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Sometimes We Must Raise Our Voices

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Visual Business Intelligence Newsletter
January/February 2009

When we create a graph, we design it to tell a story. To do this, we must first figure out what the story is. Next, we must make sure that the story is presented simply, clearly, and accurately, and that the most important parts will demand the most attention. When we communicate verbally, there are times when we need to raise our voices to emphasize important points. Similarly, when we communicate graphically, we must find ways to make the important parts stand out visually.

My original thinking about graph design was formed almost entirely by the work of Edward Tufte. I owe him not only for the formative development of my knowledge, but also for inspiring me to pursue this line of work in the first place. I left his one-day seminar over 10 years ago with my mind ablaze and my heart beginning to nourish the kernel of an idea that eventually grew into my current profession. Even after many years of working in the field of data visualization, which has involved a great deal of experience and study that has expanded my expertise into many areas that Tufte hasn't specifically addressed, I have only on rare occasions discovered reasons to disagree with any of his principles. The topic that I'm addressing in this article, however, deals with one of those rare disagreements.

The Data-Ink Ratio

In the book The Visual Display of Quantitative Information (1983), Tufte's first and perhaps finest, he introduced the concept of the data-ink ratio. It's a concept that I teach in my books and courses—one with which I heartily agree—but for one aspect, which I think Tufte took a bit too far. Here's the concept, as Tufte originally defined it:

> *A large share of ink on a graphic should present data-information, the ink changing as the data change. Data-ink is the non-erasable core of a graphic, the non-redundant ink arranged in response to variation in the numbers represented. Then,*

$$\textit{Data-ink ratio} = \frac{\textit{data-ink}}{\textit{total ink used to print the graphic}}$$

$$= \textit{proportion of a graphic's ink devoted to the non-redundant display of data-information}$$

$$= \textit{1.0} - \textit{proportion of a graphic that can be erased without loss of data-information.}$$

> (*The Visual Display of Quantitative Information*, Edward R. Tufte, Graphics Press, Cheshire CT, 1983, p.93)

Minimizing Non-Data Ink

Two principles of graph design are closely attached to this concept. The first principle is: "Erase non-data ink, within reason." (*ibid*, p. 96) I embrace this principle wholeheartedly. Any form of decoration and even some standard components of a graph (for example, axis lines) do not represent data, and therefore fit into the category of non-data ink. Any non-data ink that serves no meaningful and necessary purpose should be erased, for it can only distract from the data. On the other hand, non-data ink that supports the display of data in useful ways, such as the ink that forms a graph's axis lines, should remain, but its visual salience should be reduced until it's visible enough to do its job but not so visible that it competes with the data for attention.

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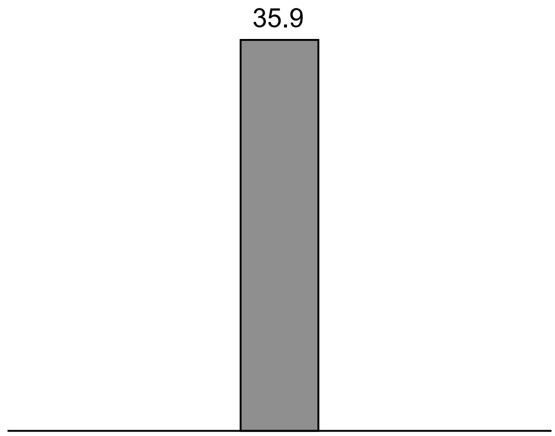
Minimizing Data-Ink

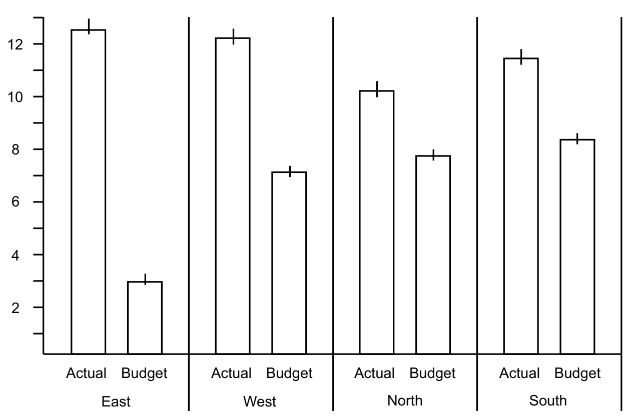
The second principle is: “Erase redundant data-ink, within reason.” (*ibid*, p. 96) Regarding this principle, although Tufte and I agree in spirit, we part ways in degree. We draw the line differently between redundant data-ink that is useful and should therefore remain, and that which is not and should therefore be removed. Tufte explained this principle using the following example:

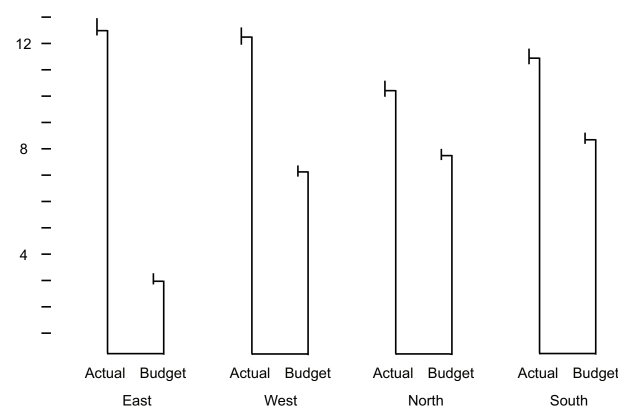


> *“Redundant data-ink depicts the same number over and over. The labeled, shaded bar of the bar chart, for example, unambiguously locates the altitude in six separate ways (any five of the six can be erased and the sixth will still indicate the height): as the (1) height of the left line, (2) height of shading, (3) height of right line, (4) position of top horizontal line, (5) position (not content) of number at bar’s top, and (6) the number itself.”*
>
> (*ibid*, p. 96)

Actually, this single bar only encodes its value of 35.9 in one rather than six ways—the text label that appears above the bar—for without other bars to provide points of comparison, all attributes of the bar that rely on its height are meaningless. If we assume, however, that more than one bar like this appears in a graph, then it is true that these six attributes redundantly represent a single value. Even so, must we conclude that all but one should be removed? I believe that some redundancy in a value’s graphical display is useful.

Tufte further made his case using several examples of graphs with redundant data ink, which he redesigned to remove redundancy. Below, I’ve recreated one of his examples: a bar graph. The one on the left is fairly typical and the one on the right is Tufte’s “improved” version. (In my recreation of Tufte’s example below, I replaced the data labels with some that are more familiar (actual, budget, etc.), and reduced it to a portion of the original.) Notice that each vertical bar on the left has been reduced to a single vertical line on the right.





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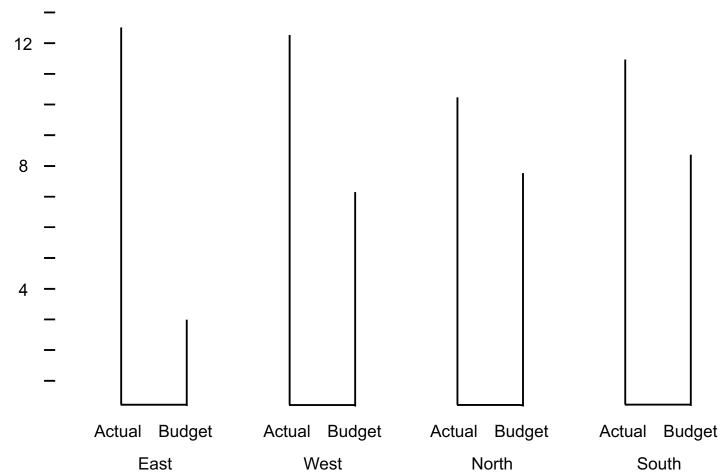
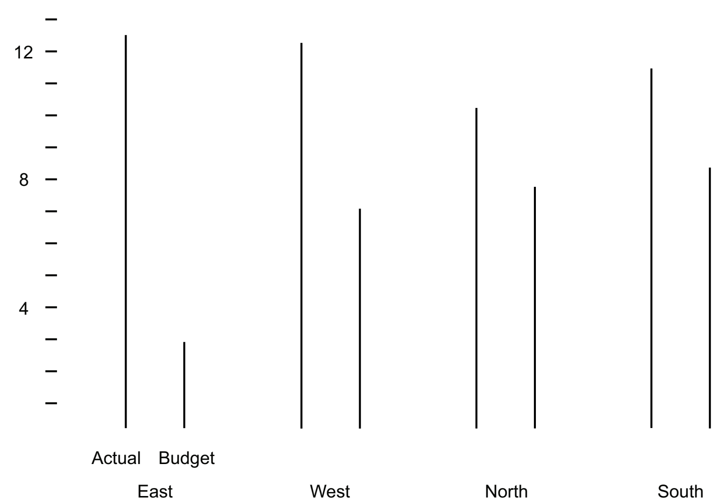
Notice that by removing the vertical lines that divide the regions—something that the white space between the regions alone does quite well—avoidable clutter has been eliminated. I believe that the other reductions, however, have gone too far. Before I make my case, it's worth noting that Tufte's redesign could have been pared down even more. If the original bar graph didn't include confidence intervals (the short vertical line at the top of each data bar, a.k.a. error bars), then Tufte's version could have been further reduced to something like this:



Even now, we're not finished, for one more redundancy reduction can be made. In the spirit of Tufte's intention, we could reasonably argue that proximity alone is enough to link the actual and budget pairs of bars, so we could erase the horizontal lines that connect them at the bottom, and we could also get by with showing the "Actual" and "Budget" labels only once, resulting in the following:



We could, but should we? I don't think so.

Speaking Above a Whisper

I believe that data-ink usually requires some redundancy for a graph to be easily read and used to make comparisons. Also, I believe that by reducing the size and visual weight of data-encoding objects, such as these bars, we force our eyes to work too hard, which slows us down. Based on several small, minimalist examples in his books, I suspect that Tufte has incredibly good eyesight—certainly better than mine, even with my glasses. Most of us benefit from making text and images a little larger than the minimum that the telecommunications industry decided long ago was acceptable for phone books.

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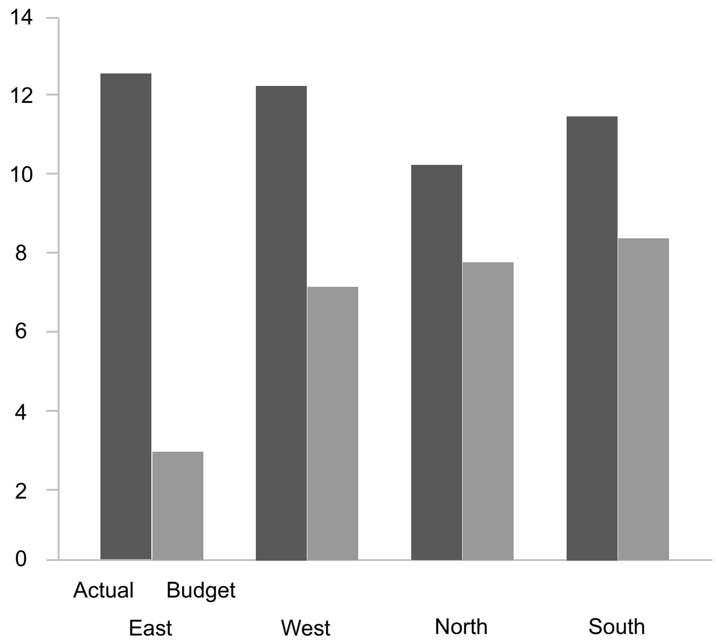
Here's the same actual versus budget information, this time displayed in a way that is easier and faster to read. The message hasn't been altered in any way, but it's more clearly represented.



Now, even if the graph were made smaller, we could still easily read and compare the values. The width of the bars gives them additional visual weight without forcing the graph to take up more space on the page and without forcing our eyes to process meaningless visual content.

Let's now look at the other examples of ink (both data-ink and non-data-ink) that have been added to this graph to determine if they're useful. First, let's consider the additional numbers along the Y-axis to label the quantitative scale. Tufte's design proposed that the 14-value scale (0 through 13) would work as well with labels for only three values: 4, 8, and 12. These numbers are data-ink—they provide information—but Tufte felt that we could easily fill in the missing numbers based on the three that are there, so he deemed the others redundant. It's certainly true that we can figure out the missing numbers, but which is more costly: the existence of more numbers along the scale or the extra time and effort that's required to mentally fill them in? I believe that by labeling the beginning and end of the scale (values 0 and 14) and including every other number (0, 2, 4, etc.), the scale can be read and understood more efficiently. I chose to only include every other number along the scale because including them all would have produced visual clutter, drawing undue attention to the Y-axis. I believe this design choice results in a better balance between too much and too little information, making the graph as easy as possible to read and interpret without adding so much visual content along the axis to cause visual distraction.

What about the axis lines themselves—are they useful? I should mention that even Tufte put the X-axis back on his graph after removing it, even though it wasn't strictly necessary, because the data bars seemed to float uncomfortably in space without them. So the only difference that remains regarding axes is whether the vertical Y-axis line is useful. Similar to the odd appearance of data bars when they lack a baseline to ground them at zero, I find that tick marks look odd without an axis line to anchor them, and I like the container for the graph's plot area (the data region) that's formed by the framework of both axes. Whether an axis line that joins the tick marks along a quantitative scale actually assists us or not while reading and interpreting a graph, I'm confident that a thin light-gray line of non-data ink won't hinder the process.

I like the way the actual and budget bars are labeled in this graph, because it eliminates the need for a legend, which definitely includes redundancy that we should avoid whenever possible. Unfortunately, we don't always have the space that's required for labels of this type (that is, without resorting to vertically-oriented text, which is hard to read), nor do the products that we use to produce graphs always give us the option of including two

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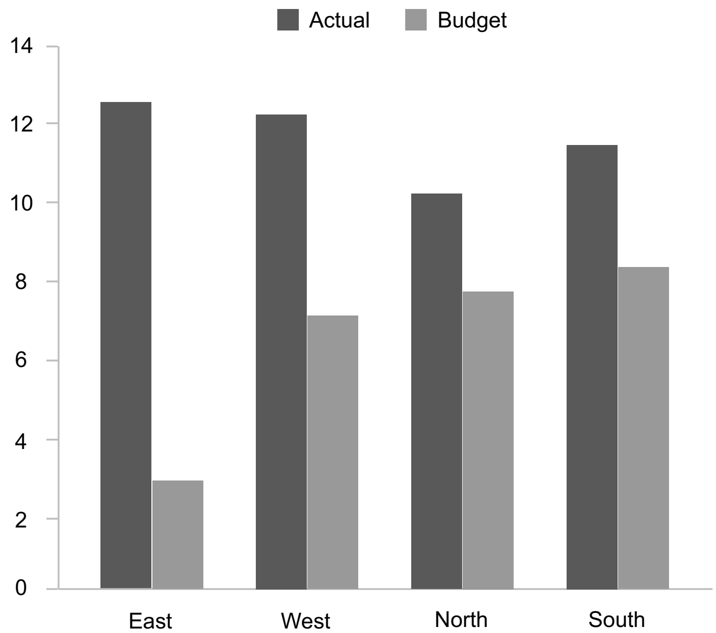
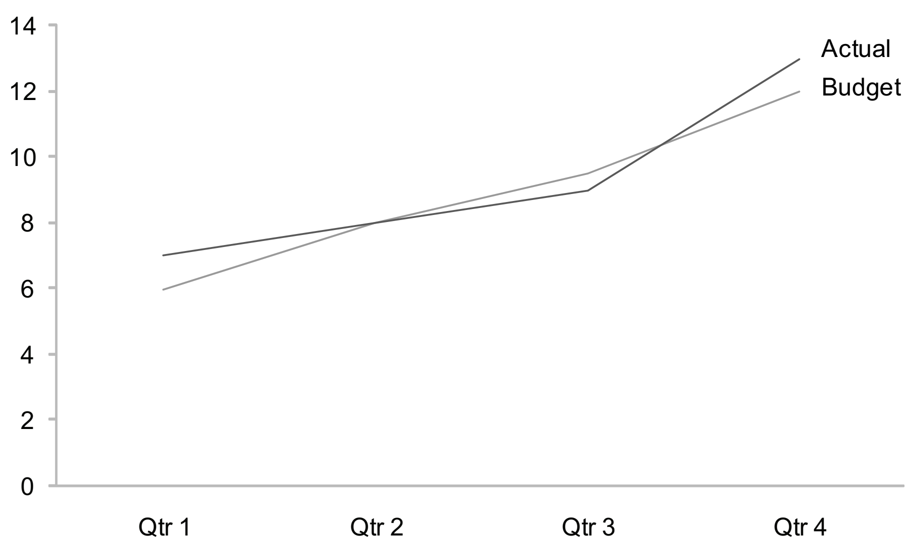
levels of labels along a single axis (in this case, regions and the distinction between actual and budget). When we can't label data objects in this manner, a legend is often unavoidable, as illustrated below. I created my version of the graph using Excel, which wouldn't allow me to place the actual and budget labels directly under the bars (without playing a trick, that is), so a legend was my only labeling option. The small colored squares next to the actual and budget labels are a repetition of the colors that already appear in the bars, and thus redundant, but even if we stick to Excel's limitations, we can at least make it relatively easy to associate the labels with the bars by arranging them side-by-side in the same order as the bars, rather than above and below one another to the right of the graph, which is Excel's default.



To further appreciate the usefulness of data-ink with greater than minimal visual weight, look at the following line graph of actual versus budget data by quarter.



We can certainly see the thin actual and budget lines, but when they're rendered this small, we must work harder than necessary to differentiate them, even though their colors are the same two shades of gray that appear in the previous bar graphs. By increasing the stroke weight of the lines in the following example, we've increased the amount of ink that's being used to display the data, but to a degree that does no harm while clearly making it easier to read and compare the two lines.

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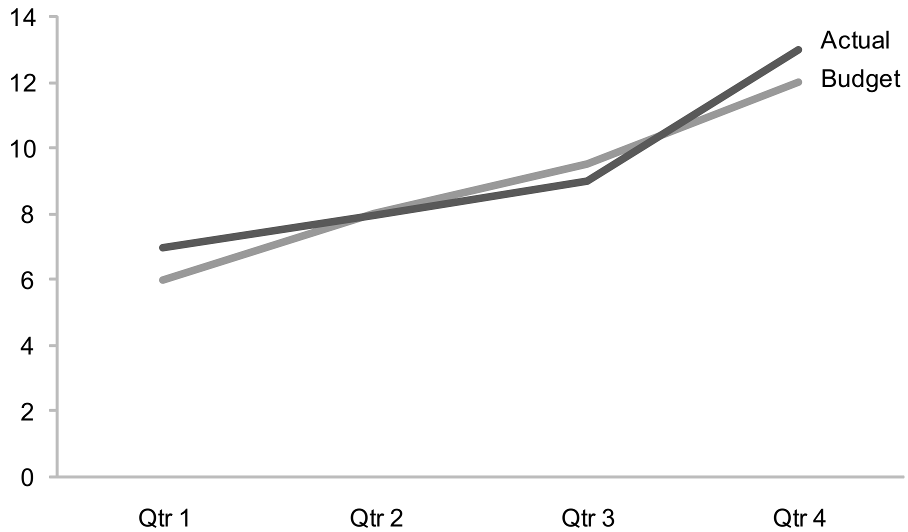
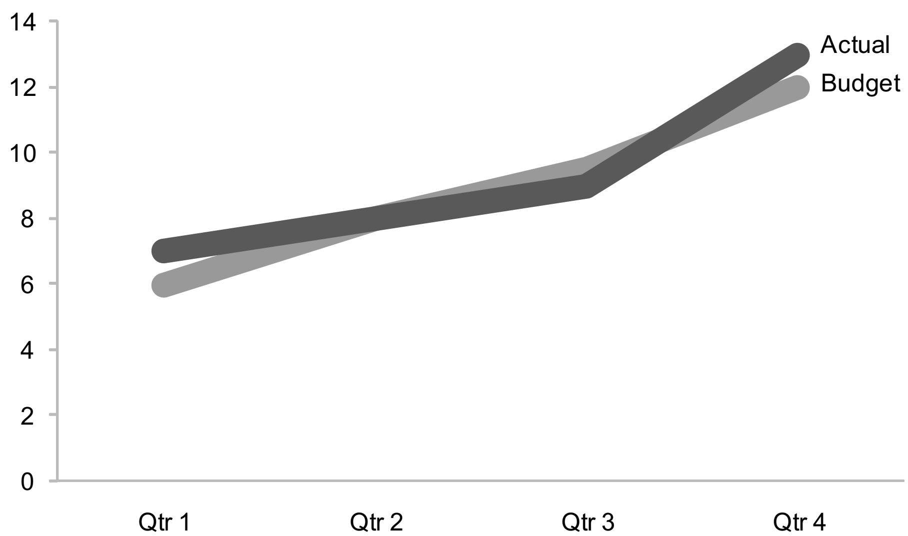


We could certainly take this too far, making the lines so thick that we can no longer read and compare them accurately, as I've done below, but it isn't difficult to strike a useful balance between too little and too much data-ink.



Shouting to Emphasize What's Important

Not all information is created equal. This is certainly the case when we're trying to communicate a particular message. Key points might need to be emphasized to get the message across. When presenting information graphically, this emphasis must be created visually to express the equivalent of a raised voice and more precise enunciation. In the following graph, which displays a ranked list of the 10 countries with the highest per capita gross domestic product (GDP), each country is displayed in precisely the same manner.

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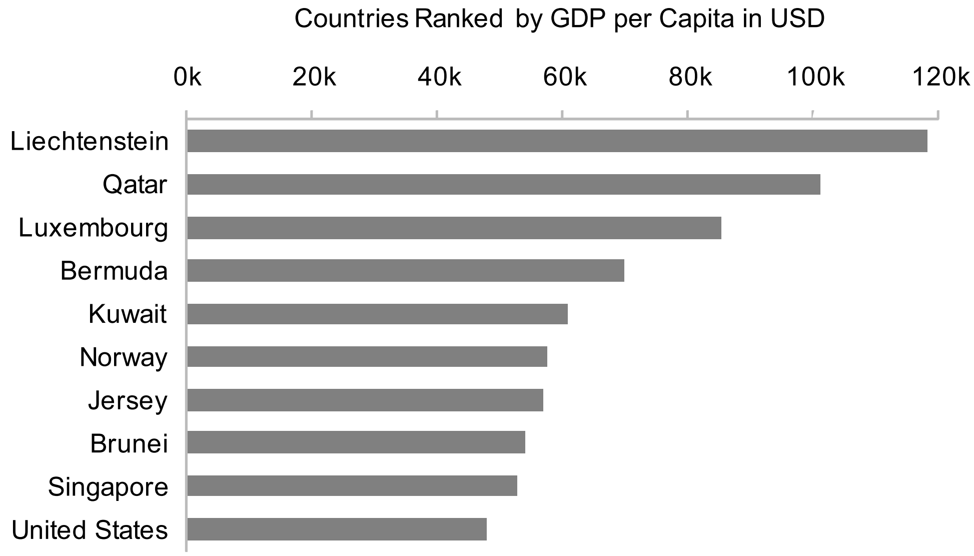
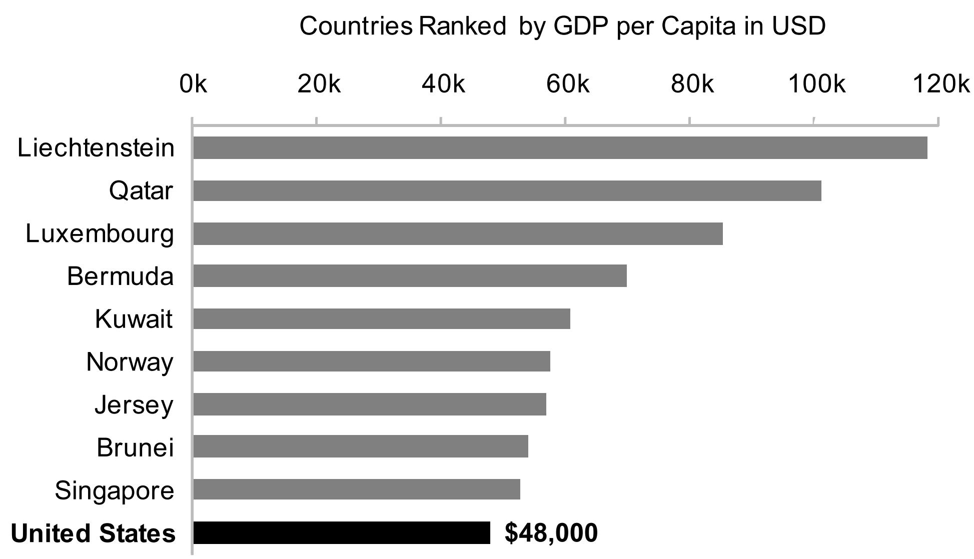


(Source: *The World Factbook*, published by the Central Intelligence Agency (CIA), based on data collected between 2004 and 2008)

This graph tells the story clearly, if you don't wish to focus your audience's attention on any particular country. If, however, you wish to emphasize the fact that the United States comes in last among the top 10 countries when ranked by GDP, it would be helpful to increase the salience of parts or all of the items that represent the United States. Here's an example that increases the salience of the bar, its label, and adds redundant data-ink to display the value as text.



By leaving everything else alone and increasing the salience of the United States only, we've raised our voices in an appropriate and useful manner.

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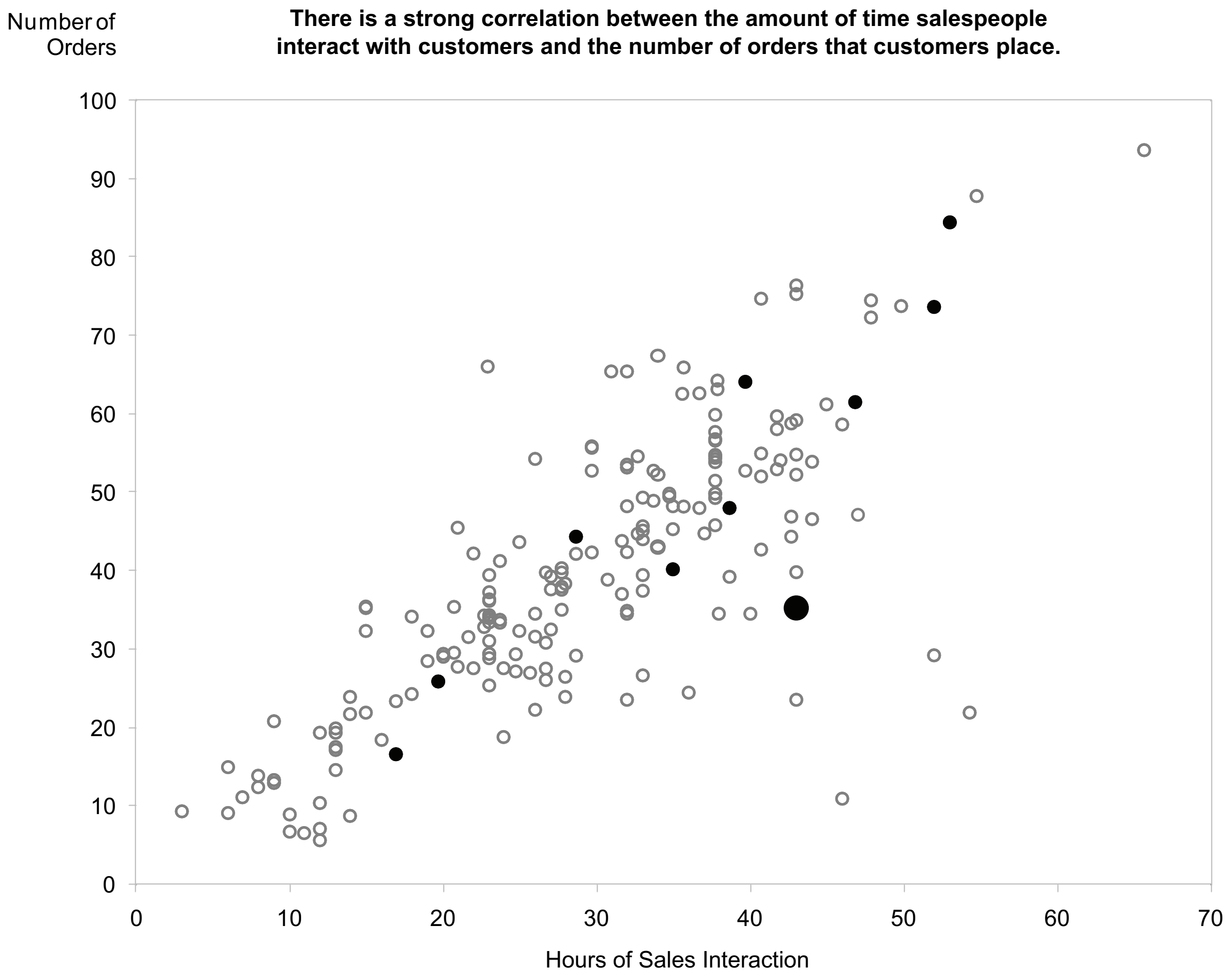
Let's look at one final example. The scatterplot below has been designed to tell the story of the strong correlation that exists between the amount of time that salespeople spend on sales calls with customers and the resulting number of sales.



(Dark data points ● represent last year's top 10 customers based on the number of orders placed. The largest data point represents last year's top customer.)

A key point is being emphasized in this scatterplot to further illustrate the strength of the correlation: the fact that high sales in the past don't guarantee ongoing high sales, which is demonstrated by the fact that the previous year's top customers were not necessarily the current year's top customers, but instead moved to positions in the current year that were strongly related to the amount of time that they received from the sales team. Without distinguishing the prior year's top customers through extra visual salience, achieved in this case by increasing the data-ink associated with those values (by adding fill color, and for the top-ranked customer, by increasing its size as well), this aspect of the story would not have been presented clearly.

In Summary

While data-ink should never be arbitrarily increased beyond the minimum that's required, we shouldn't hesitate to increase it to a degree that will improve a graph's ability to tell its story clearly and in a way that reduces the audience's effort to read and understand that message to the minimum. Like musicians, we must find the right volume to optimize the audience's listening experience and the right dynamics of soft and loud to touch their hearts and minds in the ways we intend.

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About the Author

Stephen Few has worked for over 25 years as an IT innovator, consultant, and teacher. Today, as Principal of the consultancy Perceptual Edge, Stephen focuses on data visualization for analyzing and communicating quantitative business information. He provides training and consulting services, writes the monthly *Visual Business Intelligence Newsletter*, speaks frequently at conferences, and teaches in the MBA program at the University of California, Berkeley. He is the author of two books: *Show Me the Numbers: Designing Tables and Graphs to Enlighten* and *Information Dashboard Design: The Effective Visual Communication of Data*. You can learn more about Stephen's work and access an entire library of articles at www.perceptualedge.com. Between articles, you can read Stephen's thoughts on the industry in his blog.

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