Choices in statistical graphics: My stories

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New York Data Visualization Meetup
14 Jan 2013
My earlier talk on tradeoffs in statistical graphics

- Originally: Infoviz vs. stat graphics
  - The best information visualizations are grabby, visually striking
  - The best statistical graphics reveal patterns and discrepancies
  - Different goals, different looks
- Lots of negative reactions
  - (Some) infoviz people felt we were trivializing their work
  - (Some) statisticians felt we gave infoviz too much respect
- Our new theme: tradeoffs in statistical graphics
We did not come to mock...
Instead, compare a bare-bones infographic . . .

**African Countries by GDP**

**TOP COUNTRIES BY GDP IN U.S. $ BILLIONS**
Gross domestic product (GDP) refers to the market value of all final goods and services produced within a country in a given period (2005 - 2009).

**GDP CALCULATION**
private consumption + gross investment + government spending + (exports − imports)

- **$ 285.4 b** SOUTH AFRICA
- **$ 188.4 b** EGYPT
- **$ 173 b** NIGERIA
- **$ 140.6 b** ALGERIA
- **$ 91.4 b** MOROCCO
- **$ 75.5 b** ANGOLA
- **$ 62.3 b** LIBYA
- **$ 39.6 b** TUNISIA
- **$ 29.4 b** KENYA
- **$ 28.5 b** ETHIOPIA
- **$ 26.2 b** GHANA
- **$ 22.2 b** CAMEROON
To a corresponding statistical graphic . . .
Another example . . .
The statistician’s version . . .

![Graph showing life expectancy versus health care spending for various countries. The graph includes points for Japan, Switzerland, Australia, Spain, France, Canada, Norway, N.Zealand, Austria, UK, Luxembourg, Denmark, Czech, Poland, Mexico, Slovakia, Turkey, Hungary, and the USA.](image-url)
A legendary early infographic . . .

http://www.Florence-Nightingale-Avenging-Angel.co.uk/Coxcomb.htm

Diagram of the Causes of Mortality in the Army in the East.

2.
APRIL 1855 TO MARCH 1856.

1.
APRIL 1854 TO MARCH 1855.

The areas of the blue, red, & black wedges are each measured from the centre as the common vertex.
The blue wedges measured from the centre of the circle represent area for the deaths from Preventible or Mitigable Zymotic Diseases, the red wedges measured from the centre the deaths from wounds, & the black wedges measured from the centre the deaths from all other causes.
The black line across the red triangle in Nov' 1854 marks the boundary of the deaths from all other causes during the month.
In October 1854, & April 1855, the black area coincides with the red, in January & February 1856, the blue coincides with the black.
The entire areas may be compared by following the blue, the red & the black lines enclosing them.
How we would display it...

Mortality rates in the Crimean War from April 1854 to March 1856

- **Zymotic diseases**
- **Wounds, injuries**
- **All other causes**

Sanitary commission arrives

British Army Size in the Crimean War from April 1854 to March 1856

Average Army Size

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I’m not saying that the boring plots (constructed by Antony Unwin and myself using R) are better than Florence Nightingale’s beautiful images!

Rather, I’m saying that Nightingale’s graphic and ours serve different purposes:

- She dramatizes the problem with a unique and visually-appealing image that draws the casual viewer in deeper
- We display the data to reveal patterns, for viewers who are already interested in the problem

In any case, this is not my main point today. We’ll spend most of our time discussing the choices involved in graphs that I’ve made over the years.

Now, back to our regularly scheduled presentation . . .
All graphs are comparisons
All of statistics are comparisons
Specific recommendations

- Multiple plots per page (small multiples)
- Don’t clutter each plot
- Line plots are great—they facilitate more comparisons
Don’t clutter each plot: example

From *Graph Design for the Eye and Mind* by Stephen Kosslyn:

![Graph showing the contrast in slope of lines for different age groups and income levels.]

Figure 1.6. The contrasting slope of one line makes the odd group easy to spot; no such visual cue can be given in a table.
Redo using small multiples!
Choices in statistical graphics: My stories

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Line plots: Cleveland’s principle

- Always ask: What is the comparison?
- Example: an analysis from market research
Improvement?

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Choices in statistical graphics: My stories
Line plot is better

Consider the comparisons you can make!
Statistics is . . .

- Measurement
- Variation
- Comparison

Statistics
(Some of) my examples from (nearly) 30 years of applied research

Choices involved in making the graphs

What works, what doesn’t, and why

You must participate!
1984: “The effects of solar flares on single event upset rates”

Figure 4: The integral LET spectra for the composite worst-case solar flare particle event outside the magnetosphere. These spectra are behind aluminum shielding of the indicated thicknesses. These thicknesses correspond to 0.025, 0.1, 0.5 and 2.0
1984: “The effects of solar flares on single event upset rates”
1986: “Reduced subboundary misalignment in SOI films scanned at low velocities”

Fig. 9 Measured average crystallographic angular misalignment $\bar{\theta}$ for a number of subboundaries as a function of the average lateral spacing $s$ of those subboundaries as obtained from the experiment of Fig. 8.
1989: “Constrained maximum entropy methods in an image reconstruction problem”

Fig. 1b: Iterates of the EM algorithm: fit to truth in image and data space
1990: “Estimating the electoral consequences of legislative redistricting”

Table 1. Votes Received by Democrats and Republicans in Ohio Legislative House Districts, 1972-1974

<table>
<thead>
<tr>
<th>District</th>
<th>Democrat</th>
<th>Republican</th>
<th>District</th>
<th>Democrat</th>
<th>Republican</th>
<th>District</th>
<th>Democrat</th>
<th>Republican</th>
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<td>22,488</td>
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<td>1</td>
<td>20,490</td>
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<td>52</td>
<td>24,336</td>
<td>14,083</td>
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<td>20,272</td>
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<td>10,212</td>
<td>54</td>
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<td>5</td>
<td>11,711</td>
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<td>6</td>
<td>28,309</td>
<td>0</td>
<td>56</td>
<td>21,603</td>
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<td>3,656</td>
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<td>66</td>
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<td>10,403</td>
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<td>21,489</td>
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<td>18</td>
<td>22,416</td>
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<tr>
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<td>23,462</td>
<td>69</td>
<td>16,502</td>
<td>21,816</td>
<td>19</td>
<td>12,431</td>
<td>19,822</td>
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</table>

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1990: “Estimating the electoral consequences of legislative redistricting”

Figure 1. Stem-and-Leaf Plot of the Proportion of the Vote Received by a Party in a Contested District Election, Immediately Preceding an Election in Which That Party Was Unopposed in That District.
1990: “Estimating the electoral consequences of legislative redistricting”

Figure 7. Ohio House, 1968–1980.

Figure 9. Wisconsin House, 1968–1980.

Figure 3. Estimates of Incumbency Advantage

Proportion Advantage

Year

± 1 SE:
2008: “Estimating incumbency advantage and its variation, as an example of a before/after study”
2008: “Estimating incumbency advantage and its variation, as an example of a before/after study”

(a) Average Incumbency Advantage

(b) SD of District Effects

(c) SD of Incumbency Advantage

(d) Residual SD of Election Results
<table>
<thead>
<tr>
<th>Normal-theory posterior interval</th>
<th>Potential scale reduction</th>
<th>Simulated quantiles</th>
</tr>
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<tr>
<td></td>
<td>2.5%</td>
<td>25%</td>
</tr>
<tr>
<td>2.5%</td>
<td>97.5%</td>
<td></td>
</tr>
<tr>
<td>$a_1$</td>
<td>5.66</td>
<td>5.73</td>
</tr>
<tr>
<td>$a_2$</td>
<td>5.82</td>
<td>5.89</td>
</tr>
<tr>
<td>$a_3$</td>
<td>5.64</td>
<td>5.71</td>
</tr>
<tr>
<td>$a_4$</td>
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<td>5.48</td>
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<td>$a_{17}$</td>
<td>6.00</td>
<td>6.07</td>
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<tr>
<td>$\sigma_a$</td>
<td>0.09</td>
<td>0.14</td>
</tr>
<tr>
<td>$\beta$</td>
<td>0.17</td>
<td>0.32</td>
</tr>
<tr>
<td>$\lambda$</td>
<td>0.07</td>
<td>0.12</td>
</tr>
<tr>
<td>$\tau$</td>
<td>0.74</td>
<td>0.85</td>
</tr>
<tr>
<td>$\sigma_{obs}$</td>
<td>0.18</td>
<td>0.19</td>
</tr>
<tr>
<td>$\sigma_{a}/\sigma_{obs}$</td>
<td>0.50</td>
<td>0.74</td>
</tr>
</tbody>
</table>

$-2 \log(\text{density})$ = 727.81, 747.33, 766.86
1992: “Inference from iterative simulation using multiple sequences”
1993: “Why are American Presidential election campaign polls so variable when votes are so predictable?”

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Choices in statistical graphics: My stories
1993: “Why are American Presidential election campaign polls so variable when votes are so predictable?”

- **7A: Estimated heterogeneity among Republican groups**
- **7B: Estimated heterogeneity among Democratic groups**
- **7C: Estimated heterogeneity among Independent groups**
1994: “Enhancing democracy through legislative redistricting”
Figure 2. Fig. 2a, Effect of weighting on proportion of women. Fig. 2b, Proportion of women over time. $a = \text{ABC/Washington Post/Chilton;}$ $c = \text{CBS;}$ $g = \text{Gallup;}$ $h = \text{Harris;}$ $l = \text{Los Angeles Times;}$ $m = \text{Media General/AP;}$ $r = \text{Roper;}$ $y = \text{Yankelovich.}$ Capital let-
1996: “Physiological pharmacokinetic analysis using population modeling and informative prior distributions”
1996: “Physiological pharmacokinetic analysis using population modeling and informative prior distributions”

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Population prior</th>
<th>Posterior distributions for individuals</th>
<th>Population posterior</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ventilation/perfusion ratio (VPR)</td>
<td>(1.6(\hat{x} \div 1.3))</td>
<td>(1.16) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.14) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.13)</td>
<td>(1.19)</td>
</tr>
<tr>
<td>Blood flow, well-perfused tissues (Fwp)</td>
<td>(0.47(\hat{x} \div 1.17))</td>
<td>(0.653) (\hat{x} \div 1.06) (\hat{x} \div 1.07) (\hat{x} \div 1.07) (\hat{x} \div 1.06) (\hat{x} \div 1.08) (\hat{x} \div 1.08)</td>
<td>(0.637)</td>
</tr>
<tr>
<td>Blood flow, poorly perfused tissues (Fpp)</td>
<td>(0.20(\hat{x} \div 1.22))</td>
<td>(0.121) (\hat{x} \div 1.12) (\hat{x} \div 1.13) (\hat{x} \div 1.13) (\hat{x} \div 1.12) (\hat{x} \div 1.13) (\hat{x} \div 1.13)</td>
<td>(0.129)</td>
</tr>
<tr>
<td>Blood flow, fat (Ff)</td>
<td>(0.07(\hat{x} \div 1.27))</td>
<td>(0.048) (\hat{x} \div 1.13) (\hat{x} \div 1.13) (\hat{x} \div 1.14) (\hat{x} \div 1.13) (\hat{x} \div 1.14) (\hat{x} \div 1.14)</td>
<td>(0.0488)</td>
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<tr>
<td>Blood flow, liver (Ff)</td>
<td>(0.25(\hat{x} \div 1.15))</td>
<td>(0.173) (\hat{x} \div 1.15) (\hat{x} \div 1.16) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.16) (\hat{x} \div 1.15)</td>
<td>(0.179)</td>
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<tr>
<td>Volume, well-perfused tissues (Vwp)</td>
<td>(0.27(\hat{x} \div 1.36))</td>
<td>(0.189) (\hat{x} \div 1.14) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.15) (\hat{x} \div 1.15)</td>
<td>(0.196)</td>
</tr>
<tr>
<td>Volume, poorly perfused tissues (Vpp)</td>
<td>(0.55(\hat{x} \div 1.17))</td>
<td>(0.649) (\hat{x} \div 1.04) (\hat{x} \div 1.05) (\hat{x} \div 1.05) (\hat{x} \div 1.05) (\hat{x} \div 1.04) (\hat{x} \div 1.04)</td>
<td>(0.641)</td>
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<tr>
<td>Volume, liver (VI)</td>
<td>(0.033(\hat{x} \div 1.1))</td>
<td>(0.032) (\hat{x} \div 1.1) (\hat{x} \div 1.1) (\hat{x} \div 1.1) (\hat{x} \div 1.1) (\hat{x} \div 1.1) (\hat{x} \div 1.1)</td>
<td>(0.033)</td>
</tr>
<tr>
<td>Partition coeff, blood/air (Pba)</td>
<td>(12(\hat{x} \div 1.5))</td>
<td>(15.1) (\hat{x} \div 1.04) (\hat{x} \div 1.03) (\hat{x} \div 1.04) (\hat{x} \div 1.04) (\hat{x} \div 1.04) (\hat{x} \div 1.04)</td>
<td>(16.0)</td>
</tr>
<tr>
<td>Partition coeff, well-perfused (Pwp)</td>
<td>(4.8(\hat{x} \div 1.5))</td>
<td>(1.83) (\hat{x} \div 1.15) (\hat{x} \div 1.16) (\hat{x} \div 1.16) (\hat{x} \div 1.16) (\hat{x} \div 1.15) (\hat{x} \div 1.14)</td>
<td>(1.92)</td>
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<tr>
<td>Partition coeff, poorly perfused (Ppp)</td>
<td>(1.6(\hat{x} \div 1.5))</td>
<td>(2.94) (\hat{x} \div 1.08) (\hat{x} \div 1.09) (\hat{x} \div 1.09) (\hat{x} \div 1.08) (\hat{x} \div 1.09) (\hat{x} \div 1.15)</td>
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<td>Partition coeff, fat (Pf)</td>
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<td>(82.3) (\hat{x} \div 1.08) (\hat{x} \div 1.08) (\hat{x} \div 1.08) (\hat{x} \div 1.08) (\hat{x} \div 1.09) (\hat{x} \div 1.07)</td>
<td>(84.1)</td>
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<td>Partition coeff, liver (Pl)</td>
<td>(4.8(\hat{x} \div 1.5))</td>
<td>(2.93) (\hat{x} \div 1.32) (\hat{x} \div 1.33) (\hat{x} \div 1.32) (\hat{x} \div 1.33) (\hat{x} \div 1.33) (\hat{x} \div 1.32)</td>
<td>(3.08)</td>
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<td>Max metabolic rate in liver (VMI)</td>
<td>(0.042(\hat{x} \div 10))</td>
<td>(0.0011) (\hat{x} \div 1.41) (\hat{x} \div 1.37) (\hat{x} \div 1.30) (\hat{x} \div 1.34) (\hat{x} \div 1.30) (\hat{x} \div 1.38)</td>
<td>(0.00191)</td>
</tr>
<tr>
<td>(K_m) in liver (KMI)</td>
<td>(16(\hat{x} \div 10))</td>
<td>(0.801) (\hat{x} \div 1.63) (\hat{x} \div 1.61) (\hat{x} \div 1.59) (\hat{x} \div 1.57) (\hat{x} \div 1.59) (\hat{x} \div 1.60)</td>
<td>(0.729)</td>
</tr>
</tbody>
</table>
1996: “Physiological pharmacokinetic analysis using population modeling and informative prior distributions”
1997: “Poststratification into many categories using hierarchical logistic regression”

Figure 3: Estimated Bush support estimated separately from seven individual polls taken shortly before the election: for (a) the entire U.S. (excluding Alaska, Hawaii, and the District of Columbia), (b) a large state (California), (c) a medium-sized state (Washington), and (d) a small state (Nevada). Each plot shows the raking estimates as a dotted line and the estimates from hierarchical model
1998: “Estimating the probability of events that have never occurred: When is your vote decisive?”

Figure 3. Probability That a State Is Decisive Given Tied Versus the Probability That the State Is Tied for 1992 Plotted on a Log Scale.
2009: “The probability your vote will make a difference”
1999: “All maps of parameter estimates are misleading”

Fig. 6. Four multiple imputations. For each map, the shaded counties are those in which the imputed rates, $\theta_j$, drawn from their posterior distribution, are in the top 10 per cent of U.S. counties, for that imputation. Compare these maps to the map of the highest true county parameters in Figure 4. These maps have no systematic artefacts due to variation in the
2000: “Type S error rates for classical and Bayesian single and multiple comparison procedures”

Figure 2: Probability of making a claim with confidence for classical and Bayesian comparisons: long-run frequencies are shown as a function of the variance ratio $\tau/\sigma$. 
2002: “A probability model for golf putting”
2003: “Forming voting blocs and coalitions as a prisoner’s dilemma: a possible theoretical explanation for political instability”
2004: “Standard voting power indexes don’t work”
2005: “Multiple imputation for model checking: completed-data plots with missing and latent data”

Figure 4. Summary of pain-relief responses over time under different doses from the clinical trial with nonignorable dropout discussed in Section 3.2. In each summary bar, the shadings from bottom to top indicate “no pain relief” and intermediate levels up to “complete pain relief.” The graphs in the top row include only the persons who have not dropped out (with the
2006: “The boxer, the wrestler, and the coin flip”

Bayes prior

0 1
X

1/4 1/4

1/4 1/4

Bayes posterior

0 1
X

1/2 1/2
2007: “An analysis of the NYPD’s stop-and-frisk policy in the context of claims of racial bias”

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Choices in statistical graphics: My stories
2009: “Beautiful political data”

**Figure 19-3.** Some graphs showing recent patterns of voting by age. The top-left graph shows my first attempt, created on election night based on immediate exit poll data. The top-right graph was created by Hober Short, a student who saw my graph on the Web and made his own, displaying time on the x-axis. The lower-left graph is my cleaned-up version of Short's graph, labeling all four age categories directly on the lines of the graph. All these graphs show the dramatic difference between 2008 and the two previous elections. Finally, the lower-right graph extends the data back to 1988, showing that Bill Clinton in 1996...
Figure 1. Correlations and logistic regression coefficients for predicting opposition to health care reform. The black closed circles are estimates for 2000 and the red open circles correspond to 2004. Logistic regression coefficients have been divided by 4 to correspond to approximate changes on the probability scale (e.g., Gelman and Hill, 2007), and the continuous inputs in the regression have been scaled by dividing by two standard deviations so that their coefficients are comparable to those of binary predictors.
2010: “Public opinion on health care reform”

Should federal gov't spend more money on health care for the uninsured (2004 survey)?

Income under $20,000 | $20-40,000 | $40-75,000 | $75-150,000 | Over $150,000

Age
18-29

30-44

45-64

65+

U.S. avg. - 25% | U.S. avg. | U.S. avg. + 25%

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2011: “Tables as graphs: The Ramanujan principle”

Larger digits look bigger!

Number of segments in digit (in "calculator font")

Digit

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Figure 1. Hypothetical picture of idealized Bayesian inference under the conventional inductive philosophy. The posterior probability of different models changes over time with the expansion of the likelihood as more data are entered into the analysis. Depending on the context of the problem, the time scale on the $x$-axis might be hours, years, or decades, in any case long enough for information to be gathered and analysed that first knocks out hypothesis 1 in favour of hypothesis 2, which in turn is dethroned in favour of the current champion, model 3.
2013: “Election turnout and voting patterns”

2008 election: McCain share of the two-party vote in each income category within each state among all voters (gray) and just non-Hispanic whites (orange).

Dots are weighted averages from pooled June-Nov Pew surveys; error bars show +/- 1 s.e. bounds. Curves are estimated using multilevel models and have a s.e. of about 3% at each point.
2008 election: McCain share of the two-party vote in each income category within each state among all voters (gray) and just non-Hispanic whites (orange)
Gradual improvements in technique . . . and understanding

Often, what we’re plotting is *not* “data”

Research vs. publications: “Let me tell you about my first wife”
Take-home points

- Small multiples
- Line plots
- Try to make a display self-contained, then add words
- Graphs are comparisons
Some references


Andrew Gelman (2004). Exploratory data analysis for complex models (with discussion by Andreas Buja and rejoinder by Gelman). *Journal of Computational and Graphical Statistics* 13, 755–787. [An expression of the idea that exploratory graphics are a form of model checking: the better the model, the more effective the graphics. Thus, statistical modeling and graphics are not competitors (as is often thought) but can work together.]


Andrew Gelman, Cristian Pasarica, and Rahul Dodhia (2002). Let’s practice what we preach: turning tables into graphs. *American Statistician* 56, 121–130. [Proof of concept: we went through an issue of the *Journal of the American Statistical Association* and converted all the tables into graphs, in each case displaying all the information using less space.]

Andrew Gelman and Gary King (1993). Why are American Presidential election campaign polls so variable when votes are so predictable? *British Journal of Political Science* 23, 409–451. [We resolved in writing this paper to do all the analysis using graphs, no tables. It worked well: we told a story and backed it up with evidence.]