

Communicating with Graphs

The suitability of a graph type depends on what the reader is expected to do in interpreting information presented

RICHARD D. POWERS

People do not read surface charts and segmented bar graphs correctly—correct interpretations run as low as 15 per cent. There are other types of graphs that can be used. Decisions on what type to use should depend on what the reader is expected to get from the presentation. Such decisions should depend not only on what the message is, but also on the complexity of the material to be presented. Objective research evidence from about 2000 persons provides the basis for such conclusions. The research summarized dealt with the question of whether or not data could be effectively presented graphically, as well as with selection of graphs to best serve specific purposes. The graph types discussed are used both to convey the findings of the research and to illustrate the relative merits of each type.

WHAT GOOD is a graph? And if graphs are any good, what is a good one? These are pertinent questions for Extension workers who want to communicate data to planning groups or to the general public in reports, meetings, or television programs. Whenever statistical data are to be presented, graphs are a possible way of conveying the information clearly and understandably. But they do not always succeed.

Objective evidence that can guide decisions about data presentation has been hard to find in the past though there has been no shortage of opinions. Objective recommendations have been provided by several research projects conducted during the last ten years by University of Wisconsin agricultural journalists. These projects exposed almost 2000 persons to various types of statistical communication, including graphs. Their success in interpreting the

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information was determined by carefully controlled tests, including standard methods for evaluating significance of differences. These projects have supplied some rather definite answers to many questions of graphic communication to the non-professional public. This paper deals with the findings of these studies.

For example, the first question above—are graphs any good?—can be answered with a definite “yes.” Gloria Feliciano¹ compared well-designed graphs (based on previous graph research), short summary tables of figures, long detailed tables, and textual statements of the statistics. Figure 1 shows that she found graphs superior to the other methods, with short tables ranking next in suitability. A combination of graph and text was also advantageous. Her subjects were rural women and college freshmen.

With high school students, the best graphs commonly elicited 80 to 90 per cent correct answers to certain questions. Thus there is little doubt that graphs can communicate certain kinds of information effectively, even to non-professional persons. But there is also ample evidence that some types of graphs are much less effective than other types, and some are particularly less suited to communicating specific types of data.

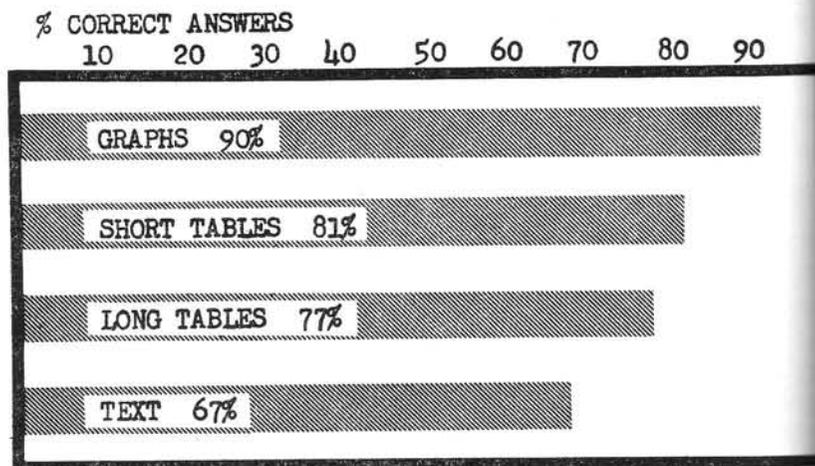


Figure 1. Comparison of per cent of correct responses in interpreting data presented by four different methods.

¹Gloria D. Feliciano, “The Relative Effectiveness of Seven Methods of Presenting Statistical Information to a General Audience” (unpublished Ph.D. dissertation, University of Wisconsin, Madison, Wisconsin, 1962). Also, G. D. Feliciano, R. D. Powers, and B. E. Kearl, “The Presentation of Statistical Information,” *Audio-Visual Communication Review*, XI (May-June, 1963), 32-39. A summary of practical advice is available from the Department of Agricultural Journalism, University of Wisconsin.

MANNER OF PRESENTING DATA

There are several variations in the manner data can be presented graphically. For example, divisions of 100 per cent can be shown equally well by two methods (see Figure 2). Labelling and identifying quantities directly on the graph are helpful features. Variations can be used in the manner of identifying segments and determining quantities.

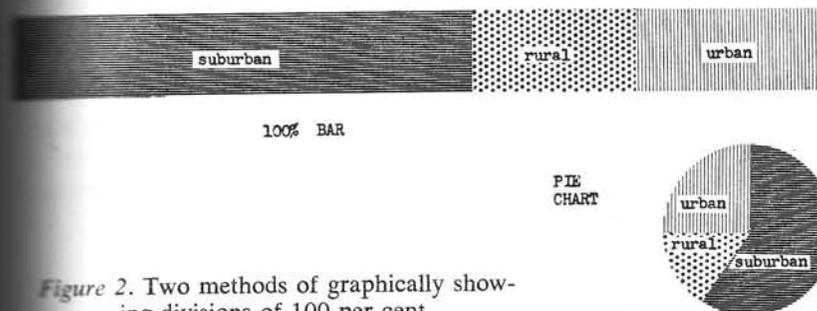


Figure 2. Two methods of graphically showing divisions of 100 per cent.

Bar graphs can be made with either horizontal or vertical bars. For bar graphs that are distinguished by various cross-hatch designs, it is necessary to refer to a key and legend to determine what they represent; some bar graphs have identification printed directly on the bars or have symbols indicating what the bars represent. To determine numerical amounts for the bar graphs in Figure 3, you must refer to the quantities on the margin; some bar graphs have figures showing the quantity represented by each bar, as in Figure 4. The bars in the pictured graphs are differentiated by cross-hatching; in some presentations, color can be used for differentiation. Also, graphs can have varying degrees of complexity—more or fewer lines on a line graph, more or fewer bars on bar graphs, more or fewer plotting points on line graphs or surface charts. The research reported here touched on all these variations in design.

Culbertson² and Flores³ established conclusively that there is no consistent difference between vertical and horizontal arrangement

²Hugh M. Culbertson, "Some Basic Factors Influencing the Comprehension of Graphs" (unpublished Master's paper, Department of Agricultural Journalism, University of Wisconsin, Madison, Wisconsin, 1958). Also, H. M. Culbertson and R. D. Powers, "A Study of Graph Comprehension Difficulties," *Audio-Visual Communication Review*, VII (Spring, 1959), 97-110. A summary of practical advice is available from Department of Agricultural Journalism, University of Wisconsin.

³Thomas G. Flores, "The Influence of Certain Graph Variables on Suitability of Graphs for Certain Interpretive Operations" (unpublished Ph.D. dissertation, University of Wisconsin, Madison, Wisconsin, 1958). Also available in condensed form from Department of Agricultural Journalism, University of Wisconsin.

per se for bar graphs. But they also found an advantage for having each bar labelled with its identification and with the quantity it represents. Labelling is much easier to do on horizontal bar graphs than on vertical arrangements. The opportunity for labelling makes the group bar graph more attractive than the line graph for general use. While lines can carry identifications, it is practically impossible to indicate numerical quantities directly on the line graph.

Using symbols rather than words for graph-element identification did not give any advantage in Culbertson's and Flores' tests. Merrill Oster⁴ studied use of color instead of cross-hatching for keyed graphs and did not find enough advantage in comprehension to justify the expense of color printing. It should be noted that Oster's research did not concern the value of color in attracting reader attention, nor the ease with which color can be referred to in an oral presentation.

BASIC TYPES OF GRAPHS

Figure 3 shows the four basic types of graphs studied. A set of data portrayable in one of these forms can be cast equally well in any of the other forms. In fact, the data in the figure are the same for all graphs. There are two dimensions of difference: (1) continuous plotting (as in the line graph and surface chart) vs. discrete plotting (as in the bar graphs); and (2) differences in segmentation, involving the point of origin for various elements of the graph. Essentially, everything on line graphs and grouped bar graphs originates at the base line of the graph; surface charts and segmented bar graphs have some elements which originate from the point at which another element ends.

What Is the Message?

The suitability of a graph type depends to some extent on what readers are expected to do in getting the message. This has special pertinence to the choice between line graphs and grouped bars.

As part of the research, readers were asked to make "point" estimates or comparisons—for example, to determine from Figure 3 the number of hogs marketed in 1960, or to compare this with the number of sheep marketed in 1940. The seven questions of this type varied in complexity. Some merely asked which quantity was largest; others required an estimate of the difference. One operation

⁴ Merrill Oster, "Color Keying as It Affects Graph Comprehension" (unpublished Master's paper, Department of Agricultural Journalism, University of Wisconsin, Madison, Wisconsin, 1962).

required readers to add the quantities of hogs, sheep, and cattle for a given year—that is, to estimate totals.

For point estimates of a single quantity there was little difference between the grouped bar graph and the line graph. The segmented arrangements (segmented bars and surface charts) were best for estimating total quantities. But grouped bar graphs were consistently better than line graphs for any question which involved comparison of two quantities or estimation of the amount of difference between two quantities.

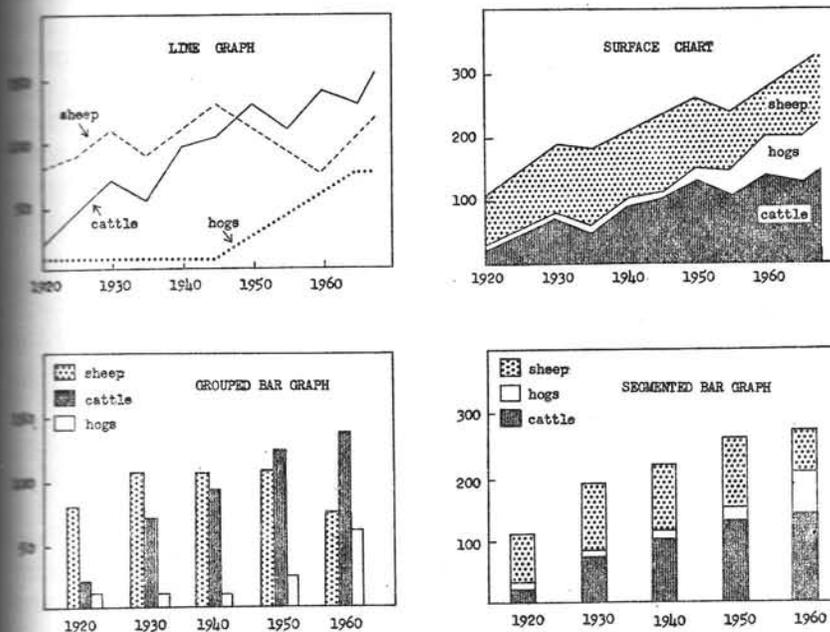


Figure 3. Four types of graphs that may be used to present the same data.

So Culbertson's and Flores' tests suggest that grouped bar graphs should be preferred when the main concern is to have the reader make point estimates and comparisons of variables on the graphs. But Parker's research gives a much different recommendation when the primary aim is to portray a trend.⁵ In terms of graphs in Figure 3, Parker asked readers to indicate such things as which class of livestock experienced the highest rate of growth for a given period, or to pick out the period during which cattle numbers increased

⁵ J. H. Parker, "A Study of the Influence of Type of Graph and Other Variables on Comprehension of Trend Information" (unpublished Ph.D. dissertation, University of Wisconsin, Madison, Wisconsin, 1963).

most rapidly. For some of Parker's questions the reader merely had to state the year in which the number of cattle exceeded the number of sheep, or estimate how many more hogs there were in 1960 than in 1940. Two questions for each graph required the reader to predict the future by indicating what hog numbers would be in 1980 (a point not shown on the graph) or to say whether there would be more sheep than cattle in 1980.

Parker found that grouped bars and line graphs were about equal for simply estimating the amount of change in a trend. Bars were as good as or better than lines when only one variable was plotted on the graph, as in Figure 1. But for all other trend interpretation situations, the line graphs outperformed the grouped bar graphs consistently. Surface charts were consistently the poorest method for portraying trend information. So Parker's conclusion is that line graphs are preferable for simultaneous display of two or more trends when the reader is supposed to determine what is happening over time, to compare this with what is happening to another trend on the same graph, or to forecast behavior of trends in the future.

The foregoing shows that some features of the graph will help viewers perform one kind of calculation or make a certain type of interpretation from the graph. The same features may have no benefit for another calculation or interpretation. They might, in fact, be a hindrance.

How Complicated?

Complexity is one of the first things a graph user considers. How many different things should be plotted on a graph? How many points should be plotted for each trend or element shown? Our research gives limited evidence on these points.

First, it must be noted that the two questions above suggest two ways in which graphs can become complex. One way is to show the behavior of several variables on a single graph. All Figure 3 graphs show three variables, for example. Adding variables results in more lines on a line chart, more bars in each set on grouped bar graphs, and more segments in segmented bars or surface charts.

Graphs can also become more complex by addition of plotting points. For the graphs in Figure 3, this would result in showing statistics for more years. This kind of increased complexity would seem more apparent in bar charts, where adding another plotting point means adding a bar or group of bars. Line graphs or surface charts normally accommodate this kind of complexity with only a more jagged appearance to the lines.

Parker's findings indicate that line graphs remain clearer than grouped bar graphs as complexity of either type increases. He also found it is rather advantageous to use more plotting points on line graphs as the number of trends or variables increases—in other words, to increase complexity purposely in one respect as necessity forces increased complexity in the other. Parker's findings are only suggestions as to what happens on line graphs which attempt to portray four or more variables, however. His tests dealt with graphs having from one to three variables. Figure 4 shows how readers of line graphs and grouped bar charts responded to the increased com-

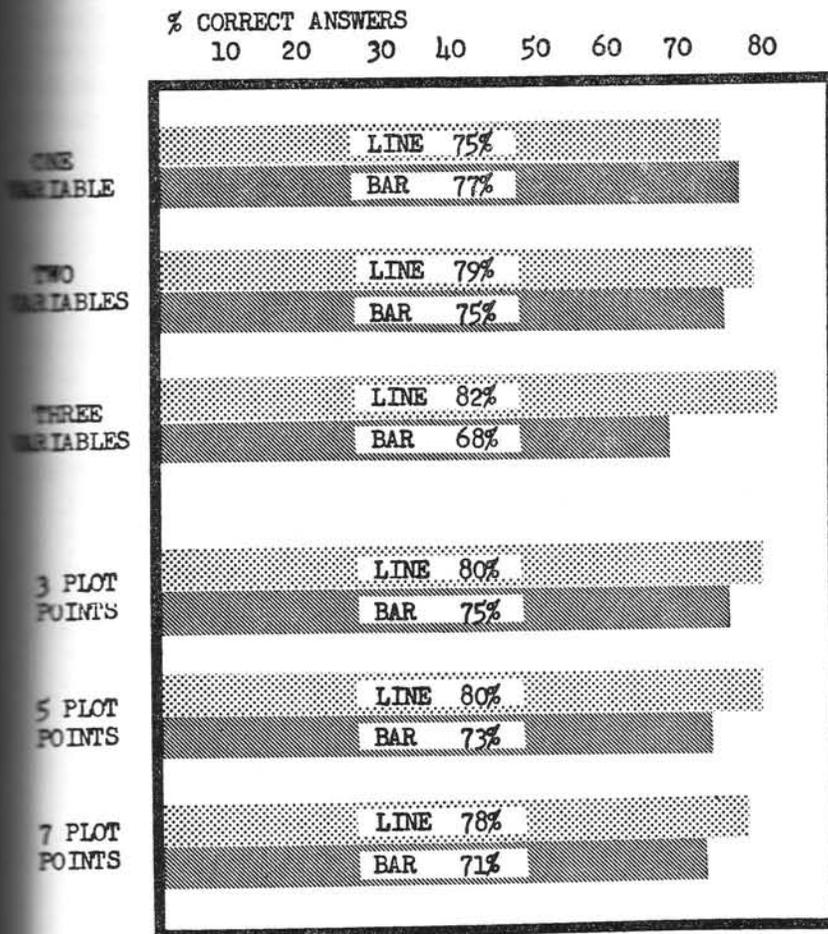


Figure 4. Comparison of correct interpretations elicited from data presented in line and bar graphs as complexity is increased by adding variables or plot points.

plexity brought about by additional variables and increased numbers of plotting points.

Surface Charts and Segmented Bars?

The segmented arrangements—surface charts and segmented bars—proved extremely difficult to interpret except in estimating total quantities. People definitely do not read them correctly. Results clearly indicate that most readers consider all quantities as originating at the base line of the graph. There is, in the logic of the graph, no reason why they should think otherwise. Thus unless a person has been specifically instructed in the conventions of the surface chart, it will at best be ambiguous to him and at worst actually misleading. The typical reader of segmented graphs can estimate totals (indicated by the top line) fairly well. In fact, segmented charts are unbeatable for this. The quantity of the bottom segment is estimated almost as accurately as for grouped formats. But the central segments are consistently misinterpreted.

Those who use surface charts and segmented bars should be acutely aware of this. The differences in comprehension due to such erroneous reading were large (see Figure 5). For some types of questions used by Parker, less than 15 per cent of the students got correct answers from surface charts—even though the trend in question originated at the base line in some cases. Tests by Culbertson and Flores yielded a similar picture.

Summarizing the findings, we can say that surface charts and

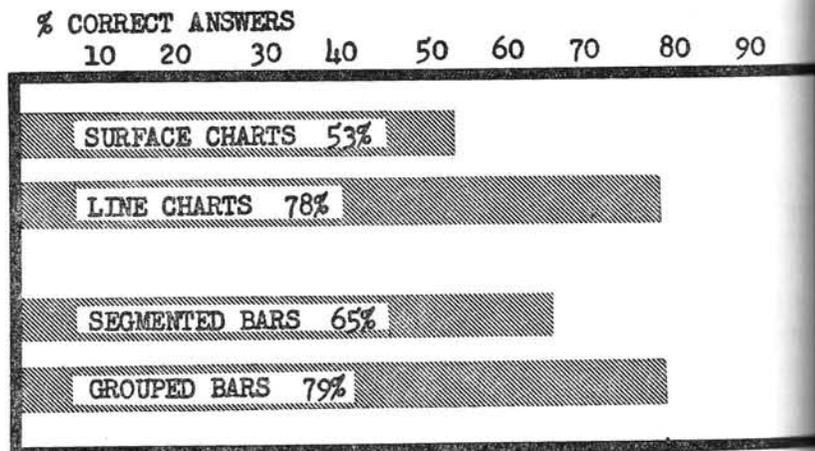


Figure 5. Comparison of correct interpretations elicited from data presented by four different types of graphs.

segmented bars have little to offer for graphic communication. So far as basic design is concerned, this leaves grouped bar charts and line charts as possible alternatives. The bar chart has the advantage of being most amenable to labelling and statement of quantities on the bars; the line chart has the advantage of suffering less from increasing complexity. In relatively simple graphs, grouped bars seem to be the safest kind; for more complex situations line graphs would be indicated.

CONCLUSION

A logical strategy of graph design would be first to decide what functions a graph is to perform—what readers are supposed to get from the graph and what they have to do to extract such information—and then to design a graph which will perform the functions most effectively and surely. But most graph users want their graphs to serve several functions. They would like viewers to make point estimates and comparison, for which grouped bar graphs seem best. But they also want the presentation to permit estimation and comparison of trends, for which line graphs seem much preferable. At this stage, all you can do is decide what functions are most important. Once the decision is made, the research conclusions reported in this article can suggest the design most likely to accomplish the desired ends. And perhaps the resulting graph will also serve the other functions—especially for highly skilled readers, and if supplementary verbal explanations are provided.

BECAUSE EXTENSION agents do not have a captive audience and because they do have the responsibility for securing the adoption of new information when it becomes available, they have devised ingenious ways to carry on their informal educational work. They are at home in any teaching situation—a field, a backyard, a church kitchen. They have learned to put complex information into simple terms. They teach through demonstrations when this is appropriate, and use any modern method of communication when it fills a need.

— MARGARET C. BROWNE.

TODAY'S TECHNOLOGICAL REVOLUTION offers both problem and opportunity. Science and technology are speaking loudly, but man—caught up in increasingly complex socioeconomic forces—finds the message hard to decipher. In striving to harness the new opportunities, man's biggest problem is man himself as the vital resource—a resource beset with limited experiences, obsolescent traditions, and lagging intellectual capacities.

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