Interaction

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CS 294-10: Visualization
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Last Time: Perception
Detection and Magnitude Estimation

Just noticeable difference

JND (Weber’s Law)

\[ \Delta S = k \frac{\Delta I}{I} \]

- Ratios more important than magnitude
- Most continuous variations in stimuli are perceived in discrete steps
Compare areas of circles

Compare lengths of bars
Steven’s power law

\[ S = I^p \]

- \( p < 1 \): underestimate
- \( p > 1 \): overestimate

Exponents of power law

<table>
<thead>
<tr>
<th>Sensation</th>
<th>Exponent</th>
</tr>
</thead>
<tbody>
<tr>
<td>Loudness</td>
<td>0.6</td>
</tr>
<tr>
<td>Brightness</td>
<td>0.33</td>
</tr>
<tr>
<td>Smell</td>
<td>0.55 (Coffee) - 0.6 (Heptane)</td>
</tr>
<tr>
<td>Taste</td>
<td>0.6 (Saccharine) -1.3 (Salt)</td>
</tr>
<tr>
<td>Temperature</td>
<td>1.0 (Cold) – 1.6 (Warm)</td>
</tr>
<tr>
<td>Vibration</td>
<td>0.6 (250 Hz) – 0.95 (60 Hz)</td>
</tr>
<tr>
<td>Duration</td>
<td>1.1</td>
</tr>
<tr>
<td>Pressure</td>
<td>1.1</td>
</tr>
<tr>
<td>Heaviness</td>
<td>1.45</td>
</tr>
<tr>
<td>Electric Shock</td>
<td>3.5</td>
</tr>
</tbody>
</table>

[Psychophysics of Sensory Function, Stevens 61]
Compare areas of circles

**Apparent magnitude scaling**

\[ S = 0.98A^{0.87} \]

[Cartography: Thematic Map Design, Figure 8.6, p. 170, Dent, 96]  
[from Flannery 71]
Proportional symbol map

Newspaper Circulation

Graduated sphere map

[Cartography: Thematic Map Design, Figure 8.8, p. 172, Dent, 96]

Cleveland and McGill

Figure 4. Graphs from position–length experiment.

[Cleveland and McGill 84]
Figure 3. Graphs from position–angle experiment.

[Cleveland and McGill 84]
Relative magnitude estimation

Most accurate
- Position (common) scale
- Position (non-aligned) scale
- Length
- Slope
- Angle
- Area
- Volume

Least accurate
- Color hue-saturation-density

Mackinlay’s ranking of encodings

<table>
<thead>
<tr>
<th>QUANTITATIVE</th>
<th>ORDINAL</th>
<th>NOMINAL</th>
</tr>
</thead>
<tbody>
<tr>
<td>Position</td>
<td>Position</td>
<td>Position</td>
</tr>
<tr>
<td>Length</td>
<td>Density (Val)</td>
<td>Color Hue</td>
</tr>
<tr>
<td>Angle</td>
<td>Color Sat</td>
<td>Texture</td>
</tr>
<tr>
<td>Slope</td>
<td>Color Hue</td>
<td>Connection</td>
</tr>
<tr>
<td>Area (Size)</td>
<td>Texture</td>
<td>Containment</td>
</tr>
<tr>
<td>Volume</td>
<td>Connection</td>
<td>Density (Val)</td>
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</tbody>
</table>

Conjectured effectiveness of visual encodings
Preattentive vs. Attentive

How many 3’s

128176875613897546984506985604982826762
9809858458224509856458945098450980943585
9091030209905959595772564675050678904567
8845789809821677654876364908560912949686

[based on slide from Stasko]
How many 3’s

1281768756138976546984506985604982826762
9809858458224509856458945098450980943585
90910302099059595772564675050678904567
8845789809821677654876364908560912949686

[based on slide from Stasko]

Visual pop-out: Color

http://www.csc.ncsu.edu/faculty/healey/PP/index.html
Visual pop-out: Shape

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

Feature conjunctions

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

[Information Visualization. Figure 5. 5 Ware 04]

More preattentive features

- **Line (blob) orientation**: Julesz & Bergen [1983]; Wolfe et al. [1992]
- **Length**: Triesman & Gormican [1988]
- **Width**: Julesz [1985]
- **Size**: Triesman & Gelade [1980]
- **Curvature**: Triesman & Gormican [1988]
- **Number**: Julesz [1985]; Trick & Pylyshyn [1994]
- **Terminators**: Julesz & Bergen [1983]
- **Intersection**: Julesz & Bergen [1983]
- **Closure**: Enns [1986]; Triesman & Souther [1985]
- **Intensity**: Beck et al. [1983]; Triesman & Gormican [1988]
- **Flicker**: Julesz [1971]
- **Direction of motion**: Nakayama & Silverman [1986]; Driver & McLeod [1992]
- **Binocular lustre**: Wolfe & Franzel [1988]
- **Stereoscopic depth**: Nakayama & Silverman [1986]
- **3-D depth cues**: Enns [1990]
- **Lighting direction**: Enns [1990]

Preattentive conjunctions

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

Most conjunctions are not preattentive

Feature-integration theory

Treisman’s feature integration model [Healey04]

Feature maps for orientation & color [Green]
Multiple Attributes

One-dimensional: Lightness

- White
- White
- Black
- White
- Black

- White
- White
- Black
- Black
- White
One-dimensional: Shape

- Square
- Circle

Correlated enc.: Shape or lightness

- Circle
- Square

- Square
- Circle
Orthogonal enc.: Shape & lightness

Circle
Square
Circle
Square

Speeded classification

Redundancy gain
Facilitation in reading one dimension when the other provides redundant information

Filtering interference
Difficulty in ignoring one dimension while attending to the other
Speeded classification

Types of dimensions

- Integral
  Filtering interference and redundancy gain

- Separable
  No interference or gain

- Configural
  Only interference, but no redundancy gain

- Asymmetrical
  One dimension separable from other, not vice versa
  Stroop effect – Color naming influenced by word identity, but word naming not influenced by color
Correlated enc.: Size and value

W. S. Dobson, Visual information processing and cartographic communication: The role of redundant stimulus dimensions, 1983 (reprinted in MacEachren, 1995)

Othogonal enc.: Aspect ratio

FIGURE 3.38. An example of the use of an ellipse as a map symbol in which the horizontal and vertical axes represent different (but presumably related) variables.

[MacEachren 95]
Orientation and Size (Single Mark)

How well can you see temperature or precipitation? Is there a correlation between the two?

[MacEachren 95]

Shape and Size (Single Mark)

Easier to see one shape across multiple sizes than one size of across multiple shapes?

[MacEachren 95]
Summary of Integral-Separable

Gestalt

[Figure 5.25, Color Plate 10, Ware 00]
Principles

- figure/ground
- proximity
- similarity
- symmetry
- connectedness
- continuity
- closure
- common fate
- transparency

Figure/Ground

Ambiguous

Principle of surroundedness

Principle of relative size

http://www.aber.ac.uk/media/Modules/MC10220/visper06.html
Figure/Ground

http://www.aber.ac.uk/media/Modules/MC10220/visper06.html

Proximity

[Ware 00]
Similarity

Rows dominate due to similarity [from Ware 04]

Symmetry

Bilateral symmetry gives strong sense of figure [from Ware 04]
**Connectedness**

Connectedness overrules proximity, size, color shape [from Ware 04]

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**Continuity**

We prefer smooth not abrupt changes [from Ware 04]

Connections are clearer with smooth contours [from Ware 04]
Continuity: Vector fields

Prefer field that shows smooth continuous contours [from Ware 04]

Closure

We see a circle behind a rectangle, not a broken circle [from Ware 04]

Illusory contours [from Durand 02]
Common fate

Dots moving together are grouped

http://coe.sdsu.edu/eet/articles/visualperc1/start.htm

Transparency

Requires continuity and proper color correspondence [from Ware 04]
Layering and Small Multiples

Layering: Gridlines

Signal and background compete above, as an electrocardiogram trace-line becomes caught up in a thick grid. Below, the screened-down grid stays behind traces from each of 12 monitoring leads.4

Electrocardiogram tracelines [from Tufte 90]
Layering: Gridlines

Stravinsky score [from Tufte 90]

Setting Gridline Contrast

How light can gridlines be and remain visible? How dark can gridlines be and not distract?

Safe setting: 20% Alpha

[Stone & Bartram 2009]
Layering: Color and line width

IBM Series III Copier [from Tufte 90]

Small multiples

[Figure 2.11, p. 38, MacEachren 95]
Small multiples

Operating trains. Redrawn by Tufte to emphasize colored lights. [from Tufte 90]

Change blindness

[Example from Palmer 99, originally due to Rock]
Rensink’s demonstration

http://people.usd.edu/~schieber/coglab/ChangeBlindness.html

Summary

Choosing effective visual encodings requires knowledge of visual perception

Visual features/attributes
- Individual attributes often preattentive
- Multiple attributes may be separable, often integral

Gestalt principles provide higher level design guidelines

We don’t always see everything that is there