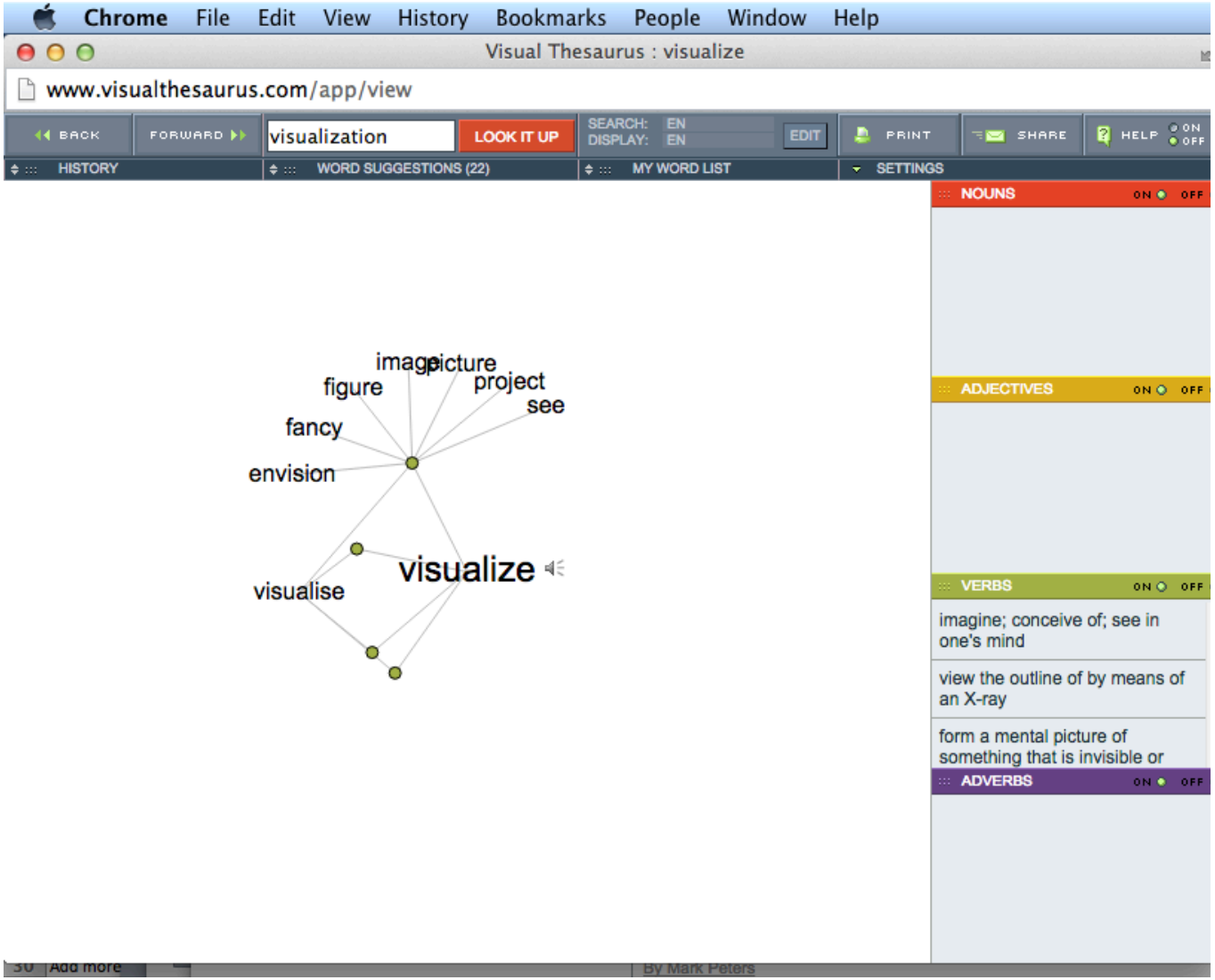
Baby Name Voyager (River)



MoodPlay (Asterism?) (I. Andjelkovic)



Visual Thesaurus (Node-link)



Attribute quality (variable types)

Nominal data

- Labeling function (e.g. apple, orange), category data that can be directly compared (=)

Ordinal data

- Sequencing things, ranking (<,>)

Quantitative data

- Real numbers (e.g. object A is twice as big as B, can do arithmetic on them, ratios)
- And Interval data
  - Able to derive gap between data values (e.g. time of departure and arrival of an aircraft)

We can sometimes transform one type of data into another

Exploit Human Perception

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Fast, parallel

Pattern recognition

Pre-attentive

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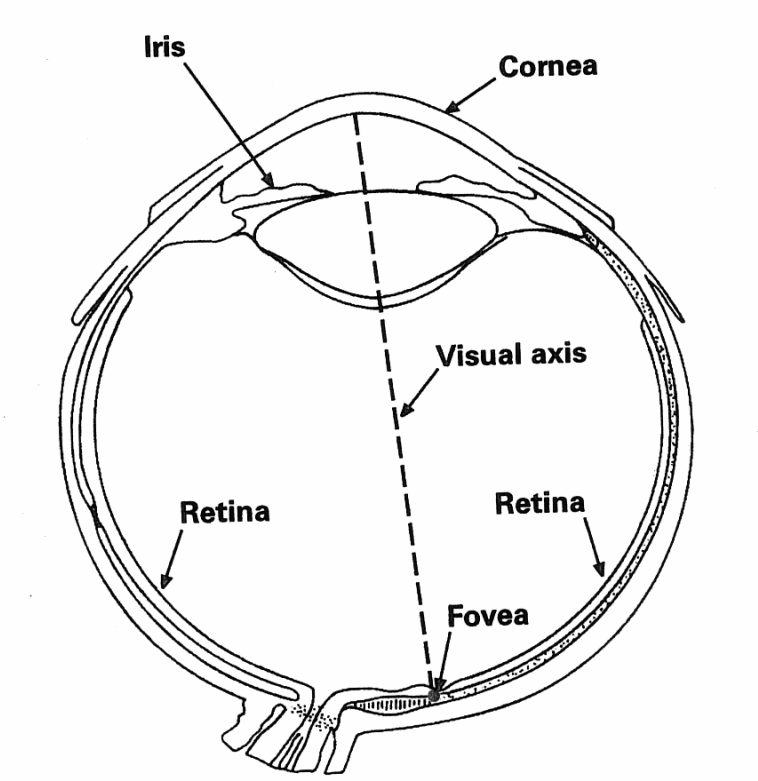
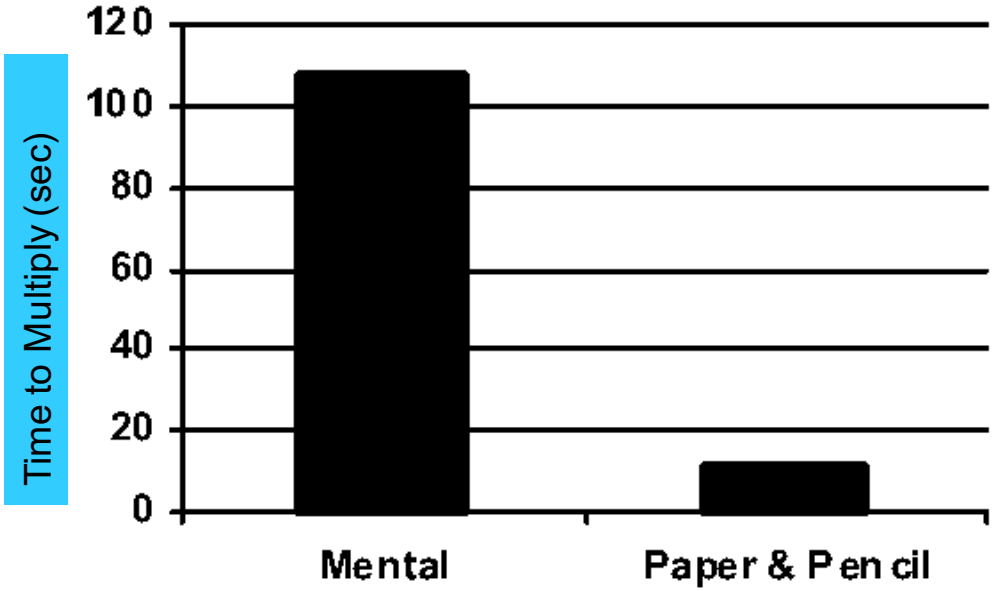
People think visually



Impressive. Lets use it!

Strategy: Use External World (Externalize)

$$\begin{array}{r} 34 \\ \times\ 72 \\ \hline 68 \\ 23^{2}80 \\ \hline 24^{1}48 \end{array}$$



How Many Zeros in 100 Digits of PI?

3.1 4 1 5 9 2 6 5 3 5 8 9 7 9
3 2 3 8 4 6 2 6 4 3 3 8 3 2 7
9 5 0 2 8 8 4 1 9 7 1 6 9 3 9
9 3 7 5 1 0 5 8 2 0 9 7 4 9 4
4 5 9 2 3 0 7 8 1 6 4 0 6 2 8
6 2 0 8 9 9 8 6 2 8 0 3 4 8 2
5 3 4 2 1 1 7 0 6 7 9 8 2 1 4

How Many Red Objects?

3.1 4 1 5 9 2 6 5 3 5 8 9 7 9

3 2 3 8 4 6 2 6 4 3 3 8 3 2 7

9 5 0 2 8 8 4 1 9 7 1 6 9 3 9

9 3 7 5 1 0 5 8 2 0 9 7 4 9 4

4 5 9 2 3 0 7 8 1 6 4 0 6 2 8

6 2 0 8 9 9 8 6 2 8 0 3 4 8 2

5 3 4 2 1 1 7 0 6 7 9 8 2 1 4

Which state has highest Income?

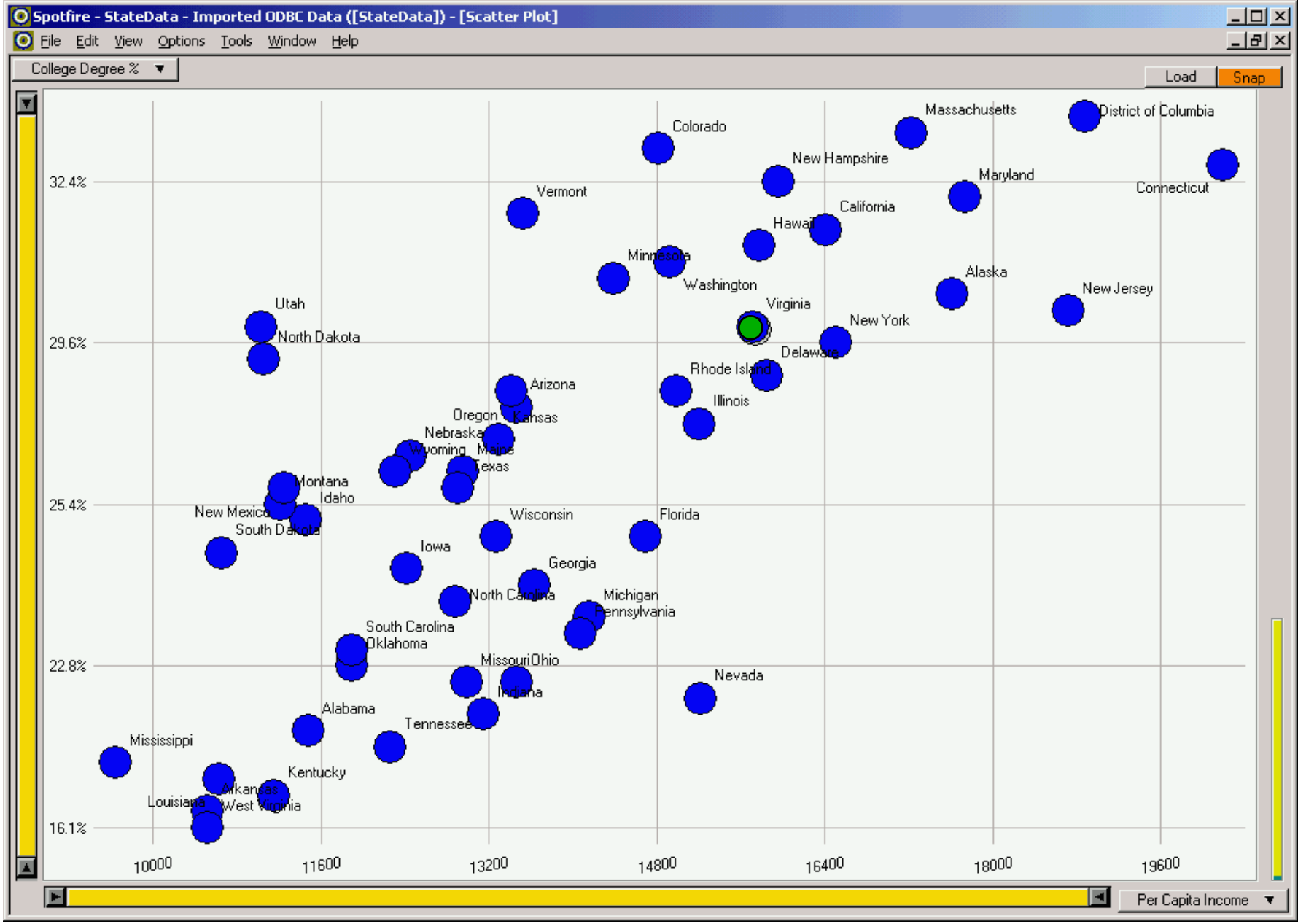
Relationship between Income and Education?

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



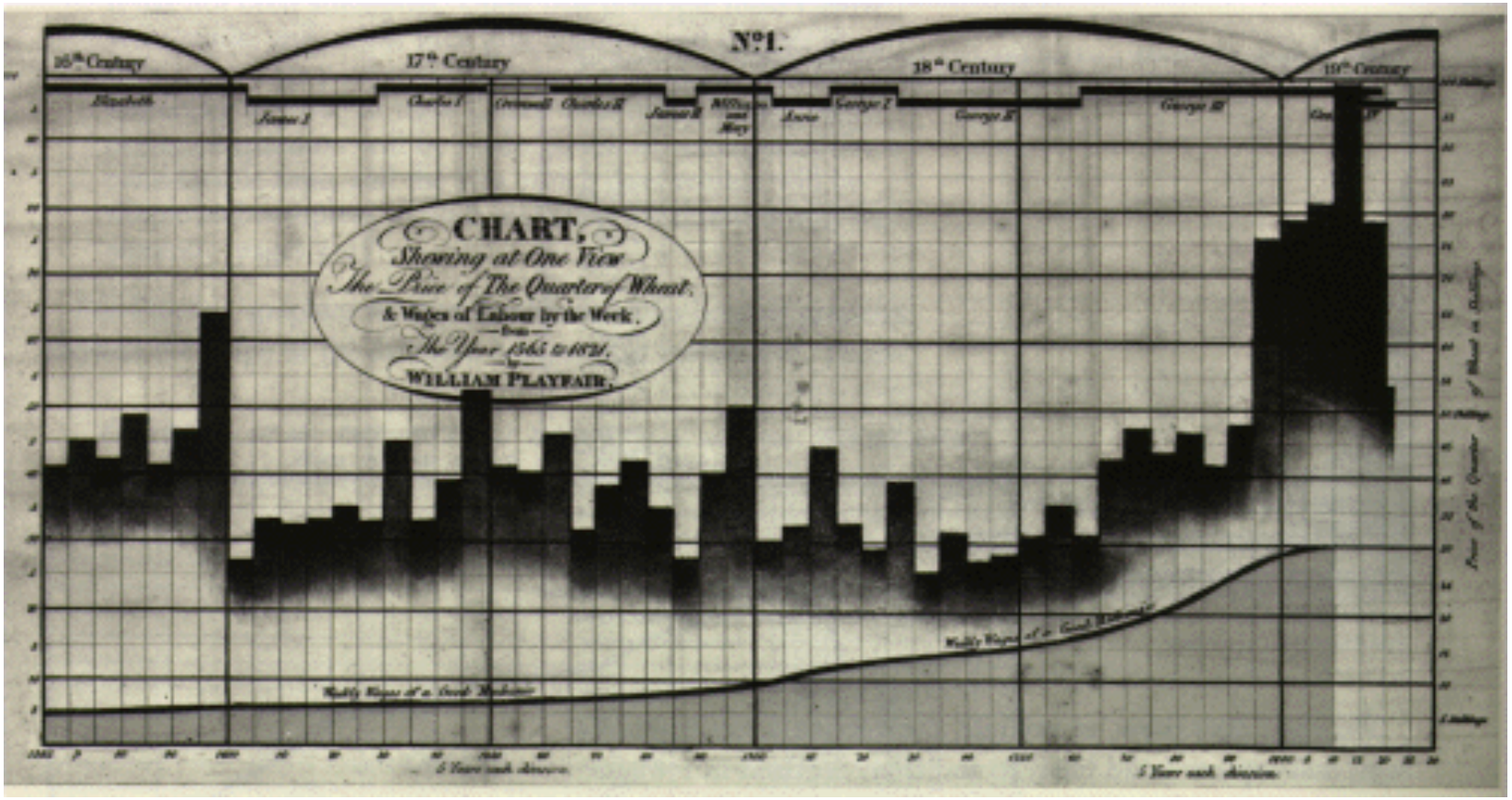
College Degree %

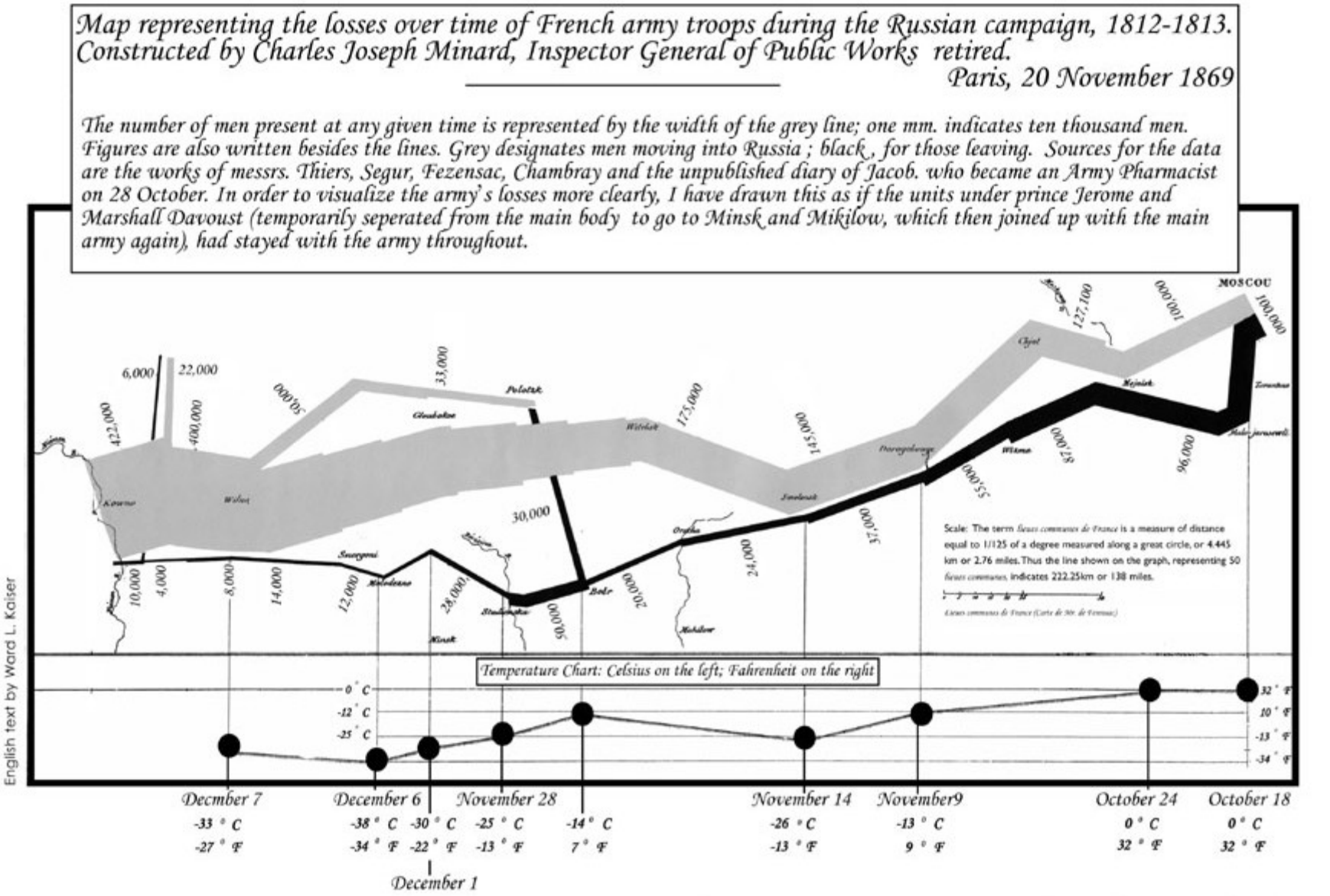
Per Capita Income

William Playfair

Scottish political economist. "Father of statistical graphics" (together with J.H. Lambert)

1786 published the first presentation graphics





Editor s note: dates & temperatures are only referenced for the retreat from Moscow

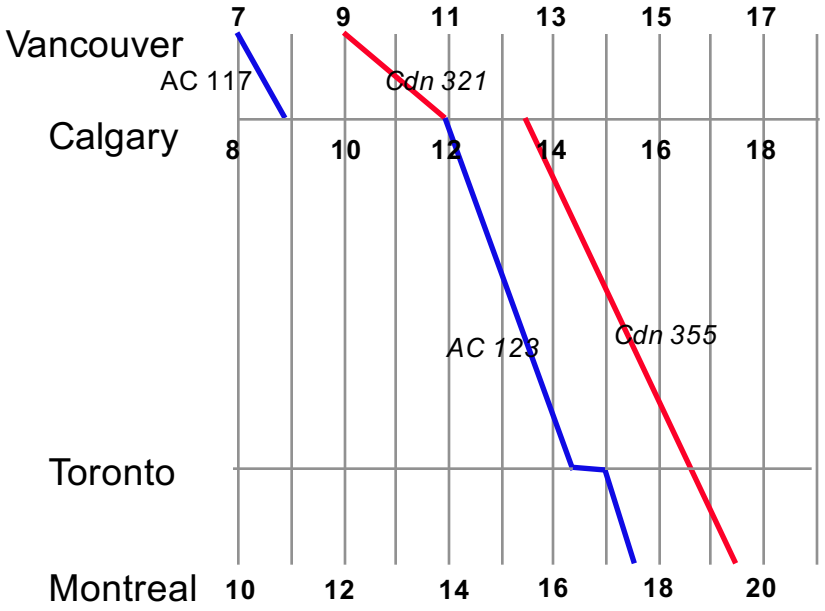
Figure 58. ***Minard s map of Napoleon s Russian campaign.***
This graphic has been translated from French to English and modified to most effectively display the temperature data.

Which is the best flight?

length, stop-overs, switches...

		depart	*arrive*
AC 117	Vancouver - Calgary	7:00	9:00
Cdn 321	Vancouver - Calgary	9:00	12:00
Cdn 355	Calgary - Montreal	13:30	19:30
AC 123	Calgary - Toronto	12:30	16:30
AC 123	Toronto - Montreal	16:45	17:30

*time zone: +1 van-cal, +2 cal-tor, mtl



Principles for Information Visualization

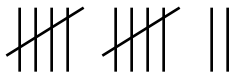
Graphics should reveal the data

- show the data
- not get in the way of the message
- avoid distortion
- present many numbers in a small space
- make large data sets coherent
- encourage comparison between data
- supply both a broad overview and fine detail
- serve a clear purpose

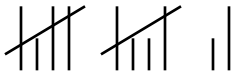
E. Tufte
Visual Display of Quantitative Information

- *many visual examples on the following slides are taken from Tufte's books*

Show The Data

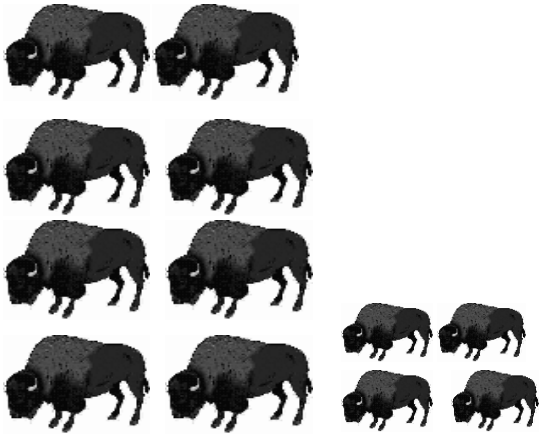


 # Buffalo

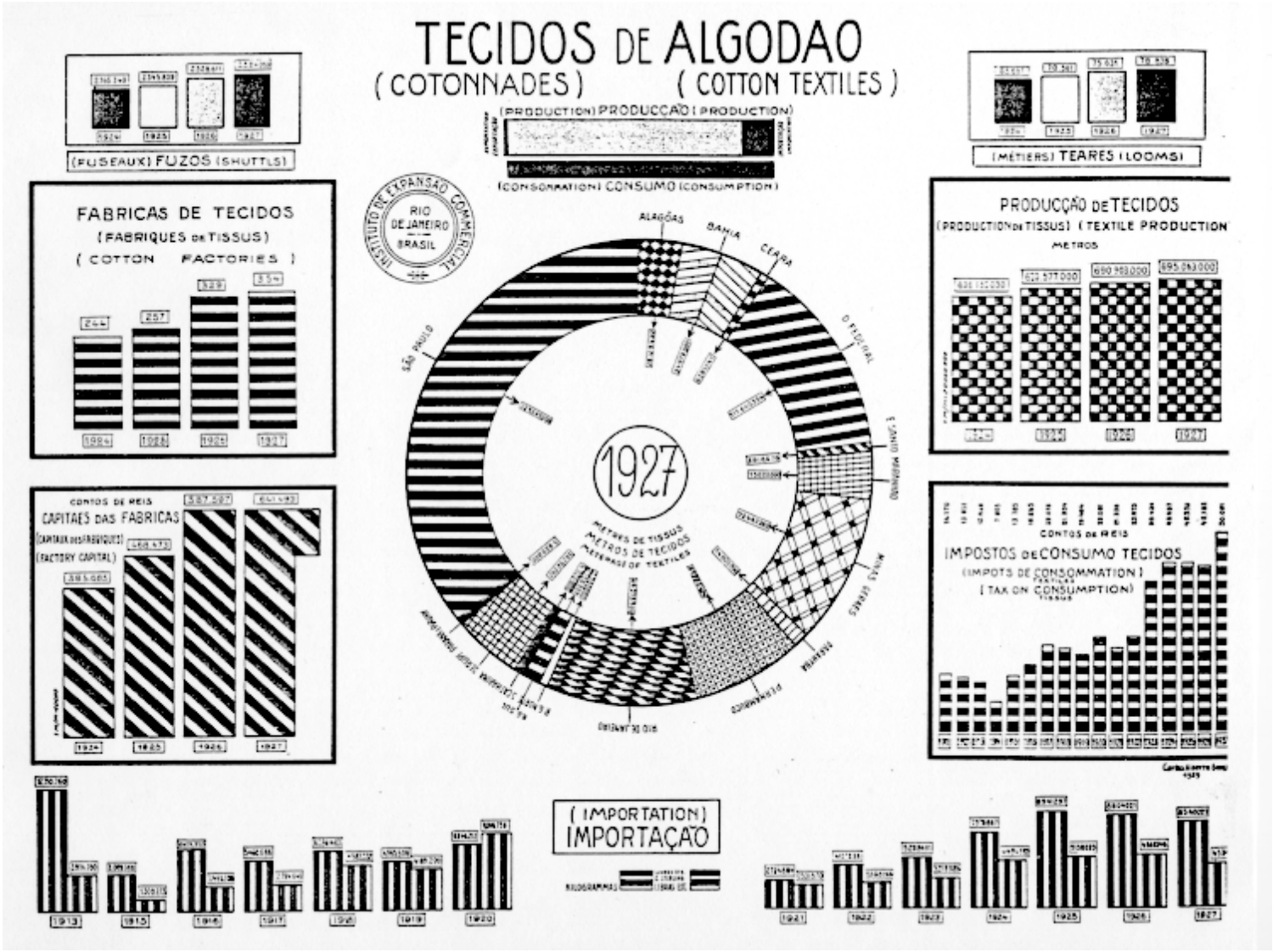


 # Buffalo

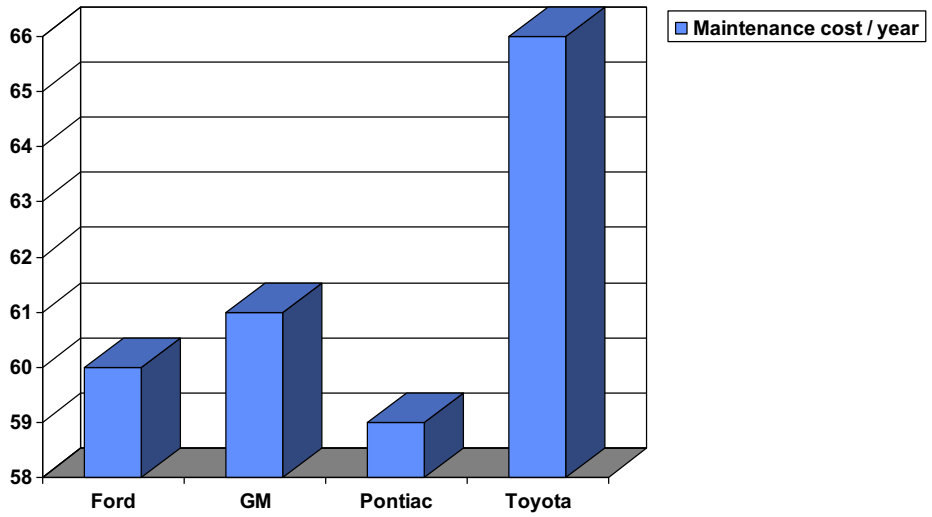
 # Adults *# calves*

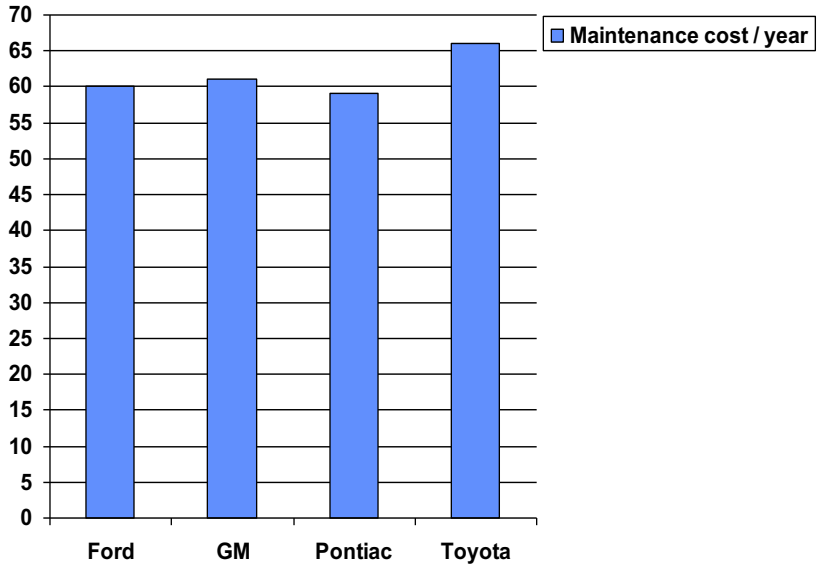


Do Not Get In The Way Of The Message



Avoid Distortion





Broad Overview And Fine Detail

Mutually Exclusive Views

Icewind Dale (Black Isle)

Broad Overview And Fine Detail

Overlay

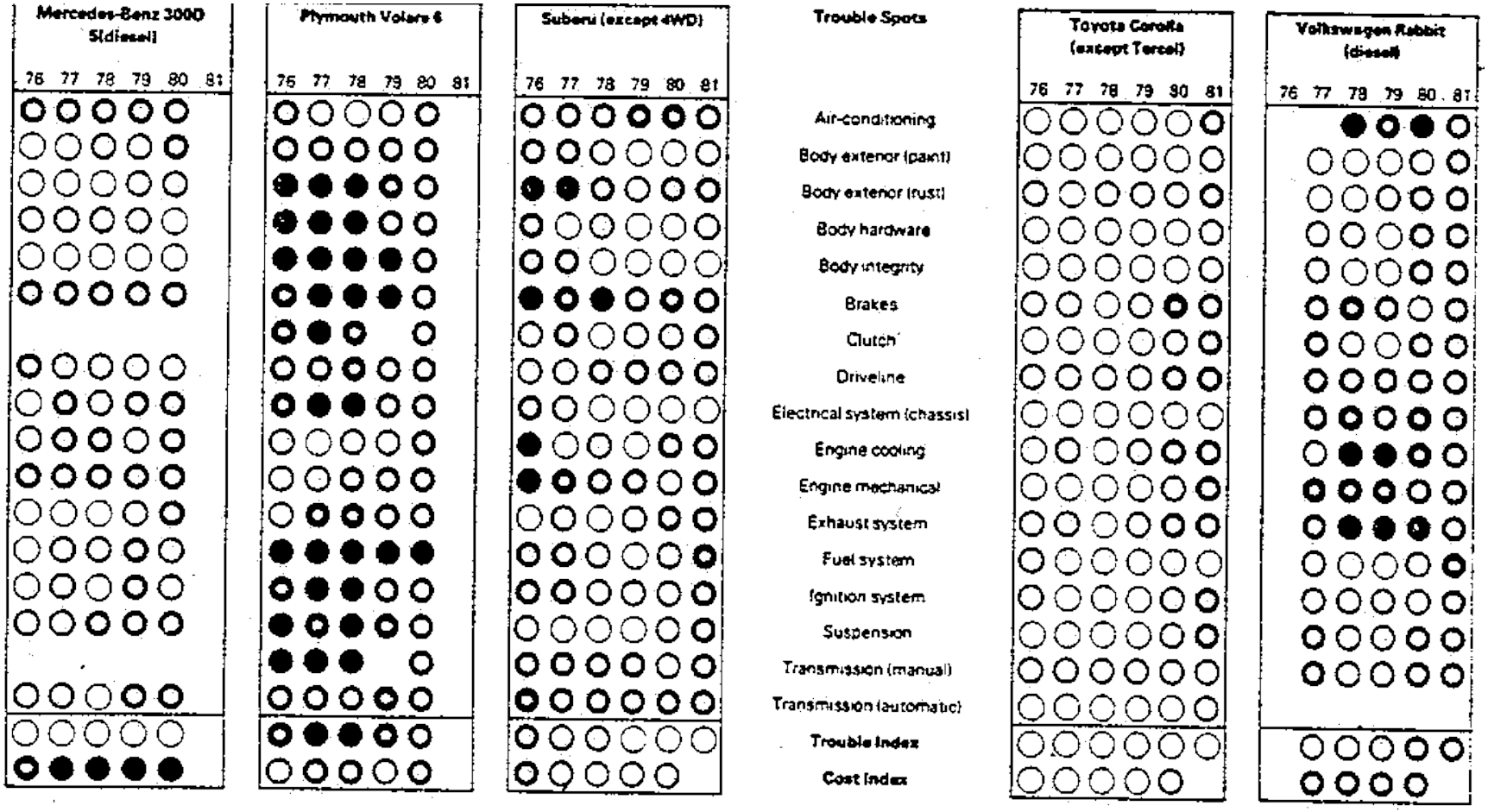
Diablo (Blizzard)

Broad Overview And Fine Detail

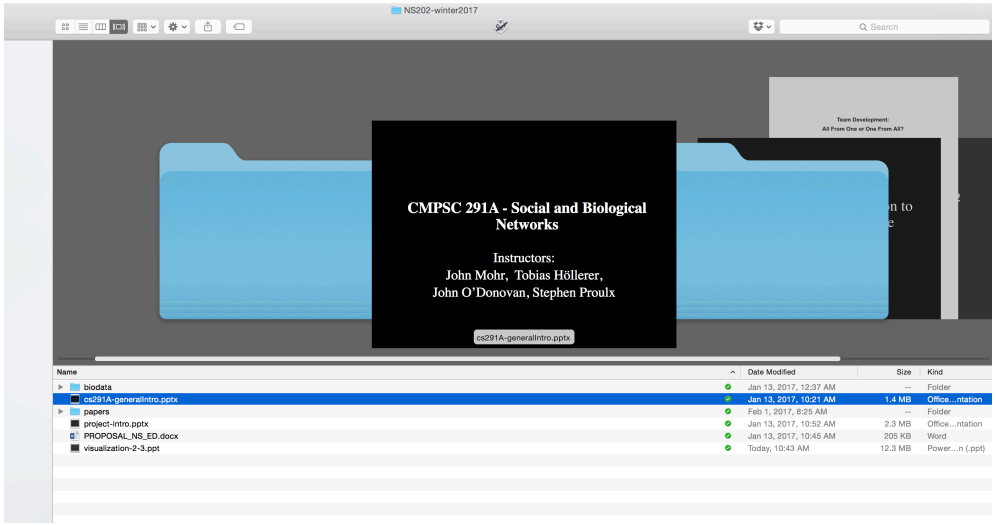
Separate Views

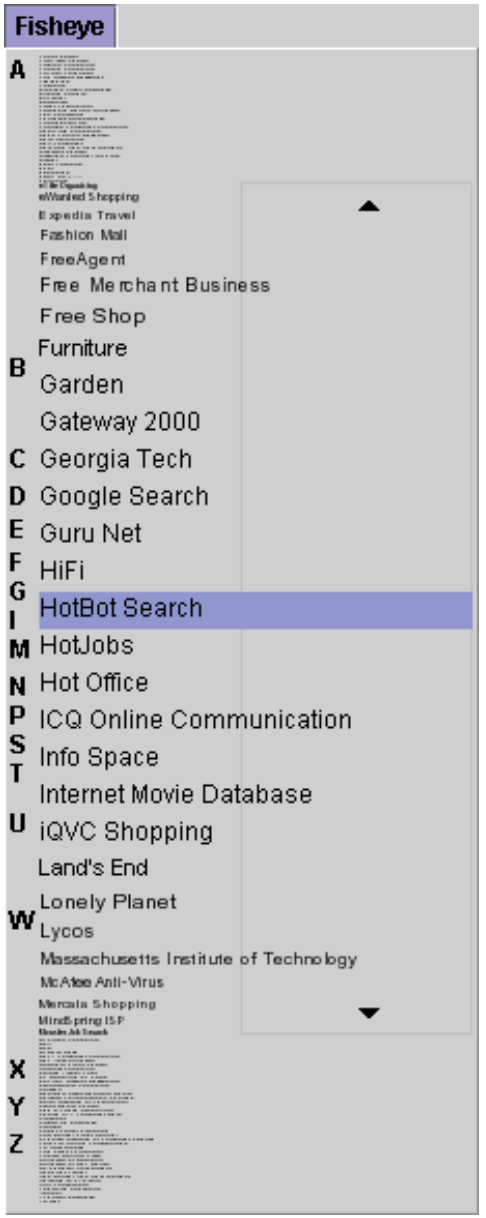
Defender (Williams Electronics)

Broad Overview And Fine Detail



Broad Overview And Fine Detail

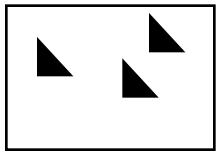




Bederson, B.B. (May 2000)
University of Maryland
www.cs.umd.edu/hcil/fisheyemenu/

Visual Variables (Jacques Bertin)

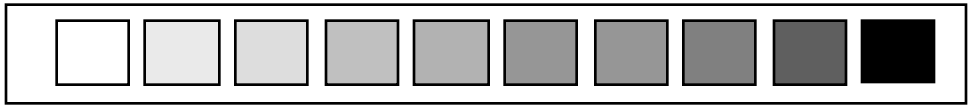
Position
- Changes in the x, y, z location



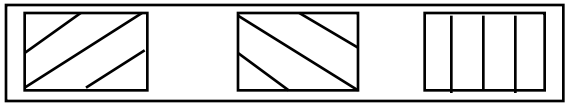
Size
- Changes in length, area or repetition

Shape
- Changes in form

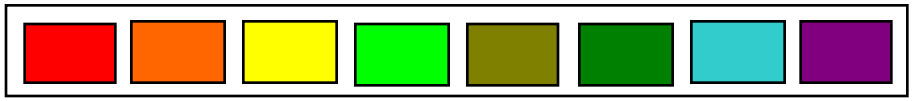
Value
- Changes in brightness



Orientation
- Changes in alignment



Color
- Changes in hue



Texture
- Variations in pattern

Motion

Visual Variables

Visual variables can affect how you interpret information

- **selective**
  is a change in this variable enough to allow us to select things from a group?

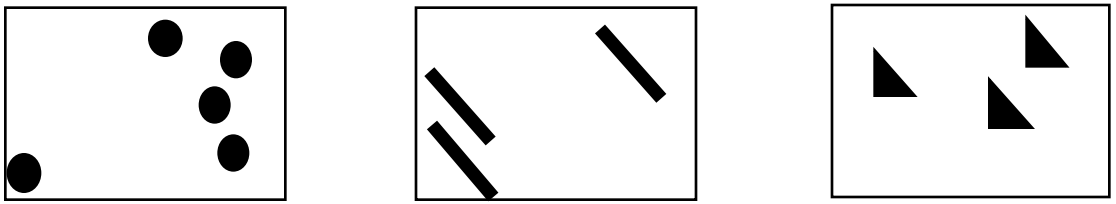
- **associative**
  is a change in this variable enough to allow us to perceive things as a group?

- **quantitative**
  is there a numerical reading obtainable from changes in this variable?

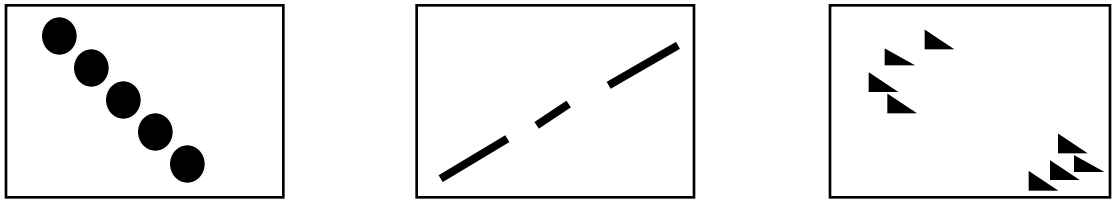
- **order**
  are changes in this variable perceived as ordered?

Visual Variable: Position

? selective

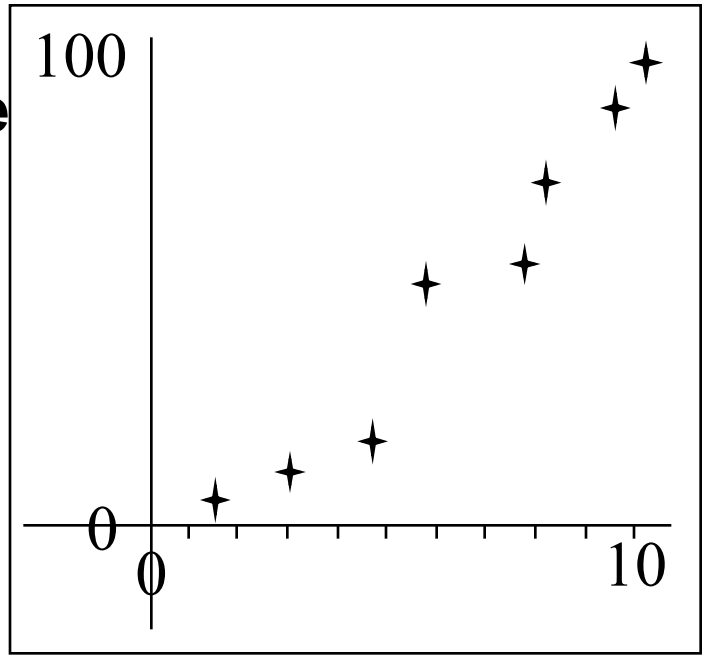


? associative



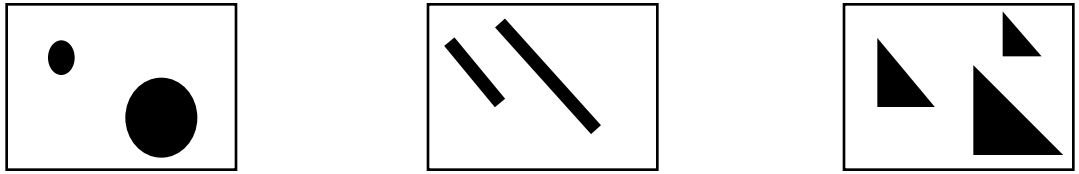
? quantitative

? order

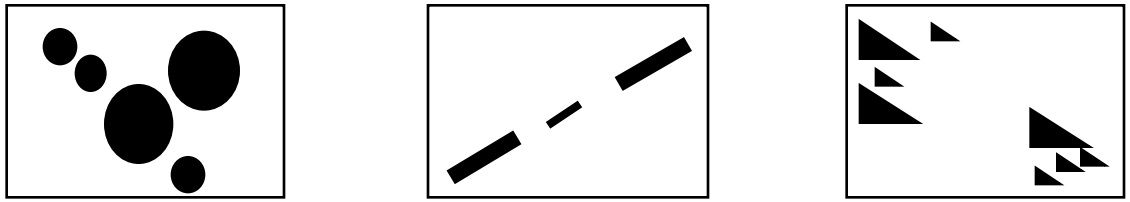


Visual Variable: Size

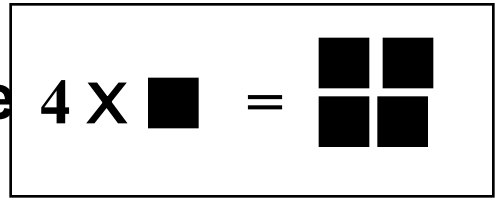
✓ selective



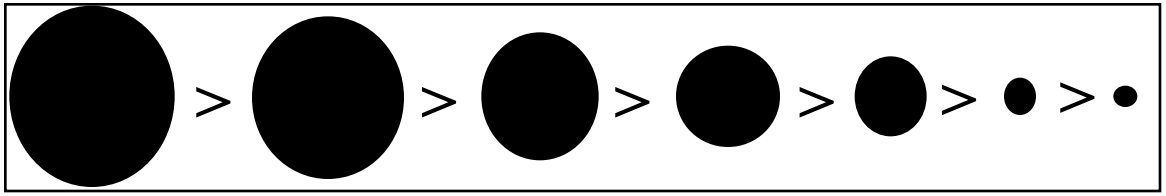
✓ associative



≈ quantitative

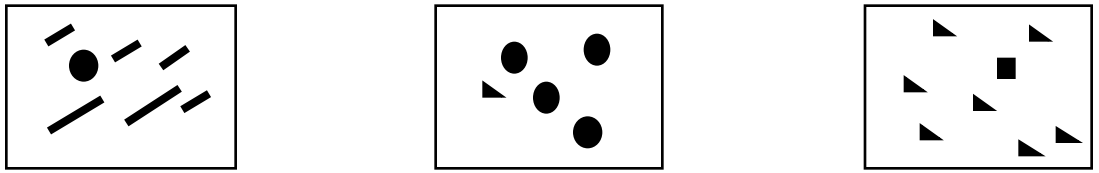


✓ order

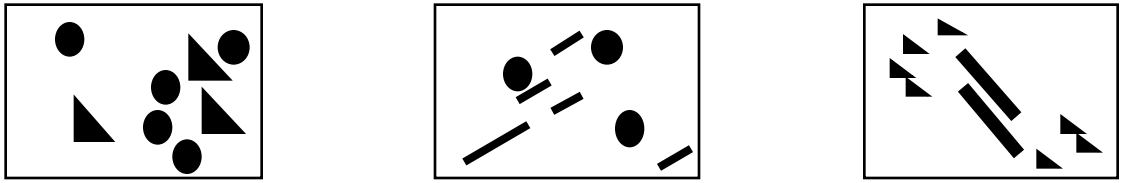


Visual Variable: Shape

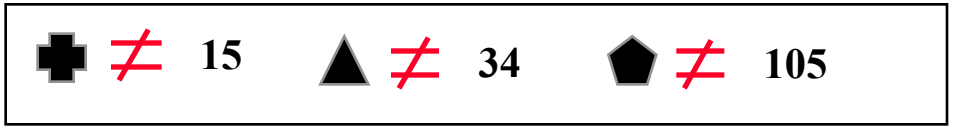
≃ selective



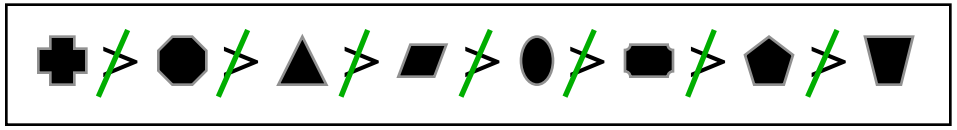
≃ associative



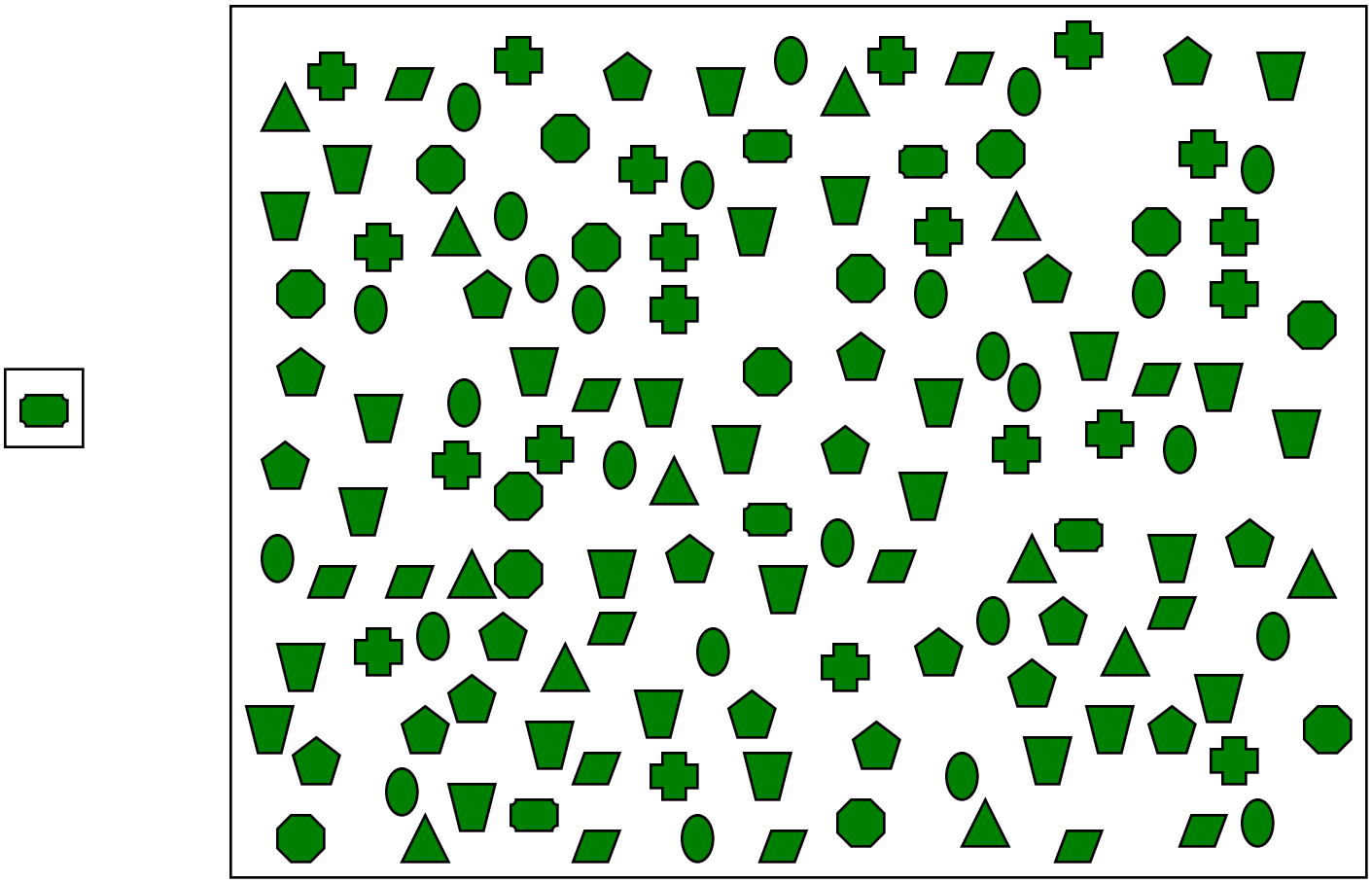
≠ quantitative



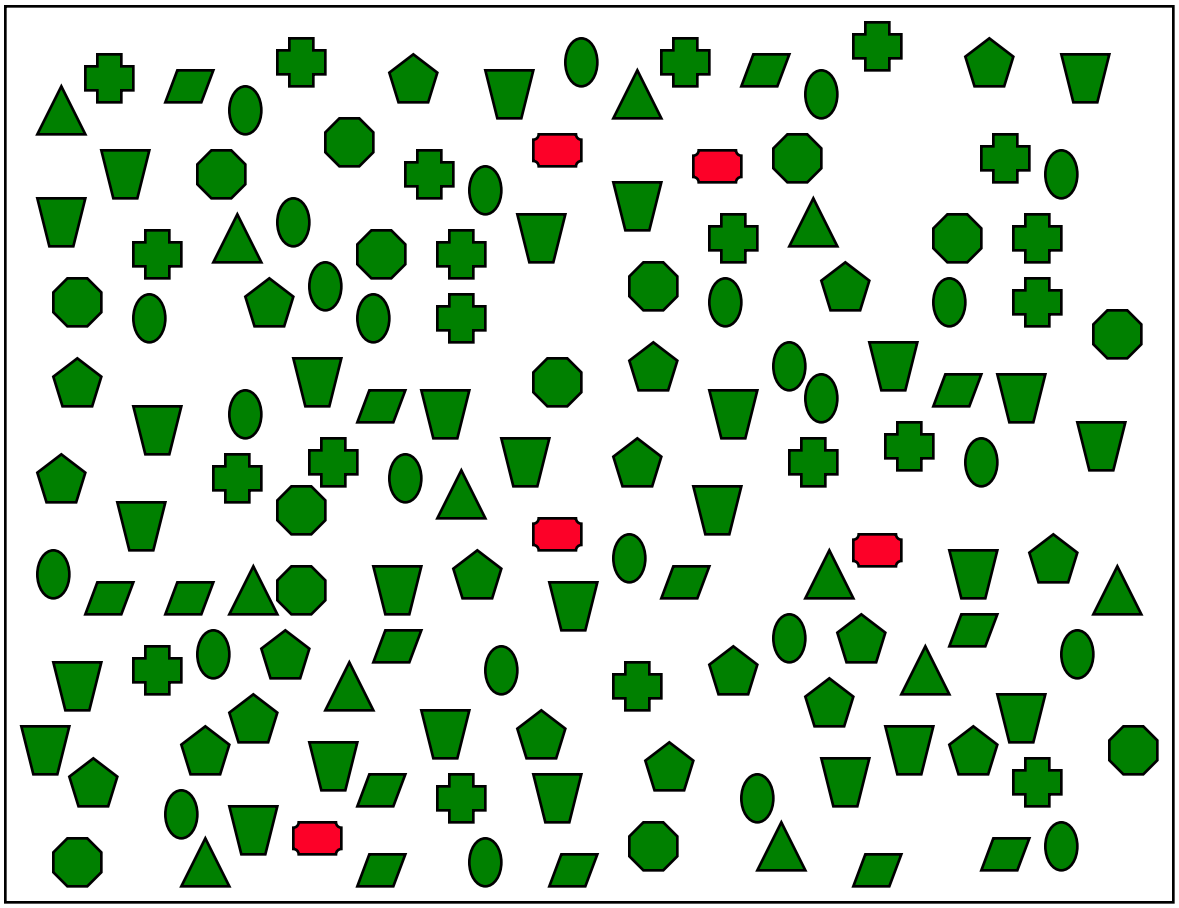
≠ order



Shape

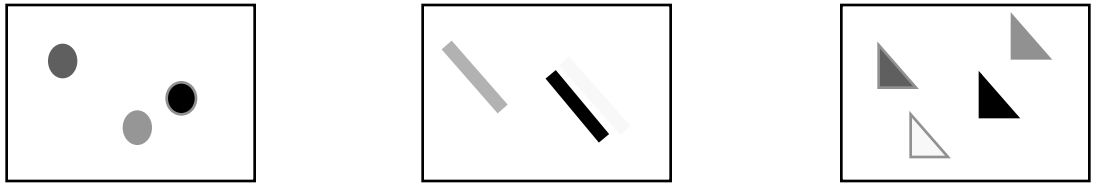


Shape

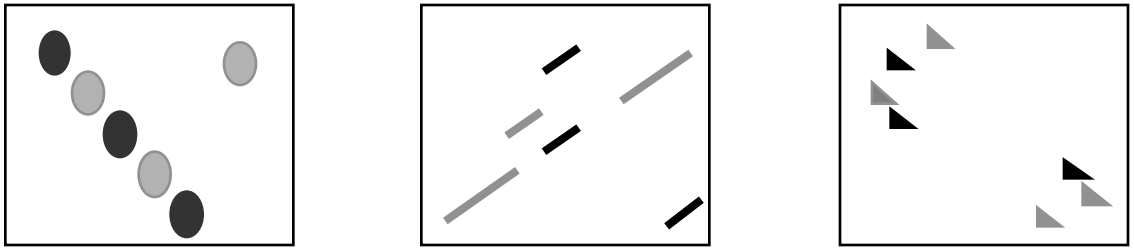


Visual Variable: Value

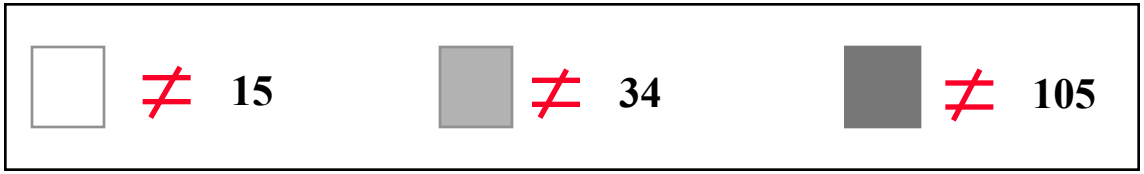
✓ selective



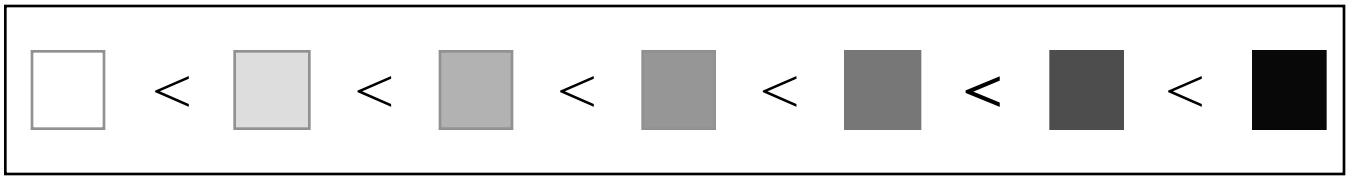
✓ associative



≠ quantitative

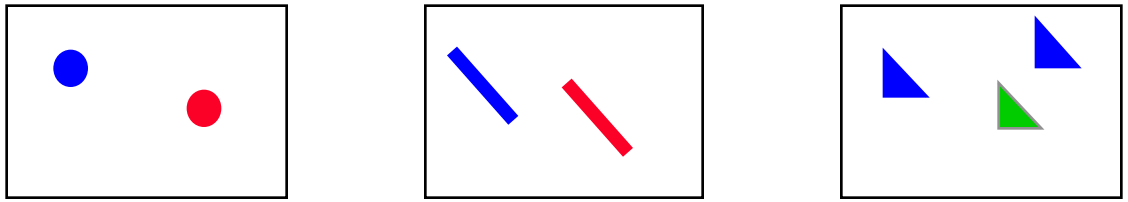


✓ order

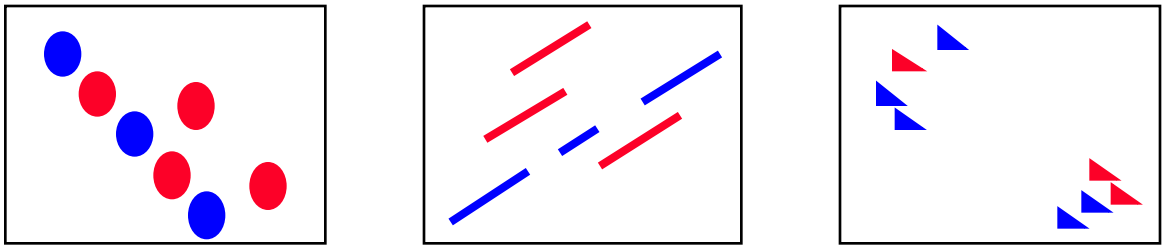


Visual Variable: Color

✓selective

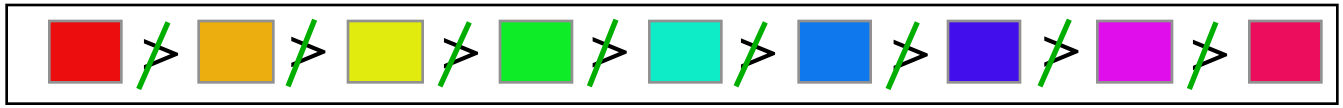


✓associative

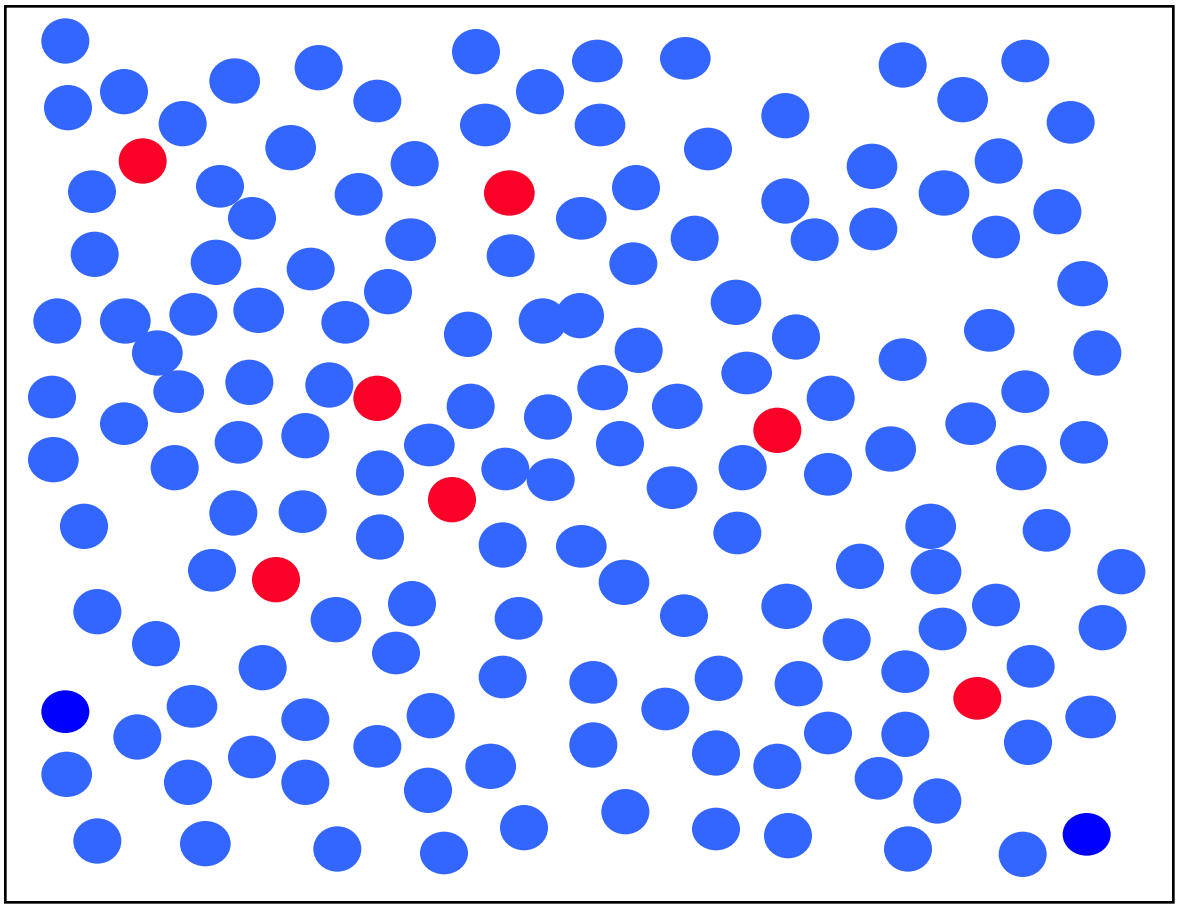


≠quantitative

≠order



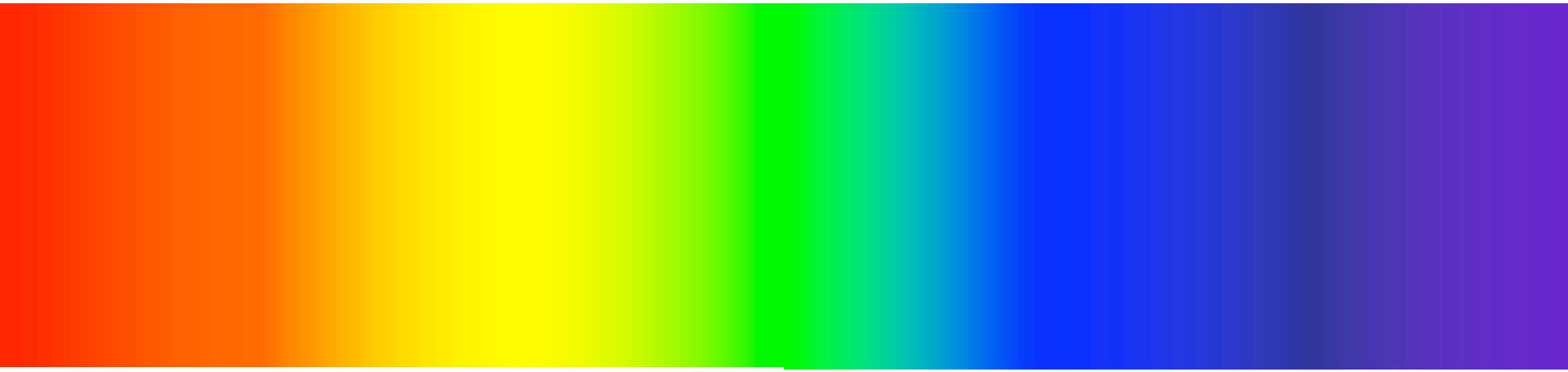
Color

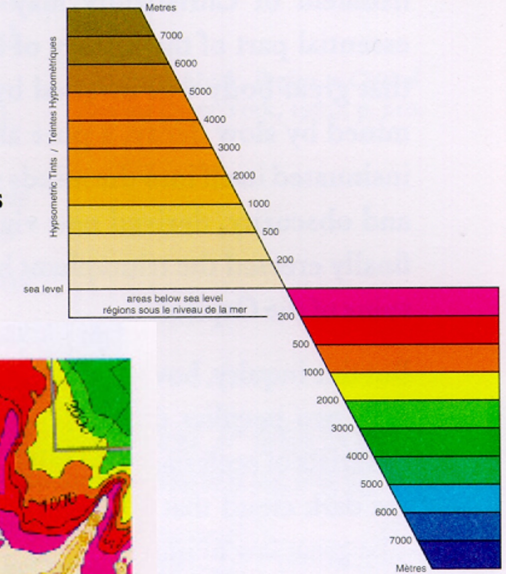


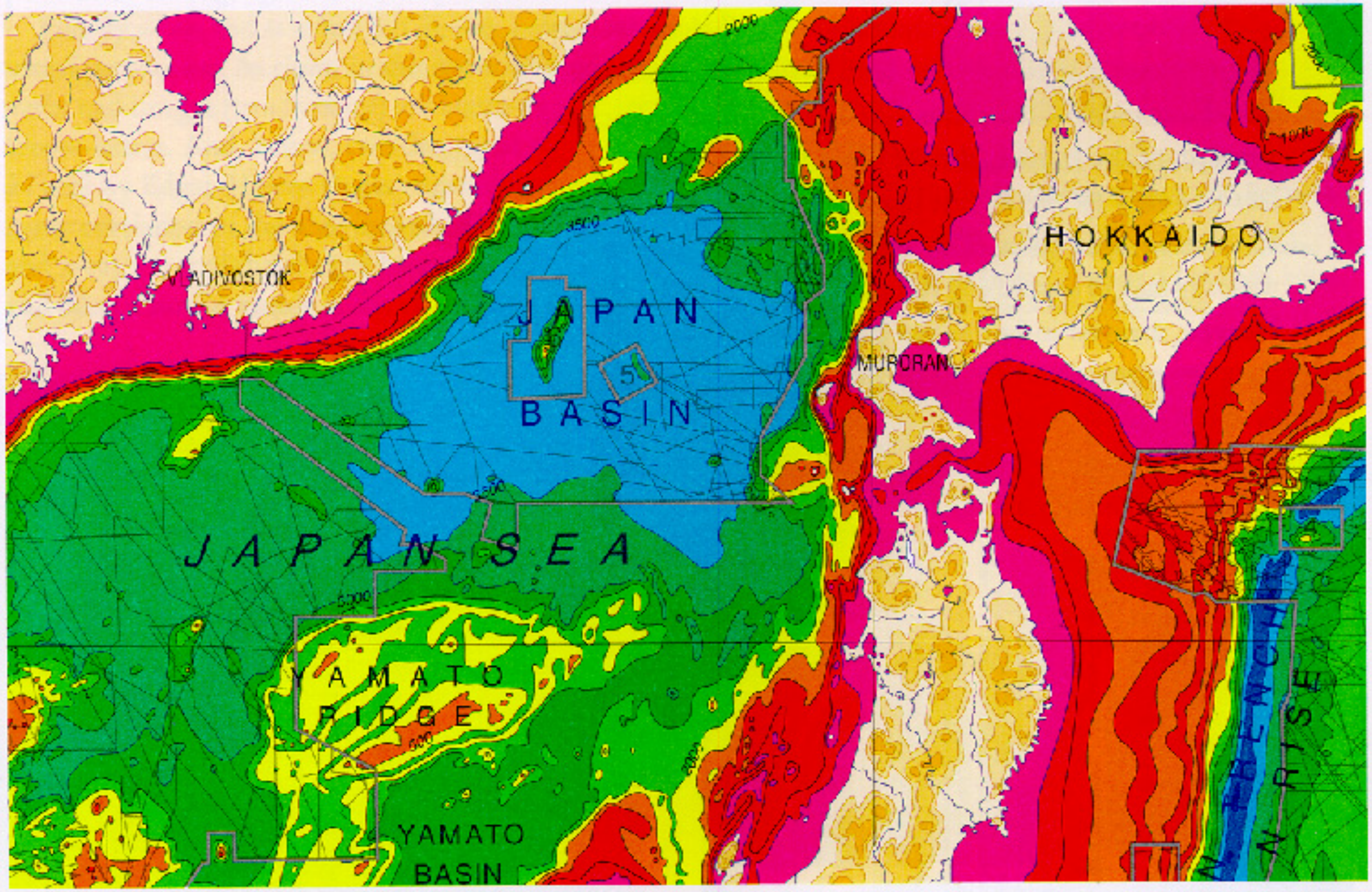
Encoding

Common (bad) advice says use a rainbow scale

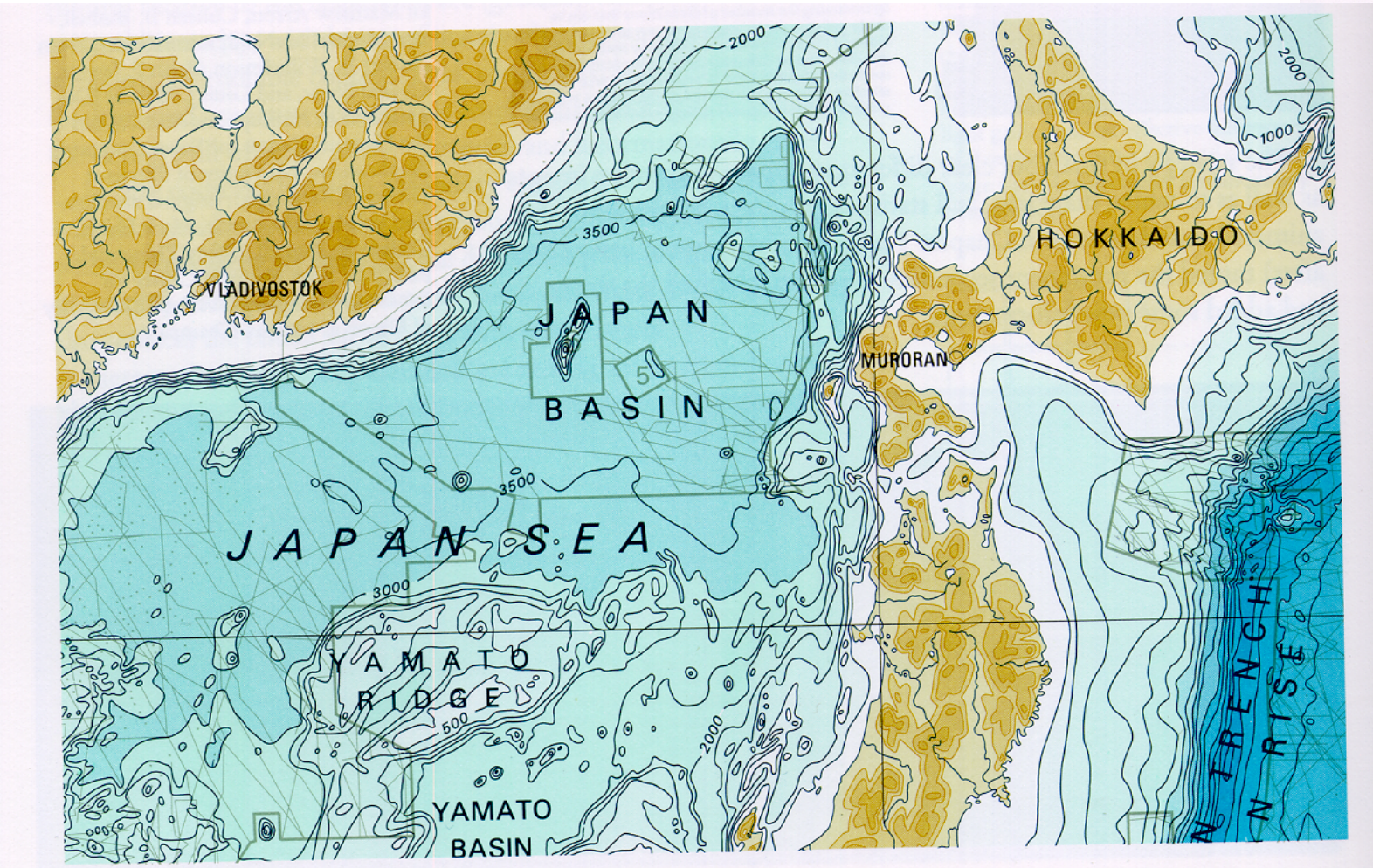
- Marcus, Murch, Healey
- problems with rainbows

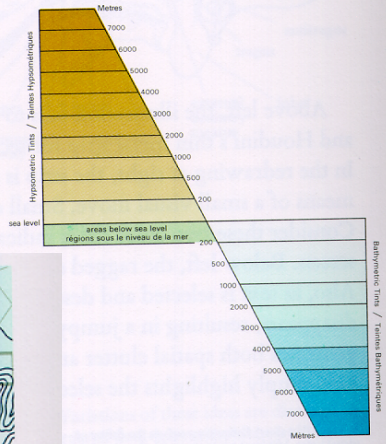



Metres
7000
6000
5000
4000
3000
2000
1000
500
200
Hypsometric Tints / Teintes Hypsométriques
sea level
areas below sea level
régions sous le niveau de la mer
200
500
1000
2000
3000
4000
5000
6000
7000
Mètres
Bathymetric Tints / Teintes Bathymétriques


VLADIVOSTOK
JAPAN
BASIN
JAPAN SEA
HOKKAIDO
MURORAN
YAMATO
RIDGE
YAMATO
BASIN
TRENCH
RISE
2000
3500
1000

General Bathymetric Chart of the Oceans, International Hydrographic Organization (Ottawa, Canada, 5th edition, 1984). 5.06.

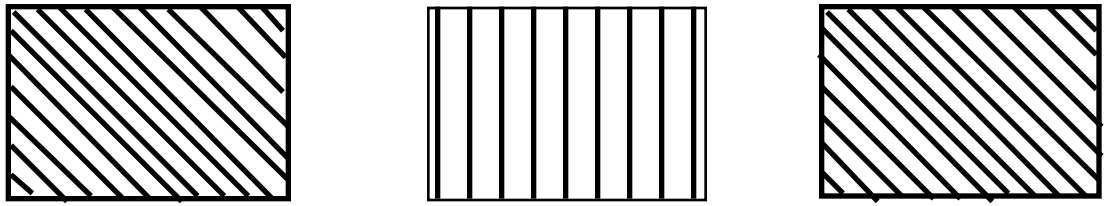




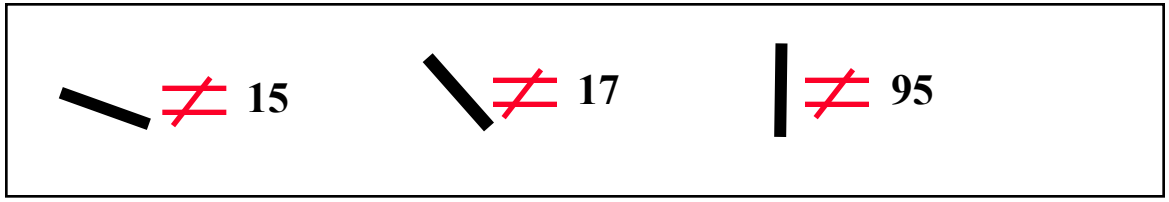
Visual Variable: Orientation

✓ selective

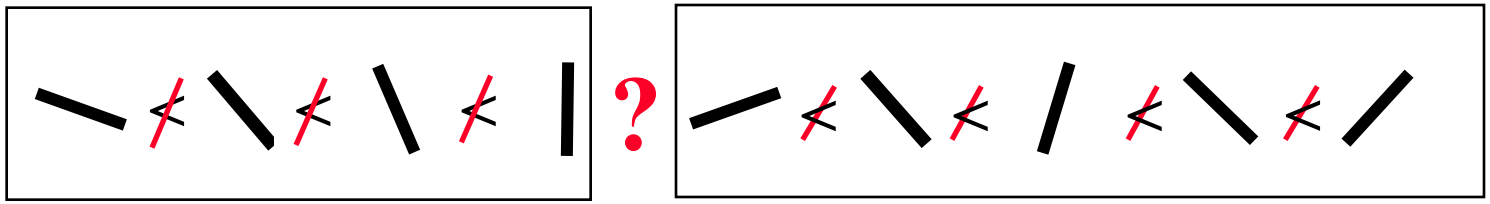
✓ associative



≠ quantitative



≠ order

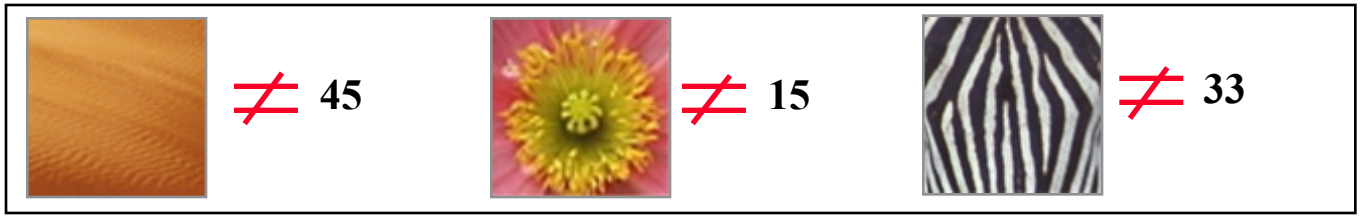


Visual Variable: Texture

✓ selective

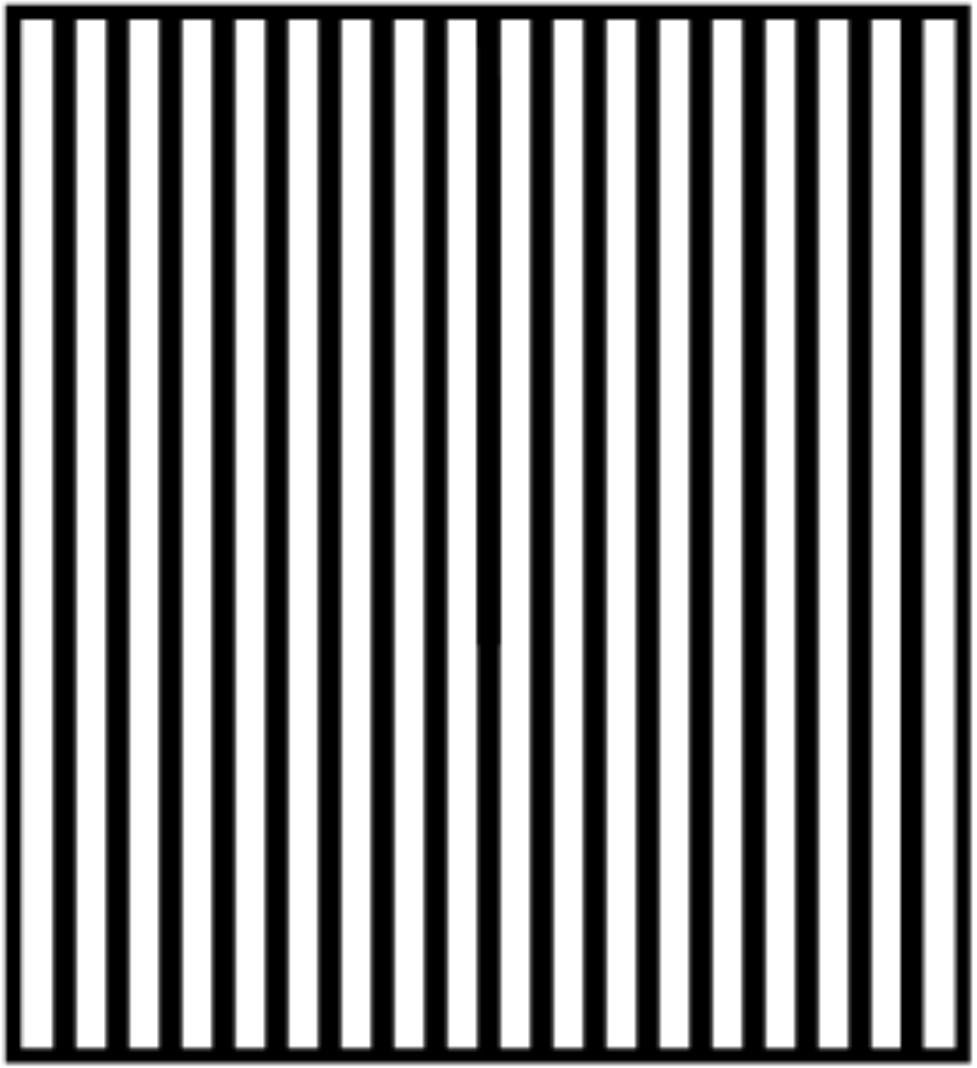
✓ associative

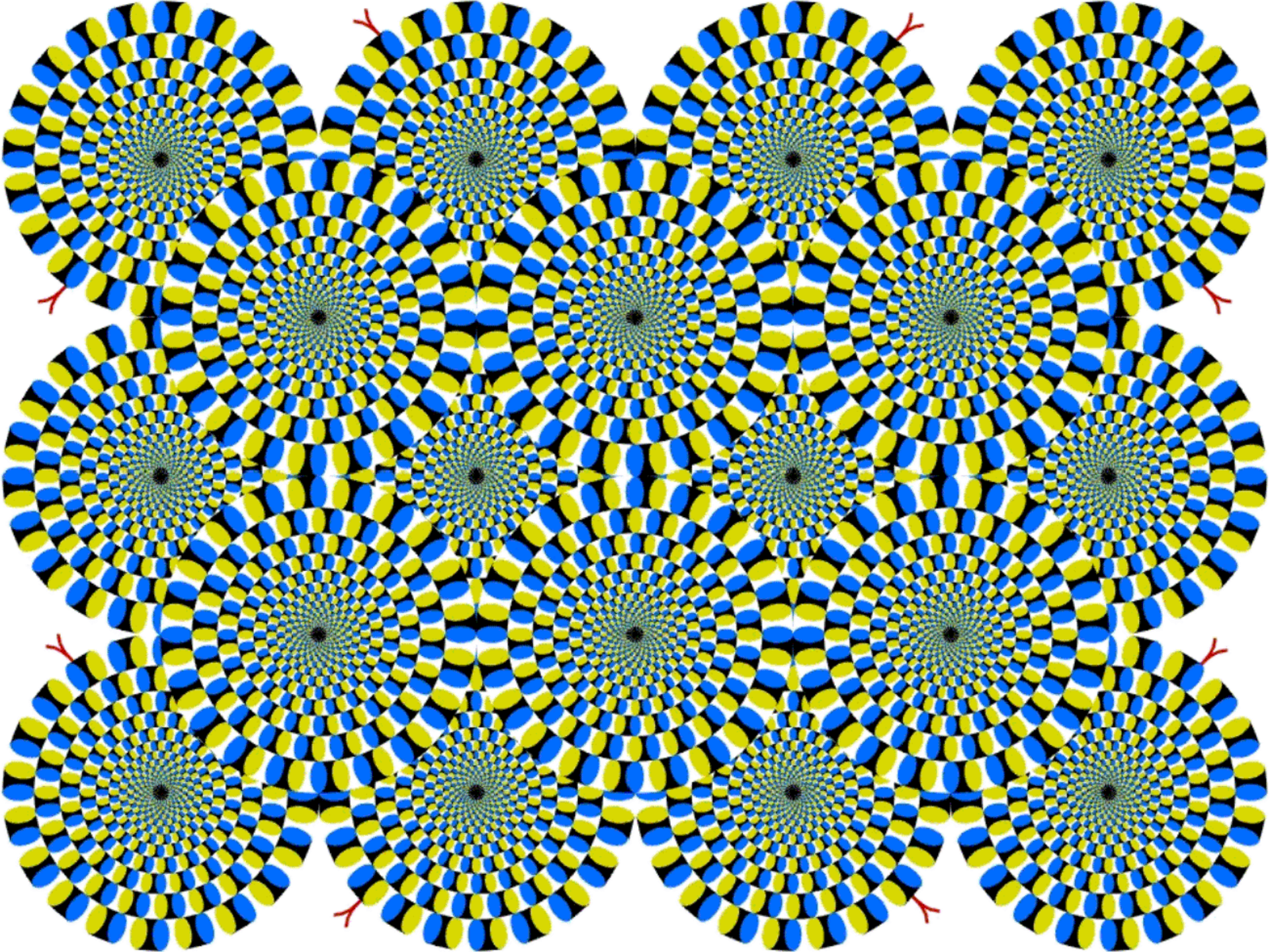
≠ quantitative



≠ order

Texture: Vibratory Effects





Visual Variable: Motion

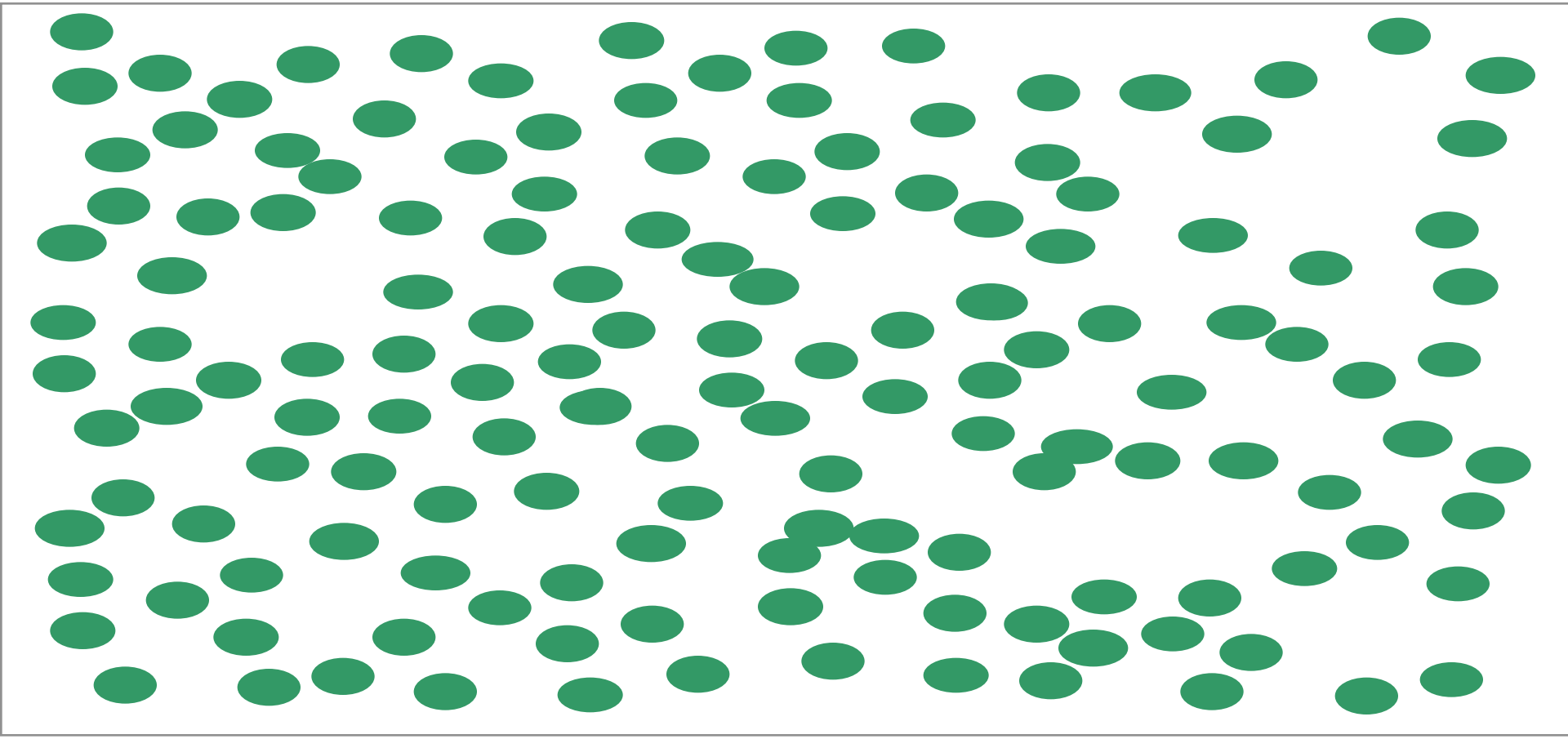
✓ **selective -** motion is one of our most powerful attention grabbers

✓ **associative –** objects moving in unison groups them effectively

≠ **quantitative -** subjective perception

≠ **order**

Motion



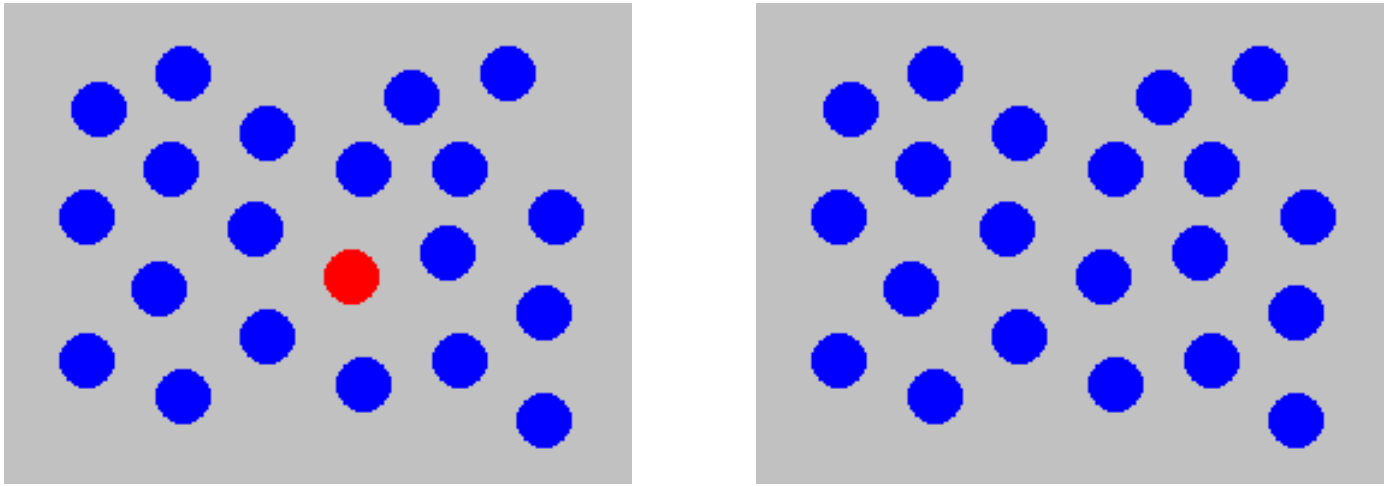
What is Pre-attentive Processing?

- Refers to cognitive operations that can be performed prior to focusing attention on any particular region of an image

- Estimation based on viewing experiments:
  <200-250 ms qualifies as pre-attentive

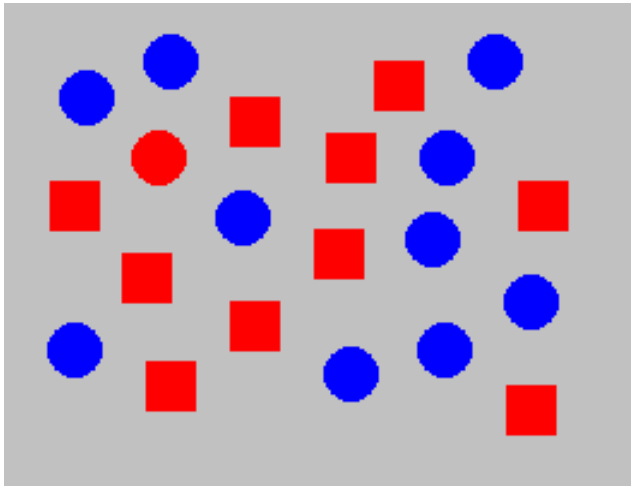
Pre-attentive Processing

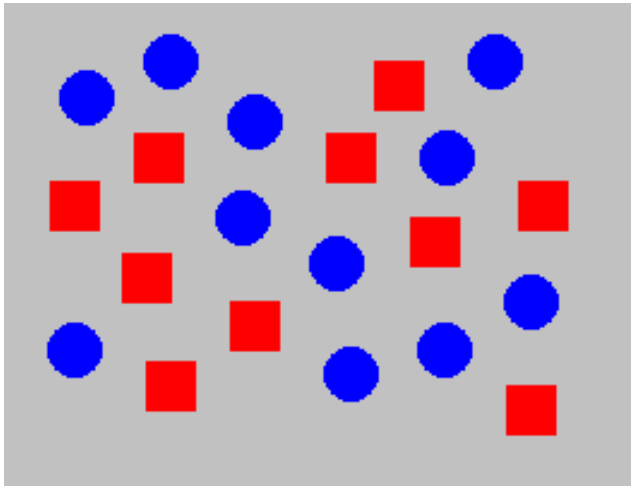
Target has a unique feature (color) from the distracters. Hence it can be detected pre-attentively.



Pre-attentive Processing

Conjunction of features: No unique feature distinct from its distracters. Hence difficult to detect.



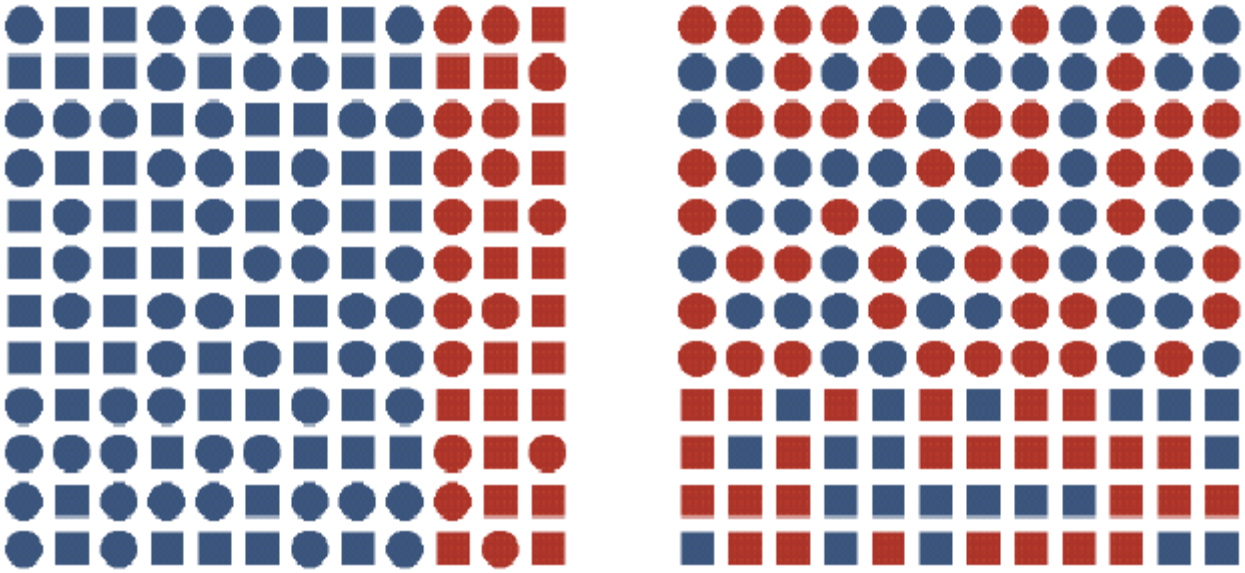


http://www.csc.ncsu.edu/faculty/healey/PP/PP.html

Pre-attentive Processing

Example: Hue Vs Form

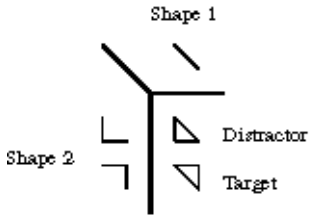
Feature Interference: **Variation of form did not interfere with hue segregation. Varying hue within a display region interfered with boundary detection based on form.**

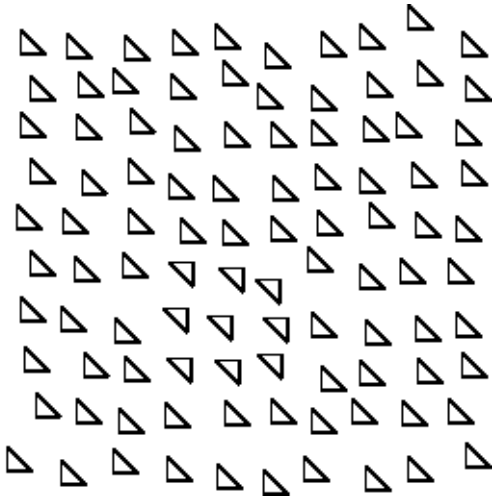


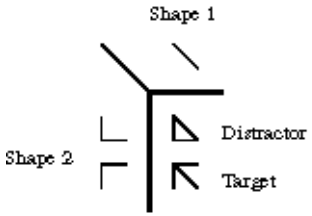
(a) (b)

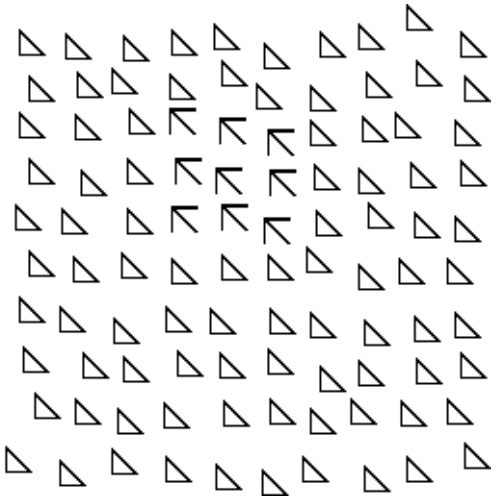
Emergent Features

- Target in (a) contains no unique feature.
- Target in (b) contains non-closure as unique feature.





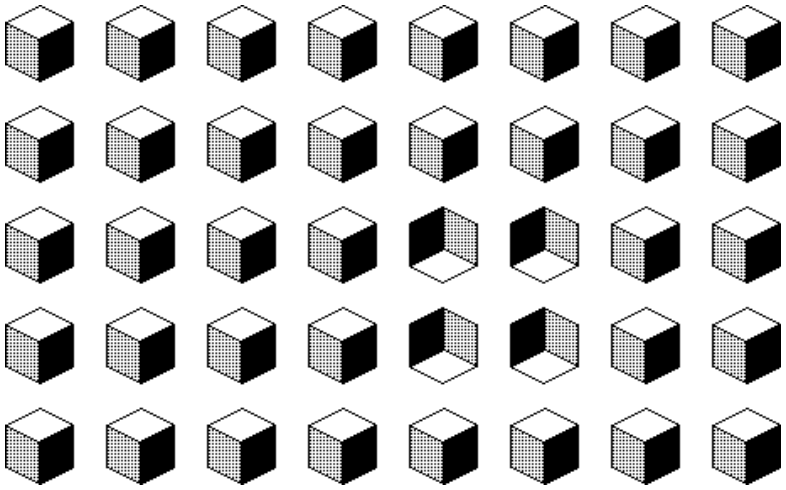


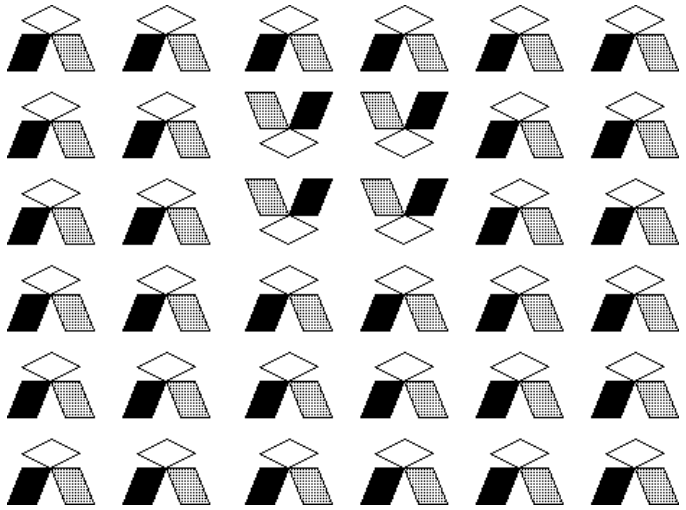


2D or 3D?

When the cubes appear "three-dimensional", the 2x2 group with a different orientation is pre-attentively detected

When three-dimensional cubes are removed, the unique 2x2 group cannot be pre-attentively detected.





Chernoff Faces

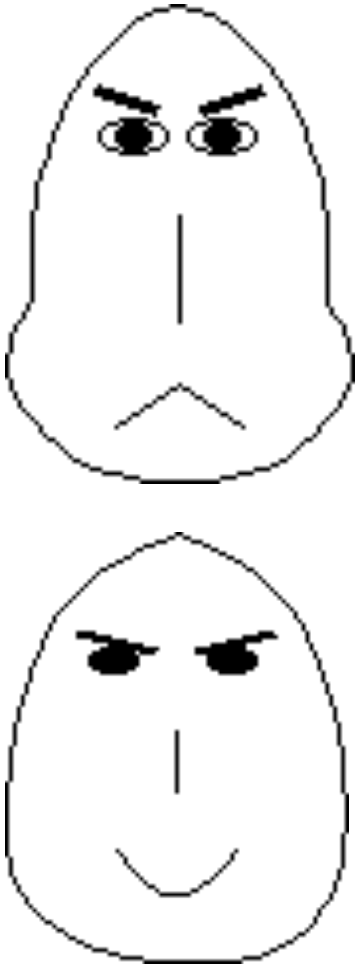
Use faces with different expressions to represent multidimensional data

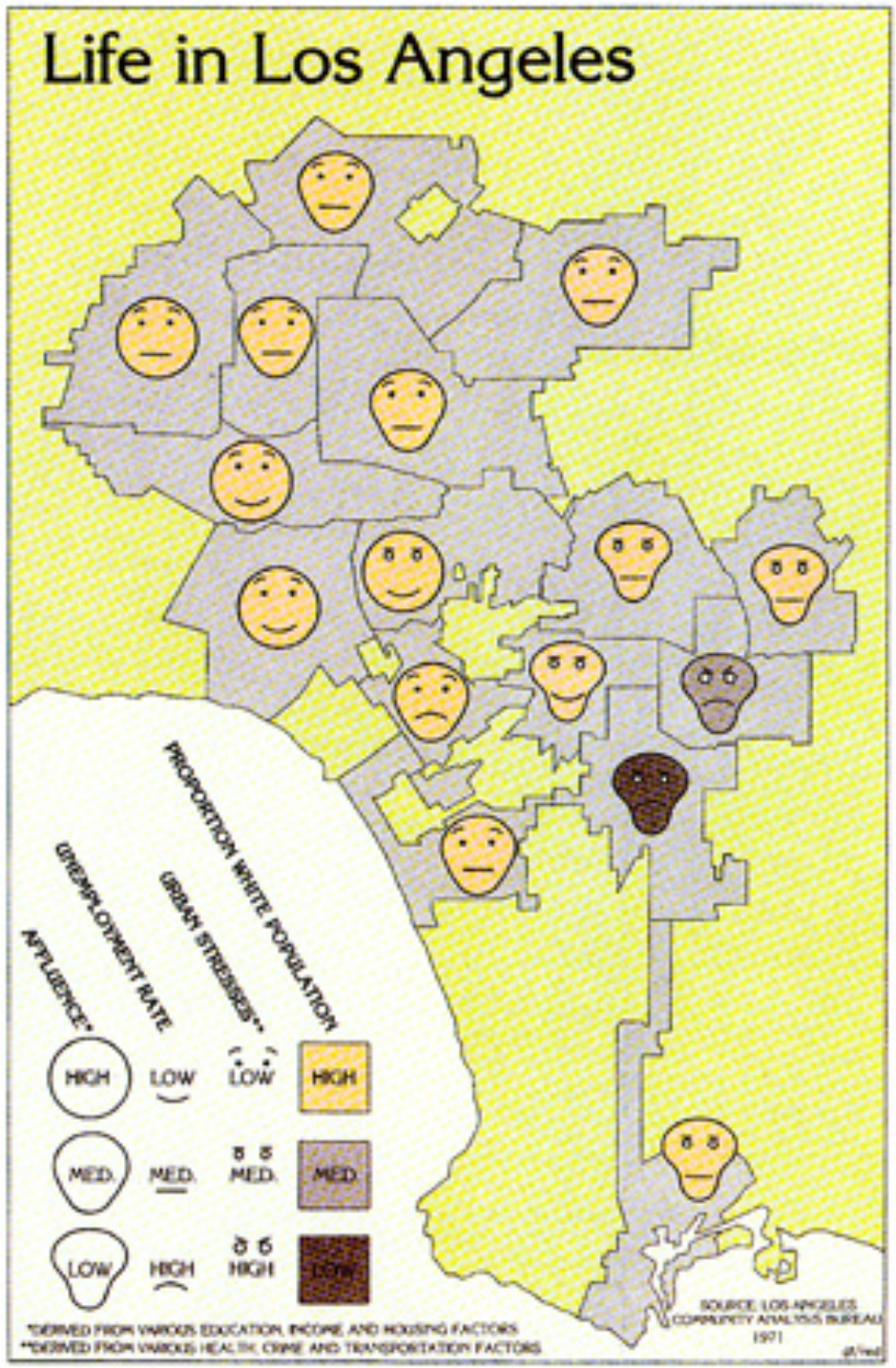
Each data value in a multidimensional data element controls an individual facial characteristic

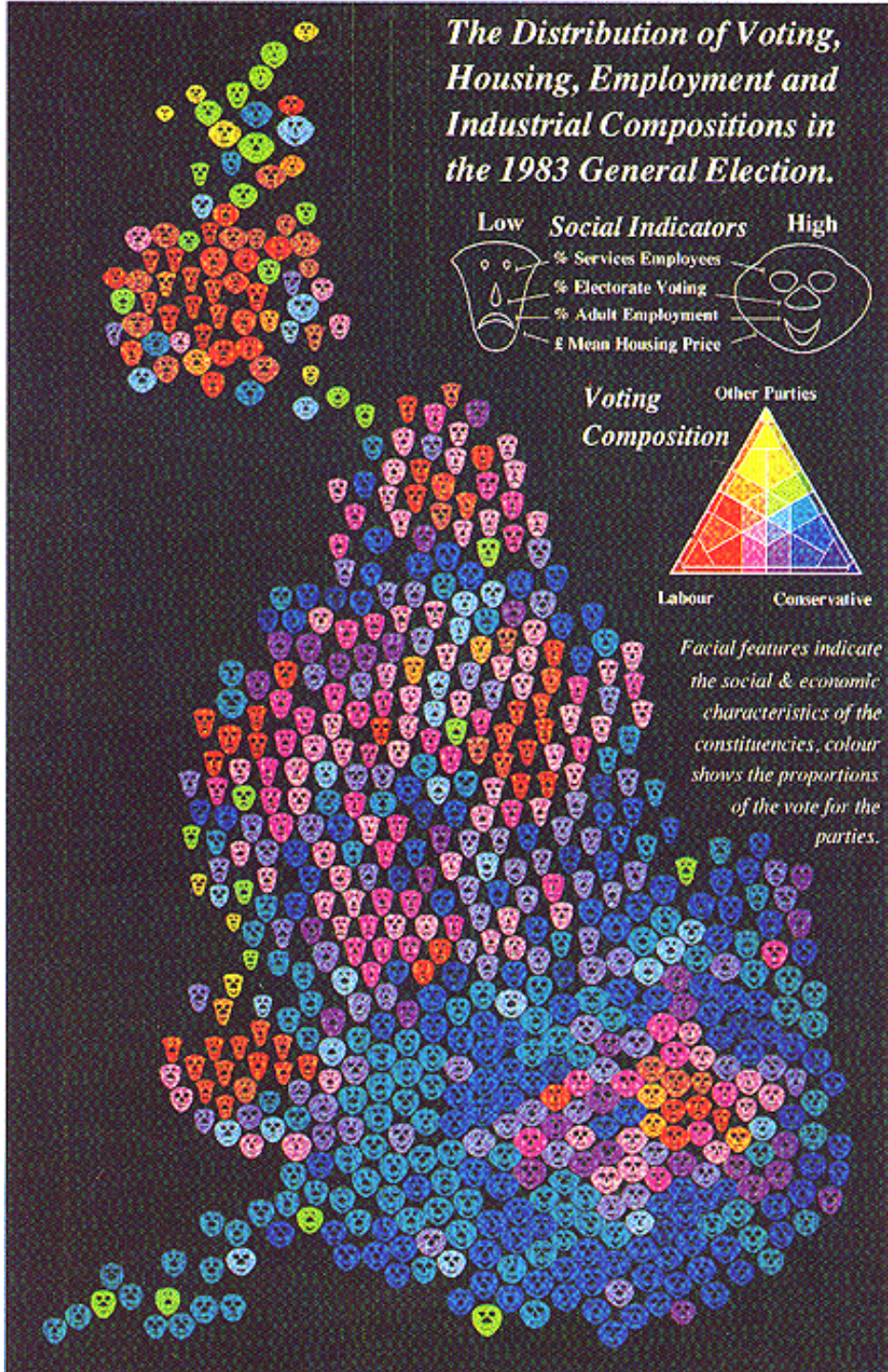
Examples of these characteristics include the nose, eyes, eyebrows, mouth, and jowls

Can support data with up to eighteen dimensions

Groupings in coherent data will be drawn as groups of icons with similar facial expressions




Life in Los Angeles
PROPORTION WHITE POPULATION
URBAN STRESSES**
UNEMPLOYMENT RATE
AFFLUENCE*
HIGH
LOW
LOW
HIGH
MED.
MED.
MED.
MED.
LOW
HIGH
HIGH
LOW
*DERIVED FROM VARIOUS EDUCATION, INCOME AND HOUSING FACTORS
**DERIVED FROM VARIOUS HEALTH, CRIME AND TRANSPORTATION FACTORS
SOURCE: LOS ANGELES COMMUNITY ANALYSIS BUREAU 1971


The Distribution of Voting, Housing, Employment and Industrial Compositions in the 1983 General Election.
Low
Social Indicators
High
% Services Employees
% Electorate Voting
% Adult Employment
£ Mean Housing Price
Voting Composition
Other Parties
Labour
Conservative
Facial features indicate the social & economic characteristics of the constituencies, colour shows the proportions of the vote for the parties.

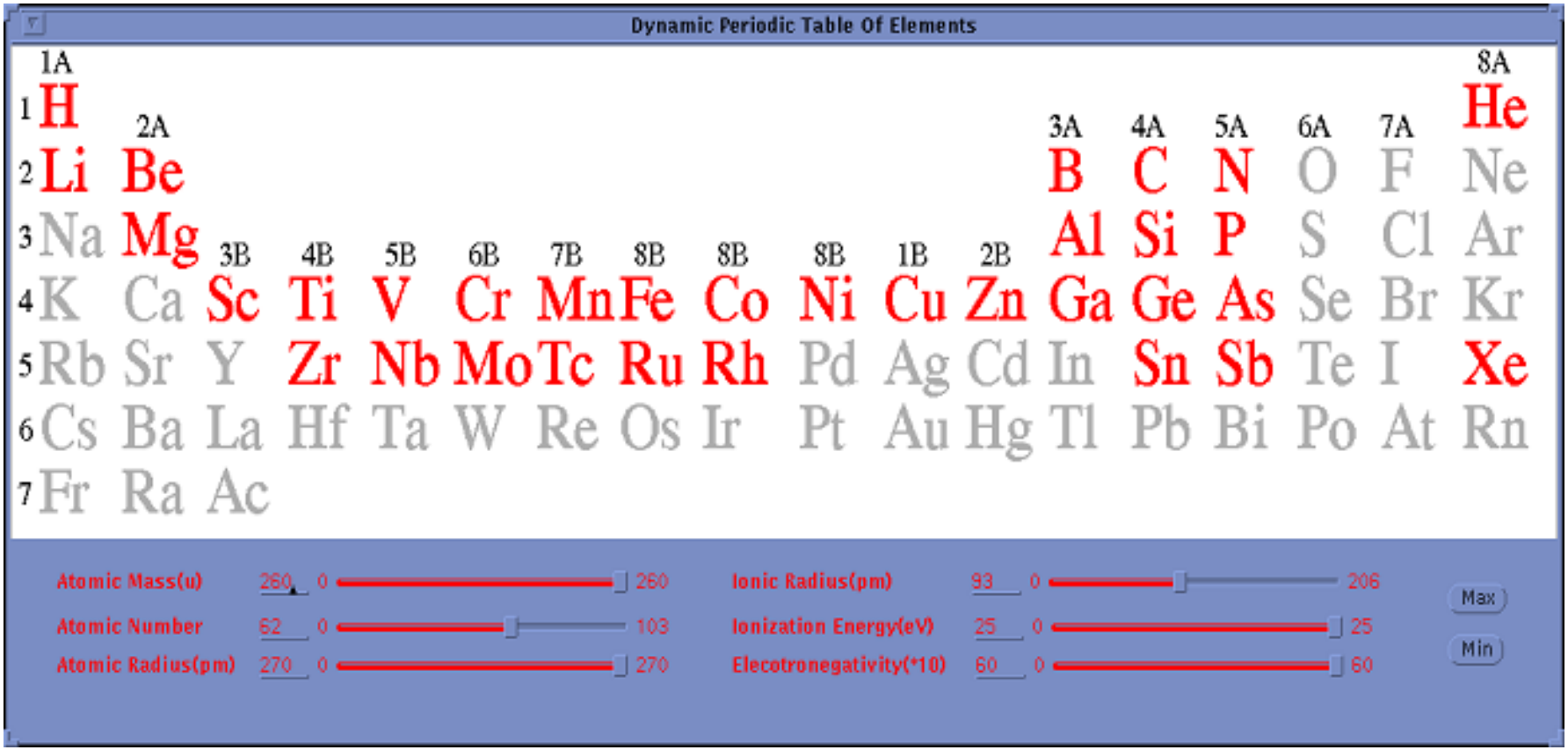
Dynamic Queries

Selecting value ranges of variables via controls with real time feedback in the display

Principles:

- Visual presentation of query's components
- Visual presentation of results
- Rapid, incremental, and reversible control
- Selection by pointing, not typing
- Immediate and continuous feedback
- Support browsing
- Details on demand

Examples



Periodic Table of the Elements

Adjust properties with sliders on the bottom to highlight matching elements.

MoodPlay Visual Music Recommendations: Live Study

http://bit.ly/1XPSGot