03 Visual Perception

36-721 Statistical Graphics and Visualization

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9/8/15
Last time

- Legible graphs: image format and quality
- Comprehensible graphs: labels, titles, and annotations
- Core charts in base R
- HW 1
Today

- Quantitative comparisons: basic perceptual tasks, distance
- Grouping and search: preattentive processing, gestalt, separable dimensions, alignment
- Cognition: derived variables, ranking
- Consistency: across small multiples, in design, with semantic associations
- R: choosing color, point symbol, line type
- text, matplot, RColorBrewer
- mfrow, layout, mtext
Today

Follow along:

- Editable code in 03_Perception_code.R
- Code with output examples in 03_Perception_code.html
Quantitative comparisons

- Basic perceptual tasks
- Distance
Quantitative comparisons

Experiment on next few slides:

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
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</thead>
<tbody>
<tr>
<td>Positions</td>
<td>1</td>
<td>?</td>
<td>?</td>
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<tr>
<td>Lengths</td>
<td>1</td>
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<tr>
<td>Angles</td>
<td>1</td>
<td>?</td>
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<tr>
<td>Areas</td>
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</tbody>
</table>
Quantitative perceptual tasks: position, aligned
Quantitative perceptual tasks: length
Quantitative perceptual tasks: angle
Quantitative perceptual tasks: area
Quantitative perceptual tasks: answers

<table>
<thead>
<tr>
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<th>B</th>
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<tbody>
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<tr>
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<tr>
<td>Areas</td>
<td>1</td>
<td>2/4</td>
<td>1/4</td>
<td>3/4</td>
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</tbody>
</table>

Cleveland and McGill (1984)

Cleveland, *The Elements of Graphing Data*
Quantitative perceptual tasks: effect of angle orientation

Same angle looks wider when bisector is horizontal.
Ordering of perceptual tasks

Cleveland and McGill’s ordering

- 2D position along common, aligned scale
- 2D position along common, but unaligned scales
- Length

Allows more accurate comparisons
Ordering of perceptual tasks

- Colour hue
- Volume
- Area
- Slope
- Angle
- Colour intensity

Allows more generic comparisons
Distance

Cleveland and McGill (1984)

Figure 4. Graphs from position–length experiment.
Quantitative perceptual tasks

Lessons:

- Best to show quantitative variables with position or length
- Bars encode length, so start bars at 0; to zoom in, use dotplots (position) instead
- Avoid stacked bars (not aligned); use dots or lines (aligned baselines) instead
- Avoid pies, area, and volume entirely
- Choose and order hues sensibly; use Color Brewer
- Place things-to-be-compared near each other
Grouping and Search

- Preattentive processing
- Gestalt
- Separable dimensions
- Alignment
Preattentive processing: example task

Find and count the 6s

0 5 0 8 2 4 9 3 2 0 6 9 0 0 3 0 4 6 2 7
9 0 1 1 7 9 9 7 9 3 4 6 4 4 9 7 4 8 0 7
3 7 6 5 2 7 5 9 5 5 9 2 7 3 1 0 0 3 6 8
4 4 5 5 4 6 7 2 7 3 2 4 3 8 5 0 3 6 2 7
4 7 4 1 5 5 1 8 1 3 7 9 9 1 1 2 2 1 5 2
Preattentive processing: example task

Find and count the 6s now

<table>
<thead>
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<th>6</th>
<th>9</th>
<th>0</th>
<th>0</th>
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<th>0</th>
<th>4</th>
<th>6</th>
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<th>7</th>
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<tbody>
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<td>6</td>
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<td>8</td>
<td>1</td>
<td>3</td>
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Preattentive processing

We automatically process and notice certain features, while others require conscious thought to find.

We process faster when there are few categories to distinguish.
Preattentive processing: features

Colin Ware, *Information Visualization*

Orientation  
Curved/straight  
Shape

Shape  
Size  
Number
Preattentive processing: features

- **Gray/value**
  - Diagram showing various gray and white dots.

- **Enclosure**
  - Diagram showing black and white circles enclosed by other shapes.

- **Convexity/concavity**
  - Diagram showing gray spheres, some concave and some convex.

- **Addition**
  - Diagram showing black and white segments with a red line.

- **Juncture**
  - Diagram showing various black angles and segments.

- **Parallelism**
  - Diagram showing black parallel lines spreading across the page.
Preattentive processing

Lessons

▶ Distinguish categorical groups by features like hue & shape
▶ Hue also lets you use direct labels instead of a legend
▶ Don’t try to show too many groups on one plot; use small multiples to show more sub-groups
▶ If highlighting one group, use a preattentive attribute
Gestalt

=Gestalt = “pattern” in German

We automatically structure data into patterns / groups using certain features
Lessons

- Distinguish categorical groups by similarity, proximity, or enclosure
- Use proximity to structure your layout (arrange small multiples)
- Use connection to show groups on line chart, parallel coordinates chart, network graph, etc.
- To highlight one group, use gestalt principles such as enclosure or similarity
Separable dimensions

Some examples from Colin Ware, *Information Visualization*

<- More integral ... More separable ->

red-green  yellow-blue  x-size  y-size  size orientation  color shape  color motion  color location
Integral dimensions example

US Census Bureau map using hue and saturation
Separable dimensions

Lessons

- Use color and another variable (shape, size, orientation, motion)
- Use small multiples rather than different plotting symbols
- Avoid mixing 2 aspects of color, or 2 aspects of size
- Don’t combine too many grouping variables at once
Alignment

Among male newborns, compare by race
Among male newborns, compare by race: easier search now, though harder comparison.
Alignment

Lessons

▶ Decide on visual task, and helpfully align elements to be compared
▶ During EDA, try several arrangements
Cognition

- Derived variables
- Ranking
Derived variables

William Playfair, one of the earliest line charts
What does the difference look like?
Derived variables

Differences shown directly, by Cleveland and McGill

Figure 28. Playfair data.
Ranking: alphabetical

Western state areas (1000s of sq miles)
Western state areas (1000s of sq miles)
Derived variables and Ranking

Lessons

- If differences or ratios are interesting, compute and plot them directly
- Order your dots/bars meaningfully: ranked by a variable, not alphabetical
Consistency

- Across small multiples
- In design
- With semantic associations
Consistency

Which age group weighs the least?
Consistency

Give all small multiples the same structure, usually including axis limits, to make comparisons easier and reduce cognitive load.
Consistency

Ensure *design changes* are meaningful (tied to data changes)
Consistency

More consistent redesign, Stephen Few
Consistency

Avoid meaningless visual variables like shadow or 3D
Consistency

Lessons

- Use consistent mappings (colors and shapes, axis limits) across graphs
- Don’t reuse same mappings for a different data variable
- Avoid meaningless variety in design
- Avoid shadow, 3D, and other variables not mapped to data
Semantic associations

Orange vs blue crab species: I’ve seen this in a talk (crabs dataset in MASS package)
Semantic associations

Lessons

- Use meaningful mappings: orange vs blue crab species = orange and blue symbols
- Use conventional mappings: blue = cold, red = hot
- “More = more”: deeper saturation or larger size = higher value of variable
Choosing color, point symbol, line type

- text, matplot, RColorBrewer
- mfrow, layout, mtext
For next time

- We’ll cover the Grammar of Graphics framework, and how it is the basis for ggplot2 and Tableau
- HW 2 due Saturday at 5pm, through Blackboard