LEARNING FROM GRAPHS IN THE BUSINESS WORLD

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The craft of data visualization is quietly being taught to the world at large, not in classrooms and courses, but by a more powerful force: ordinary exposure to newspapers, magazines, annual reports and the like. These forms of communication have helped to make a few graphing techniques ubiquitous and familiar, and have bestowed on them the sheen of being professional, accepted and approved.

Although my focus will be on graphs in the business world, most of the observations apply to the popular press as well.

The reach of business graphics produced by corporations and the business press has increased in recent years, in part because of growth in the use of the Web. Another important factor is the general public’s expanded share ownership, through mutual funds and otherwise, which gives rise to financial reports that arrive by mail in homes all over North America and beyond. The ever-increasing ease with which graphs can be created, along with the notion that readers expect attractive visuals, suggests that business communicators are producing more graphs. A bigger potential audience coupled with the likelihood that more graphs are being produced means that a larger population sees business graphs.

Almost effortlessly, people learn fashions of all kinds (speech, dress, etc.) from everyday exposure, so the type and style of business visualizations are bound to influence what the world thinks graphs should be like.

Unfortunately, however, too much of what people absorb about visualization from the varied sources of business information is third-rate. Extensive academic studies show that many graphs in the annual reports of major corporations are seriously flawed. In 1992, Beattie and Jones published their study of annual reports from 240 of the 500 largest UK companies. They found that 30% of key financial variables graphed suffered from substantial measurement distortion. Earlier, Steinbart reached similar conclusions about graphs in the annual reports of the largest American companies. The Canadian Institute of Chartered Accountants expressed like concerns in a less quantitative 1993 research report. A newer study by Beattie and Jones considered graphs in the annual reports of major corporations in the US, the UK, France, Germany, the Netherlands and Australia. It showed that the extent and nature of problems is fairly consistent across borders. Another study, by Courtis, covered Hong Kong, finding that graphs were used less frequently but that problems were more common. A comparison of US annual reports from 1991-93 and from 1996-97 showed that 33% and 17%, respectively, “distorted the graphs in some way to make them appear more favorable.”

One eye-opener is the fact that distortions tend to favour the reporting entity, suggesting an intentional bias. The flip side of that finding is disturbing as well: some graphs in sophisticated corporate reports are distorted in ways that make things look worse than they really are. The people behind those annual reports seem to have failed to grasp the basic workings of graphs.

Casual observation suggests that business graphs elsewhere are no better.

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1 For example, the percentage of U.S. households owning mutual funds doubled over ten years to reach almost 50% in 2000, as reported in Investment Company Institute (2000). Fundamentals, August v. 9 No. 4, http://www.ici.org/pdf/fm-v9n4.pdf.


Of course, the failure of individual graphs does not reflect any fundamental shortcoming of the graph as a form of presentation, any more than muddled language dams the use of prose. On the contrary, properly designed graphs do an exceptionally good job of conveying financial information. Even allowing for occasional human error, many problems can be attributed to inadequate care, lack of knowledge, or lapses of judgment. These all suggest that insufficient attention is being paid to the way graphs communicate and how they reflect on the companies that publish them.

This sorry state of affairs may have a positive side for those interested in teaching the craft of data visualization. The very fact that bad graphs abound can be used to justify the need for people to develop strong critical skills, whether they are creating visualizations themselves or using visualizations that others have produced. Readers don’t want to be fooled, and those communicating information don’t want to risk being caught distorting or deceiving. Those are potentially strong motivations for learning graph craft – at least the basics.

The examples below illustrate specific problems that are reasonably common. They are more valuable, however, as examples of how critical thinking about graphs can be exercised, and what happens when it is not.

### Some Common Problems

**Annoying labels**

Although the geometry of a graph is obviously fundamental, labels (text and/or numbers) within a graph are also critical. The labels in the pie chart in Figure 1 appear tidy and organized at first. However, they are in a different sequence than the slices. Effort must be diverted from understanding the data to identifying the slices.

![Figure 1](image1.png)

#### Labels should relate effortlessly to the data

Sales by City ($millions)

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<tr>
<th>City</th>
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<tr>
<td>Lethbridge</td>
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Among the many eye-straining techniques used for labelling is the one exemplified here. The sequence of the labels does not match that of the data, and the parallel lines from the labels to the data produce an uncomfortable “op art” effect. The reader must work hard to connect the information in the labels with the data.

The 3-D effect compounds the difficulty of reading this chart.

In the bar chart (Figure 2), grid lines are at intervals of 23, and the tick marks at 7 2/3. These awkward choices are neither standard nor convenient for a reader. Poor labeling – in this case the choice of which grid lines to show and label – ruins an otherwise good graph.

**Distortion**

Graphs can be distorted in a variety of ways. Sometimes they are not plotted to scale, either entirely or in part. Readers are entitled to expect graphs to be drawn to scale, with reasonable accuracy. This fundamental failure is illustrated in Figures 3 and 4.

Non-zero baselines can be considered a form of distortion, because they make apparent proportions differ from the proportions of the underlying quantities.
Strange intervals for grid lines or tick marks make graphs unnecessarily difficult to read. In the example on the left, it is a struggle to tell that the middle bar represents about $38 million and the one on the left $61 million.

People are used to estimating values when the intervals are round numbers, such as 1, 2, 5, 10 or 20. Intervals of 23 (as here) reflect a lack of consideration. The improved version (right) with intervals of 20 is far more convenient.

The pie chart (top) is distorted. Adding the 21% for Asia and the 27% for the US yields 48%, but the total is clearly a little more than half of the pie. Similarly, the 12% for Europe appears to be about half of the 40% for Canada. In this graph, everything is wrong.

One benefit of computer-drawn graphs ought to be that such errors are a thing of the past. They are not. The simple pie chart (bottom) is drawn to proportion and has the added benefit of not being 3-D.

In contrast, in the version with a zero baseline (on the right), the reader does not have to struggle to reconstruct relative changes. Non-zero baselines can be considered a form of distortion, because they make apparent proportions differ from the proportions of the underlying quantities.

Non-zero baselines occasionally have a valid role in that they allow relatively small variations to be clearly visible. The challenge is to make the fact that the baseline is not zero so obvious that a reader can’t miss it. In Figure 5, the baseline is clearly labelled “$300.” Adding visual cues would be better still. For example, the spacing between the two bottom horizontal grid lines could be increased or decreased, clearly signalling that something important is different at the bottom of the graph. A non-zero baseline graph in which less than half of the graph has been removed
is sacrificing proportionality for, at most, a doubling of the detail. That trade-off is hard to justify.

Some non-zero baseline graphs label the baseline as zero. (If the left-hand graph in Figure 5 were designed that way, the $300 in the would be labelled “$0.”) That makes a reader more likely to misread the graph, because a glance at the baseline provides misleading information.

Perhaps the nastiest members of the non-zero baseline family are those that lack a scale on the axis, and in which some or all of the bars (or points on a line) are labelled with their values. To determine whether the graph has a non-zero baseline, the reader must waste a lot of mental effort. (See Figure 4, which also illustrates other problems.)

The implications are clear: don’t use a non-zero baseline unless it is justified, and ensure that any non-zero baselines are clearly marked. Otherwise, comparisons are hindered, and the graph won’t do its job.

Somewhat similar to non-zero baselines are graphs (usually bar graphs) that are truncated. Typically, the longest bars have a gap to indicate that they have been shortened. While this approach is a reasonable way of dealing with an unusually large value, it can undercut a fundamental characteristic of a good graph, i.e., that distances are proportional to quantities. The danger is that the visual impression that a reader gets from a truncated plot is that the truncated quantity is much smaller than it really is.

Figure 6 shows truncation with an extra wrinkle. The longer negative bar is truncated, ending precisely on the only negative grid line. That negative grid line is at the same spacing as all the other grid lines. However, in the case of the negative quantity, that spacing represents a quantity six times as large. In this example, the spacing of the grid lines reinforces a reader’s natural inclination to concentrate on the length of the bars, notwithstanding the truncation. That conveniently minimizes the loss, which, but for the truncation, would be the longest bar on the graph. The grid line also makes the most recent year’s negative result ambiguous. It does not appear to be truncated, so perhaps it should be measured using the normal scale. On the other hand, it, perhaps it should be measured using the negative scale.

While the example in Figure 6 used a different scale in the negative part of the graph, another type of truncation is more shocking: hiding all negative results. This is like showing a homebuyer a picture of the front of a house, while obscuring the fact that the back has collapsed. Of course, if the deception comes to light, credibility evaporates. Figure 7 is an example of a graph with hidden negatives. In that example, the missing negative quantities far exceed the visible positive ones. At the very least, this convenient omission is a striking example of graphical non-disclosure.

Graphs that hide important information also obscure trends, relative quantities and even absolute quantities. The graph provides visual misinformation.

Another phenomenon that can be considered a form of distortion is the backwards-time graph. In a graph, later times are normally towards the right. If later times are towards the left, declines look like increases, and vice versa. The convention that time flows to the right in a graph is so strong that no matter how well the reversal is marked, the reader is likely to interpret and remember the graph with trends reversed. Even a reader who knows exactly what is happening will find the illusion difficult to counteract. While the geometry of the graph may be correct, apart from being
mirror image, the reader’s impression of the data is distorted.

![Figure 8](image)

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Time reversal creates a false impression

Net Income per Share

A bank reversed time, making a decrease look like an increase. The motivation was not deceit, but rather an attempt to make the data in the graph line up with the columns of financial results on the same page. Nevertheless, the result is unacceptable, because it gives a false impression of trends.

An interesting interaction of two conflicting conventions can make backwards time understandable as a design experiment, although ultimately unacceptable. By convention, the columns of financial results in an annual report start with the year that is being reported on the left. The next column to the right is the previous year, and so on. A designer might quite reasonably be tempted to link the graph to the columnar results, but the good motive does not justify the inevitable confusion. The graph in Figure 8 is modelled on one in an annual report that fell into this trap.

**Bad logarithmic graphs**

In the business world, logarithmic or ratio graphs are not especially common, which in itself is somewhat disappointing, given that they are ideally suited to portraying growth, and make comparisons of growth rates as simple as comparing slopes – a potential boon to visual arithmetic. When they do appear, they seem particularly prone to problems. Zero is sometimes included (even though if plotted to scale it would have to be infinitely far below anything else on the graph). Maintaining a consistent scale seems to be challenge. (Figure 9) And too often, readers have to work hard even to determine that the graph has a non-linear scale. Logarithmic or ratio graphs should be apparent as such at a glance – from the spacing of the lines or at least from a clear label.

**What’s Going Wrong?**

The prevalence of bad graphs in the business world prompts one to wonder: *What is going wrong?*

Discussions with graphic artists, writers and editors of business publications, investor relations professionals and others involved in business communications, suggest the following are among the factors behind the publication of bad graphs:

1. To professional designers, numbers are often a mystery.
2. To business people, designers are a mystery, and often, data visualizations get inadequate attention.
3. Software frequently encourages bad graph design.

These observations suggest some responses. When dealing with professional designers, one ought to assume complete innumeracy, remaining open to being convinced otherwise. Assume that everything will be distorted. The vigilance required extends every aspect of the design, but key aspects are proportionality and consistency.

Innumerate or not, designers are capable of becoming more aware of the need to preserve numerical relationships in visual presentations. This can be reinforced in working relationships with design professionals and in design studies. (For example, for each of the last six years I have given talks about graphs to students in an information design course at Sheridan College, near Toronto.) In other words, the combination of formal education and of standards imposed by non-designers can change the way designers think about data visualizations.
Many business people and others recognize that visualizations are important parts of their reports and presentations, and are not merely “eye candy.” Some do not. One can argue that if a picture is worth a thousand words, graphs (as pictures of numbers) deserve the same editorial care as a thousand words of text. The point can be made that a misleading or otherwise faulty graph can undercut the credibility of the individual or organization, with the potential to undercut sales, share price, etc., and could even lead to litigation. The danger is that this will merely discourage the use of graphs altogether, rather than encourage better care and higher quality.

When working with designers, as with other suppliers and advisors, business people have to decide when to follow suggestions and when to require something else. This can be a difficult balance in any situation, and does not lend itself to rules. When it comes to graphs, however, business people have to be willing to demand that designers not allow broad design templates (e.g., every graph should have six horizontal grid lines) to interfere with visual arithmetic.

As for software that encourages bad design choices, two fronts suggest themselves. One is to encourage users (students, for example) to use the best options that are available. Another is to complain to manufacturers, who, however, are likely to claim that they are offering what purchasers want, and that they have provided other options.

The main goals of teaching the craft of data visualization ought to be to encourage critical thinking and to emphasize that design must demonstrate respect for both the readers and the data. Any progress will tend to encourage a virtuous circle: readers who demand better graphs and graph creators (whether professional designers or otherwise) who are more discerning will promote a higher standard of visual display. That, in turn, will influence companies and the business press. Whether any of this will be sufficient to overcome other forces that are at play is doubtful, but the effort is worthwhile.