Displaying Numerical Information

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In determining how to best present numerical information to a jury, the attorney must keep in mind that visual displays have both informational value and interest value. However, the information actually relayed and interest actually generated by visual displays depend on their design. Set forth here are the considerations to be made when choosing a format for displaying numerical information, as well as when determining various attributes of the format.

Numerical information that exemplifies, explains, and supports what is said at trial is frequently presented visually as well as verbally to jurors. These visual displays improve communication by relaying numerical information more clearly and heightening jurors' attention and interest. Visual aids help jurors grasp and absorb what is otherwise difficult information for them to process, retain, and recall. Jurors also become more alert and concentrate harder when numerical information is visually displayed. As a result, visual displays of numerical data have both information and interest value, and either purpose is reason enough to justify their use.

Despite their potential, the information actually relayed and interest actually generated by visual displays depend on their design. Poorly designed visual displays of numerical information are confusing and irritating rather than informing and interesting. Displays must therefore be designed so as to maximize information and interest value. A format must be chosen for displaying the numerical information, and decisions about various attributes of the format (for example, geometry, texture, color) must also be made.

DISPLAY FORMATS

Types

Tables and graphs are the primary formats used to represent numerical information visually.

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Tables provide precise values and encourage jurors to focus on recall of exact numbers. Graphs enable jurors to take in quantitative information, organize it, and see patterns and structures not readily revealed by focusing on precise quantities. If the only goal is to convey numbers, tables are superior to graphs. If the only goal is to convey patterns and structures, graphs are superior to tables.[1]

Using a graphical format by itself and/or to complement a tabular format increases significantly the interest value of a visual display of numerical information.

Tables and graphs can both be used in a visual display to represent the same numerical information. Jurors typically need more time to grasp the meaning of a visual display containing both tabular and graphical formats of the same numerical information. Such time is often worth the investment, however, because jurors' comprehension of numerical information is greatly improved when it is provided visually in both tabular and graphical forms.[2] Accordingly, to increase the speed at which a visual display of numerical information is comprehended, use of both a table and a graph should be avoided; one or the other should be used depending on whether jurors need to focus on exact numerical values or on patterns and structures. To increase the accuracy at which a visual display of numerical information is comprehended, both a table and a graph should be used; jurors will then be able to extract precise values as well as patterns and structures in the numerical information.[3]

The interest value of tables and graphs must be considered along with their information value. Even when jurors prefer that numerical information be presented in tables (due to a need for precise numerical quantities), they nonetheless still significantly more *enjoy* a graphical format.[4] Further, a graphical format displayed with precise numerical estimates most *influences* decision makers, affecting how many ultimately agree with recommendations for action. The most agreement occurs when data are presented in both numerical and graphical forms.[5] Thus, using a graphical format by itself and/or to complement a tabular format increases significantly the interest value of a visual display of numerical information.

While tables are typically numerical in format, standard graphical formats such as bar charts, pie charts, and line graphs differ considerably from each other. No one tabular or graphical format is universally superior to others for visually displaying numerical information. Each format encourages jurors to make certain inferences, is more or less easily used for certain judgments, and is best comprehended by certain jurors.

Jurors have expectations about the message being communicated by different visual display formats. With tables, jurors expect to need to recall precise quantities, so they try to memorize tables by rote rather than grasping the general tenor of the meaning of the numbers. With pie charts, jurors expect to compare individual slices to the whole, and hence spontaneously make proportion-of-the-whole judgments and suppress recall of precise quantities and comparisons between slices. With bar charts, jurors expect to compare the length of the bars to each other, and so spontaneously make comparison judgments as to which are larger and which are smaller, but bar charts inhibit memorizing precise quantities or making proportion judgments. Line graphs encourage jurors to make individual trend judgments such as "increasing," "no change," or "up and down," or comparative trend judgments, such as "changing at the same rate" or "one group is increasing faster," but discourage a focus on precise quantities and proportion judgments. Thus, the usefulness of a table or graph depends on what type of information jurors need to extract and how that fits with their expectations of what they should do given the type of visual display.[6]

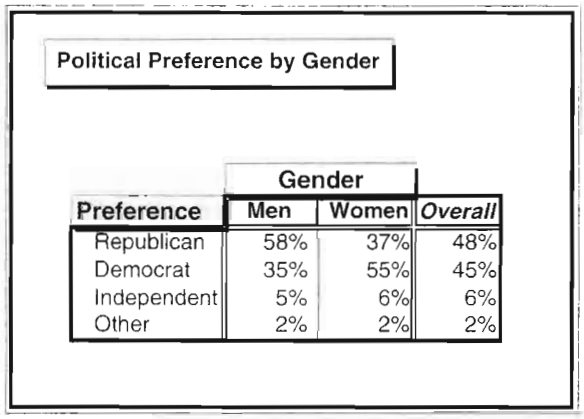
Tables

The different display formats vary in how easily jurors can extract desired information. Tables are difficult for jurors to decipher, thus hurting their information value despite their containing a great deal of information. For example, **Figure 1** uses a tabular format to display political preferences (Republican, Democrat, independent, other) as a function of gender (men, women). The table needs to be *studied* to grasp its meaning and, for the most part, one's focus is on the precise percentages provided rather than on comparisons between those percentages. Tables such as this are the fastest and best format for jurors to use to learn precise

quantities,[7] but they are one of the most difficult formats for jurors to use to make comparison judgments between point estimates.

Comparisons between numbers in tabular format are more easily made across columns than across rows.[8] So, for example, in **Figure 1** it is easier to compare men's and women's political preferences than it is to compare the gender makeup of Republicans and Democrats. Thus, tables are most useful for helping jurors extract specific numbers, but they make grasping other meanings, structures, and patterns difficult.

Figure 1. Tabular Format: Political Preference by Gender



	Gender		
Preference	Men	Women	*Overall*
Republican	58%	37%	48%
Democrat	35%	55%	45%
Independent	5%	6%	6%
Other	2%	2%	2%

Bar Charts

Bar charts can be used to display tabular information graphically. In bar charts, the geometric length of a bar is used to represent the absolute size of a number. This visual representation allows for easy identification of the long and short bars and is among the most convenient formats to use when making comparison judgments (that is, which bar is longest, second longest, and so forth). Precise quantities are difficult to extract from bar charts, which can partially be overcome by printing the precise numbers by each bar. Bar charts can employ either a horizontal or vertical orientation, as shown in **Figures 2** and **3**, respectively. Jurors generally find it easier to extract information from vertical bars (a judgment of height) where they can gaze up and down, such as in **Figure 3**, than from horizontal bars (a judgment of width) where they typically turn their heads sideways to regain an up-and-down orientation, such as in **Figure 2**.

Figure 2. Horizontal Bar: Political Preference by Gender

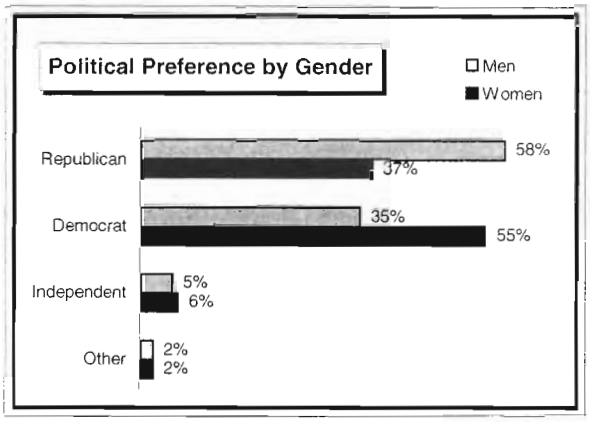
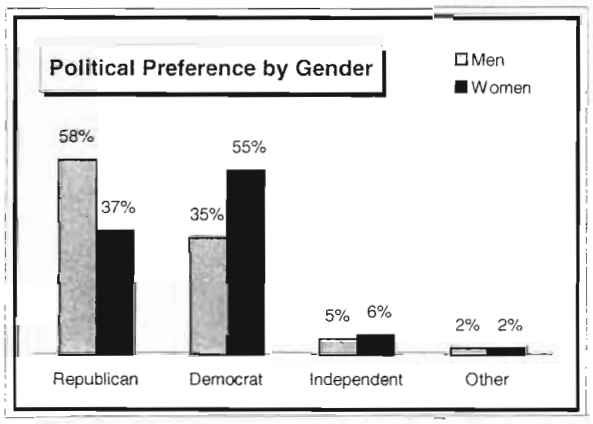


Figure 3. Vertical Bar: Political Preference by Gender

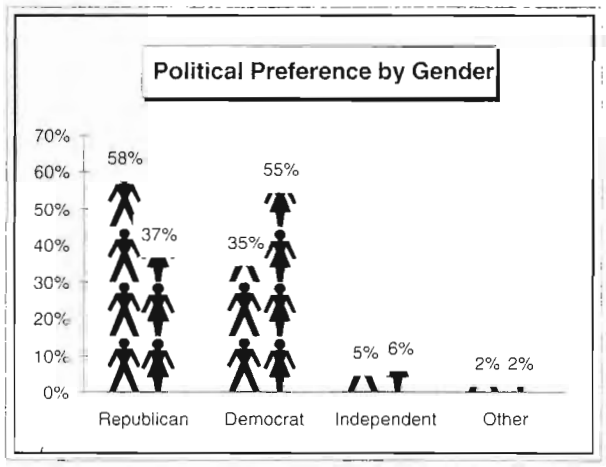


Each bar in a bar chart must be defined semantically, which can be accomplished either through direct labeling of bars or indirectly differentiating bars via color codes or patterning. A legend that labels each bar color or pattern is needed whenever bars are not labeled directly. Direct labeling of bars generates quicker readings and one-third fewer errors than reliance on legends because fewer cognitive steps and less dependence on short-term memory are needed. Indirectly labeling bars via legends requires additional time, effort, and memory on the part of jurors to translate each color or pattern into its assigned meaning.[9] Thus the charts in **Figures 2** and **3** could be improved if the bars were directly labeled not only with their precise numerical amounts but also their gender category.

Object displays can be used in bar charts to provide direct *visual* labeling when direct *verbal* labeling is impractical or dispreferred due to label length, loss of clarity, or other design considerations.

Object displays require finding a symbol that, when presented visually, easily and conveniently generates the correct verbal label in jurors' minds. For example, *figures* of men and women can be used to provide direct visual labeling of the different bars, as is exemplified in **Figure 4**. Object displays in bar graphs facilitate jurors' performance *only* if they are *relevant* to what is being judged and *immediate* in their meaning.[10] Though equally relevant, scientific symbols for men and women (depicted by a circle combined with either an arrow or a cross) are much less immediate in their meaning than are figures of men and women and so should be avoided as object displays in bar charts. Bar charts encourage jurors to make comparative judgments, which are facilitated by using a vertical orientation and direct labeling to reduce the cognitive load involved in making those judgments.

Figure 4. Object Display: Political Preference by Gender



Pie Charts

Pie charts are particularly well suited to determining sizes of parts of a whole and provide an alternative graphical representation to bar charts of tabular data. Pie charts provide an *integrated display* (the slice is provided relative to the pie as a whole), allowing proportion-of-the-whole judgments to be made more quickly and accurately than with *separated displays* such as bar charts or line graphs (where jurors must mentally compute the size of the bar or line relative to the whole). Pie charts also compare favorably with bar charts when making comparisons of combinations of proportions.[11] For example, in **Figure 5** the data on political preferences of men and women are provided in a pie chart format. Without much cognitive effort, more women are seen to be Democrats and more men are seen to be Republicans in their political preferences than anything else. Further, though somewhat more difficult, a visual comparison of the two largest slices from the women's and men's pies suggests the inversion of Democrat and Republican preferences evidenced previously, and about equally as well, in the bar chart.

Figure 5. Pie Chart: Political Preference by Gender

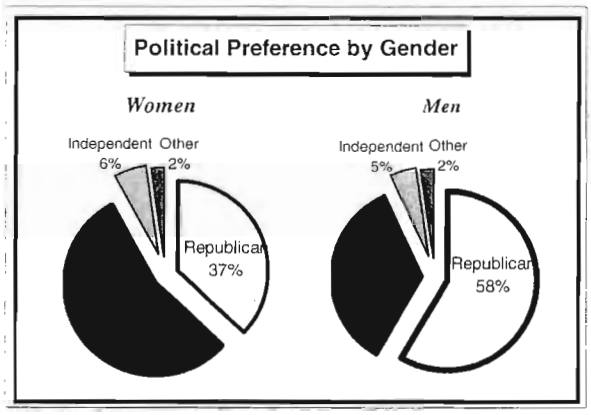
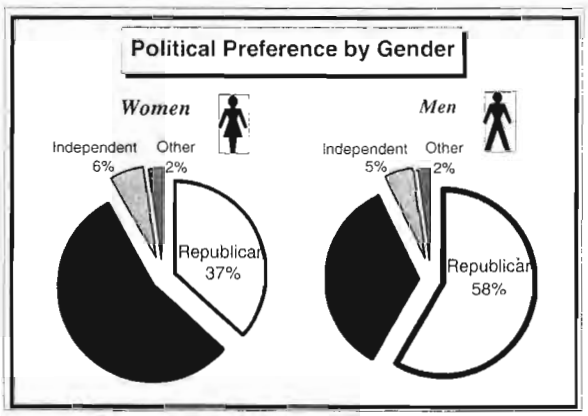


Figure 6. Pie Display: Political Preference by Gender



As with the bar chart, a pie chart can include precise quantities and direct labels—both verbal and visual—to permit jurors to assign meaning more easily to what they see. **Figure 6** inserts the figures for women and men as object displays, and comparison of it to **Figure 5** demonstrates the superiority of direct *visual* labeling over even direct *verbal* labeling when making estimates, judgments, and comparisons with graphical displays of numerical information. In their most basic form, pie charts are most suitable for proportion-of-the-whole judgments, while needing adjustment through use of direct labeling, listing of precise quantities, and use of object displays to

extract and grasp other meanings both accurately and rapidly.

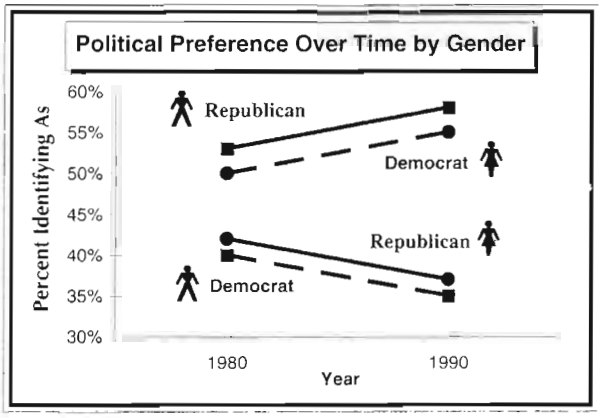
Line Graphs

Line graphs use *spatial* relations (directions of lines) to represent nonspatial relations (changes in values), such that moving from one point to another point on a line represents a change in the values of *two or more* variables simultaneously. Jurors are capable of extracting trend and change information from line graphs directly without having to examine individual points one by one. Accordingly, line graphs encourage jurors to extract information about trends and change while discouraging extraction of, or comparisons between, precise point values. Trends and change are judged more quickly and accurately with line graphs than pie charts, and this is particularly so when the rate of change is small (that is, the line has a very small slope).[12]

The most common form of line graph relates the values of two variables to each other, showing how changes in one variable correspond (if at all) to changes in the other variable. So, for example, line graphs are used to show how oil prices (variable 1) have fluctuated over the past 20 years (variable 2), or how minority employment (variable 1) is related to salaries (variable 2) in a particular firm. Jurors deal more competently with two-variable line graphs when one variable, plotted along the horizontal axis, is defined by time (for example, seconds, days, years, and so forth) or is time-dependent (for example, educational level, age, and so forth).[13] The concept of change and trend then becomes one of "change over time" or "trend over time."

Jurors often have more trouble extracting relevant information from line graphs (that is, change and trend information) than they have extracting display-appropriate information from bar charts (comparisons) or pie charts (proportions). In general, jurors are not very good at reading line graphs. It is not a matter of lacking the requisite cognitive skills, but instead not using them spontaneously.[14] Jurors who have trouble reading line graphs fail to engage in "graph checking," that is, examining the axes, naming the labels, identifying units of measurement and ranges of values, and so forth, and thus are often unable even to extract information spontaneously from line graphs displaying time-based relationships (change over time). As more trend lines are added to the same graph, more and more jurors fail to focus spontaneously on these judgments of change over time (20 percent to 40 percent of those who view the display).[15] Thus, jurors need to be assisted in their perception of line graphs by having witnesses engage verbally in "graph checking," thereby encouraging and permitting extraction of trend information.

Figure 7. Line Graph: Political Preference by Gender



For example, consider **Figure 7**, in which trend lines are provided for both men and women Republicans and Democrats for the years 1980 and 1990. This line graph contains three variables (political preference, gender, year) and four trend lines representing changes in political preference by males and females over a decade. This is a complex line graph requiring considerable cognitive effort to grasp its meaning. Because up to 40 percent of jurors may not make the desired trend inferences spontaneously, the witness or attorney introducing the graph should provide a verbal graph-check as part of testimony or argument. Graph-checking in this case would involve verbally naming the three variables, noting that the graph focuses on the percentage of men and women who identify themselves as Republicans and Democrats in each of two years (1980, 1990), and then examining how those political preferences have changed over time for men and women Republicans and Democrats (men have become increasingly conservative while women have become increasingly liberal).

Because this line graph is complex, direct visual and verbal labeling is used to help reduce the cognitive load required to understand the graph. Gender is dually coded visually with object displays of male and female *figures* and the use of circles (for women) and squares (for men) marking the *endpoints* of the relevant lines. Similarly, political preference is also dually directly coded, via *verbal* labels (Republican, Democrat) and visu-

al distinctions in *line type* (continuous for Republican; dashed for Democrat). As with bar charts, directly labeling the lines reduces judgment errors substantially versus relying on legends to the side or below the graph.[16] Even so, **Figure 7** illustrates the more difficult task of assessing change over time that is magnified by including three variables and four trend lines in the line graph. Nonetheless, line graphs are still *superior* for extracting trend information compared to other numerical display formats.

Dimensionality

Standard bar charts and pie charts rely on *two*-dimensional objects (rectangles, circles) to represent the proportional distribution (the grouping, arrangement, and configuration) of *one*-dimensional variables. For example, **Figures 2** through **6** use such two-dimensional objects as horizontal and vertical bars, gender figures, and pie slices to depict the proportional classification of men's and women's political preference along *one* dimension, that being "political party affiliation." These two-dimensional representations use objects having height and width, but not depth. Three-dimensional bar charts and pie charts are constructed by adding depth to the objects, using *boxes* rather than *rectangles* and using *wedges* rather than *slices*, as is depicted in **Figures 8** and **9**, respectively. While these three-dimensional bar and pie charts are aesthetically more pleasing to the eye, they offer no *new* information, they are more difficult to read and remember accurately, and jurors feel less confident using them. Three-dimensional objects depict one-dimensional variables poorly.[17]

Like bar and pie charts, line graphs can be drawn in either two or three dimensions. However, unlike bar and pie charts, line graphs depict relationships *between* two or more variables simultaneously; that is, line graphs inherently depict *two*-dimensional (or higher) relationships of variables. As was the case with three-dimensional charts, jurors find three-dimensional line graphs more difficult to use and remember accurately.[18]

Higher dimensional graphs of any type—line, bar, pie—are judged more *quickly* than their two-dimensional counterparts, though this speed comes at the expense of accuracy. Jurors read and recall three-dimensional graphs less well than two-dimensional graphs, suggesting use of higher dimensions should be avoided (unless inaccuracy is desired!).[19] Three-dimensional representations are superior only when the third dimension is necessary to understand the numerical information.[20]

Figure 8. 3-D Bar Chart: Political Preference by Gender

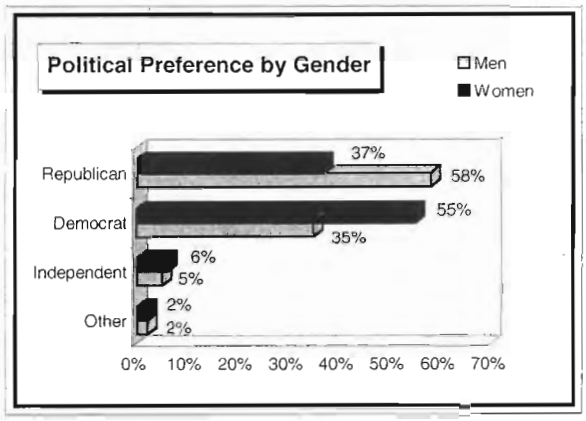
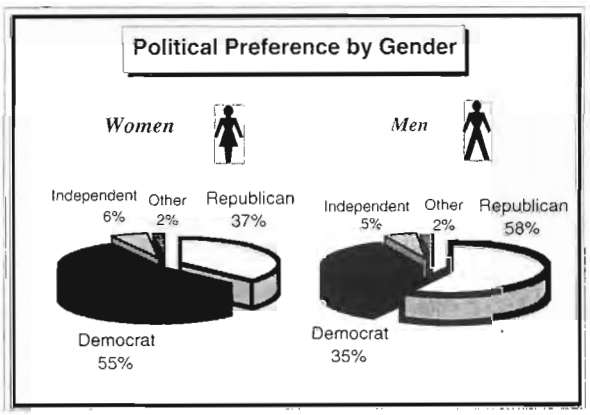


Figure 9. 3-D Pie Display: Political Preference by Gender



Color

Tables and graphs can be designed with or without color. Jurors *prefer* tables and graphs that use color, giving them more attention and finding them more interesting. This increased interest occurs not only if color is used meaningfully (for color coding of bars, pie slices, and so forth), but also if only used decoratively (for aesthetic purposes on borders, labels, and so forth). Color enhances the interest value of visual displays of numerical information.[21]

Using color also improves jurors' performance in reading tables and graphs. Jurors find colored displays less effortful to read and so do so more rapidly. Using color helps jurors better comprehend

tables and graphs if it replaces the need for a separated legend, but otherwise tends not to influence the accuracy of their judgments.[22] Thus, using color promotes the interest value of tables and graphs and might help jurors better encode their information value.

What's the "Optimal" Display Format?

No one display format is universally superior to another. Tables, bar charts, pie charts, and line graphs each encourage jurors to make certain inferences and are more or less easily used for certain judgments. The "optimal" display format for numerical information depends on *what* information is critical for jurors to extract (precise quantities, comparisons, proportions, trends) and *which* format best encourages extraction of that information. Displays should be designed to maximize both their information and interest value.

JURORS' UNDERSTANDINGS OF VISUAL DISPLAYS

While the display format influences jurors' attention and learning of the numerical information, the jurors themselves are not passive participants in the process. *Who* the jurors are and *how* they think affect what they will learn and the judgments they will draw from the displays. The effectiveness of visual displays of numerical information depends not only on the nature of the display, but also on those who perceive it, that is, on the jurors, their natures, and how they, as individuals, think.

Differences Among Jurors

Jurors are rarely a homogeneous group, instead differing among themselves both psychologically and sociologically in their preferences for, and ability to comprehend, different display formats.

Certain display formats are preferred and better understood by certain jurors than others. Less intelligent and less well educated jurors prefer pictorial charts to other display formats, and are much less positively predisposed to line graphs than more intelligent and better educated jurors.[23] Logical thinking structures and skills are related to the ability to interpret line graphs correctly.[24] Bar and pie charts are easier to use because they require fewer mental operations to understand them.[25]

Who *the jurors are and* how *they think affect what they will learn and the judgments they will draw from the displays.*

While jurors' *levels* of technical training do not affect the accuracy of their judgments of different display formats,[26] their *familiarity* with the format matters greatly. Display formats with which jurors are familiar are judged as less complex and easier to comprehend, and jurors perform better with them. For example, businesspeople are accustomed to and do better with tables, while engineers are more familiar and do better with line graphs.[27] Familiarity perhaps accounts for why men outperform women in reading graphs but are equal in their ability to read tables.[28] Unfamiliar formats can be introduced by first providing the information in a familiar form.[29]

Biases in Perception

Visual displays of numerical information, particularly graphs, are not perceived by jurors without distortion. The *objects* used in visual displays, the *reference points* by which jurors orient, and the *scaling* and layout of graphs all influence the understandings, estimates, comparisons, and judgments made by jurors of the depicted numerical information.

Objects Used in Displays

Which objects are used in graphs—be they circles, bars, boxes, or wedges—matters to how accurately jurors extract the numerical information. Visual perception of objects can distort the true mathematical distributions and relationships. Jurors' judgments of *length* of objects in graphs tend to be unbiased, whereas their judgments of area and volume show systematic distortions. Jurors quite accurately estimate and compare the length of bars in two-dimensional bar charts, but are more prone to making systematic errors in comparing areas of circles (as in pie charts) or volumes of boxes and wedges (as in three-dimensional bar and pie charts).[30] For example, when the *area* of a *circle* is used to indicate the *amount* of a variable, jurors will *misperceive*

the differences between circles. In **Figure 10**, total minority hires in a firm over a 30-year period are represented by circles drawn on a *diameter* basis, and the far-right-hand circle representing the number of 1990 minority hires shows up *more prominently* than the *actual* figures would justify. Circles sized on a *diameter* basis mislead jurors into *overestimating* differences. In this case, jurors overestimate the increase in minority hiring, especially from 1980 to 1990. In **Figure 11**, total minority hires are represented by circles drawn on a total-area basis, and the right-hand circle now visually appears less prominently than the figures would justify. Circles sized on a total-area basis mislead jurors into underestimating differences. In this case, jurors underestimate the increase in minority hiring, especially from 1980 to 1990. Thus, when accuracy is desired in comparisons, pies of different sizes should never be used; bars should be used instead, as they have all the advantages of circles with none of the disadvantages. When objects vary in their area or volume, jurors can be expected to reach incorrect conclusions, either over- or underestimating actual differences.

Reference Points for Comparisons

Jurors *orient* to visual displays, locating *reference points* on which to make comparisons and extract information. The "middle" is an important reference point in almost all types of graphs. For example, the "middle" or "50 percent" point is an important reference point in the spatial judgment of proportion. Jurors estimate the proportions of bars and pie slices nearer to the 50 percent point in area more accurately than bars or slices that are very large (over 75 percent of the area in size) or very small (less than 25 percent of the area in size). Very small bars and slices are *overestimated*, that is, jurors believe that these small amounts are bigger than they actually are. By contrast, very large bars and slices are *underestimated*, that is, jurors believe that these very large amounts are smaller than they actually are. If the accurate perception of such very small or very large amounts is critical, then a *table* should be used rather than a graph, as it prevents visual displays from distorting jurors' perceptions. Use of visual displays depicting very large or very small amounts is likely to lead jurors to believe the amounts are closer to the "middle" or "50 percent" point than they actually are.[31]

Figure 10. Circle Chart Based on Diameter (1990 Increase Overestimated)

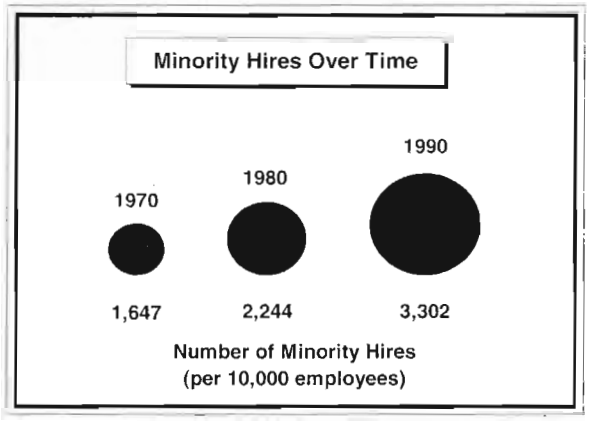
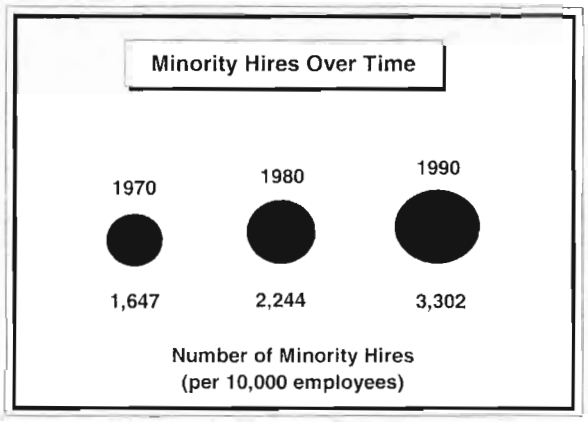


Figure 11. Circle Chart Based on Total Area (1990 Increase Underestimated)



Jurors also orient to the "middle" on line graphs, but here the middle is an imaginary line crossing in a *diagonal* direction across the graph. An "increasing" diagonal line is a *reference line* following a 45-degree angle starting from the lower left-hand corner of the graph and moving toward the upper right-hand corner, and is used to orient to "increasing" functions. A "decreasing" diagonal line is a *reference line* following a 45-degree angle downward starting from the upper left-hand corner of the graph and moving toward the lower right-hand corner, and is used to orient to "decreasing" functions. **Figure 12** illustrates each of these reference lines.

Jurors will perceive lines as being *closer* to the 45-degree angle than they really are. If line graphs depict relationships between variables that increase sharply relative to the reference line, jurors will perceive the increases *less* sharply than they *actually* are. Similarly, if line graphs depict relationships between variables that increase

slightly relative to the reference line, jurors will perceive the increases *more* sharply than they *actually* are.[32] Thus, similar to perception of extremes in judgment of proportions in bar and pie charts, extremely small or extremely large changes in variables in line graphs tend to be "regressed" to a middle range.

Figure 12. Reference Lines Used for Orienting to Line Graphs

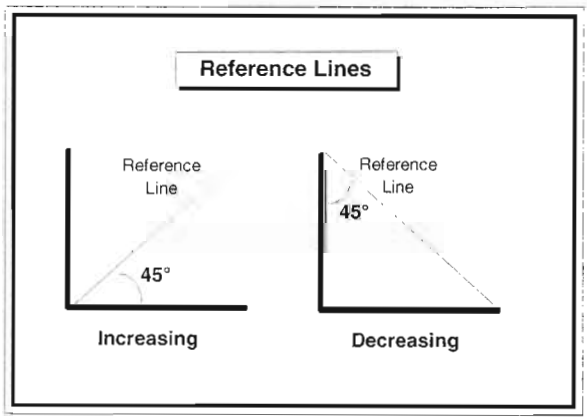
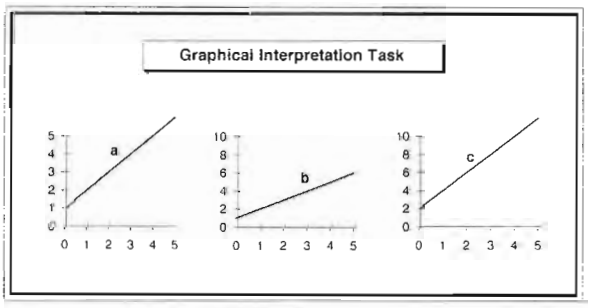


Figure 13. Graphs Illustrating Visual and Numerical Similarities and Differences



Scaling and Layout

The steepness and inclination of lines in line graphs are, however, greatly dependent on their scaling. Changing a graph's height relative to its width—that is, changing its *aspect ratio*—alters how *steeply* lines depicting numerical information are drawn relative to *fixed* reference lines (which maintain 45-degree angles). Line graphs are rescaled, that is, their aspect ratio is altered, by stretching or shortening their axes or by enumerating different ranges of values on the axes. Such rescaling can make *identical* information seem *different* and *different* information seem *identical*. For example, **Figure 13** shows plots of three line graphs. Two of these graphs (a and c) are similar *visually* and two are similar *numerically* (a and b); however, the *visually* similar graphs (a and c) are not *numerically* similar, that is, the visually similar graphs plot different information while the visually dissimilar graphs plot the same information. Rescaling of the line graphs makes the identical information in graphs a and b appear different and the different information in graphs a and c appear identical. Roughly 30 percent to 50 percent of jurors focus on a graph's *visual layout* without examining its *exact scaling* and, therefore, misjudge the "true" steepness and similarity of lines plotted on differently scaled line graphs.[33]

Line graphs can be scaled, that is, their aspect ratio set, so as to generate desired perceptions of steepness. For example, the *mildly* increasing and decreasing changes in political preferences by men and women between 1980 and 1990 depicted previously in **Figure 7** are now *definitely changing* in **Figure 14** but *nearly unchanging* in **Figure 15**. In **Figure 14**, the graph's height is increased (vertical axis stretched) and its width decreased (horizontal axis shortened), and the plotted lines appear *steeper*. In **Figure 15**, the height of the graph does not change but a greater range of values are enumerated vertically (20% to 70% versus 30% to 60% in **Figure 7**) and the horizontal axis is "stretched," thereby greatly reducing the slopes of the lines. The reference lines remain at 45-degree angles in both figures, but rescaling of the graphs by changing their heights relative to their widths alters the *extent* to which change over time *appears visually* to be occurring.[34]

The extent to which lines rise upward or downward not only influences jurors' *visual perception*, but also their *verbal conceptualization* of the nature of the relationships between the variables. Jurors do not verbally encode visual information from line graphs in precise, quantitative ways; rather, visual information is condensed and summarized and assigned a linguistic label capturing the "essence" of what is perceived. The *angle* (or slope) of a line is directly related to whether jurors will use the *linguistic* labels of "slightly increasing" and "sharply increasing" to describe verbally what they perceive visually. Lines rising upward at a 40-degree angle are labeled verbally by 70 percent of jurors as "sharply increasing," while 90 percent of jurors will so label lines rising upward at a 60-degree angle. Lines that rise upward at no more than a 15-degree angle are verbally comprehended by 90 percent of jurors as "slightly increasing," while nearly every single juror labels a line that way if it rises upward at no more than a 5-degree angle. Jurors have an extensive mental vocabulary

for describing the shapes and directions of lines, and words in this vocabulary are *activated* by the *angles* at which lines are drawn in line graphs. Thus, line graphs can be *scaled* to *activate* desired linguistic labels.[35]

Figure 14. Rescaled Line Graph (Definitely Increasing/Decreasing)

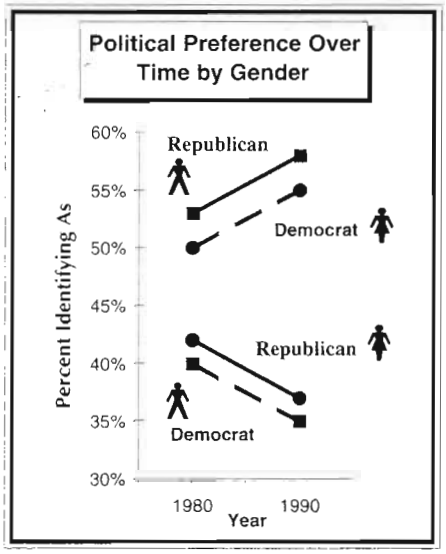
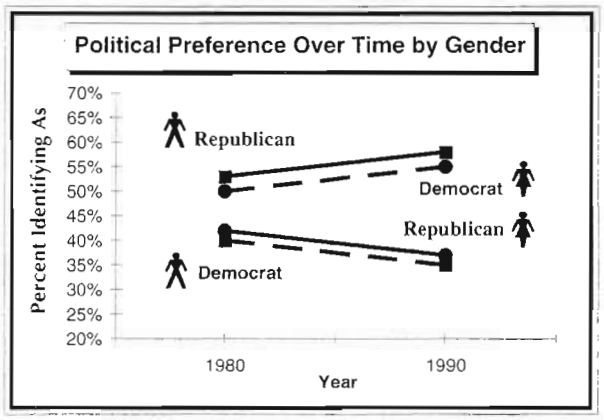


Figure 15. Rescaled Line Graph (Barely Increasing/Decreasing)



Bar charts as well as line graphs can be *scaled visually* to alter jurors' verbal conceptualizations of the numerical information in displays. Bar charts and line graphs require slightly different slopes to achieve the same level of agreement that a change is "slightly increasing" or "sharply increasing." The slope needed for bar charts is less than the slope needed for line graphs to get the same percentage agreement of the applicability of the label. Suppose, for example, you want jurors to infer from a bar chart that the price of oil increased sharply during the late 1970s. The underlying slope of the displayed trend in oil prices needs to be chosen so jurors' verbal description will be a label of "sharply increasing" when they see the chart. To get 70 percent of jurors to agree that oil prices sharply increased based on their visual perception of a bar chart, the slope of the trend line going through the bars must rise upward at a 32-degree angle (somewhat less than the 40-degree angle needed for line graphs). This 32-degree angle translates into an aspect ratio of 0.62:1 (that is, the vertical scale for prices must be .62 the size of the horizontal scale for months/years).[36] Thus, altering the aspect ratio of visual displays, line graphs, *or* bar charts alters jurors' verbal conceptualization of the numerical information.

Visual displays of numerical information, particularly graphs, are not perceived by jurors without distortion. Jurors' understandings of graphs are influenced by the graphs' designs. Changes in design affect jurors' interpretations of amounts, judgments of trends, comparisons of similarities, senses of proportional distributions, and opinions of the relationships between variables.[37] The *objects* used in visual displays, the *reference points* by which jurors orient, and the *scaling* and layout of graphs all affect jurors' understanding of the depicted numerical information.

Further, who jurors are as people and how they comprehend visual displays matter as much to the effective communication of numerical information as does the choice of display format. Jurors' familiarity with display formats and their intellectual skills and abilities affect how well they use and comprehend the displayed numerical information. The information value of visual displays is determined not only by the displays' formats, but also by the jurors for whom the displays are made.

EFFECTIVE DISPLAYS *INFORM* AND *APPEAL*

Visual displays are designed not only to convey numeric information, but also to have that information comprehended and understood in particular ways. Different display formats emphasize the importance for jurors of drawing different judgments about the numerical information. Tables focus jurors on the importance of recalling precise quantities; bar charts emphasize comparisons of one category to another; pie charts highlight judging the size of one category relative to the

whole; and line graphs center jurors on trend information. Jurors themselves vary in their familiarity with, and ability to comprehend, different display formats. And, the formats themselves can be designed to influence how the numerical information is conceptually understood. Effective visual displays help jurors both grasp what is otherwise complex and attend to what is otherwise dull.

Jurors *like* and *are influenced by* well-designed visual displays of numerical information. Both interest value and information value should be considered when designing visual displays. Interesting displays that confuse, and dull displays that inform, might be useful under certain conditions, but the most effective displays do both. Poorly designed visual displays confuse and irritate while effective visual displays both inform and appeal.

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ENDNOTES

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