Make Your Figures Count

by Christopher G. Edwards

Abstract

Your illustrations are a fingerprint of your entire research paper. It pays to learn the general principles of designing graphs and figures, which will help you present data persuasively in the smallest possible amount of space. This article describes some of the pioneering design principles of Edward Tufte and how you can use them to improve your graphics.

How important are good illustrations?

On the day before a government agency was to begin an important scientific experiment, one of the equipment manufacturers warned the agency that it should cancel the experiment because of equipment problems. The company faxed 13 charts to support its concerns. The agency examined the charts, pointed out their flaws, and challenged these last-minute recommendations. The company then reexamined its own figures and withdrew its warning.

Good figures could have saved the Space Shuttle.

The agency was NASA, the company was Thiokol, and the experiment was the launch of the Space Shuttle *Challenger*. A minute after lift-off, the ship exploded, and its crew of seven perished in a cascade of flames. The exact cause of the tragedy was anticipated by engineers at Thiokol, who had debated for hours on the previous day about whether the O-rings on the ship would fail catastrophically because of cold weather. The data existed to predict correctly and thus prevent the disaster, but it was not adequately presented in the poorly conceived figures [1].

The moral of the story: the way in which you illustrate your scientific results is extremely important. In some cases, as with the O-ring studies, or with some biomedical experiments, it can determine life or death. Therefore, it is imperative to learn how to design figures carefully when reporting on experiments. Scientists who are most familiar with your field will pay very close attention to your illustrations, sometimes reading them as shorthand for your entire paper.

Learn the principles of design.

Without knowledge of the basic principles of illustration, it may be tempting to overly rely on your text, and show too little in your figures. I have also frequently observed the opposite situation, where young biomedical scientists tried to squeeze all their points into one or two graphs or figures. By stuffing an illustration with data points, however, you diminish the information value of the graph or figure, rather than enhancing it. Try to highlight your key points simply instead of overwhelming your reader with irrelevant data. At all costs, avoid adding material that you feel is notable simply because it represents very intensive work on your part. You won't get extra credit for hard work; in fact, it will count against you because it will obscure your significant results.

If you are willing to learn the principles of scientific illustration, you can soon design figures that are extremely persuasive, while reducing the time and effort expended on them. A number of authors have addressed this subject, but one name stands above the rest: Edward Tufte, a polymath who holds positions in political science, statistics, and computer science at Yale. He has outlined and illustrated his theories in a trilogy of books: The Visual Display of Quantitative Information, Envisioning Information, and Visual Explanations. As he puts it, the books explore pictures of numbers, nouns, and verbs, respectively.

Graphical excellence is possible.

In the first book, Tufte begins with published figures that represent their data poorly or extremely well. Citing striking historical examples, as well as instances in the fields of geography, journalism, medicine, and others, he establishes basic principles of graphical excellence and integrity. As Tufte sees it, graphics should be designed as an instrument to assist readers to reason in new ways about data. Therefore, as an illustrator, you need to learn how to think about graphical space in new ways.

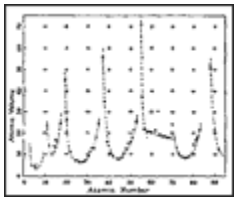
Maximize data/ink ratios.

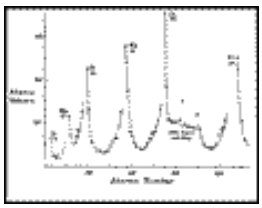
I would like to paraphrase some of Tufte's basic points about graphical excellence. Firstly, graphics should present interesting data well, communicating complex ideas clearly, precisely, and efficiently. They should help the reader to examine the data at different levels of detail, presenting information in ways that can't be done efficiently with text. Good graphics should complement the text and refer directly to the text. Secondly, graphics should present the greatest number of ideas, using the smallest amount of space and ink. (Strive for the highest ratio between the data and the ink you use.) The complexity of your graphics should directly correspond to the complexity of the data you want to present. Thirdly, graphics usually enable readers to make comparisons between many variables, using visual techniques that encourage and simplify this task. By easily making these comparisons, the reader should be stimulated to think more deeply about the data, not just observe it. Finally, graphics must enlighten and never mislead - as happened in the case of the Space Shuttle disaster.

Tufte supplies a multitude of examples that use or ignore these principles. He cites the EEG readout as an example where the data-to-ink ratio is extremely high. To fully appreciate his ideas, you should examine his illustrations and practice with your own graphics. As Tufte shows, selectively erasing your first draft of the figure can pare it down to the essentials, eliminating distractions and highlighting the important relationships. If you have important data that doesn't fit the purpose of the illustration, you can erase it and/or save it for an additional figure.

Tufte illustrates erasing in figure 1, which comes from Linus Pauling's General Chemistry [2]. (All figures are enlarged at bottom of article)

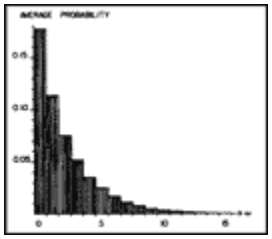
As Tufte suggests, the essential data is overwhelmed by the crosshatches, which look like "a precision marching band of 63 mosquitoes" [3]. Tufte's makeover, which erases almost all non-essential data and provides useful additional labels of the elements, looks like figure 2.

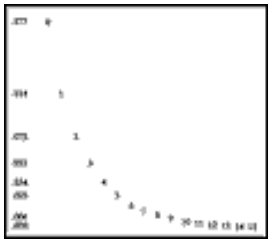




Here is another useful makeover. In figure 3, which Tufte culled from a style sheet of the American Statistical Association, the reader must look at the top of each bar, then scan over to the margin to estimate the actual number.

Tufte simplified this figure (figure 4) by using the numbers that formerly appeared on the X-axis as actual datapoints, thereby eliminating both the bar and the X-axis. He transformed the Y-axis into a series of numbers that more accurately depicted the old Y values while making them easy to read in tandem with the numbers.





Tufte offers some general guidelines to make graphics easier to read: spell out words rather than abbreviating them; run words from left to right (instead of running them along the vertical axis); explain the data within the graphic instead of in the legends, whenever possible; avoid unnecessary colors; and choose a clear type face.

With enough attention and practice, you can create scientific illustrations that are striking, perhaps even elegant. The clarity and precision of such figures can give your findings the prominence they deserve.

References

1. Tufte, E.R. 1997. Visual Explanations: Images and Quantities, Evidence and Narrative. Graphics Press, Cheshire, Conn., p. 39.

2. Pauling, L. 1947. General Chemistry. W.H. Freeman, San Francisco, Calif., p. 64. Shown in Tufte, E.R. 1983. The Visual Display of Quantitative Information. Graphics Press, Cheshire, Conn., pp. 102-104.

3. Tufte, 1983, p. 102.

Figure 1.

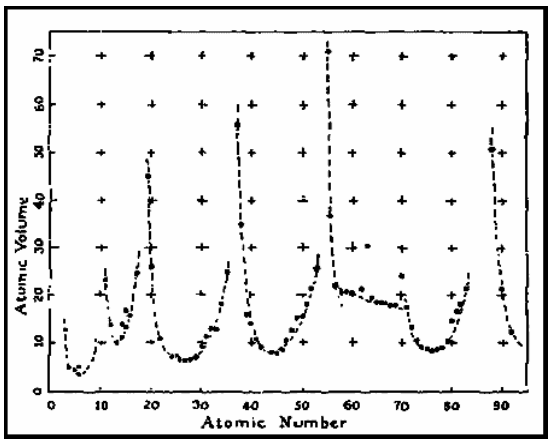


Figure 2

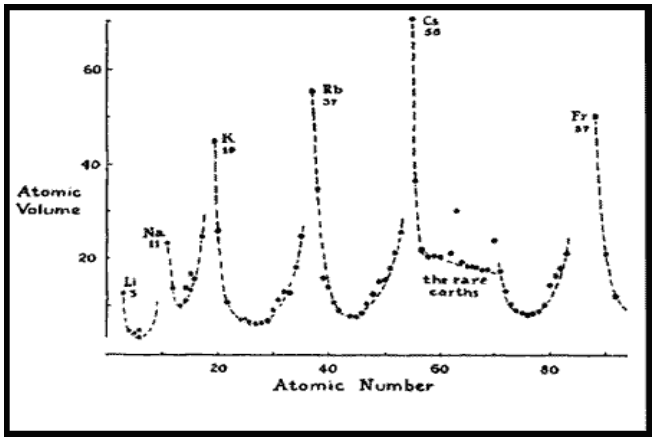


Figure 3

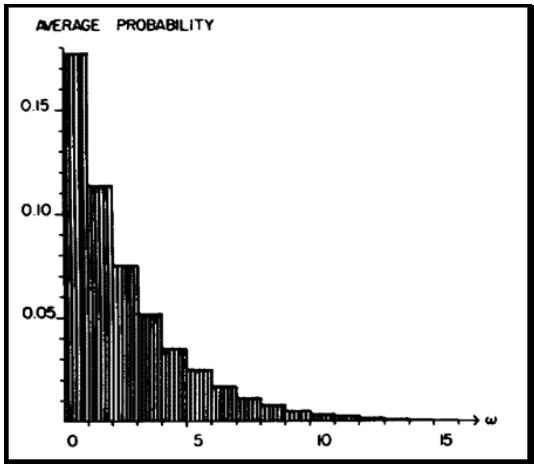
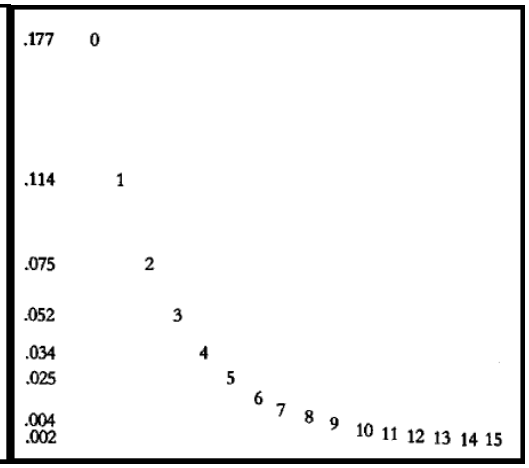


Figure 4



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