ABSTRACT

SPARKLINES AS EFFECTIVE GRAPHICS

This research explores a method of graphical display called a sparkline. Sparklines are a valid method to convey statistical information, supported by an easy familiarity among users and a desire, expressed by information design expert Edward Tufte, for greater density in data display. The subject is examined in light of the broader concept of the integration of pictures and text, tracing this tradition back to medieval illuminated texts, through history to Galileo, and to such diverse modern techniques as emoticons. The historical perspective is expanded upon through an examination of perception theory and implications for data graphics. Ethical issues of graphic display are discussed. A test of sparklines compared with numeric displays for comprehension — possibly the first of its kind — was conducted as part of this project, and the results are reported here. While not without drawbacks, which are discussed, sparklines are demonstrated to be appropriate for certain uses, with a key caveat that they should be accompanied by a means of "drilling down" to the actual data. Sparklines fit into a long tradition of other graphic display methods.

SPARKLINES AS EFFECTIVE GRAPHICS

by
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SPARKLINES AS EFFECTIVE GRAPHICS

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This thesis is dedicated to my wife, Patti, and son, Brendan. They have been neglected because of this project, yet endlessly tolerant and encouraging of it, despite the time and financial sacrifice that have accompanied it.

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CHAPTER 1

INTRODUCTION AND BASIS FOR SPARKLINES

Place the data directly in the text. That is the idea with sparklines. Why separate the data into a graphic or table when the graphic can be placed directly in or alongside the writing? The eye passes over this little image — a jagged line, curve, or slope, as the reader absorbs the text. What has the brain extracted from that brief glance at the graphic? A greater understanding of the subject at hand? A richer context to complement the information that is being processed? That is the goal of using sparklines.

For example, rather than just give the latest glucose reading of an ill diabetic patient, the sparkline adds the past six weeks of results like this: 〰〰 glucose 126. Instantly the physician can see where this patient started, and the highs and lows. Armed with that information, the doctor might be able to make a prediction about the patient's prognosis, based on knowledge and past experience. At least the doctor might determine what further numbers are needed in order for him to make a more confident diagnosis. Now imagine a dozen such images and numbers (an example can be seen below in Figure 1.1). This wealth of information presents a much more complete medical picture.

This is just one example of the uses of sparklines. It is also one of the concepts that this research attempts to examine: To study sparklines, their role in technical communication, how they can be created, and their potential effectiveness and limitations.

Sparklines are one of the latest projects of Edward Tufte, the accomplished guru of contemporary data graphics and information presentation. They will be featured prominently in his forthcoming book, <u>Beautiful Evidence</u>. Beginning from the currently

available draft of the sparkline section of the book and expand and add my own research and extrapolations to what Tufte is putting forth.

1.1 Introduction to Sparklines

Sparklines is a term coined by Tufte to describe word-sized, intense graphics that convey a lot of information and provide context. They have so far usually been represented as line graphs, but are not limited to this form, as we will see.

There has been some discussion on the Tufte web boards on the naming of this graphic. One suggestion to the web board offered "daticons," with the "i" in a short pronunciation, as in "if." Tufte didn't like this term, replying that "cons" portion carried with it too many negative associations (Sparklines or Wordgraphs--some draft pages from Beautiful Evidence message board). Another person suggested *graphwords*. *Spotchart* and *spotgraph* were two other suggestions. One of the priorities for this message poster was the number of hits that each word generated in a Google search. He was worried about confusion with other meanings and usages.

The problem with the term *sparklines* is that there's little relevance to the "spark" part. Tufte said he chose the term because of their "spark-like" appearance, as in a bolt of electricity. It does convey energy. And there is the positive association with the spark of inspiration. But it also has an automotive context. And while they certainly could be used to display fuel efficiency or tire tread life, sparklines don't inherently have an automotive use.

Tufte appears to have closed the discussion on the name when he wrote on Aug. 30, 2004, in the same Sparklines or Wordgraphs web board: "I've settled on sparklines."

The purported benefit of these diminutive graphs is that they can portray a trend, or recent history, in a small amount of space, without lifting the eye from the flow of words.

One of Tufte's recurring themes is that humans can absorb quite a bit more information than they're provided. Thus, for instance, he argues for dense, link-packed Web site design — none of this minimalist approach! Check, for instance, The New York Times site, the academic site Arts and Letters Daily, or the most consistently useful, non-search Web site ever, the comprehensive Refdesk.com.

The idea of sparklines is that you are looking at anywhere from several hours to potentially years of data, depending on the scale chosen for the graph. As Tufte says in an excerpt from Beautiful Evidence, his forthcoming book:

> By showing recent changes in relation to many past
> changes, sparklines provide a context for nuanced analysis
> — and, perhaps, better decisions.

One idea would be to incorporate the graph into standard text, as shown above in the glucose example, or this:

> The patient's heart rate, after administering drug X,
> measured ~~~~ 101

We can superimpose the patient's actual readings upon a band that represents the normal range for a person of the patient's sex, age, or other criteria: ~~~~ . In this way, we can make instant comparisons about the patient's condition versus that of a "normal" individual.

The page following shows an example of a precursor of sparklines from Tufte's Visual Explanations. It offers a glimpse into the evolution that leads to sparklines. (This

is copyrighted material, Tufte's creation. Possibly he has more elaborate hopes and plans

for this invention.)
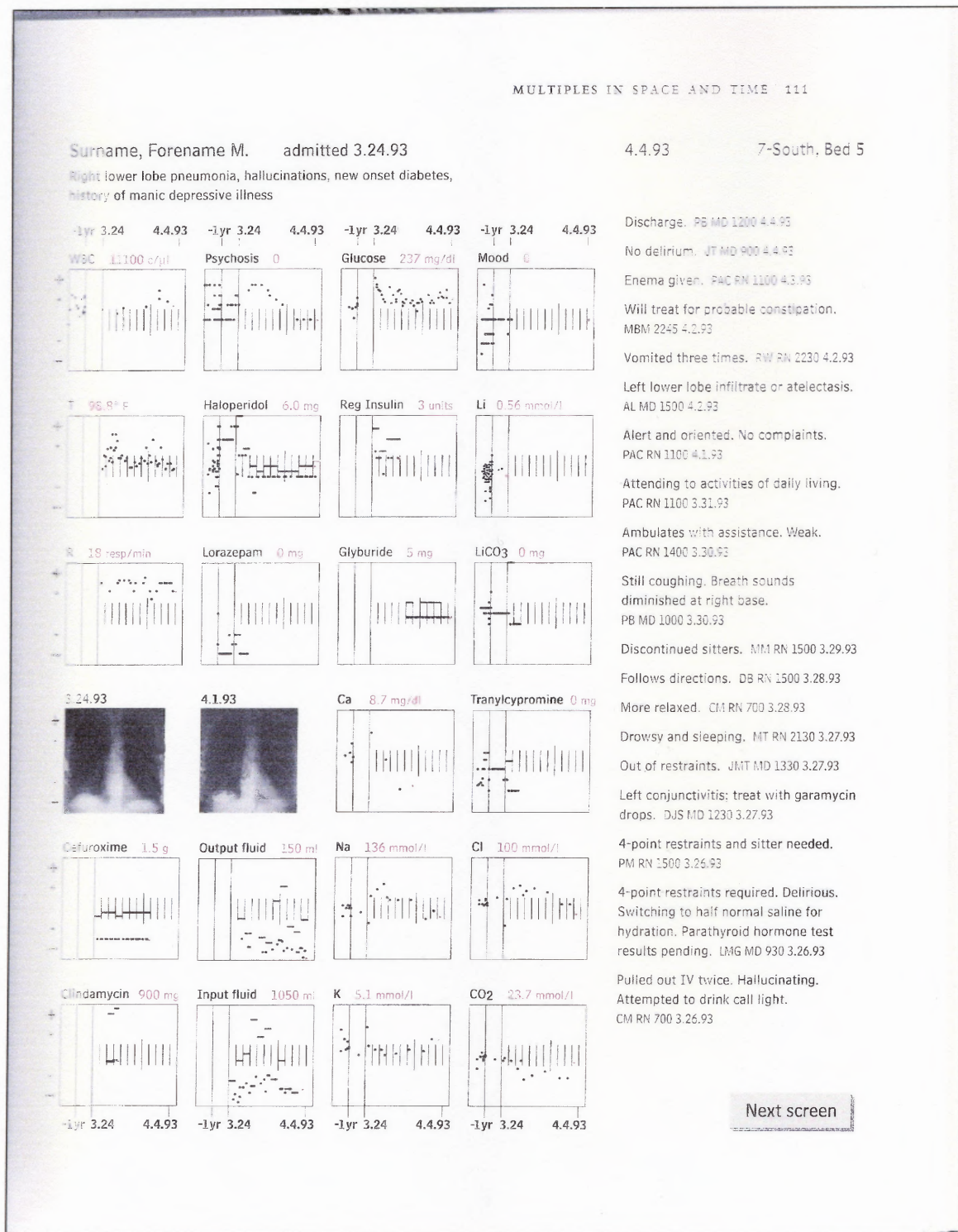
Figure 1.1 Medical Chart on Computer Screen, Prototype of What Sparklines Might Look Like (Tufte, <u>Visual Explanations</u>, 111).

These charts are intriguing for, among other reasons, they show the one-year-ago figure. However, Tufte and collaborator Seth Powsner presented this concept in the medical journal <u>Lancet</u> in 1994 and it is not clear that it has gained acceptance.

> We propose a graphical summary of patient status to overlay the traditional medical record with a report primarily to serve medical care. Numerical data are plotted to reveal the course of an illness and response to treatment. The most recent values are shown numerically as well as graphically. Notes and stamp-sized medical images are included in a form appropriate for high-resolution computer display or laser-printed page. The consequence is a richly detailed, one-page summary of patient status.

Another prime example is the myriad use to which sparklines could be put in financial contexts:

American Growth Fund

The technique of a *stack* places several of these word-graph combos on top of one another to provide comparison.
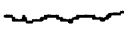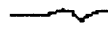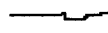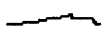
American Growth Fund

National Investments

Cody Group Fund

Investor Club

California Public Fund

Figure 1.2 Stacked Sparklines.

Small graphics of this type are already common at Web sites like Yahoo Finance. What is the difference, however, between this graphic and any other? This stacked graphic begs the question of whether it is still even a sparkline. If the line graphs were

embedded in text, then it would be clear, at least under one working definition of sparklines. But as they are above, they seem as much like a table as a series of sparklines.

One of the key rules to follow when presenting these or any monetary sparklines, is to adjust dollars for inflation, or make them constant. This is one of the rules that Tufte lays out in <u>Visual Explanations</u>, citing himself from the first book and Samuelson and Nordhaus in their classic Economics text. To do otherwise is to present inaccurate data, confuse the viewer, etc. These rules must be observed with sparklines as well as with any data.

One of the limitations of these line graphs is their inability to present four-dimensional data. The example that is available (How can information in 4-dimensions be pictured using 2-dimensional diagrams?, from the <u>Ask E.T.</u> Web boards) tries to display two companies, making a product, and the *quantity* of the product fluctuates in reaction to one another. Those are the two dimensions. Then add the dimension of multiple products made by each respective company, and now you have the third and fourth dimensions. This seems an entirely realistic scenario; financial barons might want this type of data. One suggestion was that this type of data display really becomes more like a *surface*. Though hard to visualize, this has some ring of truth to it, and the graph can be pictured much like a 3D landscape, with contours that would represent the variables of the products. I don't know if this will fit well in a sparkline-sized graphic, or we have something else that is being embedded into the document. Other individuals found other ways of displaying the data.
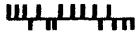
Bertin, however, in his discussion of the limits of the graphical system, entirely dismisses the whole discussion of three dimensions:

Actual relief representations (the physical third dimension)
has no place here and will be referred to only for the
purposes of comparison.

A variation of the sparklines we have seen so far, called a *binary* sparkline, displays only yes-no data, or data with two possible values. They look like this:

In the example that Tufte provides, they could have an application in sports. In this iteration, each "whisker" extending up represents a win and each downward whisker represents a loss. For instance, you would write:

The New York Giants ended their season with a trio of defeats: .

You could also imagine how the binary sparklines might be stacked to display the entire NFC East.

This approach, of course, is more efficient than simply writing the Giants' record: 12-4; but it does display how the team arrived at that season's record. Imagine the length of sparkline that would be needed to portray an entire baseball season! The point is not to use less space, but to provide added detail and perspective.

Hockey and soccer, with their ties, present an interesting dilemma.

I have devised my own version of a sparkline. Using the notion of a bar chart, this one uses area to convey data. Each block represents a reading at a given time interval, say, one month, and the filled area within that block represents a measurement. This example of how one might appear, reports on the height of a river:

The height of New Jersey's Raritan River
threatened homes and a handful of businesses in three
counties early spring, but then subsided.

In addition to heights or weights, this type of sparkline could be used in any application that needs to show quantity, perhaps the sweetness of chocolate, or the pollution levels of a major city. As with the line graph, and indeed with many of the sparklines, this one shows change over time.

A definition may be in order, to establish the scope of the this project. John M. Lannon writes in <u>Technical Communication</u>, a standard textbook on the profession:

> Graphs translate numbers into shapes, displaying at a
> glance a set of quantitative values, the point being made
> about those values, and the relationship being emphasized.
> Plotted as a series of points (a series) on a coordinate
> system, a graph shows the relationship between two
> variables. Graphs have a horizontal and vertical axis. The
> horizontal axis shows categories (the independent variables)
> to be compared, such as years within a period (1970, 1978,
> 1986). The vertical axis shows the range of values (the
> dependent variables) for comparing or measuring the
> categories, such as the number of people who died from
> heart failure in a specific year. (302)

This is a workable definition. Throughout this paper, particularly in the history section, that will be referred to "graphics." This is a truly far-reaching term, but in this case, graphics that display data are the subject. This discussion really does not encompass schematics, icons, flowcharts, or any of the myriad possibilities that could fall under the rubric of "graphics."

There are seven major sections that constitute the scope of this thesis.

First there is an introduction to sparklines, likely a new concept to some. This is to introduce sparklines and tout some of their benefits. Second, I cover the background for human perception and construction of graphics in general. This covers the psychological underpinnings of the sparklines — a brief introduction to the concepts of

how we perceive information and process it. Third, the history of graphics will be covered. Fourth, there is a brief section on the ethics, with some of the well-known guidelines and their affect graphics and graphic construction. Then there is a section on criticisms of sparklines. It is better to be upfront about these weaknesses and shortcomings - and there are true weaknesses. With these criticisms in mind, the reader can fairly evaluate the material that follows, and judge whether these sparklines have value or not. The seventh and final chapter, perhaps the most important, contains a field trial of sparklines with actual users. This is a small trial, but appears to the first published research testing sparklines.

Also as part of this project will be the construction of a Web site containing the contents of this study, possibly with links to other resources as well as slightly more interactive displays.

As an aside, one of the drawbacks and strengths of this exploration so far has been the newness of sparklines. There is no research currently to elucidate sparklines, providing a clean slate to work with. This is both a blessing and a curse in that it allows freedom to pursue any course, but there is also nothing upon which to base the work either for jumping-off points for future research or commonly accepted practices for the study of the sparklines.

Conversely, there is a vague sense that sparklines are not all that innovative. While there is no evidence that they exist before in precisely this form, it seems fairly simple — put the picture within the words. This can be said of a lot of Tufte's work, in that he doesn't originate many of the graphical display concepts, he popularizes them. This leads into the following major section on the history of data graphics.

In medical applications, Tufte and collaborator Powsner express some self-doubt that their creation is capable of nudging out familiar, traditional medical charts, which have proved stubbornly resilient.

> The traditional record is such an easy device to use that it has proved difficult to replace.

Nonetheless, they argued that their creation is relevant because doctors are looking merely for summaries of the relevant information:

> Two studies indicated that doctors work from just a small portion of a traditional record. Provided with a *summary*, physicians requested full records in only 26% of rheumatology clinic visits.

They also likened them to similar data presentation methods that were already present in hospitals:

> Often used in intensive-care units, flowsheets tabulate patient information over time and can be computer-generated. Since a flurry of activity produces a flurry of columns, many flowsheets have an arbitrary time-scale based on the occurrence of events and measurements rather than on regular intervals. Color might call attention to organs at risk.

Even in their first paper on the topic, Tufte and Powsner postulated about the software that would be needed to realize their invention:

> The customized software includes numerical tables that specify the scale for each finding and treatment.

> Medical computer systems will soon be able to print a fresh summary for each patient every day. Our proposal for a graphical summary should encourage doctors and nurses to reshape, perhaps re-invent, the medical record before computer programmers cast institutional convenience into silicon. Legal and organisational demands for detailed information will not disappear, but these demands need not

compromise clinical needs for accessible patient information.

It is a high-resolution display that invites the viewer to assess relations between findings and treatments, and allows for consideration of alternative diagnostic and management strategies. Instead of a 5 cm thick record, a single page reveals the data graphically. Graphical summaries will be especially useful during case conferences or teaching exercises; all the participants, each with a copy, can review the history and treatment.

1.2 Parallelism

One of the benefits of sparklines, at least acquired over time, is their repetitive nature. There does not seem even to be a learning curve, an acclimation to the sparklines, as anyone who has learned to read has likely been exposed to graphics meant to convey data next to text from an early age. What seems valuable about sparklines is that they will acquire familiarity as their use proliferates. They will become second nature. And when used in certain contexts, as a doctor comparing heart rate before and after administering a certain drug, they will provide an easy means of comparison. Tufte expounds a full chapter on this topic of parallelism. He almost runs the risk of overdoing it: "Parallelism becomes the poetry of visual information." (Visual Explanations, 103). I will not try to apply this concept too much to sparklines. There is an elegance, like a poem, to sparklines, and the sense of conveying a lot in a small space. But sparklines and poetry convey different levels of information.

1.3 The Trail to Sparklines

Although he likely had no inkling of sparklines at the time, Tufte foreshadows them, and succinctly sums up the case for them quite neatly from early in his first breakthrough work, <u>The Visual Display of Quantitative Information</u> (111), stating:

> Words and pictures belong together, genuinely together.

There is further support for the concept of sparklines in <u>Envisioning Information</u>, where he writes about the problems of placing a graphic in one place and the key to the graphic in another:

> Separating text and graphic, even on the same page, usually requires encoding to link the separate elements. ...Attentive readers must repeatedly jump back and forth between text and graphic, which are connected by up to 22 letters. Alphabetical labels bestow a sequence on the illustrations, but otherwise are just arbitrary codes...

What he is getting at, in a way, is his famous goal to "escape from flatland," a topic relevant to sparklines also - how can the sparklines seek to convey the richness of data in two dimensions, at reduced size?

A natural concern with sparklines is whether they can be legible at word-size. A full 12 years ahead of the introduction of sparklines in <u>Visual Display</u>, Tufte addressed this, at least conceptually, in terms of human perception, if not technically - in terms of software or other mechanisms to create sparklines:

> Many data graphics can be reduced to an area half their currently published size with virtually no loss in legibility and information. (169)

There seem to be no tests comparing the size of graphics, of, say, one group being tested on full-size graphics and another with small graphics. They could then be tested to

see if there is any correlation between the size of graphic and the information gained. But this is a potential area of future study.

But this concept of being able to perceive "small" information rings true when you consider maps. Granted, it's a different context, but how many times have we traced a road, or perhaps for hikers, a trail affected by gradations in the land, all precisely laid out in topographic lines. Elsewhere in Visual Display, Tufte cited cartographer D.P. Bickmore, who said, "the resolving power of the eye enables it to differentiate to 0.1 mm where provoked to do so" (162). Tufte writes:

> Maps routinely present even finer detail …Our eyes can
> make a remarkable number of distinctions within a small
> area (161).

To return to a theme that was touched on earlier, one argument in favor of sparklines is Tufte's assertion that humans can take in a great deal more information than we are given credit for:

> How many statistical graphics take advantage of the ability
> of the eye to detect large amounts of information in small
> spaces? (162)

A final argument in favor of sparklines comes again from the Visual Display book. In it, Tufte lays out a data-ink maximization principle, arguing that all ink should be in the service of presenting data, so elements like a table lines are wasteful. There is a lack of specificity on Tufte's part about this principle. How much of a data-ink ratio is acceptable? What is the formula? Are there exceptions that are needed, for when the data needs to more clearly displayed? However, I think the connection to the data-ink ratio is that by placing the graphic within the text, rather than separate and larger on its own, with a need for labeling and the like, we save ink. This could allow for even more graphics. To be clear, the point here is not minimizing ink out of some cost-cutting measure, but of

having all the ink that is presented expended in the service of displaying the data, so as not to have marks that distract from the information.

We can perhaps see Tufte beginning the process that would lead toward sparklines, indeed, one of their origins, if we look again back to Tufte's Visual Display, where, in the preface to the second edition (2001), he talks about the process of making a book, and some of his goals for the publication of this much-praised book:

> We were able to integrate graphics right into the text, sometimes into the middle of a sentence, eliminating the usual separation of text and image — one of the ideas *Visual Display* advocated." (Introduction to the Second Edition, unnumbered).

Toward the end of the book, he talks about techniques for data graphical display, and points out one of the weak ways to convey information:

> The conventional sentence is a poor way to show more than two numbers because it prevents comparisons within the data. The linearly organized flow of words, folded over at arbitrary points (decided not by content but by the happenstance of column width), offers less than one effective dimension for organizing the data. (178)

The sentence is not the way to convey data, but it is part of the mix. We would see later that Tufte came to put the graphics into the text.

This admonition almost seems to speak against the use of sparklines, as if we should eschew entirely the idea of trying to convey numbers in text. But Tufte soon expands upon the idea:

> Words and pictures are sometimes jurisdictional enemies, as artists feud with writers for scarce space. An unfortunate legacy of these craft-union differences is the artificial separation of words and pictures: a few style sheets even forbid printing on graphics. What has gone wrong is that the techniques of production instead of the information conveyed have been given precedence.

> Words and pictures belong together. Viewers need the help
> that words can provide.

And later:

> Words, graphics and tables are different mechanisms with
> but a single purpose — the presentation of information.
> Why should the flow of information be broken up into
> different places on the page because the information is
> packaged one way or another ? (181)

This all seems to point toward a framework for what would later become

sparklines. He does not do this unreservedly, however.

> Finally, a caveat: the use of words and pictures together
> requires a special sensitivity to the purpose of the design —
> in particular, whether the graphic is primarily for
> communication and illustration of a settled finding or, in
> contrast, for the exploration of a data set. Words on and
> around graphics are highly effective — sometimes all too
> effective — in telling viewers how to allocate their
> attention to the various parts of the data display. Thus, for
> graphics in exploratory data analysis, words should tell the
> viewer how to read the design (if it is a technically complex
> arrangement) and not *what* to read in terms of content (182).

1.4 Emoticons

A cousin of sparklines, perhaps, and another example of the integration of text and

graphics are *emoticons,* the series of keystrokes: ;) for a winking eye, or :), for a smile, or

tiny faces, such as a smiling likeness ☺. These are intended to add meaning to a written

communication, usually e-mail. The smiling wink, as used above, can certainly be

considered to convey the writer's feeling more quickly and precisely, with little chance of

misinterpretation, than writing: "Trust me, I'm with you on this," or a similar sentence.

Franklin Krohn has considered the appropriateness of emoticons in a business

context and has recommended a "generational recipient determinism (GRD), in which the

age of the potential reader of the emoticon is the determiner for whether to include emoticons. "GRD seems to be the way to convey the standards of the past with the reality of the present and future (326).

I think there is no need for similar consideration about the appropriateness of sparklines, as they are more purely data-oriented. As the name implies, emoticons are more geared toward the expression of emotions, and this introduces the possibility to offend or be misinterpreted.

> **Extejt specifically recommends that emoticons be used in business communication only when the tone is casual and the writer is certain that the recipient will understand their meaning. (324)**

Curiously, there is no discussion by Krohn of whether the added adornment of emoticons is a distraction, detracting from the transfer of meaning.

Sparklines and emoticons are kindred in that they are examples of non-verbal communication, Krohn asserts (322). And so the discussion of sparklines and emoticons touches upon the question of what part of speech they are.

The connection and parallel between sparklines and emoticons are that they both convey information more efficiently, in less space, than does standard text.

1.5 Work

The background of this exploration would not would be complete without mentioning the influence of my job. As a technical writer at a small software company, I am constantly striving for better, faster ways to communicate, as are all technical writers. No one wants to read more than he absolutely have to, particularly about software, and even more

particularly when they are stressed to complete a task. This desire set me toward a goal of conveying information with a graphic rather than with words. While this goal seems to have little application (at present) in the documentation of software itself — the instructions on how to use the product, I find that it might have application within the product. The software produced by my company is concerned with presenting data, in the form of reports and displays, both on-screen and in print. And in this respect, learning to effectively present data can make for a better product.

This is hardly a new idea or goal. What if we could convey information with a single glance at a graphic? Wouldn't that save the user time? Wouldn't the user have more time to do other tasks, and perhaps even be appreciative? This might even gain the trust and confidence of the user, because we had served her interests by saving her time, thus making her more likely to read our words. We will never completely eschew our dependence on words, nor would I want to.

1.6 Technology To Create Sparklines

How to create these little graphics?

Any discussion of the software that can be used to create sparklines is likely to be out-of-date as soon as it is published, so this section will be brief, focusing on solutions available as of May, 2005. Tufte's own recommendation seems to lean toward Adobe Illustrator. In the years to come, as software evolves, one would have to look for programs equivalent to Illustrator as the tool to create sparklines. Perhaps if sparklines proliferate, the means to create them will be built into existing applications — a single button to produce a sparkline from a set of data.

Whatever software solution is chosen, it needs to be highly automated and self-sufficient. There would have to be an interface between the software that generates the sparklines and the application that stores or creates the data. If a human is required to manipulate the data, this defeats the benefit of sparklines being quick to create.

Coworkers report, and personal experience reinforces the view that Microsoft Excel is able to create these graphs. The drawback is that once they are created, the sparklines must be shrunk to fit within whatever authoring application is being used, such as a word processor or HTML design program. Although Tufte derides the Excel solution, he does say that some of his students have been able to "hack" Excel to make it a smoother process. While it is possible to use Excel, this is a fairly inefficient solution. One of the challenges is getting the data into a format that is readily accessible to Excel. This could require yet another interface, to a database. Manually inserting and resizing sparklines into text, as I have done in this thesis, is time-consuming, tedious and impractical.

There has been extensive discussion of the available programs for creating sparklines, and their pros and cons, on the "Graphing Software" and other message boards on the "Ask E.T." Web site. Custom code that is designed to produce sparklines has been written for Macromedia's Flash.

Tufte's initial recommendation, as stated above, seems to be toward products such as Adobe Illustrator, but among those that have also been mentioned are Quark Express, and such specialized statistical packages such as DP Graph and Grapher, Origin 6, SYSTAT, Datadesk, STAT, SAS, SPSS, SigmaPlot, IgorPro, and Statistica.

One of the possible solutions can be found at James Byers' sparklines.org Web site. Byers has developed a .PHP script, a type of programming language, that can apparently be incorporated into HTML code to produce sparklines.

In <u>The Grammar of Graphics</u>, Leland Wilkinson has created a construction set for the basics that go into any graphic. As the title of his book implies, Wilkinson suggests a set of rules for the statistical models surrounding the construction of graphics. For instance, he calls the line or bar that represents the data a graph, but the physical representation of those data on paper or computer screen is the graphic. A simple but subtle distinction. He goes further into variable sets, data sets and functions, which are the calculations that are performed on the data. Wilkinson's "grammar" was deployed in the software he developed, Grapher, which is written in the Java programming language. Wilkinson asserts that his program is transmutable to any other language, such as C.

CHAPTER 2

GRAPHIC BACKGROUND

This study of sparklines arises from the premise that, in some cases, a graphic can convey information more quickly than, and is preferred by the viewer over, text or tabular data or long lists of numbers. It's that simple.

But that is also quite a far-reaching hypothesis. It should be amended to say that in some cases an individual can learn more quickly from a picture than from words. Thomas Williams and Deborah Harkus have written that "there is a strong...text bias among writers — a general reluctance to use pictures — that arises partially out of habit and partially out of a belief that words are the appropriate medium for any serious discourse" (33). While acknowledging that some concepts are very difficult to express pictorially (citing the game Pictionary), Williams and Harkus go on to say that symbol systems — words and pictures — can occasionally overlap, and "the same idea often can be expressed symbolically" (34). This is an idea that will be echoed later when we explore image theory. Williams and Harkus suggest it is the job of the editor of visual material to sort out what "will be the most useful to the reader/viewer given the nature of the task he or she wishes to accomplish with the information provided."

They cite the benefits of using graphics:

> To a considerable degree, pictures and other visual forms
> such as diagrams are not constrained by the sentential
> structure of text and can thus preserve the author's complex
> view of the relationships that exist among ideas. (44)

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This could be especially true in medical, scientific, or financial fields, or nearly any complex context in which there is a need to convey a large amount of data. In a situation, like medical patient care, there often are no easy answers — the heart rate went up, then down, remained stable, then suddenly shot up again — all of this presenting a complex patient history. And it is then be incumbent upon the physician to dig deeper, to look at relevant conditions for each of those fluctuations, and to adjust treatment accordingly.

The same is often true of financial data: the stock dropped, then leveled, then went up gradually. This is the kind of activity over time that is readily and quickly revealed with sparklines. From there we can begin asking questions: What industry is the stock a part of, and what conditions affect that industry that caused the stock to drop or rise? Was there a war underway? What was going on within the company to influence stock price?

Again citing Williams and Harkus (35): "much of the processing we perform on the visual world occurs rapidly, simultaneously, and unconsciously." They are citing precisely the kind of instantaneous visual processing that I have been asserting based on purely intuitive or anecdotal evidence.

"In summary, then, pictures hold the promise of considerable efficiency in delivering certain kinds of messages because they can deliver those messages directly," Williams and Harkus write.

Claire Harrison reaffirms this in a piece primarily about how people derive meaning from images:

> Readers/users no longer rely solely on written text for comprehension; they absorb and process all that they see within a document to create meaning for themselves.

By inference, we could apply this to assert that the eye glancing over the sparkline takes in the patient history, or the stock price, or the team's won-loss record, in one brief glance.

Starting from that simple basis, one of my goals is to find ways to replace paragraphs with pictures in specific relevant and appropriate contexts. The effectiveness of replacing text with graphics could itself constitute a study, and perhaps ultimately this will be the path of a more extended research. But to hone in here on a specific topic, I choose to look at sparklines. This research attempts to explore an untraveled path. Sparklines are still relatively new territory, but one that could be of emerging importance. Or maybe sparklines will morph into something entirely different, or lead to yet another means of data display.

I do not assert that sparklines will work in every situation. There are some concepts we can explain only with words, as I am doing now. I could not use sparklines to explain sparklines. There will always be a need for words. But what sparklines can do is to integrate the text and data seamlessly, to provide a richer understanding.

At the risk of being too basic, a more fundamental goal is a hope that this research will, in some small way, help technical communicators more effectively convey information.

The goal of this research is to explore the value and viability of sparklines.

2.1 The Graphic Problem

We come to the basic graphic problem: whether to use a graphic at all. Jacques Bertin, author of the most important and seminal book I found on the topic, The Semiology of Graphics describes the graphic problem as depending on time considerations and efficiency of each language—sign system. The first consideration involves a second question — what type of graphic should be used?

Writing in the early 1980s, Bertin proceeds from the assumption that graphics are time-consuming to produce. Now in 2005, this issue is not totally resolved. But the availability of sophisticated software that is available to us for producing nearly any graphical representation or animation, graphic production has become far easier, with skills and knowledge that is within reach of the average person. Bertin's disposition seems to arise out of the long-standing difficulty of either hand-produced or individually plated graphic elements in books.

Efficiency is a key concept, perhaps the most important consideration, as mentioned above in Bertin's statement of the graphic problem. Efficiency is the time of perception and comprehension of the graphic, the mental cost it takes to acquire (to put together) the image from its components, which are made up of elements which convey the information.

Efficiency is the criterion applied to a graphic to gauge whether it is the best construction. "If, in order to obtain a correct and complete answer to a given question, all other things being equal, one construction requires a shorter observation time than another construction, we can say that it is more efficient for this question (139)." Bertin

goes on to explain that in most cases, the difference between an efficient construction and an inefficient one is extremely clear.

Of course, this test depends on the asking of a specific question. By this I mean that we must have in mind a specific piece of information that we want to obtain in order to gauge whether one solution (graphic) is more efficient than another.

Bertin discusses George Kingsley Zipf's notion of mental cost to obtain information, as explored in his The Psycho-biology of Language. This relates to perception theory and the psychology aspect.

Efficiency is linked to the degree of *facility,* characterizing each stage in the reading of a graphic.

All of this forms one of the key considerations in whether to use sparklines — if we have a tool to create them quickly, then fine. Otherwise...

We proceed to answer the question posed by the graphic problem by saying: "A graphic is justified only for transcribing intermediate complexities, that is, problems relating to statistical studies," Bertin writes (166). Anything too scattered and random, or at the other end of the spectrum - within only two extremes, can be described with words.

2.2 Categories of Images

Harrison (50) has segregated images into three categories:

- Icon
- Index
- Symbol

The *icon* is a semi-realistic image meant to represent something we are familiar with, such as a tiny house representing a home page on an Internet browser. An *index* is

an image that is recognizable, but not as itself, but as the concept that it stands for, as with a weathervane. I think the rounded image of a man or woman, to represent a restroom, is another example of this, in it does not represent a man or woman, but a bathroom. A *symbol*, lastly, has no visual relation to the concept it is intended to represent. We know the meaning of the symbol only because we have learned it. A word is an example of a symbol.

Sparklines fit into the symbol category. The little whiskers of a won-loss record in no way precisely represent games that were played and either won or lost. And the jagged line of a graph can in no way be thought to literally look like the fluctuations of a bond price over time. These are merely meanings we have given to these images, through cultural usage.

Drawing on the work of Kress and vanLeeuwen, Harrison also describes the three important metafunctions that graphics perform:

1. representational,

2. interpersonal,

3. compositional.

The representational metafunction answers the question "what is the image about?" — through the use of people, places and objects, which are named "representational participants."

A subset of the representational metafunction is the "conceptual image." As the name implies, "Conceptual images do not involve action or reaction on the part of RPs but represent participants in terms of their more generalized and more/less stable and timeless essence" (52).

The interpersonal metafunction answers the question "How does the image engage the viewer?" This could involve the gaze of the subject of the picture looking directly at the viewer, or the gaze of the subject of the picture looking at someone or something else in the photo, and how this affects the viewer. This metafunction is likely not involved with sparklines.

The third, the compositional metafunction, take the first two and asks how they relate to one another to form a whole. As the name implies, it considers the composition of the image. The compositional metafunction creates a syntax between the components of the image, just as we must have a syntax in language, or we would be left with a jumble of elements that we could not make sense of. With sparklines, for example, the compositional metafunction could be the relation of the graph to the x and y axes, for example.

The three functions of graphic representation are essential, foundational aspects of the issue:

1. recording information — storing data into a repository,

2. communicating information — doing something memorable, creating an impression

3. processing information — (and this is really the key one) providing a simplification which allows you to see something new from the information. This is what I call the "value-added" function of a graphic, to show you something you never knew before, things that bring insight. Tufte speaks at several occasions to this point.

Bertin lays out a construction kit, or perhaps also a de-construction kit of building graphics. The components are the variables, or the individual bits of data. And the components are further broken into elements, the individual lines or bars or dots.

One of Bertin's recommendations is to lay out the variables in a double-entry table before attempting to represent it in a graphic. I think this procedure is sound because it enables you to see the lay of the land, to get a feel for the data. But perhaps more important, it will give you the number of components, (which will be discussed shortly), and in turn will determine the most efficient graphic system.

Bertin makes the point that perception of a graphic can be instantaneous. Perception of a table of numbers, on the other hand, naturally take longer. In a 100 by 100 table, for instance, based on 2 "instants" per entry, would take 20,000 instants to perceive (3). Now, granted, that's to perceive the whole thing, while what we're doing in perceiving a graphic is something less than such complete comprehension. But still, we're getting the gist of it.

"The graphics can lead rapidly to the intended result: perception of similarities" (112). This covers just one of the types of information that the author may be trying to convey.

We can look at Bertin's idea in relation to sparklines, because they do not have a title, at least in the incarnations we have seen thus far. They are therefore without the invariant, and I wonder what Bertin would think of them. I suspect that he might find this a key missing detail, one that might disqualify sparklines from serious data display. But of course the text around a sparkline is the context, the invariant, telling you what you're looking at.

Harrison constructs a set of rules for evaluating the usefulness of a particular picture. While her work referred primarily to photographs, there are elements that can be applied to statistical graphics. Not to detract from a topic that will be covered in the

section on the perception of graphics, but Harrison also touches upon the distinctions between the graphic — the sign — and the signified — the meaning taken away from the graphic.

Once we have answered the dilemma posed by the graphic problem, we have levels of organization into which graphics may fall:

1. qualitative — the nomimal level, the concepts that differentiate one thing from another, mammals from shellfish for instance. Or one type of car from another. These things are all of equal importance — languages, social classes, languages, products. And thus they can be placed in any order.

2. ordered level — concepts that allow ranking of the elements. We can get into trouble with generalizations like these, but the concept is that any person would agree that this comes before that, and that reordering them would cause confusion. Which is more or less than the other?

3. quantitative level — enables counting of the elements — this is one-fourth of that, those are three times the number of these, etc. This is where we get into the statistical stuff, dividing by 100, 1000, etc., to establish the portion of the whole, or how things relate to one another. What is the ratio between the things measured? (39)

These three can be overlapping. But all graphics are concerned with demonstration of these three, which collectively allow us to identify the perceptual approaches a component can generate.

2.3 Perception

I turn now to a general discussion of the psychological concept of perception theory — a whole field of study concerning how we take in the world around us. Then I will make a connection to the theories behind graphic construction, first in broad philosophical concepts, and then in the mechanics of how to construct graphics.

There is a considerable body of perception theory, summarized in the seminal work of E.G. Boring, <u>The History of Experimental Psychology</u>. Boring discusses the sensation of an event — in our case the viewing of a graphic, although this could be applied to anything — and the lasting perception of that experience. The former, the sensation, is called the *anschaung*, or *wahrenung,* the experience of viewing a graphic.

It may seem obvious, but the perception of a graphic is only one of the vast range of human experience, but this perception of graphics is the one upon which this study focuses.

Then there is the *vorstellung*, which is the perception we are left with after experiencing whatever external phenomena are presented to us. What do we take away from the sparkline? To use the medical sparkline example, how does the doctor react to the glucose reading? Or how does the broker invest, to use the financial example. How does the gambler place his bet, based on the past record of the two teams competing? These are the outcomes, or vorstellung, of viewing the sparkline.

A relevant section of Boring's comprehensive work is a recounting of the history of the physiology of vision, going back to Isaac Newton's <u>Optik</u> in 1704, and the works that influenced it. Muller argued that what we perceive directly is not the matter itself, but the properties of objects left on the nerve endings of the eyes (101).

An interesting paradox is that our eyes produce one vision, one perception of an object or image, but our other senses do not. Imagine the confusion if the eyes didn't return one image, but produced two different images on the brain. Or, conversely, if we were able to adapt to this, it could open a whole new human capability — if we were able to look at and understand two things at once — read and watch TV, etc.

The theory of perception is also called the "psychological theory of matter," how we take in physical objects in our world. Another relevant portion of Boring discusses John Stuart Mill's postulations about our ability to retain the sensation of objects after they have left our immediate ability to perceive them (229). The simple example offered is of a piece of paper on a table. I can leave the room where the table is located, but still perceive the paper. This is called the permanent possibility of perception. We are not sensing the matter, but perceiving the sensation that represents the matter, the paper in this case. Or, I think there might be a simpler name for this: memory.

> One may be conscious of the possibilities of sensation
> without being conscious of the sensation. (232)

The relevant part in this context is that we can continue to retain the meaning of a graphic after we have seen it. And we can act upon it. A very basic point, to be sure, but a key one in the understanding of graphics.

It seems that one of the things that is relevant is whether a graphic the size of a sparkline is perceived differently than a so-called "full-sized" graphic, exiled to a box outside the text. Does the doctor react differently, or the investor act differently, confronted with one size graphic or the other? Do we perhaps take less seriously the smaller graphic?

An element that is missing from this discussion of perception is the intended meaning of the graphic. And there may be none, but we have to start from the assumption that the other placed the sparkline in her book, or on his website, for a reason. It didn't get there itself. Indeed, it may even have been created by a machine, with no human interaction, if we are to take some of the possibilities of statistical software that have been discussed elsewhere. This possibility raises interesting questions about what would

happen if the machine was to develop artificial intelligence, or self-awareness, as has been discussed by Hayles, (as well as Asimov, among others, in a science fiction context). But that is a digression for another time.

There is a whole body of research that Boring cites, by Hemholtz and Volkman, into the physiology of visual perception: what happens when we see.

2.4 Basis and Image Theory

Image theory consists of five aspects, and each of these in turn are composed of several sub-factors or aspects. Bertin recounts these on pages 140-154:

1. Stages in the reading process:
   A. External identification, in which the reader must identify the components of the image, allowing us to isolate the domain of the information.
   B. Internal identification — the representation of the variables in the graphic, the visual variables. And when a retinal variable is involved, a key must be provided to translate the meaning.
   C. The perception of new correspondences that are conveyed in the graphic.

2. Possible questions:
   There are as many types of questions as components in the information.
   Elementary - On a given date, what was the price of a stock? Group of elements: Over three days, what was the movement of the stock? Overall: During the entire period, what was the trend of the stock?

3. Definition of an image
   The most efficient constructions are those in which any question, whatever it's type and level, can be answered in a single instant of perception, that is in a single image. Multiple images, on the contrary, are "figurations."

4. Construction of an image
   Rectilinear scanning, homogeneous elements, orthogonal construction, or orthogonal differentiation, which I think means distinguishing between two planar systems to facilitate identification, "The image is formed within a homogeneous field, in which any rectilinear scanning, suggested by the construction, groups identical elements. The standard differentiation between two planar systems of identification is orthogonal differentiation." This also touches on learning to read

an image, at the elementary, intermediate, and overall level.

5. Limits of an image:
When the information necessitates more than three variables, we cannot construct a figure which will provide an immediate response to all types of questions. The image will not accommodate the representation of a meaningful fourth variable.

About the first point, I would elaborate by saying that we could not interpret a graphic about stock prices without first knowing what a stock is. And the third point is key, giving voice finally to what is so great about graphics.

In Image Theory, one of the key issues is the levels of reading. There are levels of reading a graphic.

1. elementary reading — one bar on the graph,

2. intermediate reading — looking at several bars at once, comparing, isolate parts of the image,

3. overall reading — taking in the whole; the totality, all bars, and making conclusions from that cluster.

An image can accommodate no more than three variables, Bertin asserts (12). I find this questionable, and some of the discussion that is underway (in the Tufte web boards and in Leland Wilkinson's work, for instance) is trying to solve just this problem. Bertin calls the third dimension "relief representation" (42).

The graphic system Bertin discusses does not include movement. A minor point, (but this is not cinematography), which he describes as an "overwhelming" element. Here's a great point to debate — Numbers would not have been invented if quantitative visual perception had the precision of numerical measurement (48). The implications are bold.

Bertin describes the three types of sign systems.

1. A monosemic system — is one in which the meaning of the sign is known prior to the observation.

2. The second, a polysemic system — is one in which the meaning of the symbols can only be comprehended once the entirety, the collection of the symbols is observed. This quality makes them debatable, which is the key distinction from a monosemic system. I assert that this is the system into which sparklines fall.

3. Then there is a pansemic system, which is meant to signify everything, all meanings are possible. Abstract art is an example of this. (2) This is really not relevant to sparklines.

In these, the prefix of the word indicates the number of interpretations of meanings that can be derived from that system. What this means is that, in a polysemic system, all of the lines in a line graph or bars in a bar chart, or slices of the pie in that kind of chart need to be taken together to derive a meaning. Whereas, the words that I am writing now have a meaning that is defined in a dictionary and in the mind, and comprise a monosemic system.

2.5 Credibility

From a different angle, a case for sparklines can be made for the richness they add to an otherwise dry recitation of numbers and facts. Tufte makes the case in Envisioning Information that a paragraph without substantiation — data, could be a threat to the credibility of whatever the work is:

> Emaciated, data-thin designs, in contrast, provoke suspicions — and rightfully so — about the quantity of measurement and analysis. (32)

I assert that sparklines actually add substance and credibility to a text, by displaying a potentially lengthy series of data, regardless of whether the viewer actually tries to discern those tiny fluctuations.

In addition, I find personally that sparklines add visual appeal by breaking up a block of text.

There is nearly always something to be gained from viewing a graphic, if it is properly presented and clear. And even if it is not, then we learn that we need another tool to understand whatever it is we are communicating about. Whether the graphic communicates its intended message is a different and important question. Consideration must be given to the segment of the population who, through disability, psychological or epistemological traits in the way they receive and process information, do not take away meaning from a graphic, or any written communication.

2.6 Foundations of Graphic Construction

This research into sparklines requires a discussion of the psychological factors that are at work when we *take in* a graphic. This includes the underpinnings and some of the enormous body of research into *how* we learn from graphics. Or, perhaps more fundamentally, *whether* we learn from graphics.

We'll come back around to that subject by first making an exploration into the construction of a graphic - graphic theory.

In Bertin's <u>Semiology of Graphics,</u> he plots out all the constituent parts and means of perception, classification, and construction of graphics. Where Tufte seems a

little glib, but entertaining, Bertin is theoretical, but more difficult and drier (somewhat like Wilkinson).

Bertin's book is essential for anyone who wants to know this subject, but unfortunately out of print. Much of what we need to know flows from him. Tufte "borrows" from it or builds much of what his assertions upon Bertin's earlier work.

First, let's start off with some definitions, at least as they are used by Bertin. Any study of graphics begins with the study of the *information* to be transcribed. *Information* is one of the terms that he gives new meaning to, and has a specific meaning in his context. We might also call it the data, or the statistics, or simply, the numbers.

There is an <u>invariant</u>, which, as the name implies, is the constant in the sign, as opposed to the <u>components</u>, such as value and time, which are the variables of the graphic. Later, Bertin talks about this being the title of the graphic, the one thing that orients the viewer, speeds the perception of the viewer, tells the viewer what she is looking at; the data may be whatever they are, but the fact that we are looking at stock over a period of time, or at the speed of cyclists in the Tour de France will not change.

The most basic element, at least in physical representation, that makes up any graphic, is the mark. Marks are items at the disposal of the designer, which can be either line, point, or area. These must be a minimum of 2 mm to be perceived. The marks are known as the *implantations,* which then are placed on the plane. (But in another place, Bertin says the minimum is 1.5 mm.)

- **Point** has no length or area, but does take up more or less space on the plane, depending upon its diameter,

- **Line** also has no area, but does have a length — a bus route or border of a country on a map are examples,

- **Area** — can change position but cannot change its size, orientation or position without changing its meaning. It's whole point is to display its size.

The *length* of a component is the number of things that component could possibly contain. For many components, the length will be infinite, because we cannot foresee the end of data collection on any particular topic. Conversely, if we are talking about the sex of humans, the length of the component is two (at this time). A small point, but he recommends that these components be labeled in **bold** and CAPITALS. Of course, this does not seem to apply to sparklines.

The *image* in Bertin's context, is the minimum instant of vision that it takes to acquire the meaningfulness of the information (11).

As for the shape and size of the sparkline, the preferred method seems to be that they fall into what Tufte calls the "golden rectangle," referring to the shape of the graphic. He cites Leonard Zusne's <u>Visual Perception of Form</u> for what he calls immense literature on the subject. Basically, horizontal graphics should be 50 percent wider than tall (Tufte's <u>Envisioning</u>, 190). Thus we have the reason for the shape of the sparkline (as opposed to, say, an equilateral) we have seen earlier in this paper:

Related to this is a concept that Bertin covers, **diagonalization,** the tendency of a diagram to move from lower left to upper right.

Obvious? Certainly. But consider that these things did not happen accidentally, but are a result of planar coordinates and Euclidean geometry which will be covered in the history section, chapter 3.

Bertin lays out eight different characteristics or attributes of which a graphic can be comprised. These are the eight visual, or retinal variables of the graphic system:

1. Coordinates on the paper (which constitutes two, the x and y), the plane has the highest level of organization, can represent any of the components.

2. Size,

3. Color,

4. Value,

5. Texture,

6. Shape,

7. Orientation

Graphics can be implanted with these to make distinctions and convey the relevant information. There is no particular significance to the order in which they are listed.

The following chart provides some examples of each:
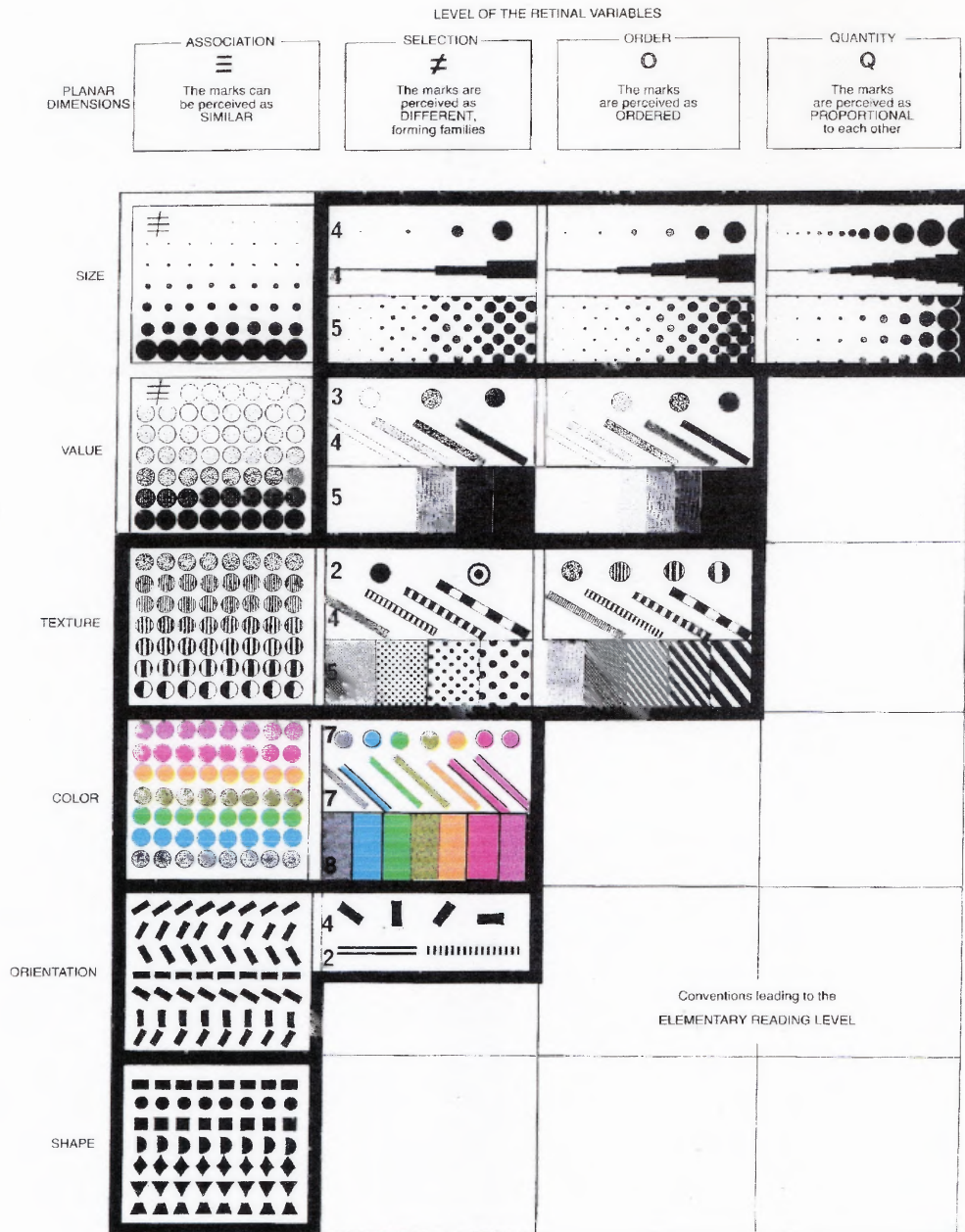
Figure 2.1 Examples of the Visual or Retinal Variables (Bertin, 96).

The two dimensions on the plane are also known as the imposition of the graphic.

The others are also known as retinal variables.

The use of color in graphics will lead to confusion if color does not correspond to a component (46). Also with colors, there is one "pure" instance of the color, when it is at full saturation (85). And this assertion might spark some debate as Bertin says there are only eight distinct colors, all the infinite variations are produced by saturation and hue of the relevant color.

These collectively constitute the *visual variables*. The two planar values constitute two different variables - a horizontal and a vertical property — and are isolated from the other six elements because the latter six can then be "elevated" (42), or superimposed on the planar values to give added meaning. Example: we can have a red (color property) triangle (shape property) at any given planar variables.

Of these visual variables, which he also refers to as "retinal variables," size may be the one that has the most relevance to sparklines. It could be possible, for instance to vary the thickness of a line or a dot to represent a quantitative difference. And quantitative perception is the quality that is most pertinent to sparklines among those that Bertin lays out as the different levels of perception that these variables can convey. He offers this caution, however, and a reminder of one of the weaknesses of the sparkline compared with numbers: "We must remember that quantitative perception represents an accurate approximation but not a precise measurement" (69).

Selectivity, the ability to pick out one variable from another, is at maximum near the fully saturated color; thus fully-saturated colors are the best choice (87). Countering this, the smaller the mark, the less distinguishable the color.

These visual variables are pressed into service for at least two functions, depending on what the designer of the graphic is trying to emphasize:

- **selective** — which is of a certain value? Cities of 15,000, death rate of more than 10 percent, we can make selections among things

- **associative** - what is the distribution of the things?
  With color, Bertin seems to have in mind the cultural or perhaps even instinctive (red=danger) reactions that we may have to color: "Above all, color exercises an undeniable psychological attraction." (91)

A non-ordered retinal variable cannot be perceived in a single image. (158) Shape variation is most useful when the density of the signs is the significant information (95). There can be an large number of shapes that have the same area.

Quantitative perception seems to be the most closely related to sparklines, in the thickness, size, color of the line.

Any other variable combined with a size variation will be dominated by size. "Color, for example, becomes imperceptible," Bertin writes (69).

General Rules of Legibility.

Ten signs (marks) per square centimeter is an upper limit for what humans can perceive, Bertin asserts. But it is a bit more confusing than that, because Bertin also makes the point that there is no upper limit to the density of an image (177). And here I believe he is talking about photographic images, which can support endless examination and study of details.

As to angular legibility, (the curve or angle that scale provides the best legibility for the graphic), near 70 degrees is optimal, at least for elementary reading. For retinal legibility, about 5-10 percent of the plane in black promotes accurate reading of the graphic, so that we can distinguish between one element on the plane and another (181).

The following is a summary of Bertin's conclusions about legibility:

- Overall figure should tend toward the form of a square or rectangle. Ratio not to exceed 1-2, generally.

- The entire range of visual variables should be used, up to 5 -10 percent black.

Graphic density can be high (a recommendation repeated by Tufte).

- Best visual selection is produced by the plane, and this speaks to why line graphs work so well and bodes well for sparklines.

- The number of steps of retinal variables should not exceed five (five shapes, five colors, five textures).

- Separable shapes should be at least 2 mm.

- Redundant combinations increase the separation between steps of retinal variables.

- Variety in implantation creates the best differentiation. This sounds very much like the point about the plane. (190)

The process of construction consists of two steps:

1. Determine the form of representation,

2. Record the correspondences,

For pointed curves, the scale of quantity (Q) should be reduced (to flatten the curve). For flat curves, the scale of Q should be increased to make the curve more pronounced.

The key, always, is to show the scale. You are relying on the reader to take note of the scale, and if it changes you can get into a misleading situation. This could be a real problem with sparklines, which don't have scales inherently.

General Rules of Construction:

1. Present the information in a single image, or in the minimum number of images needed.

2. Simplify the image without reducing the number of correspondences. (This ties into Tufte's ideas about revealing complexity — showing the depth and breadth of the data.)
3. Simplify the image by reduction and thus create a clear and efficient message. Removing clutter, getting the message down to its essence, another of Tufte's principles, data ink ratios.

"In a signifying space, absence of signs signifies absence of phenomena" (46). Bertin also makes the point that an absence of data — unknowns or missing data — must be clearly marked as such, and made clear; otherwise the lacuna might be interpreted as null value in that place.

Bertin recounts George Guilbaud characterizing visual forms by these two characteristics:

- **Connectivity** — homogeneous, not having gaps
- **Convectivity** — being delimited according to the convex angles; a line crosses only once, a uniform area. (166)
Any visual simplification will tend toward these two characteristics.

Bertin constantly refers to line graphs as diagrams, to distinguish them from maps.

One caveat about Bertin, however, is that none of his assertions are cited or annotated. There are no references to any of the things he says, and he mentions only a handful of other theorists who came before him. I don't know if we are to take from this that he is making all these assertions himself, or, as I am doing in this thesis, summarizing what is known to this point (with the key difference that I am using citations). Much of what Bertin says has the "ring" of truth to it, but it is hard to believe that neither he nor his editors or publishers had a concern about citing the previous work.

2.6 Effectiveness of the Graphic Elements

To explore the effectiveness of some of these graphical elements, I turn now to the research of William Cleveland and Robert McGill. They found that perceiving "position along a common scale" is the first distinction that we humans are able to make when viewing graphics. Line graphs, the most analogous graphic to sparklines, placed squarely in the middle of the results of graphical perception accuracy.

Leland Wilkinson reproduces Cleveland's results as follows:
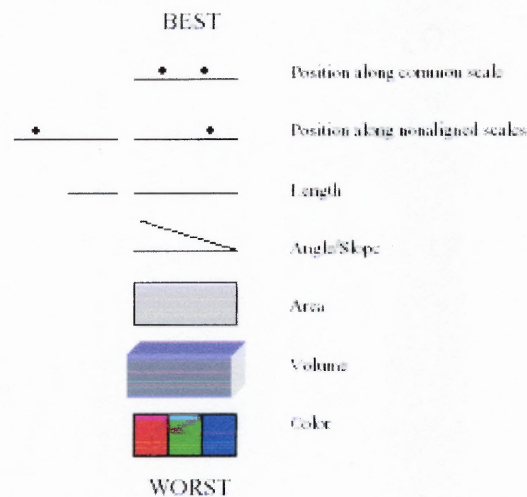
Figure 2.2 Perception of Different Graphic Types (Wilkinson, Presentation Graphics, 5).

Wilkinson cites the Cleveland experiments as the impetus for psychologists to turn their attention to statistical graphics perception. Their research dealt with testing to see which graphing elements produced the highest percentage of errors in perceived versus actual answers. This finding bodes fairly well for sparklines.

If we take the Tufte example of a glucose reading, as above, and establish clearly in the text that the scale is, say, 100-200, and the length of time is six months, then it is

valid to conclude that a medical professional or layperson reading this data would be able to understand the fluctuation in glucose over the given period.

There may be a learning curve, but it is likely that the scale becomes inherent and second-nature with repeated use.

Of course, scale is everything. Because there is no room in the sparkline itself to display scale, it must be established up-front, in the text. It may be just as easy to display the graph separately, with the scale displayed along the x and y axes, instead of having to write about it in the text. But if sparklines become common usage, conventions for scale may become inherent in whatever discipline they are used.

We can take a further step into the construction of sparklines, and what it is about them that works, by looking at some of the rest of Cleveland's results. While cautioning that further experimentation is necessary and that some of his ordering is based on conjecture, Cleveland (830) lays out the accuracy perceptive tasks like this:

1. position along a common scale

2. position on identical but non-aligned scales

3. length

4. angle

5. slope

6. volume
   density (tie)
   color saturation (tie)
7. color hue

Cleveland and McGill continue:

> The ordering provides a guide for data display that results
> in more effective graphical perception. (833)

Options should be selected that result in perceptual tasks as high in the ordering as possible. This increases the accuracy of our perception of important patterns in the data. The ordering does not result in a precise prescription for displaying data but rather is a framework within which to work (830).

In other words, when presenting data, we should choose from this list, in the order that will work best with our data. These prescriptions could be synthesized with Tufte's pronouncements for data presentation, which are more in the realm of graphic design, to create "perfect" graphics.

Clearly, sparklines incorporate many of these qualities, further buttressing their viability in terms of conveying information. Furthermore, Cleveland and McGill say elsewhere, "Our visual system is geared to judging angle rather than slope." Cleveland is somewhat the "hard science" counterpart to Tufte, laying out at least some statistical bases for his pronouncements.

Wilkinson has a novel take at information graphics, approaching them from three innovative vantage points:

1. Geometry

2. Coordinates

3. Uncertainty

This examination is intended to evaluate the effectiveness of the various forms of graphics — how well they convey various types of information. In geometry, he looks at the various forms that graphics can take, and displays how those graphics are perceived, based on their various shapes. For coordinates, he is looking at the points, as in a scatterplot, that result from certain types of data. Uncertainty, the slimmest of the three,

demonstrates the nonetheless important concept of embodying the possibility for error in the graphic.

Williams and Harkus would classify a sparkline as a "non-representational" graphic, by which they mean that it does not depict what it was intended to depict, in the way that a guidebook to trees would depict each different tree.

Setting out from my desire to convey information quickly and succinctly, this chapter has briefly discussed the ways that we, as humans, perceive information. There followed some of the theory behind graphic and means of graphic construction, some of which inform and apply to the creation of sparklines. The perception and graphic construction elements are tied together in Cleveland's study of which graphic elements are most effectively picked up.

CHAPTER 3

GRAPHIC HISTORY

This section will demonstrate a historical context for sparklines, displaying their ancestors and use in other forms under other names.

Wainer correctly advises:

> A great deal is known about display, but there is much that
> is still shrouded. Progress is best made if we learn what is
> known and proceed from there. (346)

I turn now to a survey of the history of graphics. This brief overview proceeds roughly chronologically, with a significant exception explained at the end of this section.

Without digging too far into prehistory to the paintings of cave dwellers, or hieroglyphics that Funkhouser mentions (269-270), I restrict myself to printed works. While they certainly have a role in the entire development of the graphic method, it is the printed materials that are most relevant. Perhaps a little narrowing or boundary-setting of the topic is in order. My focus here is on graphics that are intended to convey information, largely data displays. Even the most abstract art conveys a message, as does a commercial advertisement, but the intent here is to look at information graphics, the kind that would be most relevant to technical communication, including bar graphs, pie charts, diagrams, cartographic displays, and line graphs, the species out of which the most common examples of sparkline arise. There are surprisingly few histories of graphics, and only in scholarly articles, or sections of books about other topics. The history of graphic display has not been given book-length coverage (though Gray Funkhouser's

136-page treatise comes close). This is territory that has been covered, but not exhaustively, and is still ripe for exploration.

Some of the works are not available in English. Several of the authors I will discuss mention E.J. Marey's _Le Methode Graphique dans les sciences experimentales_ by, which rose out of the flourishing French data graphics that will be covered below.

Leland Wilkinson, developer of the SYSTAT computer program, lays out a concise, excellent history of graphics. He points out the interconnections of the language that is related to the graphic practice — that the Latin root of _chart_ and _cartography_ are the same — _charta_ — meaning sheet of paper. Wilkinson also points out that the word _state_ and _statistic_ are from the same root.

Just as the desire to record and collect known facts led to the development of writing, so did the resulting desire to display more numerous, detailed, and complicated information naturally lead to the development of graphics. Beniger and Robyn make the point: "Statistical graphics, beginning with simple tables and plots, date from the earliest attempts to analyze empirical data" (1).

3.1 Leaps in Graphic Development

Wilkinson lays out a series of "remarkable leaps" that occur in the development of graphics — from a world of continuous rectangular (or spherical) space to other worlds that are categorical (worlds with gaps), multidimensional (worlds beyond three dimensions) and topological (worlds in abstract coordinate systems)" (2).

Similarly, Beniger and Robyn chart four major problems that had to be overcome to arrive at the present state of graphic depictions:

1. spatial organization

2. discrete comparisons

3. continuous measurements

4. multivariate distribution and correlation

To cover each of these briefly, we find that Edmund Halley, (of the comet) was in the 1600s one of the first to employ the spatial organization techniques. These are the Cartesian coordinates discussed below, and Halley, a scientist of impressive reach beyond astronomy, used them to map magnetic forces of the earth (Beniger and Robyn 2).

In discrete quantitative comparison, we find the basis for much of the analytic tools that Tufte, Tukey, Cleveland, and others have explored so thoroughly: This is the simple comparison of x with y. This becomes fully realized until the comparison of multivariate data, in step four.

Continuous distribution was made necessary by the preponderance of vital statistics. The first graphics of this type had for their subject topics like crime statistics and the population of Paris by age groupings. Beniger and Robyn's description(4) is a little hard to follow. But these types of graphs stacked, for instance, the population of one age group on top of another, and so on, to display the sizes of each group.
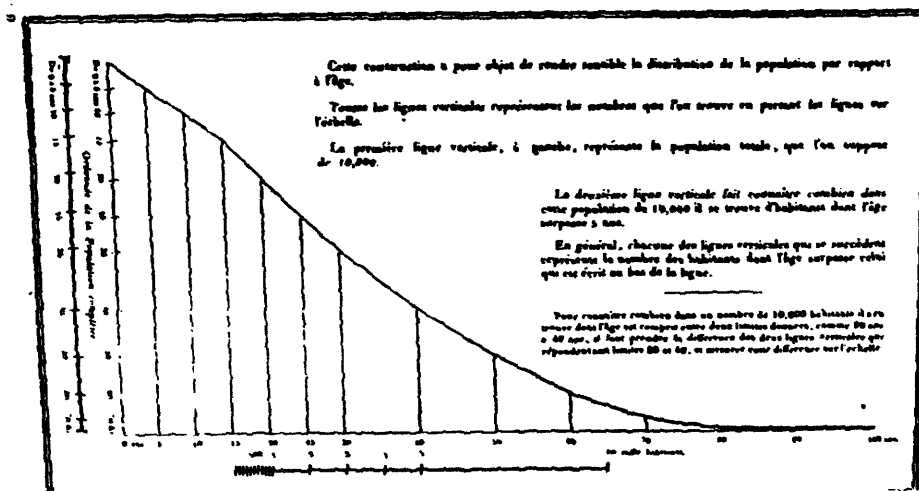
Figure 3.1 J. B. J. Fourier's graphing of the population of Paris by age grouping, (Beniger and Robyn, 4)

The innovation in J.B.J Fourier's 1821 chart above (though likely impossible to see as reproduced here) is the stacking of different age categories on top of one another, along the x axis, revealing the continuous distribution of these age groups.

The "ogive" and the histogram are examples of this form.

The fourth problem identified by Beniger and Robyn was an exponential expansion of the problem solved in point two, in which bi-variate data were expanded to three dimensions. Thus we have today the three-dimensional graphics that produce a "surface," much like a landscape, that can show the variation of data and comparison in relation to one another, or three sets of data.

Wilkinson, citing Beniger and Robyn, points out that Egyptians seem to be the first to use coordinates, in their surveying process (perhaps the first example of technical communication?). This dates back as far as the third century B.C.!

3.2 A Place to Put Them: Coordinates, Grids and Planes

It may seem no great advance now, but how would a scientist or statistician even know where to place the graphic? We owe our taken-for-granted system of x and y axes to Descartes, in laying out the Cartesian grid. He did this to lay out points in abstract space. Aside from his fundamental philosophical contributions, Descartes was also a mathematician. And this plotting system, dating from the 1600s, was itself an evolution of Euclidian geometry. It's hard to imagine now, but even this simple idea of a line meandering across a rectangular space would not be possible without Descartes' grid, as Funkhouser tells us:

> Descartes...great contribution to mathematics lies in his showing in a general manner how a curve can be characterized by its equation, that is, by the relation which exists between the coordinates of each of its points, and how every equation can be represented by a curve. For the statistical graph the principle of coordinates and the idea of functionality are sufficient. (Historical Development of the Graphical Representation, 277)

While Descartes may be responsible for his namesake plotting system that is now familiar to us, Funkhouser cites an even earlier example of a grid, from the 10th or 11th century, which was an early astrological attempt that endeavored to display the motion of planets. Looking carefully, you might just be able to make out the names, above each star-shaped figure at left, of Venus, Mercury (MECVR), etc.
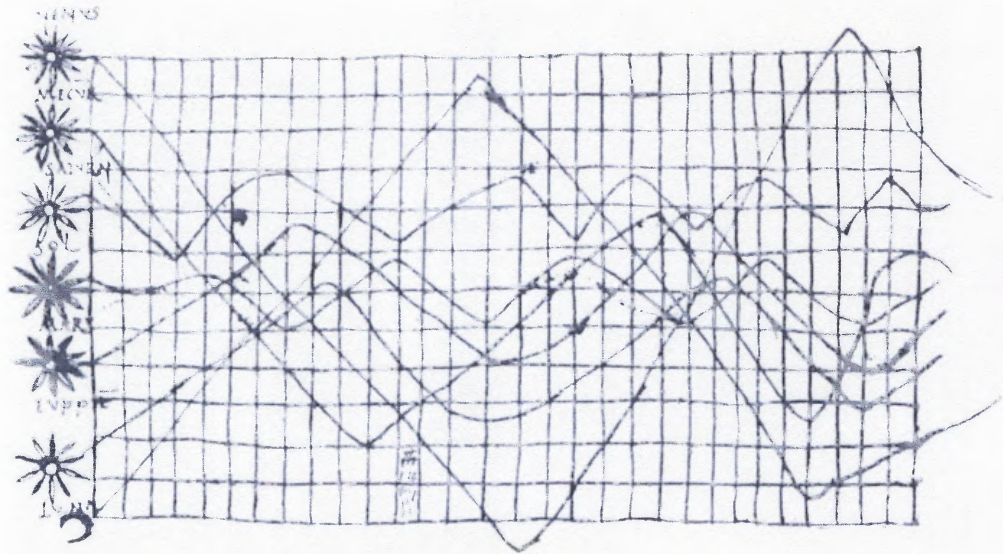
Figure 3.2 Example of early grid showing planetary movement, (Funkhouser, <u>Note on a Tenth-Century Graph,1</u>).

Based on this grid, Funkhouser summarizes the history:

> The use of a coordinate system as a field of operation for the study of curved lines occurs in the Middle Ages; analytic geometry was invented by Descartes in 1637; the beginnings of statistical compilation occur also in the Middle Ages; the final step was taken in 1786 by William Playfair who may be called the father of the graphic method in statistics. (273)

While Descartes paved the way, and had a foot in both the "soft" sciences, like philosophy, and the hard science of mathematics, he was the exception. Social sciences are actually the least frequent discipline to use graphics in journal articles. They devote the least amount of space to graphic displays, as compared with the broad categories of physical, mathematical, and life science journals, as discussed in William Cleveland's 1984 study.

The advance of the production of graphics, as Michael Friendly and Daniel Denis recount, begins with graphics are drawn individually, by hand, one for each book. The

labor is impressive, mirroring the monks toiling over the medieval illuminated manuscripts.

The huge innovation, as Walter Ong has ably described, is the printing press, in 1430. Its effect on civilization as a whole cannot be overemphasized. It seems a slight to this absolutely crucial development to spend so little time on Gutenberg's innovation, but the press was not devised specifically for graphics, and in one respect, did not encourage their spread.

As Bolter has pointed out, the divorce of graphics from text was a development that accompanied the printing press. If we look back to the medieval monks and scriptoria, we see evidence of the infusion of pictures among text.

3.3 Data Graphics

The development of data graphics comes shortly after the rise of the science of statistics, and the growth and development of the two disciplines can be seen to run somewhat parallel. Graphics, however, have not often been held in high esteem.

The term *statistic* came from German vital statistician Gottfried Achenwall, but his usage around 1719-1772 derived largely from numbers relating to the *state*, the government. He meant it not in the sense that we use statistics today, and Funkhouser says that Achenwall has no business being called the father of statistics. Predating Achenwall, however, is "political arithmetic," a term coined by William Petty shortly after 1662 (291).

While Funkhouser is the primary historian of what he calls the graphic method, his reach is entirely Euro- and New World-centric. It is entirely possible that William

Playfair in the late 1700s is the originator, but Funkhouser does not mention other cultures. He does not seem to have explored ancient Arabic, Indian, or Oriental texts.

To establish the approximate age of the "graphic method," the earliest examples of graphs used to convey information have been tracked down by Funkhouser, Tufte, Wainer and others, to Englishman William Playfair and his 1786 <u>Commercial and Political Atlas</u>.

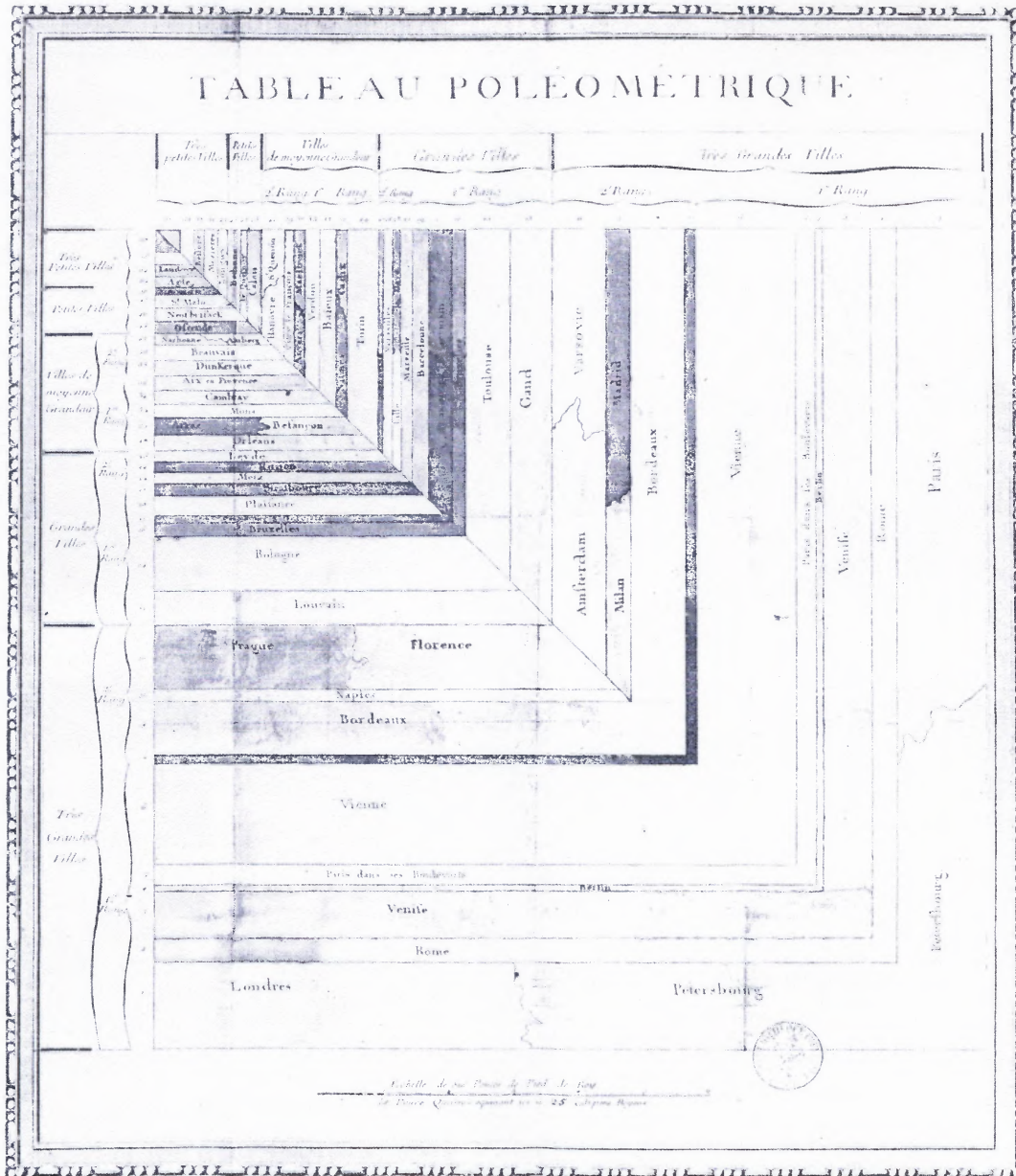This intriguing gem, however, appears to be older than Playfair's, dating from 1782:

Figure 3.3 Table of cities (Bertin, 202).

In this, from Bertin's <u>Semiology of Graphics</u> (202), the areas represent comparative size of many European cities. It reveals quickly how cities compare with one another. We can see, for example, that Venice is larger than Rome. Interestingly, this graph is oriented down and to the right, rather than the traditional up and right, as we see

in most graphics. Also, there appear to be no German or Nordic cities in the graphic, a curious omission. In any event, this seems to pre-date Playfair.

Playfair was influenced by and has acknowledged a predecessor, chemist Joseph Priestley (1733-1804), according to Wainer and Veleman (313). Priestley created a chart showing lifespan of some 2,000 famous figures in history (chosen by Priestley). This was likely the first instance of what we now known as a bar graph, but it is not considered of a kind with Playfair's work because it was not really *statistical* data. Nevertheless, Priestley's is an important development, Funkhouser asserts, because it may have marked the first time that anyone conceived of showing *time* as a line moving left to right across the page or graphic space. This trait is so inherent in line graphs that it seems to be taken for granted, yet is so crucial to the most common form of sparkline.

Beniger and Robyn also cite Priestley's time lines as one of the major breakthroughs in graphic development (3). From Priestly, it is a small but significant leap to Playfair, who brought the form into its modern use.
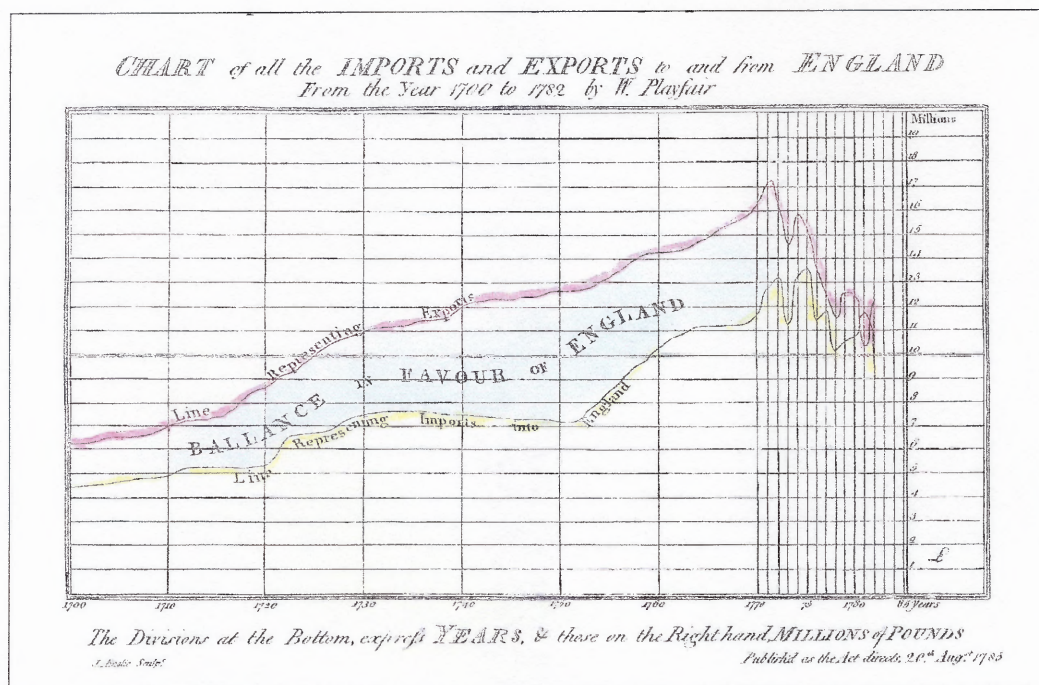
Figure 3.4 One of the earliest data graphics, by Playfair (Tufte, <u>Visual Display</u>, 32).

Playfair, incidentally, called his creation "lineal arithmetic."

He used the comparison technique (the third major development cited by Beniger and Robyn) to display trade imbalances of England and similar economic data of his day. It might not be too strong a comparison to say that Playfair's innovations are for graphics what the internal combustion engine is for the automobile. Playfair's moving to line graphs was a step away from plotting points in space (Halley, Descartes, the Egyptians) and time (Priestley) to simply show the data, as Tufte advises. As with Descartes, it is difficult to appreciate today what a breakthrough this was, we are so inundated with these types of graphics.

Funkhouser argues that because Playfair's positions were unpopular to the British government, his work was not circulated or celebrated. Though not elaborated upon by Funkhouser, looking at Figure 3.2, we see exports dropping off markedly and imports

rising and closing the gap between exports. This could not have been news that those in power would boast of. Though Funkhouser does not say this, one can speculate that a factor may also have been that the graphic was simply so new. The most similar thing to a data graphic that many at the time would have seen would be an illustrated children's books, which might have been the reason Playfair's work was at first sniffed at.

French designers took up the practice, in the mid-19th century, of expanding and realizing the potential of graphic displays. They begin to spread the practice.

Playfair's work, however, already realized a fairly mature version of what his successors would produce. According to Funkhouser,

> He presented his graphs in so finished a form that later writers have not materially improved upon his method. (287)

> Playfair first published his many excellent examples of the line graph, circle graph, bar graph and pie diagram and accompanied them with pointed expositions of the advantage of the new method for the discovery and analysis of economic trends. (280)
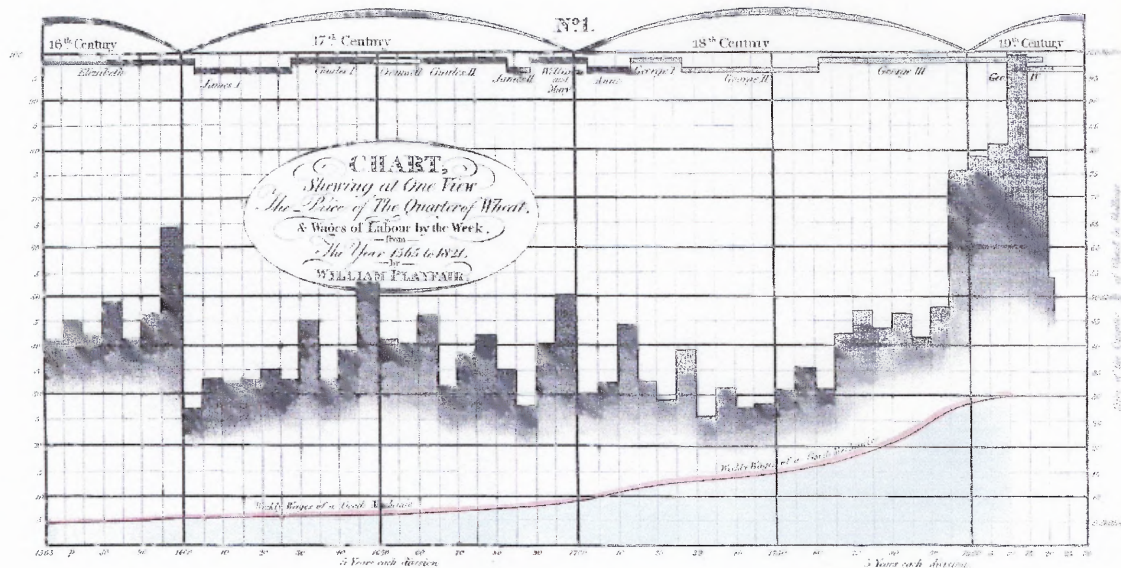
Another graphic from Playfair:

Figure 3.5 Playfair's comparison of wages and the price of wheat (Tufte, <u>Visual Display</u>, 34).

The graphic above, also from the 1786 Commercial and Political Atlas, shows, in the bars, the price of wheat in England. The line near the bottom displays the wage of "mechanics," which Playfair defines as carpenters, masons and similar tradesmen. Along the top are the kings of England. This graph covers a nearly 300-year period!

While the first data graphics are attributed to Playfair, there is a caveat: Funkhouser speculates that it is reasonable to assume that meteorological data would likely be the first example of a statistical graphics, but his 15 years of study failed to uncover one, yielding to Playfair the claim of the first statistical graphic.

3.4 The "Golden Age"

Funkhouser recounts that the graphic method is slow to take hold. Playfair's influence is not felt until the middle of the 19th century, when it is picked up by the French.

> The development of new graphic forms and the
> popularization of the graphic method were largely due to
> the efforts of the vital and moral statisticians and to the
> work of French engineers engaged in public works and
> transportation. (309)

Funkhouser crowns the era from 1860-1890 the "golden age of graphics," though

he does not show many graphics from this time to support this title.

> After 1850 the graphic method gained rapidly in
> momentum. In addition to its more serious applications in
> the study and analysis of statistical data in the work of
> professional statisticians, it became a fascinating plaything
> in the hands of many others who had little or no statistical
> training. (329)

Chief among these French practitioners of the graphic method was Charles

Minard, whose cartogram of Napoleon's fateful 1812 march to Moscow has been cited,

most notably by Tufte, as one of the most important graphics ever created. Unlike

Playfair, whose ideas were unpopular, "Minard won the approval of his sovereign, the

esteem of his contemporaries, and the official endorsement of government agencies"

(305).

There is some possibility of cartograms pre-dating Minard's, but they apparently

have not survived.

In the years 1853 to 1876, several International Congresses of Statistics were held

in major European cities, and Funkhouser says these "played an important part in the

development of the graphic method" (310). These gatherings were prompted by a

burgeoning interest in the field of statistics at the time.

He recounts the major resolutions, as these congresses called them, at various

times, for creativity, but also for standard uniformity. They suggested, for example, the

creation and adoption of a standard set of curves that would be used on all graphs (315-

319). They also seemed to observe the adage from Ecclesiastes that there could be nothing new under the sun, and asserted that the highest evolution of the form had been realized in their era: "All the graphic methods enumerated already exist and it is unlikely that a completely new one will be invented," as Funkhouser quotes the Vienna International Statistical Congress of 1857 (312).

In America, there is little to speak of in data graphics before 1850. But Funkhouser singles out a statistician of the U.S. Census Bureau, Henry Gannett, who "made the widest and most effective application of the graphic form to census figures" (342).

A significant development is the creation of three-dimensional graphics, with three variables, comes about with Gustav Zeuner and several other statisticians, circa 1865-1880. An example, perhaps the first, is the "stereogram" of Luis Perozzo in 1879, as depicted in Figure 3.5. It depicts the growth of the population of Sweden.
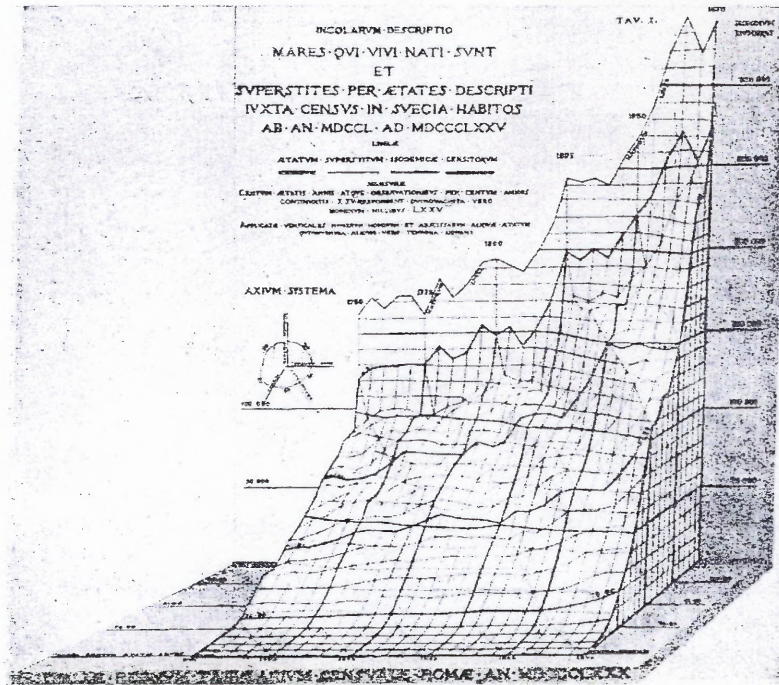
Figure 3.6 Possibly first example of three-dimensional graphic (Funkhouser, 353).

3.5 The Modern Era

Pointing to the specialization as well as the growing popularity of the display of graphical information, Funkhouser reports that around the 1930s, an American company was formed that would provide statistical graphs.

Advances in printing technology would make the mass-production and dissemination of graphic material in books less expensive and more widely available. But the basic method of creating a graphic remains static at this time: Drawing by hand, on paper, for transfer to a photosensitive plate. There are no accounts of advances in the graphic production methods until the advent of computers, which finally bring the creation of graphics to the masses.

At present, we enjoy the easiest production methods, with today's computer visual and publishing software such as Microsoft Visio and Adobe Illustrator, requiring no manual labor except for keystrokes or mouse clicks. The latest programs are endlessly customizable, enabling users to manipulate the data and create their own representations of it.

Purposely left out from this little history, until now, is perhaps the most important example that is cited here. It comes via Tufte. And it makes a case that the concept that we are now calling sparklines predated even Playfair's statistical displays. An earlier ancestor may be found by going all the way back to one of the first scientists, Galileo. In the epilogue to <u>Envisioning Information</u>, Tufte writes of Galileo's drawing his telescopic observations of Saturn directly into his Latin text, and thereby drawing in the reader:

te,perche fendo la figura di Saturno così ⊙⃝ ,come moſtrano alle perfette viſte i perfetti ſtrumenti , doue manca tal perfezzione apparifce così ⊂⊃ non ſi diſtinguendo perfetta-

Figure 3.7: Galileo's text (Tufte, <u>Envisioning Information</u>, 120).

Tufte explained the significance

> In 1613, when Galileo published the first telescopic observations of Saturn, word and drawing were as one. The stunning images, never seen before, were just another sentence element. (120-121)

Thus, Galileo may have been the first practitioner of the concept that is remarkably similar to what Tufte has now dubbed the sparkline. This evidence suggests that a precursor existed even before the advent of what we have come to know as information graphics, the familiar bar graphs and pie charts that infuse so many of our textbooks, newspapers and magazines, and now electronic media such as television news and the Internet.

CHAPTER 4

ETHICS

Figures don't lie, but liars figure.

The old saw takes on new meaning in the consideration of sparklines, which are literally *figures*, in the sense of pictures, unlike *figures* as numbers.

Of course the cliché has some truth in it, and can be taken as cautionary advice. And there is some literature to support the saying.

Let's not lose sight of the obvious by stating it: Tell the truth, whether with words, or numbers, or graphics. The same principles apply to graphics as to written communication. We need to make sure that our graphics are accurate and complete. Sparklines introduce another pitfall in that technology will almost certainly be involved, so the user should be sure that his sparklines are produced from sound math and software. We also need to ensure that sparklines are used properly and fairly, with no bias.

It is certainly possible to use sparklines, or any graphic, to make mischief and distort the truth. The person with a strong opinion could change the scale of two sparklines without informing the viewer, for instance, which is a blatant violation, to cast one point of view in a more favorable light.

The basic technical writing texts typically include these and other cautions, such as sins of omitting data. As this, from Rebecca Burnett's Technical Communication:

> Omitting certain data that would detract from an honest
> description of your engineering design isn't cricket. One
> example is the omission of outlier points from a graph
> because they wouldn't look good.

Tyanna Herrington examined the effect that graphic design could have in a report on the Bureau of Alcohol, Tobacco and Firearms' handling of the Branch Davidian standoff in Waco, Texas, in 1993. She demonstrates how use of typography and design choices could affect the message conveyed by graphics. These are fairly simple graphics, as tables, but they have the effect of summarizing, of standing out to the viewer, moreso than straight text. Looking at the tables below, in figures 1-5, we can see that the ATF details come first. Next, notice that the ATF individuals are listed in a mix of upper- and lowercase text. Third, there is an extensive listing of AFT injuries (including one injured by his boot), while there is no similar list for the Davidians. Lastly — and we could continue with this analysis — the heading of the AFT information is larger than the Davidians'.

GUNSHOT RELATED DEATHS SUSTAINED BY ATF ON
FEBRUARY 28, 1993
(according to Court Forms submitted by ATF)

	Name	Team	Injury	Cause	Hospital where treated
1	Conway LeBleu	NO	Death	Gunshot	N/A*
2	Todd McKeehan	NO	Death	Gunshot	N/A*
3	Robert Williams	NO	Death	Gunshot	N/A*
4	Steven Willis	HOU	Death	Gunshot	N/A*

GUNSHOT AND SHRAPNEL RELATED INJURIES SUSTAINED BY ATF ON
FEBRUARY 28, 1993
(according to Court Forms submitted by ATF)

	Name	Team	Injury	Cause	Hospital where treated
1	Clayton Alexander	NO	Two gunshot wounds - high in left leg, high in right leg	Gunshot	Providence
2	Roland Ballesteros	HOU	Gunshot wounds to the hand	Gunshot	Hillcrest
3	Bill Buford	NO	Gunshot wounds to both legs	Gunshot	Hillcrest
4	Samuel Cohen	DAL	Shrapnel fragments to lower right thigh	Shrapnel	Hillcrest
5	Eric Evers	HOU	Gunshot and shrapnel wounds to knee and cheek areas	Gunshot, Shrapnel	Hillcrest
6	Mark Handley	HOU	Shrapnel wounds in right leg	Shrapnel	Hillcrest
7	Walter Glen Jordan	NO	Gunshot wounds to both legs	Gunshot	Hillcrest
8	Kenneth King	NO	Gunshot wounds to arms, chest and legs	Gunshot	Providence
9	Mark Murray	DAL	Buck shot wounds in left shoulder	Gunshot	N/A*
10	Gary Orchowski	HOU	Shrapnel wounds to the right hand	Shrapnel	Hillcrest
11	Joseph Patterson	DAL	Shrapnel wounds in right cheek	Shrapnel	N/A*
12	Keenan Perris	DAL	Shrapnel wounds to right hand, wrist, to waist and left upper arm	Shrapnel	Hillcrest
13	Clark Rayburn	HOU	Gunshot wound to the hand	Gunshot	Hillcrest
14	John Risenhoover	HOU	Gunshot wounds to both legs	Gunshot	Hillcrest
15	Robert Rowe	HOU	Shrapnel wounds in right hand, large shrapnel on face	Shrapnel	N/A*
16	Michael Russell	DAL	Wound to back of left shoulder	Gunshot	N/A*
17	Larry Schroer	HOU	Multiple shrapnel wounds to left knee and groin, stray rocks to left medial foot, and tissue injury to left fingers	Shrapnel	Hillcrest
18	Steven Steele	DAL	Shot in lower lip and left hand, injury to lower back and left leg	Gunshot	Hillcrest
19	Robert White	DAL	Bullet wound in left shoulder, neck and bruise to right arm	Gunshot	N/A*
20	Curtis Williams	HOU	Bullet fragments and puncture wound to upper thigh of left leg	Gunshot	N/A*

*N/A means Not Applicable; treated by EMT at scene, or by private physician.

Fig. 3.

Figure 4.1 Alcohol Tobacco and Firearms Table, from Herrington, Ethics and Graphic Design.

Figure 4.2 ATF table, Davidians, from Herrington.

Figure 4.3 ATF table, injuries to agents, from Herrington.

One is led to ask: Why would the tables be constructed differently?

Herrington makes this general point:

> A deceptive communication, regardless of motive or utilitarian justification, is unethical and should have no place in acceptable technical communication. (153)

Her instruction:

> Technical communicators do have the opportunity to consider the ethical consequences of their graphic choices. For this reason, technical communication instructors and writers of technical documents should scrutinize the possible effect of the graphic selections available and make considered judgments for their use. (156-7)

Quoting J.E. Porter, Herrington notes:

> Ethics is not a set of answers but a mode of questioning and a matter of positioning. That questioning certainly involves principles-but it always involves mediating between competing principles and judging those principles in light of particular circumstances. (153)

Herrington starts by discussing a framework of standards developed by Ng and Bradac which include "masking," or making things seem other than what they are in reality. She also cites a couple of principles from Craig's <u>Designing with Type</u>, including :

- all uppercase letters are more difficult to read,

- material after a heading is read most closely, while material further down is skimmed,

- white space surrounding a text passage emphasizes it.

The first is certainly not applicable to sparklines, but the second and third principles could be applied. We should be mindful of these principles. The zealot looking to emphasize his position would put the sparkline with the favorable data soon after a heading, while the unfavorable data would be buried down in the material, if presented at all. A paragraph containing a sparkline with a desirable point could be isolated on the page, while undesirable sparklines could be de-emphasized by placing them in a large block of text.

Sam Dragga and Dan Voss have written of the potential "inhumanity" of graphics, urging the adoption and practice of "humanizing" graphics. One of their examples is the famous Minard graph of troops lost in the Napoleonic invasion of Russia — the soldiers who perished in this ill-fated campaign. They later expanded this argument to extend to accident investigation reports, both industrial and vehicular. They state their central proposition this way:

> We believe the practice of communicating statistical or technical information regarding human lives with utter indifference to their humanity is both biased and unethical (61).

Some of their ideas include adding photographs and more personal information of victims to accident reports, be they industrial or motor vehicle. They think that the location of those stricken in, say, an oil refinery disaster should be indicated with bodies, rather than callous, unrepresentative X-es.

There is certainly no direct reference to sparklines in Dragga and Voss, and it is somewhat difficult to imagine that their argument could be extended their to these word-sized graphics.

There are problems with their entire proposition. If we are duty-bound to follow through in every instance on their admonition to "humanize" every graphic, size should not matter, and we would have to do the same with sparklines. This is impractical. We would be hamstrung by trying to fit tiny little people into our graphics.

A graph is meant to display data, whether human lives lost in an accident or number of grains of sand on a beach. There may be no way around this problem. Given the size of sparklines, there seems to be no way to "humanize" these graphics. Any such endeavor perhaps should be undertaken with an idea in mind of the purpose of the

graphic, and possibly the audience. If we were looking to persuade, then perhaps this humanization of graphic would be acceptable and effective. But many kinds of scientific endeavors and investigations would seem to require an objectivity that could be negated by such humanizing.

Voss and Dragga seemed to anticipate this argument:

> It might be said that humanizing accident reports introduces emotions or feelings that can distract the reader from the technical information. ...The real objection here is to the specific emotions or the level of feeling that a humanized accident report might arouse...Indeed, the deliberate omission of the human element in the interest of scientific objectivity actually defeats its purpose by communicating an incomplete picture." (77-78)

But where is the balance? This kind of thing might be appropriate for accident reports, and all well and good, but to carry this argument any further would be stretching its usefulness. Or consider the application of humanizing in a legal context. Naturally, plaintiff's lawyers will want to use the most personalizing and heart-wrenching humanizing presentation of their case, and have every right to do so. But what recourse or ability to counter would the maker of a product that is under fire, or the defendant in an accident, have against these techniques? The association alone with these kinds of tactics makes humanizing suspect, in my view.

I have little patience for this king of hand-wringing, and I believe there is scant room for it in technical communication. Their point bears consideration, and one should to be mindful and sympathetic, but our task is to convey information. The concerns of the impact on the viewer is too much an "eye of the beholder" situation to leave to expend much effort and time upon. One viewer's humanizing might be another's bias-peddling.

Furthermore, that a certain objectivity about the data can be a good thing. Children are used constantly in controversies such as abortion regulation and school funding. But public policy decisions based on graphics comprised of cute little kids, might not result in the best decisions. A level of detachment from a subject is often a good thing.

CHAPTER 5

CRITIQUES

This section will cover some of the drawbacks of sparklines, so that potential users can make an honest assessment of the limitations of this method and make an informed decision about their use. A discussion of these issues might even suggest solutions to some of the problems of sparklines.

One of the major problems that has been pointed out with sparklines is their inherent lack of perspective, floating as they are in space among words. The lack of x and y axes deny the viewer a clear perspective of where the data fall. But, to qualify this objection, the words themselves give a point of reference to these squiggly lines. The words, with their short bursts of horizontal and vertical lines, give the sparklines some grounding, a grid on which to convey their information.

In their paper on visual editing, Williams and Harkus (as well as Bertin and others) suggest a means for the viewer to determine scale. It would seem that sparklines, as stand alone objects, fail at this quality. There is no room to provide the gradations of the x and y axes. One move toward overcoming this problem, however, is the gray band that represents a "normal" range, when viewing medical data.
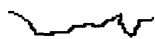
This could be adapted to fit financial data, to depict the average or median performance of an entire market or class of stocks.

This criticism also misses one of the major points of sparklines: they are not able to convey precise information, but can show general trends — up, down, or steady. The

readers should have the ability to retrieve the actual data individually if they choose. But the beauty of sparklines is that they enable a viewer you to see a "forest" view of the data, what the trend has been, where this is headed, how it compare with other entities, etc.

Tufte seemed prepared for this issue: "Too often epidemics of data-imprisonment and decorative gridding break out when contemporary commercial designers are faced with information."

In posting to "NEW... Sparklines---new revised draft from Beautiful Evidence" boards on his Web site, Tufte wrote:

> Background colors, frames and boxes don't add much.
> Avoid all data frames; the physical location of the numbers,
> words, and graphics enforces the implicit grid; that grid
> never needs to be expressed directly.

A problem that may not be so easy to get around is the outliers, anomalies in the data. Tufte points out that these are a problem in most statistical graphics, and he suggests broken graphs as one possible solution. For data with outliers, sparklines simply can't be used, for the scale that would show the extreme examples could produce a sparkline so jagged, or out of proportion, as to produce a misleading analysis. Or there would be the temptation to shift the perspective of the sparkline, which leads to a skew with other sparklines and the ethical problems discussed in the previous chapter. For data with outliers, the user might have to return to the traditional modes of display. To do otherwise might represent changes in scale that would be disorienting.

One of the limitations encountered firsthand was the inability of sparklines to cover two numbers - that is, two lines of data. At these word-sizes, any attempt to show two meaningful series of data would likely not be visible, and certainly not discernable for any precise interpretation.

Another of the prescriptions of Williams and Harkus is to provide a level of detail that is adequate to the task (39). This is challenging, because how can we ever know with certainty what level of detail the viewer desires? The sports-related, whisker sparklines are at or near the highest resolution possible. But with financial data, for instance, how could we know that an investor might need to analyze data for the last few hours, but the sparkline is depicting a year's worth of fluctuations? Perhaps in the case of electronic sparklines, there could be a "zoom" or drill-down feature, which would allow more detail, or allow the user to set the level of detail.

5.1 Pictures Among Text

Turning to the more basic issue of pictures among text, there are points of view contrary to Tufte's on the value of this approach. Hans VanDer Meij and Mark Gellevij conducted a study directed at older users learning computer instructions. Some users were given manuals with screen captures, and some were not, and then they were asked to perform tasks. Their findings show no certain benefit to the screen captures:

> We found no support for the prediction that the presence of pictures would make some manuals more effective than others. (331)

However, what the test manuals in this study did provide were icons or symbols for the assigned task, if not full screen shots. Some visual support was provided. What the van der Meij and Gellevij study did not measure was *speed* of completion of individual tasks, except that there was an overall time limit for taking the entire test. With no evidence to support or refute this, my assertion is that had the individual tasks been timed,

those participants who had seen the screen shots would benefit by not having to hunt around the screen for the relevant icon.

Later in the same paper, van der Meij and Gellevij say: "Our study shows that screen captures do provide a small and worthwhile improvement in performance." That is, all findings indicate that the negative impact of age-related factors in the cognitive area are reduced by the presence of screen captures (338). Their results show that the screens helped older people (one of the test groups in their study) complete tasks on par with younger test subjects. It's curious to me that they didn't "lead," or give greater prominence, to this finding, which supports their premise.

5.2 Time-Series Limitations

Sparklines' limitation solely to time-series statistics was another criticism in the message boards, by Jai Ranganathan (Sparklines or Wordgraphs--some draft pages from Beautiful Evidence) on Dec. 14, 2004. He said his concern is that sparklines have very little application for non-time-series data. Ranganathan suggests adding to the chapter some suggestions for adapting sparklines to non-time series. The distribution example is a good one, but it may be that sparklines lend themselves only to time-series.

The message board also included a debate over the naming of these little graphics, as well as a concern about the boundaries of sparklines. This one is particularly pertinent and on-point: when does a sparkline become a graphic?

> As much as I like the chapter and the ideas that is contains,
> I still think that the concept may be overbroad/underdefined.

This was from Alex Merz, a frequent contributor to the <u>Sparklines or Wordgraphs--some draft pages from Beautiful Evidence</u> Web board. He cited the DNA graphics that are the most colorful example in the chapter, and therefore most engaging, but hardly word-sized. And the size seems to be one of the crucial criteria for such a sparkline. Size does matter, or else what we have is a full-sized graphic? "These [DNA examples] either push Dr. Tufte's own definition of the sparkline to its limits, or really don't fit within the definition at all," Merz wrote.

There is also the possible contradiction — or at least incongruity — in that graphics were intended to supplement or complement the text, but now they are appearing *within* the text. Is this distracting? Does this in fact impede understanding of both the sparkline and the text?

A professor who was involved with the sparklines trial that will be discussed later in this paper commented that he would rather see the actual number, especially if he were making an important financial decision. The same would be even more true for medical decisions. This professor was in the accounting department of a major company, and went on to start his own distribution business, so his opinion, while anecdotal, carries some weight. This comment echoes the concern touched upon earlier for the need for detail in some situations. It's true that there is an undeniable precision in the real numbers that we don't get from sparklines. But, as noted above, one of the points of sparklines is to see general trends, or pick out one item among several.

Another potential problem arose out of the trials of live participants with sparklines. At least in the case of line graphs, there was a question of how much variation in the line is meaningful? In other words, does this sparkline represent a downward trend:

⎯⎯⎯⎯ or no change? Or, does this sparkline ⌇⌇ represent a greater upward trend than this: ⌇⌇ ? The point is that reasonable people could disagree and have different interpretations of the same sparklines. Particularly at these small sizes, it may be difficult to perceive change. Where is the cutoff point that makes for upward or downward movement? Bertin tells us that about 70 degrees is the optimal angle for detecting a change, and certainly a perpendicular variation is easy to notice, like this:

⌐|

Again, this issue of trying top detect a trend seems to point toward the need to supply the source data.

CHAPTER 6

TEST OF SPARKLINES

The real merit and viability of sparklines, of course, can be gauged from a test of them in actual use to convey data. And so a trial of sparklines was conducted. To my knowledge this is the first real-world test of sparklines.

Not to ruin the suspense, but the sparklines trailed behind the numbers overall, but tied the numeric display in one example. My hypothesis was that sparklines would perform as well as, if not better than, actual numbers in a head-to-head test. That hypothesis was not proven, but sparklines were not far behind the numeric displays. The trial consisted of three parts, and in one of the parts the sparklines tied the numbers, while they lagged behind in the other two parts. This makes sparklines a viable option for data presentation, with certain limitations, which will be explained.

6.1 Research Design

The trial was conducted on 92 undergraduate business students in management and marketing classes. Because one of the major uses of sparklines (so far) has been to report financial data, business students were specifically sought. But the test was general enough that it could have been conducted upon individuals in any discipline; it did not require any specific business knowledge.

The basic format of the study was to create two tests, one numeric and one graphic, to give each to an equal number of participants, and to determine how they fare

against one another. The actual tests are included below. Three pieces of information were presented, in the form of a trend of a key economic indicator. This was meant to simulate an executive summary, such as might be consulted for a stock purchase. The information was displayed numerically in one example and graphically in the other. The numeric information was presented in a simple, tabular data format, while the sparklines information was presented in a paragraph that took up much the same size as the tabular data. The participants were asked one question about each piece of information. The information, as can be seen from the actual survey, was straightforward and unambiguous.

This is a reproduction of the graphical test, slightly downsized to fit on the page and distinguish it from the rest of the text:

Company summary, graphic:			
Over the past three months, the trend of Abaco, Inc. stock has been _____ , while its costs for raw materials have followed this trend _____ as a new supplier was brought on board. Based on history, the company's sales for the third quarter have shown the following movement: _____ .			
Questions — Please circle the correct answer:			
1. Is Abaco's stock trend over the last three months	higher	lower	unchanged ?
2. Is the trend of their raw materials costs moving	higher	lower	unchanged ?
3. Is their sales history for the third quarter	higher	lower	unchanged ?

Figure 6.1 Graphical test administered to subjects.

And this is the numeric test, also downsized:

Company summary, numeric:

Economic indicator	January	February	March
Stock closing price	25.8	28	29.7
Raw materials costs, millions	38	37.32	34.8
Sales figures, millions	6.1	5.25	4.9

Questions — Please circle the correct answer:

1. Is Abaco's stock trend over the last three months   higher   lower   unchanged ?

2. Is the trend of their raw materials costs moving   higher   lower   unchanged ?

3. Is their sales history for the third quarter   higher   lower   unchanged ?

Figure 6.2 Numeric test administered to subjects.

For both tests, the correct answers are higher, lower, lower.

The design was intentionally simple for the following reasons:

- **Lack of prior research** — Because there are no published tests of sparklines in existence, this test was breaking new ground and thus needed to be simple. It was difficult to know where to start, so a basic comprehension test of sparklines was judged to be in order. Similar, previous tests of this type could have served as the basis from which to explore a different aspect of sparklines.

- **Time constraints** — Because of the nature of the test, on undergraduate students in class, in a strictly voluntary setting, my promise was to restrict the test to five minutes to secure the participation of instructors.

The tables that follow summarize the data.

Table 6.1 Summary of Sparklines Test Data, Question 1

Question 1	Correct		Incorrect	
	Numeric	Graphic	Numeric	Graphic
	42	42	4	4

Table 6.2 Summary of Sparklines Test Data. Question 2

Question 2	Correct		Incorrect	
	Numeric	Graphic	Numeric	Graphic
	46	41	0	5

Table 6.3 Summary of Sparklines Test Data, Question 3

Question 3	Correct		Incorrect	
	Numeric	Graphic	Numeric	Graphic
	39	29	7	17

And of course, there should be graphic representations of the data:
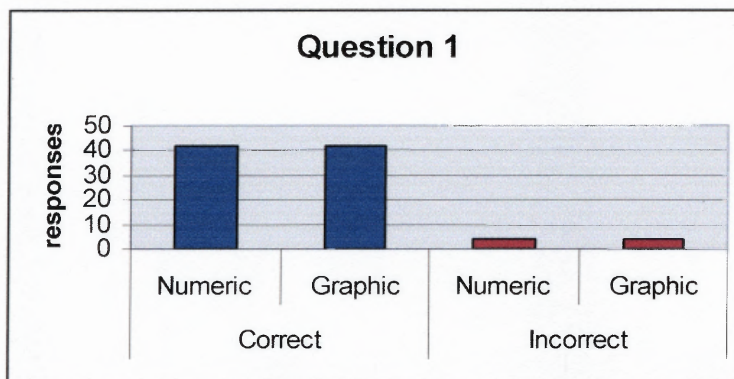

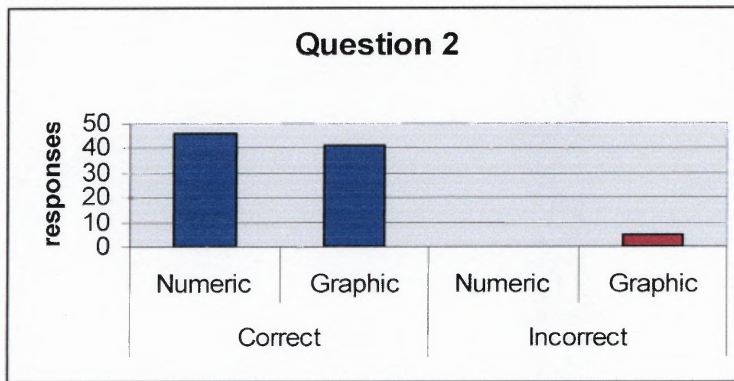**Figure 6.3** Results of Sparklines Test Question 1.

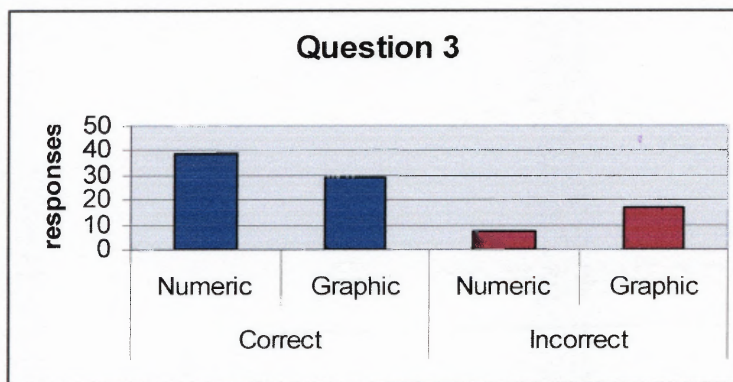**Figure 6.4** Results of Sparklines Test Question 2.

Figure 6.5 Results of Sparklines Test Question 3.

As can be seen, the participants had the most trouble with the third question, both numerically and graphically. Whether this is a result of this piece of information being a little harder to grasp, a simple rush of the participants to be done with the test, or some misconception of the question is possible.

The third question, however, contains a significant and unexpected result. That is, because of the varying shape of this sparkline, the results seem to have been significantly worse than the numeric result. The sparkline ⌐₋ₙₘ follows a wavering course: down dramatically, then up a little, down again, then slightly up. It seems the study participants had trouble discerning the overall outcome of this sparkline to a greater degree than with

the other sparklines. This is certainly an area that bears further study – perhaps of sparklines that display a clear trend up or down, head-to-head against sparklines with a more varied texture.

What I find interesting is that the sparkline data followed the trend of the numeric data. The results are not exactly parallel, of course, but close. But what this indicates to me is that where there was trouble with the data and the question, there was similar trouble with the graphic. This holds true with the other two questions, making this one of the most interesting results of the study.

One of the professors who permitted the study to be conducted with his students commented that he would like to see actual numbers on which to make a decision. This person was formerly in the financial department of a major company, then started his own distribution business. While anecdotal, this criticism should not be discounted. It seems there is a precision that is needed when important decisions are in the making.

But also, this criticism may partly miss the point of sparklines. They are intended for brief, surface interpretations of the data. And of course if further detail is needed, the ability to "drill-down" to look at the actual numbers should be provided.

A key question that may arise with sparklines and bears further exploration later is: How much change is meaningful? It may even be difficult to perceive change at these small sizes. This may be an area appropriate for further investigation, in the form of tests that compare sparklines with gradual fluctuations, to see at what point the movement of the line is perceptible, and where is the cutoff.

6.2 Conclusion and Areas for Further Study

This thesis has begun to explore the data display concept of sparklines. I do not assert that sparklines are going to revolutionize the world of graphic display. They may be one tool in an information designer's toolbox. I have tried to provide a foundation of graphic construction, largely through the work of Bertin. There has also been a brief recounting of some of the history of graphics, to demonstrate that sparklines fall into this history, primarily exemplified by Galileo's observation of Saturn. Perhaps it need not be said, but sparklines carry with them the same need for ethical considerations as in writing or presenting other kinds of information: to be honest with the data and careful in showing scale and proportion when using them for comparisons. There are significant limitations to sparklines, including their lack of scale and the almost inherent need with them to provide the detail behind the data, the "drill-down" capability, should the viewer need precision and actual numbers. There are many uncertainties in the future of these little graphics, including the technology to easily create them, their comprehensibility when presenting unusually shaped data, and their acceptance within the intended audience.

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