

1986

## Enhanced Computer Graphics for Decision Makers

Floyd James Brock Jr.  
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ENHANCED COMPUTER GRAPHICS  
FOR DECISION MAKERS

by

FLOYD JAMES BROCK, JR

A dissertation submitted in partial fulfillment of the  
requirements for the degree of

DOCTOR OF PHILOSOPHY  
in  
SYSTEMS SCIENCE

Portland State University

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TO THE OFFICE OF GRADUATE STUDIES AND RESEARCH:

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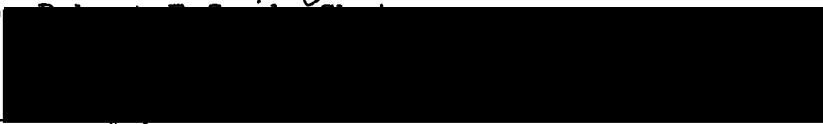


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AN ABSTRACT OF THE DISSERTATION OF Floyd James Brock, Jr  
for the Doctor of Philosophy in Systems Science presented  
February 28, 1986.

Title: Enhanced Computer Graphics for Decision Makers.

APPROVED BY MEMBERS OF THE DISSERTATION COMMITTEE:

  
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Dr Grover W Rodich

Words need a context to be understood. Visual patterns also need a context to convey their meaning. When patterns represent quantities in business graphics, decision makers (DMs) depend on contrasting visual contexts to discern patterns and discover relationships. Depending on the context in which DMs see trends, differences between two trends may point to a problem, to continuity, or to an opportunity.

Can enhancing the context in computer graphics help DMs visualize problems? To answer this research question, three experiments were done in the field on computer

graphics. One hundred five DMs tried 17 different contexts for time-series trends displayed on a microcomputer monitor. The research objective was to find out whether changing the context in graphics affected the decision efficiency (accuracy/response time) of DMs in determining relationships among trends. Essential for measuring the effect were interactive computer programs that displayed random trends in graphics of differing contexts, collected the DMs' answers to questions about the trends, and graded 1133 graphics based on the answers, response times, and trend data.

The experimental results supported the hypothesis that computers can enhance the visual context surrounding time-series trends so that DMs can better visualize problems. Results were based on comparisons of DMs' decision efficiencies between trial graphics with differing contextual enhancements and based on answers to questions about the trial graphics. The results were tested with nonparametric statistics at the 0.05 significance level. Specific findings were:

- Computer-supplied forecasts, as an enhancement, significantly helped DMs discover differences among trends.
- Although not statistically significant, stratified presentation of trends and fading chartjunk tended to increase DMs' efficiencies.

- Adding two colors, as an enhancement, made no difference in efficiency over black and white.
- Paired trends in windows did not affect efficiency significantly.
- Sequentially traced trends and composites of enhancements did not affect efficiency significantly.
- DMs preferred stratified trends most and had the most confidence in graphics with fading context. They least liked and had the least confidence in black-and-white graphics.

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Pacific Telecom Inc	Peat Marwick Mitchell & Co
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State of Washington, Dept of Transportation	
Tektronix Inc	Vancouver Federal Savings
US Geological Survey	Weyerhaeuser Company

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## CHAPTER I

### INTRODUCTION

Picture a decision maker (DM) in front of a microcomputer terminal using the integrated software, Lotus' 1-2-3. This person is trying to find relationships among sets of data. After marking the ranges of the data and selecting a line graph, the DM presses the "G" on the keyboard. Instantly the monitor is filled with strings of connected data points. Colors, titles, grids, scales, legends, and symbols are ready to embellish the context of the chart (Figure 1). This computer graphic display is truly one of the technological advances of this century.

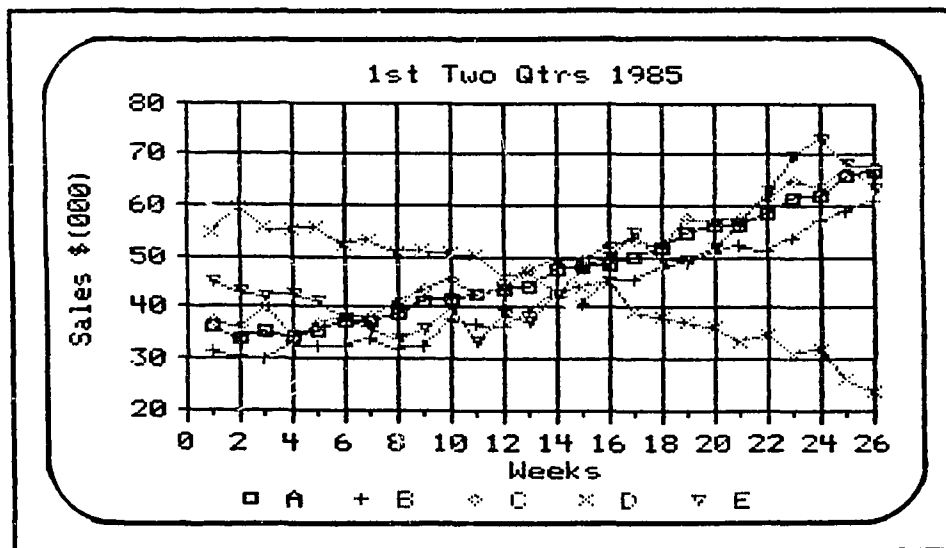


Figure 1. Lotus' 1-2-3 graphic.



But amazingly, the DM today still uses the same time-tested graphics of the last century. Line graphs appeared in 1724, bar charts in 1786, and pie charts in 1801 (Beniger, 1978: 7-8). Could the same computer that speeds the display of graphs allow exploration of new forms of business graphics?

This dissertation seeks an answer to this question. It synthesizes ideas about graphics in general and then reports on field-tested innovative forms of computer graphics of data patterns embedded in interactive computer programs.

The aim of this research was to test whether or not enhancement of the visual contexts that surround data patterns helps DMs draw inferences faster and more accurately. A visual context for a pattern was defined as all the remaining patterns and visual cues in the display, for example titles, symbols, grids, scales, and colors surrounding the pattern. The research patterns were time-series trends displayed in computer graphics. An integral part of this research was finding out which contextual enhancements were useful, impractical, and preferred.

The expectation was that this research would provide new guidelines for discerning relationships among data patterns when using computer graphics. The term "enhanced computer graphics" characterizes the researched graphics because the computer manipulated and enhanced the context

surrounding the data patterns. The research was eclectic, selecting suggested enhancements and tests of the enhancements from many disciplines. It was a search for visual aids for the "successful generalist, one [who] must study the art of ignoring data and of seeing only the 'mere outlines' of things" (Weinberg, 1975: 37).

The remainder of this chapter discusses the importance of business graphics and the objective, approach, and contributions of the research.

#### IMPORTANCE OF BUSINESS GRAPHICS

"Truly productive thinking in whatever area of cognition takes place in the realm of imagery" (Arnheim, 1969: v). DMs use graphical imagery to show where the business has been, what its composition is, and where it is going. Business graphics create images of numeric reality.

Reasons for using graphical displays are, "to record and store data compactly, . . . to communicate information to other people, . . . [and] to analyze a set of data to learn more about its structure" (Chambers, 1983: i). An example of the first is a Standard and Poor's Stock Price Index chart, a compact uncluttered chart showing 64 separate data points per linear inch (Standard & Poor's, 1984: 257). An example of the second is presentation graphics shown during a conference or committee meeting.

The third is the analytical graphics most often used to discover problems as part of the decision-making process.

Computers aid in creating analytical graphics, making experimentation easier.

Modern data analysis relies heavily on graphical analyses, which often entail [sic] a combination of careful consideration of what to compute and innovation in graphically displaying the results of the computations (Gnanadesikan, 1983: 5).

For microcomputers, "Lotus Development's 1-2-3 has become the most commonly used software for data manipulation and representation . . ." (Alperson, 1984: 157). Lotus' 1-2-3 and similar spreadsheet/graphic software possibly are the most frequently used analytical tool in individual decision support systems.

Graphics aid DMs in solving practical problems.

Cited benefits of graphics are that they:

- Save time and money (Takeuchi, 1980: 123; Sindel, 1982: 60);
- Ease data reduction, comparison, and interpretation (Wetherbe, 1982: 9);
- Communicate complex findings (Takeuchi. 1980: 123));
- Allow digestion of information more readily (Takeuchi, 1980: 123));
- Depict trends and make their analyses easier (Wetherbe, 1982, 9);

- Simplify detection of deviations from the norms/exceptions (Takeuchi, 1980: 123; Wetherbe, 1982: 9);
- Respond rapidly to "what if" questions and different scenarios (Takeuchi, 1980: 123; Wetherbe, 1982: 9; Sindel, 1982: 60); and
- Update easily at the user's fingertips (Sindel, 1982: 60).

Along with the benefits, difficulties also emerge in the use of graphics. Recent reports conclude that graphics:

- Lead to poorer quality decisions and longer decision times (Ghani, 1981: 101-102);
- Are not linked to increased management productivity (Ives, 1982: 15);
- Are remembered no better than tables when the graphics are three dimensional (Watson, 1983: 45).

Difficulties or not, DMs make important forecasting and allocation decisions based, at least in part, on what they see in graphics.

The projected size of the coming market for computer graphics in business indicates its significance. The annual growth rate of business graphics should top 40 percent through 1990. Starting as a \$500 million market in 1982, business graphics are forecast to reach \$6 billion in 1990 (Information Processing, 1984: 96). In another market

study, Frost and Sullivan predict an \$8.1 billion market in 1992 (Carlson, 1984: 82). Much of this will include micro-computers. "From 1983 until 1987 the number of personal computers used for graphics will leap from 250,000 to more than 2.5 million" (Paller, 1985: 3).

Computer graphics is a medium of growing importance, one requiring evaluation. Few specific cognitive effects produced by different graphics are known; in fact, the graphics themselves may even obscure the data (Huber, 1983: 567). Today's practice of evaluating graphics software by its performance, documentation, ease of use, and error handling, while disregarding its cognitive impact, is incomplete evaluation. The visual context provided by the software, for example, is never mentioned; and in business graphics, context is as important as the data, which cannot stand alone. Decisions spring from data that are meaningfully transformed to information. A search through the literature in several disciplines (Chapter II, "Literature Review") leads to the conclusion: context is necessary for DMs to perceive, communicate, and understand information. Contexts in business graphics convey information vital to decision making.

#### RESEARCH OBJECTIVE AND QUESTION

The research objective was to determine whether manipulating the contexts in graphics affects the speed and

accuracy of DMs in their determination of relationships among data patterns. Contexts are necessary for perception and cognition of visual data. Detecting relationships among data patterns is prerequisite to the decision-making process.

Can an enhanced context in graphics aid decision making? This is the pivotal question. Research hypotheses relating to context were tested to answer this question.

#### RESEARCH APPROACH

The approach to this research was to try out computer graphics with different contexts. Evaluation of the contexts was based on how quickly and accurately DMs answered questions about trends in the trial graphics. These trials required interactive computer programs to simulate trends and different contexts in the graphics, to capture a DM's light pen inputs (selections), and then to record the trend data and the DM's answers and response times. Subsequently, grading programs measured the DM's accuracy for each graphic, calculated decision efficiencies (accuracy/response time), and assigned grades to the trial graphics based on these efficiencies. All these programs were run on an IBM microcomputer.

Decision efficiency relates to Harrison's definition of quality of a decision, which is judged by its optimal use of information, compatibility with constraints,

timeliness, and implementation being influenced by the DM (E Harrison, 1981: 43). The DMs' decision efficiencies were measured in three experiments in the field, which were used instead of laboratory experiments to gain the participation of DMs and to try the graphics in the surroundings of business and government.

This research compared and tested six specific manipulations and then combinations of three in trial graphics. These manipulations or contextual variables were:

1. Black and white (alternative context) vs four colors;
2. Fading context (less context) vs full chart context;
3. Stratified patterns (separating the context) vs superimposed patterns;
4. Four two-line graphics in windows (simplifying the context) vs one five-line graphic;
5. Forecasts (more context) and no forecasts; and
6. Sequential painting vs concurrent painting (sequencing the context).

The trial graphics evolved from the popular business graphics program, Lotus' 1-2-3, and concepts from several disciplines. Figure 2 summarizes the three experiments and shows their trial graphics. Enhancement designs were

applications of suggestions, principles, and theories in the literature (Chapter II).

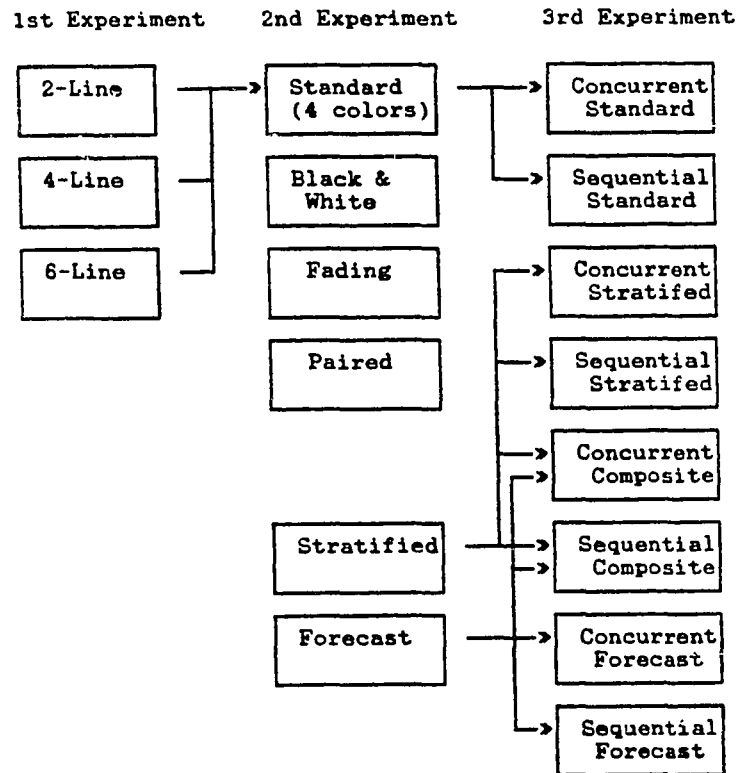


Figure 2. Research trial graphics.

These graphics were tested in three experiments. The first allowed comparison of two, four, and six lines in single, colored, multiple-line graphics. The second permitted comparisons between a standard graphic (colored) and five graphics which had different contextual variables. And the third experiment tested the sixth variable, painting, and a composite of two variables. The two composite graphics were developed from the forecast and stratified graphics. The names used for the trial graphics



essentially represent the independent variables of the three experiments; the decision efficiencies of the DMs were the dependent variables. Differences in efficiencies were the test statistics. Figures 4 through 10 in Chapter III, "Research Issues and Hypotheses," show inverse color screen prints of the graphics, in which dark hues on the screen appear light in the print and vice versa. The four colors in the actual displays are translated to print as shades of gray. Table V, also in Chapter III, relates the graphics to the research hypotheses which were to be tested at the 0.05 level of significance.

Chapter IV, "Research Design and Methodology," describes the experimental method that involved collecting 105 DMs' performances on each graphic and their preferences. This chapter also describes the microcomputer, light pen, color monitor, and software used in the experiments.

Chapter V, "Analyses of Experimental Data," describes the data from 1133 trial graphics (collected in the spring and summer 1985) and tests the 11 research hypotheses. The detailed experimental data, summaries of data, and nonparametric statistical tests are included in the appendixes.

#### CONTRIBUTION OF FINDINGS

This research confirmed that manipulating visual contexts in graphics affects the DMs' determinations of

relationships among time-series trends. Supporting this research hypothesis, specific findings regarding contextual enhancements were:

1. Graphics displaying forecasts increase significantly DMs' decision efficiencies (accuracy/time) in identifying relationships among time-series trends.
2. The DMs prefer stratified trends most and have reported the most confidence in the fading context enhancement. Conversely, the DMs neither like nor have confidence in black-and-white graphics.

Of equal importance was finding those contextual manipulations that were not statistically significant because the experimental results point to further potential research.

3. Stratifying the trends has a noticeable, not quite statistically significant, positive effect on efficiency. Fading away the context, as an enhancement, also has a positive effect.
4. Graphics displaying colored vs black-and-white trends make no significant difference in DMs' efficiencies.
5. Trends shown two-at-a-time in four small graphics (windows) have a negative but not significant effect on DMs' efficiencies when compared to single, multiple-line graphics.

6. The difference in efficiency produced with sequential painting and composites of enhancements is noticeable but is not significant.

The detailed findings are in Chapters V and VI, "Summary and Conclusions."

## CHAPTER II

### LITERATURE REVIEW

#### INTRODUCTION

The purpose of the literature review was to ascertain ideas and theories applying to problem detection among data patterns displayed in a computer graphic. These ideas would be applied to designing the experimental graphics and the experimental tasks (computer simulation).

The approach taken was a holistic focus, eclectic application, and search for isomorphisms--a systems approach (Sutherland, 1975: 3-4). The fields of art, statistics, graphics, management, human engineering, communications, information systems, forecasting, and computer systems were the sources of concepts for the design of computer graphics.

This chapter discusses the purpose and application of graphics, research and ideas on graphics design, cognitive factors in visual information processing, computer display limitations, and good graphics of data patterns. The focus of the review was how context in multiple-line, time-series graphics can be used to aid DMs find problems in a DSS.

## PURPOSE AND APPLICATION OF GRAPHICS

People search graphics looking for meaning. Most often their searches trace trends over time.

### Purpose

The general purpose of a graph is to allow comparisons between two or more quantities (Cardomone, 1981: 10). Bertin said that the objective of graphics is "to make relationships among previously defined sets appear" (1981: 176). The specific purpose of a line chart is "to depict . . . trends or changes over time [of a variable], . . . relationship[s] between . . . variables, and comparison[s] of both trends and relationships" (Lefferts, 1981: 81-82).

### Graphics in DSS

Graphics imbedded in DSS can aid DMs in finding problems. When the graphics can be manipulated, they facilitate discovery.

The DSS are computerized information systems "used by managers as an aid to their decision making in semistructured decision tasks" (Bennett, 1983: 1). Decision making, selecting a course of action to solve a problem, is part of the five-step problem-solving process suggested by Stoner (1982: 159-160), depicted in Figure 3. Problem finding precedes decision making.

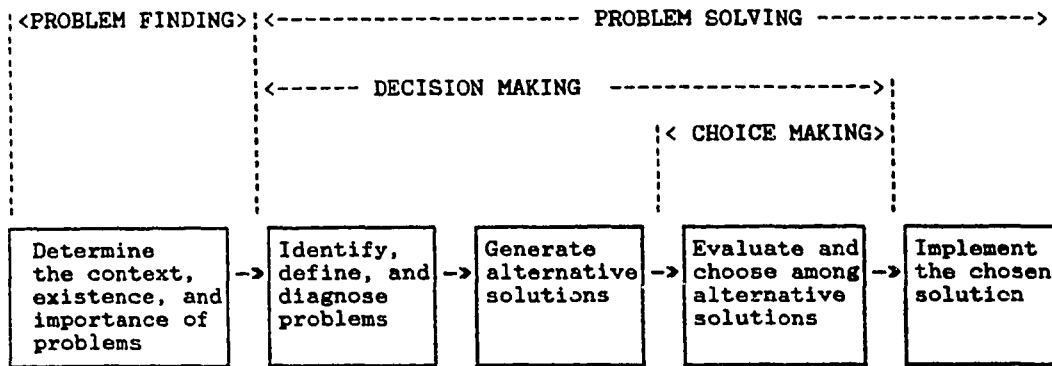


Figure 3. Problem-solving process.

A DSS can help in the problem-finding step, which is "the basis for effective managerial decisions" (Stoner, 1982: 59). Problem finding is an analytical process which becomes more meaningful with a definition of a problem. A problem is a perceived deviation, a gap, or an imbalance between what should be and what is (VanGundy, 1981: 3). It is "some sort of detection, discovery, or sensation that a need or opportunity exists" (Volkema, 1983: 639).

Implied in problem finding is the need for information, "a meaningful assembly of data, telling something about the data relationships" (Fitzgerald, 1981: 15). This assembly of data may be called a pattern, which to be meaningful requires a context (Lendaris, 1980), often a recognized constraint (Zwick, 1984: 98). DMs look for meaning in patterns:

. . . one of the principal consequences of evolution of the neocortex . . . has been to equip the human species so that man can detect and work with patterns to a greater degree than other life forms (Hall, 1981: 118-119).

"The amount of information [one has] can be measured as the amount of choice . . . out of a defined set of possibles" (Waddington, 1977: 141), specifically, the fraction of alternative choices that is eliminated (Miller, 1963: 124). To be valuable, the information must have some element of surprise, must affect directly the decision, and also must affect the performance or benefits of the decision (Mader, 1974: 329; Kleijnen, 1980: 115).

Analyzing data patterns for gaps and deviations would apply to two of Alter's seven types of DSS, data analysis systems and analysis of information systems (1980: 74-79). Their functions include comparing current and historical data, comparing company performance with competitors, finding budget variances, and forecasting sales.

Pictures and graphics have a place in the analyses. Kaufmann's general hypothesis on representation in problem solving is:

Verbal processes are bound up with the more conventional aspects of knowledge, and as such, are geared to the more reproductive functions in the problem solving process. As novel features in a problem situation appear, visual imagery as a symbolic system is more appropriate, this being especially due to its transformational property. As the novelty of a problem situation increases, there will be a corresponding increase in the need for overt, exploratory activity (Kaufmann, 1979: 82).

Graphics are needed in DSS because they aid DMs in their conceptualizations (Carlson, 1983: 20) and allow "presentation of complicated information in large 'chunks'" (Hurst, 1983: 122).

Presentation graphs are descriptions of information or data previously determined through analysis. They show what was concluded. In contrast, analytical graphs are used in searching and matching processes to analyze data. They are "designed to be the input device for the right brain pattern recognition function" (Jarett, 1983: 343). With computers, "the major objective of analysis graphics is the rapid manipulation of on-screen images to discover relationships that might have gone unnoticed from a table of numbers" (Alperson, 1984: 152). Often, the discovery is a problem.

#### Time-Series Graphs

Time-series graphs are the most frequently used graphs. Based on a random sample of 4000 graphs gathered from 15 of the world's newspapers and magazines published from 1974 to 1980, 75 percent were time series (Tufte, 1983: 28). In a small sampling of business periodicals in May 1984, this researcher found that time-series graphs (bar and line charts) represented over 80 percent of statistical graphics, graphs representing numerical data (Table I).



TABLE I  
TIME SERIES GRAPHS IN BUSINESS PERIODICALS

<u>Publication</u>	<u>Time-Series</u>	<u>Others</u>
Wall Street Journal (5/2/84 - 5/11/84)	73	6
Forbes (5/7/84)	27	1
Fortune (5/14/84)	7	6
Business Week (5/21/84)	16	3
Total	123	16

Many authors give testimonials for the use of time series.

Time-series data is the businessman's roadmap--it tells him where he has been, where he is today, and what direction he is headed in. Time-series data is [sic] also particularly well-suited to graphic representation (Friend, 1982: 24).

In writing about time-series analysis, Chambers and Mullick said that working with data representing relatively short time spans permits identification of current trends and turning points (1979: 324-336). Jones said that time-series curves should be compared in order to forecast analogous events (1978: 195-196).

Monitoring change over time is an essential function of management, and business graphics often focus on time-series information. Time series comparisons aid the business user's appreciation of trends, increases, decreases, or fluctuations in a given quantity (Szoka, 1983: 28).

Time series graphs often show before and after treatments. Displayed together, two trends can identify

possible causal explanations (Tufte, 1983: 37-39). Time series are the most common quantitative forecasting model (Wheelwright, 1977: 22). If managers use graphics to find problems, time-series graphs seem to be the most useful. Managers probably accept them because they are not complex (Yanahan, 1982: 87).

#### RESEARCH AND IDEAS ON GRAPHICS DESIGN

Application and standardization of graphics preceded research. Today's much-used time-series graphics have evolved from a 10th century monastery text (Tufte, 1983: 28), the familiar time and bar charts in 1724 and 1786 (Beniger, 1978: 1), and then the computer graphics developed as part of air defense radar systems in the 1950's (van Dam, 1984: 638).

Standardization in graphs adds a learned context; often introduced in mathematics courses and reinforced in science and engineering courses. Recently there has been research on graphics, but little research has focused on the effects of manipulating the context in computer graphics. Without much supporting research, ideas and standards flourish on computer displays and graphic design.

#### Research

DeSanctis summarized the literature about the effects of graphics on decision making. Three of her 10 research

premises specifically apply to the research reported in this dissertation:

1. There are many empirical studies on the effectiveness of various graph types, yet practical guidelines on graph selection cannot be formulated because of conflicting results and lack of systematic effort in the research.
2. Color may increase attention to a visual, but rarely does it enhance comprehension of the information or improve task performance.
3. In general, the simpler the graph design the more likely it is to be understood.  
(DeSanctis, 1984: 469-478)

Earlier Research. Schutz made important discoveries concerning graphs showing data patterns. In reading points, 10 people read a single graph of multiple lines and several single-line graphs with little difference in speed and accuracy. However, when comparing the trend effect between two lines, peoples' response speeds were better with the multiple-line graphs and slightly better when the lines were color-coded (in 5 out of 8 tested). All the lines in the artist-drawn graphs had different symbols; color was a redundant identification. Additionally, response speeds were better when no line crossed another. Schutz also found that people read line graphs faster and were more accurate in distinguishing trends with line graphs than with bar and column graphs. Incidentally, line graphs were superior both with and without missing data points (1961: 106-107, 118-119).

Recent Research. Much of the graphics research of the last 15 years compared graphics with tables and graphics interpretation with cognitive style (Lucas, 1981: 757-768; Ghani, 1981: 100-103; Doty, 1981: 74-143; Roberts, 1982: 63-72; Remus, 1984: 533-542). This recent research did not build on the contextual aspects of Schutz' work, specifically the research of different types and colors in time-series graphs. Additionally, Noyes experimented with visual search on map displays and showed that lines close to text (such as labels) have a proximity effect which prolongs word recognition time (1980: 359-360).

#### Display Format

Research and ideas relating to CRT screen displays were reviewed.

Engel and Granda wrote human factors guidelines for display terminals connected to an interactive computer system. They suggested that the display designer should:

- Highlight what is being worked on; also, highlight the important but infrequently used;
- Use structure and sequences to limit the amount of material on a display at one time;
- Reserve certain display areas for certain types of information;
- Place the most probable at the top of a list;
- Standardize and do not change; and

- Give directions before choice, for example, questions before answer fill-in space or alternative choices (1975: 3-17).

Roscoe discussed several principles of displays, specifically for airborne displays used in navigating and flying aircraft (1968: 323). Two of his principles have application to data pattern displays. The first, optimum scaling, suggests that "spatial displays present as much of the total situation as is consistent with scale-factor requirements" (Roscoe, 1968: 331). For pilots, displays should show where the aircraft has been, where it is, and where it is going without jumping off scale or being too erratic. Translating Roscoe's principles, data patterns should show the past, present, and forecasted plots using scales that dampen period-to-period irregularities.

The second principle, display integration, requires that "related information is presented in a common reference system which allows the relationships among the items to be perceived directly" (Roscoe, 1968: 323). For data patterns to have a common reference, they must have a common scale and must display two or more patterns together for comparison.

Almost in opposition to the integrated displays, Jarett said that showing all the data at once is not required in graphics. Instead, a sequence of displays may allow a great deal of data to be absorbed more quickly

(1983: 15). The graphic sequence is similar to a "semantic" sequence.

Any graphic display . . . will be perceived as an integrated image in a dimensional space. The effectiveness of information communication in a display depends on how closely the structure inherent in the information is mapped onto the modes by which the visual system processes the image (Haber, 1982: 25).

Buck asserted that "visual displays that are usually read faster are typically read more accurately" because they have effective communication qualities: visible critical elements, distinct parts and symbols, and understandable variation which leads to action (1983: 205). Buck also said that the common-sense requirements of displays include:

- Clear correspondence between what is being communicated and the display;
- Clear visibility of display elements;
- Scales that have the full range needed, orderly markings and sufficient symbols;
- Clear contrasts between figures or symbols and their backgrounds; and
- Bold distinctions for projections and alphanumeric characters (1983: 206-209).

### Graph Design

The display of graphs was reviewed. Guidelines for both hard copy (paper) and computer screen displays were collected. Guidelines on graphs and graphics are extensive

and sometimes contradictory. Those guidelines that apply specifically to line or curve charts are summarized in Appendix A, Table X.

Tufte suggested several principles, ideas, and techniques of design:

- Above all else show the data; show less art work. Eliminate moiré effects and decorative forms or computer debris (1983: 91-112).
- Maximize the data ink ratio (data ink/total graphic ink). Erase nondata ink, within reason (1983: 93-105). "Maximize data density [number of data points per area of graphic] and the size of the data matrix, within reason" (1983: 168).
- Lighten grids, use background color. Draw the lines so that contrasting thicknesses have contrasting meanings (1983: 112,186).
- Use the axes as a range frame, explicitly showing the maximum and minimum of variables. "Mobilize every graphical element, perhaps several times over, to show the data" (1983: 139).
- Design for three viewing depths: overall structure, detailed structure, and the implicit structure (1983: 155).
- Position graphics toward the horizontal, about 50 percent greater in length than height (1983: 190).

## COGNITIVE FACTORS IN VISUAL INFORMATION PROCESSING

This section reviews research and ideas on the psychological factors involved in manipulating context in graphics. Relating these factors to graphics requires interpretation because most of the ideas were not derived from graphics research. Visual information processing involves sensing through the eyes, intermediate processing, and storage. Much of visual context within a graphic depends on storage; that is, the context is learned and remembered. Contextual associations guide the access to information in memory (Rumelhart, 1977: 216). The amount of processing DMS can do has a limit, a point of data or information overload. Both perceptual and cognitive factors seem crucial to manipulating the context of graphics.

### Perception and Visual Context

Visual context refers to the setting, frame of reference, or relationships in which an entity is visually processed. Context has both external and internal references.

Maurice de Saussure, an artist, in his book Basic Design: The Dynamics of Visual Form, made two comments that have particular significance to context and plotting points on a graph.



It is virtually impossible to perceive units isolated from and unaffected by the context in which they appear. Relationship is inescapable and this makes the act of looking a dynamic experience (de Saumarez, 1964: 16).

The act of plotting points and connecting them with lines takes on new meaning after considering the following:

When two spots occur there is a statement of measurement and implied direction and the "inner" energies create a specific tension between them which directly affects the intervening space.

Freely used spots, in clusters or spread out, create a variety of energies and tensions activating the entire area . . . . All of these sensations are increased if difference in the sizes of the spots is allowed to enter. A line can be thought of as a chain of spots joined together. It indicates position and direction and has within itself a certain energy; the energy appears to travel along its length and to be intensified at either end, speed is implied and the space around it is activated.

(de Saumarez, 1964: 20)

Arnheim said that "every visual experience is embedded in a context of space and time" (1974: 48).

Context influences information processing.

Perception in general is characterized by contextual effects: whether something appears stationary or moving, how it appears oriented in the environment, . . . its size, shape, distance, and direction (Rock, 1983: 25).

Two types of context, spatial and temporal, can affect perception of a graphic. Spatial context refers to the interactions among different, static objects located in different places in a scene. Examples are the effect of the brightness in one area on an adjacent area and the effect of colored surroundings on an object's perceived

color. Perceived line length depends on adjacent line lengths, perceived size depends on surrounding sizes, and the perceived number of elements in a cluster depends on the number of elements in other adjacent clusters. Context triggers geometric illusions.

Another feature of spatial context is the cues to depth. These cues are relative size, linear perspective, texture gradient, relative elevation, relative blurring, and general pictorial relations such as interposition.

Temporal context refers to time induced interactions. An example of this contextual effect is induced movement, the effect of the motion of one area on the adjacent area, which occurs because of changes in size, position, and luminance of similarly shaped objects (Uttal, 1981: 847-922).

### Perceptual Factors

Perception may be considered one of the three interconnected subsystems of the human information processing system. The other two are the cognitive and motor systems (Card, 1983: 43). Perception transforms activity in sense organs into mental representations (percepts). The involvement of the sense organs, such as the eyes, separates perception from internal forms of cognition such as imagining, dreaming, or thinking. This review includes perceptual mechanisms which may be applied

to manipulating visual context in graphics. Many of the ideas are given as prescriptions and proscriptions.

Simplicity. Arnheim wrote in detail about simplicity, calling it

[the] basic law of visual perception: Any stimulus pattern tends to be seen in such a way that the resulting structure is as simple as the given conditions permit (Arnheim, 1974: 53).

This is similar to de Maupertius' Principle of Least Action (Kline, 1953: 228). Hochberg's definition of simplicity further explains it:

The smaller the amount of information needed to define a given organization as compared to the other alternatives, the more likely that the figure will be so perceived. [It is determined by] . . . three quantitative features: the number of angles enclosed within the figure, the number of different angles divided by the total number of angles, and the number of continuous lines (Arnheim, 1974: 57).

Simplicity interacts with the law of differentiation: "until a visual feature becomes differentiated, the range of its possibilities will be represented by the structurally simplest among them" (Arnheim, 1974: 181). When two undifferentiated straight lines cross, as in a complex graph, the direction of the lines after their crossing cannot be determine. The lines may continue in a straight line or may bend at the intersection.

Visual Variables. Graphs include various aspects of both pictures and symbols. To express differences in data, graphs can exhibit six visual variables: size, value, direction (or orientation), texture, color, and form.

Color and form were of particular interest in this research.

Color and form can provide powerful cues to link related data, to differentiate data, to highlight, and to separate prompts, instructions, and input. Color and form "are usually best for coding qualitative information because the codes use qualitative differences" (Grether, 1972: 77). Color is a qualitative variable that is less reliable than form. According to Arnheim, a reason for this is that color is always determined by its context, and the distinctive characteristics of shape are more resistant to contextual variation (1974: 333-368). According to Kantowitz, people can identify colored features in targets more accurately than they can identify size, brightness, and shape, but not as well as alphanumeric symbols can be identified (1983: 123).

Colors have established connotations and associations, for example: red--danger, yellow--caution, green--proceed (McCleary, 1983: 49). Colors should be used conservatively; eleven is the maximum number of color codes that should be used. Pastels in combination with their primary colors are difficult to distinguish when the color is not properly adjusted. Target search speed (finding a particular data point), from best to worst, is red, blue, yellow, green, black, and white across all dissimilar background colors. Eight percent of all males have

color-blindness or color weakness, particularly for red; so, techniques of testing for color-blindness and making adjustments and substitutions should be used to avoid this problem (Davis, 1983: 119-120).

Keller stated: (1) keep colors consistent and distinguishable, (2) strive for high color contrast between foreground and background, making the most important the brightest color with the greatest contrast, and (3) make text more legible by using white, yellow, or green on a black background. He also noted that a light-colored object on a dark background always seems larger than a dark-colored object on a light background (1984: 54).

Recently, Murch provided some guidelines for the proper use of color on visual displays:

1. Avoid the simultaneous display of highly saturated, spectrally extreme colors--cyans and blues cannot be viewed at the same time as reds--avoid extreme color pairs such as red and blue or yellow and purple.
2. Pure blue should be avoided for text, thin lines, and small shapes . . . blue is an excellent background color.
3. Avoid adjacent colors that differ only in the amount of blue.
4. Older operators need higher brightness levels to distinguish colors.
5. Colors change in appearance as the ambient light level changes.
6. The magnitude of a detectable change in color varies across the spectrum . . . small changes in extreme reds and purples are more difficult to detect than changes in other colors such as yellows and blue-greens.

7. It is difficult to focus upon edges created by color alone. Multicolored images should be differentiated on the basis of brightness as well as color.
8. Avoid red and green in the periphery of large-scale display . . . yellows and blues are good.
9. Opponent colors go well together . . . red and green or yellow and blue make good combinations for simple color displays.
10. For color-deficient observers, avoid single-color distinctions . . . subtle differences in color should be used with caution . . . levels of gray to distinguish elements may prove more difficult for the color-deficient observer than a color display.

(Murch, 1984: 53-54)

Form includes geometric shape, icons (used in pictographs), and alphanumeric symbols. There seems to be some lack of clarity in the roles of predictability and discriminability. The easier-to-perceive sets of forms are those that are predictable; they are symmetrical and formed with straight lines and few angles (Turnbull, 1975: 21). McCormick invoked perceptual principles and said that symbols should have a clear and stable figure-to-ground articulation; should demonstrate a contrast boundary; should use closed, simple shapes; and should be unified (1982: 112). Unified apparently means that the symbols representing a class or pattern belong to the same general shape. This appears to be contrary to highly discriminable shapes. The swastika is the easiest to discriminate, followed by a circle, crescent, airplane silhouette, cross, Star of David, oval, and rectangle (Sleight, 1952: 43).

Motion. Motion gets attention. This may be reason enough to use animation in business graphics. Movement may be induced by varying the size and shape of an object against a constant background (context). Those objects that move from a stationary position in sections that lead the whole object render an organic movement. Objects that move along their axes on oblique paths capture viewers' attention (Arnheim, 1974: 372-421). Other considerations in animation are to avoid square shapes (as in symbols), to soften edges in motion, to quicken the movement for long distances, and to represent inertia (Halas, 1976: 36). Animation's fullest capability is achieved in the presentation of processes which cannot even be perceived in actuality, because time can be expanded or contracted (Halas, 1976: 27). This particularly applies to computerized displays of time-series graphics, where drawing speeds can be changed to emphasize and deemphasize periods.

There is a caution in the use of animation. Movement reduces our sensitivity to small details (Spoehr, 1982: 34). Although Davis and Swelzey said that no animation computer graphic guidelines can be identified (1983: 116), Artwick advised the designer to choose animation methods that are easiest for the computer to deal with (1984: 289). Also, to avoid flicker (the blinking caused by a blank period between screen element erasure and generation), use high display rates (60 frames per second). Other methods

of avoiding flicker include use of double buffering (bouncing between display pages), combining intermediate operations, selective updating, and erase/redraw areas when the display generator is not scanning the same area (1984: 290-292).

Depth. Depth in a graphic may be introduced, for example, by framing, linear perspective, interposition, deformation, texture, and gradients (Arnheim, 1974: 233-278). (See Hochberg's definition of simplicity, page 28.) Relative size and motion parallax also provide depth cues (Spoehr, 1982: 34). These depth cues can muddle the perception of a business graphic (Zelazny, 1981: 13), as Haber discusses:

All the objects are perceived as related to each other--near, far, behind, adjoining . . . . The visual system attempts to interpret all stimulation reaching the eyes as if it were reflected from a real scene in three dimensions. It does this even if the information actually comes from a flat surface, as long as there is some information that is consistent with three dimensionality (Haber, 1982: 25).

Visual Acuity. Normal visual acuity, the ability to resolve small stimuli, is .005 inch (.14 mm) at a viewing distance of 18 inches (457 mm) (Spoehr, 1982: 28). This is based on the human ability to resolve one minute of visual angle (Grether, 1972: 47), represented by the formula:

$$\text{Visual angle (min)} = \frac{3438 \times \text{size of object}}{\text{Viewer to object distance}}$$

where 3438 = 60 min/degree x 360°/2pi. Visual acuity is



half the size of the dot pitch (approximately pixel size) on most personal computer monitors, (.012 inch - .017 inch), so seeing plots on a monitor should not be a problem. Seeing details in one fixation is limited to an angle of about 2 degrees across (Card, 1983: 25). At a viewing distance of 18 inches, this means that details are seen in a range of only about 0.6 inch across (that is 6 letters wide). To see more details, the eyes must move.

Pattern Processing. Figural organization in a visual scene both aids and masks data patterns. Three relatively well-known aspects of visual perception are figure-ground organization, gestalt principles, and interpretation.

Figure-ground organization, a perceptual grouping, refers to the separation of the visual field into a more distinct portion, its figure, which appears to stand out, and a less distinct portion, its ground, which appears to be further back and behind the figure. This separation has application to emphasizing data patterns (the figures) from the rest of the graph. Figures tend to separate from their ground when they have the following characteristics:

- Clearly organized outlines;
- Clear internal structure;
- Smallness and centrality;
- The appearance of being closer and brighter;
- Better figure symmetry;

- The appearance of being a closed figure;
- Alignment with the horizontal or vertical axis;
- A sharp, regular texture; and
- A convex region (Uttal, 1981: 791-797).

Gestalt principles or rules may explain some emergent features, effects that emerge from the organization of parts producing a whole which is not obvious by looking at the individual parts. These organizations or groupings of parts are called gestalts (see Table II). The effects of gestalts can lead to difficulty in pattern recognition.

In explaining how information theory can account for gestalt principles, Spoehr and Lehmkuhle reported Attneave's experiment in which the points on the contours of shapes were found to provide the most information. Spatial differences in the points on the contour provide information. Conversely, similarity and proximity in points provide redundant information, and they are perceived together (1982: 72-75). This appears to fit into Hochberg's concept of simplicity mentioned previously in this section. Haber and Hershenson said this in another way:

Perception or organization of a stimulus array is related to its information content. Further, of all possible organizations, the most probable perceptual result is one which involves the least amount of information, that is, the greatest redundancy (Haber, 1973: 194).

TABLE II  
GESTALT RULES FOR GROUPING ELEMENTS OF PATTERN

<u>RULE/PRINCIPLE</u>	<u>CAUSE OF GROUPING EFFECT</u>	<u>POSSIBLE APPLICATIONS/CAUTIONS</u>
Spatial Proximity	Close together in space	Eliminate lines between points by smaller scale [This may be the reason for putting lines between points because they are too far apart to be seen as a group.]
Temporal Proximity	Close together in time	Sequence/animate points of same period together; or, sequence or animate points of same pattern together.
Similarity	Color or geometry	Give different shaped similar points for different patterns.
Continuity	Represent a continuation of pattern	Randomly offset points of different patterns.
Closure	Form closed pattern	Save drawing time with partial figure.
Uniform Density	Equal spacing	Shade and/or texture similar bars or surfaces uniformly.
Common Fate	Parts moving simultaneously	Animate points of the same pattern, or of different patterns, at the same time.
Symmetry	Compare a symmetric form	Use symmetrical plotting points on an open rectangle.
Common Orientation	Share the same direction (vertical, horizontal, oblique)	Change the direction for attention, e.g., tilt a column.
Pragnanz	Produce the "best" figure (highest degree of goodness or minimum amount of "structural stress")	Change scaling to bring out the "best" pattern.
Einstellung	According with "objective" set of the observer, e.g., expectations	Title patterns according to their general shape, e.g., s-curve, straight line.

(Spoehr, 1982: 63-67; Uttal, 1981: 798-800; Pickford, 1972: 11)

People tend to close gaps, an interpretive process, which often inhibits problem finding. This is a perceptual process in which a person may actually fill gaps in an incomplete stimulus so that the observer perceives a physically incomplete stimulus to be complete (Uttal, 1981:

808). There are three subtopics: reversible figures (Necker cube), impossible figures (devils tuning fork), and closure and completion (geometric illusion). The reversible figures process affects 3-D graphics. The closure process is important because it describes the process of completing and filling in missing parts of visual stimuli, such as lines and data points (Uttal, 1981: 808-836).

The way in which patterns are organized affects how they are processed. A pattern that includes gestalt organizational principles, such as good continuation, produces a global view where local details become obscure (Prinzmetal, 1977 in Spoehr, 1982: 76). Global views or configurations usually are processed faster than local details, but this may depend on optimal size, a visual angle of 8 degrees or less, and the global views' being approximately 5 times the size of the details (Kinchla, 1979 in Spoehr, 1982: 79). Global to local also may explain how the configurations are stored in memory (Palmer, 1979 in Spoehr, 1982: 75-81). Navon suggested that visual processing is a top-down process, starting with global configuration and proceeding down through levels of detail (1977: 354). His suggestion is included in a basic principle of artificial intelligence.

Top-down reasoning is a goal-directed process that imposes a tightly controlled organization; bottom-up reasoning is a data-directed or stimulus-directed process that leads to more diffuse chains of association (Sowa, 1984: 30).

When applied to showing graphs, faster comprehension and remembering may be achieved by showing the lines connecting the data points before showing the individual data points.

The attributes or dimensions of stimuli affect processing. The dimensions are classified as either separable (processed independently of one another) or integral (processed together). Integral dimensions, such as height and width and hue (color) and brightness, are processed as wholes, and then later analyzed for their components (Spoehr, 1982: 81-93).

#### Cognitive Factors and Capacity Limitations

How DMs look at and react to graphics depends on their culture, inherent characteristics, and mental capacity and organization.

Left to Right Viewpoint. There is the viewpoint of the observer to consider:

. . . the observer experiences a picture as though he were facing its left side. He subjectively identifies with the left, and whatever appears there assumes greatest importance (Arnheim, 1974: 34).

This is a good reason to place the scales and headings on the left side of the graph. People of the Western cultures read from left to right (Arnheim, 1974: 13-35). This practice of placing scales and headings on the left may

bring more emphasis on older data as opposed to recent data in time-series graphics.

Information Overload. Information overload (or data overload) is "a situation in which the system breaks down when it cannot properly handle the huge volume of . . . information to which it is subjected" (Hall, 1981: 85). Experiments have shown that individuals' reaction times to a stimulus increase with the number of possible signals. Reaction times increase with both the number of different signals and the number of possible responses to be ignored (Welford, 1976: 38-39). Hick's information theory law states that the mean choice reaction time ( $t_c$ ) equals a constant times the log of the alternatives ( $N$ ),  $t_c = K \log_2 N$  (Welford, 1976: 56-58). The rate of increase in reaction time is less when signals are closely related to corresponding responses (Welford, 1976: 4). Also, the time taken to classify items increases with the number of classification criteria (Welford, 1976: 39).

Time taken for identification depends on . . . how much detail has to be noted . . . . [One can] expect greater accuracy if attention can be concentrated on one part of a figure than if it has to be spread over the whole figure (Welford, 1976: 39).

Individuals appear to have difficulty ignoring unnecessary details in making a selection (Welford, 1976: 40).

Based on consumer research, people can be overloaded with information in making a choice. If the rate of information given to people exceeds their processing

limits, they can experience an information overload which may lead to poor decision making (Crosby, 1981: 44; Malhotra, 1984: 419). People may stop short of overloading themselves and choose only a small portion of the information that is available (Jacoby, 1984: 435). People experienced with an information system, such as a DSS, develop effective ways of coping with the overload, perhaps by learning to self-organize the information flows (Hiltz, 1985: 681).

Resultant Behavior. E F Harrison discussed DMs:

Individuals tend to employ rather simple strategies, even in the presence of complex problems, to obtain desirable solutions. Further, individual decision making is constrained by imperfect information, time and cost factors, frequently severe cognitive limitations, and diverse psychological forces.

The individual usually tries to minimize cognitive strain in part by his or her choice of problem-solving techniques.

The decision maker's many-sided personality, however defined, conditions his or her behavior throughout the integrated process of choice.

The decision makers' tendency to accept or avoid uncertainty was shown to depend upon his or her perception of the desirability of the outcome of a series of choices leading toward the fulfillment of an objective.

Decision makers are unable for many reasons to avoid inaccuracies in forming impressions of people, things, and events. Stereotyping, the halo effect, projection, and perceptual defense all operate in varying combinations to limit and distort the view of the decision maker.

(E Harrison, 1981: 6,216-217)

Warfield concluded that people tend to evaluate several attributes of one object rather than one attribute of several objects (1976: 81). Relating this to evaluating time series, comparisons typically are made within a pattern and not between/among patterns.

Slovic made some keen observations regarding decision making: (1) the ability to interpret and integrate information is a key element; (2) the accuracy of prediction decreases as redundancy increases; and (3) the integration of additional information is usually an adjustment to "anchored" previous information (anchoring bias) (1982: 157,162). "Typically, the adjustment is crude and imprecise and fails to do justice to the importance of additional information" (Slovic, 1982: 163).

Using cognitive style in designing computer graphics seems untenable based on Huber's conclusions:

The currently available literature on cognitive styles is an unsatisfactory basis for deriving operational guidelines for MIS and DSS designs.

Further cognitive style research is unlikely to lead to operational guidelines for MIS and DSS designs.

(Huber, 1983: 567)

#### COMPUTER DISPLAY LIMITATIONS

The graphics are drawn on computer monitors. Liquid crystal and CRT displays limit how, where, and when information may be displayed. Newer lap computers use large liquid crystal or electroluminance displays, which is



a newer technology than CRT displays. Liquid crystal displays will likely be important in the future; but, more often CRT displays are used today in DSS.

The CRT display lights dots (picture elements or pixels) at different locations at different times as guided by graphic instructions. The optimal viewing distance is 18 inches (460 mm) with a range of 28 inches maximum to 16 inches minimum (Davis, 1983: 117).

The visual information capacity of a display is partially determined by the ratio of screen size to displayed dot or line width . . . . As the size of the minimum discernable symbol or feature increases, the visual information capacity of a given display becomes smaller (Patterson, 1983: 81-82).

In other words, to increase the visual information capability, both the screen size and number of dots need to be increased.

Screen resolution is most important; this term describes the number of pixels (dots) that appear on the screen. The more pixels displayed, generally means the sharper the images. Resolution is measured horizontally and vertically, for example, 320 x 200 means 320 pixels across by 200 pixels down. This was the first resolution on the IBM monitor in the color graphics mode of the IBM Personal Computer (PC). Higher resolutions of 1280 x 1024 in color and up to 2048 x 1536 in monochrome can be found in better monitors, Hitachi and Tektronix respectively, driven by computers with more memory than the IBM PC (Aldersey-Williams, 1985: 29-30). These higher resolutions

increase image fidelity but usually decrease animation speeds (Artwick, 1984: 312-317). Also needed for sharp images is a smaller dot pitch, which is the spacing between the pixels, which typically is between .31 mm and .45 mm (Powell, 1984: 125). If the dot pitch is too large, pixels may overlap. That is good for displaying characters; however, the overlap may cause a problem in determining minute variations in data patterns because the overlap tends to hide distinctions.

Artwick talked about cooperating with the display resolution and aspect ratio (1984: 14). For example, with a 320 x 200 resolution, multiples of this resolution are the easiest to work with when they fit a plotting coordinate system. Using the whole display, a scale of 640 x 400 works fine because all the coordinate values can be divided by 2. A scale of 365 x 365, however, does not work well because of the fractional values.

Diagonal lines in a display jump up and down between points, often with unequal steps. This stair-step effect, called jaggies, depends on the resolution of the display and the method used to generate the lines. Lines with jaggies require the viewer to interpolate the lines.

Lines drawn on a display are not as precise as lines drawn on paper. The difference can be seen in the number of dots that can be laid in a one-inch span. The minimum should be 70 dots/inch (Stahin in Davis, 1980: 115). For a

12 inch (diagonal measure) screen with IBM PC 320 x 200 graphic resolution, about 32 to 36 dots can be placed in an inch horizontally and 28 to 33 dots can be placed in an inch vertically. Phototypesetting machines, on the other hand, can print about 500 dots per inch to produce smooth-appearing lines without noticeable jaggies (Bassett, 1984: 74). Graphs on paper (hard copy) usually are better than CRT displays for reading magnitudes. Tables are better still in resolution because they obviate visual tracking and interpolation judgment; they particularly are better than graphics when reporting small data sets of 20 numbers or less (Tufte, 1983: 56). Attempting to use CRT displays to make decisions takes longer than using hard copy (Kozar, 1978: 495).

Audio output and animation can increase the available information on the screen; however, too much data may be conveyed too quickly and lead to distraction (Lay, 1982: 38). Foley believes:

Interactive computer graphics allows us to achieve much higher-bandwidth man-machine communication using a judicious combination of text with static and dynamic pictures than is possible with text alone (Foley, 1982: 6).

#### GOOD GRAPHICS OF DATA PATTERNS

Many of the characteristics of DMs appear to apply to life in general. James E Miller made several hypotheses about information processing in his Living Systems (1978:

97-101). Making a few word substitutions and paraphrasing, his hypotheses can be related to graphs of data patterns:

- The fewer the patterns relevant to a decision, the greater the probability is that each will affect the decision.
- The probability of error increases with the number of patterns.
- Less interpretation leads to more use.
- The greatest pattern intensity or greatest signal-to-noise ratio gets attention.
- The more a graph increases the strain of decision making, the more it will be rejected.
- Associations built early are more permanent than those established later. Early associations relate to Slovic's "anchoring bias" (1982: 168).
- The more deviations that occur in a new pattern the more slowly the pattern will be integrated in decisions.
- A decision about an information input [a pattern] is not made absolutely but with respect to some other information [pattern] which constitutes a frame of reference with which it can be compared (Miller, 1978: 101).

#### Opinions About Good Graphics

Several general characteristics constitute good graphics. They often conflict with each other, perhaps because authors and researchers view them differently.

Lefferts said that the characteristics of good graphics include simplicity, labeling with a minimum of words, and unity (its parts mesh and cohere). Good graphs have balance; their lines and shapes appear to balance on the right and left, and on the top and bottom of the visual center. Trends in graphs are distinctive because of contrast; the size, shape, shading, and location of the lines and symbols are different from the text. Emphasis is given to comparisons so that differences and relationships may be seen; emphasis is used to communicate meaning. Attention is focused on one quantity/quality as being more important than another and on revealing relationships, trends, and patterns (1981: 1-23).

Chernoff believes that graphics should be adjustable to facilitate understanding, attractive to a casual audience, yet comprehensive--all-inclusive, but not distracting from the important (1978: 6-7).

Schmid suggested that the layout should follow prescribed standards to ensure accuracy (1983: v); and Lay emphasized value, which is the explicit indication of data quality (1982: 40).

Tufte prescribed that graphics be lucid (communicate complexity with clarity, precision, and efficiency), concise (show the greatest number of ideas with the least ink in the smallest space), multivariate, and truthful (have graphical integrity) (1983: 51).

Recently, Cleveland said a graphic should be incisive, capable of being assimilated without having to be read (1985: 229). This is similar to Julesz's "preattentive vision: the instantaneous perception of the visual field that comes without apparent mental effort" (Cleveland, 1985: 229). A graphic that does not need reading would be similar to a pilot's attitude gyro--no interpretation is necessary.

#### Graphic Design Summary

The DMs tend to favor simple, stabilized, easy-to-compare, time-sequenced pictures--the time series. The literature provided advice and clues on methods for enhancing the displays of data patterns:

- Radically simplify the structure by reducing the number and types of angles and the number of continuous lines.
- Emphasize the data.
- Standardize displays and use simplified formats (data organization).
- Sequence patterns and separate them to avoid crossing patterns.
- Increase data density by displaying data as similarly shaped, colored, symmetrical points close together. (This will establish patterns, eliminate the connecting lines, and reduce the number of fixations.

- Remove labels and scales after they are used.
- Start with general contours and add details, for example, start with a straight line and sequentially add details and curvature.
- Provide contrasting, distinct figure and ground relationships, such as highlighting the principal data and the comparison data while subduing the axes.
- Animate to get attention, but then freeze the action to allow comparisons.
- Highlight differences and changes.
- Use color, exaggeration, and obliqueness to emphasize information.

Most of the guidelines for computer graphics are an earnest effort to standardize part of the context and are applicable to presentation graphics. Few guidelines consider making use of the power of the computer to position, to sequence, to animate trends, or to compute and display additional information about the trends. Adding computer enhancements to the guidelines for perspective comparisons of time-series trends delivers a challenge to create more fitting contexts.

## CHAPTER III

### RESEARCH ISSUES AND HYPOTHESES

#### INTRODUCTION

Regarding the impact of computer graphics in decision support systems, one important question needs answering: Can the graphics be designed to more effectively assist the decision maker discover information (patterns in data)?

Computer graphics reveal patterns in data better than details in data. Computer graphics do not allow precise scale measurement of each datum point because video monitors typically display less than 400 lines vertically or horizontally (which is less than the range of three significant digits, 0 - 999). For detailed measurements, tables are better than graphics; numbers can be printed with up to 16 significant digits. The concern with graphics in this research was as an aid in the identification and comparison of data patterns, not details. To test the effects of contextual manipulation of graphics, DMs compared patterns using seven trial graphics and two painting sequences over three experiments.

This chapter progressively narrows the focus of the research in the remaining three sections: Research Issue of



Enhanced Graphics, Graphics Design, and Research  
Hypotheses.

#### RESEARCH ISSUE OF ENHANCED GRAPHICS

The research environment was the DM viewing computer graphics of data patterns from a decision support system and attempting to find a problem, a deviation in the data. When used to find a problem or to gain insight, graphics are analytical tools. After finding the problem, used to communicate to others, graphics are presentation tools. The scope of this study was analytical graphics. The research issue was this: can computer graphics be manipulated to facilitate the identification of differences in patterns?

Answering this question required trials of graphics in three experiments. The experimental task required DMs discover distinctions and associations among data patterns. Specifically, DMs had to compare patterns and determine which of them was the most volatile, which was leading the rest, and which was changing the most. These three determinations required the discovery of diversity in relationships, prerequisites to problem solving. Similar comparisons and determinations could apply to detecting differences in budgets, market shares, revenues, quality control, inventory levels, production counts, environmental niches, and demographic mixes. For example, erratic trends

might indicate lack of control or delayed feedback. A leading trend may show a phase shift, like leading economic indicators. Trends changing at different rates than other similar ones may indicate a change in composition, such as, market share per week of products.

This research focused on six variables derived from nine of the more than 100 components contributing to the visual context of data shown on computer-generated displays (compiled here as Table III). The six variables were selected because they could be controlled. Only six variables were tested because of the size of the programming task and the limitations of the graphic languages, the microcomputer, and the video monitor.

Before testing the six variables, a pilot experiment was run to determine a perception level of data overload using presentations of two lines versus four lines versus six lines. Next, five contextual variables were tested separately:

1. Color--two colors vs four colors,
2. Chartjunk--fixed vs fading,
3. Format--single presentation of multiple trends vs multiple presentations (in windows) of paired trends.
4. Analytical data inclusion--none vs computer-calculated forecasts, and
5. Scale--superimposed trends vs stratified trends.

TABLE III  
CONTEXTUAL COMPONENTS

<u>Data Presentation</u>	<u>Display Organization</u>	<u>Symbology</u>	<u>Content</u>	<u>Formats</u>
Static	Resolution Brightness	Coding types:	Principal data	Text
Dynamic:	Light on dark	Alphanumerics:	Analytical data:	Scatter charts
Animation	Dark on light	Upper case	Average	Line plots
Scrolling	Screen place	Lower case	Std deviation	Bar charts
Zoom	Screen seq:	Both case	Range	Area plots
Sketching	Duration	Stroke width	Moving average	Cumulative
*Sequencing	Number	Alignments	*Expon'l smooth'g	(line, bar, area)
Together	Repeating	Fonts	Regression	
Separately	Chained			Pie charts
	Interrupted	Geometry:	Related data:	Segmented
Interactive:		Symmetrical	Historical	
Input:	*Spacing	Asymmetrical	Leading whole	Step charts/ plots
Mouse	Contrast		Leading var'ble	Special (high- low line)
Joystick	Flicker rate	Visual var'bles:	Similar var'ble	Multidimen- sional
Keyboard	Intensity	Size	Accuracy	Tabular
Tablet	*Colors	Value(place)		(or columns Concurrent data: *n at a time
Screen	Color mixes	Direction	Noise	
Light pen	Border shape	Orientation	Connections	
	*Border size	Texture	Dimensions	
Dialogue	Border place	Form	Actual or %	
modes:	Gray scales	*Color	Slope	
Form- filling	Animation	Highlighting:		
Menu	Info density:	Contrast		
Query	Essential:	Blinking		
language	# points	Dynamic		
User	Titles	intens'tion		
initiated	Labels	Dynamic size		
Computer	Scales			
initiated	Tic marks	Brightness		
	Grid marks	Line length		
		Line thickness		
	*Interim data	Overlap		
	*Irrelevant	Redundancy		
		Combinations		
	Connections			
	View distance			
	Vert visual field			
	Hori visual field			
	Pictograph			

\* To be tested

Chartjunk is unneeded text, scales, grids, irrelevant and interim data, and redundant symbols and lines. Stratified means stacked horizontally one on top of the other but not touching; the trends appear layered. Paired means tracing only two trends in the same graph and displaying the graphs in adjacent windows.

Last, three variables were tested together:

1. Analytical data inclusion--none vs forecast,
2. Scale--superimposed trends vs stratified trends,  
and
3. Painting--concurrent vs sequential presentation.

Painting refers to drawing a pattern with a selected color.

Besides testing the variables to find out if they revealed problems, these experimental tests would confirm or refute two premises of DeSanctis:

Color may increase attention to a visual, but rarely does it enhance comprehension of the information or improve task performance.

In general, the simpler the graph design the more likely it is to be understood.

(DeSanctis, 1984: 470)

### RESEARCH GRAPHICS DESIGN

Seven trial graphics were designed to test five of the contextual variables. One served as the standard, five contained one contextual variable changed from the standard, and one was a composite of two of the contextual variables. Four of the graphics tested the sixth, the painting variable. All graphics were multiple-line, time-series graphs. Their design evolved from Lotus' 1-2-3 graphics but included more. The trial graphics were test models of ideas gleaned from the literature.

Table IV briefly describes the trial graphics containing the contextual variables (enhancements) and

lists figure numbers of example graphics. The examples shown are inverse color screen prints of the graphics. The bold words in the table indicate variations from the standard graphic (colored). Throughout this document, the short names given the graphics are used instead of their full description.

TABLE IV  
TRIAL GRAPHICS

<u>Name</u>	<u>Type</u>	<u>Example</u>
Standard (Colored)	Traditional single multiple line showing 5 superimposed patterns with text in 4 colors	Figure 4
Black and White	Single multiple line (Lotus 1-2-3 type) showing 5 superimposed patterns with fixed chartjunk in black & white	Figure 5
Fading	Single multiple line showing 5 superimposed patterns with fading chartjunk in 4 colors	Figure 6
Stratified	Single multiple line showing stratified patterns with fixed chartjunk in 4 colors	Figure 7
Paired	Four multiple line (in windows) showing one reference pattern and four other patterns with fixed chartjunk in 4 colors	Figure 8
Forecast	Single multiple line showing 5 superimposed patterns with fixed chartjunk in 4 colors with 4-period forecasts	Figure 9
Composite	Single multiple line showing stratified patterns with fixed chartjunk in 4 colors with 4-period forecasts	Figure 10

Note: Bold words = change from the standard, the colored graphic.

The colored graphic (Figure 4) was selected as the standard because (1) Schutz' research showed that people did better with colored lines (1961: 117), (2) people

preferred it over the black-and-white graphic during pretests, and (3) it allowed all the trial graphics, except the black and white, to have four hues. The four colors were white, cyan, magenta, and black (background), which are seen more easily than the alternative brown, green, red, and black (Murch, 1984: 30-31). Additionally, cyan and magenta elude fewer connotations than green and red (McCleary, 1983: 49). Symbols with colored lines were redundant so symbols were eliminated to simplify.

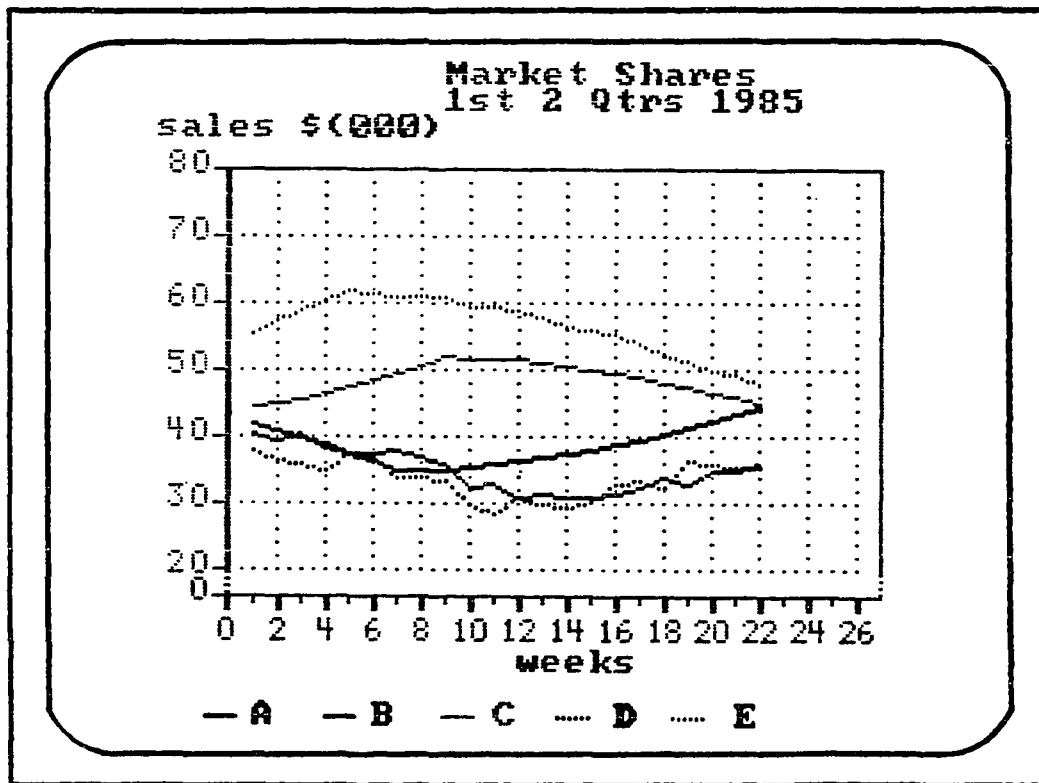


Figure 4. Trial standard graphic (colored).

The black-and-white graphic (Figure 5) differed from the colored graphic by having two fewer colors to

differentiate the patterns. Without the extra hues, symbols provided the qualitative distinction but added complexity and took longer to draw. On the other hand, Arnheim believes shape is a better means of identification than color (1974: 333,336). During pretests, patterns with symbols such as the "x" and "\*" appeared to be selected as the most volatile pattern too often; the "+" symbol became lost in the grids. To remove this apparent bias, only closed symbols were used in the black-and-white graphic.

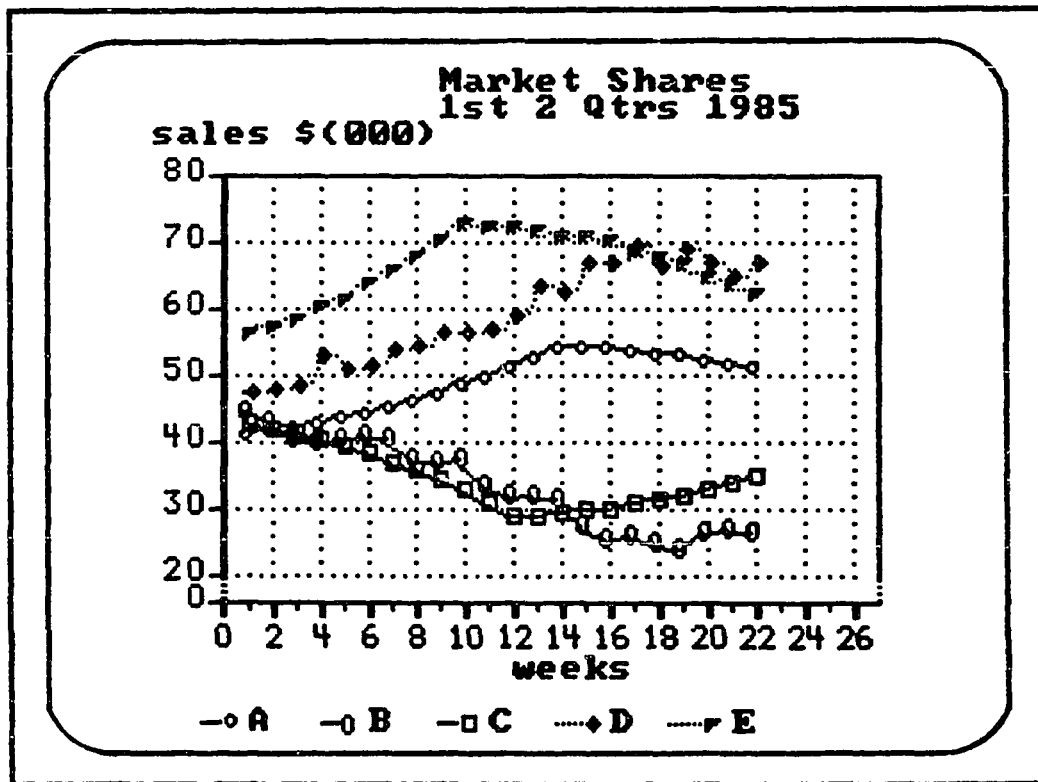


Figure 5. Trial black-and-white graphic.

The fading graphic (Figure 6) erased the chartjunk as it painted the data patterns. The erasing:

- Emphasized the figure (R Harrison, 1981: 57);
- Minimized the data to ink ratio (Tufte, 1983: 93);
- Erased nondata legends (Anderson, 1979: 29);
- Reduced information density (Davis, 1983: 116);
- Minimized labeling (Lefferts, 1981: 7); and
- Reduced the chances for geometric illusions.

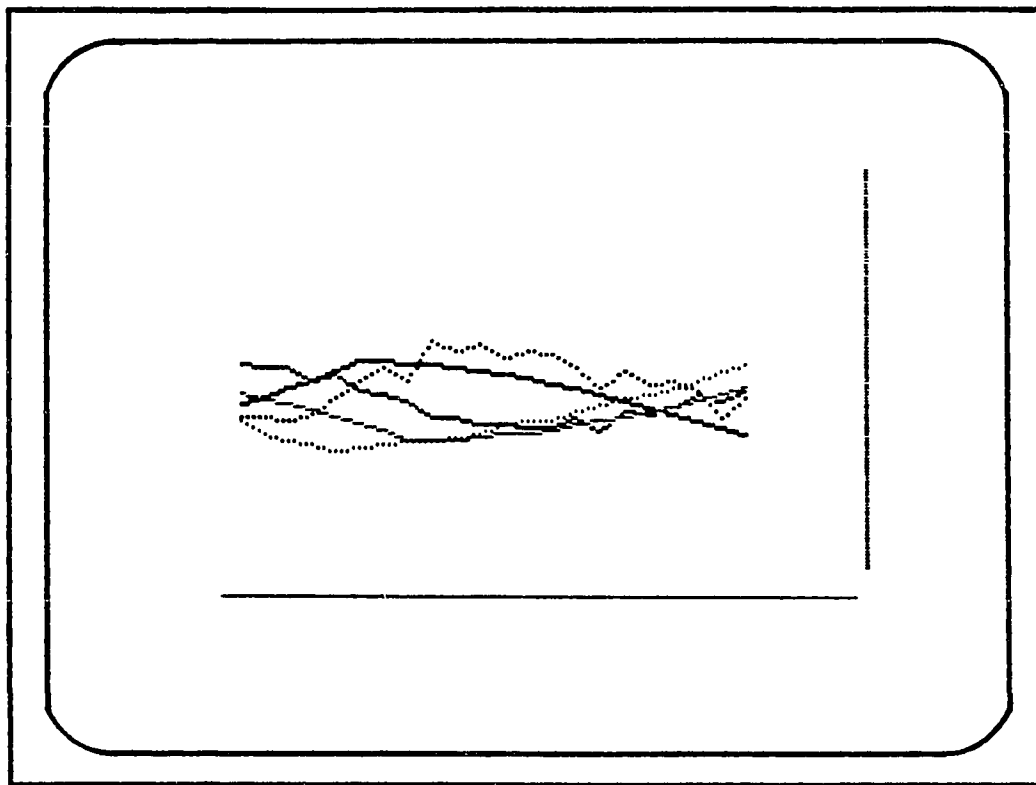


Figure 6. Trial fading graphic.

The stratified (Figure 7) separated the trends through a computer algorithm. Separation required



sequentially examining two different trends at a time. The computer found the maximum positive difference between concurrent points of the two trends, and this difference, plus the desired separation distance, was added to every point in one of the trends. The separation or stratification was devised to reverse the lengthening of response times that Schutz found with crossing lines (Schutz, 1961: 116-117). The stratification also eliminated a three-dimensional effect (Haber, 1982: 25).

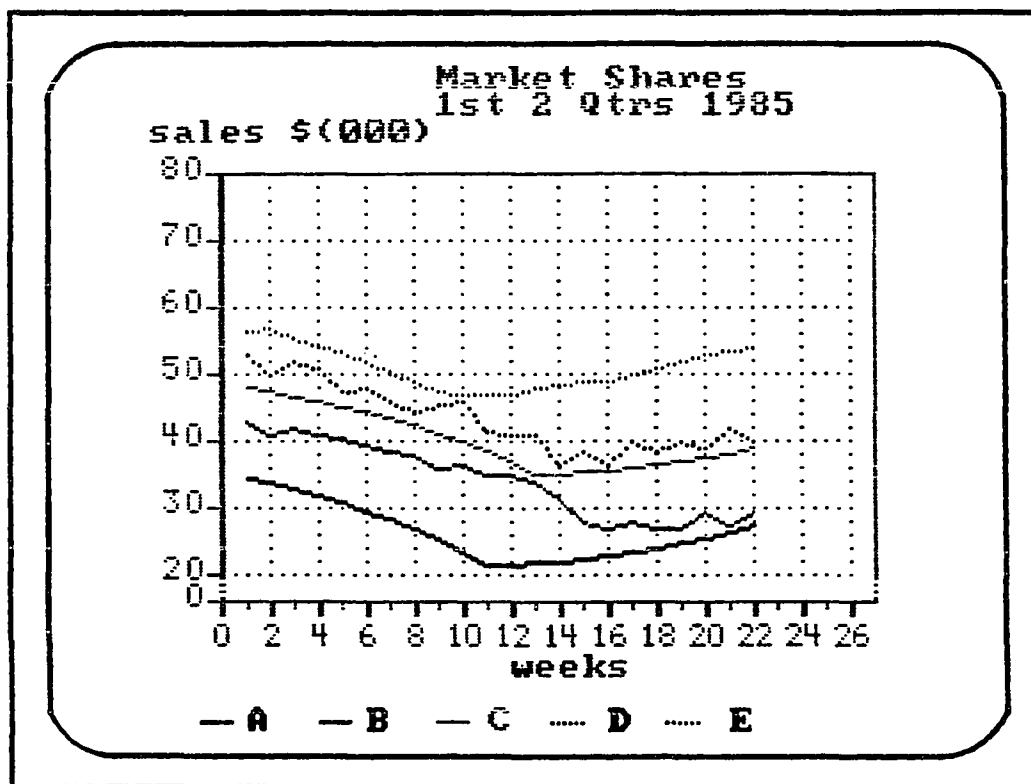


Figure 7. Trial stratified graphic.

The forecast graphic (Figure 8) added a four-period forecast to the 22-week trend. The computer calculated this forecast using Brown's quadratic exponential smoothing (Makridakis, 1978: 66). The reason for adding the forecast was simply to see whether DMs would use the calculated analytical data. The forecast provided another benefit. The consistent and similar shapes of the smoothed forecasts allowed the trends to be compared more easily. "Similarity is a prerequisite for the noticing of differences" (Arnheim, 1974: 79).

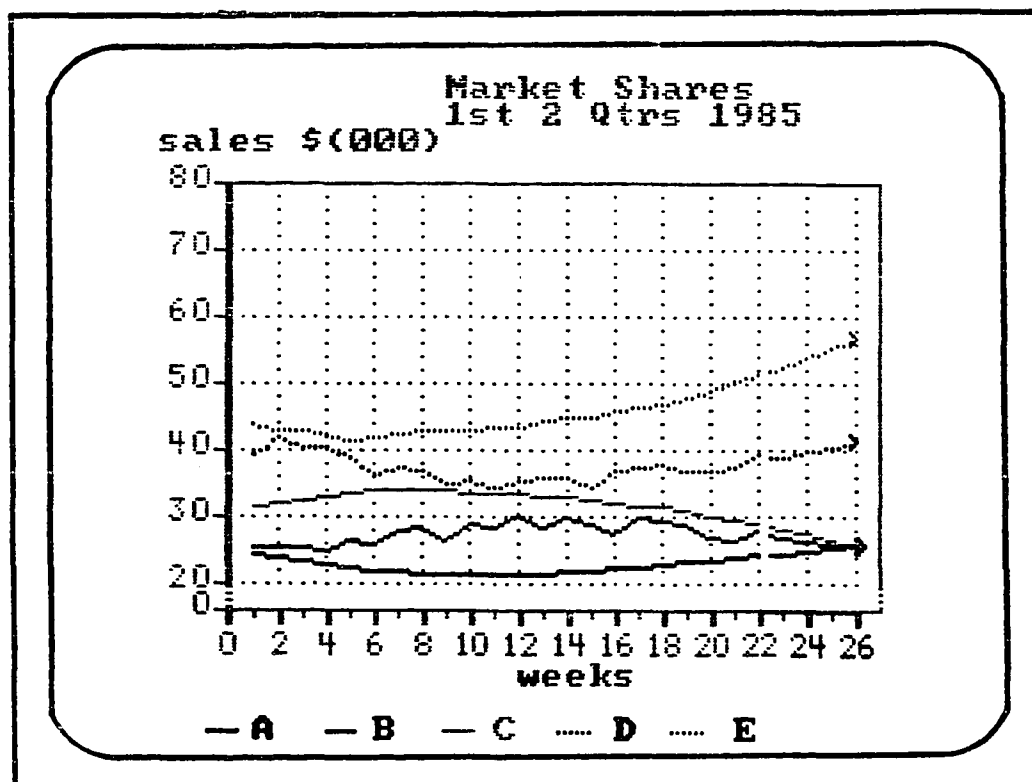


Figure 8. Trial forecast graphic.

The paired graphic (Figure 9) consisted of four small charts positioned in adjacent windows. This design

- Maximized data density (Tufte, 1983: 169-170);
- Untangled and emphasized the trends (Paller, 1981: 23); Simcox, 1984: 5; Zelazny, 1985: 39);
- Reduced eye movement to see details (the gestalt principle of proximity) (Spoehr, 1982: 28, 65); and
- Allowed concentration in one part of the screen (Welford, 1976: 39).

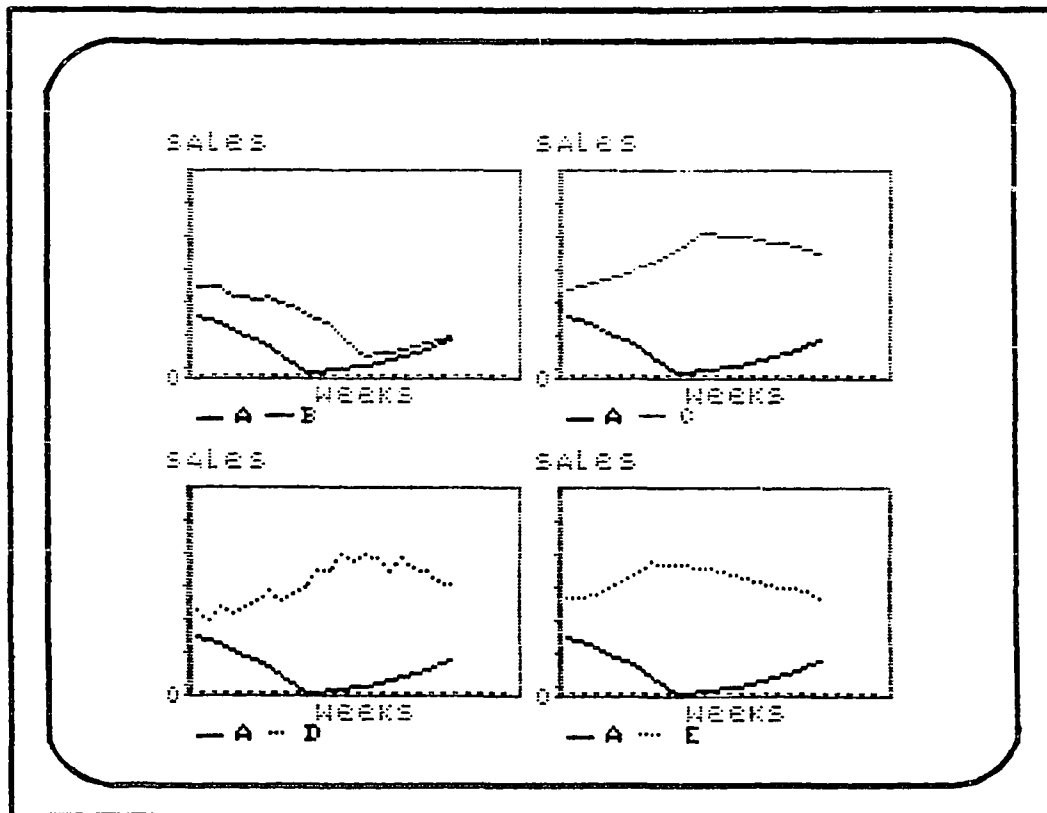


Figure 9. Trial paired graphic.

The composite graphic design (Figure 10) was simply an attempt at synergy. The design combined the stratified and forecast enhancements from the second experiment into one graphic.

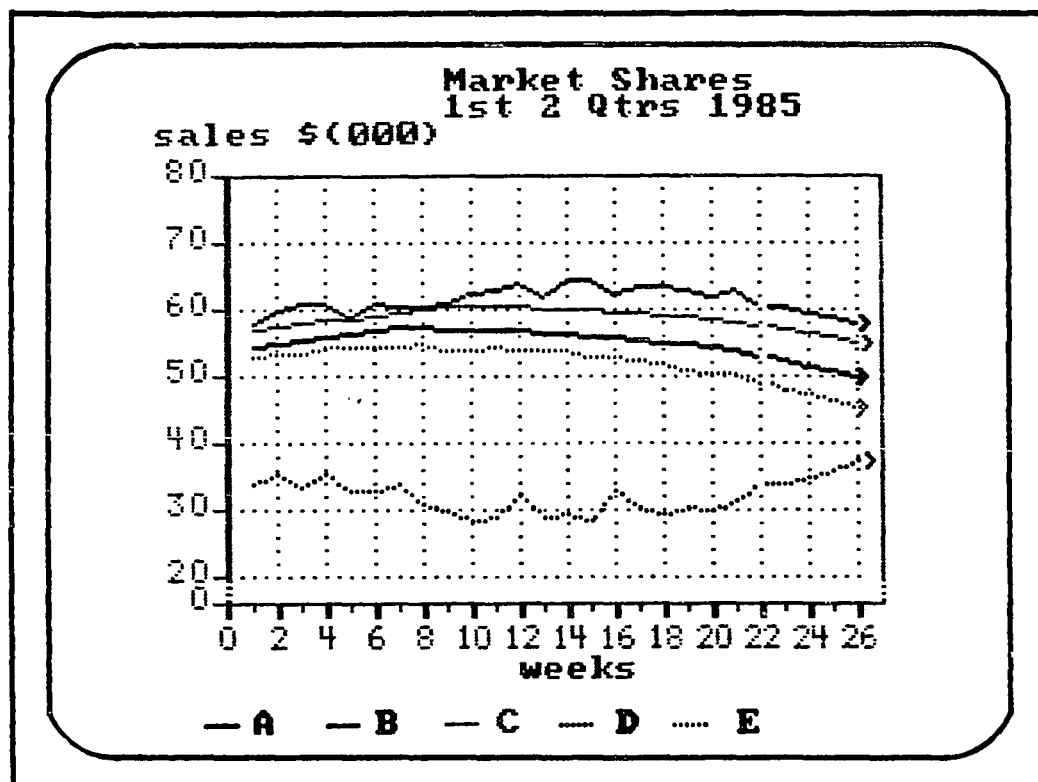


Figure 10. Trial composite graphic.

During the second experiment, the enhancement experiment, three DMs mentioned that their analyses started with the sequential display of the trends. This was the process of painting all 22 points of one trend followed by tracing all the points of another trend. The tracing was in the same sequential order, trend A, then B, then C, D,

and E. The sequential process was used in the first two experiments; but, to exaggerate the sequencing in the third experiment, a delay was added before tracing another trend. Reasons for sequencing the trends were: (1) motion gets attention (Arnheim, 1974: 372); (2) the DM can absorb the information more quickly (Jarrett, 1982: 15); (3) temporal separation may relieve processing overload (Spoehr, 1982: 23); and (4) use of the gestalt principles of temporal proximity and common fate may group the data (Uttal, 1981: 798; Spoehr, 1982: 66).

Contrasting with sequential trends were concurrent trends. In concurrent painting, the five points of one week for all trends were painted at the same time. This was followed by the same concurrent painting of points for all trends for each subsequent week. Incidentally, the sequential painting took four-and-a-half seconds longer to trace on the screen than the concurrent painting.

In displays of patterns, five is usually the recommended upper limit (Lefferts, 1981: 84). The pilot experiment showed that when the number of patterns increased from four to six accuracy decreased and response time increased. Given these results, use of more than four patterns appeared appropriate for testing the graphics at or near the region of data overload. Five was the number of patterns used throughout the trials.

Twenty-two to 26 random data points connected to make a pattern. This made a total of 110 to 130 points in the five-line graphics. The variation in the number of points depended on whether or not a graphic included forecasts. In the smaller paired graphics, the two patterns had 44 data points making a total of 176 points in the graphic. In both the two- and five-line graphics, the large number of points obliged the DMs to group the points into a pattern instead of examining individual points, thus avoiding the graphs versus tables issue which has been investigated by others. This large number of points plus their trends crossing required use of the line chart instead of a bar, column, step, or surface chart.

The recommendations in the literature guided the general design of the graphics. Many of the recommendations are listed in Table X in Appendix A.

#### RESEARCH HYPOTHESES

Two experiments conducted in the field tested a research hypothesis having eleven supporting hypotheses. Conjectured here was that comparisons among several trends are made faster with computer-enhanced graphics than with traditional graphics. The research hypothesis is:

Decision makers interacting with computer graphics compare time-series data patterns faster and more accurately using computer-enhanced graphics than traditional graphics.

Definitions of the three bold print terms in the above hypothesis are:

**Compare:** as an experimental task, determine associations/distinctions such as: (1) similar-shaped trends, (2) general trend or direction of the majority, (3) variability, (4) leading or lagging trends (period association), (5) convergent or divergent directions, and (6) differences in rates of change.

**Computer-enhanced graphics:** charts produced by computer manipulation of the context, such as changing the colors, symbols, shapes, sizes, sequences, and adding computer-calculated analytical data.

**Traditional graphics:** framed charts fully labeled, with scales and grids, having multiple lines in four colors.

Eleven experimental null hypotheses support the research hypothesis. Seven of these relate to specific aspects of making better associations and distinctions; four relate to preference, aversion, and confidence. Table V lists the hypotheses numbers and their related graphics; for example, Ho5 is null hypothesis number five, which tested the standard and forecast graphics.

For simplicity, the statements of the supporting hypotheses, given below, leave out the phrase "interacting with computer graphics" and substitute "trends" for "time-series data patterns." The difference in each null

hypothesis is in bold print. By accepted practice, all are stated in the negative.

TABLE V  
TRIAL GRAPHICS AND HYPOTHESES

Graphic Name	Tested Differences	Null Hypotheses										
		Ho1	Ho2	Ho3	Ho4	Ho5	Ho6	Ho7	Ho8	Ho9	Ho10	Ho11
Standard (Colored)	Single graph, four colors, with five trends superimposed, fixed chartjunk, no forecast	1	2	3	4	5	6	7	8	9	10	11
Black & White	Two colors	1					6	7	8	9		
Fading	Fading chartjunk		2				6	7	8	9		
Stratified	Stratified trends			3			6	7	8	9		11
Paired	Four windows of 2 trends				4		6	7	8	9		11
Forecast	Smoothing forecast					5	6	7	8	9		11
Composite	Stratified trends and smoothing forecast						6	7			10	11

Ho1: Decision makers compare trends NO more quickly and accurately with **colored graphics** than with **black-and-white graphics**.

Ho2: Decision makers compare trends NO more quickly and accurately with **fading chartjunk** than with **steadfast chartjunk**.

Ho3: Decision makers compare trends NO more quickly and accurately with trends **intentionally stratified** than with trends that **may be superimposed** on another trend.

Ho4: Decision makers compare trends NO more quickly and accurately with graphics formatted as **four windows each containing a reference trend paired with one different trend** than with graphics formatted as **one display of five different trends**.



Ho5: Decision makers compare trends NO more quickly and accurately with trends having computer-generated forecasts than with trends having no forecasts.

Ho6: Decision makers have NO preference for one type of graphic enhancement over another type of graphic enhancement.

Ho7: Decision makers have NO aversion to one type of graphic enhancement over another type of graphic enhancement.

Ho8: Decision makers have NO more confidence in one type of graphic over another type graphic.

Ho9: Decision makers have NO less confidence in one type of graphic over another type graphic.

Ho10: Decision makers compare trends NO more quickly and accurately with a composite graphic enhancement than with no graphic enhancement.

Ho11: Decision makers compare trends NO more quickly and accurately with sequential painting of trends than with concurrent painting of trends.

Sequential painting means painting all the points of a single trend, followed by painting all points of another one. Concurrent painting means painting the points of the same time period for all trends simultaneously.

To summarize, the focus of this research was on pattern comparisons as affected by six contextual variables in seven trial analytical graphics. Trial data from two experiments in the field tested 11 hypotheses. Experimentation in business and government surroundings strengthened credence in the findings.

## CHAPTER IV

### RESEARCH DESIGN AND METHODOLOGY

#### RESEARCH DESIGN

To test the 11 research hypotheses, the research design used three experiments and three nonparametric statistical tests on the trial graphics data. The experiments called for DMs to interact with computer programs displaying trial graphics with simulated 22-week trends. The DMs compared the trends and then pointed with a light pen to answer questions about the trends (Figure 11).

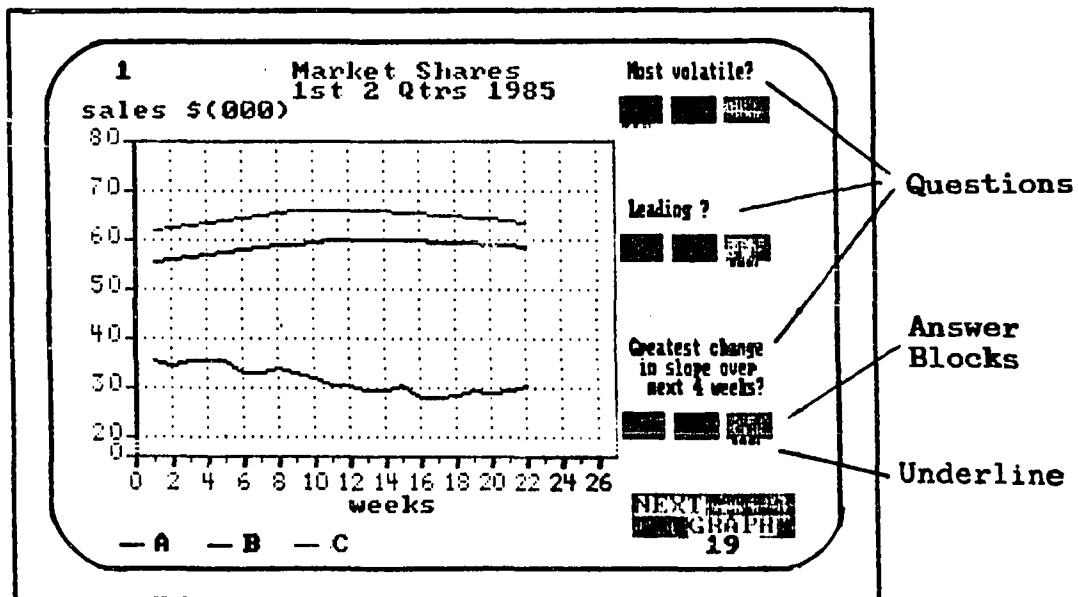


Figure 11. Sample graphic with questions and answer blocks (inverse color).

The answers and the time taken to enter the answers supplied data for testing seven hypotheses.

At the end of the trials, DMs responded to questionnaires concerning their preferences for and confidence in the graphics; this provided data for testing the four remaining hypotheses. Computer programs graded the graphics based on actual trend measurements and the DMs' time and accuracy in answering questions about the trends.

The problem-finding simulations were similar in all three experiments. Only the graphics changed. An IBM microcomputer simulated and traced unique trends for every trial graphic. The trends shown were related to a randomly-generated "mother" trend by randomly-selected parameters. The visual effect was that the trends appeared somewhat related by shape on each graphic, yet differed on subsequent graphics.

Looking at these trends, the DMs task was to find three dominant characteristics that could indicate a problem. While the DMs were selecting their answers, a digital clock at the bottom right of the graphic reminded them of how many seconds they had been looking at the trends (Figure 11). To stop the clock, the DMs had to choose to end their viewing time by selecting the next graphic. Four selections were required: three identifications and one to advance to the next graphic. The sum of the correct selections divided by the viewing time resulted

in a decision efficiency score (number correct per minute) for each graphic. Nonparametric statistical methods were used to test the differences in efficiency scores between graphics for each DM.

Although the experiments were similar, the experimental conditions did differ. One hundred five different DMs participated, and the experiments were conducted in 27 different offices and conference rooms.

This research was based on four assumptions:

1. The research would succeed only if both good and poor graphics were identified, as measured by the DMs' speed and accuracy in discovering relationships;
2. The questionnaire on preferences, aversion, and confidence in graphics would support the identification;
3. The DMs would have biases in their confidence and preference toward the traditional graphics; and
4. They would resist the changes in format of the trial graphics.

The details of the experimental design, subjects, apparatus, situation, and procedures follow.

### Experimental Design

Three progressive experiments--the pilot, the enhancement, and the composite--formed the experimental

design. Each experiment tested different variables using computer simulations.

The first was a pilot experiment with colored multiple-line graphics. "Colored" here means four hues, contrasted with two hues of black and white. The purpose of the experiment was to uncover faulty experimental procedures, refine the computer simulation, and find the number of trends, presented almost simultaneously, which produced a data overload. The overload determination was based on the DMs' deteriorating decision efficiencies with the problem-finding tasks.

After refining the experimental procedures and speeding up the computer simulation, the second experiment displayed and later rank ordered the graphic enhancements. The third experiment compared graphics made from a composite of two enhancements selected according to their rank order in the second experiment. Also added was the sequential painting of trends, which three DMs suggested as a further enhancement.

Three quantities varied throughout an experiment and among the three experiments: the independent, dependent, and random variables. The independent variables were the discrete manipulations within the trial graphics, for example, the number of lines. The independent variables were changed or controlled in successive experiments; they were the contextual variables being tested. The dependent

variable was the DMs' decision efficiencies. This was the measured variable, assumed to be continuous on an interval scale. Last, the random variables were the bounded, but randomly selected, quantities of the experiment, such as random error. The following paragraphs describe the variables in more detail and explain their function in the simulation exercise.

Independent Variables. These were the treatments in the trial graphics. They include the number of trends and the contextual variables, such as color, scale, and chartjunk that changed for each trial or every other trial depending on the experiment. Table VI shows the relationships of the independent variables in the pilot, enhancement, and composite experiments.

These variables were presented in repeating sequences in the pilot experiment and in nonrepeating sequences in the enhancement and composite experiments. In the last two experiments, the variables were counterbalanced using  $N \times N$ , "diagram-balanced Latin squares so each enhancement preceded and followed all other enhancements just once" (Wagnenaar, 1959: 384). This counterbalancing scheme randomized learning effects and varied the displays. The lists below show variables and combinations tested in the three experiments. The "n" represents the number of times the variables and combinations were tested.

TABLE VI  
TRIAL GRAPHICS AND INDEPENDENT VARIABLES\*

EXPERIMENT	Graphic Name	Independent Variables						
		Trends	Colors	Scale	Chart-junk	Format	Forecast	Presentation
PILOT	2-Line	2	Four	Super-imposed	Fixed	Multi-line	None	Seq
	4-Line	4						
	6-Line	6						
ENHANCEMENT	Standard	5	Four	Super-imposed	Fixed	Multi-line	None	Seq
	Black & White		TWO					
	Fading		Four		Fading			
	Stratified			Stratified	Fixed			
	Paired			Super-imposed		Paired		
	Forecast					Multi-line	Smoothing	
COMPOSITE	Cnc Standard	5	Four	Super-imposed	Fixed	Multi-line	None	Cnc
	Seq Standard							
	Cnc Forecast						Smoothing	Cnc
	Seq Forecast							Seq & Delay
	Cnc Stratified			Stratified			None	Cnc
	Seq Stratified							Seq & Delay
	Cnc Composite						Smoothing	Cnc
	Seq Composite							Seq & Delay

\* Blank = no change from the above entry;  
Cnc = concurrent, Seq = sequential.

The independent variables displayed in the pilot experiment were:

1. Two trends (n = 81);
2. Four trends (n = 81); and
3. Six trends (n = 81).

These variables were not considered in the research hypotheses.

In the enhancement experiment, the independent variables were displayed twice in nonrepeating sequences.

The variables were:

1. Standard or colored (n = 94);
2. Black and white (n = 94);
3. Stratified (n = 94);
4. Fading context (n = 93);
5. Paired in windows (n = 94); and
6. Extended with a four-period forecast (n = 93).

The new independent variable in the composite experiment was painting, either concurrent or sequential. Painting joined a combination of independent variables in a two-by-two-by-two factorial design. The factors were (concurrent and sequential) by (standard and stratified) by (standard and forecast), creating the following combinations:

1. Concurrent standard (n = 41);
2. Concurrent stratified (n = 41);
3. Concurrent forecast (n = 41);
4. Concurrent composite (n = 41);
5. Sequential standard (n = 41);
6. Sequential stratified (n = 41);
7. Sequential forecast (n = 41); and
8. Sequential composite (n = 41).

Dependent Variables. The dependent variable was the DM's decision efficiency, a ratio of accuracy and response



time. Decision efficiency was defined as the number of answers correct plus one divided by the response time in minutes. The "plus one" in the decision efficiency formula allowed an efficiency number to be calculated for every trial graphic. Full credit was given to a DM for coming "close" to answering the questions correctly (within 20 percent of the actual value). In all experiments, the following three questions were asked that required a comparison of trends (Figure 12):

1. Which trend is the more or most volatile? ("Most volatile" meant most erratic, noisiest, or most variable throughout the entire trend. This required a comparison of whole patterns and ties were common.)
2. Which trend is leading, showing the first change in direction? ("Leading" referred to the turning point of the whole trend, the first peak or valley starting from the left axis. This required a comparison of turning points among patterns.)
3. Which trend is likely to change the most over the next four weeks, the steepest slope? (Making a projection of the absolute change was the intent of this question. This required a comparison of change among patterns from their inflection points.)

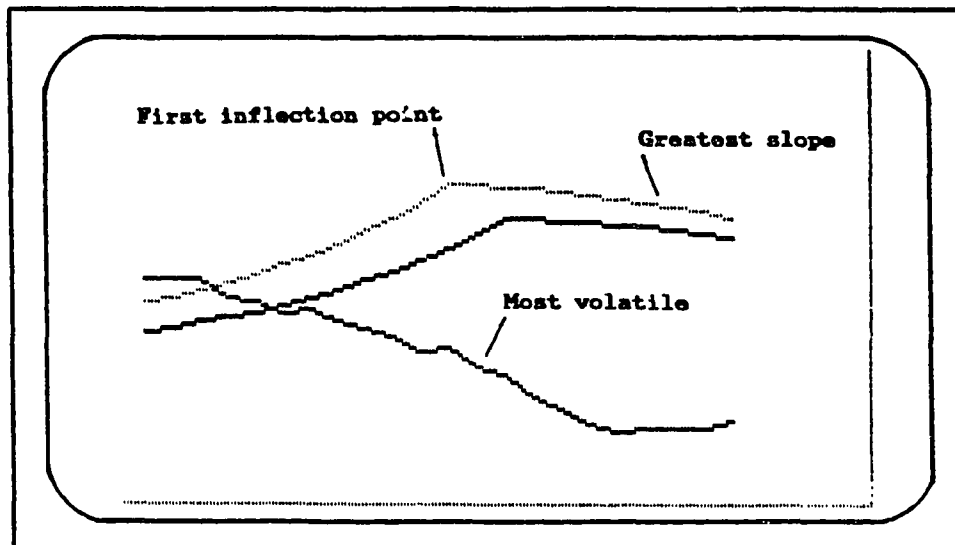


Figure 12. Trend comparison.

The DMs answered the questions (at the right-hand side of the screen) by pointing a light pen at the appropriate selection block. The computer signaled the capture of selections two ways, with different tones and by underlining the block. The measurement of response time began with the painting of the last point of the last trend and ended when the DM chose to move to the next graphic by touching the bottom block marked NEXT GRAPH (Figure 11). The DM had the option of changing any answer, at any time, and of choosing to move on to the next graphic, if all three questions had been answered.

The computer captured the DMs' answers, the order in which the answers were entered, and the response times; it then recorded these data on a floppy disk. At the same time, the computer captured and recorded the total error,

inflection point, and slope for each trend. These trend data and the DMs' answers were compared later in another computer program which graded and assigned an efficiency score to each trial graphic. During the composite experiment, the computer captured the drawing time for the trends with concurrent and sequential painting. The unedited computer program listings in Appendixes B, C, and D for the enhancement experiment show in detail how trends were simulated and the data were captured, how the graphics were graded, and how the frames were generated. The programs for the pilot and the composite experiments were similar.

Random Variables. The randomized variables were the computer-generated data patterns (the trends) and the subjects (the DMs).

The displayed trends had a wave-like shape, a crest or trough as the inflection point with asymmetrical, nonlinear sloped sides. Half of the time the trends were inverted. These trends were derived from a 37-period mother trend, having random but bounded beginning points, growth rates, and inflection points. The displayed 22 periods were from 26-period trends related to the mother trend by random, bounded parameters. These parameters included bounded percentages of the mother trend, divergent, convergent, or complementary growths, inflection points, and error limits. As the trends were generated, random error was added to each point within an error limit.

The result was that the trends appeared as a family of waves and troughs.

The parameters were bounded to keep the vertical y-scale range constant. Otherwise, the scale would have to have been recalculated for every graphic; and the scale possibly would have exceeded the horizontal lines available in the graphic. Only 22 periods were shown so that DMs could make a visual projection, while the additional four periods were used to calculate the actual slopes.

Randomizing the trends allowed generalization to a population of trends (Anderson, 1970: 46). The computer program listings in Appendix B (lines 7010 through 9350) show in detail how the trends were simulated for each experiment. Because the internal clock of the computer was the seed for the randomizing in the simulation, every trend was unique.

The computer calculated these randomized trends between graphic displays, while a text display described the type and decision objective of the next graphic. Figure 13 shows an inverse color screen print of a typical text display, with the period being calculated shown in the bottom left corner. The icon in the lower left was a remembering device used later in the questionnaire (Lodding, 1983: 12, 14). The text display disrupted the DMs' memories from one graphic to another and also allowed time for calculating the trends for the next trial graphic.

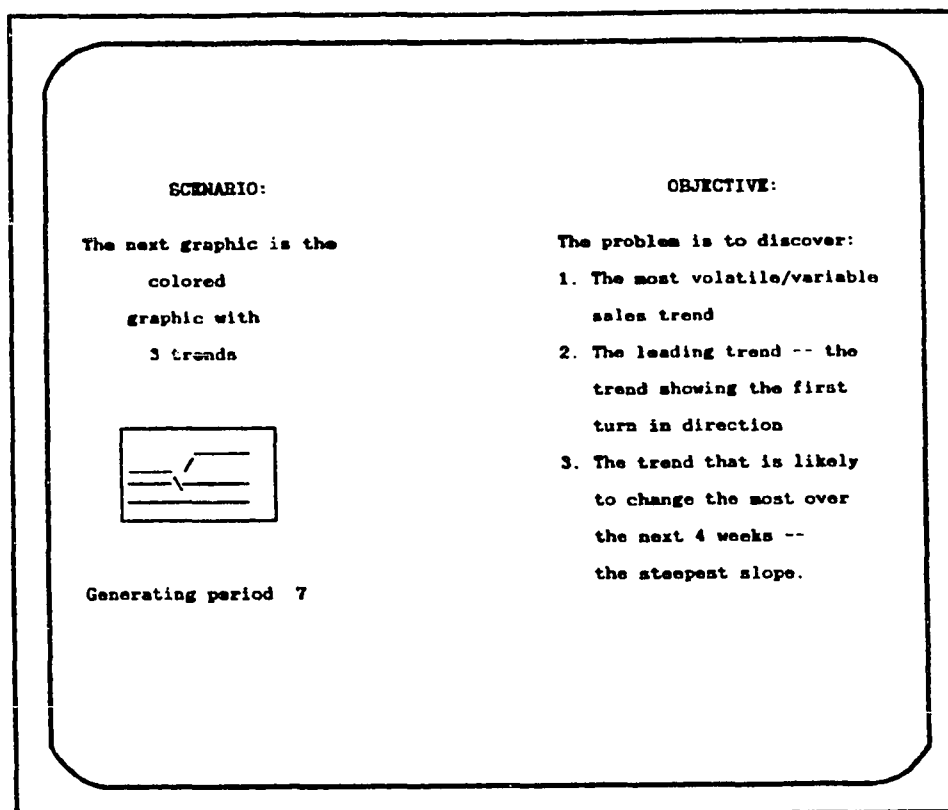


Figure 13. Text display (various colors on blue).

The random subjects were volunteer DMs from governmental, business, and educational organizations. The "DMs" are synonymous with "managers" or "staff members." Generally they used and were familiar with time-series graphics. All the DMs in the last two experiments seemed to be familiar with computer graphics. Exactly who was going to participate in the experiment was not known until the individual DM picked up the light pen in the enhancement experiment. For the composite experiment, however, five of the 10 repeat subjects were known before the start of the simulation exercise.

The planned minimum DM sample sizes were 18 for the pilot experiment, 36 for the enhancement, and 32 for the composite (the actual sizes were 27, 47, and 41). The planned sizes equated to 54 trials per graphic in the pilot, 72 trials per graphic in the enhancement, and 32 trials per graphic in the composite. The variation in efficiency was unknown.

Experimental Subjects. For the pilot, 27 volunteers were solicited from Business Administration and Systems Science faculty and graduate students at Portland State University.

Forty-seven DMs scanned graphics in the enhancement experiment, and 41 scanned graphics in the composite experiment. Telephone directories were the principal source for finding organizations to participate in these last two experiments. The leading question used to find DMs was, "Do you have anyone using Lotus' 1-2-3 graphics?" This usually provoked a yes or no answer and effectively screened out DMs not acquainted with computer graphics. The question was asked for the following reasons:

- The research was focused on finding ways to improve computer graphics not improving DMs' skills in general. Employing DMs who were unfamiliar with computer graphics or time series could have introduced too much variation in their sequential performance (Starr, 1971: 272). Decision

efficiency differences were to be due to the enhancements and not to learning.

- The DMs needed to be familiar with the limitations of microcomputer graphics, that is, few colors, large-grain resolution, small screen size, and limited character sets.
- This study was aimed at improving graphics. It was not an aptitude test for finding DMs who might or might not read computer graphics more efficiently. The anecdotal findings in the next chapter, however, discusses the wide range in DMs' decision efficiencies.

Those DMs who were familiar with Lotus' 1-2-3 were familiar with computer graphics, knew about the quality of the graphics, and had been selected by their supervisors to work on the computer. This screening process also eliminated the need to familiarize the DMs with the computer.

Experimental Apparatus. The apparatus included hardware, software, and a questionnaire.

The hardware was an IBM Personal Computer (PC) having 640K of memory, RAM disk capability, two disk drives, FTG Systems light pen, and an Amdek MAI graphics board. The simulation program accessed the 320 x 200 resolution in four colors. Higher resolutions and more colors were not used because of the line flicker and the added difficulty

of programming in the HALO graphics language. The monitor was the Amdek Color IV, which displayed a 9-inch by 7-inch screen.

The software included DOS 2.0 and Advanced BASIC, a light pen calibration program, a print enhancer program, graphic frame images, the simulation programs (trends generation and data capture), and graphic scoring programs. Figure 14 shows a flowchart of the simulation programs stream. A separate program generated the colored (cyan) and black-and-white graphic frames off-line.

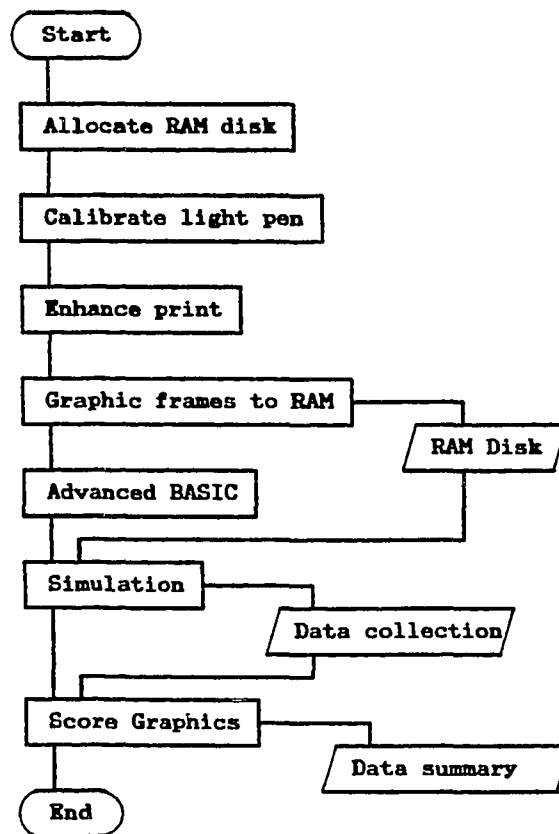


Figure 14. Programs stream.



All the graphics except the paired graphic approximated the size of Lotus' 1-2-3 graphics, 128 pixels high by 216 pixels long. Titles and legends added another 48 pixels to the height. The graphics differed from the Lotus graphics by having scale breaks and different lettering and symbols. The paired graphics were half the size of all the other experimental graphics.

The simulation program generated data plots for as many as six trends of 26 periods. Sequential painting of the trends took approximately four-and-a-half seconds longer than concurrent painting in the composite experiment. Except for the black-and-white graphic, the painting order of the trends was solid white (trend A), solid magenta (B), solid cyan (C), dotted white (D), dotted magenta (E), and dotted cyan (F). The values of the plots ranged from 20 and 80 to correspond with the vertical lines of the graphics screen. Each value equaled two pixels for the traditional sized graphics, and each value equaled one pixel for the paired graphics. This eliminated the slower multiplication and division functions and allowed the numbers to be integers, halving the computer memory requirements. Speed and memory became critical in the simulation program for the enhancement experiment because of the length of the program. The efficiency of the programs progressively improved over the three experiments.

### Data Collection

Collected experimental data and on-line questionnaire data were written out to a floppy disk during the experiment. Computer programs graded these collected data at the end of every test, displayed the decision efficiencies for each graphic and the DM's preferences, and summarized the new data on another file on the same disk. Symphony, the integrated software program from Lotus Development Corporation, provided a method to import the files into a spreadsheet and database.

## METHODOLOGY

### Experimental Method

Three computer programs graded the graphics based on a matching of answers with the actual errors, inflection points, and slopes. Answers, however, were judged correct if they were within 20-percent of the highest error, leading trend, and steepest slope. The 20 percent leeway allowed more personal satisfaction for the DMs. Percentages of leeway ranging from zero to 50 were tried during the pilot experiment, and the 20-percent leeway was chosen because it allowed average efficiency to be greater than 50 percent.

The planned tests were the Multivariate Analysis of Variance (MANOVA) for carryover effects (Hull, 1981: 28-29) and the one-way ANOVA with Scheffé's method for multiple

comparisons (Guenther, 1964: 57, Norusis, 1982: 73). Since the variations in efficiency of the pilot experiment were high and nonhomogeneous using ANOVA (Cochran's C equaled .67 and  $p = 0.0$ ) (Nie, 1975: 430), comparisons were made with nonparametric methods, specifically the Wilcoxon signed rank test (Mendenhall, 1979: 492) and the Friedman test (Conover, 1971, 264). The statistics from these two tests were the differences in efficiencies. The actual number of preferences and confidences for a graphic were tested using Cochran's Q test (Runyon, 1977: 59). The critical values used for these tests were taken from Mendenhall's Table 9, "Critical Values of T in the Wilcoxon Matched-Pairs Signed Rank Test" (1979: 547); Table A26, "F Distribution with  $k_1$  and  $k_2$  Degrees of Freedom (0.95 Quantiles) for the Friedman Test" (Conover, 1980: 483); and Table C, "Table of Chi-square for the Cochran's Q Test" (Runyon, 1977: 157). The significance level was 0.05. The Cochran Q test was used to verify that the number of answers was different for all the graphics. The data base features in Lotus' Symphony, such as row-to-column transforms and sorting, eased comparisons of the trial graphics.

#### Experimental Process

One hundred five DMs tried the graphics; 10 tried graphics in two experiments. All but two DMs tested the graphics in offices or conference rooms within their organizations; two tested at private homes. Lighting,

noise levels, and the table height of the CRT varied from place to place. Where space permitted, the monitor and light pen were placed adjacent to the computer and keyboard. Often during the trials, the Test Administrator (TA) would leave the immediate area to relieve the simulation situation, to talk to the next subject, and to intercept questions of passersby. Short interruptions were not uncommon.

All three experiments required DMs to dialogue with a microcomputer through a CRT display and a light pen. Figure 15, which is a modification of Buck's communication process (1983: 196), shows the dialogue between the computer displaying graphics and the DM (the human information processor). For input to the computer, a light pen in the hands of a DM is the fastest and easiest-to-use selector device (Foley, 1984: 30-31).

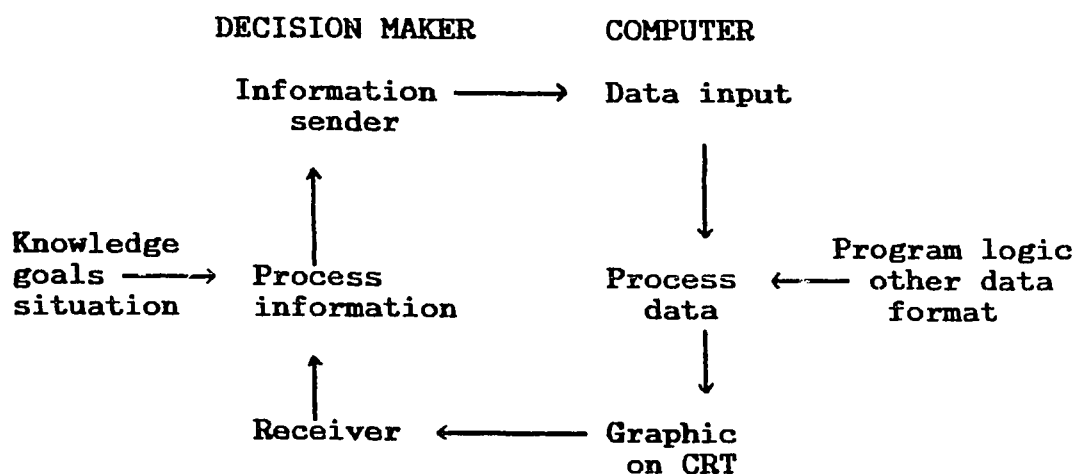


Figure 15. Communication through computer graphics.

The dialogues involved communicating with a simulated DSS in which the screen formats for the dialogue remained constant (Engel, 1975: 3-17; Bennett, 1983: 62) even though the trial graphic changed. The experimental processes in the experiments were different but generally the same, for example, the pilot experiment demonstrated two trends first, but the enhancement and composite experiments demonstrated three trends first. Table VII, "Experimental Process Sequence of Events," summarizes the sequence of events for all three experiments. The sequence of screens for the enhancement experiment with its accompanying verbal instructions, except for the trials, are in Appendix E as an example. While the computer was being set up, most of the DMs saw the same sample of screen prints.

Before the dialogue started, the sequence of trial graphics was set up for each experiment (Step 0 in Table VII). In the enhancement experiment, the TA entered one of the following graphics sets:

Set 1 = 1,1,2,2,3,3,4,4,5,5,6,6;

Set 2 = 2,2,4,4,1,1,6,6,3,3,5,5;

Set 3 = 3,3,1,1,5,5,2,2,6,6,4,4;

Set 4 = 4,4,6,6,2,2,5,5,1,1,3,3;

Set 5 = 5,5,3,3,6,6,1,1,4,4,2,2; or

Set 6 = 6,6,5,5,4,4,3,3,2,2,1,1;

where 1 was black and white, 2 was colored, 3 was fading, 4 was stratified, 5 was paired, and 6 was a forecast graphic.

TABLE VII  
EXPERIMENTAL PROCESS SEQUENCE OF EVENTS

Step	Events*
0	ENTERED GRAPHIC SEQUENCE FROM COUNTERBALANCING SCHEME.
1	STARTED DEMONSTRATION.
2	Showed the standard graphics having 3 easy-to-identify characteristics.
3	SHOWED HOW TO ANSWER QUESTIONS WITH LIGHT PEN.
4	STARTED WARM-UP.
5	ENTERED PERSONAL IDENTIFICATION NUMBERS AND PREFERENCE FOR GRAPHICS OR TABLES [recorded numbers, preferences, sequence, and the time.]
6	Showed test graphic with 3 or 5 trends. [Randomly generated trends and calculates slopes, separations, and forecasts.]
7	Asked for comparisons of (1) Variability, (2) Lead/Lag, (3) Projection of greatest slope.
8	Prompted for answers regarding the patterns with the start of the clock. [recorded time].
9	<u>ENTERED ANSWERS AND ADVANCE TO NEXT GRAPHIC WITH LIGHT PEN.</u>
10	[Recorded the time, answers, and trend data.]
11	Indicated the correct answers to the questions after the second graphic.
12	[Continued simulation from step 6, until all test graphics were shown.]
13	Held (pause) for DMs questions. ANSWERED DMs QUESTIONS.
14	STARTED SIMULATION TRIALS OF GRAPHICS.
15	[Selected the graphic from the sequence. Recorded the time.]
16	Described the scenario and decision objective; announced the type of graph and number of trends. [Randomly generated trends, calculated slopes, separations, and forecasts.]
17	Showed graphic and questions.
18	Prompted for answers to questions. [Recorded the time.] IF NO ENTRY AFTER 60 SECONDS, VERBALLY PROMPTED FOR INPUT.
19	<u>ENTERED ANSWERS AND ADVANCED TO NEXT GRAPHIC WITH THE LIGHT PEN.</u>
20	[Recorded the time, answers, and trend data.]
21	[Continued simulation, from step 15, until 15 minutes have elapsed, then stopped the simulation.]
25	Showed questionnaire questions.
26	<u>VERBALLY ANSWERED QUESTIONS.</u> ENTERED ANSWERS.
27	[Graded graphics based on answers and trend data.]
28	Printed the times, answers, and decision efficiency scores.

\* All capitals = Test Administrator's (TA) Action  
 Underlined capitals = Decision Maker's (DM) Action  
 Lower case = Computer Program (CP) Action: those in brackets not displayed.

The first section of the simulation programs demonstrated the types of graphs used in the test (Step 1 in Table VII). The data patterns were a family of partially controlled, wave-like patterns. Noise, the volatility, was apparent in one of the trends. The leading trend was evident, and the trend having the greatest change in slope was exaggerated (Figure 11). This three-trend graphic demonstrated lead/lag and similarities/differences in noise and growth rates.

The TA read the sample questions, explained the differences in the trends, and linked the legend and trends to the answer blocks shown at the same time. Reassurances were given that the graphics were being evaluated--not the DM's performance. The TA entered the DMs' responses to questions with the light pen and demonstrated how answers could be entered in any order and changed. The TA also mentioned the running digital clock at the bottom of the screen. The DMs' first interactions with the TA usually were verbal, but four or five picked up the light pen and proceeded with the demonstration on their own.

Next, the dialogue involved the DMs in a warm-up exercise (Step 4). This warm-up consisted of a set of simple wave-like patterns in a traditional, unenhanced format; and the DMs were asked to respond to the questions about the data patterns. The DMs simply touched a colored

block or symbol enclosed in a rectangle on the screen to signify a selected trend with the light pen. The computer responded by underlining the selected answer block and issuing an audible tone, with different tones for different answers. Throughout the first two experiments, the titles and scales on the traditional graphic remained the same. In the last experiment, the last two scaling numbers for weeks 24 and 26 were changed from cyan to magenta to highlight the forecast periods.

After the first graphic in the warm-up, the computer displayed as many as six trends in each type of graphic. Most of the parameters for the remaining graphs in the warm-up stayed constant, so approximately the same family of trends was seen in all the trial graphics. When five or more trends were displayed, the computer printed the relative volatility levels, inflection points, and slopes for each trend below the answering blocks (Figure 16). This provided feedback and aided the DMs' interpretations of the trends before continuing to the next graphic. Before proceeding to the next graphic, the DMs were asked if they could see the differences in the trends. The feedback stopped at the end of the warm-up.

From the beginning of the warm-up through the end of the test, the computer recorded answers and trend data in disk files. These files had been given identification



numbers at the beginning of the warm-up, most often it was the DM's business telephone number (Step 5).

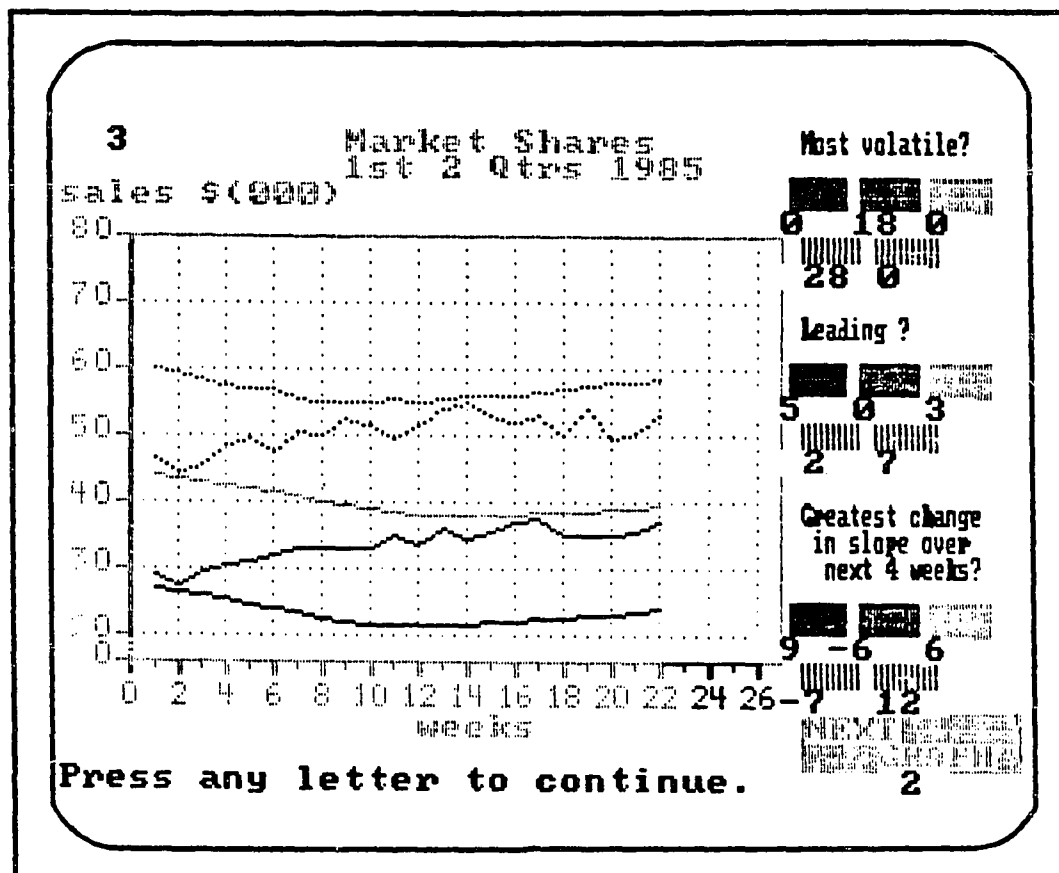


Figure 16. Screen print of demonstration graphic (inverse color).

Before the DMs started the actual trials, the TA answered their questions. The DMs were told that the average time per graphic was 30 seconds but to proceed at a comfortable speed. The TA also told the DMs that only procedural questions would be answered until after the end of the simulation. At this time, the TA moved approximately five feet back and away from the computer.

The trials began with a prearranged sequence of graphs that had been entered into the simulation at the beginning. The data patterns were all generated randomly; no one saw the same patterns. The reasons for this were to avoid the DMs' remembering the same patterns and answers from trial to trial and to avoid statistical biases. Every DM saw a different set of patterns; therefore, there was no reason for competition between these people. Often, however, a DM's first concern was how their scores compared with other DMs' scores.

The sequence of graphics after the warm-up included nine trial graphics for the pilot simulation, 12 for the enhancement, and eight for the composite. After the DM either had completed the trials or had spent 15 minutes working on the trial, the simulation ended. If a trial was in progress at the end of 15 minutes, the simulation program would permit its completion. The 15-minute limit was employed to ensure that the exercise did not last too long--which nevertheless happened twice in the enhancement experiment. During the trials, the TA estimated and recorded the DM's eye distance from the monitor; and the TA also noted whether the DM touched the monitor (some DMs traced the trends).

Toward the end of the enhancement and composite experiments, the simulation programs asked questions of the DMs about their graphics preferences, their professions,

and their graphics usage. The TA entered the answers to these questions, which were recorded with the test data.

At the end of the simulations, other computer programs graded the graphics to show the scores of the types of enhancements or number of patterns. These scores provided immediate feedback to the DMs on how the graphics were graded. From start to finish, the simulations took between 20 and 60 minutes. Most of the differences in duration resulted from the TA answering questions about the simulations and discussing the graphics.

Generally, the DMs followed the procedures and tried the graphics with earnest concentration. But, the composite experiment was shortened approximately 10 minutes because of a few DMs' remarks and impatience in the enhancement experiment. It was too long.

## CHAPTER V

### ANALYSES OF EXPERIMENTAL DATA

#### INTRODUCTION

The purpose of these analyses was to test the 11 null hypotheses discussed in Chapter III and to uncover related information. Tables VIII and IX summarize the findings at the 0.05 level of significance. Efficiency in the hypotheses refers to decision efficiency (accuracy/time). Six hypotheses were not rejected, but five were rejected.

TABLE VIII

#### HYPOTHESES NOT REJECTED

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<u>No.</u>	<u>Null Hypothesis Summary</u>
Ho1	No significant efficiency difference between colored and black-and-white graphics.
Ho2	No significant efficiency difference between fading and steadfast chartjunk.
Ho3	No significant efficiency difference between stratified trends and superimposed trends.
Ho4	No significant efficiency difference between four windows and single multiple-line graphics.
Ho10	No significant efficiency difference between composite and standard graphics.
Ho11	No significant efficiency difference between sequential and concurrent painting.

---

TABLE IX  
HYPOTHESES REJECTED

<u>No.</u>	<u>Null Hypothesis Summary</u>
Ho5	No significant efficiency difference between graphics with and without computer-generated forecasts.
Ho6	No significant differences in preference among the types of graphics.
Ho7	No significant differences in aversion among the types of graphics.
Ho8	No significant differences in confidence among the types of graphics.
Ho9	No significant differences in uncertainty among the types of graphics.

Analyses of the experimental data related to these hypotheses are in three sections: the pilot experiment, the enhancement experiment, and the composite experiment. Each section is divided into five parts: Tests or Tests of Research Hypotheses, Descriptive Statistics and Graphs, Questionnaire Results, Anecdotal Findings, and Implications and Limitations. The part on tests contains most of the essential experimental results; the other parts include details and comments. Appendixes F through K contain the statistical and test summaries and the experimental data.

Decision efficiency or efficiency, the crucial determinant mentioned in the hypotheses summaries, referred to the DMs making selections "quickly and accurately" as

stated in the original hypotheses. Decision efficiency was a measure relating the amount of output to the amount of input. It was the calculated ratio of the number of correct selections and response times, for example, 3 correct/0.5 minutes, or 6 correct/person-minute (Mercer, 1978: 52). This timed accuracy was how each graphic was scored. The differences in efficiencies between and among the graphics were tested for Ho1 (color), Ho2 (fading), Ho3 (stratified), Ho4 (paired), Ho5 (forecast), Ho10 (composite), and Ho11 (painting).

The unexpected variation in one of the two components of efficiency, response time, probably caused wide variation in the decision efficiency which lead to using nonparametric statistical tests. The correct selections number was the numerator of efficiency and was the computer-captured number of correct answers plus one, an integer value ranging from one to four. The response time was the denominator in the efficiency calculation, captured in seconds and ranging from seven seconds to 105 seconds. Later, the computer transformed the seconds to fractions of minutes in calculating efficiency.

The charts shown throughout this chapter follow the same sequence for the three experiments: DM's differences in efficiency (tally graph), average efficiency (floating bar), correct selection response (bar), and response times (floating bar). The charts show summary statistics on all

the trial graphics tested in an experiment so that all may be compared together.

The descriptive statistics and nonparametric statistical tests were calculated using Symphony, the integrated software program from Lotus Development Corporation. The test statistics were medians of the efficiencies for a type of graphic seen three times for the 27 DMs in the pilot and a type of graphic seen twice for the 47 DMs in the enhancement experiments. But, the test statistics for the 41 DMs in the composite experiment were the single efficiency scores of a graphic. This difference in test statistics resulted in the composite experiment's having a larger variation than the enhancement experiment, and this affected the outcomes of the nonparametric tests.

#### ANALYSIS OF THE PILOT EXPERIMENT

The purpose of the pilot was to determine the number of lines to be used in the enhancement experiment and to explore and modify experimental procedures. The number of lines in a graphic needed to be high enough to make the experimental task difficult, but not so high that the lines were too difficult to distinguish.

Twenty-seven DMs tried 243 line graphics during the spring of 1985; each DM tried three two-line, three four-line, and three six-line graphics. Tests confirmed that efficiencies were significantly different for the two-line,

four-line, and six-line graphics. Median efficiency scores deteriorated with the number of lines. The accuracy component of efficiency, however, was highest with four lines, next highest with six lines, and lowest with two lines. The reduction in accuracy after four lines eventually contributed to selecting five lines for the next two experiments.

A thorough analysis of the experimental data did not reveal that one of the trend measurements was missing, but the effect of the missing data on the results was inconsequential.

### Tests

Two nonparametric within-subject tests were conducted on the trial results, to find a point of data overload. Based on the DMs' median efficiencies, Friedman's test statistics for the three graphic types was significantly different. The T-statistic was 11.61, and the critical region for  $\alpha = 0.05$  corresponded to all values of T greater than 3.22, the 0.95 quantile of the F distribution with  $k_1 = 2$  and  $k_2 = 52$  (Conover, 1980: 299, 483).

Using the Wilcoxon signed rank test, the two-line efficiency medians vs the four-line ones was  $T = 71$  with  $n = 27$ ; and the four-line medians vs the six-line ones was  $T = 58$  with  $n = 27$ . Both tests were significantly different; the critical value is 84 at  $\alpha = .005$ , where



numbers less than the critical value are in the rejection region (Mendenhall, 1979: 547).

Figure 17, a tally graph, shows a tally of efficiency deviations, also within subjects. The tally graph is similar to Wilkinson's Fuzzygram (Haber, 1982: 30), except that the tally graph also shows four statistics.

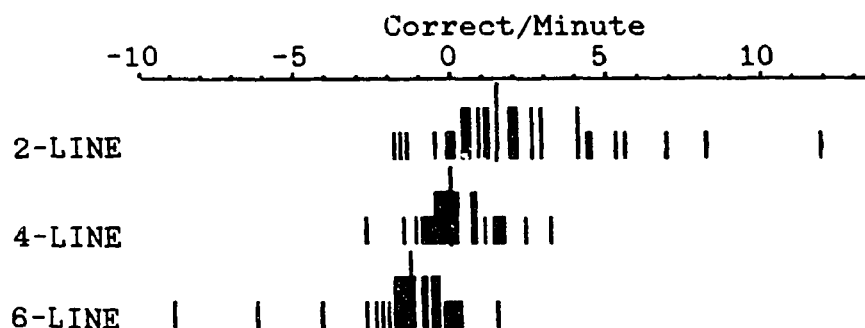


Figure 17. Efficiency differences decrease with increasing number of lines (pilot efficiency differences).

In Figure 17, each vertical line represents one deviation; and the group of vertical lines approximates the distribution of deviations for each type of graphic. The three line sizes represent statistics: the tallest vertical line represents the second quartile or median, the medium-sized lines represent tallies within the interquartile range, and the short lines represent tallies in the upper and lower quartiles. The distance between the far right and far left short lines is the range. For instance, in the top group of vertical lines, each line represents the difference of each DM's two-line median for three graphics from his/her

overall median for nine graphics. The tallest line indicates the median deviation for all 27 DMs, which was a difference of about 1.5 correct/minute from their overall median efficiencies. The medium-sized lines indicate an interquartile range of 0 to 4, and the first and last short lines, from left to right, indicate a range of -2 to 12.

A tally of deviations from each DM's average efficiency indicated that the two-line graphic had the greatest number of positive deviations. A comparison of the three groups of tallies shows that individual efficiency generally deteriorated with the number of trends presented in a graphic. Those tallies to the right of zero indicate DMs' average efficiencies for a graphic that are higher than their overall average efficiencies. Those to the left of zero indicate lower than average efficiencies for a graphic. The distances from zero indicate the size of the deviation. The median deviations for all DMs for the two-line, four-line, and six-line graphics were 1.5, 0.0, and -1.3, respectively.

#### Descriptive Statistics and Graphs

Average Decision Efficiency. Extreme variation characterized the efficiency scores. Again, decision efficiency was the ratio composed of two measured components: correct selection response (the numerator) and the response time (the denominator). Figure 18 shows the medians and ranges for the two-, four-, and six-line graphics on a

floating bar chart. The horizontal bar represents ranges, and the thin, dark vertical column marks the medians. The medians were 6.95, 5.81, and 4.13, respectively, for the two-, four-, and six-line graphics. The corresponding means were 8.60, 6.27, and 5.13, confirming that the distribution was positively skewed as shown in Figure 18. The four-line graphic had the least variation, which the narrower horizontal bar suggests. The coefficient of variation was 0.70 for the two-line, 0.54 for the four-line, and 0.65 for the six-line graphic. Appendix F provides more details. In spite of extreme variation, the averages indicated deteriorating efficiency with an increasing number of lines. This was not so for the correct selection component of efficiency.

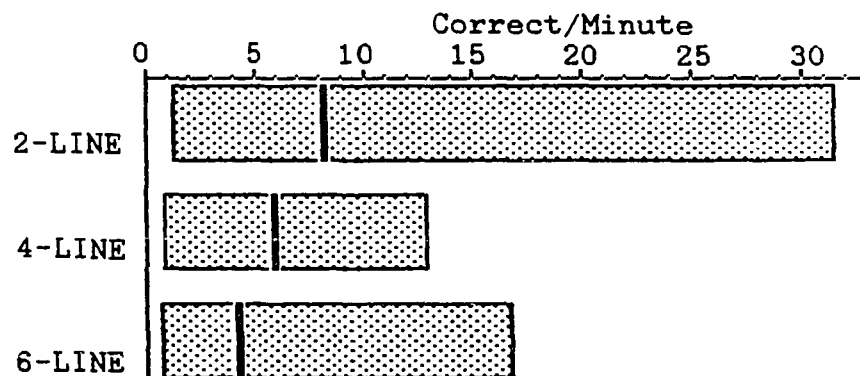


Figure 18. Decreasing median efficiency with increasing number of lines (pilot median efficiencies).

Performance did not appear to improve with successive trials. Figure 19 shows little or no learning.

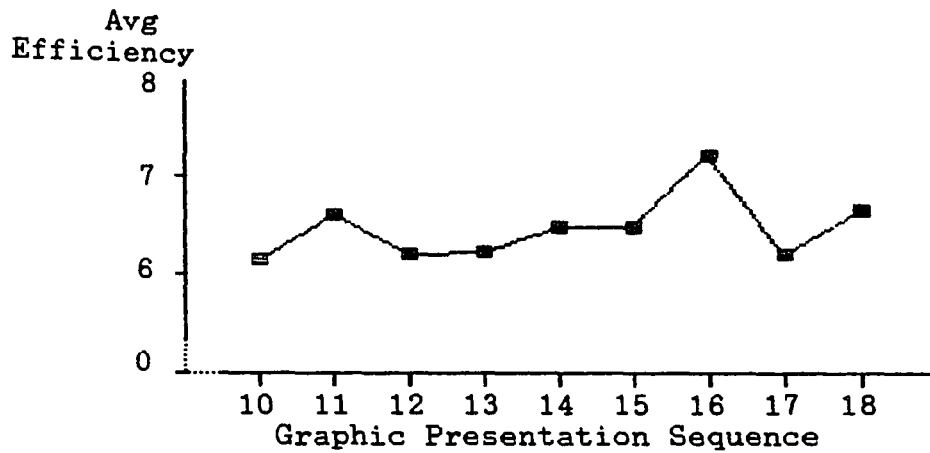


Figure 19. Little learning from practice (pilot sequential average efficiency).

Correct Selection Response. Accuracy differences were not explained by the increasing number of lines. The medians for correct selections were 2, 3, and 3 for the two-line, four-line, and six-line graphics, respectively. The corresponding means were 2.22, 2.79, and 2.59, as shown in Figure 20. These numbers must be explained further because of missing data.

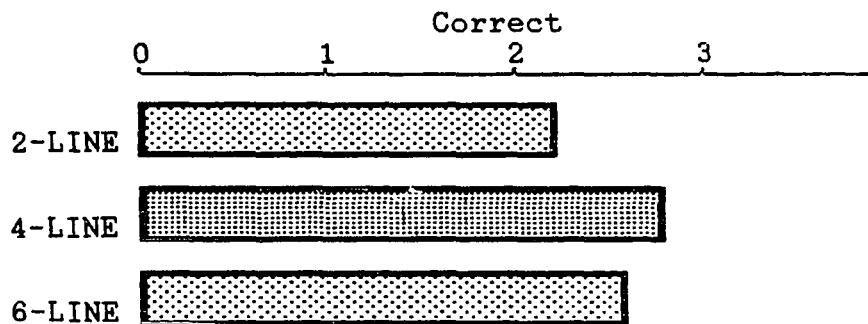


Figure 20. Four-line best (pilot correct selections).

The computer program did not record total error for Line B under the volatile question. It was not discovered that these data were missing until the middle of the third experiment. The effect on the two-line, four-line, and six-line accuracy was  $1/2$  (one answer in two possible),  $1/4$ , and  $1/6$ , respectively, based on the random trend generation in the simulation program. Even disregarding the missing volatile data and considering only the answers from the leading and slope questions does not change the order, as Figure 21 shows. Regardless of the missing data, the four-line graphic produced more correct answers than either the two- or six-line graphics. The two-line graphic was least accurate.

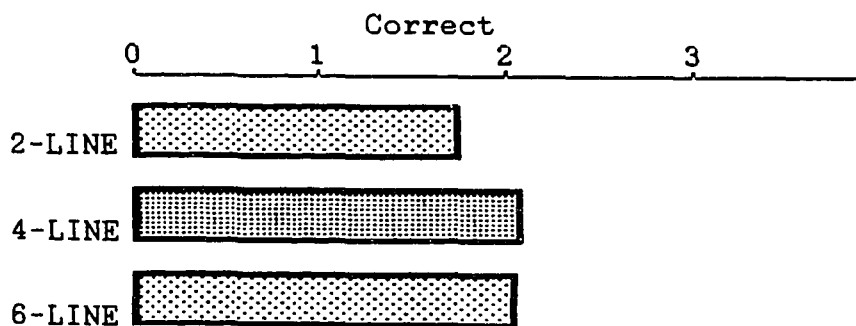


Figure 21. Four-line best regardless (pilot correct selections less volatility question).

Response Times. Figure 22 shows the increasing response times medians and ranges with increasing additional lines. The medians were less than the means, resulting in the skewed distributions. The two-line graphic had a median of 16.09 and mean of 19.33, the

four-line had 28.48 and 32.28, and the six-line had 33.09 and 37.53. Figure 22 confirms the skewed distribution with the range bars to the right of the vertical median marks.

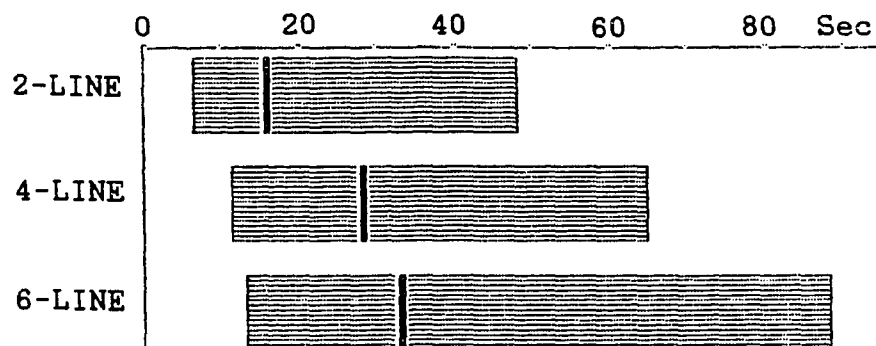


Figure 22. Increasing response times (pilot response times).

### Questionnaire Results

One question was asked in the simulation program regarding the DM's preference for tables versus graphics. Three DMs preferred tables, three were indifferent, and 21 preferred graphs.

### Anecdotal Findings

The following anecdotal findings influenced the design of the enhancement and composite experiments:

- One DM was asked why his accuracy was higher on the four-line graphics than the two- or six-line ones. He said that the two-line graphic was so easy that he did not spend much time on it, the four-line

required concentration, and the six-line introduced frustration. Other DMs agreed with these comments, which may have indicated that the point of information overload was more than four lines.

- Many DMs wanted to start answering questions before or after seeing only one demonstration. Many DMs also asked about testing the graphics after the three warm-up trials instead of the six programmed ones. Most were reluctant to give an identification number at the beginning of the warm-up.
- Three or four DMs said that they were making paired comparisons for volatility as the trends appeared on the screen. When the first trend was displayed, it was used to judge other trends as they came on the screen until a more volatile trend appeared, and then that more volatile trend became the baseline from which to judge.
- All the DMs desired to see the results and waited to see how the graphics were graded and compared.
- When a notebook was used to read the script to subjects, most DMs attempted to read the notebook instead of looking at the screen. After switching to palmed 3" x 5" cards, the DMs still attempted to read the cards.
- The DM having the highest average efficiency was a full-time Systems Science PhD student who had an

MBA. This DM had an uncanny ability to sift through the six-line graphics more efficiently than anyone else, besides being the second fastest person overall and achieving 59 percent accuracy (16 correct out of 27 possible). For comparison, this DM's highest efficiency was four times the median for all subjects for the six-line graphic and his lowest was twice the median for all subjects. When asked to explain his high efficiency, the DM said that his ability to concentrate and shut out distractions helped. An F-4 radar observer who flies with an Air National Guard unit attained the second highest efficiency. This DM was 63 percent correct in answering questions and was the third lowest in average response time. The overall fastest and most vocally confident DM gained the third highest efficiency. But this DM's percentage of correct answers was only 33; he answered only one out of nine leading questions correctly. The two DMs who had the highest percentage correct (78) were slower in answering the questions than the higher performers. Of these two, one DM's average response time was 183 percent that of the highest performer, and the other DM's time was 329 percent that of the highest. Coincidentally, the Pearson



coefficient of correlation was  $-0.02$  for the 27 DMs' average response times and correct selections. The lowest performer did not appear earnest. The third to the lowest mentioned color deficiency. This latter subject identified none of the slopes and only one of the leading trends correctly; and he mentioned a nonexistent blue line.

- Many people used either the light pen or their fingers to trace and project the path of the lines on the screen.
- Several subjects backed away as far as three feet to view the screen; one DM's tilted head indicated difficulty in seeing through bifocals.

#### Implications and Limitations

The pilot experiment showed that DMs' efficiencies decreased with the number of lines on a graphic. The DMs' accuracy, however, was highest with four lines, next highest with six lines, and lowest with two lines. The decrease in accuracy with the two-line graphic appeared to result from a lack of concentration.

The principal purpose of the pilot experiment was to find the number of lines that would produce data overload or avoidance. The experiment provided a partial answer. The absence of data for a three-line and a five-line graphic prohibited a conclusion. An indication of data overload would have meant a noticeable decrease in

efficiency. The lowest efficiency median was for the six-line graphic, and the greatest difference was between the four- and the six-line graphics. The accuracy component was highest with the four-line and then decreased with the six-line graphic. The decreases in both efficiency and in accuracy after the four-line graphic probably occurred because of data overload or avoidance. Since the overload happened after four lines but before or at six lines, five lines were chosen as the number to be tested to ensure that the DMs were at or near overload.

Most of the DMs were anxious to participate in the experiment; one demonstration graphic was enough. Asking for telephone extension numbers relieved their hesitancy in giving identification numbers. Having familiarity with a CRT probably has an effect on a DM's efficiency. The DM having the highest efficiency, however, did not have extensive computer familiarity when compared with the DM having the second-highest efficiency. This led to the supposition that extensive familiarity with the CRT was not a necessary prerequisite to high efficiency scores.

#### ANALYSIS OF THE ENHANCEMENT EXPERIMENT

The purpose of the enhancement experiment was to evaluate enhancements, the five contextual variables (Chapter III). These included color (two color vs four color), chartjunk (fixed vs fading), format (multiple line

vs paired), analytical data (none vs forecast), and scale or spacing (superimposed lines vs stratified lines). Nonparametric statistics tests showed no significant difference in decision efficiency among four of the five variables at the five percent significance level. Only the forecast graphic proved significantly different from the standard graphic. In another test of all the efficiency scores, the differences among the scores demonstrated that enhancements do affect efficiency. Without the redundancy of symbols, color differences proved insignificant.

The 47 DMs who tried the 562 trial graphics during the spring and summer of 1985 had differing preferences for, aversions for, and confidence in the six types of trial graphics. Based on the DMs' preferences, the order was: (1) stratified, (2) fading, (3) colored (standard), (4) forecast, (5) paired, and (6) black and white graphics.

The hypotheses tests, descriptive statistics, questionnaire results, and anecdotal findings are described below. The test summaries, statistical summaries, and experimental data are in Appendixes H and I.

#### Tests of Research Hypotheses

Hypotheses Ho1 (colored), Ho2 (fading), Ho3 (stratified), and Ho4 (paired) could not be rejected; however, hypothesis Ho5 (forecast) could be rejected. This was based on five matched comparisons of 47 efficiency medians of six trial graphics. Two of the same type of

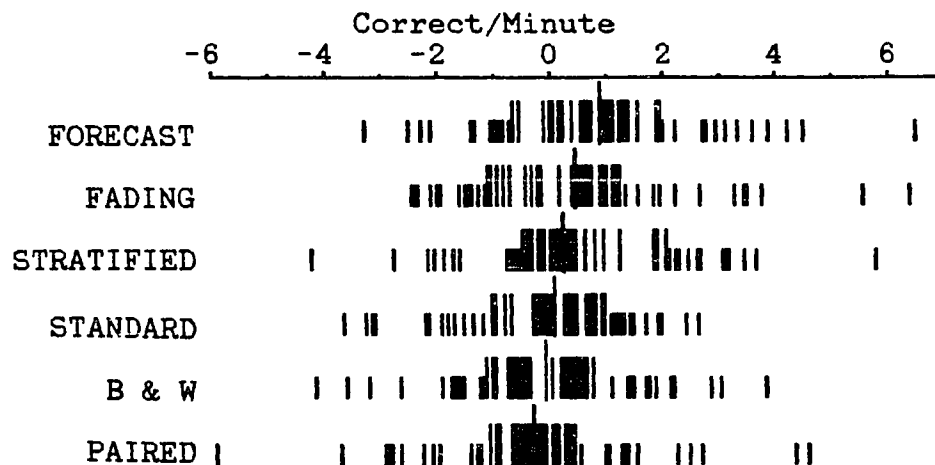
graphic were shown to each DM during the trials, except for two DMs who did not get to the second trial of the last graphic because of the 15-minute time limit in the simulation program. Using the DMs' efficiencies median of the trial graphics in the Wilcoxon signed rank tests, only the efficiency medians from the forecast graphic proved to differ significantly from the standard graphic that had no forecast. Thirty of 47 efficiency medians for the forecast graphic were higher than the efficiency medians for the standard graphic. The T-statistic was 362, which was less than the column critical value (379) for  $\alpha = 0.05$ , two-sided, and  $n=47$  (Mendenhall, 1979: 547). The smaller T-value indicates significance in this test. The stratified graphic failed the test at 385, which was higher than the  $\alpha = 0.05$  level but below the  $\alpha = 0.10$  critical value of 408. It was close.

Friedman's test relating to enhancements in general proved significant at the 0.05 level. The T-statistic was 2.72 and the critical region for  $\alpha = 0.05$  corresponded to all values of T greater than 2.29, the 0.95 quantile of the F distribution with  $k_1 = 5$  and  $k_2 = 230$  (Conover, 1980: 299, 483).

Cochran's Q test demonstrated a significant difference in the DMs' preferences, aversions, and confidences (Ho6, Ho7, Ho8, and Ho9). The four Q scores for the questions on the graphic liked most, the graphic least

liked, the graphic most confident in, and the graphic least confident in were all 74 or above with a critical value of 11 (see Table XVII).

Figure 23 shows a tally of within-subjects efficiency deviations. The tally graph is explained on pages 98 and 99. Each line represents the difference of each DM's median for each of the six trial graphics from his/her overall median efficiency for 12 graphics (11 graphics for two DMs). In comparing the six tally groups, the forecast graphic had the highest number of tallies to the right of zero (the approximate point where there is no improvement in an individual's overall efficiency). The medians for the tallies were forecast (0.86), fading (0.42), stratified (0.15), standard (-0.02), black and white (-0.15), and paired (-0.34).



**Figure 23.** Forecast efficiency differences highest (enhancement efficiency differences).

Descriptive Statistics and Graphs

Average Decision Efficiency. Figure 24 shows the ranges, first and third quartiles, and medians for the six enhancement graphics. The wide horizontal bars represent the ranges of the efficiencies; and the two thin, solid vertical lines cutting through the horizontal bars represent the first, second, and third quartiles; and the thickest of the three vertical lines represent the medians (second quartiles). The forecast graphic had the highest median, indicated by the darkest bar. The forecast and stratified graphics were the two graphics that differed significantly from the standard at the 0.10 significance level in the Wilcoxon tests, and these two graphics were considered candidates for the composite graphic in the subsequent experiment. The fading graphic had a high average, but did not test significant at even the 0.10 level.

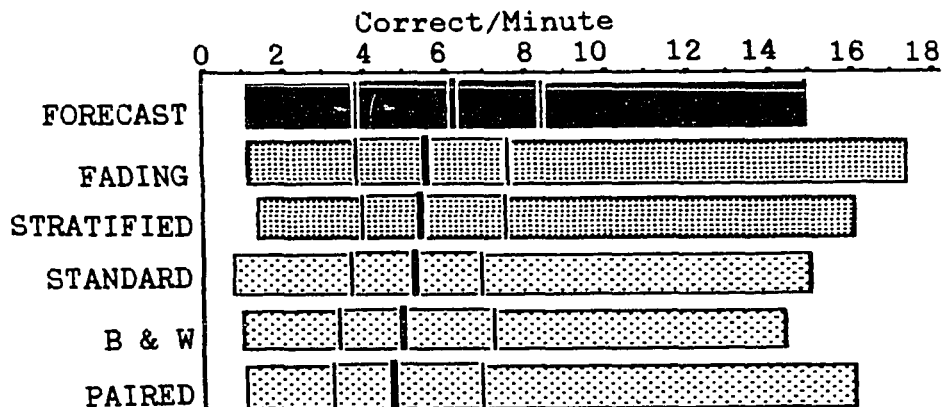


Figure 24. Forecast had highest efficiency median (enhancement median efficiencies).

The forecast graphic had the highest efficiency median and mean, 6.24 and 6.60 respectively. The forecast average was 19 percent higher than the standard, which had a median of 5.23 and a mean of 5.54. The other candidate, the stratified graphic, had a median of 5.40 and a mean of 6.22. These averages may be compared with the efficiency median and mean for all 562 trial graphics, 5.32 and 5.90, respectively. These two averages indicate that the distribution of efficiency was skewed positively, which partially explains why the range bars are so asymmetrically balanced on the medians.

Data within the high side of these asymmetrical ranges appears to indicate the potential of the enhancements, or highly skilled DMs, or both. The mean of the top 25 efficiency scores for each of the graphics were: forecast, 11.1; fading, 10.4; stratified, 10.3; standard, 9.1; black and white, 9.6; and paired, 9.0. The order of these means is the same order as their respective third quartiles. Again the forecast mean was better than the standard mean, by 21 percent. The stratified and fading means were better, by over 13 percent.

Figure 25 shows the average efficiency on the graphics throughout the trials. Learning from practice (constantly increasing efficiency) does not seem to exist.

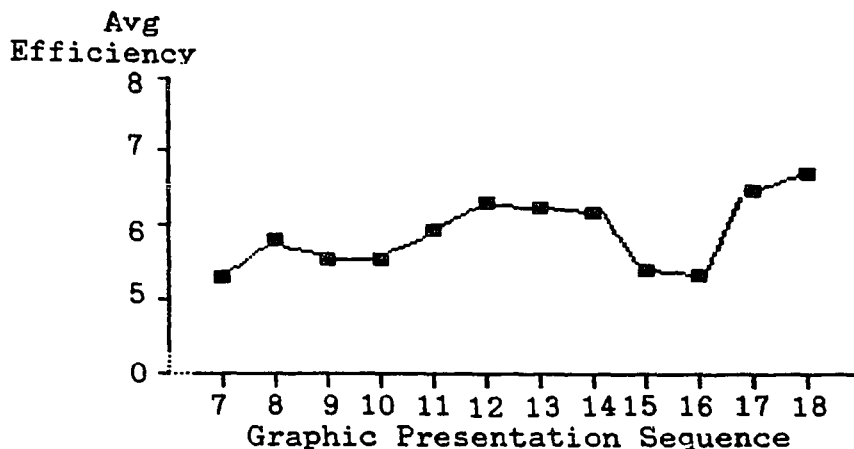


Figure 25. Zigzag efficiency with practice (enhancement sequential average efficiency).

Correct Selection Response. All the graphics had the same correct selection median: 3. The means of the correct selection, however, showed a slight difference among the graphics (Figure 26). The forecast had the highest mean correct, 3.05, and black and white had the lowest, 2.73. The mean of all graphics was 2.87. The

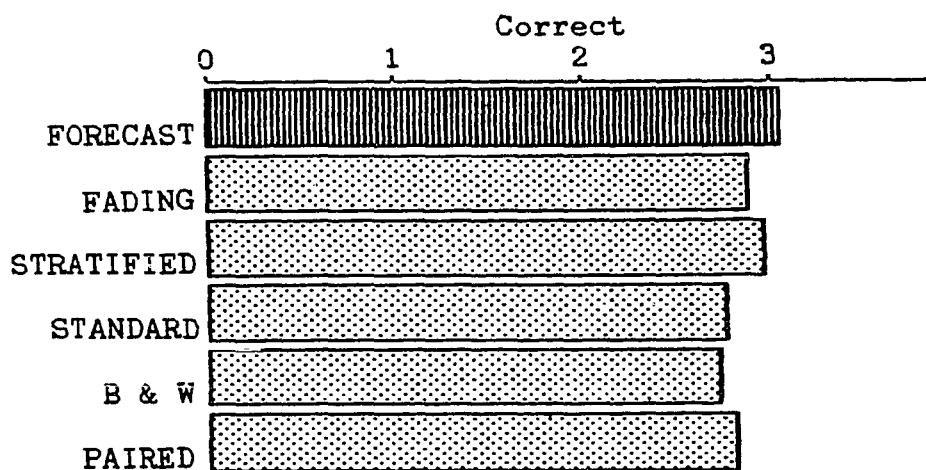


Figure 26. Forecast 10% better than standard (enhancement correct selections).



missing data for the one volatility question affected all graphics in the same downward direction, approximately 0.20. This difference would change the average efficiency by approximately seven percent, from 5.90 to 6.33.

Response Time. Figure 27 shows that the forecast graphic required the least median response time (32 seconds) and the lowest range (14 to 64 seconds). Looking at all the times, the coefficient of variation was 0.39. The variation in response times was 30 percent more than the variation in correct selection response.

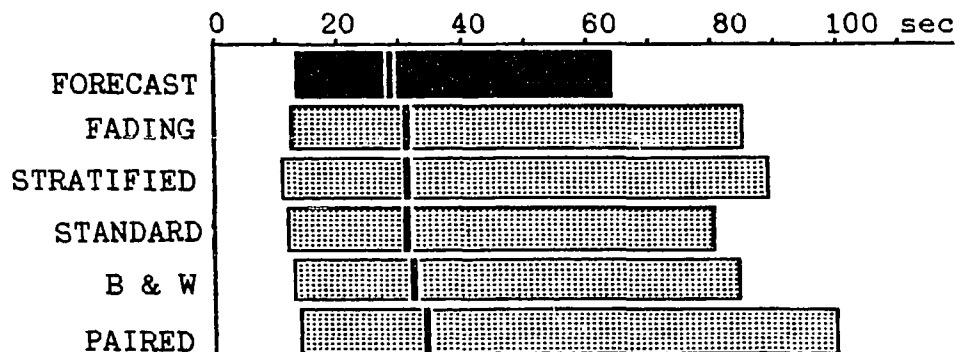


Figure 27. Quick forecast response times (enhancement response times).

### Questionnaire Results

Data from the questionnaire were used to test four hypotheses: Ho6 (preference), Ho7 (aversion), Ho8 (confidence), and Ho9 (less confidence). Table XVII in Appendix H lists the details, including Cochran's Q test results that indicated the answers were significantly different from each other.

Seventeen DMs (36.2 percent) liked the stratified graphic the most. The fading graphic was the second most liked with 14 of 47 (29.8 percent); this also was the one that most DMs felt confident in (27.6 percent). The DMs least liked (80.0 percent), and had the least confidence in (74.4 percent), the black-and-white graphic. Twelve of 47 (25.0 percent) wanted to see a combination of the stratified and fading--the favorite combination of enhancements.

Seventy-seven percent of the DMs claimed to be on professional and technical staffs, 19 percent were managers or administrators, and four percent were sales persons. Fifty-three percent of the DMs wore glasses or contact lenses, and 46 percent reported using more than four graphics in a day.

#### Anecdotal Findings

- Several DMs expressed dislike for the color combinations of white, cyan, magenta, and black. Two mentioned that the color influenced which trend they chose for an answer. One DM said that answers on the black-and-white graphic were often guesses.
- The DMs' average efficiency was 5.9 correct selections per minute, about three correct out of four possible selections in 30 seconds. The highest average efficiency was 10.5 correct per minute, and the lowest average was 3.07 correct per minute. The DM scoring the highest average

efficiency had scores of 13.1 and 15.4 for the two paired graphics (windows) he tried. This DM designs computer graphics (in windows) for an electronics-component manufacturer, has a BS in history with a minor in journalism, and has a hobby of computing. The DM scoring the next highest average efficiency (9.54) scored 15.7 and 16.1 with the fading graphics. She is a technical writer for an electronics component manufacturer, has a BSEE, and has hobbies of piano, sewing, gardening, and Chinese cooking.

- Twenty percent or more of the DMs asked for an additional explanation of the leading trend. Some selected the leading trend correctly in the warm-up, but then selected the lagging trend during the test of the trial graphics. Additionally, the term "greatest rate of change" posed questions, so the "greatest slope" was substituted.
- DMs generally made selections in sequential order: volatile, leading, slope, and next graph. They appeared to be less patient in receiving a feedback tone as they progressed through the selections. Often, DMs would push the slope and next graph selection blocks more than once trying to get a feedback tone. The volatile selections being first may be partially explained by the way people

process pictures--they look at contours of high information content (Spoehr, 1982: 163-166).

### Implications and Limitations

The enhancement experiment showed that contextual manipulation of data affects DMs' efficiencies in determining relationships among trends. The effects were positive, neutral, and negative. The positive effects were fading away chartjunk, stratifying trends, and providing smoothing forecasts. However, only the last proved to be a significant improvement at the 0.05 level of significance. A probable reason that the fading graphic did not produce better efficiency scores was because the trends could not be positioned along a common scale (Cleveland, 1985: 229).

The difference in efficiency between color and black and white was nil. Although not significantly different from the standard, splitting the data into separate windows (the paired graphic) had a detrimental effect on efficiency. The paired graphics in windows, however, may be a tool for experienced users based on the high scores of the DMs having the highest average efficiency.

The tests were conducted in both quiet conference rooms and offices and in crowded, noisy offices. The decision efficiency of a DM using a graphic was no doubt affected when a fellow worker snickered in the background. It was certainly different when the subject's concentration was disrupted with an outside question of "New game?" On

the other hand, one DM seemed to be able to concentrate on the trials even with chanting protesters marching outside the office window. The lack of control over such surroundings definitely limited this experiment. Experiments in the workplace may therefore not be suitable for testing nuances in graphical contexts; but, for testing obvious differences in context, experiments in the field are better than the laboratory for evaluating the graphics with a potential business application.

Nevertheless, the office noise does not explain the extreme variations in efficiencies. Half or more of the DMs knew exactly what they were looking for when they tested the graphics. Conversely, three or four seemed hypnotized. This experiment did not uncover reasons for the three-to-one difference among the high and low average efficiencies. The two top performers interviewed had one thing in common: they both worked with the design of computer graphics.

The DMs appeared to be annoyed with the questions concerning their confidence in a graphic that followed the questions about their preferences. Most regarded these questions as redundant. Five DMs indicated that the test was too long.

The painting sequence for lines was the same in all graphics: A, B, C, D, and E. This sequence may have given weight to a trend because of its position, shape, color,

and temporal sequence (Arnheim, 1974: 23). This sequencing particularly applies to the stratified graphic where trends were isolated, ordered (from the bottom), and free of interference.

The efficiency with the black-and-white graphic may have been aided because of the oblique effect (Spoehr, 1982: 20). Two of the symbols placed horizontal lines at every datum point. Horizontal lines would be easier to see than the oblique trends in the standard colored graphic. The oblique effect also could influence the trends in all the graphics; trends with higher slopes would be more difficult to see than those with lesser slopes.

#### ANALYSIS OF THE COMPOSITE EXPERIMENT

The purpose of the composite test was to evaluate combined enhancements. These included painting trends sequentially and combining the stratification and forecast of trends. All the graphics were different from those shown in the enhancement experiment. Nonparametric statistical tests showed no significant differences in efficiency among the graphics tested.

The test data in this experiment differed from the test data in the pilot and enhancement experiments which used the medians of the efficiency scores. Use of the medians smoothed the extreme variation. In this experiment

there was only one trial of each graphic, so the actual efficiency scores were tested instead of medians.

During the summer of 1985, forty-one DMs tried eight types of graphics: the concurrent standard, concurrent stratified, concurrent forecast, concurrent composite, the sequential standard, sequential stratified, sequential forecast, and sequential composite.

The hypotheses tests, descriptive statistics and graphs, questionnaire results, and anecdotal findings are described below. The test summaries, statistical summaries, and experimental data appear in Appendixes J and K.

#### Tests of Research Hypotheses

Hypotheses Ho3 (stratified), Ho5 (forecast), Ho10 (composite), and Ho11 (sequential painting) cannot be rejected. Twenty-one Wilcoxon signed rank tests for paired experiments ( $\alpha < 0.05$  for one-sided and  $\alpha = 0.10$  for two-sided) showed that the differences between efficiency-score medians were not significant (Mendenhall, 1979, 492, 547). Details about these rank tests are in Appendix J, Table XX.

Ranked differences in efficiency medians were high between only two pairs of the eight graphics, but both were not statistically significant. Fifty-nine percent of the DMs (24 of 41) performed more effectively with the sequential stratified graphic than with the concurrent

standard graphic. Sixty-one percent (25 of 41) did better with the sequential composite than with the sequential standard.

For the concurrent vs sequential graphics test, 59 percent of the medians were higher with the sequential graphics than the concurrent, but not significantly higher. The medians for this test were derived from each DM's efficiency scores for the four concurrent and four sequential graphics; all 328 graphics were used.

Hypotheses Ho6 (preference) and Ho7 (aversion) could be rejected based on the questionnaire data. Cochran's Q test showed that DMs had preferences and aversions for the standard, stratified, forecast, and composite graphics (Runyon, 1977: 59). Fifty-three percent of the DMs liked the stratified graphic the most, and sixty-eight percent liked the standard least (see Table XXIII in Appendix J).

Figure 28, the tally chart of efficiency, shows the deviations within a subject. The tally graph is explained on pages 98 and 99. The medians for the tallies were: concurrent standard (-0.14), concurrent stratified (-0.11), concurrent forecast (-0.19), concurrent composite (-0.12), sequential standard (0.05), sequential stratified (0.24), sequential forecast (-0.14), and sequential composite (0.39). The tallies did not show that any one graphic was much different from the rest. The tallies, however, did show the wide range of deviations.



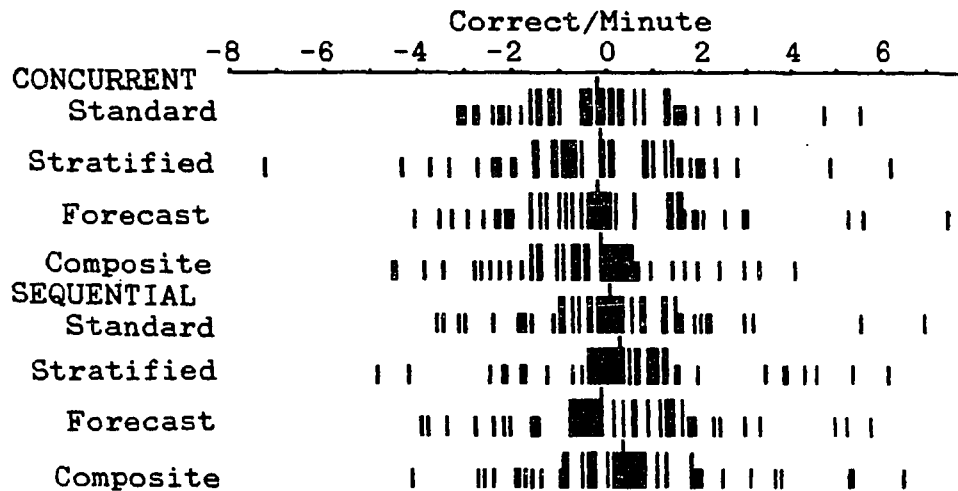


Figure 28. No significant differences in efficiencies (composite efficiency differences).

#### Descriptive Statistics and Graphs

Average Decision Efficiency. Figure 29 shows the efficiency medians and ranges for the eight graphics evaluated in the composite test. The sequential composite had the highest median and mean, 6.23 and 6.29, respectively; it also had a coefficient of deviation and coefficient of variation of 0.33 and 0.51, respectively. The concurrent composite had the lowest averages. Its efficiency median was 4.69, and its mean was 5.32 with 0.38 and 0.53 coefficients of deviation and variation, respectively. The median and mean efficiencies for all 328 graphics were 5.49 and 5.90, respectively, with coefficients of deviation and quartile variation of 0.40 and 0.51, respectively.

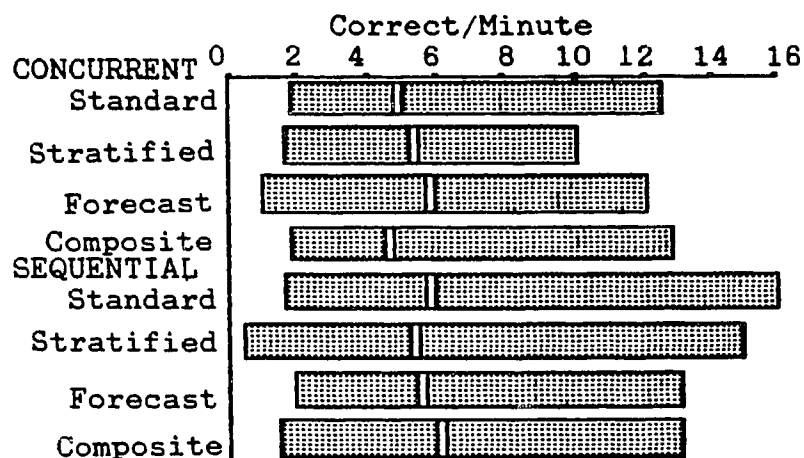


Figure 29. Insignificant decision efficiency differences (composite median efficiencies).

Figure 30 shows the efficiency averages of the trial sequence, 6 through 13. There was no evidence of learning with practice. Statistical details on averages and variation for the measured data are shown in Appendix J.

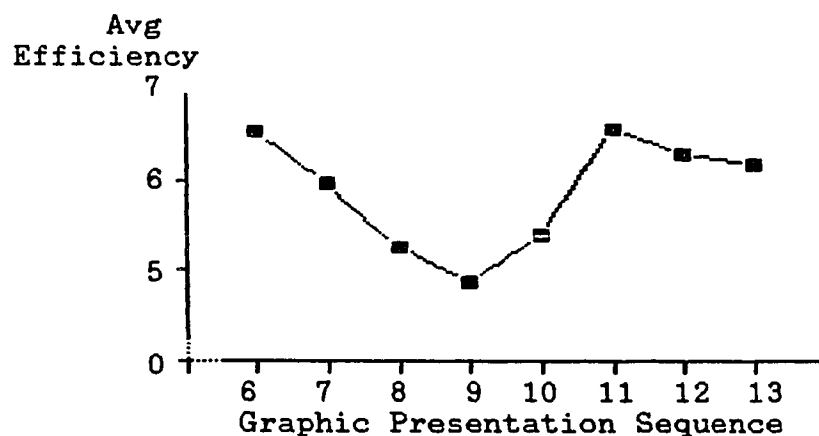


Figure 30. No existent learning curve (composite sequential average efficiency).

Correct Selection Response. The mean correct selection for all 328 graphics was 3.05 out of a possible

4.00. Figure 31 shows an almost equivalent average for correct selections for the eight graphics. The sequential composite had the highest average correct, 3.14. In contrast, the concurrent composite had the lowest average, 2.83 out of a possible 4.00. If the correct selection for choosing the next graphic block is subtracted, about two-thirds of the questions were answered correctly. The volatile question had 71 percent correct, the leading question had 65 percent, and the slope question had 69 percent.

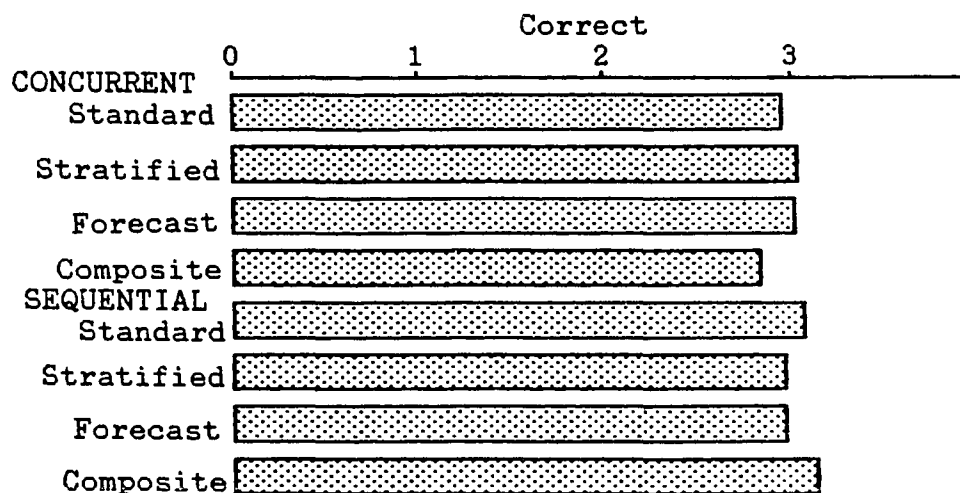


Figure 31. Little difference in correct selection (composite correct selections).

Regarding the missing Line B data, the researcher modified the data capture routine half way through this set of trials. The volatile answer was 63 percent correct before the modification and increased to 76 percent after the modification. Ten of the 22 DMs viewing the graphics

after the modification had participated in the previous enhancement experiment; the 10 DMs who had participated before did better in this experiment, which may account for some of the increase in percentage. None of the 19 DMs who participated in the first half of the experiment was a repeat subject.

Response Time. Figure 32 highlights the medians and wide range for the eight graphics. Two examples provided some insight into the small differences in the medians and the variations in the data. The concurrent standard had the lowest median, 29 seconds, and a range of 15 to 84 seconds. It showed the most skewed distribution of the eight graphics and had a coefficient of deviation of 0.31. The sequential standard had the highest median, 35.0 seconds, and a range from 11 to 103 seconds.

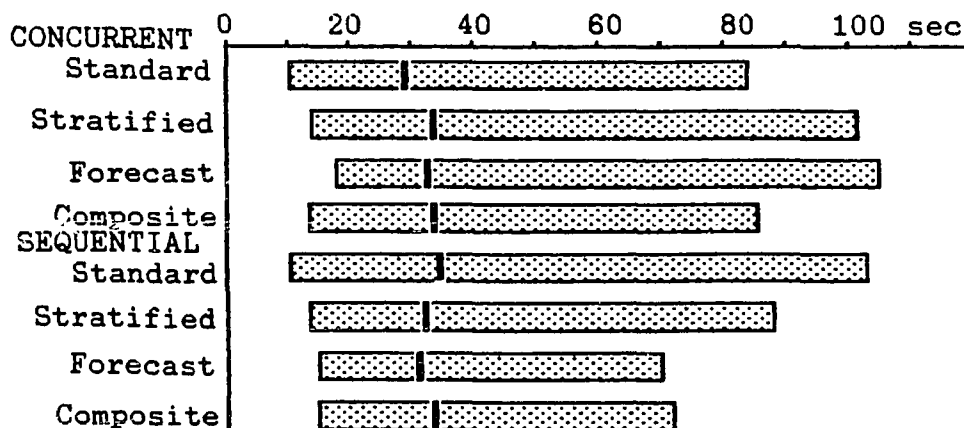


Figure 32. Positively skewed response times (composite response times).

### Questionnaire Results

For the 36 DMs responding (out of 41 DMs), 19 (52.8 percent) preferred the stratified, 15 (41.7 percent) preferred the composite, 2 (5.6 percent) preferred the forecast, and no one preferred the standard. These preferences relate to hypothesis Ho6. Percentages of aversion to the graphics, based on 38 DMs, were 68.4 percent for the standard, 15.8 percent for the forecast, and 7.9 percent for both stratified and composite. These aversions relate to hypothesis Ho7.

Some demographics were recorded by the TA from observations made during the trials and questions asked of the DM at the end of the trials. Eighty-five percent (35 of 41) claimed to be professionals or technicians, and the rest claimed to be managers. Twenty of the 41 DMs (48 percent) wore glasses or contact lenses. One claimed to have a color deficiency. Forty-six percent (19 of 41) routinely used more than four graphs a day.

The tables of preferences, demographics, and observations made by the TA appear in Appendix J.

### Anecdotal Findings

- No correlation between accuracy and response time existed in four of the graphics. In the other four, correlation existed, but not at a significant level. One DM mentioned disliking the clock

running on the screen; the clock apparently created some pressure.

- The average efficiency of a DM seemed to be correlated with his or her estimated distance from the screen ( $r = 0.31$ ,  $t = 2.04$ ,  $n = 41$ ) (Rodich, 1980: 190). The 10 people who tended to view the screen from less than 25 inches had an average efficiency of 4.49 correct/minute. Conversely, the 31 people who viewed the screen from 25 inches or more had an average of 6.36 correct/minute.
- Most of the professionals appeared to be scientists, engineers, or technicians; a few were supervisors. Many asked how their performances compared with others.
- DMs with bifocals had difficulty in positioning themselves to see the screen when it was placed on top of the computer or table.
- The DMs' mean efficiency was 5.9 correct selections per minute, the same average as in the enhancement experiment. The 10 DMs who participated in both experiments had an average of 6.5 in the enhancement experiment and 6.8 in the composite experiment. The highest average efficiency was 10.4 correct per minute, and the lowest was 2.18 per minute. The DM scoring the highest average efficiency ranked second highest in consistency,

having a coefficient of deviation of 0.16, whereas the average was 0.37. This DM is a Data Base Manager for an electronics-components manufacturer, has an MS in computer science, and has photo-journalism as a hobby. Coincidentally, photography was the hobby of the DM having the second highest efficiency. This DM is a computer programmer at a government agency and has a BS in mathematics.

#### Implications and Limitations

The results of the composite experiment were inconclusive. Apparently some combinations of enhancements can have a negative effect, or perhaps there was some resistance to so many enhancements. Simplicity in design won.

This experiment employed fewer than half the graphics used in the enhancement experiment (41 rather than 94). Twenty-one Wilcoxon signed rank tests ordered the raw efficiency scores for 328 graphics. In the enhancement experiment, six Wilcoxon tests ordered the averages of two efficiency scores for 564 graphics. The latter showed seven percent less variation as a result of using the averages. The coefficient of variation in this composite experiment was 0.507, while in the enhancement it was 0.436. The difference in variation was probably the reason that the results in the composite experiment were inconclusive.

Several DMs had difficulty in answering the question of which graphic they preferred. The question asked for a choice from among four types of graphics, excluding the painting. This led to some confusion, because several DMs liked the sequential painting.

If little or no correlation exists between accuracy and response time as mentioned in the Anecdotal Findings section, the trials of graphics in the future should be timed to move automatically on to the next graphic. Forty-five seconds would have been long enough for three-quarters of the graphics in this experiment (Figure 32).

Contrary to expectations, many people were willing to try the new graphics. There were more volunteer subjects than planned. In fact, ten of the subjects were repeat DMs from the enhancement experiment.



## CHAPTER VI

### SUMMARY AND CONCLUSION

Can computer-enhanced graphics more effectively assist the decision maker (DM) discover information than traditional graphics? This research question led a search through the literature of nine disciplines, followed by three experiments in which 105 DMs from 27 organizations tried 1133 graphics. The answer is yes, for some enhancements, no for others. Most of the trial results were as expected.

This chapter answers the research problem, summarizes the results of the research, and recommends areas for further research.

### ANSWER TO THE RESEARCH PROBLEM

The objective of the research problem was to find out whether manipulating the context in graphics affects the speed and/or accuracy (efficiency) of DMs in their determination of relationships among data patterns. The problem was solved successfully, substantiated by the results. The interactive computer simulations portrayed trends so realistically that the DMs often responded to the challenge as if their jobs depended on the outcome. Not

one said the simulations were unrealistic or the enhancements were trivial. Further, the experiments proved that research with computer graphics can be conducted in the field with subjects who are actively engaged in business and government. Computers can manipulate the visual context surrounding time series so that DMs can better visualize problems.

#### RESULTS OF THE RESEARCH

Six specific computer enhancements and four combinations of enhancements were tried. One enhancement significantly increased DMs' decision efficiency (accuracy/response time) in finding differences among trends. Two contextual enhancements made noticeable differences; three made little or no difference. None of the combinations of enhancements made a significant difference. All of these results can be applied to graphics design.

Results were based on nonparametric statistical tests on efficiency scores of and questions about the trial graphics at the five percent significance level. These scores were based on each DM's ability to identify diversity or problems in time-series trends in multiple- and two-line graphics. The results of the tests were:

- Added computer-generated forecasts significantly helped DMs in finding diversity among trends. The

average efficiency of the forecast graphic was 19 percent better than a standard colored graphic.

- Although not statistically significant, stratified trends and fading chartjunk tended to increase DMs' efficiencies. Test results were consistent with, but did not verify, DeSanctis' premise that simplicity aids understanding. Both enhancements were over 10 percent better than the standard.
- Color made no difference in efficiency. Although DMs did not like black-and-white graphics, there was no difference in efficiencies between trends displayed in black and white and those displayed in four colors. The results were consistent with DeSanctis' research premise that color alone does not increase comprehension. As a redundant attribute, color probably would make a difference in the efficiency of certain DMs (Benbasat, 1985: 1348).
- Although the DM's efficiency using the paired trends in windows was not significantly different from the standard, the average efficiency of the paired was below that of the standard.
- Sequentially traced trends did not improve efficiency significantly over concurrently traced trends.

- Composite graphics containing trends that were stratified and forecasted, traced either sequentially or concurrently, had little effect on efficiency compared to the standard.

Opinions about the graphics were mixed. The DMs preferred stratified trends most and had the most confidence in the fading graphics. Black-and-white graphics were different. People neither liked nor had confidence in black-and-white graphics, which are two good reasons to look at more colors.

Two findings were unexpected. In the first experiment, people appeared to be more accurate in identifying problems among four and six trends than between two trends. And, the abilities of the DMs was varied; 47 DMs' average decision efficiency ranged from 3.1 to 10.5 in the second experiment. Of added interest, the DMs' accuracies and response times were correlated, but not significantly, on four of the eight graphics in the third experiment; the other four graphics showed no correlation at all. Viewing patterns longer does not necessarily aid interpretation speed and accuracy. Viewing distance, however, was positively correlated with the DM's average efficiencies.

#### RECOMMENDED AREAS FOR FURTHER RESEARCH

This research demonstrated that experiments with computer graphics, such as enhancements to business

graphics, can be tried in the field (the workplace).

Similar experiments would be useful in finding:

- Effects of different hues, combinations, sequences, and brightness of colors; for example, which ones are prejudicial colors;
- Responses to sequencing of questions such as directing the detection of problems from the general and obvious to the particular and subtle;
- Gestalts when reversing the sequence of chartjunk, for example, adding chartjunk to a graphic;
- Decision efficiency differences resulting from contextual data such as different descriptive statistics and forecasts, historical data, and planned data (budget) or combinations of the other contextual variables listed in Chapter III; and
- Reasons for the wide range in peoples' ability to see differences in patterns; training is useful, but it does not explain why some people who are quite familiar with graphics have difficulty using them.

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**APPENDIX A**  
**GUIDELINES FOR LINE GRAPHS**

TABLE X  
GUIDELINES FOR LINE GRAPHS

PREFERABLE ATTRIBUTE	SOURCES
<p><b>TEXT:</b> Comprehensible title, preferable at optical center. Consistent, simple, distinguishable fonts in labeling.</p> <p>Text displayed in upper and lower case (Helvetica). Without contractions, hyphenations, abbreviations, and humor.</p>	<p>Marcus, 1982:27 Paller, 1981:14; Szoka, 1981:79 McClain, 1983:94 Engel, 1975:18</p>
<p><b>DATA:</b> Only essential data displayed.</p> <p>Interim data removed once no longer needed.</p> <p>Lines and curves thicker than grids, with pivotal the thickest.</p> <p>Different line thicknesses/patterns for comparable trends.</p> <p>Different singular line for an emphasized variable among several.</p> <p>Dashed and dotted lines for projections, extensions, or plans/budgets.</p> <p>Plotting marks for more exact amounts.</p> <p>Symmetrical, rectilinear, simple, consistent, distinct data points.</p> <p>Differentiation between point and period data, point data on grid line and period data midway between.</p> <p>With time charts, plot points on vertical grid lines. Lines at least 50 points/inch for continuity illusion. Labeled lines and curves.</p> <p>Number of lines should not exceed 5, three or fewer is ideal.</p> <p>Pairs of lines instead of tangled multiple lines. Several charts for an emphasized variable compared with each variable.</p> <p>Used sparingly, not to overload the reader.</p>	<p>Morton in Davis, 1983:116 Martin in (Davis, 1983:116 Clark, 1983:73</p> <p>Paller, 1981:9; Szoka, 1981:76 Paller, 1981:23; Szoka, 1981:75 Paller, 1981:9; Szoka:1983:29 Lefferts, 1981:102 Turnbull, 1975:21</p> <p>Schmid, 1983:32</p> <p>Lefferts, 1981:91 Grether, 1972:99 Paller, 1981:6; Szoka, 1981:76 Lefferts, 1981:89</p> <p>Zelazny, 1985:39 Paller, 1981:23; Szoka, 1981:75 Lefferts, 1981:84</p>
<p><b>HIGHLIGHTING:</b> Blinking, contrast reverse, and brightness variation to highlight.</p> <p>Highlighting limited to only 1 or 2 items. Steady messages next to blinking symbol to attract attention.</p> <p>Color levels of 4 or less, blue or green background.</p>	<p>Davis, 1983:128</p> <p>Davis, 1983:121 Smith in Davis, 1983:121 McClain, 1983:94</p>
<p><b>SCALES:</b> Horizontal labeled axes/scales, with units of measurement.</p> <p>Single scale for each axis.</p> <p>Vertical scale legend placed horizontally directly above the scale.</p> <p>Readable axis numbers.</p> <p>Same scales for comparable graphs and trends. Zero origin for comparable levels or totals.</p> <p>Scale breaks indicated.</p> <p>Major scale divisions at less than 10 or 12. Scales easily interpolated, with tick marks at 1, 2, or 5.</p> <p>Horizontal and vertical units of measure are the same distance apart.</p> <p>Height of vertical axis about 3/4 length of horizontal.</p> <p>Scales on right to stress data on right; or, if data rises sharply, to avoid confusion place figures and legends on both sides.</p> <p>Grids that aid interpolation and are few.</p>	<p>Paller, 1981:6; Szoka, 1981:79 Paller, 1981:25; Szoka, 1981:76 Schmid, 1979:37</p> <p>Paller, 1981:7; Szoka, 1981:78 Paller, 1981:7 Paller, 1981:8; Szoka, 1981:79 Paller, 1981:8; Szoka, 1981:79 Schmid, 1979:34 DeJong, 1983:50</p> <p>Lefferts, 1981:87</p> <p>Lefferts, 1981:89 Schmid, 1983:37</p> <p>Schmid, 1983:30</p>

APPENDIX B  
ENHANCEMENT PROGRAM  
(written in BASIC 2.0 by Microsoft)

## ENHANCEMENT PROGRAM

```

70 CLEAR:DIM GRF(31),LINES(31),I(31):SCREEN 0,0,0:KEY OFF:WIDTH 80:OUT &H3D8,9:C
OLOR 9,1,1:CLS:LOCATE 5,20:PRINT"Phase II -- test of 6 graphics":PRINT:PRINT "&
W = 1, Color = 2, Faded = 3, Stratified = 4, Paired = 5, Indicator = 6":PRINT
160 PRINT "Graphic Set 1 -> 1,1, 2,2, 3,3, 4,4, 5,5, 6,6":PRINT "GRAPHIC SET 2
-> 2,2, 4,4, 1,1, 6,6, 3,3, 5,5":PRINT "Graphic Set 3 -> 3,3, 1,1, 5,5, 2,2, 6,6
, 4,4":PRINT "GRAPHIC SET 4 -> 4,4, 6,6, 2,2, 5,5, 1,1, 3,3"
200 PRINT "Graphic Set 5 -> 5,5, 3,3, 6,6, 1,1, 4,4, 2,2":PRINT "GRAPHIC SET 6
-> 6,6, 5,5, 4,4, 3,3, 2,2, 1,1"
250 PRINT:INPUT"Graphic set ";SET
380 ON SET GOTO 390,410,430,450,470,490,510,530,550,570,590,610
390 GRF(8)=1:GRF(9)=1:GRF(10)=2:GRF(11)=2:GRF(12)=3:GRF(13)=3:GRF(14)=4:GRF(15)=
4:GRF(16)=5:GRF(17)=5:GRF(18)=6:GRF(19)=6:GOTO 630
410 GRF(8)=2:GRF(9)=2:GRF(10)=4:GRF(11)=4:GRF(12)=1:GRF(13)=1:GRF(14)=6:GRF(15)=
6:GRF(16)=3:GRF(17)=3:GRF(18)=5:GRF(19)=5:GOTO 630
430 GRF(8)=3:GRF(9)=3:GRF(10)=1:GRF(11)=1:GRF(12)=5:GRF(13)=5:GRF(14)=2:GRF(15)=
2:GRF(16)=6:GRF(17)=6:GRF(18)=4:GRF(19)=4:GOTO 630
450 GRF(8)=4:GRF(9)=4:GRF(10)=6:GRF(11)=6:GRF(12)=2:GRF(13)=2:GRF(14)=5:GRF(15)=
5:GRF(16)=1:GRF(17)=1:GRF(18)=3:GRF(19)=3:GOTO 630
470 GRF(8)=5:GRF(9)=5:GRF(10)=3:GRF(11)=3:GRF(12)=6:GRF(13)=6:GRF(14)=1:GRF(15)=
1:GRF(16)=4:GRF(17)=4:GRF(18)=2:GRF(19)=2:GOTO 630
490 GRF(8)=6:GRF(9)=6:GRF(10)=5:GRF(11)=5:GRF(12)=4:GRF(13)=4:GRF(14)=3:GRF(15)=
3:GRF(16)=2:GRF(17)=2:GRF(18)=1:GRF(19)=1:GOTO 630
510 GRF(8)=1:GRF(9)=2:GRF(10)=3:GRF(11)=4:GRF(12)=5:GRF(13)=6:GRF(14)=1:GRF(15)=
2:GRF(16)=3:GRF(17)=4:GRF(18)=5:GRF(19)=6:GOTO 630
530 GRF(8)=2:GRF(9)=4:GRF(10)=1:GRF(11)=6:GRF(12)=3:GRF(13)=5:GRF(14)=2:GRF(15)=
4:GRF(16)=1:GRF(17)=6:GRF(18)=3:GRF(19)=5:GOTO 630
550 GRF(8)=3:GRF(9)=1:GRF(10)=5:GRF(11)=2:GRF(12)=6:GRF(13)=4:GRF(14)=3:GRF(15)=
1:GRF(16)=5:GRF(17)=2:GRF(18)=6:GRF(19)=4:GOTO 630
570 GRF(8)=4:GRF(9)=6:GRF(10)=2:GRF(11)=5:GRF(12)=1:GRF(13)=3:GRF(14)=4:GRF(15)=
6:GRF(16)=2:GRF(17)=5:GRF(18)=1:GRF(19)=3:GOTO 630
590 GRF(8)=5:GRF(9)=3:GRF(10)=6:GRF(11)=1:GRF(12)=4:GRF(13)=2:GRF(14)=5:GRF(15)=
3:GRF(16)=6:GRF(17)=1:GRF(18)=4:GRF(19)=2:GOTO 630
610 GRF(8)=6:GRF(9)=5:GRF(10)=4:GRF(11)=3:GRF(12)=2:GRF(13)=1:GRF(14)=6:GRF(15)=
5:GRF(16)=4:GRF(17)=3:GRF(18)=2:GRF(19)=1:GOTO 630
630 OPEN "c:set" FOR OUTPUT AS #1:WRITE #1,SET,GRF(8),GRF(9),GRF(10),GRF(11),GRF
(12),GRF(13),GRF(14),GRF(15),GRF(16),GRF(17),GRF(18),GRF(19):CLOSE:WIDTH 40:GOSU
B 780:GOSUB 890:GOSUB 1030:GOSUB 1240:GOSUB 1390:GOSUB 1480:GOSUB 1580:GOTO 1800

780 SCREEN 0,1:COLOR 14,1,1:CLS:LOCATE 8,8:PRINT"Enhanced Computer Graphics":LOC
ATE 11,19:PRINT"for":LOCATE 14,14,0:PRINT"Decision Making"
860 C$=INKEY$:IF C$="" THEN 860
870 RETURN
890 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,8:LOCATE 9,7:PRINT"This experiment wil
l determine":LOCATE 11,4:PRINT"if changing the visual context":LOCATE 13,4:PRINT
"in graphic displays affects our":LOCATE 15,4:PRINT"ability to detect differenc
es"
980 LOCATE 17,4,0:PRINT "between trends."
1000 C$=INKEY$:IF C$="" THEN 1000
1010 RETURN:
1030 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,8:LOCATE 7,2:COLOR 14,9,9:PRINT "VISU
AL CONTEXT":LOCATE 7,16:COLOR 11,9,9:PRINT" refers to:":LOCATE 11,7:PRINT "- the
colors":LOCATE 13,7:PRINT"- the amount of text/symbols.":LOCATE 15,7
1160 PRINT"- number of trends shown together,":LOCATE 17,7:PRINT"- separation o
f the trends, and":LOCATE 19,7,0:PRINT"- forecasts of the trends."
1210 C$=INKEY$:IF C$="" THEN 1210
1220 RETURN:
1240 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,8:LOCATE 7,4:PRINT "Differences betwe
en/among trends":LOCATE 9,4:PRINT "are clues to potential problems":LOCATE 11,4:
PRINT "of interest to a decision maker.":LOCATE 15,5:COLOR 10,9,9
1330 PRINT "You will test 6 types of graphics.":LOCATE 17,2,0:PRINT "The follow
ing are sketches of the six."
1360 C$=INKEY$:IF C$="" THEN 1360
1370 RETURN:
1390 CLS:WIDTH 80:SCREEN 2:SCREEN 0,1:COLOR 0,0,0:CLS:DEF SEG=&H800:BLOAD "c:si
xgrfs",0:LOCATE 1,1,0

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1440 C$=INKEY$:IF C$="" THEN 1440
1450 WIDTH 40:RETURN:
1480 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,8:LOCATE 7,4:PRINT "Evaluation is bas
ed on the accuracy":LOCATE 9,4:PRINT"and the time taken in answering":LOCATE 11,
4,0:PRINT"questions about the graphics."
1550 C$=INKEY$:IF C$="" THEN 1550
1560 RETURN:
1580 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,8:LOCATE 4,4:PRINT "While viewing a g
raphic with ":LOCATE 6,2:PRINT "several trends, three questions":LOCATE 8,2:PRIN
T "will be asked about the graphic.":COLOR 7:LOCATE 11,2:PRINT "Which trend:"
1680 LOCATE 13,3:PRINT "1) is the most volatile/erratic?":LOCATE 15,3:PRINT "2
) turns first (is leading)?":LOCATE 17,3:PRINT "3) will likely have the greatest
":LOCATE 19,6:PRINT"rate of change, the steepest slope,":LOCATE 21,6
1770 PRINT"in the next 4 periods (weeks)?
1780 C$=INKEY$:IF C$="" THEN 1780
1790 RETURN
1800 SCREEN 1,0:WIDTH 40:COLOR 1,1:CLS:LOCATE 11,15,0:PRINT "Demonstration":LINE
(98,64)-(228,112),1,B:PAINT(1,1),CHR$(&H81),1
1870 C$=INKEY$:IF C$="" THEN 1870
1880 SET--1:CLEAR:SET--1:I=1:LINES(I)=3:GRF(I)=2:GOSUB 5100:SCREEN 0,0,0:SCREEN
1,0:WIDTH 40:COLOR 1,1:CLS:LOCATE 11,18,0:PRINT "Warm up":LINE(98,64)-(228,112),
1,B:PAINT(1,1),CHR$(&H42),1
2030 C$=INKEY$:IF C$="" THEN 2030
2040 SCREEN 0,0,0:WIDTH 40:OUT &H3D8,8:COLOR 1,11,11:CLS:LOCATE 3,5:PRINT:COLOR
7:INPUT"DM Id number(0000)":ID:LOCATE 4,1:PRINT " ";:PRIN
T:PRINT:PRINT:PRINT:COLOR 11:PRINT " In comparing sets of data,":PRINT
2130 PRINT " which do you prefer to use?":PRINT:PRINT:COLOR 14:LOCATE 13,10:PRI
NT "Graphs always";:LOCATE 15,10:PRINT "Graphs most often";:LOCATE 17,14:PRINT "
Graphs and":COLOR 10:LOCATE 17,25:PRINT "Tables equally"
2150 DDATE$=DATE$:OPEN "c:set" FOR INPUT AS #1:INPUT #1,SET:CLOSE
2200 LOCATE 19,10:PRINT "Tables most often";:LOCATE 21,10:PRINT "Tables always.
":COLOR 11:LOCATE 10,28:INPUT LGT$:PRINT:OPEN "b:COLLEKT" FOR OUTPUT AS #1:WRIT
E #1,ID:WRITE #1,DDATE$:WRITE #1,LGT$:WRITE #1,SET:CLOSE:SET=0
2320 CLEAR:SET=0:I=2:LINES(I)=3:GRF(I)=2:GOSUB 5100:CLEAR:SET=0:I=3:LINES(I)=5:
GRF(I)=1:GOSUB 5100:CLEAR:SET=0:I=4:LINES(I)=5:GRF(I)=3:GOSUB 5100:CLEAR:SET=0:I
=5:LINES(I)=5:GRF(I)=4:GOSUB 5100
2360 CLEAR:SET=0:I=6:DIM LINES(31),GRF(31):LINES(I)=5:GRF(I)=6:GOSUB 5100:CLEAR
:SET=0:I=7:DIM LINES(31),GRF(31):LINES(I)=5:GRF(I)=5:GOSUB 5100:CLEAR:SCREEN 1:W
IDTH 40:COLOR 9,1:LOCATE 11,15,0:PRINT "Graphics test":LINE(98,64)-(228,112),1,B

2440 PAINT(1,1),CHR$(&H81)+CHR$(&H42)+CHR$(&H24),1
2450 C$=INKEY$:IF C$="" THEN 2450
2460 SIMTIME=TIMER:OPEN "c:s" FOR OUTPUT AS #1:WRITE #1,SIMTIME:CLOSE
2500 CLEAR:DIM GRF(31),LINES(31):OPEN "c:s" FOR INPUT AS #1:INPUT #1,SIMTIME:CLO
SE:OPEN "c:g" FOR INPUT AS #1:INPUT #1,I:CLOSE:OPEN "c:set" FOR INPUT AS #1
2590 INPUT #1,SET,GRF(8),GRF(9),GRF(10),GRF(11),GRF(12),GRF(13),GRF(14),GRF(15)
,GRF(16),GRF(17),GRF(18),GRF(19):CLOSE:IF(TIMER-SIMTIME)>900 THEN 3510
2630 IF I=19 THEN 3530
2640 I=I+1:LINES(I)=5:GOSUB 5100:GOTO 2500
3510 LOCATE 10,16,0:PRINT "TIME'S UP";:
3530 KEY OFF:COLOR 6,0,0:CLS
3540 SCREEN 0,0,0:WIDTH 40:LOCATE 10,13,0:PRINT"Questionnaire":FOR QD=1 TO 1999:
NEXT QD:WIDTH 80:SCREEN 2:SCREEN 0,1:COLOR 0,0,0:CLS:LOCATE 24,1,0:DEF SEG=&HB80
0:BLOAD "C:SIXGRFS",0:LOCATE 24,1,0
3610 C$=INKEY$:IF C$="" THEN 3610
3620 COLOR 11:LOCATE 23,1:PRINT"Which graphic did you ";:COLOR 13:LOCATE 23,23:I
NPUT;"like most";LMS:COLOR 5:LOCATE 24,23:INPUT;"like least";LL$:COLOR 13:PRINT:
LOCATE 24,23:INPUT;"like next most";LNM$:COLOR 5
3690 LOCATE 25,23:INPUT"like next least";LNL$:COLOR 0,0,0:CLS:LOCATE 24,1,0:DEF
SEG=&HB800:BLOAD "c:sixgrfs",0:COLOR 13:LOCATE 23,1:PRINT"In answering the ques
tions,":LOCATE 24,1:PRINT"with which graphic were you ";:COLOR 11
3770 LOCATE 24,29:INPUT;"most confident";MCS:COLOR 3:PRINT:LOCATE 24,29:INPUT;"
least confident";LCS:COLOR 11:PRINT:LOCATE 24,29:INPUT;"next most confident";NMC
$:COLOR 3:LOCATE 25,29:INPUT"next least confident";NLC$:COLOR 0,0,0:CLS:LOCATE 2
4,1,0
3840 DEF SEG=&HB800:BLOAD "c:sixgrfs",0:COLOR 14:LOCATE 25,1:INPUT;"What combin
ation would you make";CG$:SCREEN 0,0,0:COLOR 7,1,0:CLS:LOCATE 2,3:PRINT"Using th
e following categories:":LOCATE 4,8:COLOR 15:PRINT"Professional and technical"

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3920 LOCATE 6,8:COLOR 12:PRINT " Managerial and administrative ":LOCATE 8,10:COL
OR 14,1:PRINT "Sales":LOCATE 10,10:COLOR 10:PRINT " Clinical ":LOCATE 12,12:COLOR
11,1:PRINT "Services":LOCATE 14,12:COLOR 9:PRINT " Entrepreneurial "
3970 LOCATE 16,14:COLOR 13:PRINT "Crafts":LOCATE 18,14:COLOR 0:PRINT " Design and
artistic ";;LOCATE 22,3:COLOR 7,1:INPUT;"What type of work do you do";TW$:COLOR
11:CLS:LOCATE 2,3:PRINT
";
4030 LOCATE 5,3:PRINT "In your work, how many graphs do you see a day";:LOCATE 7
,8:PRINT " 0 to 1";:LOCATE 9,10:PRINT " 2 to 4";:LOCATE 11,12:PRINT " 5 to 8";:L
OCATE 13,14:PRINT " 9 to 16 - All the graphs in The Wall Street Journal";
4080 LOCATE 15,17:PRINT "More than 16";:LOCATE 5,49:INPUT DG$:WIDTH 40:COLOR 15
,4,4:CLS:LOCATE 15,15,0:PRINT "Thank You":COLOR 4:LOCATE 25,1,0:INPUT VD$:COLOR
1,1:CLS:OPEN "b:collekt" FOR APPEND AS #1:WRITE #1,LM$:WRITE #1,LL$:WRITE #1,LNM
$
4200 WRITE #1,LNL$:WRITE #1,MCS:WRITE #1,LC$:WRITE #1,NMCS:WRITE #1,NLCS:WRITE
#1,TW$:WRITE #1,CG$:WRITE #1,DG$:WRITE #1,VD$:CLOSE:WIDTH 80:COLOR 7,1:CLS:END:G
OTO 5100
4380 '
4390 KEY OFF:T2L$="SCENARIO":LOCATE 2,10:PRINT T2L$:T5L$="The next graphic is t
he":LOCATE 5,2:PRINT T5L$:LOCATE 7,9:PRINT T7L$:T9L$="graphic with":LOCATE 9,6:P
RINT T9L$:T11L$=" trends":LOCATE 11,7:PRINT T11L$:COLOR 11:LOCATE 11,7:PRINT L
INES(I)
4530 RETURN
4540 KEY OFF:T15L$=" Üäääääääääääääé ":LOCATE 15,3:PRINT T15L$:T16L$="
":LOCATE 16,6:PRINT T16L$:T17L$=" ° ":LOCATE 16,3:PRINT T17L$:LOCATE 17,3:P
RINT T17L$:LOCATE 18,3:PRINT T17L$:LOCATE 19,3:PRINT T17L$:LOCATE 17,17:PRINT T1
7L$
4670 LOCATE 16,17:PRINT T17L$:LOCATE 18,17:PRINT T17L$:LOCATE 19,17:PRINT T17L$
:LOCATE 20,4:PRINT T22L$:T22L$=" ääääääääääääääi ":LOCATE 20,3:PRINT T22L$:RETU
RN
4800 KEY OFF:T2R$="OBJECTIVE":T5R$="The problem is to discover":T7R$="1. The m
ost volatile/variable":T9R$="sales":T9R1$="trend":T11R$="2. The leading trend --
the":T13R$="trend showing the first ":T15R$="turn in direction"
4900 T17R$="3. The trend that is likely":T19R$="to change the most over":T21R$="
the next 4 weeks --":T23R$="the steepest slope.":KEY OFF:LOCATE 2,55:PRINT T2R$
:LOCATE 5,45:PRINT T5R$:LOCATE 7,45:PRINT T7R$:LOCATE 9,48:PRINT T9R$
4990 LOCATE 9,54:PRINT T9R1$:LOCATE 11,45:PRINT T11R$:LOCATE 13,48:PRINT T13R$:
LOCATE 15,48:PRINT T15R$:LOCATE 17,45:PRINT T17R$:LOCATE 19,48:PRINT T19R$:LOCAT
E 21,48:PRINT T21R$:LOCATE 23,48:PRINT T23R$:RETURN:
5100 DEFINT P,X,Y,T:SCREEN 0,1,0:KEY OFF:WIDTH 80:ON GRF(I) GOTO 5230,5450,5730,
6130,6340,6750
5150 '
5230 SCREEN 0,1:COLOR 15,9,9:CLS:OUT &H3D8,9:LOCATE 7,5:PRINT "black and white":C
OLOR 11,9,9:GOSUB 4390:COLOR 7,0,0:GOSUB 4540:COLOR 11,9,9:GOSUB 4800:COLOR 7,0,
7:LOCATE 17,6:PRINT " / ":COLOR 15,0,0:LOCATE 16,6:PRINT " "
5370 LOCATE 17,6:PRINT " / ":LOCATE 18,6:PRINT "äääää "":LOCATE 17,6:
PRINT " ____ ":LOCATE 18,10:PRINT "\äääääää":LOCATE 19,6,0:PRINT "äääääääääääää":GOTO 6
950
5430 '
5450 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,9:COLOR 0,9,9:LOCATE 7,7:PRINT "
":COLOR 15,9,9:LOCATE 7,8:PRINT "colored":COLOR 11,9,9:GOSUB 4390:COLOR 3,0:GO
SUB 4540:COLOR 11,9,9:GOSUB 4800:COLOR 11,0:LOCATE 16,6:PRINT " "
5630 LOCATE 17,6:PRINT " / ":LOCATE 18,6:PRINT "äääää "":COLOR 13:LOC
ATE 17,6:PRINT " ____ ":LOCATE 18,10:PRINT "\äääääää":COLOR 15:LOCATE 19,6,0:PRINT "ä
äääääääääääää":GOTO 6950
5720 '
5730 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,9:COLOR 15,9,9:LOCATE 7,4:PRINT "fadin
g background":COLOR 11,9,9:GOSUB 4390:COLOR 3,0:GOSUB 4540:COLOR 11,9,9:GOSUB 48
00:COLOR 0,0:LOCATE 15,5:PRINT "":LOCATE 15,5:PRINT " "
5890 LOCATE 16,5:PRINT "":LOCATE 17,5:PRINT "":LOCATE 18,5:PRINT "":LOCATE 19,5
:PRINT "":LOCATE 20,5:PRINT "":LOCATE 20,19:PRINT "":COLOR 11,0:LOCATE 16,6:PRIN
T " / ":LOCATE 17,6:PRINT " / ":LOCATE 18,6:PRINT "":COLOR 13
6000 LOCATE 17,6:PRINT " ____ ":LOCATE 18,10:PRINT "\äääääää":COLOR 15:LOCATE 19,6,0
:PRINT "äääääääääääää":LOCATE 20,6,0:PRINT " ____ ":LOCATE 15,19,0:PRINT "":L
OCATE 16,19,0:PRINT "":LOCATE 17,19,0:PRINT "":LOCATE 18,19,0:PRINT " "
6090 LOCATE 19,19,0:PRINT "":LOCATE 20,19,0:PRINT "":GOTO 6950
6120 '

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6130 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,9:COLOR 15,9,9:LOCATE 7,6:PRINT" str
atified ":COLOR 11,9,9:GOSUB 4390:COLOR 3,0:GOSUB 4540:COLOR 11,9,9:GOSUB 4800:CO
LOR 13,0,0:LOCATE 17,6:PRINT"-----":COLOR 15,0,0:LOCATE 18,6:PRINT"-----
-----"
6290 COLOR 9,0,0:LOCATE 19,6,0:PRINT"bbbbbbbbbb":GOTO 6950
6330 '
6340 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,9:COLOR 15,9,9:LOCATE 7,10:PRINT"pair
ed":COLOR 11,9,9:GOSUB 4390:COLOR 3,0:KEY OFF:LOCATE 15,6:PRINT"Óááááááááé Óááá
ááááé":LOCATE 16,6:PRINT"" "":LOCATE 17,6:PRINT""
  "
6510 LOCATE 18,6:PRINT"áááááááááá áááááááááá":LOCATE 19,6:PRINT"Óááááááááé Óááá
ááááé":LOCATE 20,6:PRINT"" " " "":LOCATE 21,6:PRINT"" " "
  " " "":LOCATE 22,6:PRINT"áááááááááá áááááááááá":COLOR 15,0,0
6590 LOCATE 21,7:PRINT"áááááááá":LOCATE 21,18:PRINT"áááááááá":LOCATE 17,7:PRINT"á
áááááá":LOCATE 17,18:PRINT"áááááááá":COLOR 15,0,0:LOCATE 20,7:PRINT"*****":COLO
R 13,0,0:LOCATE 20,18:PRINT"*****":COLOR 11,0,0:LOCATE 16,7:PRINT"_____
"
6690 COLOR 13,0,0:LOCATE 16,18,0:PRINT"_____":COLOR 11,9,9:GOSUB 4800:GOTO 69
50
6740 '
6750 SCREEN 0,1:COLOR 11,9,9:CLS:OUT &H3D8,9:COLOR 15,9,9:LOCATE 7,3:PRINT"indic
ating (forecasts)":COLOR 11,9,9:GOSUB 4390:COLOR 3,0:GOSUB 4540:COLOR 11,9,9:GOS
UB 4800:LOCATE 13,0,0:LOCATE 17,6:PRINT" - - - ->":COLOR 12,0,0
6900 COLOR 18,6:PRINT" - - - ->":COLOR 9,0,0:LOCATE 19,6,0:PRINT" -
- - ->":GOTO 6950
6940 '
6950 KEY OFF:COLOR 11,9,9:IF SET<0 THEN 7030
7010 LOCATE 24,2:PRINT "Data Generator";:
7030 KEY OFF:RANDOMIZE TIMER:RF=3:GP=.0027:GPP=.04:MR=.8:M1=21:STP=.0019:SR=6:LL
=.7:99:S=2:H=.3:DIM M(39),T(50),A(26),B(50),C(26),D(26),E(26),F(26):DIM QSA(23),Q
SSA(23),QSSSA(23):DIM QSB(23),QSSB(23),QSSSB(23):DIM QSC(23),QSSC(23),QSSSC(23)
7340 DIM QSD(23),QSSD(23),QSSSD(23):DIM QSE(23),QSSE(23),QSSSE(23):DIM QSF(23),
QSSF(23),QSSSF(23):DIM PA(30),PB(27),PC(27),PD(27),PE(57),PF(27):DIM AQ(100),BQ(
100),CQ(100),DQ(100),EQ(100),FQ(100):M(1)=M1+10*(RND-.5):G1=GP*(RND-.5):G2=GP/2*
RND
7490 MG1=1 +G1:IF MG1>1 THEN MG1=MG1 +STP ELSE 7520
7510 MG2=1-G2-STP:GOTO 7560
7520 MG1=MG1-STP:MG2=1+G2+STP:
7560 LOCATE 24,2:PRINT"Calculating growth ";
7570 AG=(RND-.5)*GPP:BG=(RND-.5)*GPP:CG=(RND-.5)*GPP:DG=(RND-.5)*GPP:EG=(RND-.5)
 *GPP:FG=(RND-.5)*GPP:IF A80%=0 THEN AR=MR+RND/2.5 ELSE AR=1-RND/5.5
7640 AC=RND: IF AC>.499 THEN A80%= 45+(10*RND) ELSE A80%=0 'complement
7650 BC=RND: IF BC>.499 THEN B80%= 45+(10*RND) ELSE B80%=0 'complement
7660 CC=RND: IF CC>.499 THEN C80%= 45+(10*RND) ELSE C80%=0 'complement
7670 DC=RND: IF DC>.499 THEN D80%= 45+(10*RND) ELSE D80%=0 'complement
7680 EC=RND: IF EC>.499 THEN E80%= 45+(10*RND) ELSE E80%=0 'complement
7710 IF B80%=0 THEN BR=MR+RND/2.5 ELSE BR=1-RND/5.5
7720 IF C80%=0 THEN CR=MR+RND/2.5 ELSE CR=1-RND/5.5
7730 IF D80%=0 THEN DR=MR+RND/2.5 ELSE DR=1-RND/5.5
7740 IF E80%=0 THEN ER=MR+RND/2.5 ELSE ER=1-RND/5.5
7750 ML=15+INT(8.99*RND):AL=INT(LL*RND):BL=INT(LL*RND):CL=INT(LL*RND):DL=INT(LL*
RND):EL=INT(LL*RND)
7830 LOCATE 24,2:PRINT"Adding random factors";
7840 ARF=RF*RND +1:BRF=RF*RND +1:CRF=RF*RND +1:DRF=RF*RND +1:ERF=RF*RND +1:FOR T
 =2 TO ML:M(T)=M(T-1)*MG1^T:NEXT:FOR T=ML+1 TO 39:M(T)=M(T-1)*MG2^(T-ML):NEXT:IF
 SET >0 THEN 8090 ELSE IF SET=0 AND LINES(I)=5 AND GRF(I)<>1 THEN 8050 ELSE 7980
7980 AR=.75:AL=3:ARF=0:IF MG2>1 THEN AG=.005 ELSE AG=-.005
7990 BR=.95:BL=0:BRF=3:BG=.00001:CR=.85:CL=5:CRF=0:IF MG2>1 THEN CG=.002 ELSE CG
 =-.002
8010 DR=1.05:DL=1:DRF=4:DG=.0001:ER=1.15:EL=7:ERF=1:EG=.00001:A80=0:B80=0:E80=0:
RF=4:STP=.003:GOTO 8090
8050 AR=.95:AL=5:ARF=0:IF MG2>1 THEN AG=.004 ELSE AG=-.004
8060 BR=.95:BL=0:BRF=3:BG=.00001:CR=.85:CL=3:CRF=0:IF MG2>1 THEN CG=.003 ELSE CG
 =-.003
8080 EL=7:ERF=1:DL=2:DRF=5
8090 MDAO=-100:MDAB=-100:MDBC=-100:MDCD=-100:MDDE=-100:IF GRF(I) <>5 THEN PM=2 E
LSE PM=1

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8160 FOR T=1 TO 22:A(T)=ABS(M(T+AL+SR)*(AR+AG^T) -A80%):AE=ARF*(RND-.5):TAE=TAE+
ABS(AE):PA(T)=INT(PM*(A(T) +AE)):DAO=INT(1-PA(T)):IF DAO>MDAO THEN MDAO=DAO
8210 B(T)=ABS(M(T+BL+SR)*(BR+BG^T) -B80%):BE=BRF*(RND-.5):TBE=TBE+ABS(BE):PB(T)=I
NT(PM*(B(T) +BE)):C(T)=ABS(M(T+CL+SR)*(CR+CG^T) -C80%):CE=CRF*(RND-.5):TCE=TCE+AB
S(CE):PC(T)=INT(PM*(C(T) +CE)):IF LINES(I)=3 THEN 8400
8300 D(T)=ABS(M(T+DL+SR)*(DR+DG^T) -D80%):DE=DRF*(RND-.5):TDE=TDE+ABS(DE):PD(T)=I
NT(PM*(D(T) +DE)):E(T)=ABS(M(T+EL+SR)*(ER+EG^T) -E80%):EE=ERF*(RND-.5):TEE=TEE+AB
S(EE):PE(T)=INT(PM*(E(T) +EE)):
8400 LOCATE 24,2,0:PRINT "Generating period "T;
8410 NEXT:IF GRF(I) <> 4 THEN 8680
8450 LOCATE 24,2,0:PRINT "Separating trends          ";
8460 FOR T=1 TO 22:PA(T)=PA(T) +MDAO +S:DAB=INT(PA(T)-PB(T)):IF DAB > MDAB THEN
MDAB=DAB
8490 NEXT:FOR T=1 TO 22:PB(T)=PB(T) +MDAB + S:DBC=INT(PB(T) - PC(T)):IF DBC > MD
BC THEN MDDB=DBC
8530 NEXT:FOR T=1 TO 22:PC(T)=PC(T) +MDBC+ S:DCD=INT(PC(T) - PD(T)):IF DCD > MD
C THEN MDCC=DCD
8570 NEXT:FOR T=1 TO 22:PD(T)=PD(T) +MDCD+S:DDE=INT(PD(T) - PE(T)):IF DDE > MD
DE THEN MDDE=DDE
8610 NEXT:FOR T=1 TO 22:PE(T)=PE(T) +MDDE+S:DDEF=INT(PE(T) - PF(T)):IF DDEF > MD
EF THEN MDEF=DDEF
8650 NEXT:
8680 LOCATE 24,2:PRINT "Calculating slopes for the last 4 periods";
8690 FOR T=23 TO 26:A(T)=INT(M(T+AL+SR)*(AR+AG^T)):B(T)=INT(M(T+BL+SR)*(BR+BG^T)
):C(T)=INT(M(T+CL+SR)*(CR+CG^T)):D(T)=INT(M(T+DL+SR)*(DR+DG^T)):E(T)=INT(M(T+EL+
SR)*(ER+EG^T)):NEXT:SA=10*ABS((A(23)-A(26))/4):SB=10*ABS((B(23)-B(26))/4)
8790 SC=10*ABS((C(23)-C(26))/4):SD=10*ABS((D(23)-D(26))/4):SE=10*ABS((E(23)-E(2
6))/4):IF SET<0 THEN 8840 ELSE 8850
8840 C$=INKEY$:IF C$="" THEN 8840
8850 IF GRF(I) <> 6 THEN 9420
8870 LOCATE 24,2:PRINT"Calculating Brown's Quadratic Exponential Smoothing forec
ast";
8880 QSA(12)=PA(12):QSSA(12)=QA(12):QSSSA(12)=PA(12):QSB(12)=PB(12):QSSB(12)=PB(
12):QSSSB(12)=PB(12):QSC(12)=PC(12):QSSC(12)=PC(12):QSSSC(12)=PC(12):QSD(12)=PD(
12):QSSD(12)=PD(12):QSSSD(12)=PD(12):QSE(12)=PE(12):QSSSE(12)=PE(12):QSSSE(12)=PE
(12):
8940 FOR T=13 TO 22:QSA(T)=H*QA(T)+(1-H)*QSA(T-1):QSSA(T)=H*QSA(T)+(1-H)*QSSA(T
-1):QSSSA(T)=H*QSSA(T)+(1-H)*QSSSA(T-1):QSB(T)=H*PB(T)+(1-H)*QSB(T-1):QSSB(T)=H*
QSB(T)+(1-H)*QSSB(T-1):QSSSB(T)=H*QSSB(T)+(1-H)*QSSSB(T-1)
8970 QSC(T)=H*PC(T)+(1-H)*QSC(T-1):QSSC(T)=H*QSC(T)+(1-H)*QSSC(T-1):QSSSC(T)=H*
QSSC(T)+(1-H)*QSSSC(T-1):QSD(T)=H*PD(T)+(1-H)*QSD(T-1):QSSD(T)=H*QSD(T)+(1-H)*Q
SSD(T-1):QSSSD(T)=H*QSSD(T)+(1-H)*QSSSD(T-1)
8990 QSE(T)=H*PE(T)+(1-H)*QSE(T-1):QSSE(T)=H*QSE(T)+(1-H)*QSSE(T-1):QSSSE(T)=H*
QSSE(T)+(1-H)*QSSSE(T-1):NEXT:QS=QSA(22):QSS=QSSA(22):QSSS=QSSSA(22):GOSUB 9350:
FOR T=23 TO 26:PA(T)=INT(QA + QB*(T-22) +.5*QC*(T-22)^2):NEXT:
9090 QS=QSB(22):QSS=QSSB(22):QSSS=QSSSB(22):GOSUB 9350:FOR T=23 TO 26:PB(T)=INT
(QA + QB*(T-22) +.5*QC*(T-22)^2):NEXT T:QS=QSC(22):QSS=QSSC(22):QSSS=QSSSC(22):G
OSUB 9350:FOR T=23 TO 26:PC(T)=INT(QA + QB*(T-22) +.5*QC*(T-22)^2):NEXT:
9210 QS=QSD(22):QSS=QSSD(22):QSSS=QSSSD(22):GOSUB 9350:FOR T=23 TO 26:PD(T)=INT
(QA + QB*(T-22) +.5*QC*(T-22)^2):NEXT:QS=QSE(22):QSS=QSSE(22):QSSS=QSSSE(22):GOS
UB 9350:FOR T=23 TO 26:PE(T)=INT(QA + QB*(T-22) +.5*QC*(T-22)^2):NEXT:GOTO 9420
9350 QA=3*(QS-QSS)+QSSS:QB=(H/(2*(1-H)^2))*((6-5*H)*QS - (10-8*H)*QSS + (4-3*H)*
QSSS):QC=(H^2/(1-H)^2) *(QS-2*QSS+QSSS):RETURN:CLS
9420 KEY OFF:ERASE M,A,B,C,D,E,F:CLS:SCREEN 1:COLOR 8,1:CY=1:MG=2:WH=3:IF GRF(I)
=5 THEN 12040 ELSE 9510
9490 '
9510 AS$="bm-1,+1u1e1r1f1d1g111h1":BS$="bm-1,+1u3e1r1f1d3g111h1":CS$="u1r2d212u1
":DS$="bm+1,0r4h112eld4h1r2":ES$="r4g113dir1g1":FS$="bm+3,0h2f2g2":GS$="bm+2,0u1
d3":CLS:SCREEN 1:COLOR 8,1:XS=30:YS=152:IF GRF(I)=1 THEN 9790
9650 DEF SEG=&HB800:BLOAD "c:frame",0:IF LINES(I)=3 THEN 9710 ELSE 9770
9710 LINE(247,30)-(319,41),0,BF:LINE(247,86)-(319,96),0,BF:LINE(247,153)-(319,16
9),0,BF:LINE(130,190)-(238,199),0,BF:
9770 IF GRF(I)<>1 GOTO 11500
9780 '
9790 BLOAD "c:bwframe",0:IF LINES(I)=3 THEN 9820 ELSE 9870
9820 LINE(247,30)-(319,41),0,BF:LINE(247,86)-(319,96),0,BF:LINE(247,153)-(319,16
9),0,BF:LINE(130,190)-(238,199),0,BF:
9870 CY=3:MG=3:WH=3:GOTO 9920

```



```

9880 GOTO 12480
9910 '
9920 KEY OFF:X=XS:Y=YS - PA(1):SZ=4:DRAW "s=sz;":DRAW "c=wh;":DRAW "bm=x;,-y;"+A
SS:X=XS:Y=YS - PB(1):SZ=4:DRAW "s=sz;":DRAW "c=mg;":DRAW "bm=x;,-y;"+BS$:X=XS:Y=
YS - PC(1):SZ=8:DRAW "s=sz;":DRAW "c=cy;":DRAW "bm=x;,-y;"+CS$:IF LINES(I)=3 THE
N 10130
10060 :X=XS:Y=YS - PD(1):SZ=4:DRAW "s=sz;":DRAW "c=wh;":DRAW "bm=x;,-y;"+DS$:X=X
S:Y=YS - PE(1):SZ=4:DRAW "s=sz;":DRAW "c=mg;":DRAW "bm=x;,-y;"+ES$:
10130 :KEY OFF:X=XS:Y=YS - PA(1):PSET (X,Y),CY:SZ=4:DRAW "s=sz;":DRAW "c=wh;":FO
R T=2 TO 22:X=X +8:Y=YS - PA(T):YB=YS - PA(T-1):LINE(X-6,YB) - (X-2,Y),WH:DRAW "
bm=x;,-y;"+AS$:NEXT:X=XS:Y=YS - PB(1):PSET (X,Y),MG:SZ=4:DRAW "s=sz;":DRAW "c=mg
;":
10280 FOR T=2 TO 22:X=X +8:Y=YS - PB(T):LINE - (X,Y),MG:DRAW "c=mg;":DRAW "bm=x
;,-y;"+BS$:NEXT:X=XS:Y=YS - PC(1):PSET (X,Y),WH:SZ=8:DRAW "s=sz;":DRAW "c=cy;":F
OR T=2 TO 22:X=X +8:Y=YS - PC(T):LINE - (X,Y),CY:DRAW "bm=x;,-y;"+CS$:NEXT
10440 IF LINES(I)=3 THEN 10650
10450 :X=XS:Y=YS - PD(1):SZ=4:DRAW "s=sz;":DRAW "c=wh;":PSET (X,Y),CY:FOR T=2 TO
22:X=X +8:Y=YS - PD(T):YD=YS - PD(T-1):LINE(X-1,YD) - (X+2,Y),WH,,&HAAAA:DRAW "b
m=x;,-y;"+DS$:NEXT:X=XS:Y=YS - PE(1):PSET (X,Y),MG:SZ=4:DRAW "s=sz;":DRAW "c=mg;
;":
10580 FOR T=2 TO 22:X=X +8:Y=YS - PE(T):LINE -(X,Y),MG,,&HAAAA:DRAW "bm=x;,-y;
"+ES$:NEXT:
10650 :IF GRF(I)=3 THEN 11410
10670 :IF GRF(I)=6 THEN 10690 ELSE 12480
10680 :
10690 :XS=200:X=XS:Y=YS - PA(22):PSET (X,Y),WH:LINE(X,Y)-(X+3,Y),O:FOR T=23 TO 2
6:X=X +8:Y=YS - PA(T):LINE - (X,Y),WH:NEXT:X=X-1:SZ=4:DRAW "s=sz;":DRAW "c=wh;":
DRAW "bm=x;,-y;"+FS$:X=X+1:SZ=4:DRAW "s=sz;":DRAW "c=wh;":DRAW "bm=x;,-y;"+FS$:
10850 X=XS:Y=YS - PB(22):PSET (X,Y),MG:LINE(X,Y)-(X+3,Y),O:FOR T=23 TO 26:X=X +
8:Y=YS - PB(T):LINE - (X,Y),MG:NEXT:SZ=4:DRAW "s=sz;":DRAW "c=mg;":DRAW "bm=x;,-
y;"+FS$:X=X+1:SZ=4:DRAW "s=sz;":DRAW "c=mg;":DRAW "bm=x;,-y;"+FS$:X=XS:Y=YS - P
C(22)
10990 PSET (X,Y),CY:LINE(X,Y)-(X+3,Y),O:FOR T=23 TO 26:X=X +8:Y=YS - PC(T):LIN
E - (X,Y),CY:NEXT:X=X+1:SZ=4:DRAW "s=sz;":DRAW "c=cy;":DRAW "bm=x;,-y;"+FS$:X=X+
1:SZ=4:DRAW "s=sz;":DRAW "c=cy;":DRAW "bm=x;,-y;"+FS$:IF LINES(I)=3 THEN 11370
11130 :X=XS:Y=YS - PD(22):PSET (X,Y),WH:LINE(X,Y)-(X+2,Y),O:FOR T=23 TO 26:X=X +
8:Y=YS - PD(T):LINE - (X,Y),WH,,&HAAAA:NEXT:X=X+2:SZ=4:DRAW "s=sz;":DRAW "c=wh;":
DRAW "bm=x;,-y;"+FS$:X=XS:Y=YS - PE(22):X=X+1:PSET (X,Y),MG:LINE(X,Y)-(X+3,Y),
O:
11300 FOR T=23 TO 26:X=X +8:Y=YS - PE(T):LINE - (X,Y),MG,,&HAAAA:NEXT:X=X-1:SZ
=4:DRAW "s=sz;":DRAW "c=mg;":DRAW "bm=x;,-y;"+FS$:
11370 :GOTO 12480
11380 :GOTO 12480
11400 :
11410 :KEY OFF:LINE (23,159)-(235,33),O,BF:LINE (23,162)-(238,199),O,BF:LINE (25
,182)-(0,0),O,BF:LINE (20,161)-(236,164),O,BF:LINE (0,0)-(241,35),O,BF:LINE (237
,160)-(240,152),O,BF:
11500 :XS=32:X=XS:Y=YS - PA(1):IF GRF(I)=3 THEN 11520 ELSE 11580
11520 :FOR T=2 TO 22:LINE(X,33)-(X+8,155),O,BF:X=X +8:NEXT:LINE (24,33)-(236,15
5),O,BF
11580 :XS=32:X=XS:Y=YS - PA(1):PSET (X,Y),WH:FOR T=2 TO 22:X=X +8:Y=YS - PA(T):
LINE - (X,Y),WH:NEXT:IF GRF(I)=3 THEN LINE (0,0)-(241,25),O,BF
11670 :X=XS:Y=YS - PB(1):PSET (X,Y),MG:FOR T=2 TO 22:X=X +8:Y=YS - PB(T):LINE -
(X,Y),MG:NEXT:IF GRF(I)=3 THEN LINE (25,182)-(0,0),O,BF
11750 :X=XS:Y=YS - PC(1):PSET (X,Y),CY:FOR T=2 TO 22:X=X +8:Y=YS - PC(T):LINE -
(X,Y),CY:NEXT:IF GRF(I)=3 THEN LINE (23,161)-(238,199),O,BF
11830 :IF LINES(I)=3 THEN 12000
11840 :X=XS:Y=YS - PD(1):PSET (X,Y),WH:FOR T=2 TO 22:X=X +8:Y=YS - PD(T):LINE -
(X,Y),WH,,&HAAAA:NEXT:IF GRF(I)=3 THEN LINE (24,32)-(239,35),O,BF
11920 :X=XS:Y=YS - PE(1):PSET (X,Y),MG:FOR T=2 TO 22:X=X +8:Y=YS - PE(T):LINE -
(X,Y),MG,,&HAAAA:NEXT:IF GRF(I)=3 THEN LINE (237,160)-(240,152),O,BF
12000 :IF GRF(I)=6 THEN 10690 ELSE 12480
12010 :GOTO 12480
12030 :
12040 :CLS:DEF SEG=&H8800:BLOAD "c:windowe",O:IF LINES(I)=3 THEN 12070 ELSE 12120
12070 :LINE(0,103)-(240,199),O,BF:LINE(247,30)-(319,41),O,BF:LINE(247,86)-(319,9
6),O,BF:LINE(247,158)-(319,169),O,BF:

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12120 :X=10:Y=81:XX=133:YY=178:FOR T=1 TO 21:LINE (X,Y-PA(T))-(X+4,Y-PA(T+1)),WH
:LINE (XX,Y-PA(T))-(XX+4,Y-PA(T+1)),WH:IF LINES(I)=3 THEN 12190
12170 :LINE (X,YY-PA(T))-(X+4,YY-PA(T+1)),WH:LINE (XX,YY-PA(T))-(XX+4,YY-PA(T+1)
),WH
12190 :X=X +4:XX=XX + 4:NEXT:X=10:XX=133:Y=80:YY=177:FOR T=1 TO 21:LINE (X,Y-PB(
T))-(X+4,Y-PB(T+1)),MG:X=X + 4:XX=XX + 4:NEXT:X=10:XX=133:Y=80:YY=177:FOR T=1 TO
21:LINE (XX,Y-PC(T))-(XX+4,Y-PC(T+1)),CY:X=X + 4:XX=XX + 4:NEXT:IF LINES(I)=3 T
HEN 12450
12350 :X=10:XX=133:Y=80:YY=177:FOR T=1 TO 21:LINE (X,YY-PD(T))-(X+4,YY-PD(T+1)),
WH,,&HAAA:X=X + 4:XX=XX + 4:NEXT:X=10:XX=133:Y=80:YY=177:FOR T=1 TO 21:LINE (XX
,YY-PE(T))-(XX+4,YY-PE(T+1)),MG,,&HAAA:X=X + 4:XX=XX + 4:NEXT
12450 :KEY OFF:GOTO 12480
12480 :KEY OFF:LOCATE 1,2:PRINT I:NG=0:QS1=3:QS11=QS1+2:QS2=10:QS21=QS2 +2:QS3=1
9:QS31=QS3 +2:QA=32:QB=35:QC=38:QD=33:QE=36:QF=39:IF SET=>0 THEN OPEN "b:collekt
" FOR APPEND AS #1 ELSE 12840
12610 :WRITE #1,I:WRITE #1,GRF(I):WRITE #1,TAE:WRITE #1,TBE:WRITE #1,TCE:WRITE
#1,TDE:WRITE #1,TEE:WRITE #1,AL:WRITE #1,BL:WRITE #1,CL:WRITE #1,DL:WRITE #1,EL:
WRITE #1,SA:WRITE #1,SB:WRITE #1,SC:WRITE #1,SD:WRITE #1,SE:CLOSE:KEY OFF:
12840 :NG=0:START=TIMER:ON PEN GOSUB 12900
12870 :IF NG=1 THEN 13390
12880 :PEN ON
12890 :LOCATE 25,35:PRINT INT(TIMER-START)::GOTO 12890
12900 :X=PEN(1):Y=PEN(2):R=PEN(6):C=PEN(7):IF (X > 240 AND X < 319) AND (Y > 166
AND Y < 200) AND AW(1)>0 AND AW(2)>0 AND AW(3)>0 THEN NG=1 ELSE NG=0
12950 :SEQ=SEQ +1:Q1=QS3:Q11=QS31:Q=3:GOSUB 13050:Q1=QS2:Q11=QS21:Q=2:GOSUB 1305
0:Q1=QS1:Q11=QS11:Q=1:GOSUB 13050:GOTO 13360
13030 :
13050 :IF (R=Q1 OR R=Q1-1 ) AND (C=QA OR C=QA-1 ) THEN 13060 ELSE 13090
13060 :AW(Q)=1:SOUND 523,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QA-1)*8-4,Q1*8+1)-(QA*8,
Q1*8+2),1,B,&HBBBB
13090 :IF (R=Q1 OR R=Q1-1 ) AND (C=QB OR C=QB-1 ) THEN 13100 ELSE 13130
13100 :AW(Q)=2:SOUND 587,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QB-1)*8-4,Q1*8+1)-(QB*8-
1,Q1*8+2),3,B,&HBBBB
13130 :IF (R=Q1 OR R=Q1-1 ) AND (C=QC OR C=QC-1 ) THEN 13140 ELSE 13170
13140 :AW(Q)=3:SOUND 659,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QC-1)*8-4,Q1*8+1)-(QC*8-
1,Q1*8+2),3,B,&HBBBB
13170 :IF (R=Q11 OR R=Q11-1 ) AND (C=QD OR C=QD-1 ) THEN 13180 ELSE 13210
13180 :AW(Q)=4:SOUND 698,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QD-1)*8-6,Q11*8+2)-(QD*8
-2,Q11*8+3),1,B
13210 :IF (R=Q11 OR R=Q11-1 ) AND (C=QE OR C=QE-1 ) THEN 13220 ELSE 13250
13220 :AW(Q)=5:SOUND 783,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QE-1)*8-4,Q11*8+2)-(QE*8
,Q11*8+3),3,B
13250 :IF (R=Q11 OR R=Q11-1 ) AND ( C=QF OR C=QF-1 ) THEN 13260 ELSE 13330
13260 :AW(Q)=6:SOUND 880,1:AWS(Q)=SEQ:GOSUB 13310:LINE((QF-1)*8-4,Q11*8+2)-(QF*8
,Q11*8+3),3,B:GOTO 13330
13300 :
13310 :LINE((QA-1)*8-4,Q1*8+1)-(QC*8,Q1*8+2),0,B:LINE((QD-1)*8-6,Q11*8+2)-(QF*8,
Q11*8+3),0,B
13330 :RETURN:RETURN:
13360 :RETURN 12870:
13390 :PEN OFF:FINISH=TIMER:SOUND 131,5:SOUND 174,1:DU=FINISH - START:IF SET=>0
THEN 13420 ELSE 13510
13420 :OPEN "b:collekt" FOR APPEND AS #1:WRITE #1,AW(1):WRITE #1,AWS(1):WRITE #1
,AW(2):WRITE #1,AWS(2):WRITE #1,AW(3):WRITE #1,AWS(3):WRITE #1,DU:CLOSE
13510 :KEY OFF:OPEN "c:g" FOR OUTPUT AS #1:WRITE #1,I:CLOSE:IF SET<1 AND LINES(I
)=5 THEN 13580 ELSE 13770
13580 :LOCATE QS1+1,QA-2:PRINT INT(TAE):LOCATE QS1+1,QB-2:PRINT INT(TBE):LOCATE
QS1+1,QC-2:PRINT INT(TCE):LOCATE QS11+1,QD-2:PRINT INT(TDE):LOCATE QS11+1,QE-2:P
RINT INT(TEE):LOCATE QS2+1,QA-2:PRINT AL:LOCATE QS2+1,QB-2:PRINT BL
13650 LOCATE QS2+1,QC-2:PRINT CL:LOCATE QS21+1,QD-2:PRINT DL:LOCATE QS21+1,QE-2
:PRINT EL:LOCATE QS3+1,QA-2:PRINT INT(SA):LOCATE QS3+1,QB-2:PRINT INT(SB):LOCATE
QS3+1,QC-2:PRINT INT(SC):LOCATE QS31+1,QD-2:PRINT INT(SD)
13720 LOCATE QS31+1,QE-2:PRINT INT(SE):LOCATE 25,1:COLOR 8:PRINT "Press any let
ter to continue. ";
13750 :C$=INKEY$:IF C$="" THEN 13750
13760 :
13770 :B$=INKEY$:IF B$="z" THEN 3540
13780 :SCREEN 0,0,0:RETURN:IF(TIMER-SIMTIME)>900 THEN 3510

```

APPENDIX C  
ENHANCEMENT SCORING PROGRAM  
(written in BASIC 2.0 by Microsoft)

## ENHANCEMENT SCORING PROGRAM

```

10 'Score file
20 CLEAR
30 INPUT "fudge factor (0-1)";F
40 SCREEN 0,0,0:COLOR 7,1,1:CLS:KEY OFF:WIDTH 80
50 DIM GRF(31),MAXVAR(31),LEAD(31),SLOPE(31),VCORRECT(31),LCORRECT(31),SCORRECT(
31),TCORRECT(31),PERFM(31)
60 DIM ESTSPRED(31),ESTPERFM(31),ESTERROR(31),CCORRECT(31)
70 OPEN "b:collekt" FOR INPUT AS # 1
80 INPUT #1, ID
90 INPUT #1, DDATE$
100 INPUT #1, LGT$
110 INPUT #1, SET
120 OPEN "b:graded" FOR OUTPUT AS #2
130   WRITE #2, ID
140   WRITE #2, DDATE$
150   WRITE #2, LGT$
160   WRITE #2, SET
170 CLOSE #2
180 '
190 PRINT
200 PRINT"      |           |   Answered   | Resp | Selection | ESTIMATION |
ESTIMATE"
210 PRINT"Test | Graphic |   Correct   | Time | Performance | SPREAD   |
PERFORM "
220 PRINT"Seq | Type   | A1 A2 A3 A4 Total| (sec)| (corct/min) | (est/range)|
230 PRINT"-----"
-----
240 COLOR 3,1,1
250 COLOR 7,1,1
260 FOR I = 8 TO 19
270   IF EOF(1) THEN 1670
280 '
290   INPUT #1, I
300   INPUT #1, GRF(I)
310 '
320   INPUT #1, TAE
330   INPUT #1, TBE
340   INPUT #1, TCE
350   INPUT #1, TDE
360   INPUT #1, TEE
370 '
380   INPUT #1, AL
390   INPUT #1, BL
400   INPUT #1, CL
410   INPUT #1, DL
420   INPUT #1, EL
430 '
440   INPUT #1, SA
450   INPUT #1, SB
460   INPUT #1, SC
470   INPUT #1, SD
480   INPUT #1, SE
490   INPUT #1, AW(1)
500   INPUT #1, AWS(1)
510   INPUT #1, AW(2)
520   INPUT #1, AWS(2)
530   INPUT #1, AW(3)
540   INPUT #1, AWS(3)
550   INPUT #1, DU
560   IF I>7 THEN 570 ELSE 1660
570     MAXVAR(I)=0
580     LEAD(I)=0
590     SLOPE(I)=0

```

```

600 '
610 IF TAE >MAXVAR(I) THEN MAXVAR(I) =TAE 'find the max variability
620 IF TBE >MAXVAR(I) THEN MAXVAR(I) =TBE 'find the max variability
630 IF TCE >MAXVAR(I) THEN MAXVAR(I) =TCE 'find the max variability
640 IF TDE >MAXVAR(I) THEN MAXVAR(I) =TDE 'find the max variability
650 IF TEE >MAXVAR(I) THEN MAXVAR(I) =TEE 'find the max variability
660 '
670 IF AL >LEAD(I) THEN LEAD(I) =AL 'find the lead
680 IF BL >LEAD(I) THEN LEAD(I) =BL 'find the lead
690 IF CL >LEAD(I) THEN LEAD(I) =CL 'find the lead
700 IF DL >LEAD(I) THEN LEAD(I) =DL 'find the lead
710 IF EL >LEAD(I) THEN LEAD(I) =EL 'find the lead
720 '
730 IF SA >SLOPE(I) THEN SLOPE(I) =SA 'find the slope
740 IF SB >SLOPE(I) THEN SLOPE(I) =SB
750 IF SC >SLOPE(I) THEN SLOPE(I) =SC
760 IF SD >SLOPE(I) THEN SLOPE(I) =SD
770 IF SE >SLOPE(I) THEN SLOPE(I) =SE 'find the lead
780 '
790 IF AW(1)=1 AND TAE=>MAXVAR(I)*F THEN VCORRECT(I)=1
800 IF AW(1)=1 THEN VEST = TAE 'set estimate
810 IF AW(1)=2 AND TBE=>MAXVAR(I)*F THEN VCORRECT(I)=1
820 IF AW(1)=2 THEN VEST = TBE
830 IF AW(1)=3 AND TCE=>MAXVAR(I)*F THEN VCORRECT(I)=1
840 IF AW(1)=3 THEN VEST = TCE
850 IF AW(1)=4 AND TDE=>MAXVAR(I)*F THEN VCORRECT(I)=1
860 IF AW(1)=4 THEN VEST = TDE
870 IF AW(1)=5 AND TEE=>MAXVAR(I)*F THEN VCORRECT(I)=1
880 IF AW(1)=5 THEN VEST = TEE
890 VERROR = (MAXVAR(I)-VEST)/MAXVAR(I)
900 VSPREAD= VEST/MAXVAR(I)
910 '
920 IF AW(2)=1 AND AL=>LEAD(I)*F THEN LCORRECT(I)=1
930 IF AW(2)=1 THEN LEST = AL
940 IF AW(2)=2 AND BL=>LEAD(I)*F THEN LCORRECT(I)=1
950 IF AW(2)=2 THEN LEST = BL
960 IF AW(2)=3 AND CL=>LEAD(I)*F THEN LCORRECT(I)=1
970 IF AW(2)=3 THEN LEST = CL
980 IF AW(2)=4 AND DL=>LEAD(I)*F THEN LCORRECT(I)=1
990 IF AW(2)=4 THEN LEST = DL
1000 IF AW(2)=5 AND EL=>LEAD(I)*F THEN LCORRECT(I)=1
1010 IF AW(2)=5 THEN LEST = EL
1020 LERROR = (LEAD(I)-LEST)/LEAD(I)
1030 LSPREAD= LEST/LEAD(I)
1040 '
1050 IF AW(3)=1 AND SA=>SLOPE(I)*F THEN SCORRECT(I)=1
1060 IF AW(3)=1 THEN SEST = SA
1070 IF AW(3)=2 AND SB=>SLOPE(I)*F THEN SCORRECT(I)=1
1080 IF AW(3)=2 THEN SEST = SB
1090 IF AW(3)=3 AND SC=>SLOPE(I)*F THEN SCORRECT(I)=1
1100 IF AW(3)=3 THEN SEST = SC
1110 IF AW(3)=4 AND SD=>SLOPE(I)*F THEN SCORRECT(I)=1
1120 IF AW(3)=4 THEN SEST = SD
1130 IF AW(3)=5 AND SE=>SLOPE(I)*F THEN SCORRECT(I)=1
1140 IF AW(3)=5 THEN SEST = SE
1150 SERROR = (SLOPE(I)-SEST)/SLOPE(I)
1160 SSPREAD= SEST/SLOPE(I)
1170 ESTERROR(I) = VERROR +LERROR + SERROR
1180 ESTSPRED(I) = VSPREAD+SSPREAD+LSPREAD+1
1190 CCORRECT(I)=VCORRECT(I)+LCORRECT(I)+SCORRECT(I) 'chose correc
1200 TCORRECT(I)=VCORRECT(I)+LCORRECT(I)+SCORRECT(I)+1 'total correc
1210 '
1220 '
1230 PERFM(I)= TCORRECT(I) * 60/DU
1240 ESTPERFM(I)= ESTSPRED(I) * 60/DU
1250 IF GRF(I)=1 THEN 1260 ELSE 1280
1260 GT$="Blk&Wht":G1=G1+1:G1PRFM=G1PRFM+PERFM(I):G1ESTPRF=G1ESTPRF+ESTPERFM(I)

```

```

1270 VC1=VC1 + VCORRECT(I):LC1=LC1 + LCORRECT(I):SC1=SC1 + SCORRECT(I):DU1=DU1 +
DU:GOTO 1440
1280 IF GRF(I)=2 THEN 1290 ELSE 1310
1290 GT$="Colored":G2=G2+1:G2PRFM=G2PRFM+PERFM(I):G2ESTPRF=G2ESTPRF+ESTPERFM(I)
1300 VC2=VC2 + VCORRECT(I):LC2=LC2 + LCORRECT(I):SC2=SC2 + SCORRECT(I):DU2=DU2 +
DU:GOTO 1440
1310 IF GRF(I)=3 THEN 1320 ELSE 1340
1320 GT$="Faded":G3=G3+1:G3PRFM=G3PRFM+PERFM(I):G3ESTPRF=G3ESTPRF+ESTPERFM(I)
1330 VC3=VC3 + VCORRECT(I):LC3=LC3 + LCORRECT(I):SC3=SC3 + SCORRECT(I):DU3=DU3 +
DU:GOTO 1440
1340 IF GRF(I)=4 THEN 1350 ELSE 1370
1350 GT$="Stratified":G4=G4+1:G4PRFM=G4PRFM+PERFM(I):G4ESTPRF=G4ESTPRF+ESTPERFM(I)
1360 VC4=VC4 + VCORRECT(I):LC4=LC4 + LCORRECT(I):SC4=SC4 + SCORRECT(I):DU4=DU4 +
DU:GOTO 1440
1370 IF GRF(I)=5 THEN 1380 ELSE 1400
1380 GT$="Paired":G5=G5+1:G5PRFM=G5PRFM+PERFM(I):G5ESTPRF=G5ESTPRF+ESTPERFM(I)
1390 VC5=VC5 + VCORRECT(I):LC5=LC5 + LCORRECT(I):SC5=SC5 + SCORRECT(I):DU5=DU5 +
DU:GOTO 1440
1400 IF GRF(I)=6 THEN 1410 ELSE 1430
1410 GT$="Indictor":G6=G6+1:G6PRFM=G6PRFM+PERFM(I):G6ESTPRF=G6ESTPRF+ESTPERFM(I)
1420 VC6=VC6 + VCORRECT(I):LC6=LC6 + LCORRECT(I):SC6=SC6 + SCORRECT(I):DU6=DU6 +
DU:GOTO 1440
1430 'print in the chart
1440 LOCATE (I-2),2,0:PRINT I
1450 LOCATE (I-2),7,0:PRINT GT$
1460 LOCATE (I-2),17,0:PRINT VCORRECT(I)
1470 LOCATE (I-2),20,0:PRINT LCORRECT(I)
1480 LOCATE (I-2),23,0:PRINT SCORRECT(I)
1490 LOCATE (I-2),27,0:PRINT "I"
1500 LOCATE (I-2),30,0:PRINT TCORRECT(I)
1510 LOCATE (I-2),36,0:PRINT USING "###.###";DU:COLOR 15,1,1
1520 LOCATE (I-2),45,0:PRINT USING "###.###";PERFM(I):COLOR 7,1,1
1530 LOCATE (I-2),60,0:PRINT USING "###.###";ESTSPRED(I):COLOR 14,1,1
1540 LOCATE (I-2),72,0:PRINT USING "###.###";ESTPERFM(I):COLOR 7,1,1
1550 'TOP
1560 OPEN "b:graded" FOR APPEND AS #2
1570 WRITE #2,I
1580 WRITE #2,GRF(I)
1590 WRITE #2,VCORRECT(I)
1600 WRITE #2,LCORRECT(I)
1610 WRITE #2,SCORRECT(I)
1620 WRITE #2,TCORRECT(I)
1630 WRITE #2,DU
1640 WRITE #2,ESTSPRED(I)
1650 CLOSE #2
1660 NEXT
1670 CLOSE #1
1680 OPEN "b:graded" FOR APPEND AS #2
1690 WRITE #2,G1 'total bl&wh
1700 WRITE #2,VC1 'total volatile correct bl&wh
1710 WRITE #2,LC1 'total leading correct bl&wh
1720 WRITE #2,SC1 'total slope correct bl&wh
1730 WRITE #2,DU1 'total response bl&wh
1740 WRITE #2,G2 'total color
1750 WRITE #2,VC2
1760 WRITE #2,LC2
1770 WRITE #2,SC2
1780 WRITE #2,DU2
1790 WRITE #2,G3 'total faded
1800 WRITE #2,VC3
1810 WRITE #2,LC3
1820 WRITE #2,SC3
1830 WRITE #2,DU3
1840 WRITE #2,G4 'total stratified
1850 WRITE #2,VC4
1860 WRITE #2,LC4
1870 WRITE #2,SC4

```

```

1880 WRITE #2,DU4
1890 WRITE #2,G5 'total paired
1900 WRITE #2,VC5
1910 WRITE #2,LC5
1920 WRITE #2,SC5
1930 WRITE #2,DU5
1940 WRITE #2,G6 'total indicating
1950 WRITE #2,VC6
1960 WRITE #2,LC6
1970 WRITE #2,SC6
1980 WRITE #2,DU6
1990 CLOSE #2
2000 LOCATE 25,64:PRINT ID::LOCATE 25,70:PRINT DDATE$;:COLOR 7
2010 LOCATE 25,1:PRINT F;:COLOR 2
2020 LOCATE 25,64:PRINT ID::LOCATE 25,70:PRINT DDATE$;:COLOR 7
2030 C$=INKEY$:IF C$="" THEN 2030
2040 CLS
2050 '
2060 PRINT
2070 PRINT"          Comparison to Colored Graphic"
2080 PRINT
2090 PRINT"
2100 PRINT"   Graphic      Accumulated   Averages   Accumulated   Averages"
2110 PRINT"   Type          Selection     for this    Estimation    for this"
2120 PRINT" -----      Performance  experiment  Performance    experiment"
2130 PRINT" -----      -----      -----      -----      -----"
2140 PRINT" Colored
2150 PRINT
2160 PRINT" Black & White
2170 PRINT
2180 PRINT" Faded
2190 PRINT
2200 PRINT" Statified
2210 PRINT
2220 PRINT" Paired
2230 PRINT
2240 PRINT" Indicator
2250 OPEN "todate" FOR INPUT AS #3 'comparisons to date
2260 INPUT #3,SB
2270 INPUT #3,SF
2280 INPUT #3,SS
2290 INPUT #3,SP
2300 INPUT #3,SI
2310 INPUT #3,EB
2320 INPUT #3,EF
2330 INPUT #3,ES
2340 INPUT #3,EP
2350 INPUT #3,EI
2360 CLOSE #3
2370 ' LOCATE 9,20:PRINT USING "###.###";G2PRFM/G2
2380 LOCATE 9,20:PRINT USING "###.###";1
2390 ' LOCATE 11,20:PRINT USING "###.###";G1PRFM/G1
2400 LOCATE 11,20:PRINT USING "###.###";SB
2410 ' LOCATE 13,20:PRINT USING "###.###";G3PRFM/G3
2420 LOCATE 13,20:PRINT USING "###.###";SF
2430 ' LOCATE 15,20:PRINT USING "###.###";G4PRFM/G4
2440 LOCATE 15,20:PRINT USING "###.###";SS
2450 ' LOCATE 17,20:PRINT USING "###.###";G5PRFM/G5
2460 LOCATE 17,20:PRINT USING "###.###";SP
2470 ' LOCATE 19,20:PRINT USING "###.###";G6PRFM/G6
2480 LOCATE 19,20:PRINT USING "###.###";SI
2490 '

```

```
2500 ' LOCATE 9,48:PRINT USING "###.##";G2ESTPRF/G2
2510 LOCATE 9,48:PRINT USING "###.##";1
2520 ' LOCATE 11,48:PRINT USING "###.##";G1ESTPRF/G1
2530 LOCATE 11,48:PRINT USING "###.##";EB
2540 ' LOCATE 13,48:PRINT USING "###.##";G3ESTPRF/G3
2550 LOCATE 13,48:PRINT USING "###.##";EF
2560 ' LOCATE 15,48:PRINT USING "###.##";G4ESTPRF/G4
2570 LOCATE 15,48:PRINT USING "###.##";ES
2580 ' LOCATE 17,48:PRINT USING "###.##";G5ESTPRF/G5
2590 LOCATE 17,48:PRINT USING "###.##";EP
2600 ' LOCATE 19,48:PRINT USING "###.##";G6ESTPRF/G6
2610 LOCATE 19,48:PRINT USING "###.##";EI
2620 COLOR 15,1,1
2630   LOCATE 9,33:PRINT USING "###.##";(G2PRFM/G2)/(G2PRFM/G2)
2640   LOCATE 11,33:PRINT USING "###.##";(G1PRFM/G1)/(G2PRFM/G2)
2650   LOCATE 13,33:PRINT USING "###.##";(G3PRFM/G3)/(G2PRFM/G2)
2660   LOCATE 15,33:PRINT USING "###.##";(G4PRFM/G4)/(G2PRFM/G2)
2670   LOCATE 17,33:PRINT USING "###.##";(G5PRFM/G5)/(G2PRFM/G2)
2680   LOCATE 19,33:PRINT USING "###.##";(G6PRFM/G6)/(G2PRFM/G2)
2690 ,
2700 COLOR 14,1,1
2710   LOCATE 9,59:PRINT USING"###.##";(G2ESTPRF/G2)/(G2ESTPRF/G2)
2720   LOCATE 11,59:PRINT USING"###.##";(G1ESTPRF/G1)/(G2ESTPRF/G2)
2730   LOCATE 13,59:PRINT USING "###.##";(G3ESTPRF/G3)/(G2ESTPRF/G2)
2740   LOCATE 15,59:PRINT USING "###.##";(G4ESTPRF/G4)/(G2ESTPRF/G2)
2750   LOCATE 17,59:PRINT USING "###.##";(G5ESTPRF/G5)/(G2ESTPRF/G2)
2760   LOCATE 19,59:PRINT USING "###.##";(G6ESTPRF/G6)/(G2ESTPRF/G2)
2770 COLOR 3,1,1
2780 LOCATE 25,64:PRINT ID;:LOCATE 25,70:PRINT DDATES;
2790 DEF SEG=&H8800:BSAVE"b:compare",0,&H4000
2800 C$=INKEY$:IF C$="" THEN 2800
2810 END
```



APPENDIX D

GRAPHICS FRAMES PROGRAM

(written in BASIC 2.0 by Microsoft)

## GRAPHICS FRAMES PROGRAM

```

10 ' CLS:SCREEN 1:GOTO 3970
20 ' numbers file
30 CLEAR
40 '////////// DRAW 5-LINE GRAPHS 5.3.1
50 ' IN: GD(MN)
60 ' Out:GD(mn)
70 ' Set: x,y,i
80 '
90 ' DIM CONV(1000),BWCONV(1000),WINDO(4900),QUESTION(3000) ' only the bottom b&
w
100 GD=1:DIM I(13)
110 COMMON CONV,BWCONV,WINDO,QUESTION
120 KEY OFF 'Numbers and symbols subroutine ////////////
130 DEFINT A-Z:'DIM NUMS(50)
140 SZ=4 'scale, 4=1,8=2
150 DRAW "s=sz;"
160 'symbol order 0,1,2,3,4,5,6,7,8,9
170 FOR I=0 TO 9: READ NUMS(I):NEXT
180 DATA "bm+1,+0R2E1U4H1L2G1D4"
190 DATA "R2L1U6G1"
200 DATA "R4L4E4U1H1L2G1"
210 DATA "bm+0,-1f1r2eluh2e214"
220 DATA "bm+3,0u6d3r114u3"
230 DATA "bm+0,-1f1r2eluh2h113u2r4"
240 DATA "bm+1,0r2eluh113d2u3e2r1"
250 DATA "bm+1,0u2e3u114"
260 DATA "bm+1,0r2eluh112hlulelr2f1dig112g1d1"
270 DATA "bm+0,-1f1r1e2u3h112g1d1f1r3
280 ' SCREEN 2:CLS:KEY OFF:DEFINT A-Z
290 ' DIM SA(20),SB(20),SC(20),SD(20),SE(20),SF(20),SG(20),SH(20)
300 ' LOCATE 1,1:PRINT "abcdefgh"
310 ' GET(0,0)-(7,7),SA:GET (8,0)-(15,7),SB
320 'VIEW SCREEN (0,0)-(150,150)
330 ' SCREEN 1:CLS:COLOR 8,1
340 ' PUT (100,100),SA : PUT (110,100),SB
350 'VIEW SCREEN (151,151)-(319,199),2
360 ' SCREEN 1:COLOR 8,1
370 SCREEN 1:COLOR 8,1
380 'VIEW SCREEN (151,151)-(319,199)
390 'color screen
400 CY =1 :MG = 2: WH =3 'colors change
410 GOSUB 600
420 DEF SEG=&HB800 :BSAVE "c:frame",0,&H4000
430 DIM A1(90):GET (18,198)-(27,193),A1
440 DIM B1(50):GET (57,199)-(66,193),B1
450 DIM C1(50):GET (97,199)-(107,193),C1
460 DIM D1(50):GET (138,198)-(149,193),D1
470 DIM E1(50):GET (175,199)-(188,193),E1
480 DIM F1(50):GET (218,198)-(229,193),F1
490 CY=3:MG=3:WH=3 ' for b&w
500 GOSUB 600
510 DEF SEG=&HB800 :BSAVE "c:bwframe",0,&H4000
520 CY =1 :MG = 2: WH =3 'colors change
530 DIM A10(90):GET (18,198)-(27,193),A10
540 DIM B10(50):GET (57,199)-(66,193),B10
550 DIM C10(50):GET (97,199)-(107,193),C10
560 DIM D10(50):GET (138,198)-(149,193),D10
570 DIM E10(50):GET (175,199)-(188,193),E10
580 DIM F10(50):GET (218,198)-(229,193),F10
590 GOTO 2530 'bypass

600 CLS '////////// framing subroutine ////////////
610 KEY OFF
620 COLOR 8,1
630 LINE(24,32)-(240,160),CY,B

```

```

640 LINE(23,32)-(23,160),CY
650 PRESET(240,158)
660 PRESET(240,156)
670 PRESET(240,154)
680 DRAW "BM24,152;C0;12d2r3d213d2r3"
690 DRAW "bm19,160;c=cy;r5d411u4"
700 X=32 'notches
710 FOR I = 1 TO 13
720   LINE(X,160)-(X,162),CY:LINE(X+8,160)-(X+8,164),CY:LINE(X+9,160)-(X+9,164)
    ,CY:X = X + 16
730 NEXT I
740 Y=32 'horizontal notches
750 FOR I = 1 TO 7
760   LINE (24,Y) - (19,Y),CY:Y = Y+20
770 NEXT
780 X=40 ' grids down
790 COLOR 8,1
800 FOR I = 1 TO 13
810   LINE(X,33)-(X,155),CY,,&H1111
820   X = X +16
830 NEXT
840 Y = 52 'grids right
850 FOR I = 1 TO 6
860   LINE(22,Y)-(235,Y),CY,,&H111
870   Y = Y +20
880 NEXT
890 ' Numbers on the x-axis
900 SX=21 :SY=173
910 DRAW "bm=sx;,-sy;" +NUM$(0)
920 '
930 SX=38 :SY=173
940 DRAW "bm=sx;,-sy;" +NUM$(2)
950 '
960 SX=54 :SY=173
970 DRAW "bm=sx;,-sy;" +NUM$(4)
980 '
990 SX=70 :SY=173
1000 DRAW "bm=sx;,-sy;" +NUM$(6)
1010 '
1020 SX=86 :SY=173
1030 DRAW "bm=sx;,-sy;" +NUM$(8)
1040 '
1050 SX=100:SY=173
1060 DRAW "bm=sx;,-sy;" +NUM$(1)
1070 '
1080 SX=105:SY=173
1090 DRAW "bm=sx;,-sy;" +NUM$(0)
1100 '
1110 SX=116:SY=173
1120 DRAW "bm=sx;,-sy;" +NUM$(1)
1130 '
1140 SX=121:SY=173
1150 DRAW "bm=sx;,-sy;" +NUM$(2)
1160 '
1170 SX=132:SY=173
1180 DRAW "bm=sx;,-sy;" +NUM$(1)
1190 '
1200 SX=137:SY=173
1210 DRAW "bm=sx;,-sy;" +NUM$(4)
1220 '
1230 SX=148:SY=173
1240 DRAW "bm=sx;,-sy;" +NUM$(1)
1250 '
1260 SX=153:SY=173
1270 DRAW "bm=sx;,-sy;" +NUM$(6)
1280 '
1290 SX=164:SY=173
1300 DRAW "bm=sx;,-sy;" +NUM$(1)

```

```

1310 '
1320 SX=169:SY=173
1330 DRAW "bm=sx; ,=sy;" +NUM$(8)
1340 '
1350 SX=179:SY=173
1360 DRAW "bm=sx; ,=sy;" +NUM$(2)
1370 '
1380 SX=185:SY=173
1390 DRAW "bm=sx; ,=sy;" +NUM$(0)
1400 '
1410 SX=195:SY=173
1420 DRAW "bm=sx; ,=sy;" +NUM$(2)
1430 '
1440 SX=201:SY=173
1450 DRAW "bm=sx; ,=sy;" -NUM$(2)
1460 '
1470 SX=211:SY=173
1480 DRAW "bm=sx; ,=sy;" +NUM$(2)
1490 '
1500 SX=217:SY=173
1510 DRAW "bm=sx; ,=sy;" +NUM$(4)
1520 '
1530 SX=227:SY=173
1540 DRAW "bm=sx; ,=sy;" +NUM$(2)
1550 '
1560 SX=233:SY=173
1570 DRAW "bm=sx; ,=sy;" +NUM$(6)
1580 ' Numbers on the y axis
1590 SX=12:SY=33
1600 FOR YA = 1 TO 7
1610 DRAW "bm=sx; ,=sy;" +NUM$(0)
1620   SY = SY+20
1630 NEXT YA
1640 SX=4:SY=33
1650 I=8
1660 FOR YA = 1 TO 7
1670 DRAW "bm=sx; ,=sy;" +NUM$(1)
1680   SY = SY+20
1690 I = I-1
1700 NEXT YA
1710 SX=12:SY=161
1720 DRAW "bm=sx; ,=sy;" +NUM$(0) 'zero axis
1730 '
1740 'Labels
1750 DEF SEG: POKE &H4E,CY
1760 ZXAXIS$= "weeks"
1770 ZYAXIS$= "sales $(000)"
1780 ROW =23:COL=16

1790 LOCATE ROW, COL
1800 PRINT ZXAXIS$;
1810 ROW = 3: COL =1
1820 LOCATE ROW, COL
1830 PRINT ZYAXIS$;
1840 '
1850 'Titles
1860 ZTOP$= "Market Shares"
1870 ZNEXT$= "1st 2 Qtrs 1984"
1880 ROW =1:COL=13
1890 LOCATE ROW, COL
1900 PRINT ZTOP$;
1910 ROW = 2: COL =13
1920 LOCATE ROW, COL
1930 PRINT ZNEXT$;
1940 '
1950 GOSUB 1970
1960 RETURN
1970 KEY OFF ' legends
1980 DEF SEG: POKE &H4E,WH

```

```

1990 LOCATE 25,5 :PRINT "A";
2000 '
2010 DEF SEG: POKE &H4E,WH
2020 ASS$="bm-1,0ule1r1f1d1g111h1" ' circle
2030 SX=25:SY=196:SZ=4 :DRAW "s=sz;": DRAW "c3;"
2040 DRAW "bm=sx;,-sy;"+ASS$
2050 LINE(16,196)-(22,196)
2060 '
2070 '           LA$="u5e2dlr1f1d213r3d3" ' large A
2080 '           SX=37:SY=199:SZ=4 :DRAW "s=sz;": DRAW "c3;"
2090 '           DRAW "bm=sx;,-sy;"+LA$
2100 DEF SEG: POKE &H4E,MG
2110 LOCATE 25,10:PRINT "B";
2120 BS$="bm-1,+2u3elr1f1d3g111h1" ' oval
2130 SX=64:SY=196:SZ=4 :DRAW "s=sz;": DRAW "c=mg;"
2140 DRAW "bm=sx;,-sy;"+BS$
2150 LINE(56,196)-(62,196),MG
2160 '
2170 '           LB$="r3eluh111r1eluh113r1d5"B
2180 '           SX=72:SY=199:SZ=4 :DRAW "s=sz;": DRAW "c2;"
2190 '           DRAW "bm=sx;,-sy;"+LB$
2200 DEF SEG: POKE &H4E,CY
2210 LOCATE 25,15 :PRINT "C";
2220 CS$="ulr2d212u1" ' box symbol
2230 SX=103:SY=196:SZ=8 :DRAW "s=sz;": DRAW "c=cy;"
2240 DRAW "bm=sx;,-sy;"+CS$
2250 LINE(95,196)-(101,196),CY
2260 '
2270 '           LC$="bm1,0r3elg113h1u4elr2f1"C
2280 '           SX=98:SY=199:SZ=4 :DRAW "s=sz;": DRAW "c1;"
2290 '           DRAW "bm=sx;,-sy;"+LC$
2300 DEF SEG: POKE &H4E,WH
2310 LOCATE 25,20:PRINT "D";
2320 DS$="r4h112e1d4h1r2" ' diamond symbol
2330 SX=144:SY=196:SZ=4 :DRAW "s=sz;": DRAW "c3;"
2340 DRAW "bm=sx;,-sy;"+DS$
2350 LINE(133,196)-(142,196),3,,&HAAAA
2360 '
2370 DEF SEG: POKE &H4E,MG
2380 LOCATE 25,25 :PRINT "E";
2390 ES$="r4g113d1r1g1" ' TRIANGLE SYMBOL
2400 SX=183:SY=195:SZ=4 :DRAW "s=sz;": DRAW "c=mg;"
2410 DRAW "bm=sx;,-sy;"+ES$
2420 LINE(171,196)-(181,196),MG,,&HAAAA
2430 '
2440 DEF SEG: POKE &H4E,CY
2450 LOCATE 25,30 :PRINT "F";
2460 FS$="bm+2,+2u4r1d411u4r1d4" ' bar SYMBOL
2470 SX=225:SY=196:SZ=4 :DRAW "s=sz;": DRAW "c=cy;"
2480 DRAW "bm=sx;,-sy;"+FS$
2490 LINE(224,196)-(218,196),CY,,&HAAAA
2500 RETURN '//////////////////////////////////// end of framing //////////////////////////////////
2510 '
2520 '
2530 'CS$=INKEY$: IF CS$="" THEN 2410
2540 PRINT "Draw windows" SUBROUTINE 3.3.2/////
2550 DIM WV(45),WH(99)
2560 SCREEN 1,1:COLOR 8,1: KEY OFF :CLS
2570 LINE (8,20)-(117,83),1,B'vertical lines
2580 LINE(7,20)-(7,83),1
2590 PSET(6,30),1
2600 PSET(6,40),1
2610 PSET(6,50),1
2620 PSET(6,60),1
2630 PSET(6,70),1
2640 PSET(6,80),1
2650 PSET(6,83),1
2660 X = 11

```

```

2670 FOR T = 1 TO 26 'horizontal lines
2680   LINE(X,82) - (X+1,82),1
2690   X = X+4
2700 NEXT
2710 GET (7,20)-(8,80),WV
2720 GET (9,82)-(117,84),WH
2730 'Titles and legend
2740 '   draw
2750 SSS$="r3e1h112h1e1r2"
2760 SX=0:SY=14:SZ=4:DRAW "s=sz;": DRAW "c1;"
2770 DRAW "bm=sx;,-sy;"+SS$
2780 '
2790 SAS$="u2e2f2d2u113"
2800 SX=7:SY=14:SZ=4:DRAW "s=sz;": DRAW "c1;"
2810 DRAW "bm=sx;,-sy;"+SAS$
2820 SX=23:SY=96:DRAW "c3;"
2830 DRAW "bm=sx;,-sy;"+SAS$
2840 '
2850 SL$="u5d5r2"
2860 SX=14:SY=14:SZ=4:DRAW "s=sz;": DRAW "c1;"
2870 DRAW "bm=sx;,-sy;"+SL$
2880 '
2890 '
2900 SES$="r313h1u2e1r2f1g112"
2910 SX=21:SY=14:SZ=4:DRAW "s=sz;": DRAW "c1;"
2920 DRAW "bm=sx;,-sy;"+SES$
2930 '
2940 SX=28:SY=14:SZ=4:DRAW "s=sz;": DRAW "c1;"
2950 DRAW "bm=sx;,-sy;"+SS$
2960 '
2970 SW$="u4d4e2f2u4"
2980 SX=50:SY=90:SZ=4:DRAW "s=sz;": DRAW "c1;"
2990 DRAW "bm=sx;,-sy;"+SW$
3000 '
3010 SX=58:SY=90:SZ=4:DRAW "s=sz;": DRAW "c1;"
3020 DRAW "bm=sx;,-sy;"+SES$
3030 '
3040 SX=65:SY=90:SZ=4:DRAW "s=sz;": DRAW "c1;"
3050 DRAW "bm=sx;,-sy;"+SES$
3060 '
3070 '
3080 SK$="u4d3e3g2f2"
3090 SX=71:SY=90:SZ=4:DRAW "s=sz;": DRAW "c1;"
3100 DRAW "bm=sx;,-sy;"+SK$
3110 '
3120 SX=77:SY=90:SZ=4:DRAW "s=sz;": DRAW "c1;"
3130 DRAW "bm=sx;,-sy;"+SS$
3140 SOS$="u2e1r1f1d2g111h1"
3150 SX=0:SY=84:SZ=4:DRAW "s=sz;": DRAW "c1;"
3160 DRAW "bm=sx;,-sy;"+SOS$
3170 '
3180 '
3190 PUT (10,92),A1
3200 DIM WINDO(2900)
3210 COLOR 8,1
3220 GET(0,0)-(117,97),WINDO
3230 PUT(0,96),WINDO :DRAW "c1;"
3240 PUT(123,0),WINDO
3250 PUT(123,96),WINDO
3260 '
3270 SB$="R3E1H1L1R1E1H1L3R1D3" :SX = 45: SY = 96
3280 DRAW "c2;": DRAW "bm=sx;,-sy;"+SB$
3290 PUT (33,91),B1
3300 '
3310 SC$="bm+1,0r1e1g111h1u2e1r1f1": SX =171: SY = 96
3320 DRAW "c1;": DRAW "bm=sx;,-sy;"+SC$
3330 PUT (157,91),C1

```

```

3340 '
3350 SD$="r3e1u2h113r1d3" :SX = 46: SY = 192
3360 DRAW "c3;": DRAW "bm=sx;,-sy;" +SD$
3370 PUT (33,187),D1
3380 '
3390 SE$="r313u2r111u2r3": SX =173: SY = 192
3400 DRAW "c2;": DRAW "bm=sx;,-sy;" +SE$
3410 PUT (157,187),E1
3420 DEF SEG= &HB800:BSAVE "c:windoe",0,&H4000
3430 CLS ' Questions screen
3440 SCREEN 2
3450 LOCATE 1,1
3460 PRINT "Most volatile?"
3470 DIM QS1(100)
3480 GET(0,0)-(112,7),QS1
3490 '
3500 CLS
3510 LOCATE 1,1
3520 PRINT "Leading ?"
3530 DIM QS2(100)
3540 GET(0,0)-(72,7),QS2
3550 '
3560 CLS
3570 LOCATE 1,1
3580 PRINT "Greatest change"
3590 DIM QS3(100)
3600 GET(0,0)-(120,7),QS3
3610 '
3620 CLS
3630 LOCATE 1,1
3640 PRINT " in slope over "
3650 DIM QS4(100)
3660 GET(0,0)-(112,7),QS4
3670 CLS
3680 LOCATE 1,1
3690 PRINT " next 4 weeks? "
3700 DIM QS5(100)
3710 GET(0,0)-(120,7),QS5
3720 CLS
3730 'Load frame
3740 SCREEN 0: SCREEN 1:COLOR 8,1
3750 DEF SEG=&HB800
3760 BLOAD "c:frame",0
3770 '
3780 '
3790 VIEW SCREEN (242,0)-(319,175),,0 ' answee boxes subroutine ////////////
/
3800 'PAINT (203,111),2
3810 PUT (247,0),QS1
3820 PUT (247,56),QS2
3830 PUT (247,112),QS3
3840 PUT (247,120),QS4
3850 PUT (247,128),QS5
3860 ' LOCATE 3,32:PRINT"A" '(256,24)
3870 ' LOCATE 10,32:PRINT"A" '(256,80)
3880 ' LOCATE 19,32:PRINT"A" '(256,152)
3890 PUT (245,16),A1
3900 ' LOCATE 3,35:PRINT"B"
3910 ' LOCATE 10,35:PRINT"B"
3920 ' LOCATE 19,35:PRINT"B"
3930 PUT (269,16),B1
3940 ' LOCATE 3,38:PRINT"C" '(304,24)
3950 ' LOCATE 10,38:PRINT"C" '(304,24)
3960 ' LOCATE 19,38:PRINT"C" '(304,24)
3970 PUT (293,16),C1
3980 ' LOCATE 5,33:PRINT"D"
3990 ' LOCATE 12,33:PRINT"D"

```

```

4000 ' LOCATE 21,33:PRINT"D"
4010 PUT (251,32),D1
4020 ' LOCATE 5,36:PRINT"E"
4030 ' LOCATE 12,36:PRINT"E"
4040 ' LOCATE 21,36:PRINT"E"
4050 PUT (275,32),E1
4060 ' LOCATE 5,39:PRINT"F"
4070 ' LOCATE 12,39:PRINT"F"
4080 ' LOCATE 21,39:PRINT"F"
4090 PUT (301,32),F1
4100 ' Enclosures
4110 LINE(242,15)-(259,23),3,B
4120 LINE(243,16)-(258,22),3,B 'inside
4130 LINE(242,14)-(260,24),3,B 'outside
4140 LINE(261,14)-(261,24),3
4150 LINE(251,16)-(254,16),0
4160 '
4170 LINE(266,15)-(283,23),2,B
4180 ' LINE(267,16)-(282,22),2,B
4190 LINE(265,14)-(284,24),2,B
4200 LINE(281,14)-(281,24),2
4201 LINE(285,14)-(285,24),2
4202 LINE(282,14)-(282,24),2
4210 LINE(267,16)-(273,16),2:LINE(267,17)-(273,17),2
4220 PSET(279,16),2:PSET(280,16),2
4230 LINE(274,23)-(278,23),0
4240 'PRESET (274,22):PRESET(274,16)
4260 LINE(290,15)-(307,23),1,B
4270 LINE(291,16)-(308,22),1,B
4280 LINE(289,14)-(309,24),1,B
4290 LINE(310,14)-(310,24),1
4300 LINE(298,16)-(304,16),0
4310 LINE(298,22)-(304,22),0
4320 LINE(308,14)-(308,24),1
4330 '
4340 LINE(248,31)-(265,39),3,B,&HAAAA
4350 LINE(249,32)-(264,38),3,B,&HAAAA
4360 LINE(247,30)-(266,40),3,B,&HAAAA
4370 LINE(267,30)-(266,40),3,B,&HAAAA
4380 LINE(258,32)-(260,32),0
4390 LINE(258,38)-(260,38),0
4400 '
4410 LINE(272,31)-(291,39),2,B,&HAAAA
4420 LINE(273,32)-(290,38),2,B,&HAAAA
4430 LINE(271,30)-(292,40),2,B,&HAAAA
4440 LINE(293,30)-(292,38),2,B,&HAAAA
4450 LINE(281,38)-(284,38),0
4460 '
4470 LINE(298,31)-(315,39),1,B,&HAAAA
4480 LINE(299,32)-(316,38),1,B,&HAAAA
4490 LINE(297,30)-(318,40),1,B,&HAAAA
4500 LINE(318,31)-(317,39),1,B,&HAAAA
4501 LINE(309,32)-(312,32),0
4502 LINE(309,38)-(312,38),0
4510 ' Copy reply enclosures
4520 DIM REPLY(280): GET (242,14)-(318,40),REPLY
4530 PUT (242,70),REPLY
4540 PUT (242,142),REPLY
4550 VIEW SCREEN (248,176)-(318,191),1,1
4560 DEF SEG: POKE &H4E,1
4570 LOCATE 23,32:PRINT "NEXT";
4580 LOCATE 24,35:PRINT "GRAPH";
4590 VIEW SCREEN(242,0)-(319,199)
4600 DIM QUESTION (4200):GET(242,0)-(319,191),QUESTION
4610 DEF SEG=&HB800:BSAVE "a:frame",0,&H4000
4620 DEF SEG=&HB800:BSAVE "c:frame",0,&H4000
4630 SCREEN 1:CLS

```



```

4640 DEF SEG=&HB800 :BLOAD "c:bwframe",0
4650 CY=3:MG=3:WH=3 'change to b&w
4660 GOSUB 4850
4670 DEF SEG=&HB800:BSAVE "a:bwframe",0,&H4000
4680 DEF SEG=&HB800:BSAVE "c:bwframe",0,&H4000
4690 'C$=INKEY$:IF C$="" THEN 4388
4700 CLS:COLOR 8,1
4710 DEF SEG=&HB800 :BLOAD "c:windoe",0
4720 PUT(242,0),QUESTION
4730 DEF SEG=&HB800:BSAVE "c:windoe",0,&H4000
4740 DEF SEG=&HB800:BSAVE "a:windoe",0,&H4000
4750 WIDTH 80
4760 END
4770 LINE(242,14)-(260,24),3,B 'outside
4780 LINE(261,14)-(261,24),3
4790 LINE(251,16)-(254,16),0
4800 '
4810 LINE(266,15)-(283,23),2,B
4820 LINE(267,16)-(282,22),2,B
4830 LINE(265,14)-(284,24),2,B
4840 LINE(285,14)-(285,24),2
4850 VIEW SCREEN (242,0)-(319,175),,0 ' answer boxes subroutine //////////////////////////////////

4860 PUT (247,0),QS1
4870 PUT (247,56),QS2
4880 PUT (247,112),QS3
4890 PUT (247,120),QS4
4900 PUT (247,128),QS5
4910 PUT (244,16),A10
4920 PUT (268,16),B10
4930 PUT (292,16),C10
4940 PUT (250,32),D10
4950 PUT (274,32),E10
4960 PUT (300,32),F10
4970 ' Enclosures
4980 LINE(242,15)-(259,23),3,B
4990 LINE(243,16)-(258,22),3,B 'inside
5000 LINE(242,14)-(260,24),3,B 'outside
5010 LINE(261,14)-(261,24),3
5020 LINE(251,16)-(254,16),0
5030 '
5040 LINE(266,15)-(283,23),3,B
5050 ' LINE(267,16)-(282,22),3,B
5060 LINE(265,14)-(284,24),3,B
5070 LINE(281,14)-(281,24),3
5080 LINE(285,14)-(285,24),3
5090 LINE(282,14)-(282,24),3
5100 LINE(267,16)-(272,16),3:LINE(267,17)-(272,17),3
5110 PSET(279,16),3:PSET(280,16),3
5120 LINE(274,23)-(278,23),0
5130 'PRESET (274,22):PRESET(274,16)
5131 LINE(308,38)-(312,38),0
5140 '
5150 LINE(290,15)-(307,23),3,B
5160 LINE(291,16)-(308,22),3,B
5170 LINE(289,14)-(309,24),3,B
5180 LINE(310,14)-(310,24),3
5190 LINE(298,16)-(304,16),0
5200 LINE(298,22)-(304,22),0
5210 LINE(308,14)-(308,24),3
5220 '
5230 LINE(248,31)-(265,39),3,B,&HAAAA
5240 LINE(249,32)-(264,38),3,B,&HAAAA
5250 LINE(247,30)-(266,40),3,B,&HAAAA
5260 LINE(267,30)-(266,40),3,B,&HAAAA
5270 LINE(258,32)-(260,32),0
5280 LINE(258,38)-(260,38),0

```

```
5290 '  
5300 LINE(272,31)-(291,39),3,B,&HAAAA  
5310 LINE(273,32)-(290,38),3,B,&HAAAA  
5320 LINE(271,30)-(292,40),3,B,&HAAAA  
5330 LINE(293,30)-(292,38),3,B,&HAAAA  
5340 LINE(280,38)-(283,38),0  
5350 '  
5360 LINE(298,31)-(315,39),3,B,&HAAAA  
5370 LINE(299,32)-(316,38),3,B,&HAAAA  
5380 LINE(297,30)-(318,40),3,B,&HAAAA  
5390 LINE(318,31)-(317,39),3,B,&HAAAA  
5391 LINE(308,32)-(311,32),0  
5392 LINE(308,38)-(311,38),0  
5400 ' Copy reply enclosues  
5410 DIM RPLY(280): GET (242,14)-(318,40),RPLY  
5420 PUT (242,70),RPLY  
5430 PUT (242,142),RPLY  
5440 VIEW SCREEN (248,176)-(318,191),3,3  
5450 DEF SEG: POKE &H4E,3  
5460 LOCATE 23,32:PRINT "NEXT";  
5470 LOCATE 24,35:PRINT "GRAPH";  
5480 VIEW SCREEN(242,0)-(319,199)  
5490 DIM QUESTION (4200):GET(242,0)-(319,191),QUESTION  
5500 RETURN '////////// B&W questions //////////
```

APPENDIX E  
SIMULATION SCREEN SEQUENCE  
(Enhancement simulation example)

**Enhanced Computer Graphics  
for  
Decision Making**

TA: This is Phase 2 of a three phase experiment on computer graphics. Enhanced refers to changing the visual context within the graphic. You are going to test the enhancements.

**This experiment will determine  
if changing the visual context  
in graphic displays affects our  
ability to detect differences  
between trends.**

TA: The reason for the determination is to test different enhancements to the graphics to see if they aid in finding problems. This test is similar to actual problems that a decision maker encounters when looking at trends. For example, looking for the (1) leading economic indicator, (2) demographic change, or (3) change in the market place.

VISUAL CONTEXT refers to:

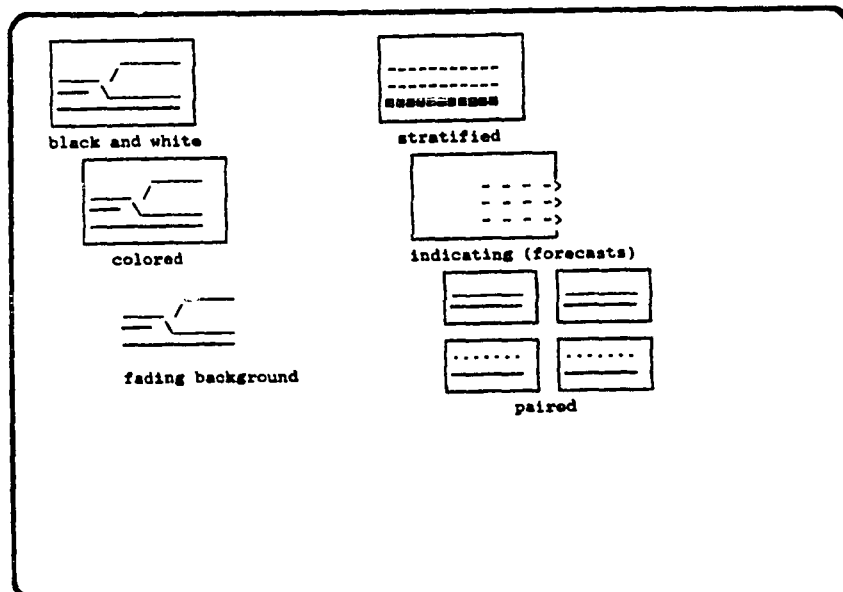
- the colors
- the amount of text/symbols,
- number of trends shown together,
- separation of the trends, and
- forecasts of the trends.

TA: We're talking about: black and white versus color; taking out the extraneous lines and numbers; pairs of trends in windows; making sure the trends do not cross; and last, showing an exponential smoothing forecast.

Differences between/among trends  
are clues to potential problems  
of interest to a decision maker.

You will test 8 types of graphics.  
The following are sketches of the six.

TA: These are all time-series graphs with the different formats,  
one in black and white and five in color.



TA: These are sketches of the six types of graphics you will see. These are the names of the graphics. At the end of the test, we will ask you which graphic you prefer and have confidence in.

Evaluation is based on the accuracy and the time taken in answering questions about the graphics.

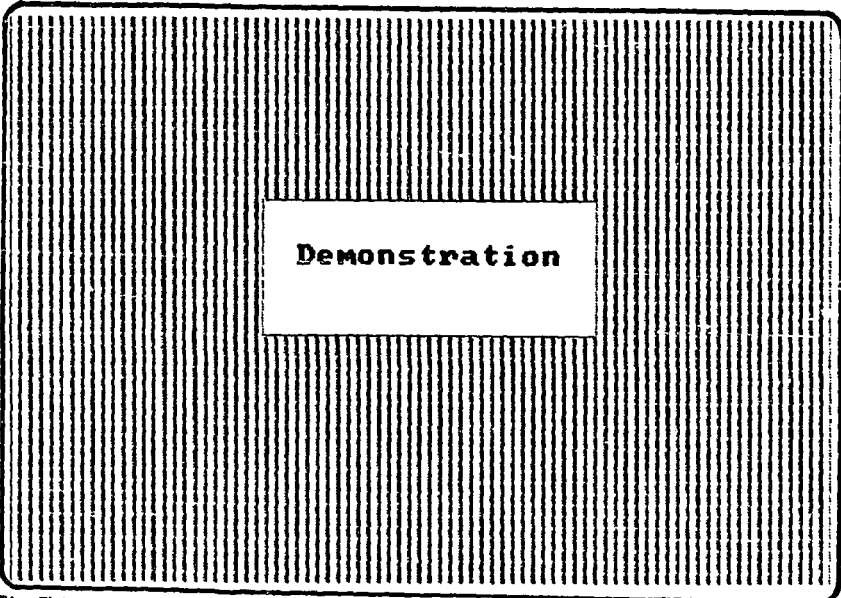
TA: The graphics are being evaluated, not you as a decision maker. All the data collected are relative in that if one decision maker takes twice as long to answer the questions as another decision maker, the results are the same. In other words, we are looking for ratios of difference in the graphics. A trend is a 26-period line or pattern. All the trends are shaped as mountains or valleys.

While viewing a graphic with several trends, three questions will be asked about the graphic.

Which trend:

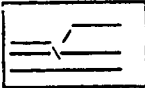
- 1) is the most volatile/erratic ?
- 2) turns first (is leading)?
- 3) will likely have the greatest rate of change, the steepest slope, in the next 4 periods (weeks)?

TA: Volatile/erratic also is called variability. It is the pattern having the most noise, jumping up and down about the trend. From left to right, leading refers to which trend is changing direction first--from sloping up to sloping down or from down to up. It is the first mountain or valley of the entire trend. All the trends are curves. One is changing faster than the rest.

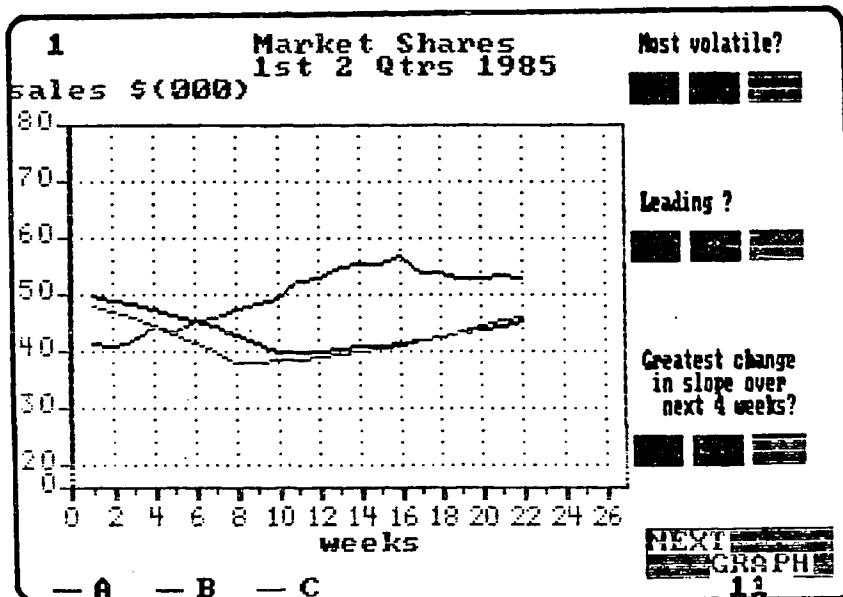


### Demonstration

TA: This demonstration is of a colored graphic with three trends. We answer the questions with the light pen.

SCENARIO:	OBJECTIVE:
<p>The next graphic is the colored graphic with 3 trends</p>  <p>Generating period 5</p>	<p>The problem is to discover:</p> <ol style="list-style-type: none"> <li>1. The most volatile/variable sales trend</li> <li>2. The leading trend -- the trend showing the first turn in direction</li> <li>3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.</li> </ol>

TA: Before each graphic you will see a screen similar to this. It tells the name and the number of trends for the graphic which will be displayed. It also reviews the three questions to be answered.



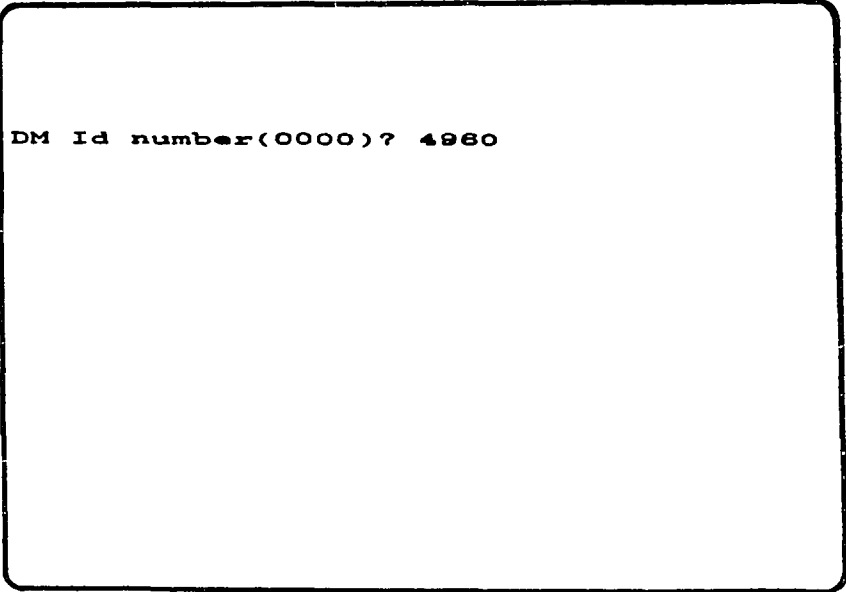
TA: Here is a colored graphic--typical of Lotus 1-2-3 graphics. Note that the lines are solid of different color. In this one B is more variable, C is leading, and A is going to change more in the next 4 periods. To answer push the pen on the chosen answer box, then release it. Within a second a tone will sound and a line will underline the chosen box. You can change your answers. After answer 3, point to the next graphic box. The screen will not change until all three questions are answered. Notice that the seconds since the graphic was completed appear under the next graphic box. This is a test of accuracy and time.





Warm up

TA: You will practice with the next six graphics. The reason is to get you acquainted with the light pen and the graphics before actually testing the graphics. In other words, it is to get you down the learning curve. Do you wish to continue?



DM Id number(0000)? 4960

TA: May I have a 4-digit ID number?

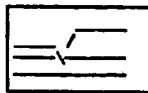
In comparing sets of data,  
which do you prefer to use?

Graphs always  
 Graphs most often  
 Graphs and Tables equally  
 Tables most often  
 Tables always.

TA: What is your preference for graphics and tables?

**SCENARIO:**

The next graphic is the  
 colored  
 graphic with  
 3 trends



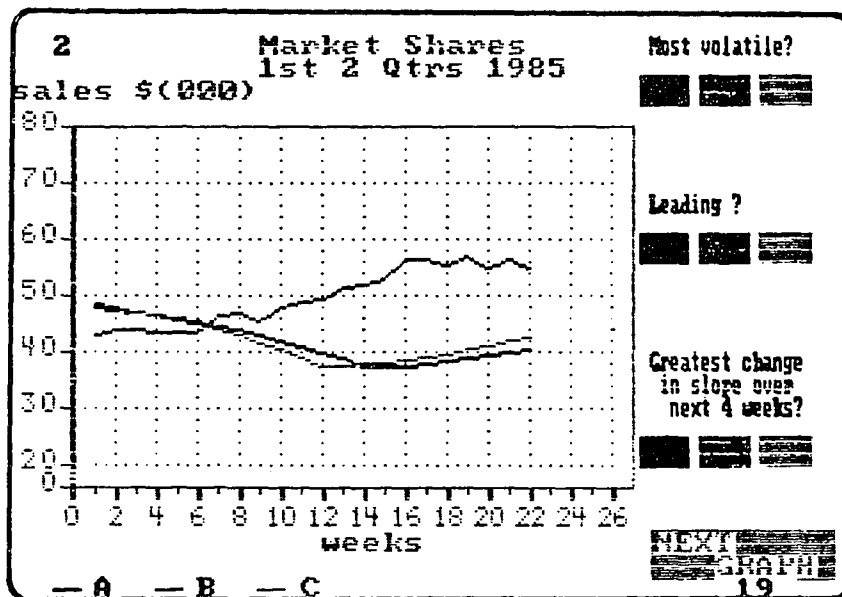
Generating period 7

**OBJECTIVE:**

The problem is to discover:

1. The most volatile/variable sales trend
2. The leading trend -- the trend showing the first turn in direction
3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.

TA: Here is that intervening screen again. Note that what the computer is doing is shown in the bottom left-hand corner. The numbers have no relation to the values on the graph.



TA: Leading refers to the overall shape of the trend. Can you see the space for a 4-week forecast?

**SCENARIO:**

The next graphic is the  
black and white  
graphic with  
5 trends

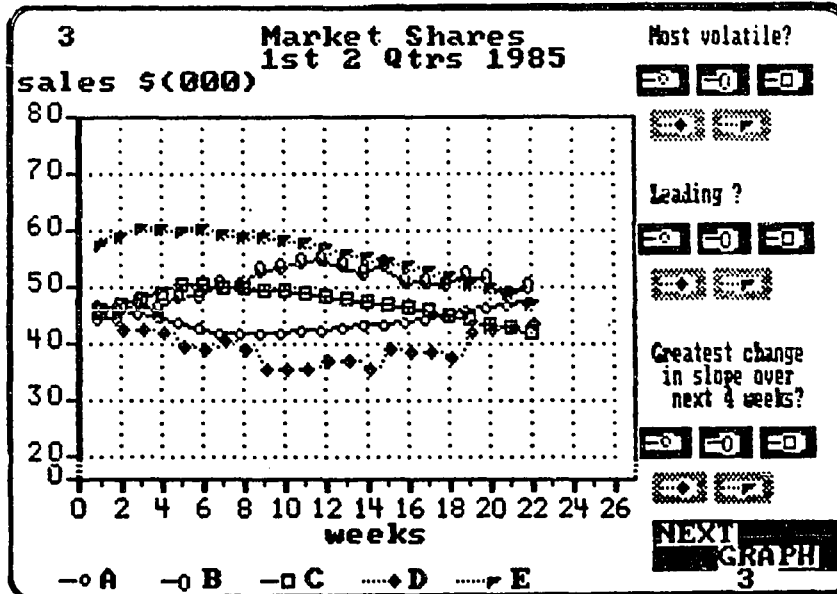
Generating period 1

**OBJECTIVE:**

The problem is to discover:

1. The most volatile/variable sales trend
2. The leading trend -- the trend showing the first turn in direction
3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.

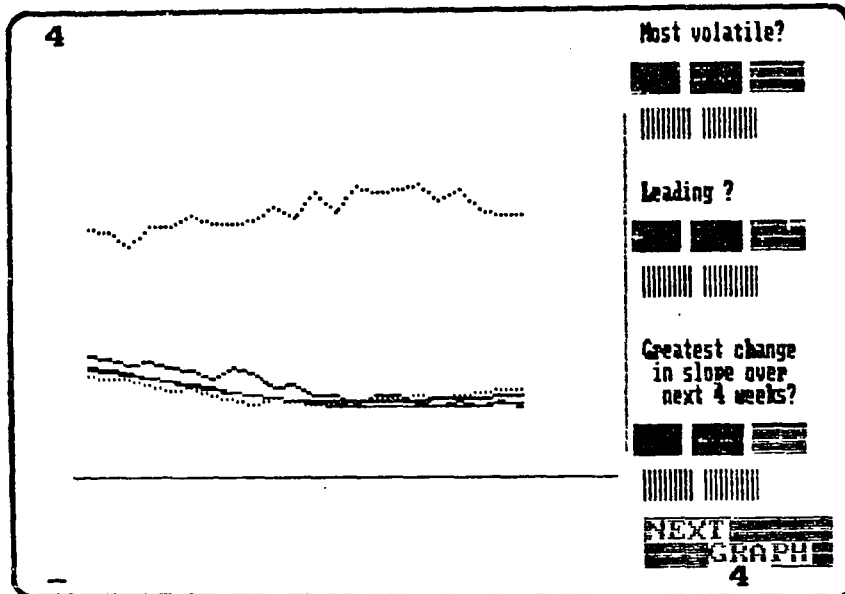
TA: Do the graphics as quickly as you feel comfortable. You can check your time as you go. An example of average time for each graphic is about 30 seconds. The test will conclude if your total accumulated time is over 900 seconds, or 15 minutes.



TA: Note the five symbols used for the black and white. The hollow symbols have solid lines, and the solid symbols have dotted lines. The answer boxes are solid or dotted also. Please note the difference in symbols. The symbol X was not used because it was always picked as the most volatile in the pretest. The plus sign symbol was not used because it blends into the grid. Here are the correct answers.

SCENARIO:	OBJECTIVE:
<p>The next graphic is the fading background graphic with 5 trends</p> <p>Generating period 10</p>	<p>The problem is to discover:</p> <ol style="list-style-type: none"> <li>1. The most volatile/variable sales trend</li> <li>2. The leading trend -- the trend showing the first turn in direction</li> <li>3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.</li> </ol>

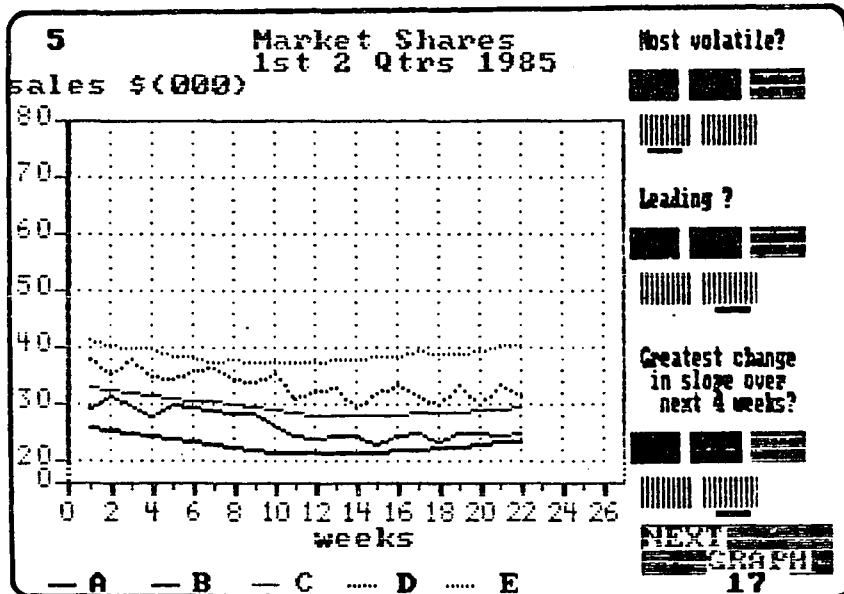
TA: This same screen appears between each graphic. The reason for the intervening display is to (1) help you forget the last graphic, (2) remind you of the questions, and (3) allow time to generate the random data for the next graphic.



TA: The axis is on the right side. Can you see the difference in the solid and dotted lines?

SCENARIO:	OBJECTIVE:
<p>The next graphic is the stratified graphic with 5 trends</p>	<p>The problem is to discover:</p> <ol style="list-style-type: none"> <li>1. The most volatile/variable sales trend</li> <li>2. The leading trend -- the trend showing the first turn in direction</li> <li>3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.</li> </ol>
<p>Generating period 4</p>	

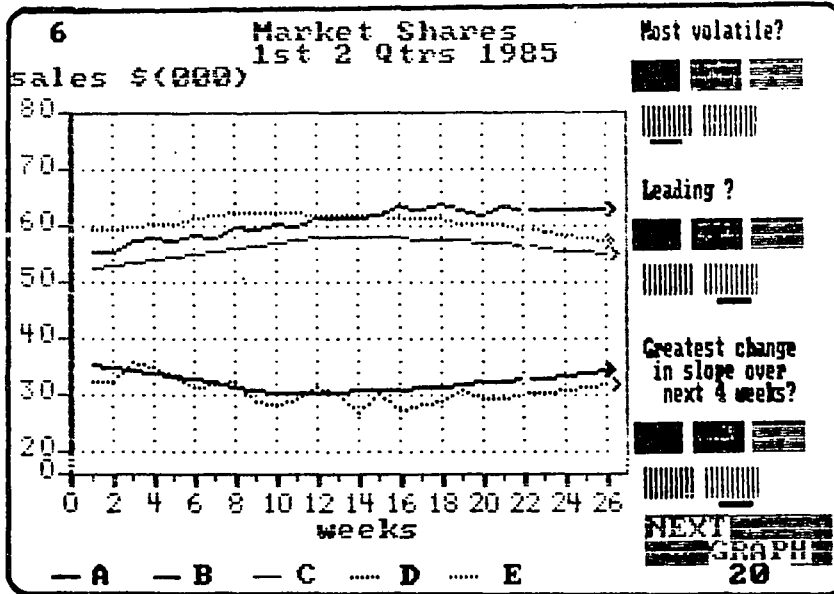
TA: Note the 4 weeks for projection of the future. The trends from graphic to graphic are unrelated because they are made from a randomly generated trend. The trends within a graphic, however are all a function of that randomly generated trend.



TA: Note that the trends never touch. Occasionally, the trends go off the chart but do not interfere with making an estimate.

<p><b>SCENARIO:</b></p> <p>The next graphic is the indicating (forecasts) graphic with 5 trends</p> <p>Generating period 2</p>	<p><b>OBJECTIVE:</b></p> <p>The problem is to discover:</p> <ol style="list-style-type: none"> <li>1. The most volatile/variable sales trend</li> <li>2. The leading trend -- the trend showing the first turn in direction</li> <li>3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.</li> </ol>
--------------------------------------------------------------------------------------------------------------------------------	---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------

TA: This includes an exponential forecast, which takes a few seconds to calculate.



TA: The break shows the start of the forecast. Note that the forecast has no noise.

**SCENARIO:**

The next graphic is the paired graphic with 5 trends

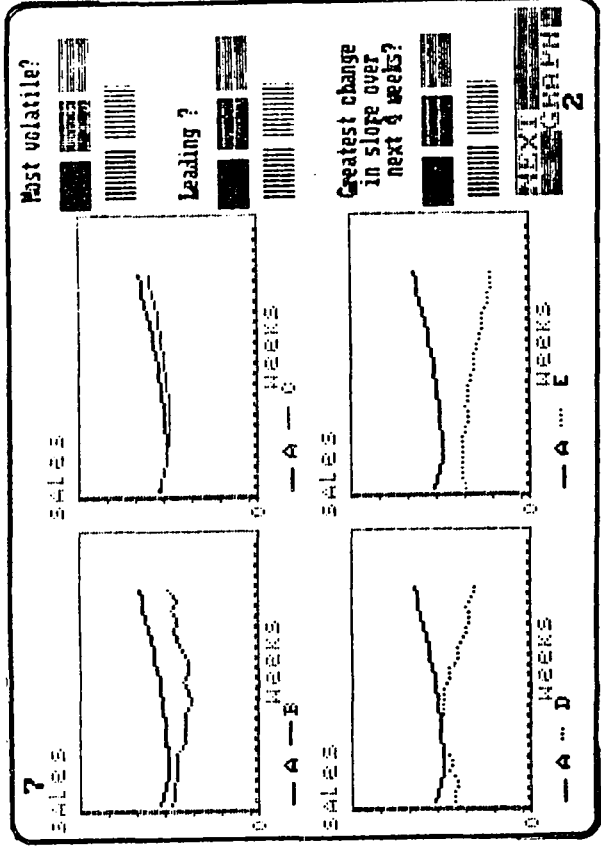
Generating period 1

**OBJECTIVE:**

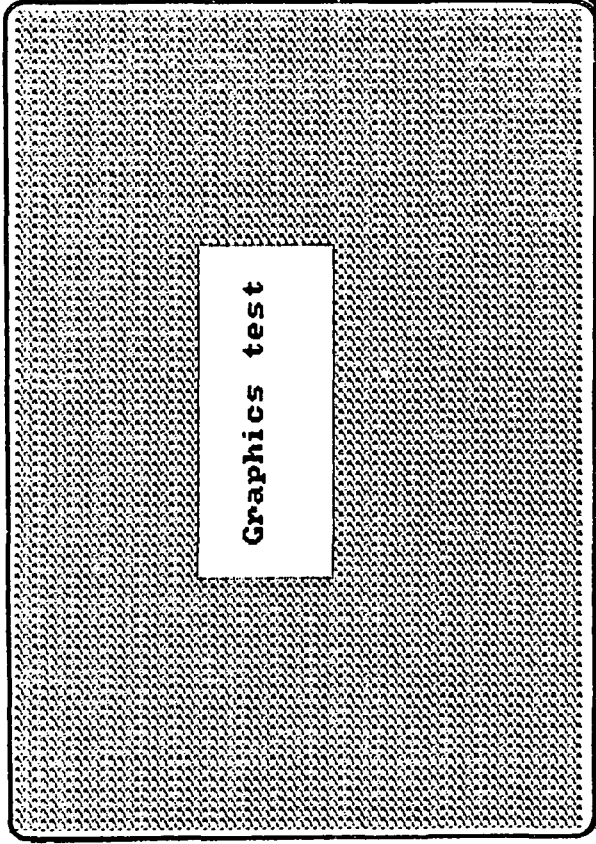
The problem is to discover:

1. The most volatile/variable sales trend
2. The leading trend -- the trend showing the first turn in direction
3. The trend that is likely to change the most over the next 4 weeks -- the steepest slope.

TA: This is the window--a new concept that is coming. The graphs are half the size of the other graphics.

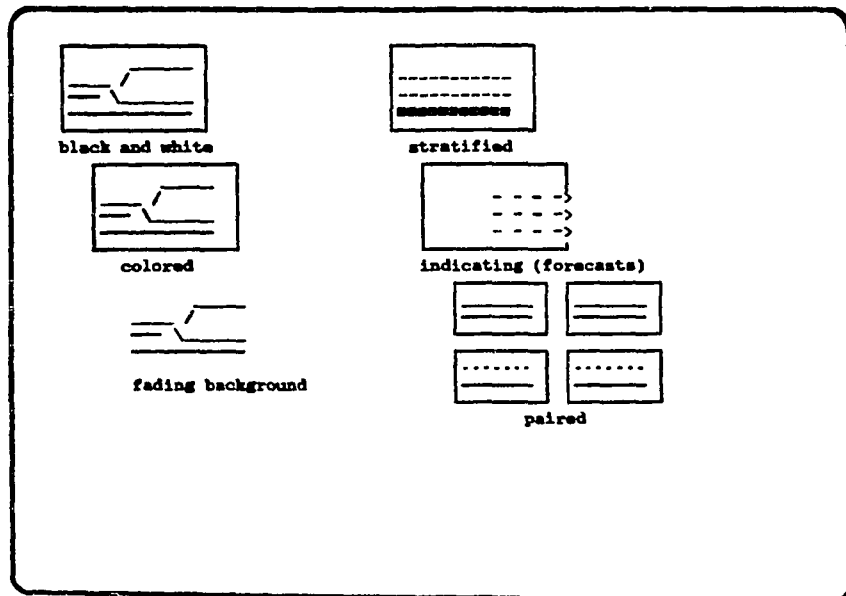
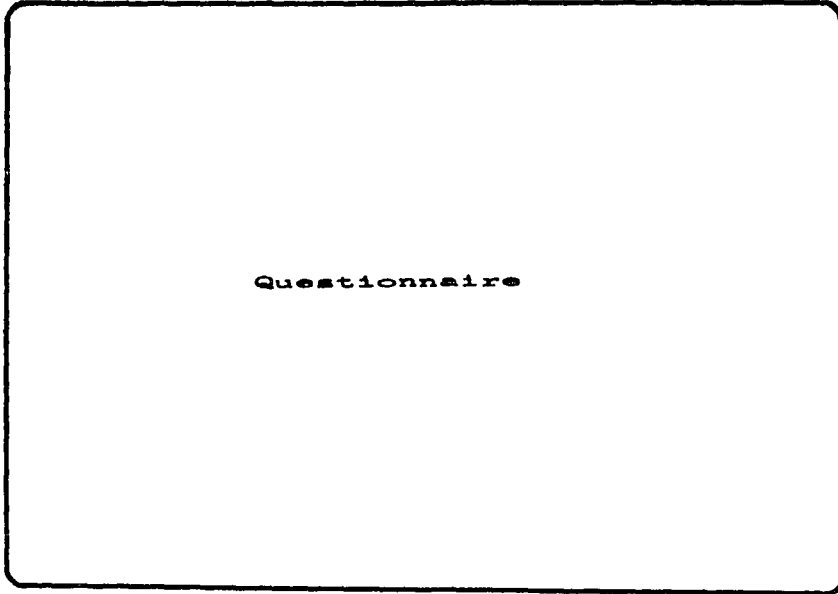


TA: The "A" trend is shown in each window.



TA: Do you have any questions? I am not going to say a word for the next 12 graphics. After the test, if you like, I will show you how the graphics are graded. Are you ready to start? Remember, it is accuracy and time that are measured.





black and white

stratified

colored

indicating (forecasts)

fading background

paired

Which graphic did you like most? a  
 like least? b  
 like next most? p  
 like next least?

black and white

stratified

colored

indicating (forecasts)

fading background

paired

In answering the questions,  
 with which graphic were you most confident? f  
 least confident? b  
 next most confident? a  
 next least confident?

black and white

colored

fading background

stratified

indicating (forecasts)

paired

What combination would you make?

Using the following categories:

- Professional and technical
- Managerial and administrative
- Sales
- Clinical
- Services
- Entrepreneurial
- Crafts
- Design and artistic

What type of work do you do?

In your work, how many graphs do you see a day?

0 to 1

2 to 4

5 to 8

9 to 16 - All the graphs in The Wall Street Journal

More than 16

Thank You

?

APPENDIX F  
PILOT TESTS AND STATISTICAL SUMMARIES

TABLE XI  
SUMMARY OF WILCOXON SIGNED RANK TESTS  
FOR PILOT EXPERIMENT

Test	Matched Pairs Graphic(s) (1)	Graphic(s) (2)	Fraction of Trials Better (2)	Total of Ranked Differences in Efficiency* (2)
1	2-Line	4-Line	7/27	71
2	4-Line	6-Line	6/27	58

---

\* Column critical value for alpha = .01, 2-sided,  
n=27, total <= 84  
Column critical value for alpha = .05, 2-sided,  
n=27, total <= 105 (Mendenhall, 1979: 547).

TABLE XII  
SUMMARY STATISTICS OF PILOT EXPERIMENT  
(MEDIANS)

	Type of Graphic			All
	2-Line	4-Line	6-Line	
Number of graphics	81	81	81	243
Relative efficiency (indv effcy/indv median effcy) Normalized to 100% of 2-line	100	81	51	
Median	1.24	1.00	0.76	
Quartile deviation	0.42	0.31	0.21	
Range	0.34-5.48	0.31-3.45	0.18-2.75	
Coefficient of quartile deviation	0.34	0.24	0.28	
Efficiency (correct/minute)				
Median*	6.95	5.81	4.13	4.37
Range	1.24-31.44	0.92-13.74	0.68-16.68	0.68-31.44
High median for DMs	16.39	11.23	12.31	16.23
Low median for DMs	1.81	2.04	1.68	1.68
Response times (sec)				
Median	16.09	28.48	33.09	26.66
Range	6.92-48.44	11.48-65.20	13.63-88.59	6.92-88.59
Correct selection response				
Median	2	3	3	3
Range	1 - 4	1 - 4	1 - 4	1 - 4

\* Tests on median scores of 27 subjects' on the 3 types of graphics:  
Friedman Multi-Sample Test for identical treatment effects,  
T = 11.61, alpha = 3.22  
Wilcoxon Signed Rank Test for 2-line vs 4-line vs 6-line,  
alpha = 0.005

TABLE XIII  
SUMMARY STATISTICS OF PILOT EXPERIMENT (MEANS)

	Type of Graphic			All
	2-Line	4-Line	6-Line	
Number of graphics	81	81	81	243
Relative efficiency (Efficiency/median effcy) Normalized to 100% Of 2-line	100	74	59	
Mean	1.29	0.96	0.76	
Standard Deviation	0.69	0.42	0.43	
Range	0.34-5.48	0.31-3.45	0.18-2.75	
Coefficient of variation	0.53	0.43	0.55	
Efficiency (correct/minute)				
Mean	8.60	6.27	5.13	6.35
Standard Deviation	6.01	3.39	3.35	4.46
Coefficient of variation	0.70	0.54	0.65	0.67
Response Times				
Mean*	19.33	32.28	37.53	29.32
Standard Deviation	9.05	13.01	15.88	15.07
Coefficient of variation	0.47	0.40	0.42	0.51
Correct Selection Response				
Mean*	2.22	2.79	2.59	2.55
Standard Deviation	0.90	0.83	1.02	0.94
Coefficient of variation	0.41	0.30	0.39	0.37
Percentage of Answers Correct				
Volatile	47%	72%	54%	58%
Leading	36%	59%	56%	50%
Slope	40%	48%	44%	44%

\* Correlation Avg Response Time vs Avg Correct,  
n = 27, Pearson's Coefficient of Correlation = -0.02.



APPENDIX G  
PILOT EXPERIMENTAL DATA



**APPENDIX H**  
**ENHANCEMENT TESTS AND STATISTICAL SUMMARIES**

TABLE XIV  
SUMMARY OF WILCOXON SIGNED RANK TESTS  
FOR ENHANCEMENT EXPERIMENT

Test	Matched Pairs Graphic(s) (1)	Graphic(s) (2)	Fraction of Trials Better (2)	Total of Ranked Differences in Efficiency* (2)
1	Black and white	Standard	26/47	598
2	Fading	Standard	20/47	470 <sup>1</sup>
3	Stratified	Standard	18/47	385 <sup>2</sup>
4	Paired	Standard	29/47	630
5	Forecast	Standard	18/47	362 <sup>3</sup>

- 
- \* Column critical value for alpha = .05, 1-sided,  
n=47, total <= 408  
Column critical value for alpha = .025, 1-sided,  
n=47, total <= 379  
Column critical value for alpha = .10, 2-sided,  
n=47, total <= 408  
Column critical value for alpha = .05, 2-sided,  
n=47, total <= 379 (Mendenhall, 1979: 547).
- <sup>1</sup> P = 0.161 (One-sided probability (P) based on  
Z Test Statistics)
- <sup>2</sup> P = 0.029
- <sup>3</sup> P = 0.016

TABLE XV  
SUMMARY STATISTICS OF ENHANCEMENT EXPERIMENT  
(MEDIANS)

	Type of Graphic						All
	Color	Black & White	Fading	Stratified	Paired	Forecast	
Number of graphics	94	94	93	94	94	93	582
Relative efficiency (graph median/indv median) normalized to 100% of Color	100%	97%	108%	103%	93%	113%	
Median	1.00	0.97	1.08	1.03	0.92	1.13	
Quartile deviation	0.24	0.22	0.23	0.23	0.16	0.28	
Range	0.47-	0.49-	0.53-	0.35-	0.37-	0.47-	
	1.63	1.19	2.34	2.02	1.57	1.94	
Coefficient of quartile deviation	0.23	0.23	0.21	0.22	0.18	0.25	
Efficiency (correct selection/minute)							
Median*	5.23	4.91	5.55	5.40	4.84	6.24	5.32
Range	0.80-	1.02-	1.04-	1.40-	1.11-	1.27-	0.80-
	15.0	14.4	17.4	16.1	16.1	14.9	17.4
1st to 3rd quartiles	3.61-	3.35-	3.84-	3.98-	3.23-	3.87-	
	6.92	7.24	7.64	7.61	6.92	8.52	
High median for DMs	10.37	11.62	13.79	15.93	14.37	12.99	15.93
Low median for DMs	1.95	2.07	1.87	2.27	1.70	2.45	1.70
Response times (sec)							
Median	31.1	32.0	31.1	30.9	33.8	28.5	31.1
Range	13.2-	12.4-	12.6-	11.1-	13.5-	13.7-	11.1-
	80.9	84.3	89.4	89.4	101	64.4	101
Correct selection response							
Median	3	3	3	3	3	3	3
Range	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4	1 - 4
Preference & confidence by percentage							
Liked most*	19.1%	0.0%	29.7%	36.1%	6.4%	8.5%	
Liked least*	0.0%	80.8%	21.2%	6.4%	10.6%	0.0%	
Most confident*	23.4%	4.3%	27.6%	23.4%	14.8%	6.4%	
Least confident*	0.0%	74.4%	21.2%	4.3%	17.0%	21.2%	

\* Tests on median scores of 47 subjects on the 6 types of graphics:  
Wilcoxon's Signed-Rank Test for colored vs stratified,  $P = .029$   
Wilcoxon's Signed-Rank Test for colored vs forecast,  $P = .016$   
Friedman Multi-Sample Test for identical treatment effects,  
 $T = 2.72$ , critical value = 2.29 at  $\alpha = 0.05$

\* Cochran Q Test,  $P = .01$

TABLE XVI  
SUMMARY STATISTICS OF ENHANCEMENT EXPERIMENT (MEANS)

	Type of Graphic						All
	Color	Black & White	Fading	Strati- fied	Paired	Fore- cast	
Number of graphics	94	94	93	94	94	93	582
Relative efficiency (graph median/indv median) normalized to 100% of Color	100%	99%	110%	112%	93%	113%	
Mean	0.94	0.93	1.03	1.05	0.91	1.12	
Standard deviation	0.36	0.41	0.44	0.41	0.38	0.46	
Range	0.44- 1.43	0.50- 1.64	0.53- 1.93	0.33- 1.89	0.39- 1.53	0.51- 1.88	
Coefficient of variation	0.38	0.44	0.43	0.39	0.40	0.41	
Efficiency (correct selection/minute)							
Mean	5.54	5.56	6.13	6.22	5.37	6.60	5.90
Standard deviation	2.75	2.99	3.20	3.16	2.87	3.30	3.08
Coefficient of variation	0.49	0.53	0.52	0.50	0.53	0.50	0.52
Response times (sec)							
Mean	34.40	35.00	33.30	32.70	36.50	32.00	34.00
Standard Deviation	13.10	14.50	14.20	11.60	15.00	11.80	13.50
Coefficient of variation	0.38	0.41	0.42	0.35	0.41	0.36	0.39
Correct selection response							
Mean	2.77	2.73	2.88	2.96	2.81	3.05	2.87
Standard deviation	0.90	0.89	0.86	0.86	0.89	0.83	0.87
Coefficient of variation	0.32	0.31	0.30	0.29	0.31	0.27	0.30
Percentage of answers correct							
Volatile	53%	56%	66%	59%	59%	61%	59%
Leading	59%	55%	63%	68%	65%	76%	64%
Slope	64%	61%	56%	69%	56%	67%	62%
All	59%	57%	62%	65%	60%	68%	62%

TABLE XVII  
 ENHANCEMENT EXPERIMENT QUESTIONNAIRE  
 PREFERENCES

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. In analyzing data for difference	Graphics always	19.2%
	Graphics more	55.3
	Graphics & Tables	17.0
	Tables more	8.5
	Tables always	0.0
2. Graphic liked most (Cochran Q = 93 critical value of chi-square = 11)	Standard	19.1
	Black & White	0.0
	Faded	29.8
	Stratified	36.1
	Paired	6.4
	Forecast	8.5
3. Graphic liked least (Cochran Q = 234)	Standard	0.0
	Black & White	80.8
	Faded	2.2
	Stratified	6.4
	Paired	10.6
	Forecast	0.0
4. Graphic most confident (Cochran Q = 74.2)	Standard	23.4
	Black & White	4.3
	Faded	27.6
	Stratified	23.4
	Paired	14.8
	Forecast	6.5
5. Graphic least confident (Cochran Q = 205)	Standard	0.0
	Black & White	74.4
	Faded	2.2
	Stratified	4.3
	Paired	17.0
	Forecast	2.1

TABLE XVIII  
 ENHANCEMENT EXPERIMENT  
 DEMOGRAPHICS AND GRAPHIC USAGE

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. Type of Work	Professional & technical	76.6%
	Managerial & administrative	19.1
	Sales	4.3
	Clinical	0.0
	Services	0.0
	Entrepreneurial	0.0
	Crafts	0.0
	Design & artistic	0.0
2. Graphs used daily	0 to 1	23.4
	2 to 4	29.8
	5 to 8	29.8
	9 to 16	14.9
	greater than 16	2.1
3. Wore glasses or contacts	glasses	21.3
	contacts	31.9
	none	46.8

TABLE XIX  
 ENHANCEMENT EXPERIMENT  
 OBSERVATIONS

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. Touch screen	Yes	10.6%
	No	89.4
2. Distance from screen	10+ inches	6.4
	15+	14.9
	20+	31.9
	25+	36.2
	30+	6.4
	35+	4.2
3. Gender	female	25.5
	male	74.5



**APPENDIX I**  
**ENHANCEMENT EXPERIMENTAL DATA**









**APPENDIX J**  
**COMPOSITE TESTS AND STATISTICAL SUMMARIES**

TABLE XX  
SUMMARY OF WILCOXON SIGNED RANK TESTS  
FOR COMPOSITE EXPERIMENT\*

Test	Matched Pairs Graphic(s) (1)	Graphic(s) (2)	Fraction of Trials Better (2)	Total of Ranked Differences in Efficiency** (2)
1	b	a	19/41	443
2	c	a	21/41	427
3	d	a	20/41	345
4	e	a	20/41	410
5	f	a	17/41	315
6	g	a	19/41	373
7	h	a	19/41	357
8	f	b	19/41	362
9	g	c	19/41	409
10	h	d	16/41	305
11	f	e	17/41	380
12	g	e	17/41	378
13	h	e	19/41	424
14	e+f+g+h (Painting)	a+b+c+d	21/41	415
15	a+c+e+g (Stratified)	b+d+f+h	20/41	419
16	a+b+e+f (Forecast)	c+d+g+h	19/41	429
17	a+c-e-g (Paint*Strat'd)	b+d-f-h	21/41	466
18	a+b-e-f (Paint*Forecast)	c+d-g-h	17/41	387
19	c+g-d-h (Strat'd*Forec't)	a+e-b-f	22/41	381
20	a+c-b-d (Strat'd*Forec't)	e+g-f-h	22/41	375
21	a+d-b-c (Paint*Strat'd*Forec't)	e+h-f-g	25/41	454

- \* a = Concurrent Standard      e = Sequential Standard  
 b = Concurrent Stratified      f = Sequential Stratified  
 c = Concurrent Forecast      g = Sequential Forecast  
 d = Concurrent Composite      h = Sequential Composite
- \*\* Column critical value for alpha = .05, 1-sided,  
 n=41, total <= 303  
 Column critical value for alpha = .05, 2-sided,  
 n=41, total <= 279

TABLE XXI  
SUMMARY STATISTICS OF COMPOSITE EXPERIMENT (MEDIANS)

	Type of Graphic				All
	Concurrent Graphics				
	Standard	Stratify'd	Forecast	Composite	
Number of graphics	41	41	41	41	328
Efficiency (correct selection/minute)					
Median*	4.83	5.50	5.97	4.69	5.49
Range	1.77-12.45	1.61-10.26	1.14-12.11	1.79-12.96	0.68-16.54
Coefficient of quartile deviation	0.44	0.36	0.23	0.38	0.40
Response times (sec)					
Median	29.00	33.70	32.90	33.50	
Range	15.6-84.0	14.1-101.0	18.4-105.0	13.8-85.5	10.8-105.0
Coefficient of quartile deviation	0.36	0.37	0.27	0.22	
Correct selection response					
Median	3	3	3	3	
Range	1 - 4	1 - 4	1 - 4	1 - 4	
	Sequential Graphics				All
	Standard	Stratify'd	Forecast	Composite	
Number of graphics	41	41	41	41	328
Efficiency (correct selection/minute)					
Median*	5.87	5.47	5.70	6.23	4.84
Range	1.56-16.54	0.68-14.92	2.00-13.16	1.46-13.20	0.68-16.54
Coefficient of quartile deviation	0.34	0.45	0.36	0.33	0.40
Response Times (sec)					
Median	35.00	32.30	31.00	33.80	
Range	10.8-103.0	13.8-88.4	15.1-70.4	15.3-72.2	10.8-105.0
Coefficient of quartile deviation	0.26	0.32	0.30	0.23	
Correct selection response					
Median	3	3	3	3	
Range	1 - 4	1 - 4	1 - 4	1 - 4	

\* Tests on median scores of 41 subjects on the 8 types of graphics:  
Wilcoxon Signed Rank Test for Cnc Standard vs Seq Forecast and Seq  
Standard vs Seq Composite indicated a difference at alpha = 0.10



TABLE XXII  
SUMMARY STATISTICS OF COMPOSITE EXPERIMENT (MEANS)

	Type of Graphic				
	Concurrent Graphics				All
	Standard	Stratif'd	Forecast	Composite	
Number of graphics	41	41	41	41	328
Efficiency (correct selection/minute)					
Mean	5.70	5.58	5.91	5.32	5.90
Standard deviation	3.05	2.49	2.71	2.82	2.99
Coefficient of variation	0.53	0.45	0.46	0.53	0.51
Response times (sec)					
Mean	36.50	37.30	36.10	36.60	38.00
Standard deviation	16.30	16.50	16.20	15.30	15.70
Coefficient of variation	0.45	0.44	0.45	0.42	0.44
Correct selection response					
Mean	2.95	3.04	3.02	2.83	3.05
Standard deviation	0.92	0.89	0.83	0.97	
Coefficient of variation	0.31	0.29	0.27	0.34	
Percentage of answers correct					
Volatile	71%	71%	66%	61%	71%
Leading	64%	66%	64%	57%	65%
Slope	59%	66%	71%	64%	69%
All	65%	68%	67%	61%	69%
	Sequential Graphics				
	Standard	Stratif'd	Forecast	Composite	All
Number of graphics	41	41	41	41	328
Efficiency (correct selection/minute)					
Mean	6.00	6.33	6.06	6.29	5.90
Standard deviation	3.37	3.62	3.17	3.20	2.99
Coefficient of variation	0.56	0.57	0.52	0.51	0.51
Response Times					
Mean	36.80	35.30	34.40	35.00	36.00
Standard deviation	16.20	17.30	13.70	13.50	15.70
Coefficient of variation	0.44	0.49	0.40	0.39	0.44
Correct selection response					
Mean	3.07	2.97	2.97	3.14	3.05
Standard deviation	0.88	0.88	0.88	0.86	
Coefficient of variation	0.29	0.30	0.30	0.27	
Percentage of answers correct					
Volatile	73%	69%	69%	73%	71%
Leading	66%	59%	64%	64%	65%
Slope	66%	69%	64%	76%	69%
All	69%	66%	66%	71%	69%

TABLE XXIII  
COMPOSITE EXPERIMENT QUESTIONNAIRE  
PREFERENCES

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. In analyzing data for differences	Verbal only	0.0%
	Verbal more	4.9
	Verbal & Graphic	43.9
	Graphic more	48.8
	Graphic only	2.4
2. Graphic liked most (Cochran Q = 25.9 critical value of chi-square = 7.8)	Standard	0.0
	Stratified	52.8
	Forecast	5.6
	Composite	41.7
3. Graphic liked least (Cochran Q = 36.0)	Standard	68.4
	Stratified	7.9
	Forecast	15.8
	Composite	7.9

TABLE XXIV  
COMPOSITE EXPERIMENT  
DEMOGRAPHICS AND GRAPHIC USAGE

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. Type of Work	Professional & technical	85.4%
	Managerial & administrative	14.6
	Sales	0.0
	Clinical	0.0
	Services	0.0
	Entrepreneurial	0.0
	Crafts	0.0
	Design & artistic	0.0
2. Graphs used daily	0 to 1	34.1
	2 to 4	19.5
	5 to 8	26.8
	9 to 16	17.1
	greater than 16	2.4
3. Graphs could use daily	0 to 1	17.9
	2 to 4	25.6
	5 to 8	20.5
	9 to 16	23.1
	greater than 16	12.8
4. Wore glasses or contacts	glasses	36.6
	contacts	12.2
	none	51.2

TABLE XXV  
COMPOSITE EXPERIMENT OBSERVATIONS

<u>QUESTION</u>	<u>CHOICE</u>	<u>PERCENTAGE</u>
1. Touch screen	Yes	10.0%
	No	90.0
2. Distance from screen	10+ inches	2.4
	15+	4.9
	20+	17.1
	25+	48.8
	30+	22.0
	35+	4.9
3. Gender	female	22.0
	male	78.0

APPENDIX K  
COMPOSITE EXPERIMENTAL DATA



124	6717	49	2115	6480	346	6002	1772	7005	6626	1157	6134	2143	6541	5364	4004	5689	3070
07-2907-3007-1807-1807-1507-0907-3007-3007-0907-3007-3007-1507-1807-1507-3007-3007-1007-22	g <sup>m</sup>	vg	g <sup>m</sup>	g <sup>m</sup>	vg	g <sup>m</sup>	g <sup>m</sup>	vg	vg	vg	g <sup>m</sup>	vg	g <sup>m</sup>	vg	g <sup>m</sup>	vg	v <sup>m</sup>
5	5	5	5	6	6	6	6	6	7	7	7	7	7	7	8	8	8
6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
5	5	5	5	6	6	6	6	6	7	7	7	7	7	8	8	8	8
1	0	0	1	1	0	1	1	1	1	1	1	1	1	1	1	1	0
0	0	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	1
1	1	1	1	0	1	1	1	1	1	1	0	1	0	1	1	1	0
3	2	2	4	3	3	4	4	4	4	3	3	3	3	4	3	4	1
35.0	36.8	24.7	21.1	32.8	13.8	18.5	18.2	23.0	16.3	20.7	28.8	18.6	16.8	37.1	62.1	38.5	40.9
5.12	3.26	4.84	11.3	5.47	12.9	12.9	13.1	10.4	11.0	8.66	6.23	9.66	10.6	6.46	2.89	6.22	1.46
8.67	8.77	8.73	8.73	8.73	8.72	8.57	0	9.50	9.5	9.51	9.5	9.5	9.33	9.5	9.5	9.50	9.5
4.11	2.63	3.58	8.03	4.32	7.97	8.86	8.65	7.36	6.97	5.94	4.68	6.40	6.87	5.14	2.51	4.99	1.18
7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7	7
3	3	3	8	8	8	8	5	5	5	5	5	5	7	7	7	7	7
1	1	1	1	1	1	1	1	1	1	1	0	1	1	0	1	1	0
1	0	1	1	1	1	1	1	1	0	1	0	1	0	1	0	0	1
0	1	1	1	1	1	1	1	0	1	1	1	1	0	0	1	1	1
3	3	4	4	4	4	4	4	3	3	3	3	4	1	3	3	2	4
38.7	27.2	35.1	21.3	26.3	19.6	31.8	0	27.5	17.4	19.9	28.1	29.3	28.5	46.1	67.0	43.7	53.2
4.64	6.60	6.83	11.2	9.12	12.2	7.53	13.5	6.54	10.3	9.00	6.40	8.16	2.10	3.90	2.68	2.74	4.50
5.82	5.82	5.76	9.28	9.33	9.33	9.33	0	8.51	8.51	8.51	8.57	8.50	9.12	9.33	9.27	9.33	9.33
4.04	5.44	5.87	7.84	6.73	8.29	5.82	9.12	4.99	6.94	6.31	4.90	6.33	1.59	3.24	2.35	2.26	3.83
8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8	8
7	7	7	4	4	4	4	8	8	8	8	8	8	6	6	6	6	6
1	0	0	0	0	0	1	1	0	1	1	1	0	0	1	1	1	0
1	0	0	1	1	1	1	1	0	0	1	1	1	0	0	1	1	0
1	1	0	1	0	1	1	1	1	0	0	0	1	0	1	1	1	0
4	2	1	3	2	3	4	4	2	2	3	3	3	1	3	4	4	1
40.3	22.1	28.5	23.6	31.8	35.3	52.6	0	39.4	18.3	19.1	27.9	24.2	29.5	33.1	53.7	46.6	88.4
5.94	5.40	2.10	7.60	3.77	5.09	4.55	8.35	3.03	6.52	9.41	6.45	7.43	2.03	5.42	4.46	5.14	0.67
9.34	9.28	9.28	5.75	5.82	5.76	5.82	0	9.28	9.28	9.28	9.33	9.12	8.51	8.35	8.50	8.44	8.51
4.82	3.81	1.58	6.11	3.18	4.38	4.10	6.30	2.46	4.33	6.34	4.83	5.39	1.57	4.33	3.85	4.35	0.61
9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9	9
1	1	1	7	7	7	7	3	3	3	3	3	3	5	5	5	5	5
1	0	1	0	1	0	1	1	0	0	1	0	1	0	0	1	0	1
1	0	0	1	1	0	1	1	0	1	1	1	1	0	0	1	1	1
1	0	0	1	1	1	1	1	0	0	1	0	0	1	0	1	0	0
4	1	2	3	4	2	4	3	1	3	3	2	4	1	1	4	2	3
28.3	27.3	44.5	25.5	42.0	25.5	23.5	0	42.0	18.4	27.3	23.9	32.9	33.2	38.4	51.1	48.0	45.0
8.45	2.19	2.69	7.04	5.70	4.69	10.1	5.38	1.42	9.78	6.56	5.01	7.29	1.80	1.56	4.69	2.49	3.99
5.54	5.49	5.49	9.93	9.93	10.0	9.87	0	6.58	6.37	6.38	6.42	5.82	9.10	9.10	8.94	9.27	9.11
7.07	1.82	2.39	5.07	4.61	3.37	7.17	4.51	1.23	7.26	5.32	3.95	6.19	1.41	1.26	3.99	2.09	3.32
10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
8	8	8	2	2	2	2	6	6	6	6	6	6	4	4	4	4	4
1	1	1	1	1	1	1	1	1	1	1	1	1	0	1	1	1	1
1	0	1	1	0	0	1	1	0	1	1	0	1	0	0	1	0	1
1	1	1	1	1	1	1	1	0	1	0	0	1	0	1	1	0	0
4	3	4	4	3	3	3	4	2	4	3	1	4	2	2	4	2	3
64.6	44.1	38.9	32.3	50.8	33.7	23.6	0	28.1	21.2	19.3	27.9	26.8	26.5	38.5	72.3	37.8	43.8
3.71	4.07	6.16	7.41	3.53	5.32	7.62	7.43	4.26	11.2	9.30	2.14	8.95	4.51	3.11	3.31	3.17	4.10
9.73	9.72	9.73	5.33	5.32	5.32	5.32	0	8.96	8.74	8.90	8.94	8.73	6.20	6.21	6.20	6.14	6.20
3.22	3.34	4.93	6.36	3.20	4.60	6.21	5.82	3.23	8.00	6.37	1.62	6.75	3.65	2.68	3.05	2.72	3.59
11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11	11
2	2	2	5	5	5	5	1	1	1	1	1	1	3	3	3	3	3
1	0	1	1	1	0	1	1	1	1	1	1	0	0	1	1	1	1
1	1	1	1	1	1	1	1	1	1	1	1	1	0	0	0	1	1
1	1	1	1	1	0	1	0	0	1	0	1	1	1	1	1	1	1
4	3	4	4	4	2	4	3	3	4	3	4	3	2	3	3	4	4
26.9	21.0	33.2	27.3	27.2	35.0	27.7	0	27.1	19.7	20.6	27.6	25.3	20.9	29.3	53.3	35.6	53.2
8.89	8.53	7.20	8.77	8.80	3.42	8.65	5.25	6.42	12.1	8.73	8.68	7.09	5.72	6.13	3.37	6.74	4.50
5.10	4.93	5.10	8.73	8.68	8.57	0	5.33	5.10	5.16	5.10	5.16	6.05	6.04	5.98	5.98	5.98	5.98
7.48	6.51	6.25	6.65	6.67	2.74	6.61	4.56	5.53	9.66	6.98	7.33	5.89	4.43	5.08	3.03	5.77	4.04

