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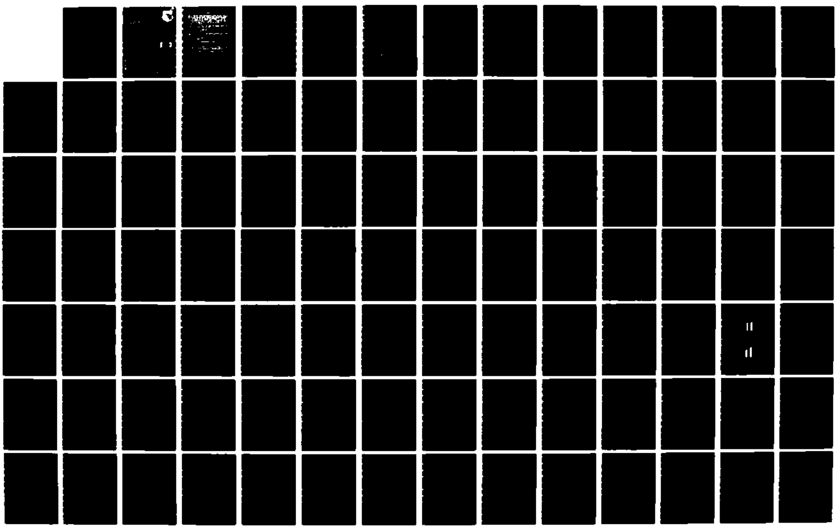

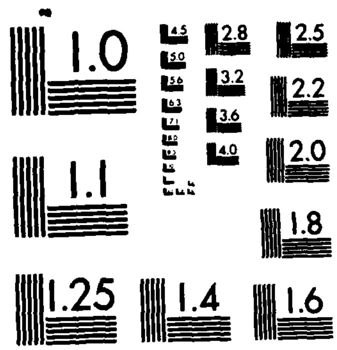


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Communication is critical to the successful operation of any organization. However, communication channels and systems can be only as effective as the information content transmitted through them. If the information is unfairly biased by the sender to support a particular viewpoint, serious misconceptions can occur.

Several techniques that may be used to bias the perception of presented information are described and specific, published examples of many of these are provided.

A controlled study using 23 human subjects was conducted to determine if these techniques could successfully bias the decisions made by the subjects. Three biasing techniques were selected for the study. Subjects were persuaded to select either of two choices depending on the biasing direction presented by the experimenter. All three techniques proved effective in persuading subjects to select the alternative targeted by the presenter.


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BIAS AND MISINFORMATION IN TECHNICAL AND MANAGERIAL COMMUNICATIONS (U)

## PREFACE

This document was produced as a Master's Degree thesis for the Sloan School of Management at the Massachusetts Institute of Technology as part of a special one year Management of Technology program. The thesis advisor for this effort was Professor Tom Allen of the Sloan School of Management. My participation in this program was sponsored by the Civilian Executive Development Program and the Human Engineering Division of the Harry G. Armstrong Aerospace Medical Research Laboratory.

Since the content of the thesis should be on interest to a wide range of individuals involved in managing technology and technical people, the thesis has been produced as an AAMRL technical report. The document does not follow standard technical report format since it was originally a thesis.

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# CHAPTER ONE

## INTRODUCTION AND BACKGROUND

Fraud in science has become a topic of interest in recent years (Broad and Wade, 1983; Woolf, 1981). Relatively recent examples of falsified data or plagiarized papers have demonstrated that not all scientists are free from bias and fraudulent practices. Reasons for indulging in fraudulent practices may vary from desiring recognition to promoting a revered theory. This last reason is of particular interest.

A less unacceptable method of promoting a pet theory is to use persuasion techniques (Hovland, Janis, and Kelley, 1953). Persuasion is probably most familiar to many of us in the form of advertising (Harris, 1983). Advertisements are required by law to be "truthful" but the information presented and the methods of presenting it are intended to persuade the viewer to buy a particular product. These methods certainly don't present the information in an unbiased fashion.

Technical communications, both verbal and written, formal and informal, most likely also suffer (in certain instances) from fraud and persuasive techniques. There have been many writings directed at "more effective" communications of technical information (Dickinson, 1963; Enrick, 1972; Golde, 1966; Rogers, 1961; Schmid, 1983; Zeisel, 1957; Zelazny, 1985). Most of these are not oriented toward describing persuasive techniques of information presentation, but rather attempt to provide guidance in effective communication (how to make your ideas clear).

One could consider a factual data presentation dimension that starts at one end with "unbiased" and ends at the opposite end with "fraud" (falsified data). Using this scale, the "effective" methods of the above noted writings might be considered somewhere just above "unbiased" with the "persuasion" techniques located just above that. The primary topic of this thesis is the next level higher on this scale, which might be labelled "biased" methods of presenting data. Thus the rules for the techniques to be described herein are that the information presented must derive from unfalsified data and all information presented must be factual, but all other biasing methods are allowed.

This area of biasing information presentation is a little studied area. Yet, for technical managers in both industry and government it could be a very critical area since many key decisions are made on the basis of technical information.

There are many ways to bias the presentation of technical information so as to support the views of the presenter. Some of these have been recognized (Huff, 1954; Reichmann, 1962) but most have not been adequately documented. Thus the main purpose of this thesis is to document these techniques and investigate the use and significance of biasing methods.

To explore this area, this thesis is divided into four main parts: 1) description of biasing techniques (Chapter two), 2) published examples of some of these techniques (Chapter three), 3) a controlled research study to demonstrate the effectiveness of three of these techniques (Chapter four), and 4) conclusions and implications of this work.

## CHAPTER 2

## DESCRIPTION OF BIAS TECHNIQUES IN DATA PRESENTATION

A number of methods have been developed to present data in a concise fashion. Graphical and picto-graphical methods of presenting data are quite often used in scientific and technical journals, business articles, conference presentations, business review meetings and many other places. The intent of providing data in this form is to allow one to rapidly determine the significance of a large amount of data. It is very difficult to assess (visually) trends and relationships by looking at tables of data; it is much easier to see effects and assimilate the impact of data if they are graphed.

However, the very techniques that allow one to readily see trends and effects in data via graphics can also be used to provide a misleading impression of the significance of the data. There are many methods by which data may be presented to support a particular hypothesis or viewpoint. It is the objective of this chapter to provide a description of many of these methods with hypothetical examples. (Chapter 3 will provide actual, published examples of several of these techniques).

The different methods have been organized into four categories which are not necessarily mutually exclusive. The categories are: 1) graphical techniques, 2) data manipulation techniques, 3) statistical problems, and 4) miscellaneous. The methods presented are probably not exhaustive of the methods that can and have been used, but they certainly provide a sound basis for analyzing the majority of techniques used.

## GRAPHICAL TECHNIQUES

Graphical techniques of biasing data are probably the most effective (especially when supported by other techniques) because of the importance of vision in assimulating information. There are a tremendous number of ways in which data may be graphed and "misgraphed". This section describes several of the ways data may be graphed to change its "visual impact".

### Truncation:

The simplest and most widely used method of "enhancing" the effect of a graph is to truncate the vertical axis of the graph. This has the effect of visually stretching the difference between data points. Figure 1 is an example of data graphed without truncating the vertical axis. Figure 2 is the same data with the vertical axis truncated by 8 units. Note that in the truncated version the data shows an enhanced functional effect with respect to the horizontal axis variable (x).

The method can also be used to enhance the differences in levels as depicted in bar graphs. Figure 3 is a "fair" bargraph with no trunction and Figure 4 uses the same data portrayed in a truncated bar graph.

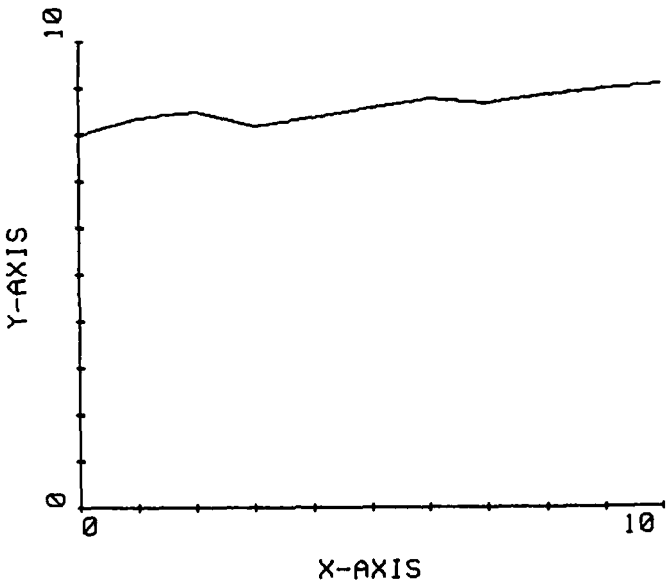



Figure 1. Line graph of data with "normal" axes (no truncation.

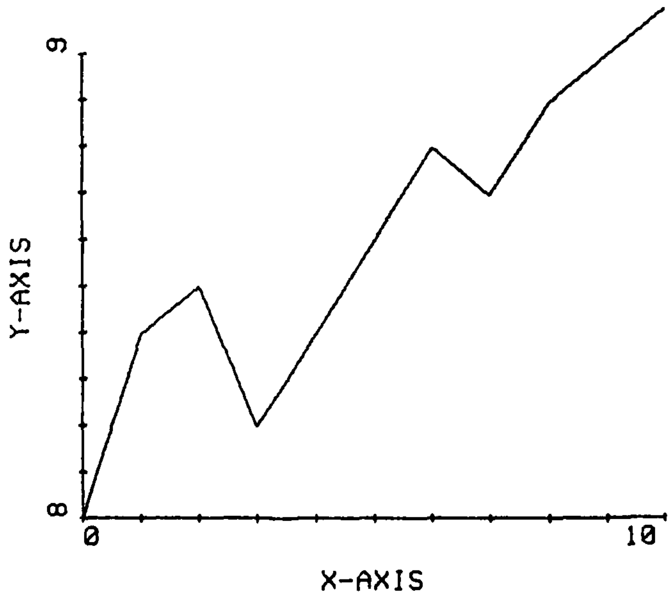



Figure 2. Line graph of same data as Figure 1, but with vetical axis truncated so that only the upper portion of the numerical values is graphed.

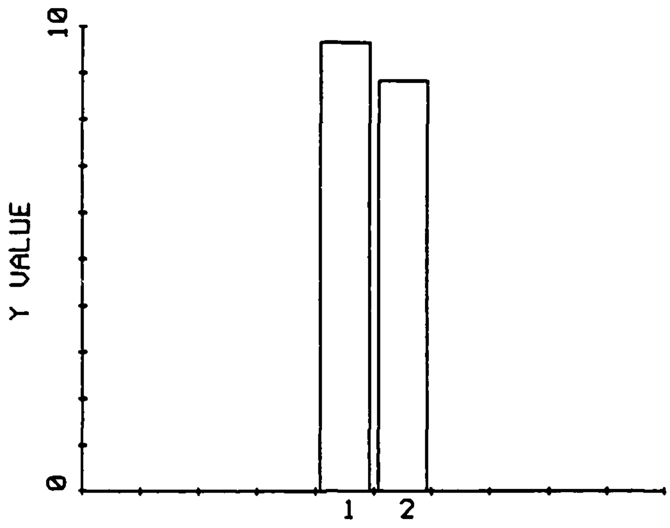



Figure 3. Bar graph of data without truncation.

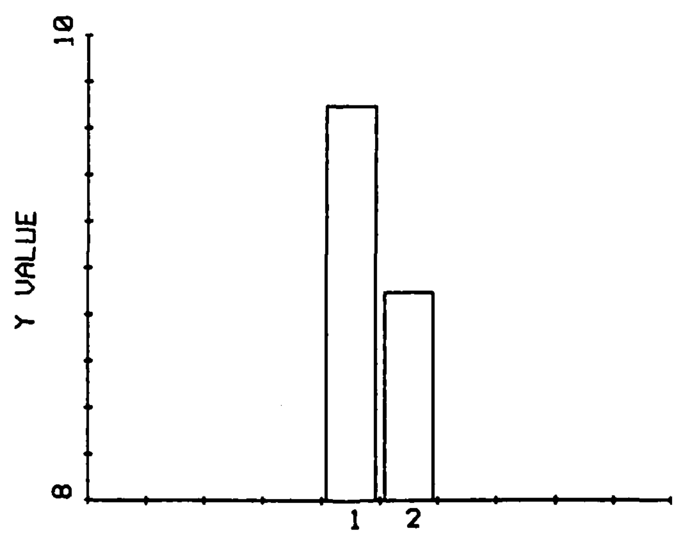



Figure 4. Bar graph of same data as Figure 3 but with the vertical axis truncated. Note the enhanced differences between bars compared to Figure 3.

## Selection of Axes:

The two most common types of line graphs use either a logarithmic scale or a linear scale. With just these two axes to choose from it is possible to have four different combinations of horizontal and vertical axes to graph data. The choice of axes may be deliberate based on underlying physical or mathematical principles. For example, in economics one is often concerned with growth rates. By graphing growth data using a logarithmic vertical axis and a linear horizontal axis, the rate of growth (if it is uniform) is directly related to the slope of the resulting line graph. Figures 5 and 6 are an example of these types of data graphed on linear-linear and log-linear axes.

However, if the underlying assumptions are not fulfilled (constant growth rate, in this case) then it is questionable as to whether or not the data should be graphed with these types of axes.

Another reason sometimes cited for using logarithmic axes is that the data extend over too large a range to graph on linear axes. Use of logarithmic axes can either visually "compress" the data or "expand" the data depending on the type of data. Figures 7 and 8 demonstrate the effect of using a logarithmic axis to expand a "notch" in the data. The "notch" is more pronounced in the log-linear version of the graph than the linear-linear version shown in Figure 7. Without further information it is impossible to determine whether or not the "notch" in Figure 8 is significant (either statistically or otherwise) but it should be apparent that one could highlight the notch or suppress it by selecting the appropriate axes.

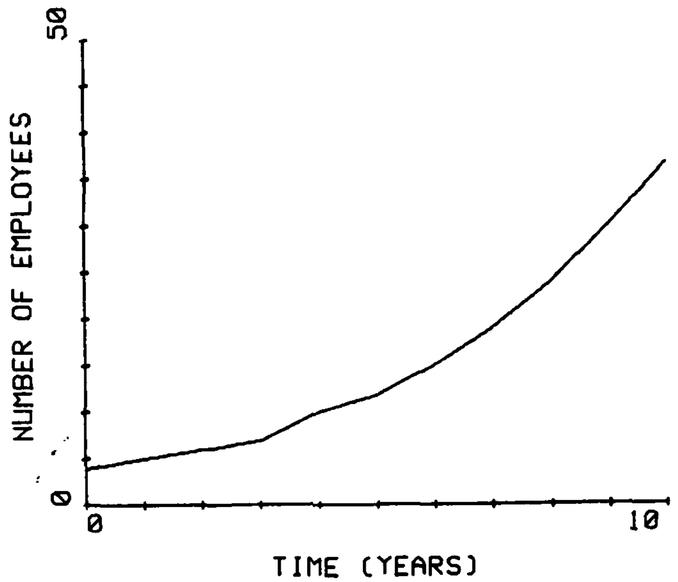



Figure 5. Graph of company growth as measured by number of employees versus time on linear-linear axes

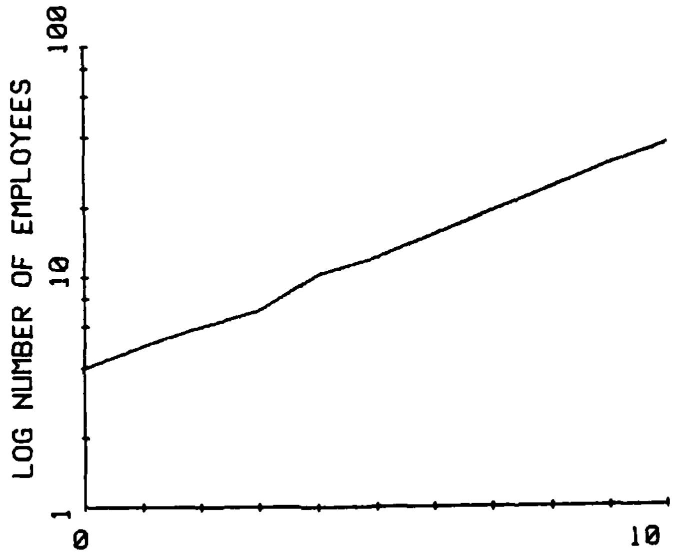



Figure 6. Graph of same data as Figure 5 except log-linear axes are used. The data show a constant 25% per annum growth rate (constant growth results in a straight line when graphed on log-linear axes which is why it is favored by economists and others looking for growth).

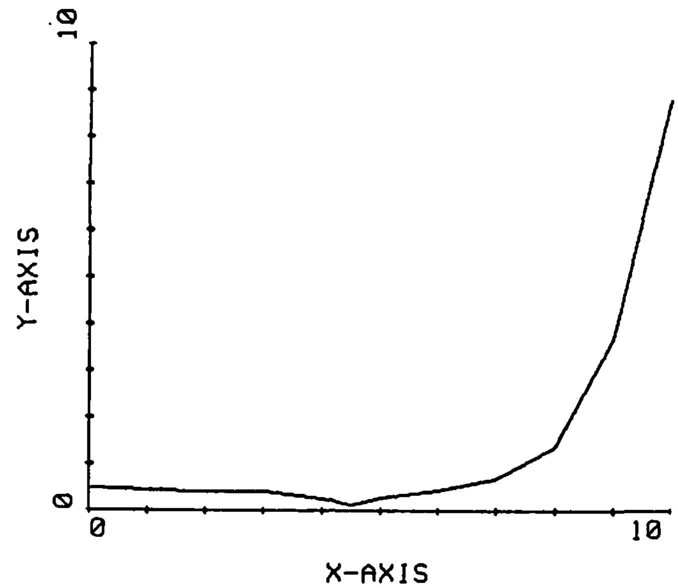



Figure 7. Graph of data on linear-linear axes

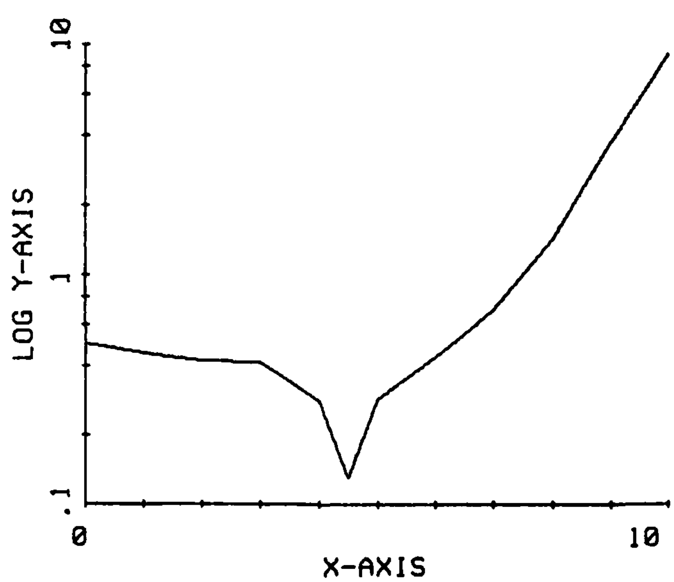


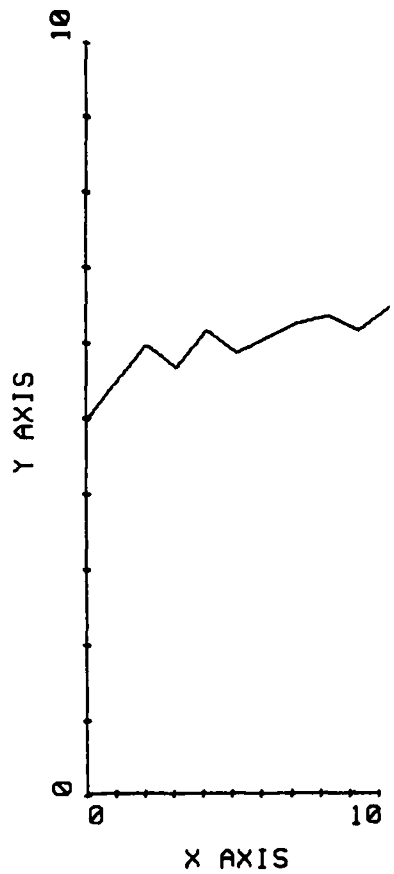

Figure 8. Graph of same data as Figure 7 but with log-linear axes used. Note the enhancement of the "notch" in the data compared with Figure 7.

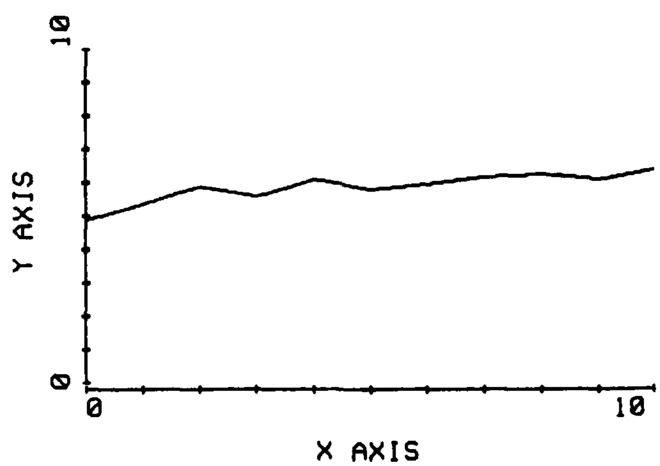
## Selection of Scale:

This is probably not a very powerful technique, but it is extremely easy to use. Selection of scale means determining the height and width of the graph as it will appear on the paper, slide or vugraph. By producing a narrow, tall graph one obtains a different visual picture of the data than if one uses a wide, short graph. Figures 9 and 10 demonstrate the change in visual impact of line graphs as the scales are changed. The reason this is probably not very powerful is that if the scales are varied too much compared to the format size possible (e.g. the full size of a 35mm slide) then the observer may seriously question the graph. Although this problem can be partially alleviated by providing other written or pictorial information in the unused space.

For example, if one wanted to make the graph wide and short (to decrease the effect of variations along the width of the graph) then one could mount the graph at the top of the format available and put explanatory information under it. Similarly, if it was desirable to produce a tall, narrow graph to enhance variations (e.g. growth), then one could put the graph to one side and put "filler" on the other side. This allows one to fully use the format available and still distort the graphic scales as desired (within limits).

Figure 9. Selection of scale and "filler" to obtain a tall, narrow graph




Fiure 10. Same data as graphed in Figure 9 except scales are chosen for a short, wide graph. Note how the growth in Figure 9 appears greater than the growth of Figure 10 because of the selection of scales.

## Picto-graphs:

Picto-graphs use drawings or pictures of an item (or items) in such a way as to demonstrate magnitudes of a variable. For example, instead of making a bar graph to show the change in daily oil production between 19XX and 19YY one could make a picto-graph by drawing barrels of oil in a line with each barrel representing 1,000,000 barrels of oil production. Thus, the number of barrels of oil clearly show the differences in production. One way to bias presentation of this type of data, is to change the size of the item used to represent the data instead of changing the number of items. In the oil example above, the modified version would only show two barrels of oil (for 19XX and 19YY) with the height of the barrels corresponding to the production.

The problem with this modified version is that the area of the barrel of oil (which governs the magnitude of the visual impact) increases with the square of the height of the barrel. Thus, while the pictograph truthfully portrays the magnitude of the two variables involved, the visual impact of the difference between the two is somewhat distorted. Figures 11 and 12 demonstrate this effect.

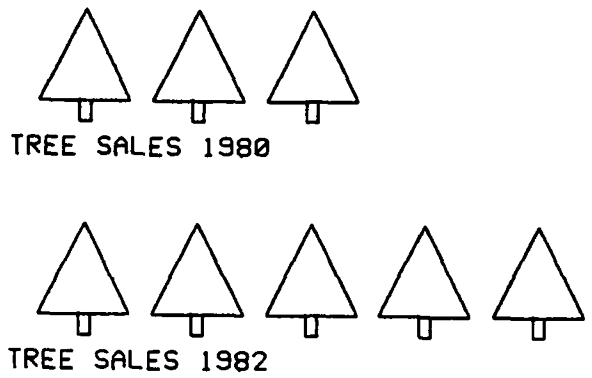



Figure 11. Pictograph in which the number of items represents the magnitude of the two variables involved


Figure 12. Pictograph in which the height of the item depicts the magnitude of the two variables involved. Compare this with the pictograph of the same data shown in Figure 11.

Pie charts:

Pie charts are a popular method of pictorially showing component values as a percentage of the "whole". Budget figures such as revenue sources and expenditures are typically shown in pie charts as percentages. These charts are generally reasonably fair, although they do concentrate attention on percentages as opposed to absolute values. A variation of the pie chart that can be used to slightly bias the appearance of the data presented is the slanted pie chart.

The slanted pie chart was probably first introduced to make the data presentation more pleasing to the eye. However, it also has another effect of modifying the relative apparent visual size of the different pieces of the pie. The slanting, or tilting, of the pie chart is achieved by "foreshortening" one dimension of the chart (typically the vertical axis). This method of tilting the pie chart maintains the same relative areas of the wedges of the pie but it does so at the expense of the angles measured from the center of the pie for each of the wedges. The visual system seems to weight the change in angles with the absence of change in relative areas of the wedges in such a way that a particular wedge may appear to become relatively larger than an adjacent wedge compared to an untilted pie chart of the same data.

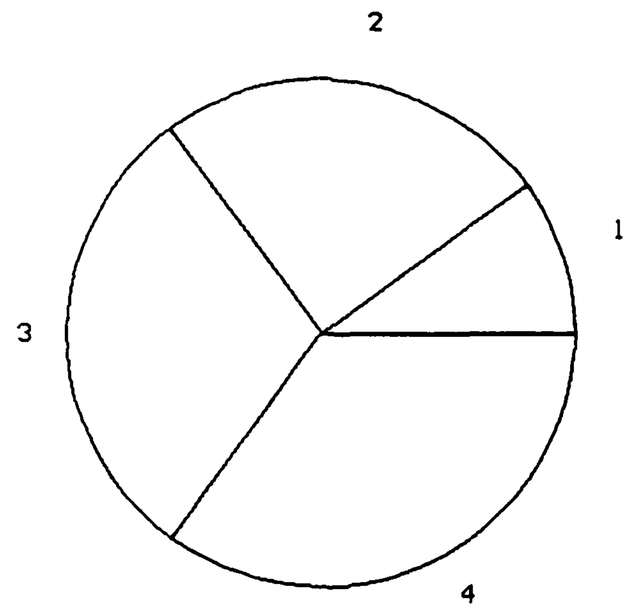



Figure 13. Example of an untilted pie chart. Note the relative sizes of sections 3 and 4 and compare with the same sections graphed below. Percentages: 1) 10 %, 2) 25 %, 3) 30 %, and 4) 35%.

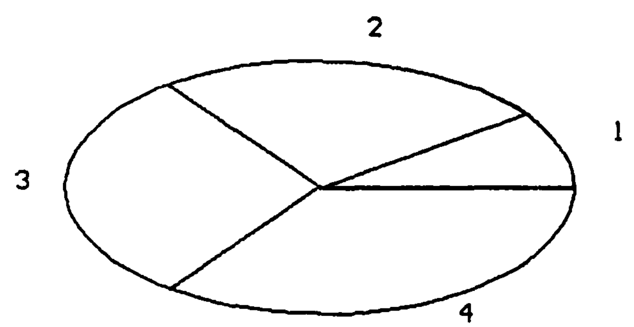



Figure 14. Tilted pie chart of the same data as Figure 13. Note the relative sizes of sections 3 and 4: section 4 now looks significantly larger that section 3 unlike pie chart shown in Figure 13.

The effect is not strong and the actual percentages are usually given on pie charts. Still, this method may tend to affect the impact of the data on the observer. Figures 13 and 14 demonstrate this effect.

## DATA MANIPULATION TECHNIQUES

Raw data typically goes through some amount of analysis before it is condensed and presented in a graphic form. This data analysis may include a number of appropriate as well as inappropriate manipulations. This section discusses several of these types of manipulations. The appropriateness of the manipulations depends heavily on the type of data and the objectives of collecting the data.

### Data conversion:

Data can be converted by a number of methods such as taking the reciprocal, converting to decibels, or some other conversion specific to a particular area. (For example, optical transmissivity may be converted to optical density by taking the logarithm of the reciprocal of the transmissivity). These conversions may be made for perfectly legitimate reasons or for suspiciously superficial reasons. It is often difficult to determine which.

Whichever the case, it can be easily demonstrated that the converted data can appear significantly different when presented in graphical form. Figures 15 and 16 show how the appearance of the data can be changed by taking reciprocals. In general, very small numbers that were at the bottom of the graph suddenly become vary large when the reciprocal is graphed. Additionally, small, absolute changes in values can become accentuated as shown by comparing the center "valley" of Figure 15 with the central twin "peaks" of Figure 16. The "reality" of this structure would need to be confirmed by statistical analysis or error analysis with respect to the measurement apparatus.

Figure 17 shows a case where Y is a linear function of X clearly indicated by the straight line. If one takes the same data set and graphs the reciprocal of Y versus X then one obtains the graph shown in Figure 18. This graphically demonstrates the non-linear effect of taking a reciprocal.

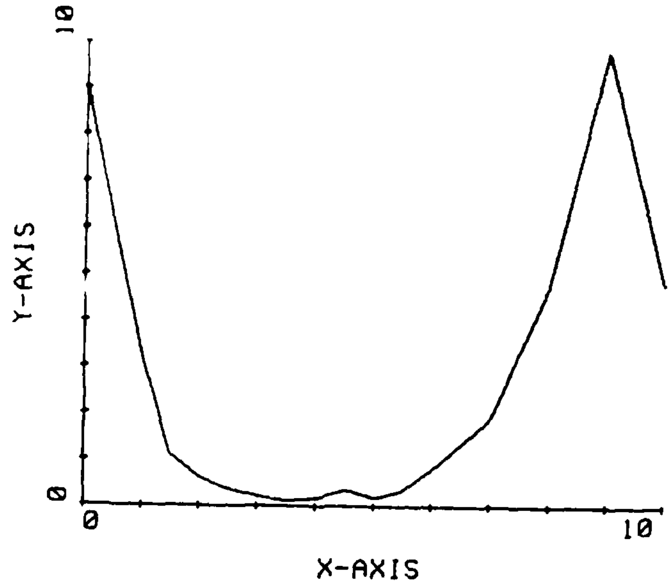



Figure 15. Graph of Y versus X on linear-linear axes

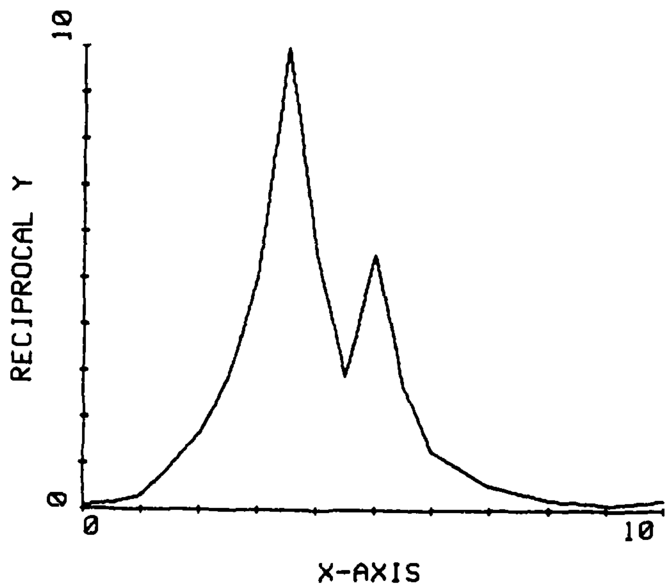



Figure 16. Graph of same data as Figure 15 but the reciprocal of Y is graphed against X. Note how the reciprocal accents the structure in the low values of Y near the center of the X range.

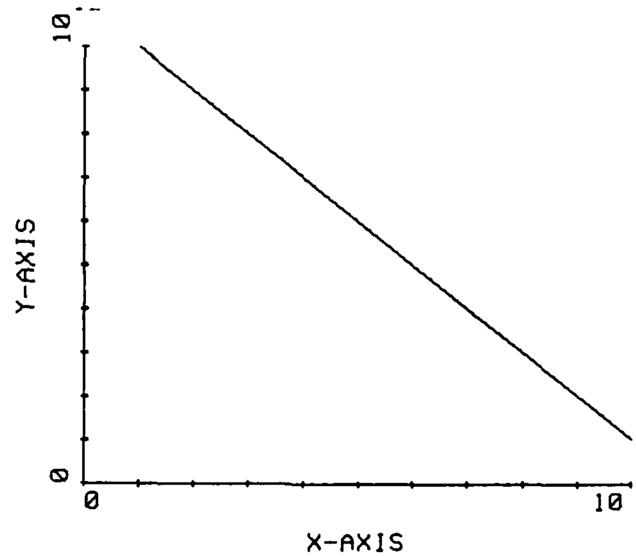



Figure 17. Graph of Y versus X for linear data

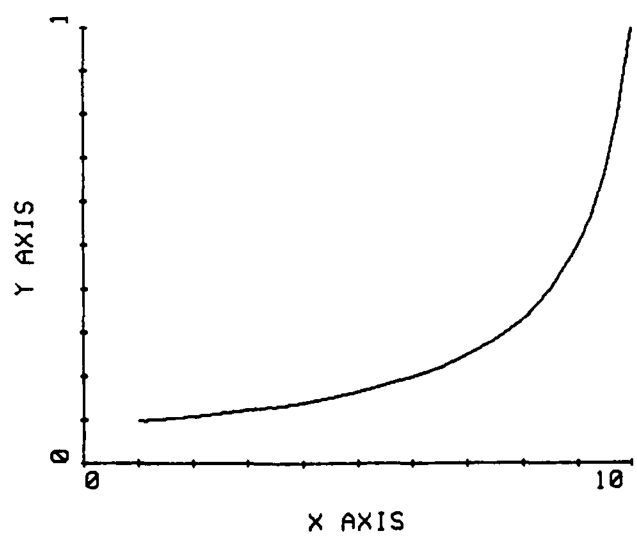



Figure 18. Graph of same data as Figure 17 except reciprocal of Y is graphed against X. This clearly demonstrates the non-linear effect of the reciprocal converstion of data.

The decibel is a unit of measure that is often used in sound and in signal to noise ratio measurements. The decibel (one tenth of a bel) derives from physics and is defined as 10 times the logarithm of the ratio of any two powers (power levels). For sound, the lower power level in the ratio is typically the power of sound required for threshold of hearing.

In the area of signal to noise ratio measurements, the voltages of the signals are usually measured instead of the power. Since the square of the voltage is proportional to the power for an electrical signal, the decibel unit for signal to noise ratio is calculated by taking 20 times the logarithm of the ratio of signal voltage to noise voltage. Figures 19 and 20 show several different signal to noise ratios graphed in histogram form as ratios and as decibels. The use of decibels tends to decrease the perceived (in the histogram) differences between some of the systems and enhances others.

Another example of data conversion comes from optical physics. Transmissivity of a filter is defined simply as the ratio of the transmitted light to the incident light. A typical type of measurement for a color filter is the transmissivity as a function of wavelength over the region of interest (e.g. the visible and near infra-red: 400 nanometers to 800 nanometers). Figure 21 is a graph of such a filter that would appear blue if viewed.

An alternate way of portraying the same data is to use optical density instead of transmissivity. Optical density is defined as the logarithm of the reciprocal of the transmissivity. The advantage of using optical density in characterising a filter is that the result of stacking several filters together is easier to calculate using optical density than transmissivity. The final transmissivity of a stack of absorptive type filters requires the multiplication of the transmissivities of each of the filters whereas the optical density of a stack of filters is simply the sum of the optical densities of each of the component filters.

This rationale for optical density is reasonable, but it can still be used as a method of biasing the appearance of the graphed data. Figure 22 is the same filter graphed in terms of optical density. Note how the structure at the right of the graph has been enhanced by using optical density instead of transmissivity. Most people knowledgeable in the area would know how to determine the real significance (or non-significance) of the structure on the right side of Figures 21 and 22, but an individual not familiar with optical terms and methods could be deceived.

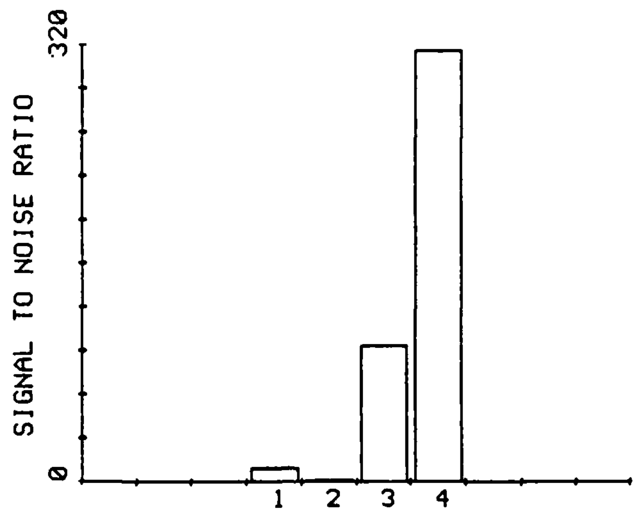



Figure 19. Histogram of different system signal to noise ratios. 1) 10.0, 2) 1.26, 3) 100, and 4) 316.

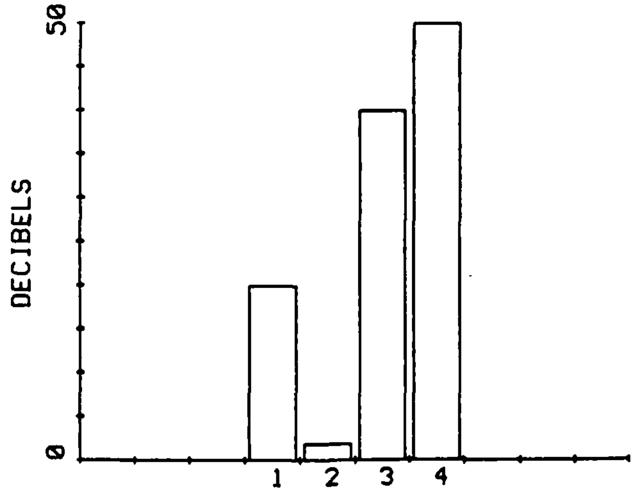



Figure 20. Histogram of same system signal to noise ratios as shown in Figure 19 except graphed in decibel units.

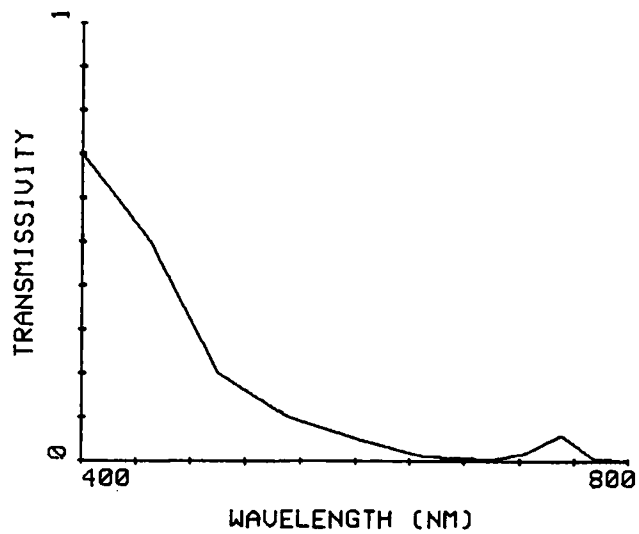



Figure 21. Spectral transmissivity of a hypothetical color filter.

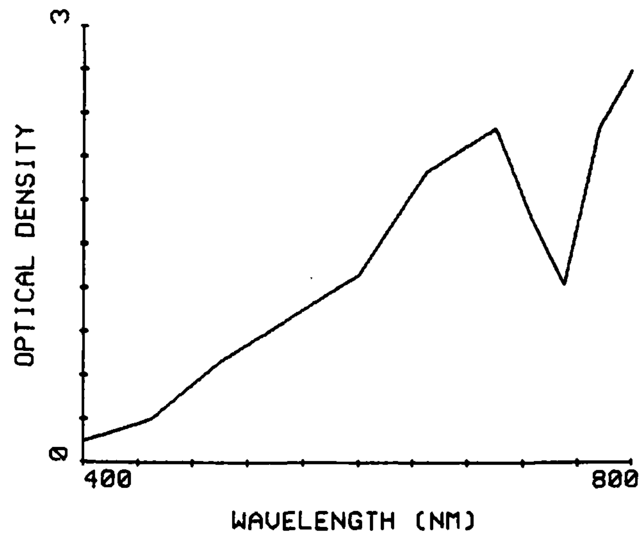



Figure 22. Same color filter as Figure 21 but graphed as optical density versus wavelength instead of transmissivity. Note the enhancement of the structure on the right of the graph by using optical density.

Ratios versus absolutes:

When analyzing data it is often necessary (or advantageous) to compare two quantities or functions. This comparison can be done in a number of different ways each of which may provide a different insight into the relationship between the two quantities or functions. The simplist method of comparing two functions is to graph the two on the same chart. Figure 23 shows two functions (which could be growth of sales vs time for two companies, for example) which are graphed on the same linear-linear axes. In this case, comparison is made visually showing that although company #1 (solid line) seems to be doing a little better than company #2 (dotted line) there really doesn't appear to be a large difference between the two.

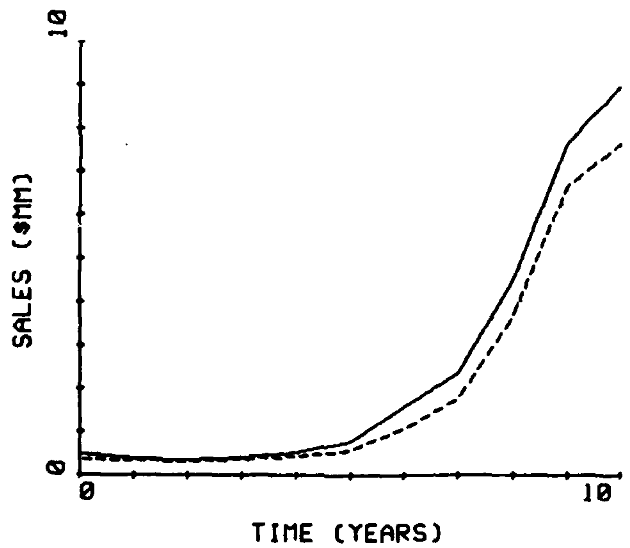



Figure 23. Comparison of two functions: e.g. sales growth of company #1 (solid line) and company #2 (dotted line) with respect to time (x axis).

Instead of simply graphing the two functions, an analyst for company #2 might wish to graph the ratio of the two to demonstrate the relative performance of the two companies. Figure 24 shows the ratio of sales of company #1 to sales of company #2 (Y1/Y2) as a function of time (x axis). This curve is obtained from the same data shown in Figure 23. The analyst from company #2 notes that although company #1 was increasing in sales faster that #2 for a portion of the time shown (2 to 6 on x axis), in the more recent time frame (6 to 9 on x axis) company #2 has been gaining on company #1 as can be seen by the declining ratio of #1 to #2.

The analyst for company #1 does not like the analysis provided by the analyst from company #2 so he devises his own means of comparing the growth data of Figure 23. Analyst #1 graphs the difference (in absolute dollars) between sales for the two companies as a function of time (x axis). The result is Figure 25, where his analysis clearly shows that his company (#1) has continuously increased the sales gap between #1 and #2 since about the second time period (2 on the x axis) as depicted by a continuously increasing function.

It should be apparent from Figures 24 and 25 that the method of comparing two functions (ratio or absolute difference) can greatly affect the visual appearance of the comparison.

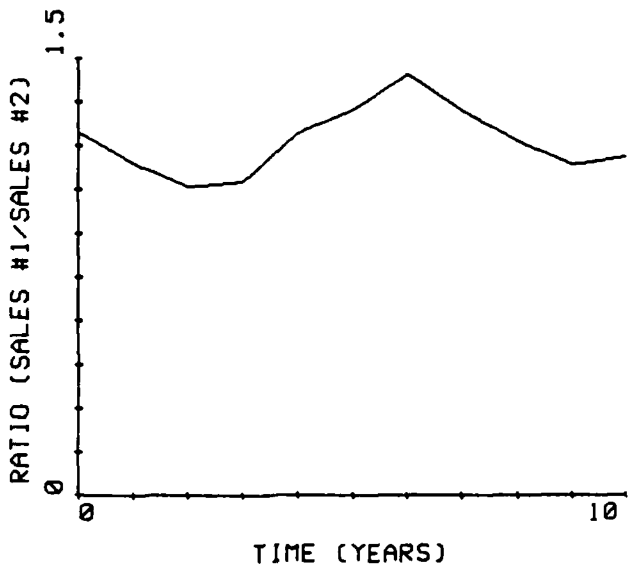



Figure 24. Ratio of Y1 to Y2 from Figure 23. Note the increase from x=2 to x=6 and the decrease from x=6 to x=9. The latter decrease suggests that Y2 is "catching up" to Y1.

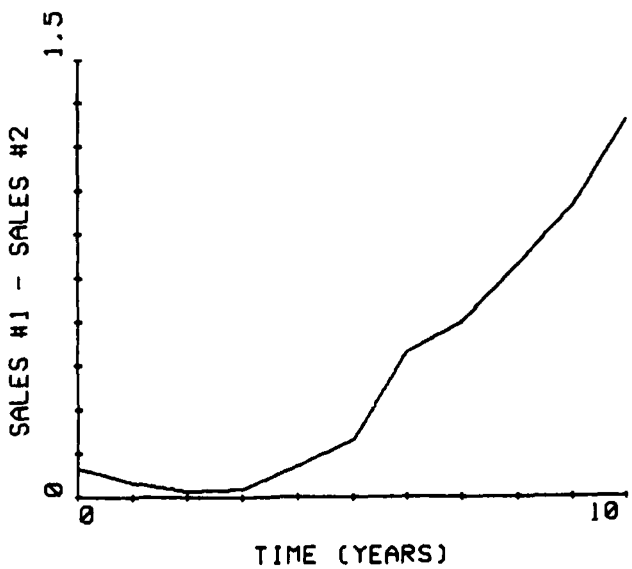



Figure 25. Difference between Y1 and Y2 of Figure 23. Note the continuously increasing function from x=2 through x=10. This suggests that Y1 is continuing to outpace Y2 and the Y2 is not "catching up" as suggested in Figure 24.

Percentage change vs absolutes:

Two functions can also be compared by changing both functions to a different basis such as percentage change from some base reference value. Figure 26 shows an example of two hypothetical company growth charts as measured by the number of employees. Company #1 (dotted line) is obviously the larger company and shows a reasonable growth in number of employees over the time periods measured. Company #2 (solid line) is smaller, but also shows a growth track.

These same data could be graphed as percent change using the 0 time period as the base reference. Figure 27 shows these same data graphed as percent change. Now, company #2 is the upper line (solid) and shows a higher average growth rate compared to company #1. Also note that what appears as a mild dip in company #2 growth in Figure 26 (at x=4) is significantly enhanced in Figure 27.

Depending on the data and the desires of the chartest, using percentage change instead of absolutes (or vice versa) can significantly affect the appearance of the comparison graphs.

This point is probably best illustrated with a specific example.

Suppose a study were done to compare the starting salaries of graduates from the Harvard Business School (HBS) with graduates from the MIT Sloan School of Management. Data collected on 200 students from each school over a three year period showed that "on average" HBS graduates received $39,600 per year starting salaries and Sloan School graduates received a mean of $39,100 per year. The difference of $500 was determined to be statistically significant at the $p=0.05$ level (t-test was done to obtain the probability level). Although the $500 is statistically significant, is it sufficiently significant in a real sense (income dollars) to motivate students to transfer from Sloan School to HBS? Probably not.

Thus it is very important to separate statistical significance from decision-making significance. Statistics is not that well understood by most people so the mere mention of "statistical significance" in presenting data probably carries more supportive weight than it should.

For graphs that compare two (or more) functions, it is helpful to provide error bars above and below the data points that represent +/- one standard deviation so that observers can determine the accuracy of the data points presented. By presenting graphical data without these error bars, one gives the impression that the data are more accurate than they really are. With the error bars, it is often easy to determine at a glance if the differences between two curves are significant (statistically) or not.

There are a number of other errors or biasing effects that can take place related to statistical analysis. These include sampling bias errors, lack of homoscedasticity, serial correlation and others that are beyond the scope of this thesis. Suffice it to state that one should pay close attention to the statistical and error aspects of data presented.

## MISCELLANEOUS BIASING METHODS

There are some methods of biasing information presentation that do not fit into the previously described categories. These are less quantitative techniques but they can be effective in achieving results.

### Use of diversions or humor:

This technique is primarily effective for verbal presentations as opposed to written material. The presenter may shift the attention of the audience at critical points in his/her presentation when the content of the material may be somewhat controversial. This can be done by shifting to a humorous slide or viewgraph that may have nothing to do with the subject at hand. This type of diversion tactic may keep members of the audience from asking difficult questions on controversial aspects of the talk. This can be caused by two factors: 1) the audience forgets about the controversial data and/or 2) the audience becomes (in general) supportive of the speaker because of the "good" (humorous) presentation. Either way, the speaker may be able to successfully present dubious data without being challenged.

Interpretation of data:

There are several techniques that fall under this general heading of "interpreting" data. One technique is to simply end the presentation with a vague reference such as: "...the data presented here have obvious significant implications for display design (or whatever)." With this method the presenter does not justify his remarks but elevates the possible importance of his results by making a nebulous reference to its importance in some related field.

Another method is to set up a logical sequence such as: "If X is true then Y is true." This is done without much justification as to why this relationship should hold and most of the time is spent presenting data supporting the hypothesis that X is true (and therefore Y, by logical implication). This method shifts attention from the quoted logical premise (which may be weak or untrue) to the predicate of the premise (whether or not X is true) for which the presenter may have very strong evidence.

The third technique that can be used is to provide a strong, concluding, "bottom line" assessment of the significance of the data presented. This "bottom line" may or may not be supported by the data presented but it can have a very strong influence on the thoughts of the audience. Especially in technical areas, people usually assume that the reason they do not understand all of what is presented is because the area is too technical and the presenter obviously knows it better than they do. These people are more than happy to receive a "bottom line" summary of the information presented so that they can "understand" the significance of the material.

In each of these methods the presenter is doing (or trying to do) some of the thinking for the audience. The important lesson here is to try to understand as much as possible of what is presented and not to assume that because some point is unclear it is due to the listener and not the presenter.

### Connotations of descriptive words:

By using words with negative or positive connotations it is possible to bias observers opinions of the data presented. For example, if a specific data value changes from value A at time 1 to a lower value B at time 2 the change might be described as; 1) "the index value decreased between time 1 and time 2", or as: 2) "the index value plunged between time 1 and time 2." Even though the actual, quantitative amount might be given elsewhere in the presentation (or writing) the connotation of the word "plunged" indicates that the loss in value was significant and worthy of concern. The word "decreased" is a disinterested term describing the event. The connotation of words used can be effective in supporting the viewpoint of the presenter.

## CHAPTER 3

## PUBLISHED EXAMPLES OF BIASING TECHNIQUES

The previous chapter described several techniques that can be used to bias the presetation of information. The objective of this chapter is to provide some examples of these techniques in use. It should be noted that the authors of these examples may not have used these biasing techniques intentionally. Nevertheless the examples in this chapter indicate that these methods are used, whether intentionally or not.

The following examples are organized in the same manner as the descriptions in chapter 2. Most examples are from popular publications since it is extremely difficult to obtain examples from company internal presentations.

### GRAPHICAL TECHNIQUES

#### Truncation of axes:

There are innumerable examples available demonstrating this technique in either line graph or bar graph form. Almost every weekday the Wall Street Journal has a small graph of some variable of interest (such as interest rates, unemployment, factory orders, etc.) located at the top center of the front page. This graph is usually truncated such that the lower part of the vertical axis starts at a value other than zero. Figure 28 is an example from the February 8, 1985 Wall Street Journal showing the increase in factory shipments for the last three years. For comparison, Figure 29 shows the same data graphed without truncation of axes.

Figure 30 is an example of axis truncation for a bar graph taken from the Boston Globe financial section for November 27, 1984. The bar graph shows the decline of the prime interest rate for the latter part of 1984. The same data is shown in bar graph form in Figure 31 without truncation.

These two examples were not specifically directed at making a particular point. However, the pictorial bar graph of Figure 32 was adjacent to a headline reading: "Vacancy rates on rise in city." This example was published in the Dayton Daily News (March 12, 1984) with the intent of supporting the story about the increase in vacancy rates and the decrease in "...the percentage of houses occupied by their owners..." Figure 33 is the same data in untruncated, bar graph form.

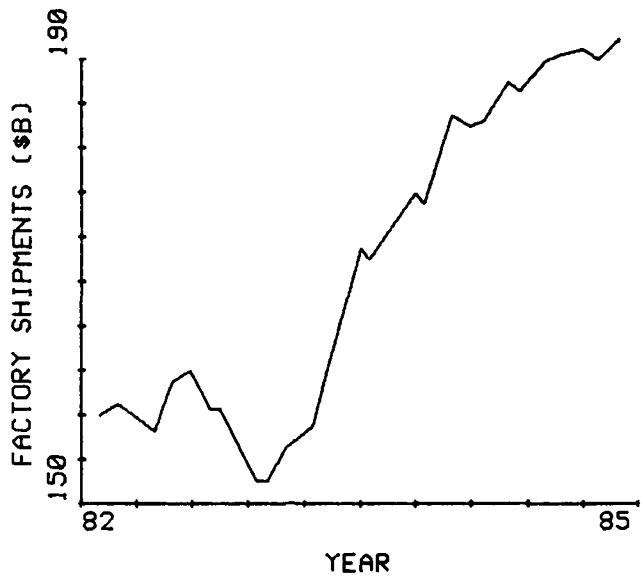



Figure 28. Truncated line graph of "factory shipments" (in billions of dollars) from the front page of Wall Street Journal (February 8, 1985).

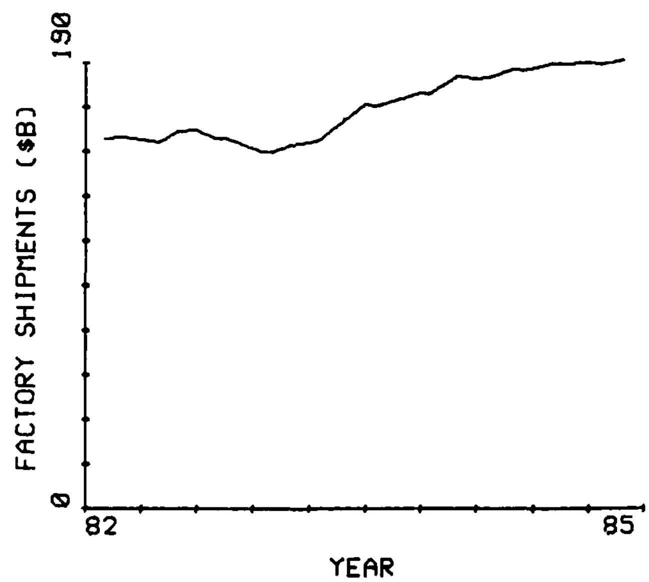



Figure 29. Same line graph as Figure 28 but without the truncated vertical axis.

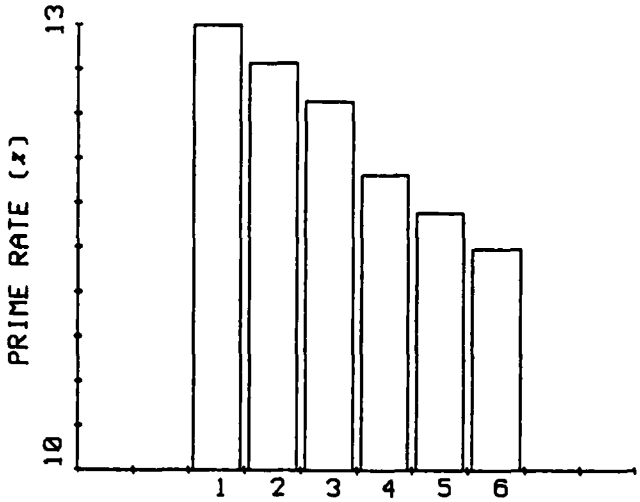



Figure 30. Truncated bar graph showing decline of prime interest rate (Boston Globe, November 27, 1984). The numbers correspond to the following dates: 1) June 25, 2) Sept 27, 3) Oct 16, 4) Oct 29, 5) Nov 7, 6) Nov 26, all 1984.

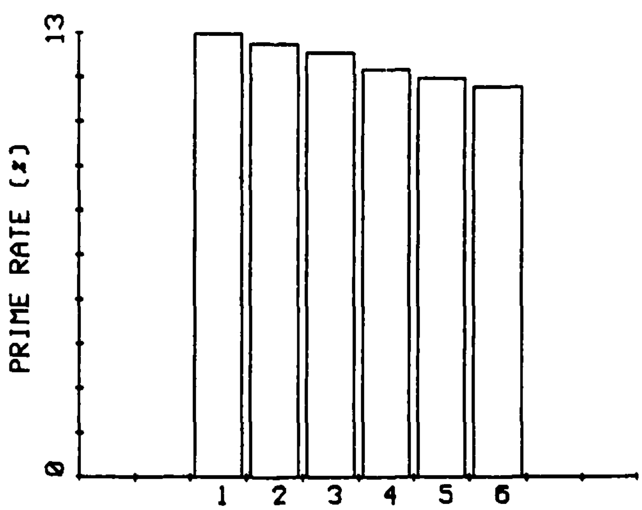



Figure 31. Same data as Figure 30 with untruncated scale.

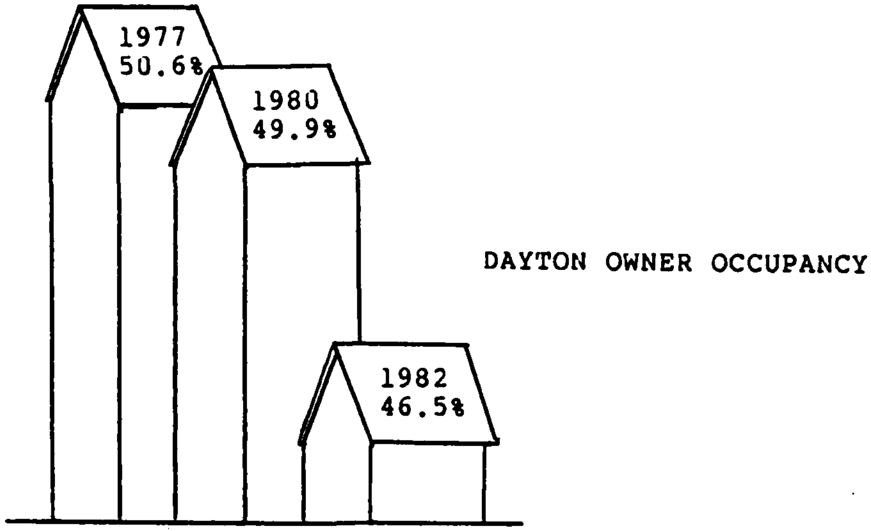



Figure 32. Pictorial bar graph (original was in full color) showing decrease in Dayton (Ohio) owner occupancy rate published in Dayton Daily News (March 12, 1984). (From left to right: 1977--50.6%; 1980--49.9%; 1982--46.5%)

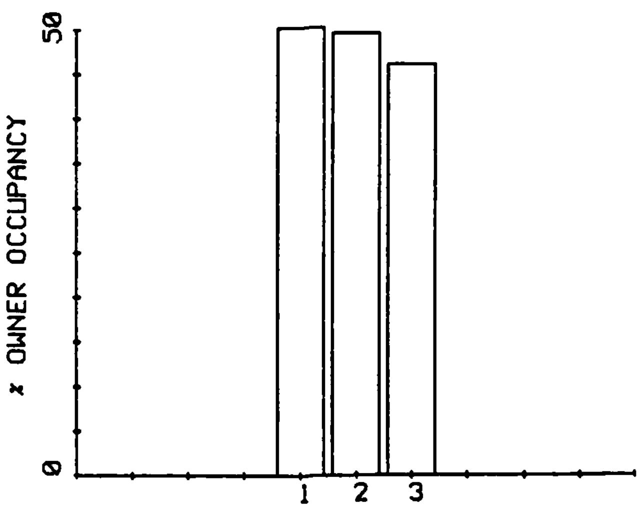



Figure 33. Same data as Figure 32 but without truncation of scale.

Selection of axes:

Business and managerial data are seldom graphed on other than linear-linear axes (with the exception of log-linear used to show growth rate). However, technical and scientific data are often graphed using different combinations of logarithmic and linear axes.

A specific example of the same type of data graphed in different ways can be found in the area of vision research. A measure of vision that has been developed over the last several decades is called contrast sensitivity. Contrast sensitivity is determined by measuring the contrast of a sine-wave target pattern for which an oberver can just barely see the pattern. The sine-wave target is a pattern that varies in luminance (brightness) in a sinusoidal fashion along one dimension. The spatial frequency of the target is defined as the number of cycles of the sine wave that are contained within a visual angle of 1 degree.

Contrast sensitivity is defined as the reciprocal of the contrast (contrast, in this case, is defined as the difference between the maximum and minimum luminance of the sine wave target divided by the sum of the maximum and minimum) of the sine wave target at threshold. The result is a curve that describes the "sensitivity" as a function of spatial frequency.

There are a total of eight ways in which these data could be graphed corresponding to all combinations of linear and logarithmic axes with contrast or reciprocal of contrast. The resulting graphs of the data will look vastly different depending on the way in which they are plotted. Examples of three of the eight combinations have been found in the literature. Figures 34, 35, and 36 show these three using the same set of data. Figure 34 is reciprocal contrast with log-log axes (Campbell and Robson, 1968), Figure 35 is contrast with log-log axes (Van Nes and Bouman, 1965) and Figure 36 is contrast with linear-log axes (Snyder, 1974). The actual data used for all graphs is based on the Campbell and Robson (1968) article.

It is apparent from these examples that the selection of axes can make a significant difference in the appearance of the data. To complete the partial set of graphs, Figure 37 shows the same data graphed with reciprocal contrast on linear-log axes for comparison purposes.

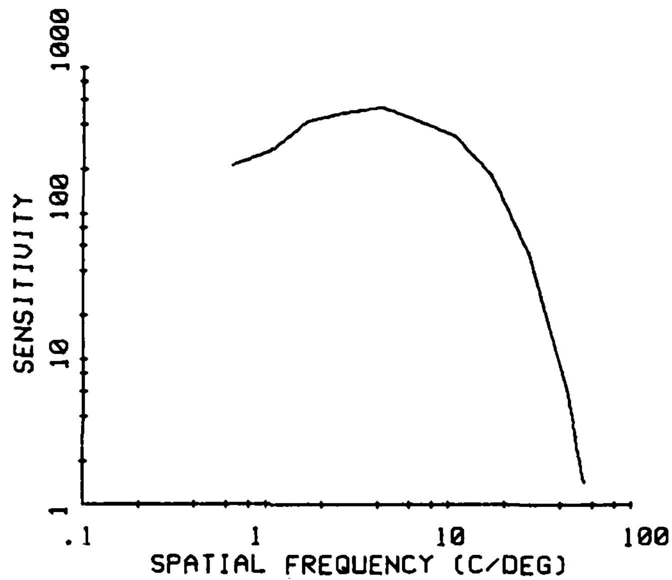



Figure 34. Vision data graphed as reciprocal contrast (contrast sensitivity) on log-log axes (Campbell and Robson, 1968).

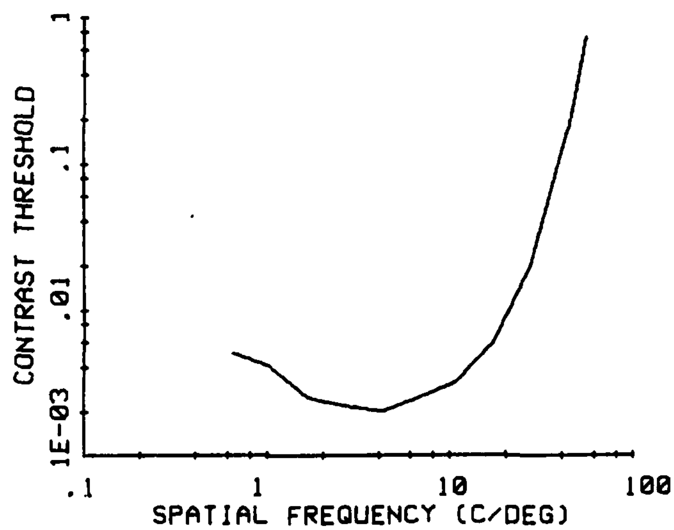



Figure 35. Vision data graphed as threshold contrast with log-log axes after Van Nes and Bouman (1965). Actual data graphed is same as used for Figure 34 for comparison.

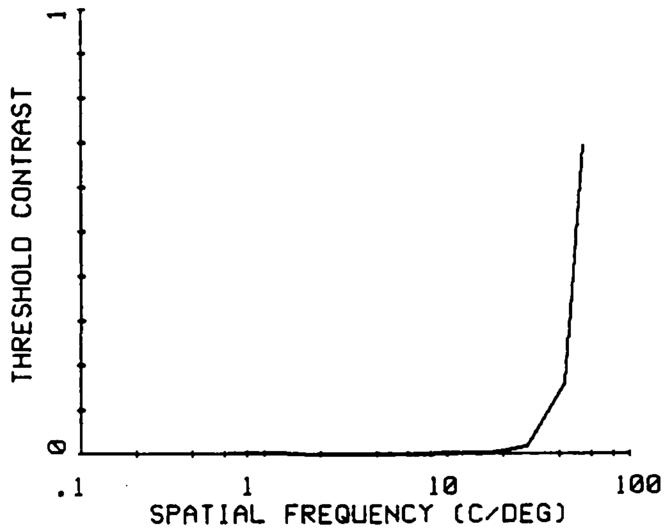



Figure 36. Vision data graphed as contrast with linear-log axes after Snyder (1974). Actual data used is same as Figure 34.

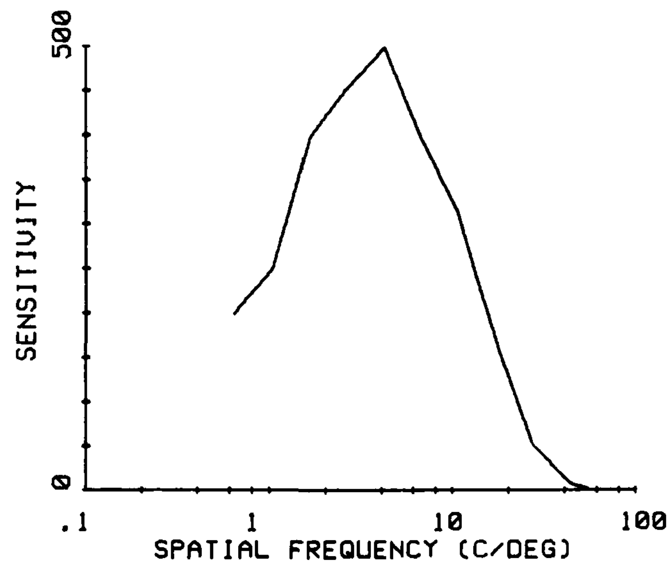



Figure 37. Vision data graphed as reciprocal contrast with linear-log axes for comparison purposes. Data is same as used in Figure 34.

Pictographs:

Figure 38 is an example of what could be termed a combination pictograph and bar graph. This pictorial bar graph is intended to show the rapid increase in usage of computers for students in public schools (Boston Globe Science - Technology section, November 26, 1984). The tops of the 3-D columns are drawings of computer "floppy disks." This type of perspective, 3-D bar graph enhances the increases indicated since the volumes of the columns do not increase proportionally with the numerical values shown. For comparison, Figure 39 is the same data graphed in a "fair" bar graph.

By using a single dimension of an object to represent the value of the variable of interest, but showing a perspective view of the entire object, it is possible to obtain a distorted perception of the facts. A very simple example of this pictograph method is shown in Figure 40 where the pictograph object is a rectagon. This example is from the business section of The Journal Herald (Dayton, Ohio, April 11, 1984) and was shown under the headlines: "White-collar women make strides." Compare the visual impact of Figure 40 to the same data shown as a bar graph in Figure 41. This is a case where the 3-D pictograph was chosen to enhance the visual impact of the data.

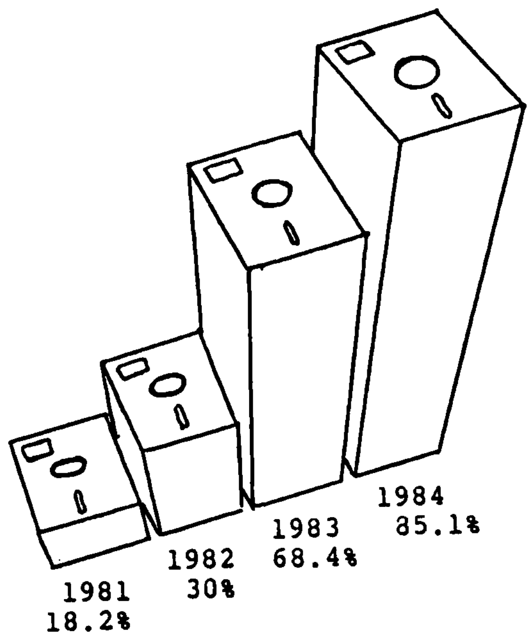



Figure 38. Pictorial bar graph demonstrating "...the explosive growth of computers in schools" from the Boston Globe Sci-Tech section November 26, 1984. 1) 18.2%, 2) 30.0%, 3) 68.4%, and 4) 85.1%.

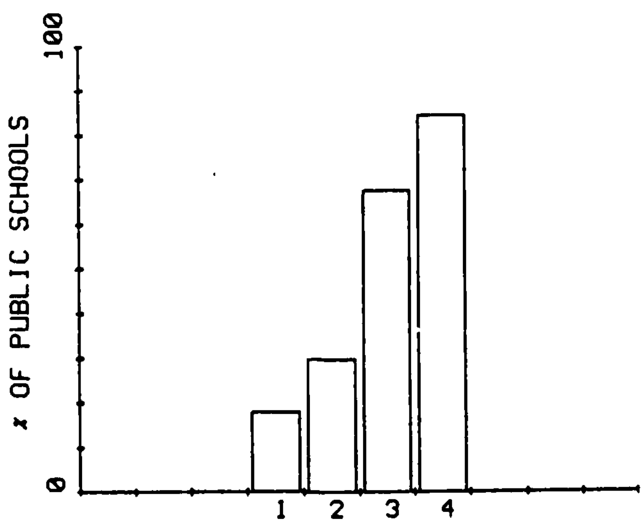



Figure 39. Bar graph of same data as shown in Figure 38. Note the perceptual difference in growth rate between Figure 38 and Figure 39.

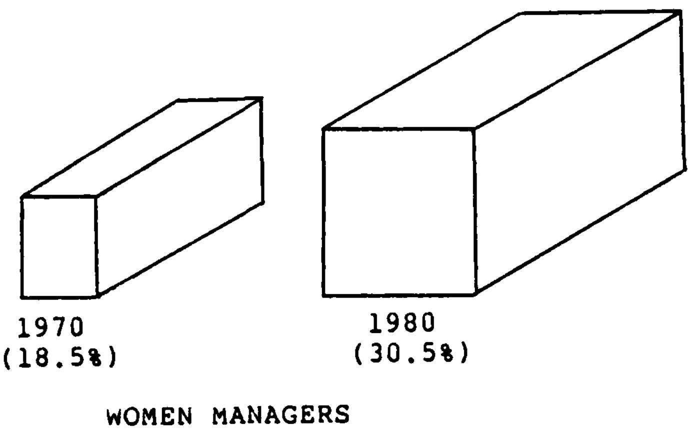



Figure 40. Pictograph (with simple rectagon as object) indicating increase in women managers from 1970 to 1980. (Journal Herald, Dayton, Ohio, Business section, April 11, 1984).

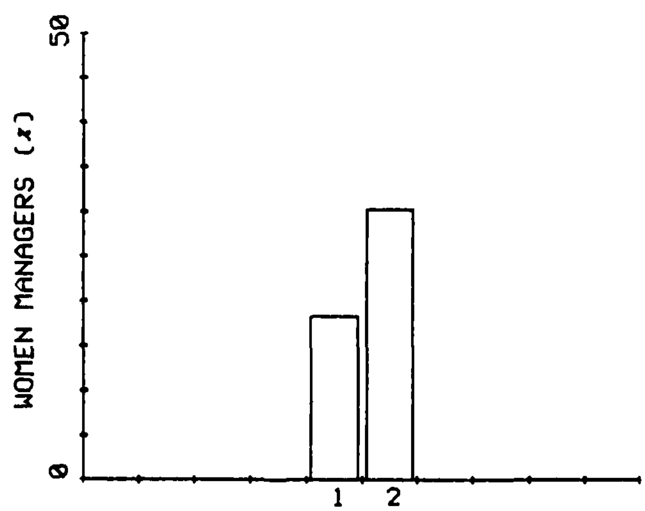



Figure 41. Bar graph of same data as shown in Figure 40. Note the perceptive difference in the two quantities (1970 & 1980) in Figure 40 compared to Figure 41.

DATA MANIPULATION TECHNIQUES

Data conversion:

Figures 34 and 35 previously described under the example of selection of axes also serve as an example of data conversion. The graph of Figure 34 is the reciprocal of the graph shown in Figure 35 (likewise for Figures 36 and 37).

Percentage change versus absolute:

Figure 42 is a graph from the Harvard Business Review (Hayes and Abernathy, 1980) showing the percent change in number of company presidents with specified backgrounds over a certain time period. The graph shows a significant increase in the number of company presidents (for the top 100 U.S. companies) with finance or legal backgrounds compared to technical or marketing backgrounds. Since the graph showed the actual percentages of company presidents in each background for the last time period, it was possible to figure out the actual number of presidents with each background for each of the time periods shown.

Figure 43 is the actual fraction of company presidents with each of the specified backgrounds for the same time periods as Figure 42. Note that the increase in financial and legal types compared to technical or marketing types is not nearly as dramatic as Figure 42.

One could consider Figure 43 as a "fair" description of the backgrounds of company presidents over the time frame indicated. However, if one wanted to drastically reverse the enhancement effects of Figure 42, it would be a simple matter. If the baseline time period is fixed at #3 (1963-1967, see graph) and the percentage change for each background were again calculated, one obtains a much different looking graph shown in Figure 44.

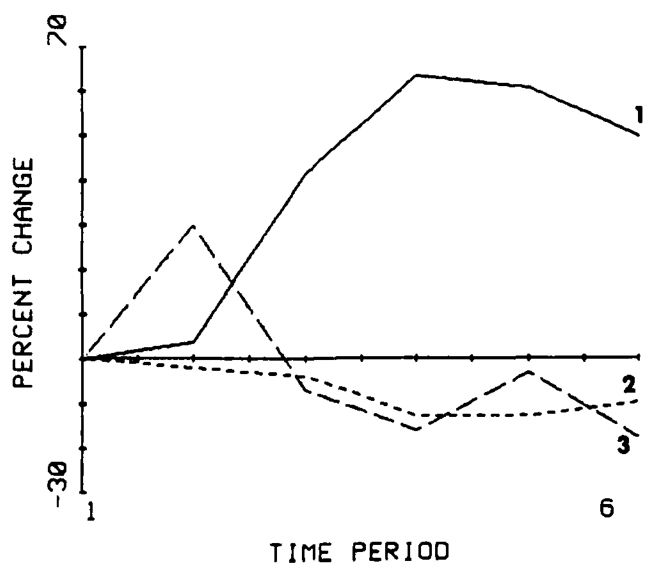



Figure 42. Percent change in number of company presidents with 1) finance or legal, 2) technical, or 3) marketing backgrounds. Time periods: 1) 1953-57, 2) 1958-62, 3) 1963-67, 4) 1968-72, 5) 1973-77. (Hayes and Abernathy, 1980).

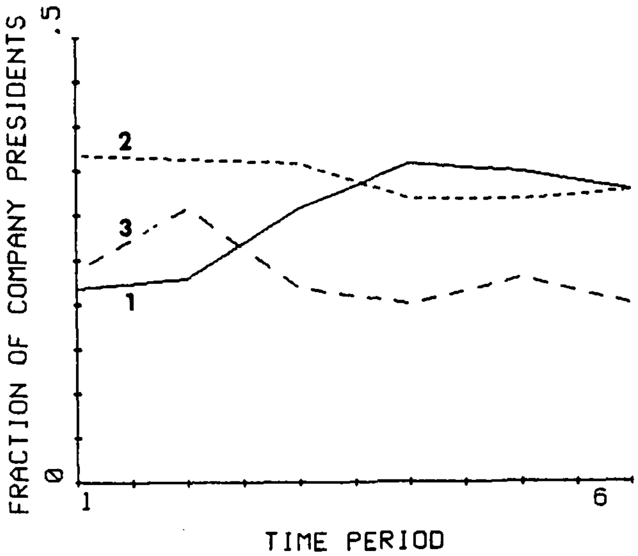



Figure 43. Same base data as for graph of Figure 42 except absolute values are graphed instead of percentage change from some baseline time period.

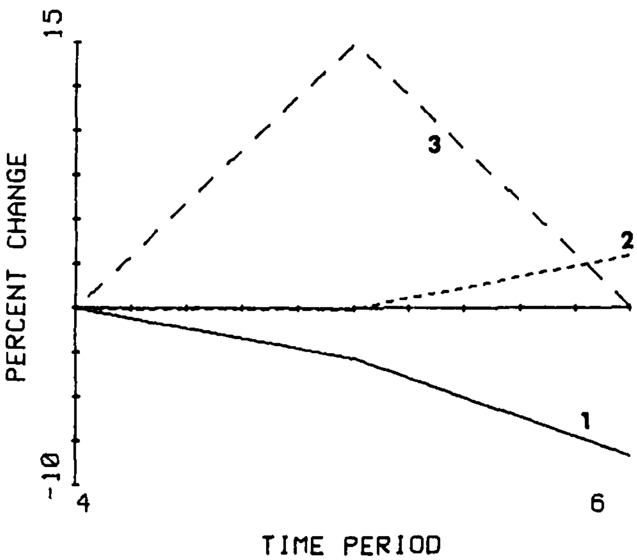



Figure 44. Percent change in number of company presidents with specified backgrounds: 1) finance or legal, 2) technical, or 3) marketing. Data is identical with base data for Figure 42 except base time period is #3 (1963-67). Note dramatic difference in graph compared with Figure 42.

MISCELLANEOUS

Interpretation of data:

Although several examples of this type can be easily found, they are not as easily presented due to the technical content. The following is such an example.

The author of this example has worked in the area of vision for several years and is highly motivated in promoting a particular measure of vision (Ginsburg, 1981); namely contrast sensitivity using sine-wave targets (previously discussed). To this end, he has attempted to "prove" that this measure is superior to any other for many areas including the evaluation of aircraft heads-up displays (HUDs) which is the subject of this example (Ginsburg, 1983).

The problem was to evaluate "...three candidate HUDs for the F-16 aircraft, two having similar refractive optics, AFTI and Production, and the third having reflective, holographic optics, LANTIRN..." It was noted that "...pilots complained that the newer LANTIRN HUDs had several optical problems..." It was further noted that "...since the primary specification for the optical quality of the HUD, optical transmission, was met by the manufacturer, it was clear that a more relevant evaluation of the HUD was necessary." (This last statement was actually false as there were several specifications other that optical transmission (Task, 1983) that could and had been measured.)

Thus the situation was that two HUDs (AFTI and Production) did not elicit pilot complaints but the third HUD (LANTIRN) did. Also, it was stipulated that physical, optical measurements of the HUDs could not account for this difference (an incorrect stipulation, as noted above).

The next step in the report was to present background data on contrast sensitivity, past studies justifying it, and a description of the methods to measure the contrast sensitivity of pilots viewing through the HUD. Many graphs of several types were presented. The graphs were small and difficult to interpret. Finally, in the last paragraph, the author presented his summation and "bottom line" statement.

He wrote: "In general, even though the three HUDs have different optical configurations that produce different sensitivity signatures, they show similar average detection range penalties of 6-8%." This was, in effect, a statement that the methods used could not produce a significant difference between the HUDs even though pilots complained about one and not the other two. This did not substantiate the claim in the beginning of the report that the stated optical measure (transmissivity) was inadequate.

Undeterred by this inconsistency, the author concluded: "The similar average detection range penalties for the three

HUDs evaluated here demonstrate the power of the CSF (contrast sensitivity function) approach to provide total system analysis for quite different optical display systems and relate system performance to detection range loss." This conclusion is totally unsupported by the data presented, but this summary "bottom line" statement makes easy and impressive reading for those unfamiliar with the specific technical area presented.

Connotations of descriptive words:

In an effort to garner support for a particular view, the use of words with strong connotations may help persuade the observer (or reader). The following example from the Boston Globe (December 6, 1984) was detected by one reader who consequently wrote to the Globe noting the technique. The reader's letter was published in the December 18, 1984 issue of the Globe.

The December 6, 1984 article headline read "Value of Harvard's investments plunged $246 million." However, from other information in the same article it could be calculated that the "plunge" actually amounted to only 3.6% of the original value of the assets. If one further adds the fact that "...the majority of investment advisers had an average decline in equities of 11.6% for the same period..." it is apparent that Harvard did not fair so poorly as the article intimated.

Another good example of differential use of words with strong connotations was found in the August 4, 1984 issue of the Boston Globe. On the front page it was noted that "...the US unemployment rate jumped to 7.5% last month..." and in the same paragraph: "In Massachusetts, the rate inched back up to 4.2 percent, but officials discounted the increase." In order to find out how large a "jump" was and what increase corresponds to "inched up" it was necessary to turn to page 17 of the same paper. On page 17 the article states that the national unemployment rate went from 7.1% to 7.5% an increase of 0.4 percentage points or a "jump" of 5.6 percent. On the other hand, the Massachusetts unemployment rate went from 3.9% to 4.2% meaning it "inched up" 0.3 percentage points or an increase of 7.7 percent.

When an increase of 5.6 percent is a "jump" and an increase of 7.7 percent corresponds to "inched up" it is evident that word connotations were employed to modify the perception of the facts.

# CHAPTER 4

## RESEARCH METHOD

The previous chapters have described various techniques that can be used to bias the presentation of technical data. Examples of these methods have been provided to demonstrate that they are indeed used (either intentionally or unintentionally). The next question is: "Are these techniques effective?"

To answer this question, a study was designed and executed to investigate the bias effect of three of the techniques. This chapter describes the study that was conducted.

### SUBJECTS:

All subjects for the study were enrolled in advanced degree programs at the Sloan School of Management, Massachusetts Institute of Technology. Subjects ranged in age from 26 years to 53 years with a mean age of 35 (standard deviation = 6.5 yrs). Management experience of subjects ranged from 1 year to 18 years with a mean of 6 years (standard deviation = 4.4 years). All 22 male and 1 female subjects were unpaid volunteers.

EXPERIMENTAL METHOD:

Three short presentations were developed to present the results of three areas of technical investigation (see Appendix D). The three technical areas chosen and the data presented were very similar to actual studies that have been done in these areas. The three presentations were depicted as part of a regular six month technical management review process. Subjects were told that the intent of this review was to provide managers outside the central laboratory with information on what efforts were underway at the central laboratory and give them an opportunity to assist in guiding future activities.

Subjects were randomly divided into two groups (12 and 11). Each group viewed a series of three presentations made by the experimenter. The presentations for each group were based on the same data for each topic area, but the data were presented (graphed) differently for each group. Additionally, the experimenter recommended a different course of action for each group that seemed to be supported by the data presented.

After each presentation, subjects were asked to fill out a short questionnaire (see Appendix A) concerning the content of the presentation and stating their choice between the two courses of action presented. They were also asked to indicate their confidence level (scale 0 to 10) that the choice they had made was the correct one and to indicate the importance of the data presented and the presenter's recommendation in their choice (scales 0 to 10).

Once the experimental procedure had started, subjects were not allowed to ask any further questions verbally concerning the presentations to prevent interactions between subjects. While this is somewhat more restrictive than one might expect in an actual situation, it is not unreasonable. Often, technical reviews are attended by many people and several technical areas are covered in a relatively short time. The number of attendees and technical areas tend to discourage questions.

Another criticism is that in an actual situation decisions would certainly be made on a more careful and extensive review of the technical areas involved. Again, the experimental situation is not unlike what actually exists since higher level management often does not have the time (nor background) to thoroughly evaluate an area before making a decision concerning its continuation. Budget cuts often require rapid and final actions that may be based on little more than a vaguely remembered technical presentation on the area.

PRESENTATION MATERIAL:

Copies of the viewgraphs for the three presentations are contained in Appendix D. Presentations were made in a small room with a viewgraph machine. Subjects participated in groups of 4 to 11 necessitated by subjects' class schedules.

The first presentation was entitled: "Contact lens vs glasses: effect on visual capability." The simulated problem was to determine which type of vision aid (contact lenses or eyeglasses) should be recommended as the best method of correcting astronaut's vision. The presentation described the circumstances of the "study" and described the method of determining visual capability as defined by contrast detection thresholds for "sine-wave" targets (fuzzy bar targets). The "study" itself is contrived, but the vision measurement technique is not (Campbell & Robson, Davis etc).

The contrast detection threshold measurement results in a measure of the contrast required to detect the sine-wave target as a function of spatial frequency (spacing of the bars). The actual data used to generate the graphs of the two conditions (contact lenses and eyeglasses) is shown in Table 1.

The basic measurement made for the contrast threshold detection is contrast as shown in the contrast columns in

Table 1. However, some researchers in the vision area prefer to work with "contrast sensitivity" which is defined as the reciprocal of contrast. These data (contrast sensitivity) are shown in the "1/contrast" columns in Table 1. Subject group #1 was shown a graph of the contrast threshold data (see Figure 43) which indicated that eyeglasses require considerably more contrast across most of the visual spatial frequency (cycles/degree) range measured than do contact lenses. For this group it was therefore recommended that the contact lens approach was the best approach for the astronauts (this was choice "A" on their questionnaire).

Table 1. Contrast Threshold Data Used to Generate Graphs for Presentation 1.

| Spatial | Eyeglasses | | Contact Lenses | |
|---|---|---|---|---|
| Frequency | Contrast | 1/Contrast | Contrast | 1/Contrast |
| 1 cycle/deg | .017 | 58.8 | .025 | 40 |
| 2 | .008 | 125 | .019 | 52.6 |
| 4 | .004 | 250 | .009 | 111 |
| 6 | .009 | 111 | .017 | 58.8 |
| 10 | .014 | 71 | .022 | 45.5 |
| 15 | .025 | 40 | .028 | 35.7 |
| 20 | .07 | 14.3 | .06 | 16.7 |
| 30 | .20 | 5 | .10 | 10 |
| 40 | .50 | 2 | .30 | 3.3 |
| 50 | .95 | 1.1 | .55 | 1.8 |
| 55 | -- | -- | .90 | 1.1 |

Subject group #2 was told about the conversion of data from contrast to contrast sensitivity (1/contast) and were shown a graph of the contrast sensitivity data (see Figure

44). Since this graph shows that eyeglasses are much more sensitive over a large portion of the visual range it was recommended to this group that the eyeglasses would be the best approach (choice "B" on their questionnaire).

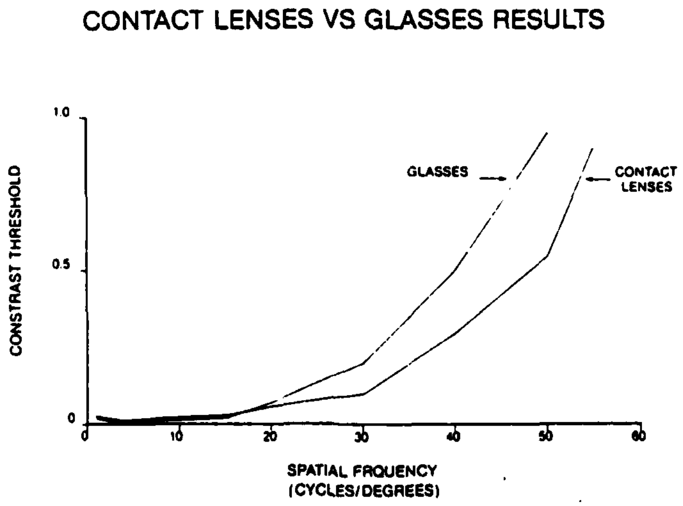



Figure 43. Graph of contrast threshold data presented to Group #1 for presentatic ı #1.

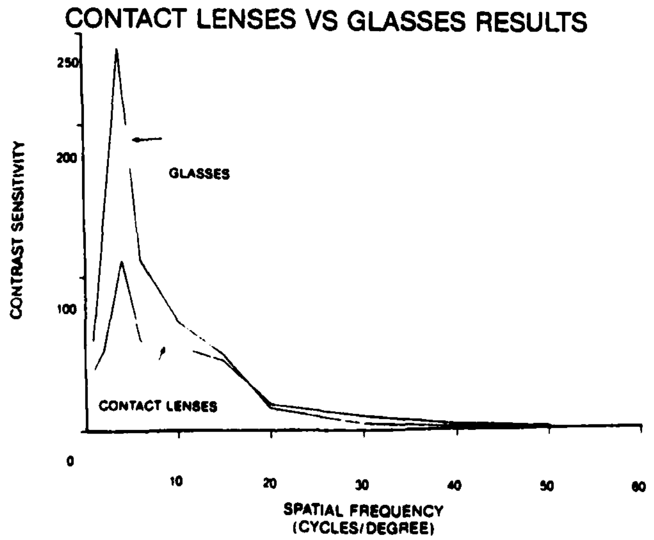



Figure 44. Graph of reciprocal contrast (contrast sensitivity) versus spatial frequency (cycles/deg) presented to Group #2 for presentation #1.

Neither group was shown the actual "raw" data but were only shown the graphs depicted in Figures 43 or 44. The intent of this presentation was to look at the effectiveness of mathematical transformations (such as taking the reciprocal) of raw data in biasing observers.

The second presentation was entitled: "Effect of yellow sunglasses on target detection performance." The problem was to determine which provided better target detection capability: yellow sunglasses or neutral gray sunglasses. Again, the actual data for this "study" is contrived but the issue of yellow filters (or headlights) versus neutral filters is real (and still unresolved as indicated by the yellow headlights of France versus the white headlights of Germany, for example).

The "study" showed the results of collecting actual target detection range data on "subjects" with yellow sunglasses and with neutral gray sunglasses. The average target detection range given for the neutral gray sunglasses was 20,843 feet and for the yellow sunglases, 21,631 feet. These data were presented in a bargraph form for each of the two groups of subjects.

Subject group #1 was shown the bargraph of Figure 45, in which the detection range scale starts at zero at the bottom and the percent difference (3.7%) is explicitly indicated. Subjects were told verbally that "...although the difference between the two cases is statistically significant, the 3.7% difference in detection range is not considered operationally significant." The recommendation to this group was to go with the neutral gray sunglasses since they were less expensive that the yellow sunglasses and showed an "...insignificant operational difference..." from the yellow sunglasses. This was choice "B" on the questionnaire.

Subject group #2 was shown a somewhat different bargraph (see Figure 46) which was truncated. Neither the percent difference nor the actual detection ranges were stated. However, the actual difference in feet and the statistical significance level used for testing significance were explicitly shown and noted. No mention of operational significance was made for this group. The recommendation was to pursue the yellow sunglasses since they showed a "...significant improvement in target detection performance compared to the less expensive neutral gray..." This was choice "A" on the questionnaire.

The intent of this presentation was to provide an example of biasing by truncating the axis of the bargraph. This was the weakest of the three presentations in that the data for both groups showed that one condition (yellow sunglasses) was better that the other. The only reason for not choosing the yellow sunglasses was due to the indicated lesser expense of the neutral gray sunglasses.

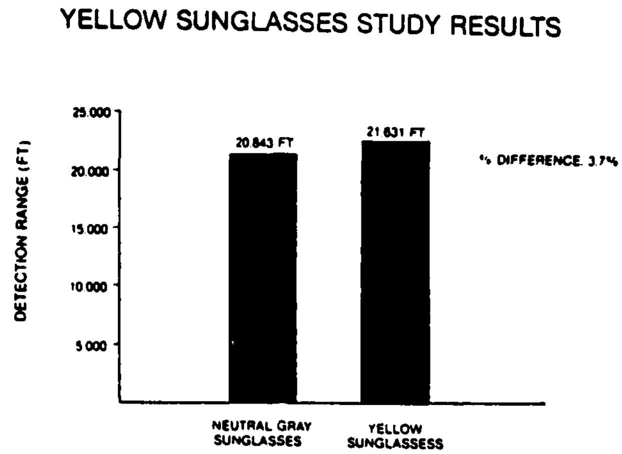



Figure 45. Bar graph of target detection range for (1) neutral gray and (2) yellow sunglasses shown to Group #1 for presentation #2.

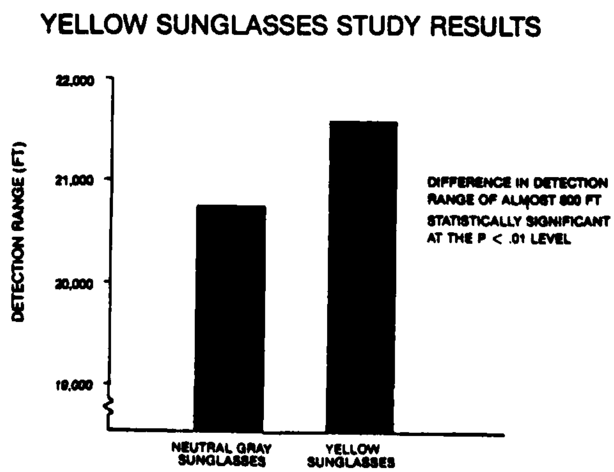



Figure 46. Truncated bar graph of target detection range for (1) neutral gray and (2) yellow sunglasses shown to Group #2 for presentation #2.

The third presentation was perhaps the most complex one from the standpoint of technical content. The decision was to determine which of two video display approaches should be further pursued by the central laboratory. The basis for making this determination was a comparison of the modulation transfer function (MTF) curves for the two display approaches. The procedure used to "measure" the MTF was described to the subjects in a single viewgraph. Once again the actual test procedures described were real (Task & Verona, 1976; Schade 1953; etc) but the data were artificially created.

As described to the subjects, the MTF of a video display is measured by first generating an electronic sine-wave signal in video format. This signal is input to the display to be measured producing a pattern of vertical "fuzzy bars." These fuzzy bars vary in luminance (brightness) as a sine wave. The contrast of the pattern is determined by dividing the peak luminance minus the minimum luminance by the sum of the peak and the minimum. The spatial frequency of the pattern is defined as the number of bright and dark bar combinations (cycles) there are across the display width. The MTF is a measure of the amount of contrast on the display as a function of spatial frequency.

Table 2 shows the data created for this presentation. The two display approaches were designated "A" and "B" with different MTFs as shown in the table.

Table 2. MTF Data for Display A and B Used in Presentation #3.

| Spatial Frequency | Display A MTF | Display B MTF |
|---|---|---|
| 10 cycles/display width | .70 | 1.00 |
| 20 | .69 | .97 |
| 50 | .66 | .89 |
| 100 | .60 | .80 |
| 316 | .45 | .49 |
| 631 | .25 | .10 |
| 708 | .20 | .01 |
| 891 | .10 | -- |
| 1000 | .01 | -- |

Subject group #1 was shown the graph of contrast versus spatial frequency as it appears in Figure 47. The data were plotted as log contrast versus linear frequency with the numerical values clearly shown. No mention was made concerning the choice of axes. The recommendation for this group was that display approach "A" was better since it had "...a far superior high frequency response compared to 'B'" and the area under the MTF for "A" was larger as could be seen from the graph. This corresponded to choice "A" on the questionnaire.

Subject group #2 saw the graph shown in Figure 48. Here, the data are plotted with linear contrast against log spatial frequency which produces a visually different curve than shown in Figure 47. Again, no mention was made concerning the choice of axes. The presenter recommended

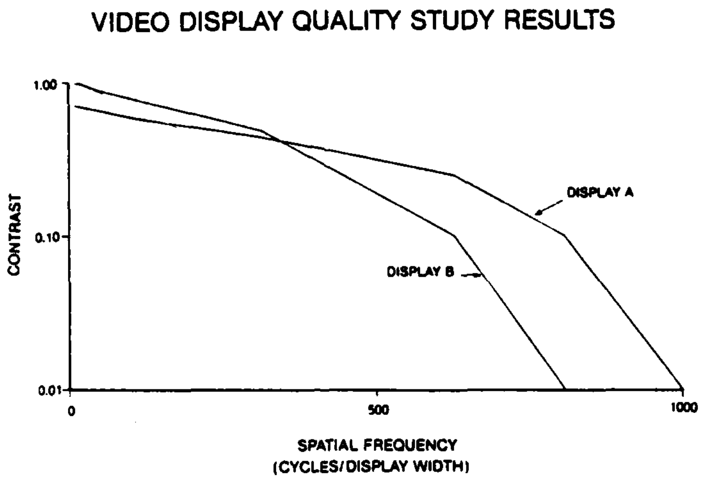



Figure 47. Modulation transfer function graph with log-linear axes shown to Group #1 for presentation #3.

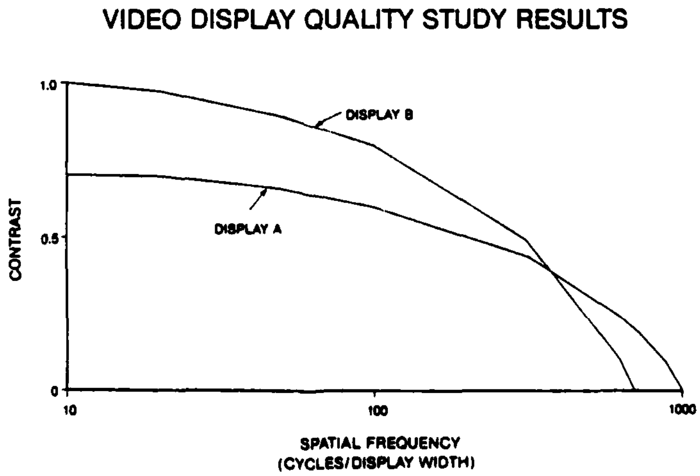



Figure 48. Modulation transfer function graph with linear-log axes shown to Group #2 for presentation #3. Note: these are the same data as graphed in Figure 47.

that "B" was better since it had "...a far superior low frequency response compared to 'A'" and the area under the MTF for "B" was larger as could be seen from the graph. This was choice "B" on the questionnaire.

This presentation was intended to test the effect of changing the axes (logarithm vs linear) on the visual impact and subsequent decisions of the observer subjects.

RESULTS:

Subjects were asked to make a choice between "A" and "B" for each of the presentations and indicate their level of confidence that the choice that they had made was the right one for their organization. Confidence was recorded on a scale of 0 (no confidence) to 10 (complete confidence). The raw data are in Appendix C.

The choice responses and the confidence scale data were combined to make a single scale ranging from -10 to +10. For purposes of simplifying the analysis and discussion, it is necessary to introduce another set of terminology. Group #1 was biased to respond with: "A" for presentations #1 and #3 and "B" for #2. Group #2 was biased to choose "B", "A", "B" for the three presentations respectively. Henceforth, the bias direction for group #1 will be referred to as the "x" direction and will correspond to positive numbers on the combined scale and group #2 bias direction will be designated as "y" and will have negative numbers (if the subject voted in favor of the bias). This somewhat complex convention allows the results to be graphed in rather easy to understand form.

In order to produce a graph of the data with relatively few subjects, it is necessary to reduce the scale range. This was done by combining scale values in groups of three. Table 3 shows the consolidated data for all three presentations (complete raw data are in Appendix C).

Table 3. Bias Scale Results for all Presentations

| Raw scale values | Condensed scale values | Group #1 (X) # responses | Group #2 (Y) # responses |
|---|---|---|---|
| 10,9,8 | 3 (x bias) | 4 | 0 |
| 7,6,5 | 2 | 15 | 1 |
| 4,3,2 | 1 | 4 | 2 |
| 1,0,-1 | 0 | 6 | 3 |
| -2,-3,-4 | -1 | 2 | 6 |
| -5,-6,-7 | -2 | 4 | 16 |
| -8,-9,-10 | -3 (y bias) | 1 | 4 |

Figure 49 shows a graph of the data from Table 3. It is quite apparent from the graph that the subjects in group #1 (who received the X direction bias) did indeed indicate choices and confidence levels that leaned in the X direction. Likewise, group #2 was effectively biased in the Y direction (negative values). A nested analysis of variance between the two groups of data bears out the graphical results with an F-ratio of 45.0 for a probability of chance less than .003 ($p < .003$). Techniques within bias were not significant (F=1.1; p=0.371).

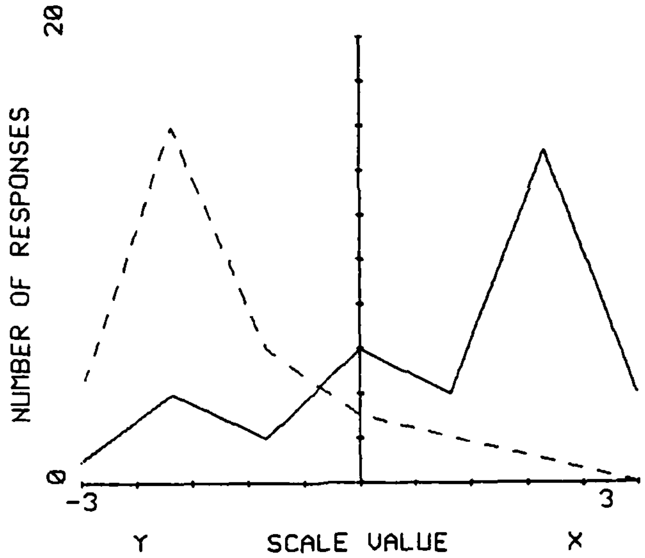



Figure 49. Bias scale data for all subjects and presentations. Group #1 was biased in the X direction (solid line) and Group #2 was biased in the Y direction (dotted line).

Table 4 shows the bias scale data for each of the presentations separately.

Table 4. Bias Scale Results for Each Presentation

| Scale value | Pres # | Group #1 (X) 1 | 2 | 3 | Group #2 (Y) 1* | 2 | 3 |
|---|---|---|---|---|---|---|---|
| 3 (X) | | 0 | 2 | 2 | 0 | 0 | 0 |
| 2 | | 6 | 4 | 5 | 1 | 0 | 0 |
| 1 | | 2 | 0 | 2 | 1 | 1 | 0 |
| 0 | | 2 | 1 | 3 | 0 | 0 | 3 |
| -1 | | 1 | 1 | 0 | 2 | 3 | 1 |
| -2 | | 1 | 3 | 0 | 3 | 7 | 6 |
| -3 (Y) | | 0 | 1 | 0 | 3 | 0 | 1 |

* Note: subject showed up late in this group and missed the first presentation so this column adds to 10 instead of 11.

Graphs of these data are shown in Figures 50, 51 and 52for presentations 1, 2, and 3 respectively.

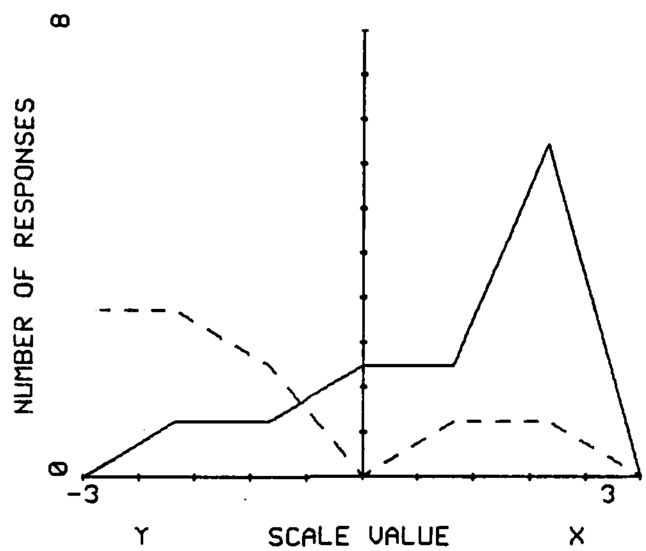



Figure 50. Bias scale data for presentation #1. Solid line is Group #1 data (biased in the X direction) and the dotted line is Group #2 data (biased in the Y direction).

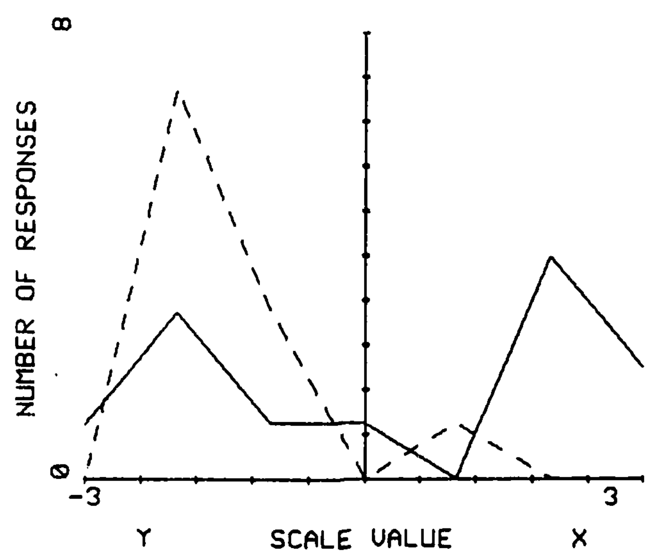



Figure 51. Bias scale data for presentation #2. Solid line is Group #1 data (biased in the X direction) and dotted line is Group #2 data (biased in the Y direction).

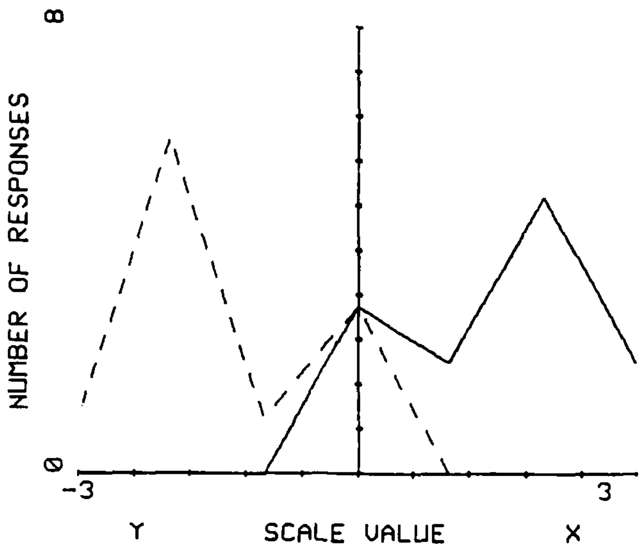



Figure 52. Bias scale data for presentation #3. Solid line is Group #1 data (biased in the X direction) and dotted line is Group #2 data (biased in the Y direction).

Table 5 shows the results of an analysis of variance for each of the presentations (corresponds to the graphs of Figures 50, 51 and 52).

Table 5. Analysis of Variance Summary Results for Each Presentation

| Pres # | Group #1 (X) Mean | S.D. | Group #2 (Y) Mean | S.D. | F-ratio | Prob |
|---|---|---|---|---|---|---|
| 1 | 3.25 | 4.27 | -4.20 | 5.10 | 13.96 | <0.002 |
| 2 | 1.17 | 6.78 | -4.55 | 2.73 | 6.78 | <0.02 |
| 3 | 4.75 | 3.11 | -4.18 | 2.93 | 50.11 | <0.001 |

The preceding data show that the presentation differences between Group #1 and Group #2 were significant in affecting the subjects' choices. The next question is what was the relative importance of the data presented versus the recommendations of the presenter? Subjects were asked to indicate the importance of the data presented and the importance of the recommendations of the presenter on a 10 point scale ranging from 0 (no importance) to 10 (very important). Table 6 summarizes the analysis of variance for each presentation and group combination and the importance of data presented versus presenter's recommendations.

Table 6. Analysis of Variance Summary Results for Importance of Data Versus Presenter's Recommendation.

| Pres - group | Data Pres Mean | Data Pres S.D. | Recommendation Mean | Recommendation S.D. | F-ratio | Prob |
|---|---|---|---|---|---|---|
| 1-1* | 6.67 | 2.90 | 5.42 | 3.53 | 0.90 | 0.64 |
| 1-2 | 6.40 | 2.91 | 5.60 | 2.50 | 0.43 | 0.53 |
| 2-1 | 7.50 | 2.84 | 3.17 | 2.17 | 17.62 | <0.001 |
| 2-2 | 6.73 | 1.74 | 5.18 | 1.94 | 3.87 | 0.06 |
| 3-1 | 5.83 | 2.64 | 5.50 | 3.30 | 0.07 | 0.79 |
| 3-2 | 6.73 | 2.53 | 6.27 | 2.45 | 0.18 | 0.68 |

* Note: 1-1 is presentation #1, subject group #1, etc.

Another question of interest was whether or not subjects tended to link the importance of data presented and the importance of the presenter's recommendation. In other words, if they rated one high in importance did they also rate the other one high? Table 7 is a summary of regression between importance of data and importance of presenter's recommendation for each presentation and group combination.

Table 7. Summary of Regression Results Between Data Importance and Recommendation Importance

| Pres - Group # | Correlation Coefficient | Degrees of Freedom | F-ratio | Prob |
|---|---|---|---|---|
| 1-1 | 0.69 | 1 & 10 | 9.06 | 0.01 |
| 1-2 | 0.51 | 1 & 8 | 2.84 | 0.13 |
| 2-1 | 0.04 | 1 & 10 | 0.02 | 0.89 |
| 2-2 | 0.40 | 1 & 9 | 1.71 | 0.22 |
| 3-1 | 0.42 | 1 & 10 | 2.15 | 0.17 |
| 3-2 | 0.25 | 1 & 9 | 0.62 | 0.54 |

## DISCUSSION AND CONCLUSIONS:

The primary results of this study as shown in Table 3 and graphed in Figure 49 clearly show that, overall, the subjects were successfully biased by the presentation techniques used. The nested analysis of variance of the overall data resulted in an F-ratio of 45 (probability of chance $p < .003$). This substantiates the graphical data of Figure 49 that the two groups of subjects were indeed persuaded along the lines desired by the presenter even though the underlying data for presentations for both groups were identical.

Tables 4 and 5 and Figures 50, 51 and 52 indicate that the three different techniques used in the three presentations were not equally effective in persuading the subjects to choose a particular course of action. Looking at the probability levels shown in Table 5 it would appear that the third presentation was the most effective followed by the first and the second respectively. The third presentation used the technique of changing the axes upon which the data were graphed (e.g. log-linear axes instead of linear-log axes). However, before one jumps to the conclusion that this technique was more effective than the other two, it should be noted that the content of the third presentation was probably the most difficult from the standpoint of technical complexity. Thus one might conjecture that subjects would tend to be less confident in their choice and/or would tend to depend more on the presenter's recommendation in making their choice. Neither of these conjectures appears to be satisfactory in light of the mean confidence level for presentation #1 shown in Table 5 and the relatively high importance of data presented indicated in Table 6.

The truncated bargraph technique used in presentation #2 seemed to clearly be the weakest. In the other two presentations the graphs of each of the two items plotted were distorted in such a way that by changing from the X bias condition to the Y bias condition the relative superiority of the two items graphed was clearly reversed. However, with the truncated bargraph technique of presentation #2 the superiority of one condition over the other was not reversed between bias X and bias Y, it was only increased in magnitude (by truncating part of the scale). Thus, the only reason subjects might choose the lesser item (lower value on the bargraph) is if there were some mitigating factor to consider.

The mitigating factor that was introduced to temptsubjects away from the "better" item (the yellow sunglasses with larger detection range) was a nebulous reference to the more "expensive" aspect of the "better" item. This resulted in a trade-off decision between expense and performance (detection range) with the performance quantified in graphic form and the expense left ill-defined. Even though this technique was the weakest, it still showed significant effect ($p < 0.02$) as indicated in Table 5. It is apparent from the low mean confidence level and high standard deviation of group #1 (who were biased to select the less expensive, lower performing option) that there was considerable variation in responses and that the difference in bias X and bias Y was not symmetric.

Having clearly demonstrated that the two versions (X and Y) of the three presentations, resulted in successful biasing of the subjects in the direction desired by the presenter, it is now necessary to determine if the biasing effect was due to the biased presentation of the data or the presenter's recommendation. These two factors were measured by the two scales: Importance of Data Presented and Importance of Presenter's Recommendation. Table 6 contains the intercorrelations for these two measures.

For most presentation-group combinations there was no difference between the importance of the data presented and the importance of the presenter's recommendation in subject's choices and confidence levels. One notable exception is for presentation #2, group #1 where analysis of variance indicates a highly significant difference between the importance of the data presented and the recommendation of the presenter ($p < 0.001$).

In this case, the data presented were deemed more important than the presenter's recommendation (7.5 data importance level versus 3.2 for recommendation). Thus for all cases, either the data presented was more important in subjects' decisions or there was no statistically significant difference between the importance of the data and the presenter's recommendation. From this it is possible to conclude that, at a minimum, the bias techniques in presenting the data were at least as effective in persuading subjects as was the presenter's recommendation (assuming subjects' responses were correct assessments of their true feelings about the data and recommendations).

Another side issue of interest was whether or not subjects who indicated high levels of importance of the data presented also indicated high levels of importance for the presenter's recommendations. If so, this could be a signal that subjects tended to "vote a straight ticket" instead of thinking about the real influence of data versus the presenter's recommendation on their choices.

Except for presentation #1 group #1 there was very little evidence that the two factors were linked in any significant way. Group #1 for presentation #1 did show a mild correlation between their response on data importance and presenter's recommendation ($r = 0.69$; $p = 0.01$ ).

Question #4 on the questionnaire was intended to try and obtain some indication of the visual impact that the graphed data had. Since the questions for each presentation were the same, subjects could be expected to pay closer attention to the graphs in presentations #2 and #3. Table 8 shows a summary of the characteristics of the subjects' responses to question #4. (Question #4 asked subjects to replicate the graph of the data that had been presented to them in the presentation).

Table 8. Percent of Correct Characteristics Drawn by Subjects in Response to Question #4

| Item | Pres #1 | Pres #2 | Pres #3 |
| --- | --- | --- | --- |
| Lines (Shape) | 81.8 % | 100.0 % | 100.0 % |
| Lines Labelled | 87.0 % | 100.0 % | 95.7 % |
| Axes Labelled | 73.9 % | 89.1 % | 93.5 % |
| Axes Numbered | 21.7 % | 84.8 % | 56.5 % |
| Axes Type* | 17.4 % | 15.2 % | 45.7 % |

* Note: Subjects were scored with 1.0 for axes type if the numbers on the axes were sufficient to determine if axes were logarithmic or linear.

The information for Table 8 was collected by looking at the graphs each subject had drawn and determining if it had certain characteristics. The five characteristics that were checked for were: 1) general shape of the graphed line (bar), 2) correct labels for lines (bars), 3) correct labels on the axes, 4) numerical values on scales, and 5) notation of the type of axes (linear, log). Scoring was done be the following method: if the graph was essentially correct for a characteristic then it was assigned a score of 1.0, if it was partially right it received a score of 0.5 and if it was missing or totally incorrect then the score was 0.0. The data of Table 8 show the fraction of correct characteristics (based on the above scoring system) for all of the subjects.

The cleanest data in Table 8 are those for presentation #1 since the subjects did not know ahead of time that they were going to be asked to draw the graphs presented to them. For each of the other presentations it must be assumed that at least some of the subjects figured that they would probably be asked the same question for the other presentations and paid attention accordingly.

In any event, the data of Table 8 shows (roughly) the heirarchy of visual impact of the graphs on the subjects. Note that the shape of the drawn lines and the labels of the lines (which condition is "better") is remembered best by subjects but the type of axes (log or linear) and the numerical value of the ranges graphed are not recalled to the same degree. This study was not designed to investigate this particular aspect of technical data recall,so only a qualitative statement is appropriate. It appears that subjects tend to remember the general shape of a line graph and not the actual scale values or whether the scales are logarithmic or linear (or other). This apparent fact is a contributing factor to the success of some of the biasing techniques described in this thesis.

The last item on the questionnaire provided subjects with the opportunity to state what further information they would like to have had before they made their decisions. It is fully recognized and noted that in an actual technical management review there would typically be at least some time and provision for participants to ask questions. The primary intent of this item (question #5) was to determine what type of further information subjects wanted. In particular, did they have doubts or concerns about some of the data presented?

It is difficult to assess the subjects' answers to this question in terms of the major theme of this thesis. In most cases, subjects wanted more technical or managerial (e.g. cost) data about the presentation but did not question the data that was presented to them. There were some exceptions where individuals noted the problems with the data presented.

A good example is in presentation #3 which showed two display MTF curves. For each group (#1 and #2) one of the two axes of the MTF curve was logarithmic. Subjects were told that the better display system was the one with the larger area under the curve. Of the 23 subjects, only three commented on the logarithmic nature of the graphs and of them only one noted the critical fallacy of "area under a curve" when one (or both) of the axes are logarithmic. If one of the axes is logarithmic, then there is no "bottom" to that axis (it does not and cannot start at zero since log(0) is not defined). Thus, the "area" can be as large or as small as desired by adjusting the starting point of the axes. Visually, the areas can be adjusted differentially by plotting one or the other axis logarithmically, which is exactly what was done to achieve the biased graphing of presentation #3.

Subject response to question #5 was excellent. Every subject responded for every presentation when asked what further information they would like (even if that response was "none"). I am convinced that if these questions had been allowed to be made verbally, that subjects would have done a good job in reviewing the technical presentations made. However, I am also equally convinced that a seasoned presenter could have handled most of those questions in such a way as to leave the biasing effect intact.

This study has provided sufficient evidence to demonstrate that at least some of the biasing techniques presented in this thesis can be effective in persuading observers to adopt a particular point of view. From the data, it is apparent that some techniques are obviously superior to others. It should also be noted that both the data presented and the recommendations of the presenter carried weight in biasing subjects. In this case, the "track record" or credibility of the presenter in the technical area presented was not apparent to the subjects. If the experiment were repeated whereby the presenter was given a "good" or "bad" track record of success then one could expect some variations in the relative importance of the data presented and the presenter's recommendations.

# CHAPTER 5

# CONCLUSIONS

Chapters one through four have attempted to demonstrate that 1) biasing techniques exist, 2) biasing techniques are used, and 3) they can be effective in affecting the decision making process.

These biasing techniques may be employed in a number of areas encompassing both verbal and written communications and ranging from scientific and engineering information to managerial and marketing information. Although this thesis has not addressed the question of how often these methods are used in data presentation, the examples presented in Chapter three and the effectiveness results of Chapter four indicate that this subject area could be of vital importance to managerial and technological decision-makers.

The purpose of this thesis was to make scientists, engineers and managers aware of some of the methods that could be used (and have been used) to bias information without falsifying it. It was written with the intent that forewarned is forearmed. It was not intended that this thesis should serve as a training manual for those who might wish to employ the techniques described; but it's obvious it could be so used.

The study in Chapter four is probably the first of its kind to determine the effectiveness of three of the techniques discussed. It is apparent that considerably more research could be conducted to explore the effectiveness of these and other techniques for various types of communication environments (written vs verbal, formal vs informal, technical vs non-technical, etc.).

With the many critical decisions that industry and government must make concerning funding and regulation of research, development and business activities, it is essential that these decisions be based on sound, unbiased information. The ability to recognize potential biases in presented information is a necessary first step in reducing the incidence of bad decisions based on biased data.

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APPENDIX A
QUESTIONNAIRE

GENERAL QUESTIONNAIRE

1) Number of years of management experience: ______________

2) Total number of years of work experience: ______________

3) Formal educational background: (check applicable items)
   * Science
   * Engineering
   * Management
   * Other ________________________________________

4) Highest degree earned: __________________________

5) Year of highest degree: _________________________

6) Age ______________

THE FOLLOWING IS TO BE FILLED OUT AFTER THE SESSION IS OVER:

7) If you think you know what the specific objective of this study is, please write your guess below:

8) This spacе provided for any comments you may have:

## QUESTIONNAIRE 1

1) If you are forced to choose one or the other of the two alternatives presented without any further information, which would you select? (circle your choice):

a) Contact Lenses b) Glasses

2) Indicate your level of confidence that this is the correct decision for your organization:

No confidence Very Confident
0 1 2 3 4 5 6 7 8 9 10

3) Indicate the importance of the following factors in making your decision:

** The data presented
No importance Very important
0 1 2 3 4 5 6 7 8 9 10

** The recommendations made by presenter
No importance Very important
0 1 2 3 4 5 6 7 8 9 10

4) To the best of your recollection, draw a graph of the data that was presented.

5) What further information (if any) would you like to have to aid in making your decision (what other questions would you like answered)?

## QUESTIONNAIRE 2

1) If you are forced to choose one or the other of the two alternatives presented without any further information, which would you select? (circle your choice):

a) Yellow sunglasses    b) Neutral gray sunglasses

2) Indicate your level of confidence that this is the correct decision for your organization:

No confidence                                        Very Confident
0 1 2 3 4 5 6 7 8 9 10

3) Indicate the importance of the following factors in making your decision:

** The data presented
No importance                                        Very important
0 1 2 3 4 5 6 7 8 9 10

** The recommendations made by presenter
No importance                                        Very important
0 1 2 3 4 5 6 7 8 9 10

4) To the best of your recollection, draw a graph of the data that was presented.

5) What further information (if any) would you like to have to aid in making your decision (what other questions would you like answered)?

## QUESTIONNAIRE 3

1) If you are forced to choose one or the other of the two alternatives presented without any further information, which would you select? (circle your choice):

a) Display A b) Display B

2) Indicate your level of confidence that this is the correct decision for your organization:

No confidence Very Confident
0 1 2 3 4 5 6 7 8 9 10

3) Indicate the importance of the following factors in making your decision:

** The data presented
No importance Very important
0 1 2 3 4 5 6 7 8 9 10

** The recommendations made by presenter
No importance Very important
0 1 2 3 4 5 6 7 8 9 10

4) To the best of your recollection, draw a graph of the data that was presented.

5) What further information (if any) would you like to have to aid in making your decision (what other questions would you like answered)?

## APPENDIX B

## INFORMED CONSENT FORM

The purpose of this form is to provide you with specific information required for any study done at MIT and to obtain your written consent to participate in the study as described.

A set of three 10 minute presentations will be made to you. After each presentation you will be requested to fill out a short questionnaire pertaining to that presentation. These questionnaires will form the basis for investigating communications between technical personnel and their management chain. There are no risks or discomforts involved in this study.

You may benefit from this study by becoming aware of an aspect of technical communications that you were not previously aware of. A full presentation of the results and the specific objectives of this study will be provided to all participants during the Spring of 1985.

If you have any questions concerning the experiment please feel free to ask the investigator. You may discontinue participation in the study at any time without prejudice. All responses will be kept confidential and participants' names will not be included on the questionnaire.

The following is a required statement:

There is no other form of compensation, financial or insurance, furnished to research subjects merely because they are research subjects. Further information may be obtained by calling Thomas Henneberry at 253-2822.

I have read and understood this form and hereby give my consent to participate in this study.

Signed: ------------------------- Date: -----------

## APPENDIX C

## RAW QUESTIONNAIRE DATA FOR QUESTIONS #1, #2, #3

Table C. Raw Data for questions #1, #2, #3

| Subj No. | Pres #1 Conf | Pres #1 Data | Pres #1 Prs | Pres #2 Conf | Pres #2 Data | Pres #2 Prs | Pres #3 Conf | Pres #3 Data | Pres #3 Prs |
|---|---|---|---|---|---|---|---|---|---|
| Group #1 (X bias) | | | | | | | | | |
| 1 | 7 | 8 | 8 | -9 | 9 | 0 | 0 | 5 | 0 |
| 2 | 6 | 8 | 8 | -6 | 8 | 2 | 7 | 8 | 10 |
| 3 | 7 | 9 | 10 | 9 | 10 | 7 | 6 | 6 | 9 |
| 4 | 3 | 6 | 8 | -4 | 5 | 3 | 9 | 9 | 9 |
| 5 | 1 | 5 | 1 | 7 | 8 | 5 | 4 | 6 | 6 |
| 6 | 0 | 10 | 5 | 0 | 0 | 3 | 0 | 0 | 0 |
| 7 | 3 | 9 | 9 | -5 | 10 | 3 | 3 | 8 | 3 |
| 8 | -2 | 0 | 0 | -6 | 10 | 0 | 1 | 1 | 7 |
| 9 | -6 | 3 | 2 | 7 | 7 | 4 | 7 | 8 | 4 |
| 10 | 6 | 6 | 7 | 7 | 6 | 5 | 8 | 7 | 7 |
| 11 | 7 | 9 | 6 | 8 | 9 | 5 | 6 | 6 | 8 |
| 12 | 7 | 7 | 1 | 6 | 8 | 1 | 6 | 6 | 3 |
| Group #2 (Y bias) | | | | | | | | | |
| 13 | * | * | * | 7 | 10 | 5 | 5 | 7 | 9 |
| 14 | 4 | 7 | 7 | 5 | 7 | 7 | 0 | 10 | 2 |
| 15 | 10 | 10 | 5 | 5 | 4 | 7 | 7 | 6 | 8 |
| 16 | -5 | 3 | 2 | -3 | 6 | 2 | 2 | 2 | 2 |
| 17 | 9 | 8 | 8 | 6 | 7 | 5 | 8 | 9 | 6 |
| 18 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| 19 | 7 | 9 | 8 | 6 | 8 | 5 | 6 | 5 | 6 |
| 20 | 8 | 8 | 8 | 7 | 6 | 8 | 7 | 8 | 8 |
| 21 | -4 | 3 | 1 | 4 | 8 | 3 | 0 | 9 | 9 |
| 22 | 3 | 2 | 7 | 4 | 5 | 7 | 5 | 4 | 7 |
| 23 | 5 | 9 | 5 | 4 | 8 | 3 | 1 | 9 | 7 |

* Subject arrived late

Note: Conf = confidence level that decision was correct one (negative values indicate choice against the bias direction), Data = importance of data presented in making decision, Prs = importance of presenter's recommendation in making decision. All scores on scale of 0 to 10 (-10 to 10 for Conf due to including bias direction factor).

AD-A162 605 BIAS AND MISINFORMATION IN TECHNICAL AND MANAGERIAL COMMUNICATIONS(U) HARRY G ARMSTRONG AEROSPACE MEDICAL RESEARCH LAB WRIGHT-PATTERSON AFB OH H L TASK SEP 85 2/2

UNCLASSIFIED AAMRL-TR-85-054 F/G 5/11 NL

1.0
1.1
1.25
1.4
1.6
1.8
2.0
2.2
2.5
2.8
3.2
3.6
4.0

MICROCOPY RESOLUTION TEST CHART
NATIONAL BUREAU OF STANDARDS-1963-A

APPENDIX D

TRANSPARENCIES USED FOR PRESENTATIONS

APPLIED VISION RESEARCH PROGRAM
REVIEW

- EFFECT OF YELLOW SUNGLASSES ON TARGET DETECTION PERFORMANCE
- COMPARISON OF CONTACT LENSES VERSUS GLASSES: EFFECT ON VISUAL CAPABILITY
- DISPLAY IMAGE QUALITY: A COMPARISON OF DISPLAY APPROACH A AND B

D-1. Transparency #1: both groups

CONTACT LENSE VS GLASSES:
EFFECT ON VISUAL CAPABILITY

- PROBLEM:
  - SHOULD ASTRONAUTS WHO REQUIRE VISUAL CORRECTION BE FITTED FOR GLASSES OR CONTACT LENSES
- APPROACH:
  - MEASURE CONTRAST DETECTION CAPABILITY OF TWO GROUPS OF SUBJECTS: ONE GROUP WITH GLASSES, THE SECOND GROUP WITH CONTACT LENSES

D-2. Transparency #2: both groups; presentation #1

## CONTACT LENSES VS GLASSES STUDY

- 44 TOTAL SUBJECTS (22 WITH GLASSES, 22 WITH CONTACT LENSES)
- ALL SUBJECTS WERE FITTED FOR STUDY
- SUBJECT GROUPS WERE BALANCED FOR AGE, GENDER AND LEVEL OF CORRECTION REQUIRED
- CONTRAST DETECTION ABILITY WAS MEASURED USING STANDARD SINE WAVE (FUZZY BARS) TECHNIQUE
- EACH SUBJECT WAS MEASURED 5 TIMES OVER A PERIOD OF 4 WEEKS
- CONTRAST DETECTION ABILITY WAS COMPARED BETWEEN THE TWO GROUPS

D-3. Transparency #3: both groups; presentation #1

## CONTRAST DETECTION TECHNIQUE

- SUBJECTS WERE ADAPTED TO ROOM ILLUMINATION LEVEL
- SINE WAVE TARGET (FUZZY BARS) WAS PRESENTED ON VIDEO SCREEN AT VERY LOW (SOMETIMES ZERO) CONTRAST
- TARGET CONTRAST WAS INCREASED UNTIL SUBJECT COULD DETECT TARGET
- PROCEDURE WAS REPEATED 6 TIMES AND AN AVERAGE CONTRAST WAS RECORDED
- TARGET SPATIAL FREQUENCY WAS INCREASED (SMALLER FUZZY BARS, CLOSER TOGETHER) AND PROCEDURE WAS REPEATED
- AVERAGE DETECTION CONTRAST AS FUNCTION OF SPATIAL FREQUENCY WAS RECORDED

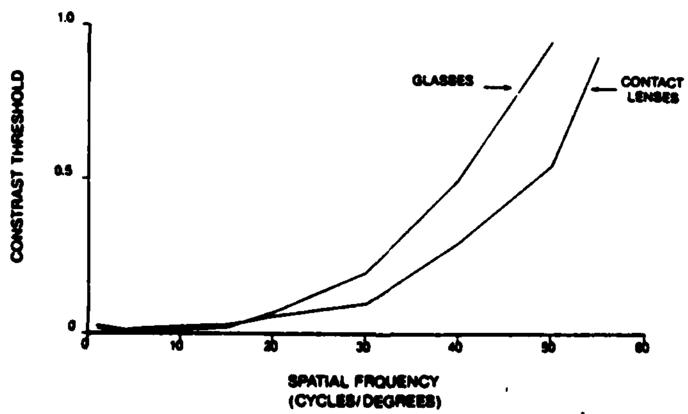
D-4. Transparency #4: both groups; presentation #1

## CONTRAST DETECTION TECHNIQUE

- CONTRAST DETECTION THRESHOLD WAS CONVERTED TO A CONTRAST SENSITIVITY BY TAKING THE RECIPROCAL OF THE CONTRAST THRESHOLD
- THIS HAS THE ADVANTAGE OF PROVIDING LARGER NUMBERS FOR BETTER PERFORMANCE INSTEAD OF VICE VERSA

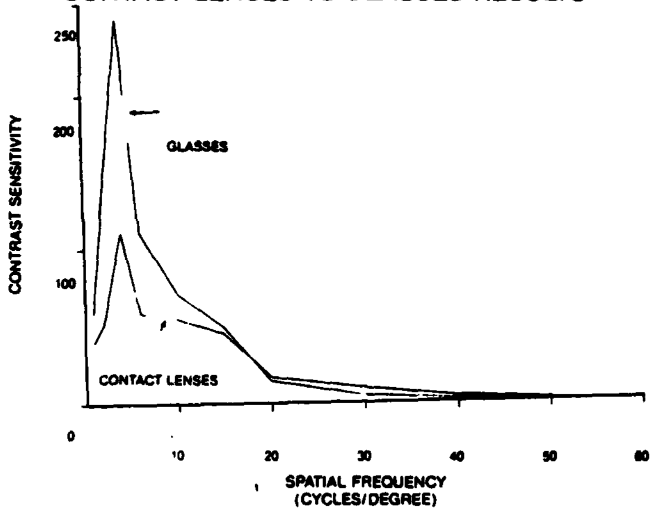
D-5. Transparency #5B: group #2 only; presentation #1

## CONTACT LENSES VS GLASSES RESULTS




D-6. Transparency #6A: group #1 only; presentation #1

CONTACT LENSES VS GLASSES RESULTS




D-7. Transparency #6B: group #2 only; presentaton #1

CONTACT LENSES VS GLASSES
CONCLUSIONS

- CONTACT LENSES RESULT IN SUPERIOR VISUAL PERFORMANCE AT THE HIGH FREQUENCY END COMPARED TO GLASSES
- RECOMMENDATION:
  - ASTRONAUTS SHOULD BE ISSUED CONTACT LENSES

D-8. Transparency #7A: group #1 only; presentation #1

CONTACT LENSES VS GLASSES
CONCLUSIONS

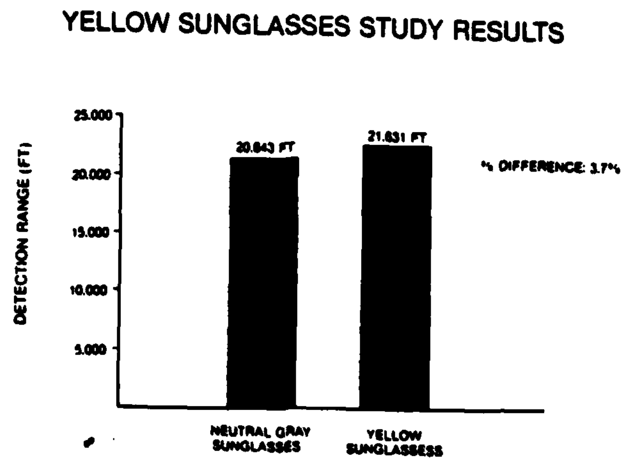
- GLASSES RESULT IN SUPERIOR VISUAL PERFORMANCE AT THE LOW FREQUENCY END COMPARED TO CONTACT LENSES
- RECOMMENDATIONS:
  - ASTRONAUTS SHOULD BE ISSUED GLASSES

D-9. Transparency #7B: group #2 only; presentation #1

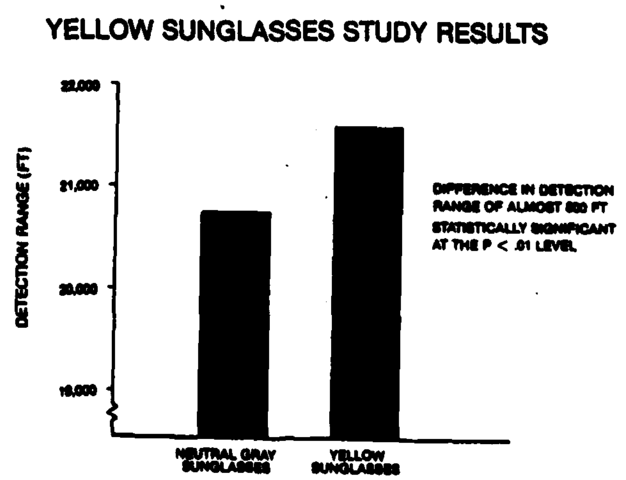
EFFECT OF YELLOW SUNGLASSES ON
TARGET DETECTION PERFORMANCE

- OBJECTIVE:
  - DETERMINE IF YELLOW SUNGLASSES IMPROVE GROUND-TO-AIR TARGET DETECTION PERFORMANCE COMPARED TO STANDARD NEUTRAL GRAY SUNGLASSES
- EXPERIMENT:
  - 20 TRAINED OBSERVERS SERVED AS SUBJECTS
  - SUBJECTS PARTICIPATED IN PAIRS: ONE WITH YELLOW SUNGLASSES, ONE WITH NEUTRAL GRAY
  - SUBJECTS' TASK WAS TO DETECT "AS SOON AS POSSIBLE" INCOMING AIRCRAFT
  - 40 TRIALS PER SUBJECT; 800 OBSERVATIONS TOTAL
  - RANGE TO TARGET AT DETECTION WAS RECORDED

D-10. Transparency #8: both groups; presentation #2




D-11. Transparency #9B: group #1 only; presentation #2




D-12. Transparency #9A: group #2 only; presentation #2

YELLOW SUNGLASSES STUDY
RECOMMENDATIONS

- CONCLUSION:
  - INSIGNIFICANT OPERATIONAL DIFFERENCE BETWEEN YELLOW SUNGLASSES AND NEUTRAL GRAY
- RECOMMENDATIONS:
  - DISCONTINUE RESEARCH IN YELLOW SUNGLASSES AND PROCEED WITH LESS EXPENSIVE NEUTRAL GRAY SUNGLASSES

D-13. Transparency #10B: group #1 only; presentation #2

YELLOW SUNGLASSES STUDY
RECOMMENDATIONS

- CONCLUSION:
  - YELLOW SUNGLASSES SHOW A SIGNIFICANT IMPROVEMENT IN TARGET DETECTION PERFORMANCE COMPARED TO THE LESS EXPENSIVE NEUTRAL GRAY
- RECOMMENDATION:
  - CONTINUE FUNDING R&D IN YELLOW SUNGLASSES TO REDUCE COST AND DEVELOP PRODUCTION PROTOTYPE

D-14. Transparency #10A: group #2 only; presentation #2

## VIDEO DISPLAY IMAGE QUALITY: A COMPARISON OF DISPLAY APPROACH A AND B

- EVALUATION OF TWO COMPETING VIDEO DISPLAY TECHNOLOGIES
- OBJECTIVE:
  - DETERMINE WHICH OF THE TWO TECHNOLOGIES SHOULD BE FUNDED FOR FURTHER DEVELOPMENT
- APPROACH:
  - COMPARE PHOTOMETRIC MEASUREMENTS OF EACH DISPLAY TYPE UNDER STANDARD OPERATING CONDITIONS

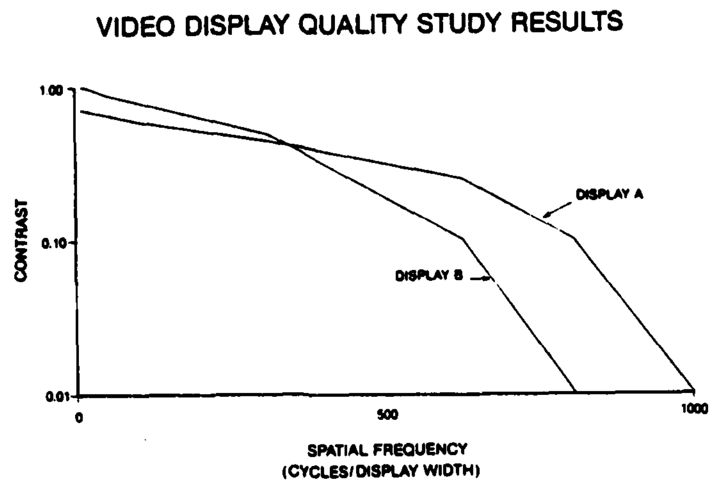
D-15. Transparency #11: both groups; presentation #3

## VIDEO DISPLAY QUALITY

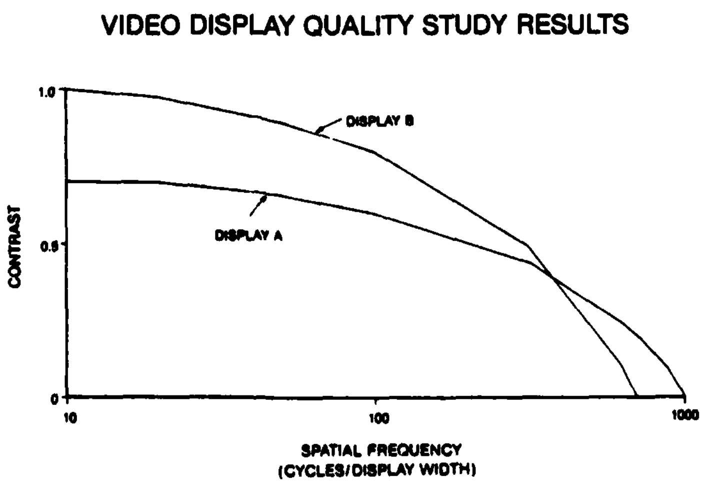
**MEASUREMENT PROCEDURE**

- MODULATION TRANSFER FUNCTION (MTF) WAS USED AS MEASURE OF IMAGE QUALITY
- MTF PROCEDURE DESCRIPTION:
  - INPUT SINE WAVE SIGNAL TO OBTAIN IMAGE OF SINE WAVE ON DISPLAY (FUZZY BARS)
  - USE PHOTOMETER TO MEASURE CONTRAST (MODULATION) OF IMAGED SINE WAVE
  - REPEAT STEPS WITH HIGHER FREQUENCY SINE WAVE (FUZZY BARS ARE SMALLER AND CLOSER TOGETHER)
  - MTF IS GRAPH OF CONTRAST VS FREQUENCY

D-16. Transparency #12: both groups; presentation #3




D-17. Transparency #13A: group #1 only; presentation #3




D-18. Transparency #13B: group #2 only; presentaton #3

VIDEO DISPLAY QUALITY CONCLUSIONS

- DISPLAY APPROACH "A" HAS A FAR SUPERIOR HIGH FREQUENCY RESPONSE COMPARED TO "B"
- RECOMMENDATION:
  - CONTINUE FUNDING "A"; DISCONTINUE FUNDING FOR "B"

D-19. Transparency #14A: group #1 only; presentation #3

VIDEO DISPLAY QUALITY CONCLUSIONS

- DISPLAY APPROACH "B" HAS A FAR SUPERIOR LOW FREQUENCY RESPONSE COMPARED TO "A"
- RECOMMENDATION:
  - CONTINUE FUNDING "B"; DISCONTINUE FUNDING FOR "A"

D-20. Transparency #14B: group #2 only; presentation #3

THAT CONCLUDES THE RESEARCH REVIEW BRIEFING

- PLEASE ANSWER QUESTIONS ON QUESTIONNAIRE
- IF YOU HAVE ANY QUESTIONS CONCERNING THE MATERIAL PRESENTED (i.e. YOU FEEL MORE INFORMATION IS NEEDED) PLEASE **WRITE** THESE QUESTIONS ON THE QUESTIONNAIRE IN THE SPACE PROVIDED
- WHEN YOU ARE FINISHED, PLEASE HAND IN QUESTIONNAIRE AND PLEASE **DO NOT DISCUSS THIS PRESENTATION WITH ANYONE OUTSIDE THIS ROOM!**
- THANKS FOR YOUR PARTICIPATION

D-21. Transparency #15: both groups; conclusion



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