Graphs or Tables?†

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The main advantage of graphs is in communicating qualitative aspects of the data.

Many people say that graphs make data easier to see. But this is not always so. Many graphs are not easy to follow.

Graphs usually fail if they do not have a simple story-line to tell. This restricts them to communicating qualitative aspects of the data, i.e. shapes or orders of magnitude. For this they can excel.

In contrast, detailed *quantitative* features are usually difficult to read off from a graph. For that well-designed numerical tables may be better, as already suggested elsewhere (Ehrenberg, 1975, 1977b, 1977c). In this paper I try to analyse this distinction further, using illustrative examples. Formal proof is difficult. It would require an extensive series of studies. Nonetheless, there are points to be made. It is left to the individual reader to relate these suggestions to his own experience.

My aim is to go beyond the cliché that how one's data are to be presented all depends on the audience and on the use that is to be made of the information. Instead, there are aspects of data presentation which appear to be general and which can be made more explicit. One is the qualitative and quantitative distinction. Another is that in looking at a graph the eye has to relate widely-separated items of information, such as the captions, the horizontal scale, the vertical scale, and the actual items in the body of the graph. The eye has to move round a good deal. This can make for perceptual difficulties. It explains why numerical detail is difficult to read off, since the eye has to travel constantly from the plotted readings to the two scales.

A Good Graph And Its Limitations

I first learned to distinguish the advantages and limitations of graphs from the example shown in Figure 1. This compared certain theoretical and observed values (Ehrenberg, 1959) and showed that the fit was good for relatively low values, but that there were systematic discrepancies for

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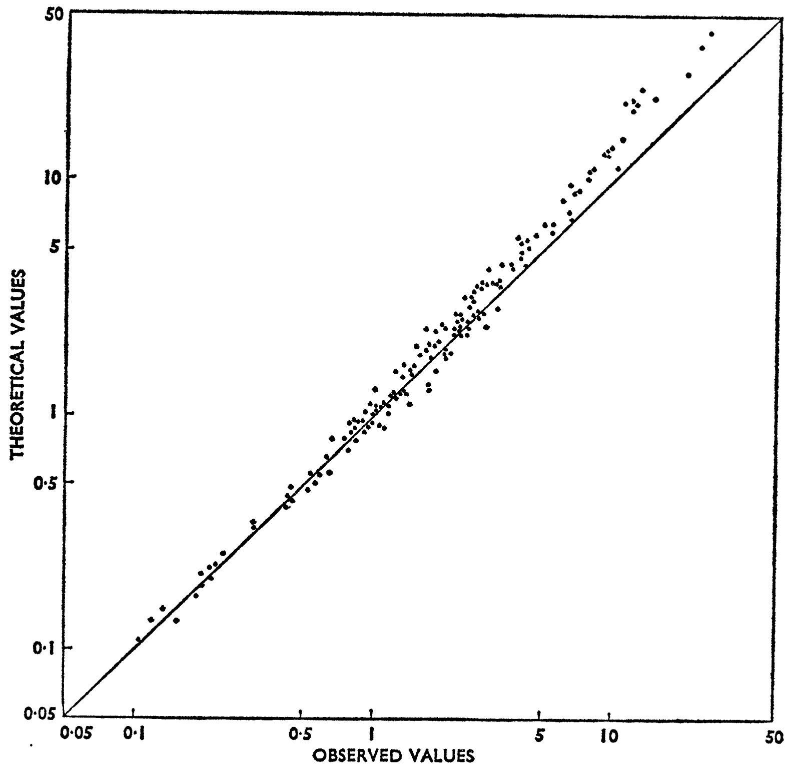

Figure 1

Comparison of "theoretical" and "observed" values for the standard deviation of the frequency distributions of consumer purchases.

higher ones, the theoretical values always being too big. So far so good: there was a simple and clear-cut story-line, and the graph told it well.

Later we had to analyse many further sets of such data (e.g. Chatfield *et al.*, 1966). Qualitatively the results were in line with those in Figure 1, i.e. theoretical values which were too high when the absolute values were high. But it was not easy to assess whether any new pair of readings, such as a theoretical 15 and an observed 12, agreed *numerically* with the earlier pattern. Such quantitative comparisons turned out to be far easier when the earlier results had been summarized in a numerical table or, better still, by a mathematical formula. The lesson was that the graph was not of much use in quantitative analysis even though it told a clear story-line well.

Some Problems With Graphs

Not all graphs even tell a clear "qualititative" story-line. Too many have no story-line at all.

They usually attempt to show too much numerical detail. I now illustrate the problem for some simple line graphs.

I quote (with permission) Figures 2 and 3 from a draft paper by Howard Lyons (1976). They summarize assessments of the nutritional and economic value of 8 food products from bread to milk, made by samples of consumers and retailers. (We need not concern ourselves with the substantive content of the illustration.)

Having perpetrated his graphs, Mr Lyons quickly realized they were somehow not very appropriate. The challenge to the professional statistician or teacher is to spell out for Figure 2, say:

(i) What are its specific faults?
(ii) What would a "better" graph look like?
(iii) What other alternatives are there (if any)?
(iv) What are the underlying principles or theories (i.e. how do the answers to (i), (ii) and (iii) apply to other cases)?
(v) Where are these principles discussed in the literature?

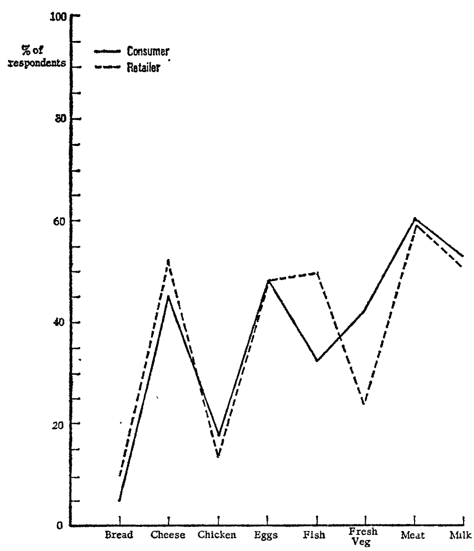

Figure 2

Consumer's and Retailers' rankings of the nutritional value of food.

For example, it might be argued that one should use bar charts instead, or that one should order the data in decreasing order of size of one of the variables. But would these really be better? And where are such ideas developed formally, as precepts for the preparation of graphic displays?

I have deliberately chosen the examples in Figures 2 and 3 as fairly extreme (but simple) illustrations. They appear peculiarly wrong (e.g. why line graphs when the variable plotted on the x-scale is neither quantitative nor even ordered?). This reinforces the challenge to us as trained statisticians. Do we really know the answers to the above questions? Could we teach them at the drop of a hat?

It might be said that most of the points made here are normal good practice and should be obvious to a qualified statistician. But are they? Are they practised even by those who write in our statistical journals?

In fact Figure 2 is not *all* bad. It tells a fairly clear story, namely that the two variables vary together except in the case of Fish and Fresh Vegetables. This could however be communicated as clearly and rather more briefly in words – as I have just done. But the graph does at least show it fairly clearly in chart form.

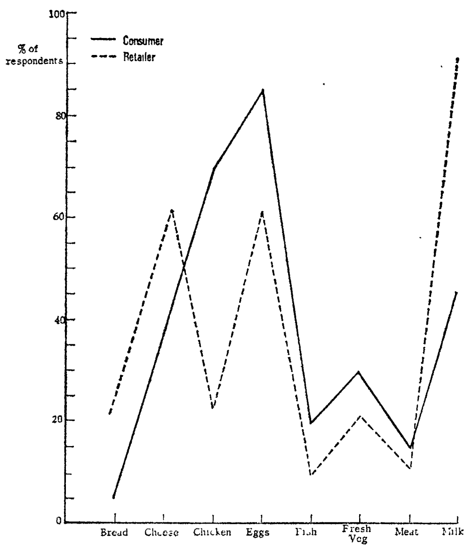

Figure 3

Consumers' and retailers' rankings of the economic value of food.

Where Figure 2 fails more specifically is in communicating its detailed quantitative information, e.g. that bread is at about the 5 per cent level, cheese and eggs at about 50 per cent and so on. To see this the reader has to compare the graph lines with the scale on the left. Similarly, the numerical size of the discrepancies for fish and fresh vegetables is not apparent at a glance – the reader has to do quite a lot of work to estimate them. This is not difficult, but it is time-consuming. The question is whether such work could largely be avoided by alternative forms of presentations, e.g. ones which give the numbers more explicitly.

The difficulties are even greater in Figure 3, which gives the same respondents' rankings of the *economic* value of the different foods. The results are more mixed. They are less easy to summarize in words (except to say that there is no simple pattern). The graph is typical of many which do not seem to create a lasting mental picture – something that graphs are, if anything, supposed to foster. All that we can see at all easily is that sometimes the two lines agree and sometimes not.

This brings out a major perceptual problem which occurs with many graphs. It is that we have to relate so many different things visually. In the present case these are:

the two lines in the body of the graph,
the labels on the horizontal axis (bread, cheese, etc.),
the scale of the vertical axis,
the key at the top (saying which line referred to the consumers' or retailers' rankings).

The eye has to move a great deal to take all this in and to remember it. Yet that is what one has to do when scanning and trying to understand the data.

The problem becomes worse when we try to relate information from different sources, e.g. Figures 2 and 3. We can see that the nutritional and the economic ratings for bread and cheese go roughly together, but as for the rest, what can one see and remember about the two graphs as a whole?

Another Version of the Graphs

There are of course other ways of graphing these data. Bar-charts and ordering by size are two possibilities. (In Figures 2 and 3 the chosen order of the food items on the x-axis was merely alphabetical and not even invariant to translation.) But are any of the alternatives radically better? None seem to avoid the difficulties already raised – in particular those of seeing the quantitative detail and remembering it.

To illustrate, consumers' rankings can be plotted vertically against retailers' rankings horizontally, either on two separate graphs for the nutritional and economic rankings, or jointly as shown in Figure 4.

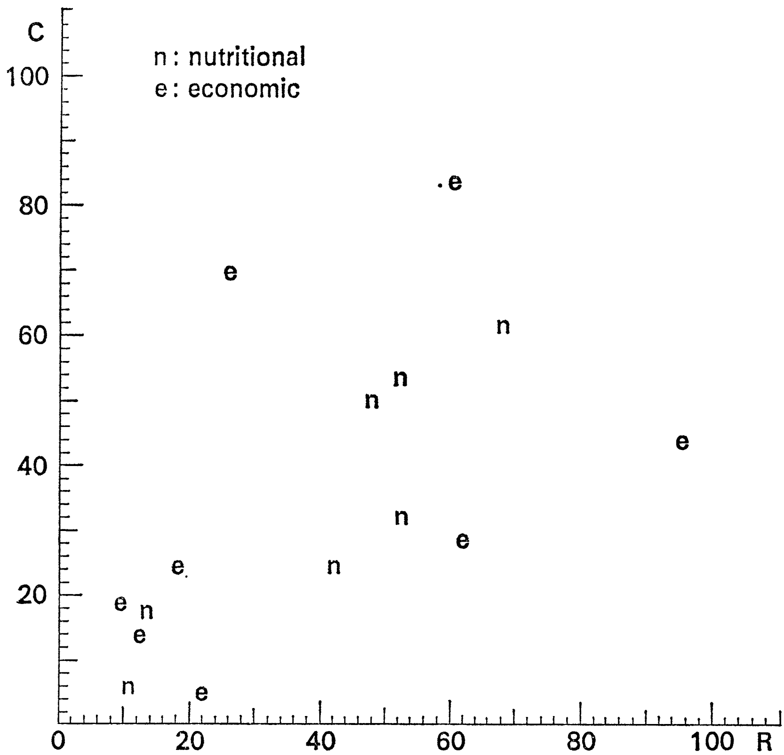

Figure 4

Plotting Consumers against Retailers. Nutritional, n, and economic, e, ratings.

One can again see how the nutritional ratings generally agree with each other and how the economic ratings do not. But this is a qualitative point which could of course again have been summarized in words (as I have just done). The graph would only be of additional value if it made this point more graphic and more memorable.

It still is not easy to read off any *numerical* features of the data. In addition, the identity of the particular points is lost. Labelling them (e.g. bread, cheese, eggs, etc.) would not be simple or "graphic". Nor does the idea of joining up the pairs of corresponding points for each food item. This example suggests that there may be no very effective ways of graphing the data to bring out the numerical detail.

One such example obviously proves nothing. But if graphs *can* communicate anything other than the simplest qualitative notions (for which they can be splendid), it must be easy for readers to produce many examples from the literature or from their own past experience.

We can look at a textbook, a journal, a newspaper or a government statistical publication which carries graphs and examine them. Does each graph have a major message? If so, does it communicate this well (e.g. can it be readily summarized in a few words or numbers)? Does it communicate anything *other* than its major message? Is it easy to read off and remember any of the numerical detail?

Or was the graph in question perhaps just a record of more or less undigested data, provided in case somebody else wants to analyse them? If so, does the graph do *this* job well (i.e. will it in fact be easy for anyone else to analyse the data further in this form)? Many published graphs do not seem to come out well of such a check. The only ones which do are ones with a simple qualitative message (e.g. "It goes up" or "It's a straight line"). That at least is my own experience – and I do use graphs a lot for such qualitative purposes.

Tables With Words

The ideal way of summarizing detailed numerical data is by mathematical models. But they are usually only worth developing at a relatively late stage of analysis. The more directly comparable alternative to a graph is probably a table of numbers.

Numerical tables are widely unpopular, probably because they are mostly badly designed. This I have already extensively discussed elsewhere (Ehrenberg 1975; 1977a, b, c).

My proposition now is that to compare with a graph, a table needs to be not only well laid out, but that it should be accompanied by a brief *verbal commentary*. This would bring out the main qualitative features of the data, i.e. those which a good graph would highlight. Without such a summary, the analyst is leaving the work to the reader. The summary should help the reader not only to see what the table (or graph) is saying, but also help him to take away a memorable abstraction of the data. In that respect the table with verbal summary would probably be no better than a good graph, and might often be worse. But the table would additionally provide a more usable presentation of the numerical details of the data.

To illustrate, Table 1 gives the data from Figures 2 and 3.

Table 1

Consumers' (C) and Retailers' (R) ratings of the nutritional and economic values of different foods

Foods	*Nutritional*		*Economic*	
	C	*R*	*C*	*R*
Meat	62	58	14	11
Milk	55	52	44	95
Eggs	49	48	85	61
Cheese	45	52	30	62
Fresh Veg.	42	24	25	18
Fish	33	52	20	10
Chicken	18	13	70	25
Bread	5	11	5	21

*In decreasing order of Consumers' Nutritional Ratings.

The verbal summary (given in the text) might be "Consumers' and retailers' *nutritional* ratings for the different foods tend to agree. But the two *economic* ratings often differ both from each other and from the nutritional ones." Aided by such a verbal summary, any reasonably experienced person can see it in a reasonably well laid-out table. (I am at this stage not concerned to communicate such data to someone who has never seen a table of numbers before.)

Table 1 apparently shows up the main patterns adequately. In addition it also records the numerical detail in a usable manner. The figures can easily be read off, compared, differenced, averaged, or whatever may be required in any further analysis. *This is unlike anything that can readily be done with graphical presentations such as those in Figures 2 to 4.*

It might seem unfair to compare a well laid-out table with what might be regarded as the "bad" graphs used in my illustration. But if so, the reader can see whether he can devise any graphical presentation of the data that would do that much better. More important, what is his conclusion about the presentation of *other* kinds of data?

Discussion

In considering data presentation, it helps to differentiate between three main stages of empirical analysis, as stressed by Cox (1977): (i) exploration, (ii) detailed analysis, and (iii) presenting the results to others. The preceding arguments imply that graphs tend to be useful only in the first and third stages, that is for the analyst getting a "feel" of new data, and for his later presenting broad conclusions to others.

These two uses of graphs concern "qualitative" apects, i.e. shapes and orders of magnitude. They are not concerned with the more detailed quantitative aspects of the data, which are dealt with in the second stage of analysis. Here it seems that tabular and mathematical forms of analysis are usually required.

Graphs for the Ignorant

Exploratory analysis and presenting the results to others seem at first sight to have little in common. A statistical analyst using graphs in his exploratory work must differ from how he (or someone else) will communicate the final results to a non-statistical audience. There is however a common element, namely that in both cases one is communicating to the *ignorant*.

In exploratory analysis it is the analyst *himself* who is ignorant. He does not yet know the nature of his data and therefore plots it on the back of an envelope to get a feel for it – is it a curve or a straight line, is it homo-scedastic or not, are there any outliers, and so on.

In presenting the results to others, the presenter presumes his *audience* to be ignorant. They do not yet know what he is talking about, and therefore have to be introduced to basic concepts and patterns in simple, graphic terms.

This notion of "graphs for the ignorant – me or others" is a telling criterion for judging when to use graphs and when not to. But it seems to limit the use of graphs greatly, since neither the analyst nor the audience are seldom altogether ignorant of the subject-matter. As discussed elsewhere (Ehrenberg, 1976), most data situations are repetitive rather than purely exploratory, i.e. previous similar data have already been analysed or shown before.

There are however many repetitive situations where the task is to remind the audience of previous results. This is a case of quasi-ignorance, i.e. the audience are treated as if they were ignorant of that kind of data, even though strictly they are not or should not be. But the message must again be qualitative. The audience must be reminded of broad patterns ("Ah yes, I knew that, didn't I?"), not of the numerical detail. Some deliberate oversimplification is therefore needed rather than detailed numerical documentation. For this, well-designed graphs can be most suitable.

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