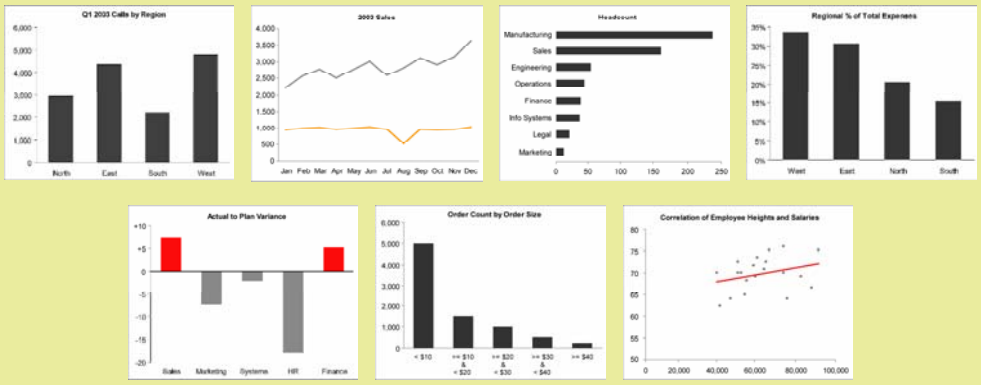
Show Me the Numbers

Designing Tables & Graphs to Enlighten

Presented by Stephen Few



Data visualization for enlightening communication.

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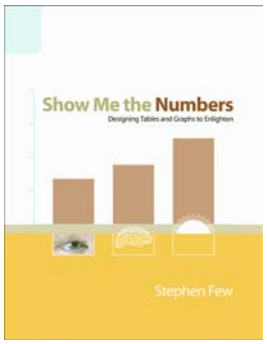
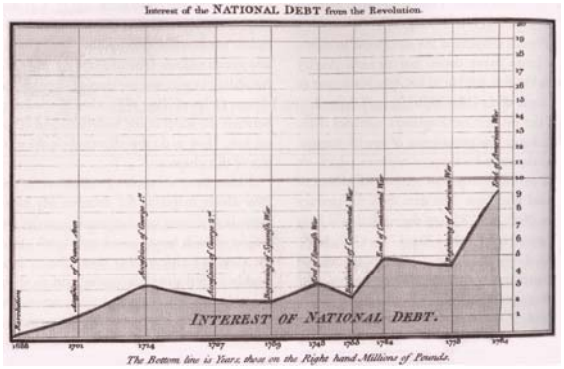
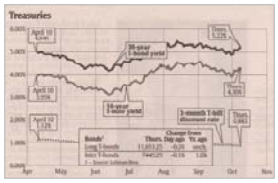


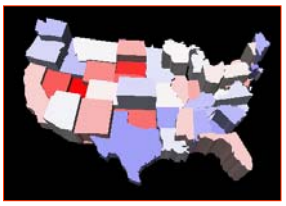
In 1786, an iconoclastic Scot – William Playfair – published a small atlas that introduced or greatly improved most of the quantitative graphs that we use today.



Prior to this, graphs of quantitative data were little known.

Today, 220 years later, partly due to the arrival of the PC, graphs are commonplace, fully integrated into the fabric of modern communications.





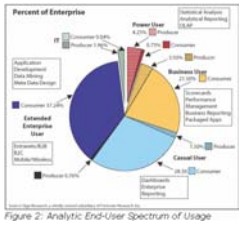
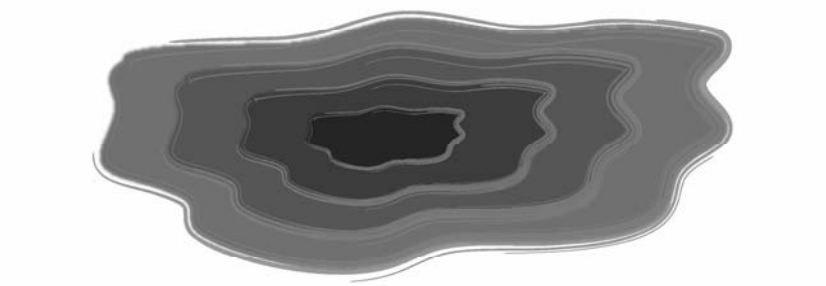


Figure 2: Analytic End-User Spectrum of Usage

Surprisingly, however, Playfair's innovative efforts – sprung from meager precedent – are still superior to most of the graphs produced today.

A powerful language,
with such promise,
is largely being wasted!

Despite a recent explosion in available data, most lies stagnant in ever-expanding pools.

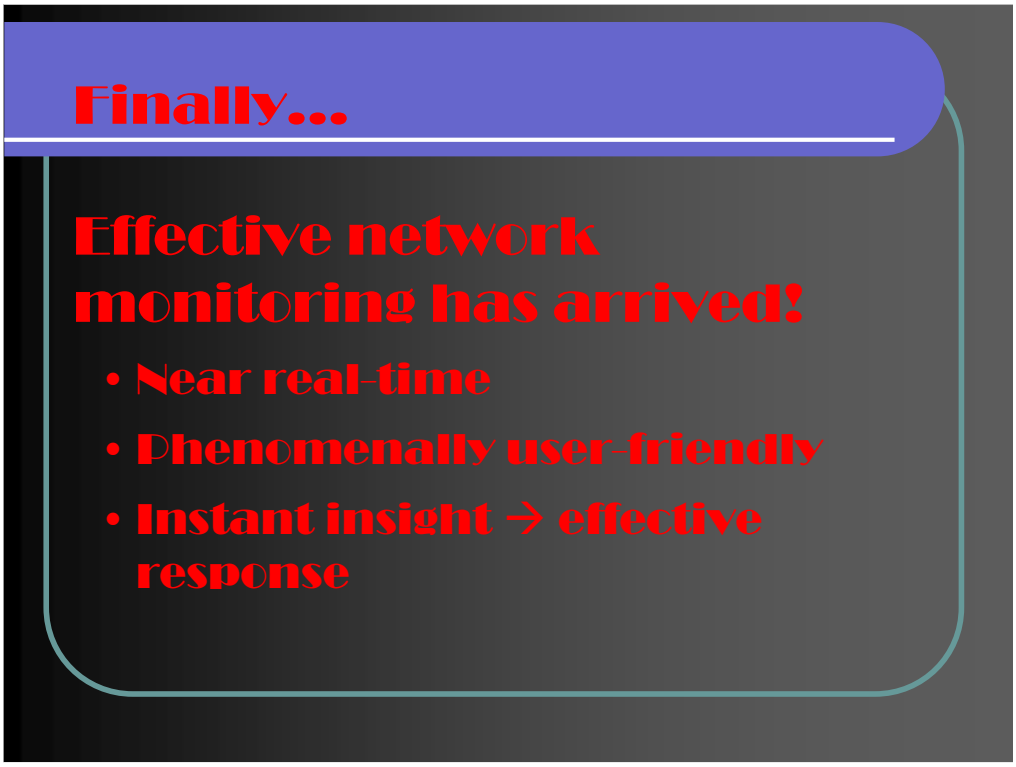


Data is useless until we understand what it means and can clearly communicate that meaning to those who need it, those whose decisions affect our world.

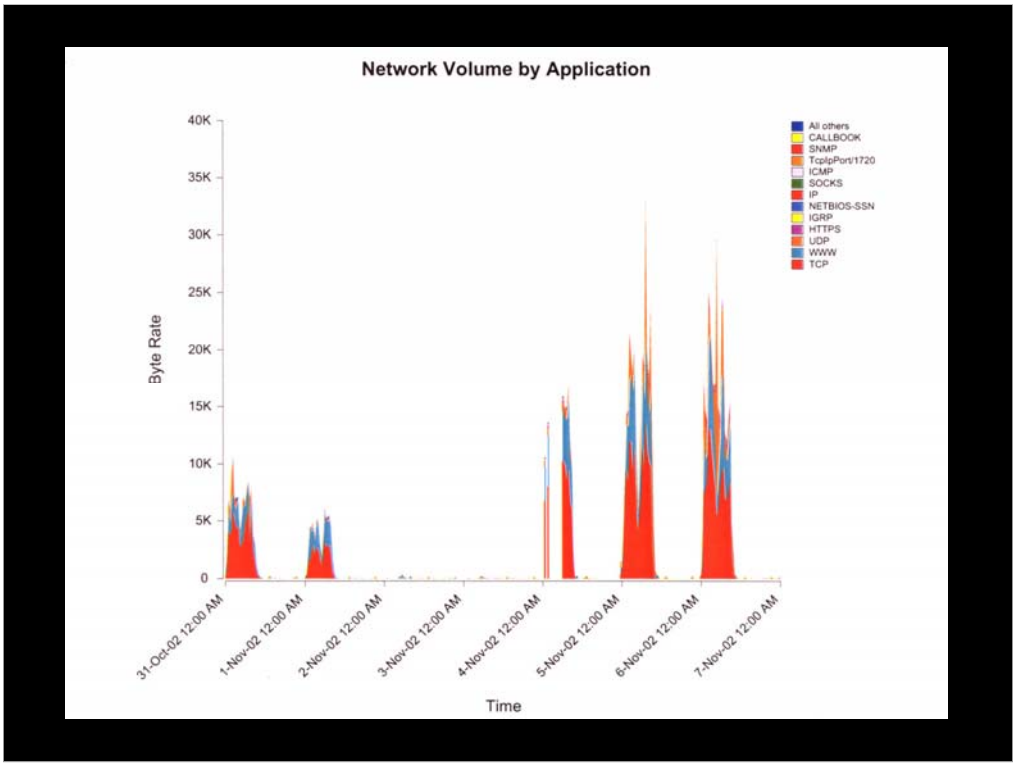
So…here you are today.

Good choice.

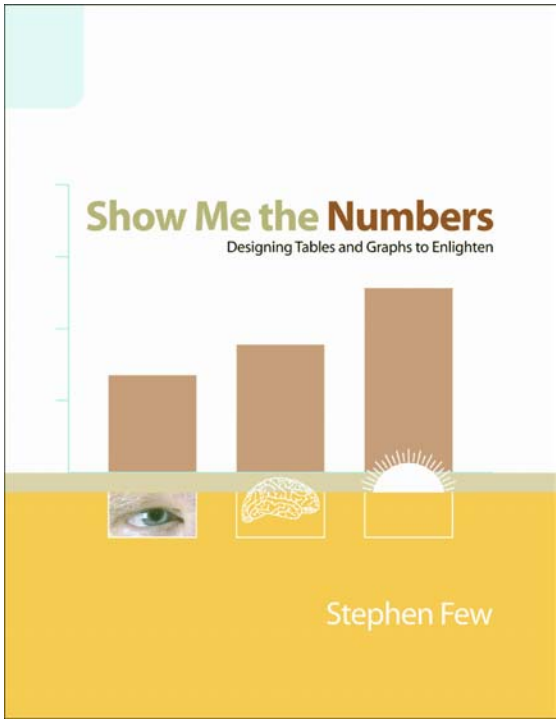
Excellent beginning.



You've been invited to another of the many meetings that you're required to attend. You're one of many managers in the Information Technology department. Like most meetings, this one begins with the light of a projector suddenly illuminating a screen.



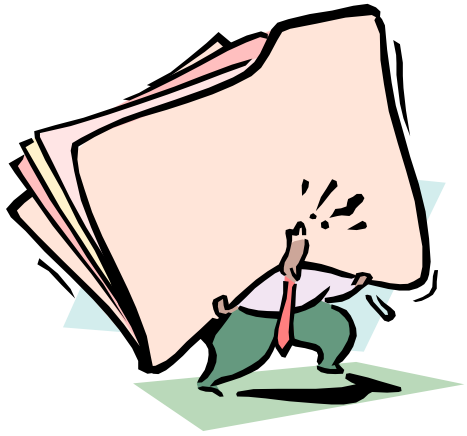
Bursting with excitement, the speaker announces that you and everyone else in the room will now receive a daily report that will inform you how the network is being utilized, and then this graph appears. You stare at it very intently, trying your best to keep any hint of confusion from crossing your face. From your peripheral vision you can see that the CIO (Chief Information Officer) is smiling broadly and nodding with obvious understanding. You and everyone else in the room begins to nod enthusiastically as well. You feel very dumb. What you don't realize is that you are not alone.



I wrote the book, ***Show Me the Numbers: Designing Tables and Graphs to Enlighten***, published by Analytics Press in 2004, to help business people like you respond to the challenges that you face every day when presenting quantitative information.

We are awash in data.

"Just show me the numbers!"



We live in the so-called "information age." So much information is available, without proper care and skill we can easily drown in it.

The phrase, "Just show me the numbers," is especially popular among those responsible for sales organizations who are often frantic to know how sales are going. They can't afford to wade through lengthy reports and unnecessary detail; they just want to see the important numbers right now!

Why? Numbers are critical to business.

Everyone is scrambling for metrics, key performance indicators (KPIs), scorecards, and digital dashboards. Quantitative data is what we rely on most to measure the health of our businesses, to identify opportunities, and to anticipate the future.

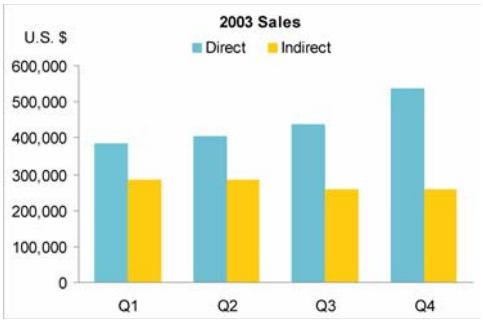
We’re getting better at handling numbers –

Right?

Wrong! We’re getting worse. Despite great progress in our ability to gather and warehouse data, we’re still missing the boat if we don’t communicate the numbers effectively. Contrary to popular wisdom, information cannot always speak for itself.

Quantitative information is primarily communicated through tables and graphs.

	Expenses			
Department	Jan	Feb	Variance	Change %
Sales	9,933	9,293	-640	-6%
Marketing	5,385	5,832	+447	+8%
Operations	8,375	7,937	-438	-5%
Total	$23,693	$23,062	-$1,327	-3%



But few communicate effectively. Why?

Why? Few people are trained.

Why? Few people recognize the need.

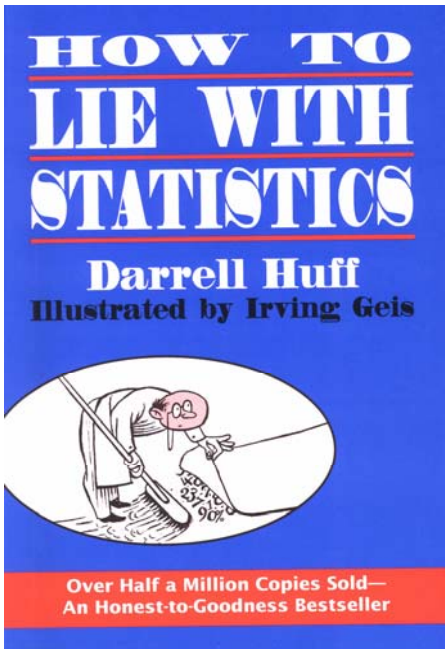
Why? Few examples of good design exist to expose the problem.

"Poor documents are so commonplace that deciphering bad writing and bad visual design have become part of the coping skills needed to navigate in the so-called information age." Karen A. Schriver, *Dynamics in Document Design*, John Wiley & Sons, Inc., 1997.

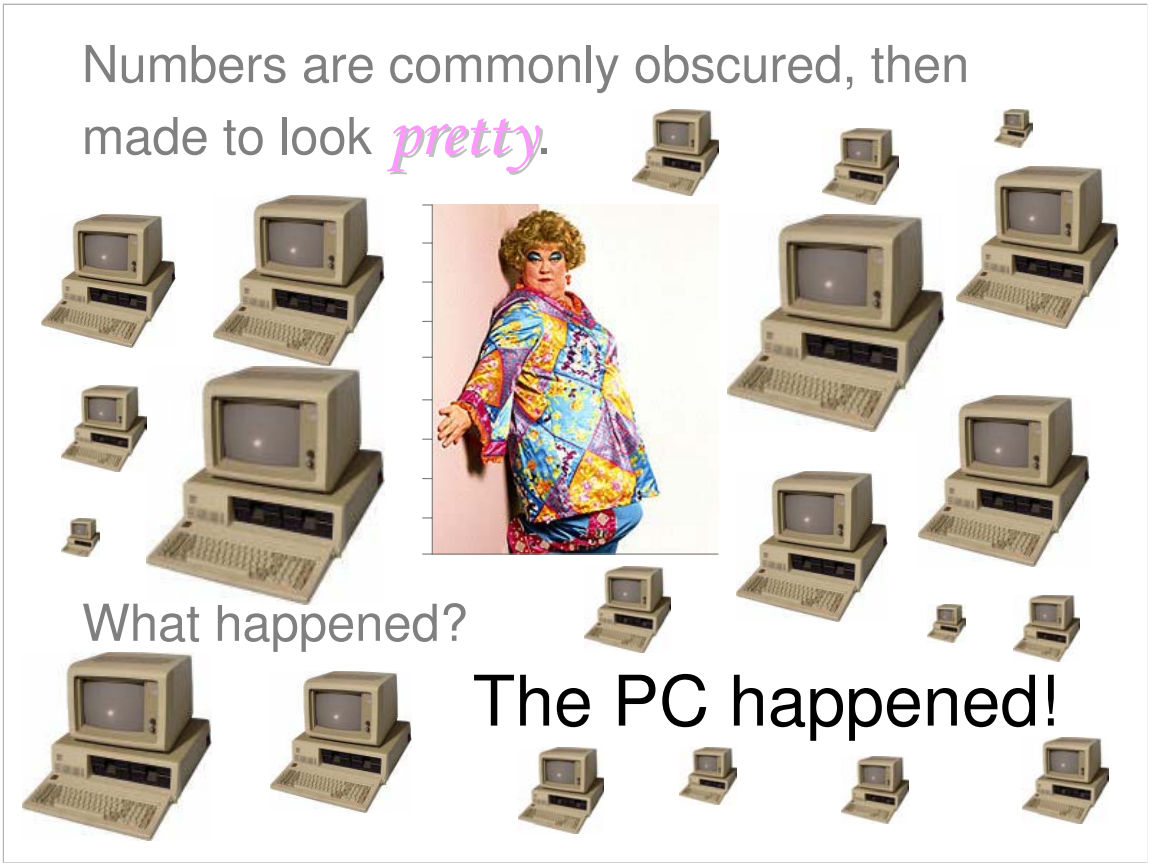
"The public is more familiar with bad design than good design. It is, in effect, conditioned to prefer bad design, because that is what it lives with. The new becomes threatening, the old reassuring." (Kevin Mullet and Darrel Sano, *Designing Visual Interfaces*, Sun Microsystems, Inc., 1995 – quoting Paul Rand, *Design, Form, and Chaos*)

Effective communication is not always intuitive – it must be learned.

Intentional deceit is no longer our biggest problem



In 1954, Darrell Huff wrote his best-selling book about how people often intentionally use graphs to spread misinformation, especially in favor of their own products or causes. Today, vastly more misinformation is disseminated unintentionally because people don't know how to use charts to communicate what they intend.

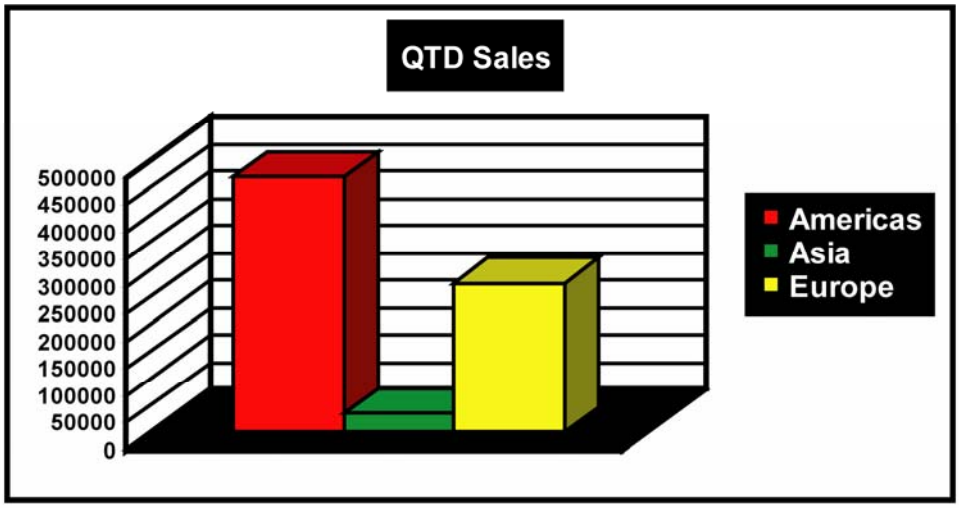


When the PC was introduced, software soon made the arduous task of table and graph creation as easy as 1-2-3 (literally “Lotus 1-2-3”, the software that was the first to legitimize the PC as a viable tool for business). Unfortunately, this improvement in ease and efficiency was not accompanied by instruction in visual design for communication. People today think that if they know how to click with the mouse to create a table or graph, they know how to present data effectively.

“In the two centuries since [the invention of the first graphs], …charts have become commonplace. With the advent of modern computer tools, creating graphs from data involves trivial effort. In fact, it has probably become too easy. Graphs are often produced without thought for their main purpose: to enlighten and inform the reader.” Jonathan G. Koomey, *Turning Numbers into Knowledge*, Analytics Press, 2001

I can talk about this all day, but the best way to make my point convincingly is to show you.

Example #1 - Poor



What does this graph tell you? Is the resulting information worth the effort?

Example #1 - Good

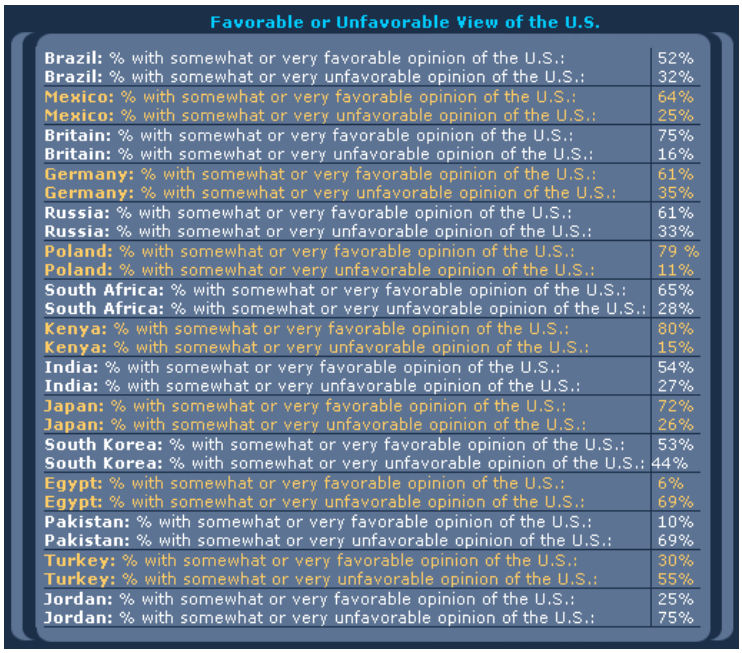
2003 Q1-to-Date Regional Sales
March 15, 2003

	Sales (U.S. $)	Percent of Total Sales	Current Percent of Qtr Plan	Qtr End Projected Sales (U.S. $)	Qtr End Projected Percent of Qtr Plan
Americas	469,384	60%	85%	586,730	107%
Europe	273,854	35%	91%	353,272	118%
Asia	34,847	5%	50%	43,210	62%
	$778,085	100%	85%	$983,212	107%

Note: To date, 83% of the quarter has elapsed.

This table presents the same information that appears in the graph and more, but it does so clearly and simply. One common problem in the display of quantitative information is that people often choose the wrong medium of display – a graph when a table would work better and vice versa. Too seldom do report developers consider their message and carefully design its presentation to communicate that message effectively.

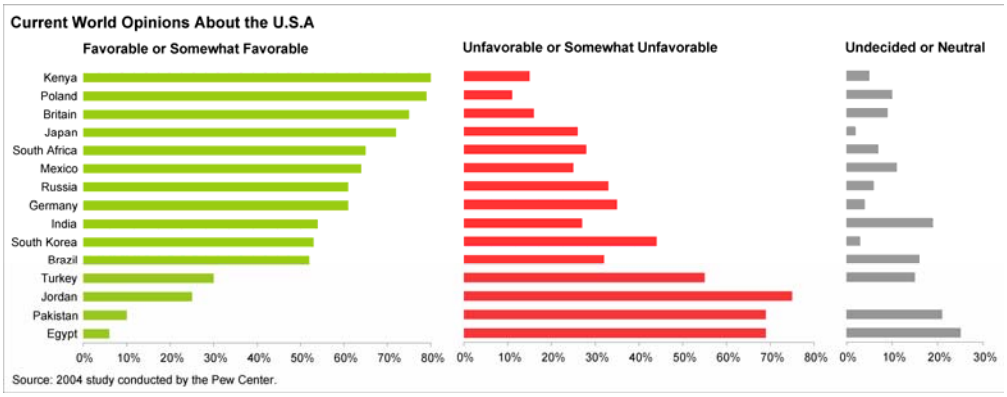
Example #2 - Poor



Favorable or Unfavorable View of the U.S.	
Brazil: % with somewhat or very favorable opinion of the U.S.:	52%
Brazil: % with somewhat or very unfavorable opinion of the U.S.:	32%
Mexico: % with somewhat or very favorable opinion of the U.S.:	64%
Mexico: % with somewhat or very unfavorable opinion of the U.S.:	25%
Britain: % with somewhat or very favorable opinion of the U.S.:	75%
Britain: % with somewhat or very unfavorable opinion of the U.S.:	16%
Germany: % with somewhat or very favorable opinion of the U.S.:	61%
Germany: % with somewhat or very unfavorable opinion of the U.S.:	35%
Russia: % with somewhat or very favorable opinion of the U.S.:	61%
Russia: % with somewhat or very unfavorable opinion of the U.S.:	33%
Poland: % with somewhat or very favorable opinion of the U.S.:	79 %
Poland: % with somewhat or very unfavorable opinion of the U.S.:	11%
South Africa: % with somewhat or very favorable opinion of the U.S.:	65%
South Africa: % with somewhat or very unfavorable opinion of the U.S.:	28%
Kenya: % with somewhat or very favorable opinion of the U.S.:	80%
Kenya: % with somewhat or very unfavorable opinion of the U.S.:	15%
India: % with somewhat or very favorable opinion of the U.S.:	54%
India: % with somewhat or very unfavorable opinion of the U.S.:	27%
Japan: % with somewhat or very favorable opinion of the U.S.:	72%
Japan: % with somewhat or very unfavorable opinion of the U.S.:	26%
South Korea: % with somewhat or very favorable opinion of the U.S.:	53%
South Korea: % with somewhat or very unfavorable opinion of the U.S.:	44%
Egypt: % with somewhat or very favorable opinion of the U.S.:	6%
Egypt: % with somewhat or very unfavorable opinion of the U.S.:	69%
Pakistan: % with somewhat or very favorable opinion of the U.S.:	10%
Pakistan: % with somewhat or very unfavorable opinion of the U.S.:	69%
Turkey: % with somewhat or very favorable opinion of the U.S.:	30%
Turkey: % with somewhat or very unfavorable opinion of the U.S.:	55%
Jordan: % with somewhat or very favorable opinion of the U.S.:	25%
Jordan: % with somewhat or very unfavorable opinion of the U.S.:	75%

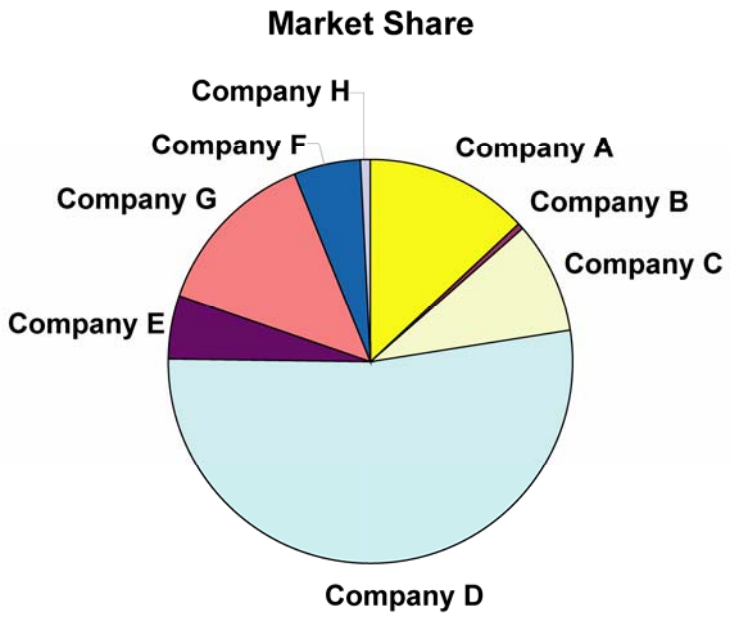
I found this table on the Web site for Bill Moyers' public television show "Now". I felt that it provided important information that deserved a better form of presentation. In this case the story could be told much better in visual form.

Example #2 - Good



This series of related graphs tells the story in vivid terms and brings facts to light that might not ever be noticed in the table.

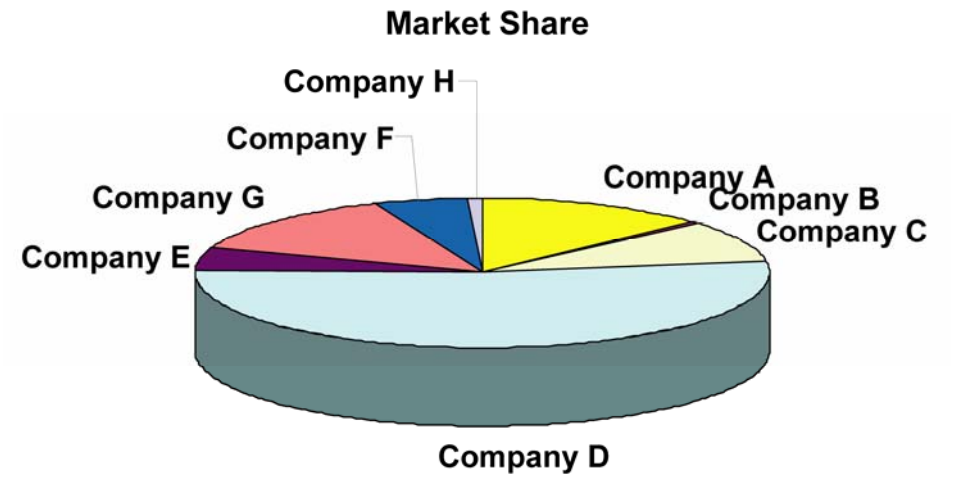
Example #3 - Poor



The purpose of this graph is to display how *Company G* is doing in relation to its competitors. Is its message clear?

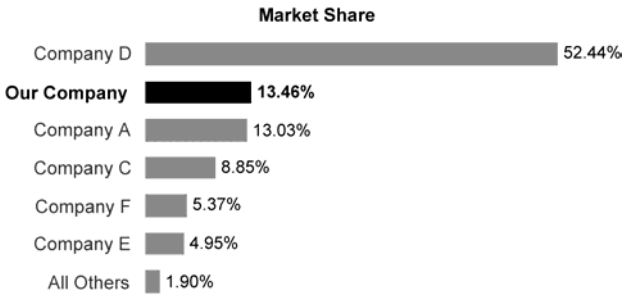
Often, when someone creates a graph that appears inadequate somehow, they try to fix it with sizzle, as in the next slide.

Example #3 - Worse



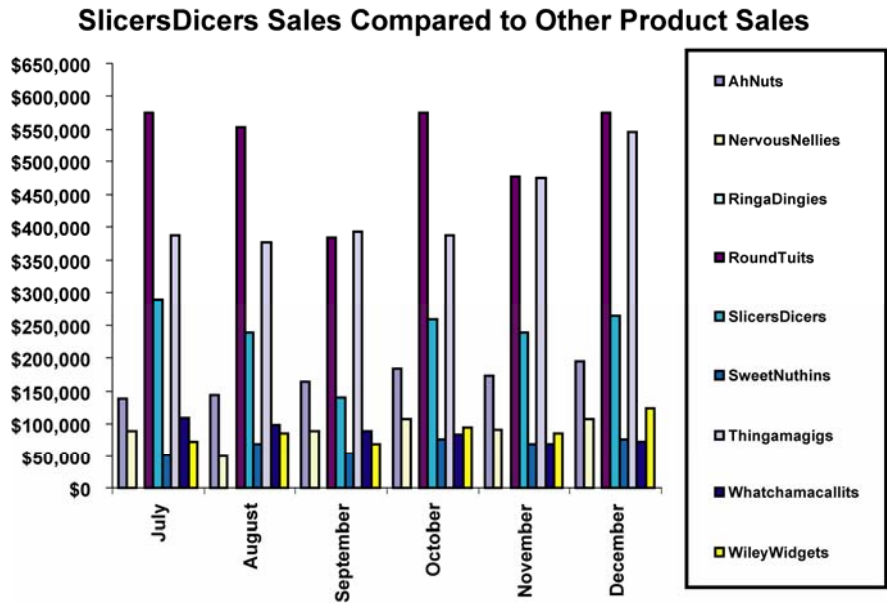
Does the addition of 3D improve this pie chart? Definitely not. In fact, it actually makes it harder to read.

Example #3 - Good



Though it lacks flash and dazzle, this simple bar graph tells the story elegantly.

Example #3 - Poor

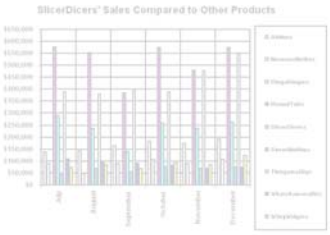


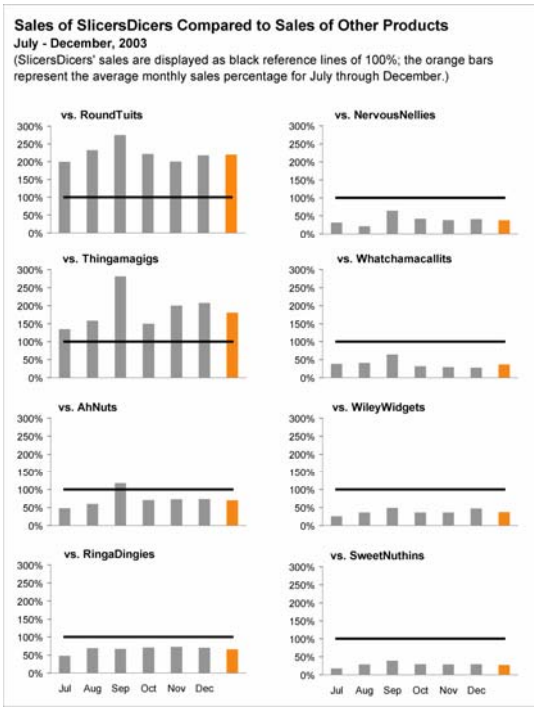
Without the title, could you determine the purpose of this graph? The design of a graph should clearly suggest its purpose.

In the general field of design, we speak of things having “affordances.” These are characteristics of something’s design that declare its use; a teapot has a handle and a door has a push-plate. Graphs should also be designed in a manner that clearly suggests their use.

Besides the lack of affordances, what else about this graph undermines it ability to communicate?

Example #3 - Good





The design of this quantitative message ties clearly to its purpose. It is obvious to the reader that its intention is to compare the performance of SlicersDicers to that of the other eight products.

This solution uses a technique called “small multiples” – a series of related graphs that differ only along a single variable, in this case the various products. This technique has been known for over 20 years, but I bet you’ve never used software that makes this easy to do.

Warning!

Even software vendors encourage poor design

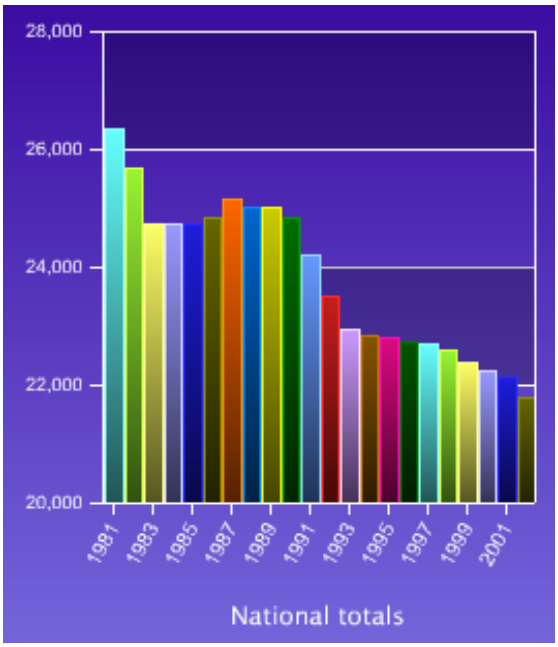
They encourage poor design by:

- providing useless features and gizmos
- providing formatting defaults that undermine a clear display of the data
- producing documentation that demonstrates poor design
- marketing flash and dazzle, rather than good design

“There are two ways of constructing a software design [or a table or graph design]: one way is to make it so simple that there are obviously no deficiencies; the other is to make it so complicated that there are no obvious deficiencies.” C. A. R. Hoare

Let’s take a quick tour of several graph examples from the user documentation and Web sites of several software vendors to illustrate my point.

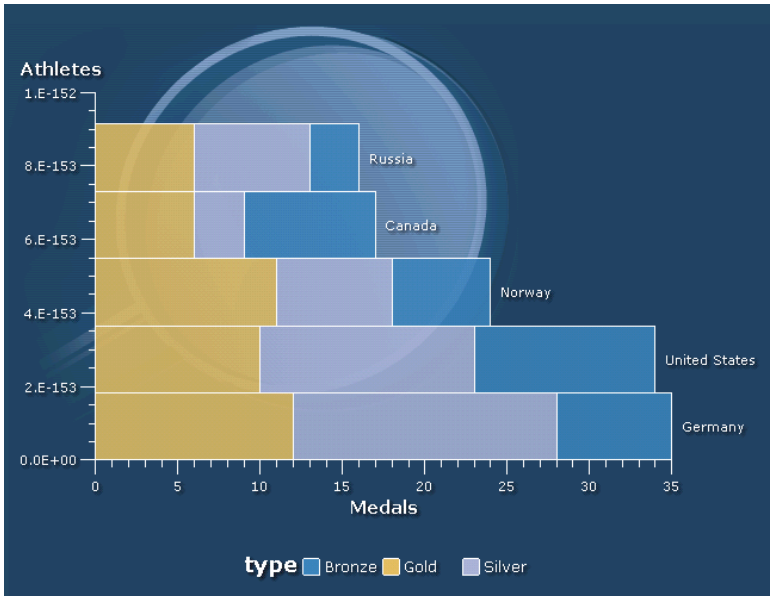
Example: Totals of something or other by year



This graph gets extra points for the creative use of color – a bit too creative, don't you think? What do the different colors mean?

(Source: Web site of Corda Technologies, Incorporated.)

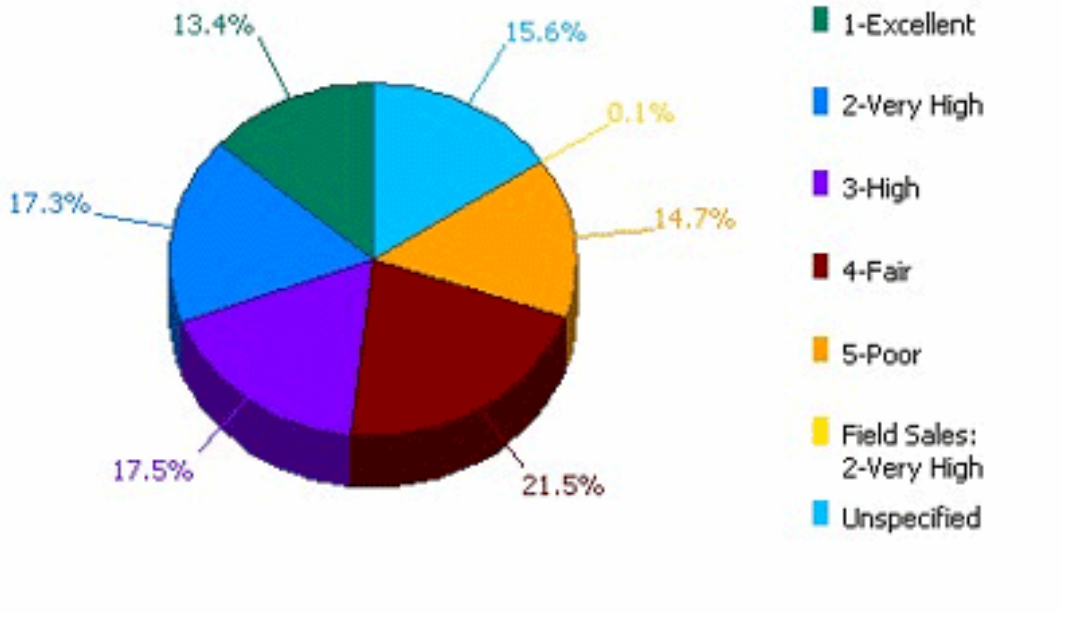
Example: Total medals by country and type



I guess the round object in the background is a medal. Even if it looked more like a medal, it would still do nothing but distract from the data itself. Can you make sense of the quantitative scale along the vertical axis?

(Source: Web site of SAS Institute Inc.)

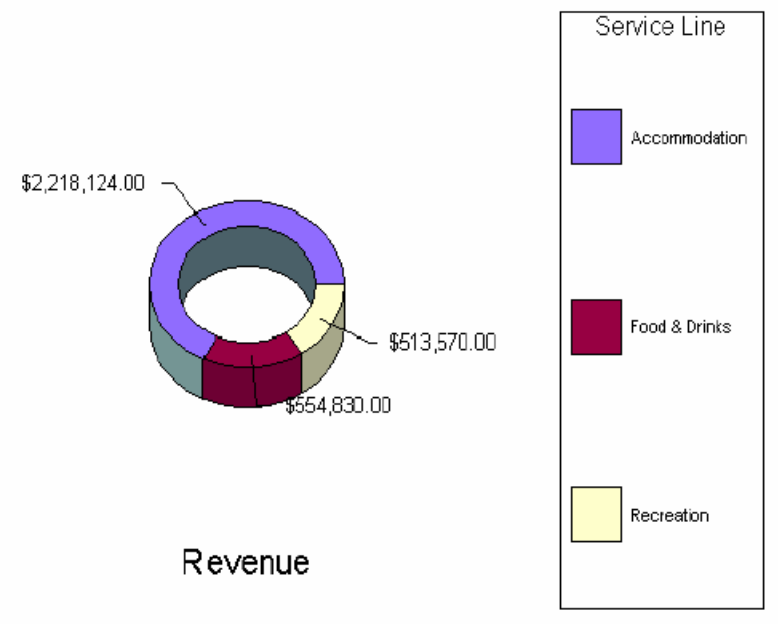
Example: New sales opportunities by lead quality



Notice the effort that is involved in shifting your focus back and forth between the pie chart and the legend to determine what each slice represents, especially given the fact that the order of the items in the legend does not match the order in the pie. Also notice how slices that are different in value often appear to be the same size.

(Source: Web site of Siebel Systems.)

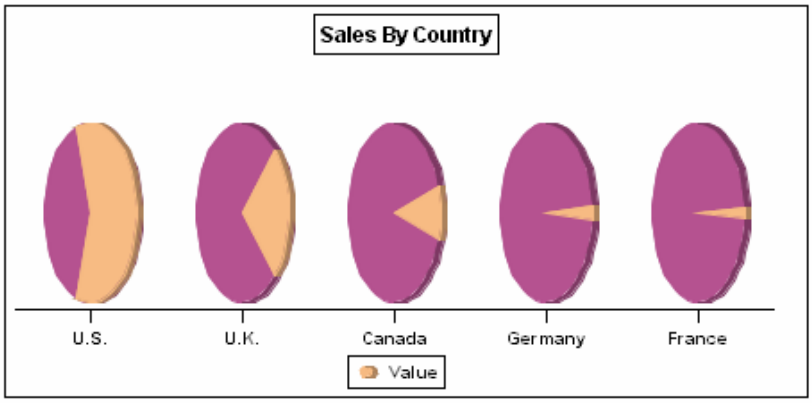
Example: Revenue by service line



Even turning a pie into a donut doesn't make it any more palatable. A donut chart is just a pie with a hole in it.

(Source: User documentation of Business Objects.)

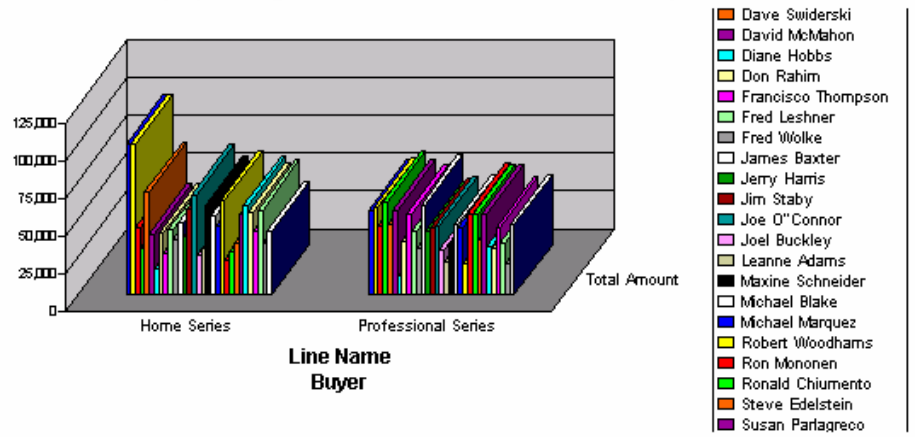
Example: Percentage sales by country



Breaking a single pie into five pies and tilting them to the left doesn't seem to help either.

(Source: Web site of Visual Mining, Inc.)

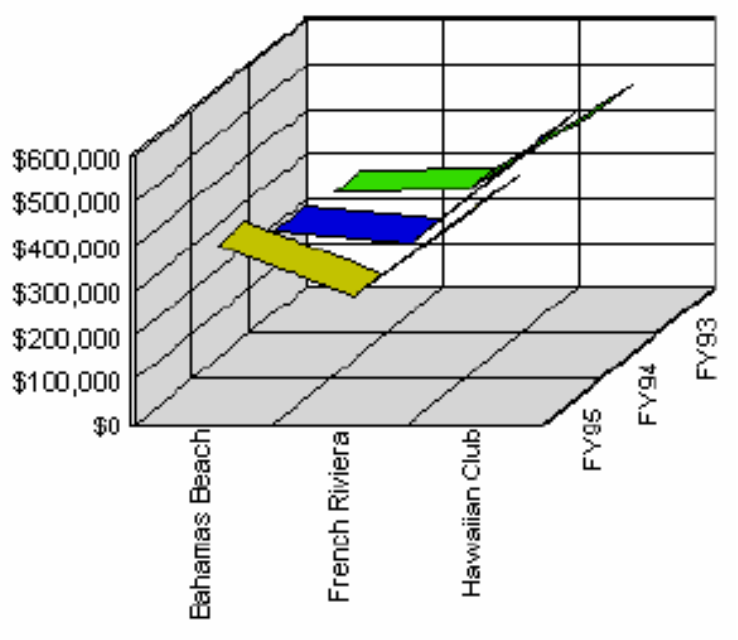
Example: Purchases by product line and buyer



When you design a graph that is almost unreadable, you can always add 3D and hope your audience is too impressed to care. (You know I'm kidding – right?)

(Source: Web site of Brio Software, prior to its acquisition by Hyperion Solutions Corporation.)

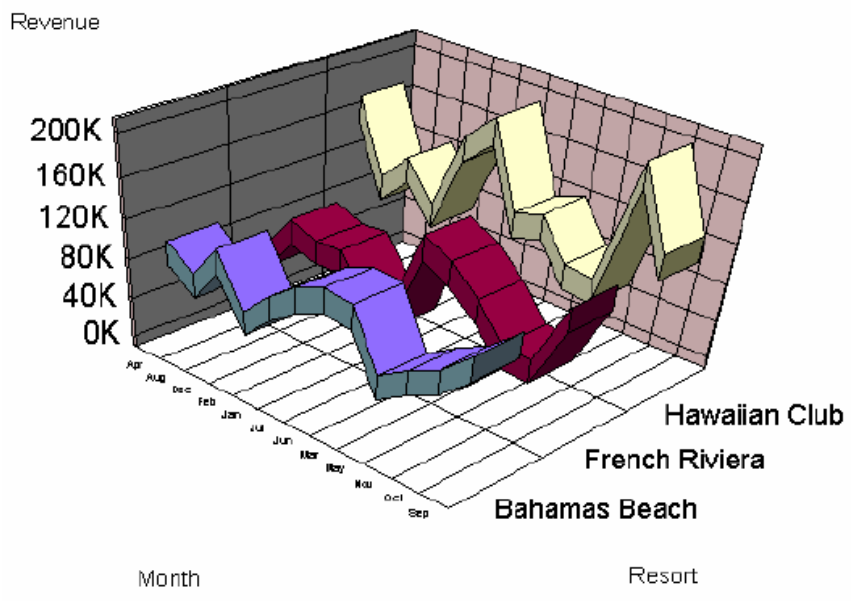
Example: Revenue by resort and year



2-D lines are so much more interesting than the regular ones. Don't you agree? (By now, I'm sure my sarcasm is evident.)

(Source: User documentation of Business Objects.)

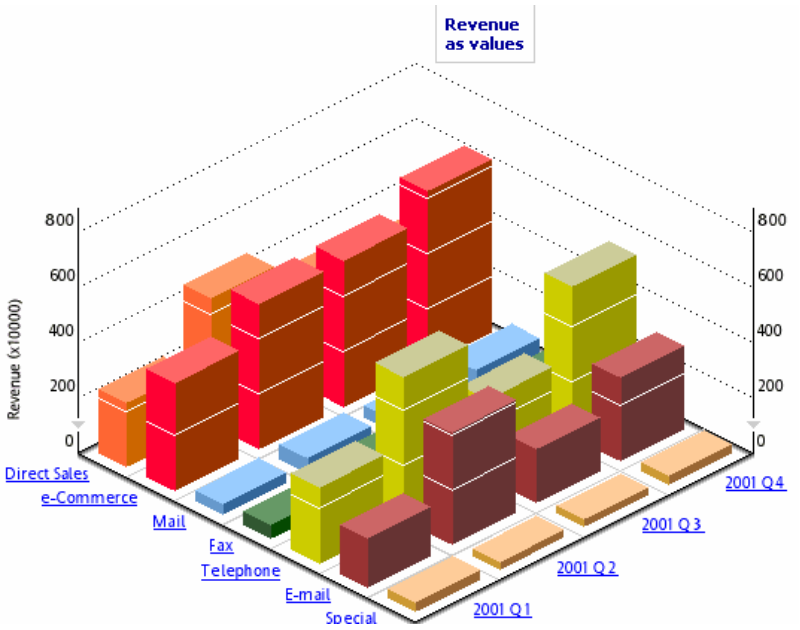
Example: Revenue by resort and month



But 3-D lines are the height of fashion. And time trends with the months sorted in alphabetical rather than chronological order are so much more creative.

(Source: User documentation of Business Objects.)

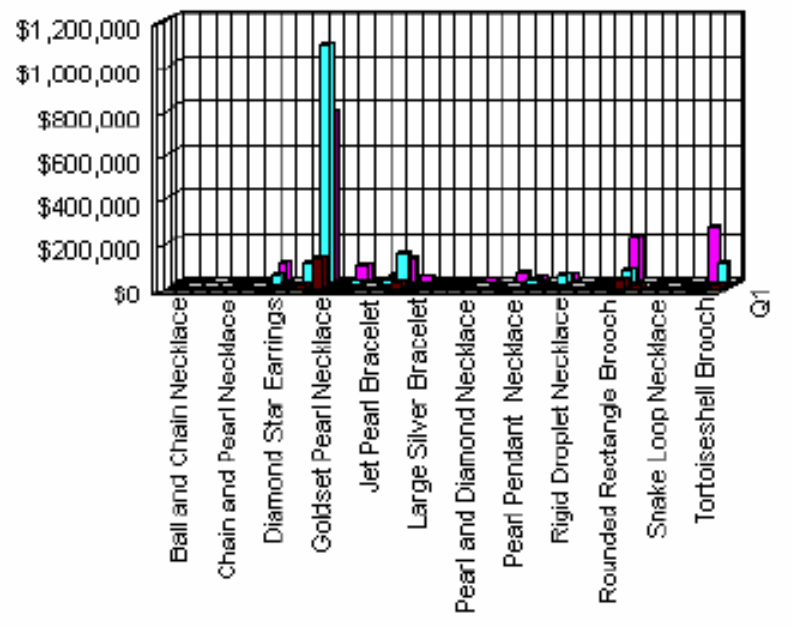
Example: Revenue by sales channel and quarter



No matter how bright the bars, you can't see them if they're hidden behind others. Can you determine fax revenue for Q3 or direct sales revenue for Q4? This problem, when data is hidden behind other data, is called *occlusion*.

(Source: Web site of Cognos Incorporated.)

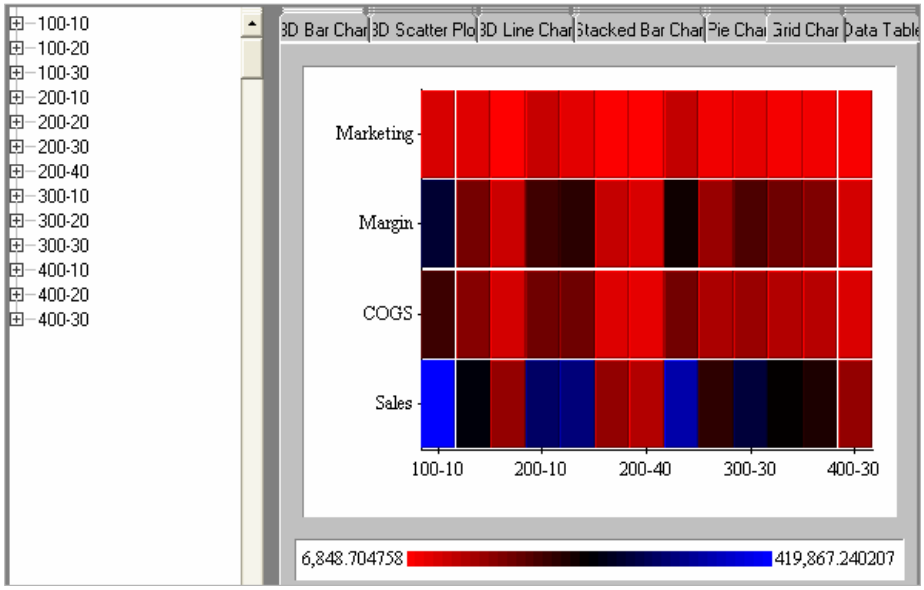
Example: Revenue by product and quarter



Most of the bars in this graph are so short, they're barely visible, and impossible to interpret. Notice that this graph contains four quarters worth of data, but the sole label of "Q1" suggests otherwise. And what do you think of the dark grid lines? They make this graph look a little like a prison cell from which the numbers will never escape!

(Source: User documentation of Business Objects.)

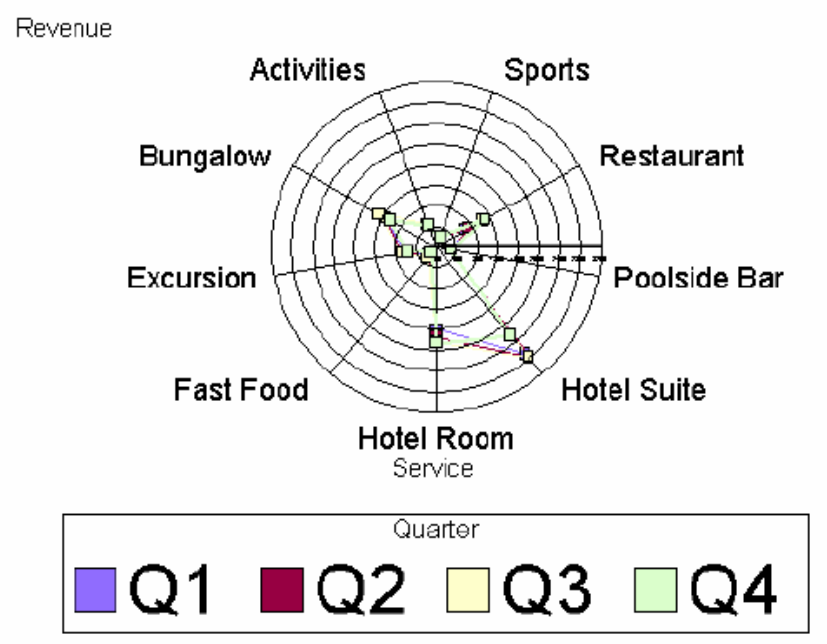
Example: Expenses by GL account category and account



I call this a “Scottish Graph,” because it looks a lot like the tartan print of a kilt. This is just plain absurd. Does this vendor really believe that people can interpret numbers as a continuum of color ranging from red through black to blue? The quantitative key at the bottom is a hoot. It includes six decimal places of precision for what must be dollars, but you’d be lucky to interpret any of the numbers in the graph within $10,000 of the actual value.

(Source: Web site of Visualize, Inc.)

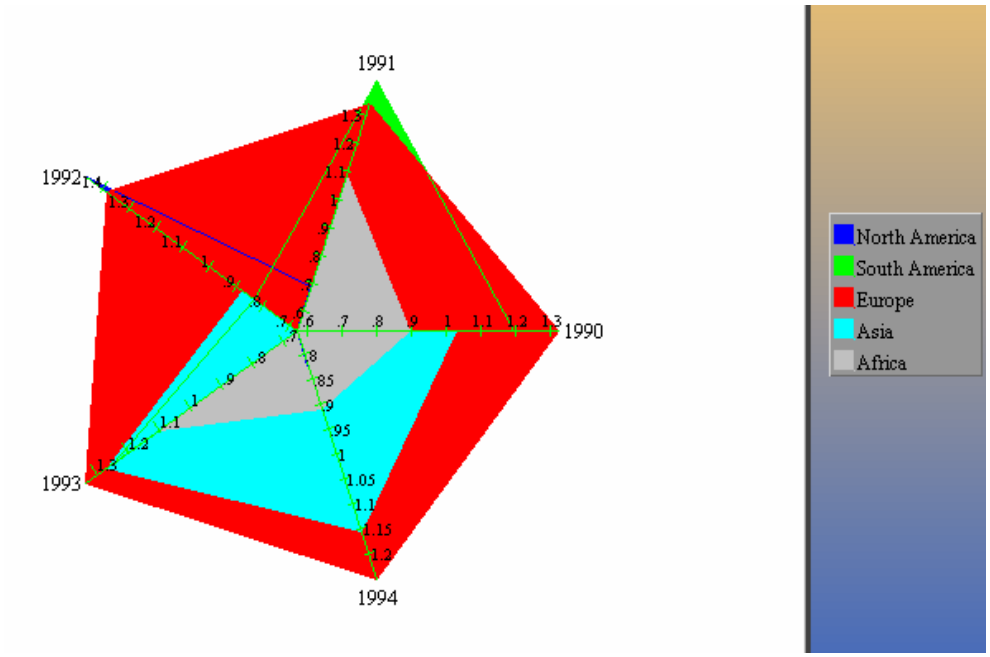
Example: Hotel revenue by service and quarter



Good thing the quarters are labeled so largely in the legend, otherwise I'd never be able to make sense of this radar graph.

(Source: User documentation of Business Objects.)

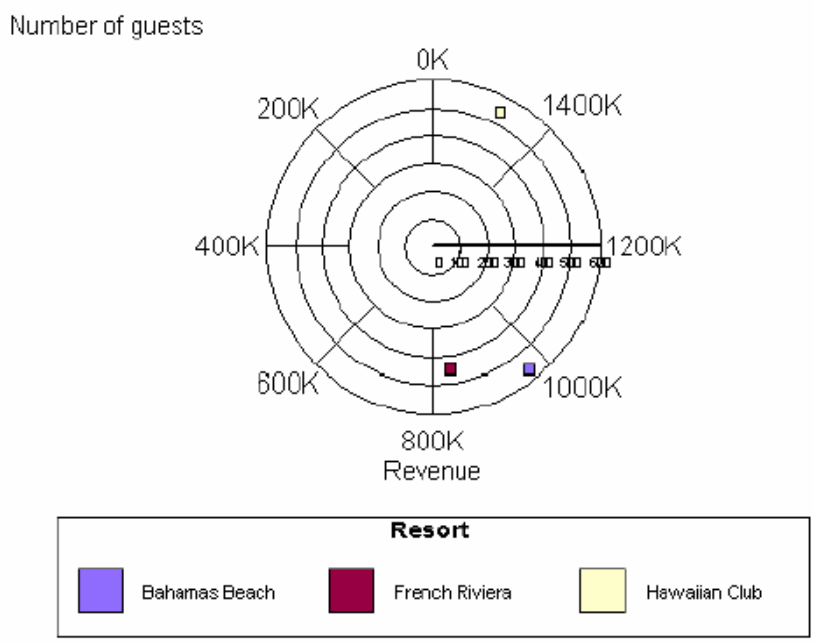
Example: Revenue by region and year



How can I obscure thee? Let me count the ways: 1) Overlapping areas, 2) years running counter-clockwise, and 3) a different scale on the 1994 axis. If I use a simple bar chart instead, my manager might think that I'm lazy and unsophisticated. This will show her how valuable I am.

(Source: Web site of Visualize, Inc.)

Example: Guest count and revenue by resort

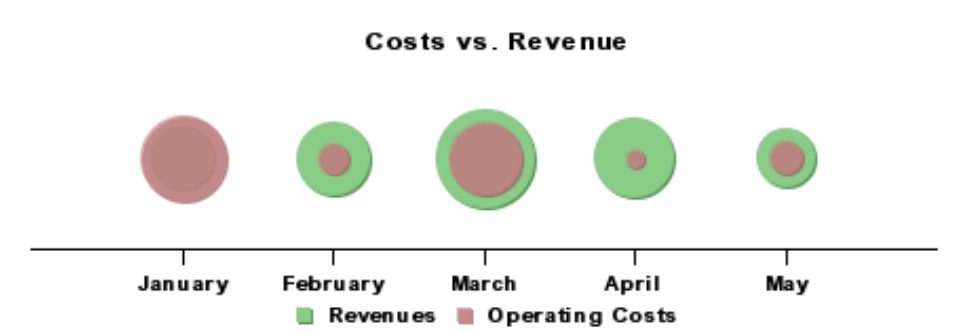


Why use a scatter plot to display the correlation between guest count and revenue when you can use a polar graph with counter-clockwise measures of revenue? See if you can make sense of this graph.

(Source: User documentation of Business Objects.)

Note: You might have noticed that several of these examples of poor graph design have come from Business Objects' user documentation. This is not because Business Objects contributes more to poor graph design than other software vendors, but simply because I have convenient to their user documentation and not to that of the other vendors.

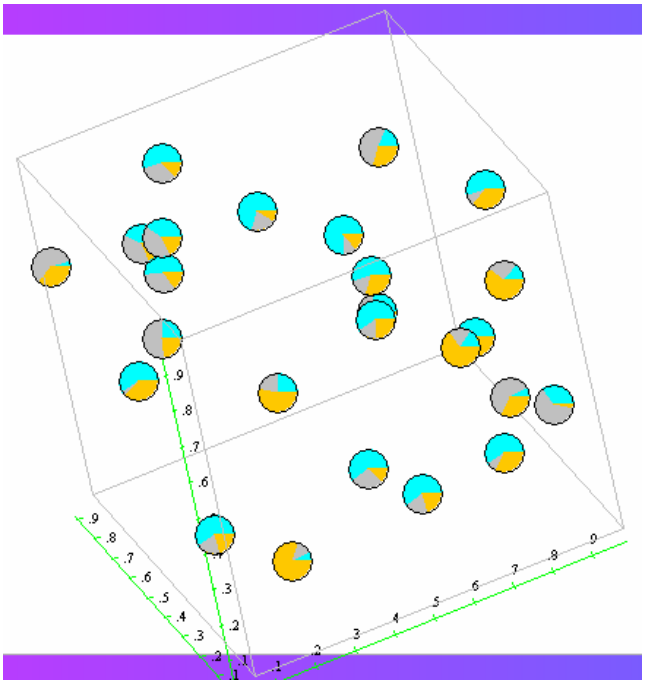
Example: Revenue vs. costs per month



Circles within and behind circles. Pretty! Pretty silly that is.

(Source: Web site of Visual Mining, Inc.)

Example: Your guess is as good as mine



Pies in 3-D space. Awesome!

(Source: Web site of Visualize, Inc.)

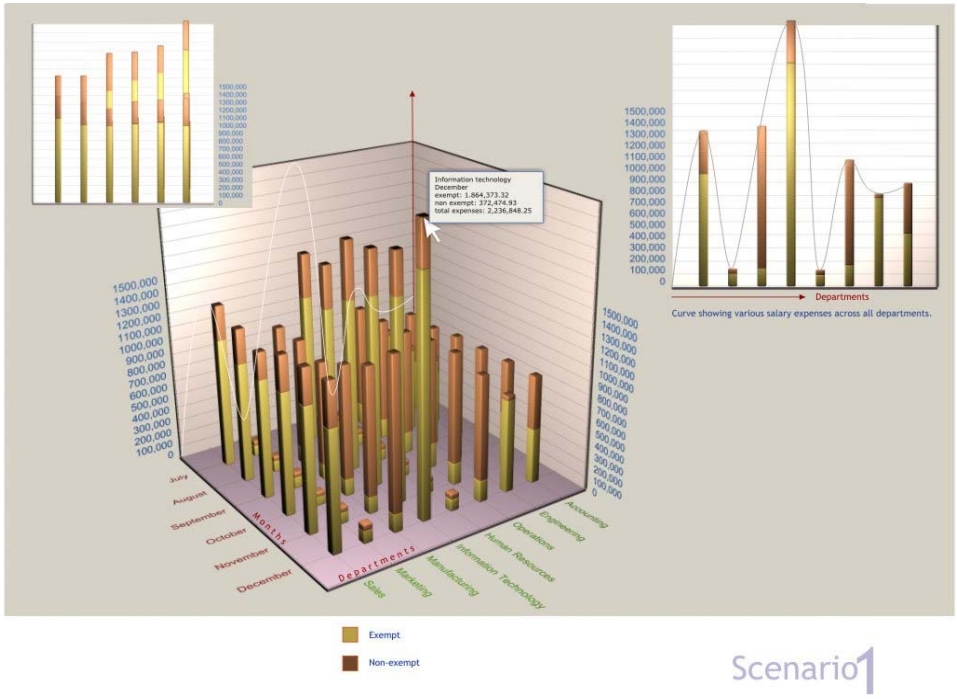
Do the vendors poor examples matter?

Contest Scenario:

This scenario involves the display of departmental salary expenses. It is used by the VP of Human Resources to compare the salary expenses of the company's eight departments as they fluctuate through time, in total and divided between exempt and non-exempt employees.

You might argue that the poor example set by the vendors doesn't really influence people in the real world. Unfortunately, that's not the case. Take a look at a few examples of data presentations that were submitted by graphing specialists to a competition sponsored by DM Review magazine.

Time-Series Solution #1

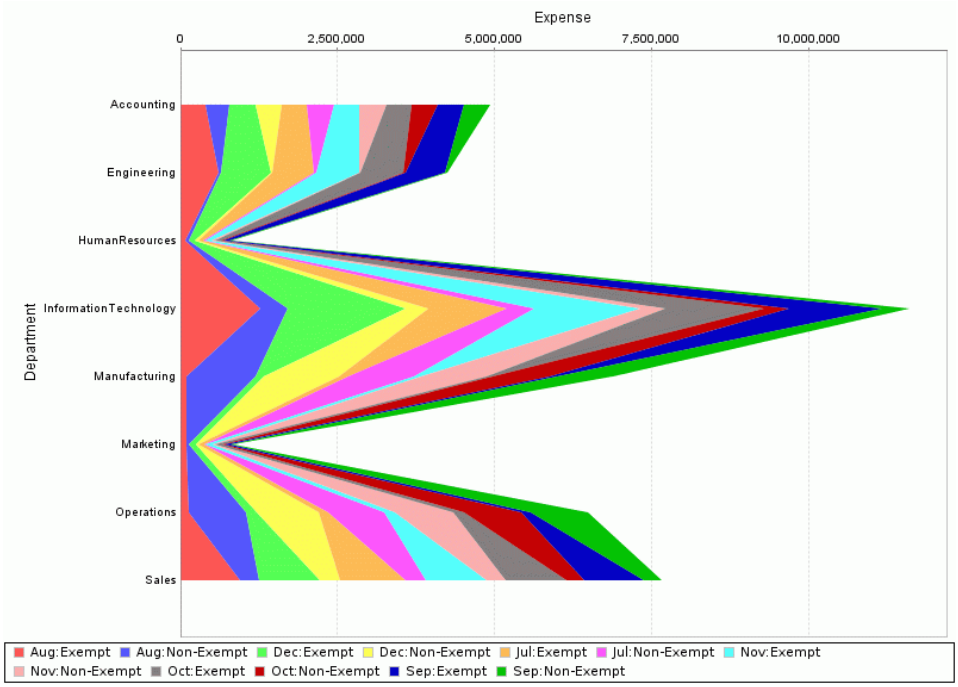


Every charting software vendor out there, with almost no exceptions, feature 3-D graphs. They look so impressive, but do they work? Users fall prey to the notion that 2-D displays are old-school, and that they must advance to displays like the one shown above to be taken seriously. The problem with 3-D displays of abstract business data, however, is that they are almost impossible to read.

Time-Series Solution #2

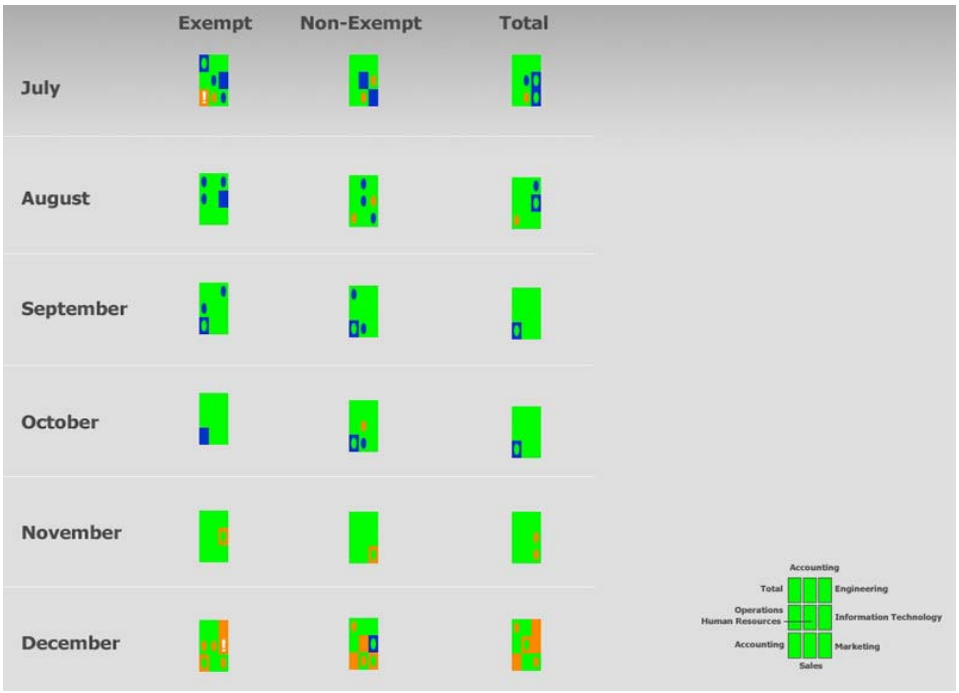
Vendors introduce display methods that are absurd, that show a complete ignorance of visual perception. Trends cannot be discerned by examining a series of pie charts and quantitative values cannot be effectively encoded as differing hues.

Time-Series Solution #3



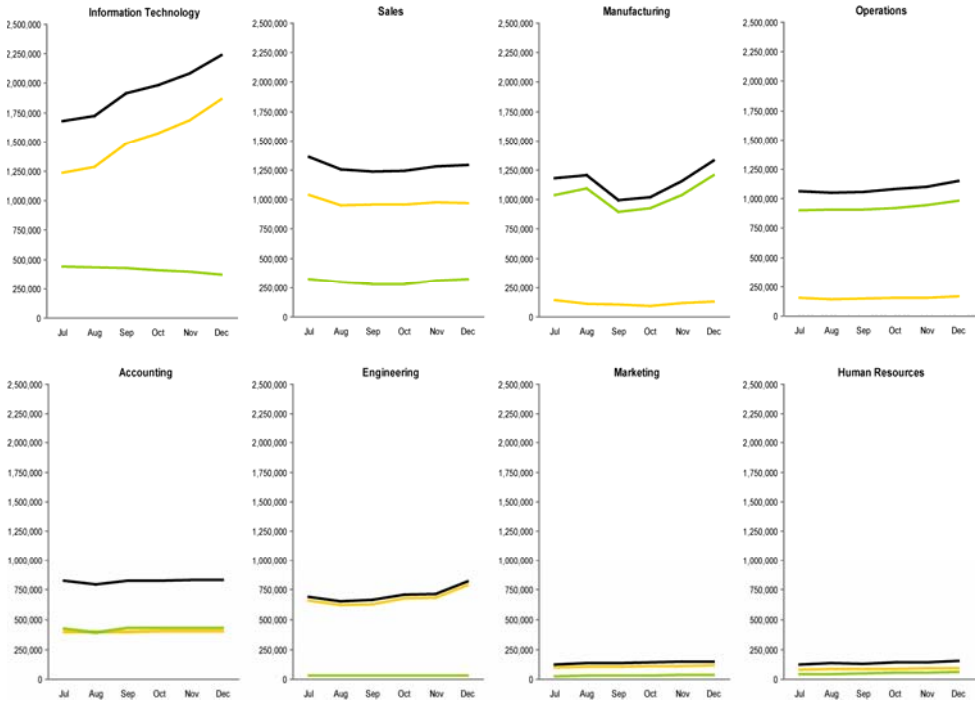
Based on the example set by the vendors, users attempt to dazzle their audience with bright colors and pretty pictures, often resulting in displays like this that completely obscure a relatively simple message. I challenge you to make sense of this graph.

Time-Series Solution #4



This example features software that uses a visual object called a glyph, which is meant to simultaneously encode multiple variables about an entity. In this case a set of nine small rectangles represents a company's expenses for a given month, and each of the individual small rectangles encodes the expenses in dollars of a single department for a given month. Glyphs are meant to do something quite different from this example. They are not meant and are not able to effectively encode departmental expenses as they vary through time. Why has this user applied this software so absurdly? Because the vendor itself promotes such use.

Time-Series Solution – One that works



Finally, we see a visual display that works. Departmental expenses are encoded as simple line graphs, which beautifully present the overall trend and individual ups and downs of the values through time. This arrangement of eight graphs within eye span, one per department, sorted from the greatest to least expenses, tells the data's story clearly. Here's a rare case where a vendor's expert design and thoughtful examples encouraged users to communicate effectively.

What is the goal of tables of graphs?

Communication

"Above all else show the data."

Edward Tufte

This Edward R. Tufte quote is from his milestone work, *The Visual Display of Quantitative Information*, published by Graphics Press in 1983.

In tables and graphs:

- The message is in the data.
- The medium of communication, especially for graphs, is visual.
- To communicate the data effectively, you must understand visual perception – what works, what doesn't, and why.

Communication problems – whether verbal or visual – are basically the same

I returned, and saw under the sun, that the race is not to the swift, nor the battle to the strong, neither yet bread to the wise, nor yet riches to men of understanding, nor yet favor to men of skill; but time and chance happen to them all.

Ecclesiastes 9:11 (King James version of the Bible)

Objective consideration of contemporary phenomena compels the conclusion that success or failure in competitive activities exhibits no tendency to be commensurate with innate capacity, but that a considerable element of the unpredictable must invariably be taken into account.

George Orwell's rewrite of this passage into bloated prose

The problems that are common in verbal language, which obscure communication, are the same as those we must learn to avoid in data presentation. We have a tendency to complicate what we have to say, rendering our message difficult to understand. In his book entitled *On Writing Well*, William Zinsser suggests four best practices for good writing:

1. Clarity
2. Simplicity
3. Brevity
4. Humanity

These closely parallel the practices that I teach for good data presentation.

Three important business competencies

Literacy

Numeracy

Graphicacy

All three seem to be declining in America.

My friend Howard Spielman argues that there are three basic competencies that are needed in business:

- **Literacy**: the ability to think and communicate in words, both spoken and written
- **Numeracy**: the ability to think and communicate in numbers
- **Graphicacy**: the ability to think and communicate in images

I believe that businesses in America are failing in all three areas today, especially in graphicacy, which involves a set of skills that very few people have ever learned, but rely on every day.

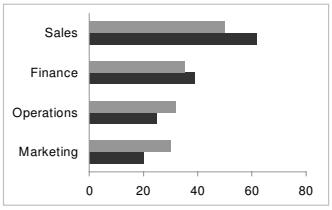
The two fundamental challenges of data presentation

1. Determining the medium that tells the story best

Either

Product	Units Sold	Revenue
Food	34,837	746,383
Beverage	42,374	845,984
Total	77,211	1,592,367

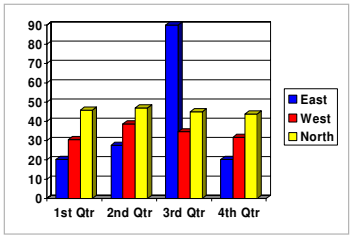
or



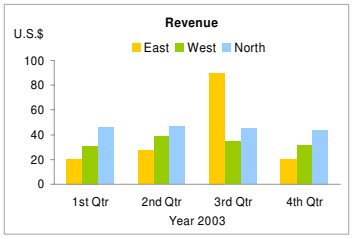
and
which kind?

2. Designing the visual components to tell the story clearly

From



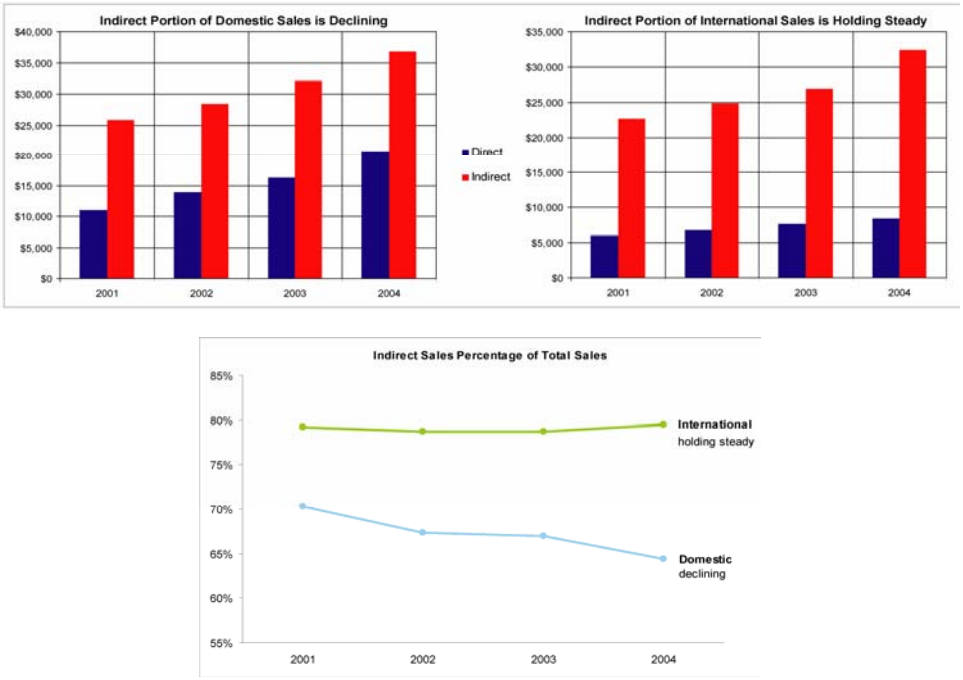
to



1. You begin by determining the best medium for your data and the message you wish to emphasize. Does it require a table or a graph? Which kind of table or graph?
2. Once you've decided, you must then design the individual components of that display to present the data and your message as clearly and efficiently as possible.

The solutions to both of these challenges are rooted in an understanding of visual perception.

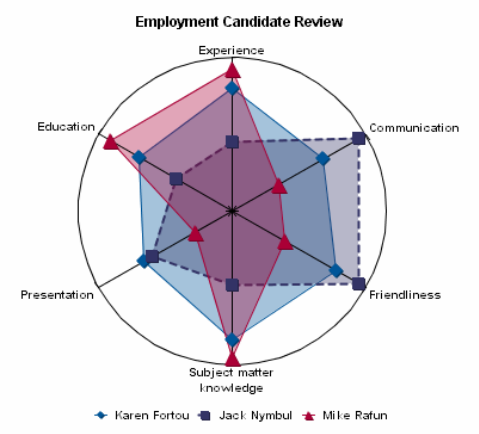
Match the display to your message



In the top example, the message contained in the titles is not clearly displayed in the graphs. The message deals with the ratio of indirect to total sales – how it is declining domestically, while holding steady internationally. You'd have to work hard to get this message the display as it is currently designed.

The bottom example, however, is designed very specifically to display the intended message. Because this graph is skillfully designed to communicate, its message is crystal clear. A key feature that makes this so is the choice of percentage for the quantitative scale, rather than dollars.

Eeney, meeney, miney, moe – what type of display should I use this time?



or

Employment Candidate Review

	Candidates		
Rating Areas	Karen Fortou	Mike Rafun	Jack Nymbul
Experience	4.00	4.50	2.50
Communication	3.50	2.00	5.00
Friendliness	4.00	2.00	4.50
Subject matter knowledge	4.00	5.00	2.50
Presentation	3.00	1.50	2.75
Education	3.50	4.50	2.00
Average Rating	3.67	3.25	3.21

If you were the person responsible for creating a means to display the relative merits of candidates for employment, you would have to choose the best visual means to communicate this information. You shouldn't just choose any old method, and especially not a particular one because it looks the snazziest. A graph isn't always the best way to get your message across. In this case a simple table would do the job better.

(Source: the radar graph on the left was found on the Web site of Visual Mining, Inc.)

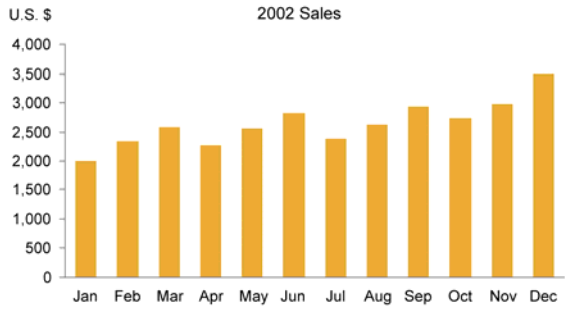
What characteristics define tables?

Product	Units Sold	Actual Revenue	% of Total	Fcst Revenue	% of Fcst
Product A	938	187,600	47%	175,000	107%
Product B	1,093	114,765	28%	130,000	88%
Product C	3,882	62,112	15%	50,000	124%
Product D	873	36,666	9%	40,000	92%
Product E	72	2,088	1%	50,000	4%
Total	6,858	$403,231	100%	$445,000	91%

- Data arranged in columns and rows
- Data encoded as text

Notice that I didn't say that grid lines are essential to tables. Spreadsheet software and its ever-present grid lines to outline each cell incorrectly suggests that grid lines are necessary, but they are not.

What characteristics define graphs?



- Values are displayed in an area defined by one or more axes
- Values are encoded as visual objects positioned in relation to the axes
- Axes provide scales (quantitative and categorical) that assign values and labels to the data objects

Quantitative graphs were originally an extension of maps, with their scales of longitude and latitude.

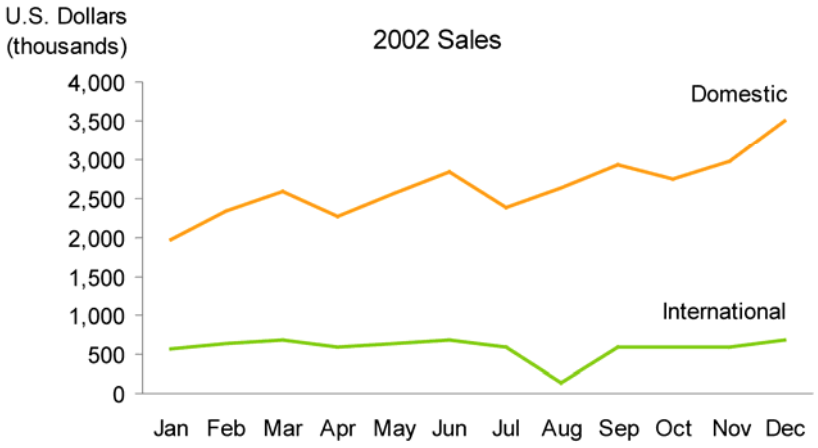
Tables work best when

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Annual
1990	127.4	128.0	128.7	128.9	129.2	129.9	130.4	131.6	132.7	133.5	133.8	133.8	130.7
1991	134.6	134.8	135.0	135.2	135.6	136.0	136.2	136.6	137.2	137.4	137.8	137.9	136.2
1992	138.1	138.6	139.3	139.5	139.7	140.2	140.5	140.9	141.3	141.8	142.0	141.9	140.3
1993	142.6	143.1	143.6	144.0	144.2	144.4	144.4	144.8	145.1	145.7	145.8	145.8	144.5
1994	146.2	146.7	147.2	147.4	147.5	148.0	148.4	149.0	149.4	149.5	149.7	149.7	148.2
1995	150.3	150.9	151.4	151.9	152.2	152.5	152.5	152.9	153.2	153.7	153.6	153.5	152.4
1996	154.4	154.9	155.7	156.3	156.6	156.7	157.0	157.3	157.8	158.3	158.6	158.6	156.9
1997	159.1	159.6	160.0	160.2	160.1	160.3	160.5	160.8	161.2	161.6	161.5	161.3	160.5
1998	161.6	161.9	162.2	162.5	162.8	163.0	163.2	163.4	163.6	164.0	164.0	163.9	163.0
1999	164.3	164.5	165.0	166.2	166.2	166.2	166.7	167.1	167.9	168.2	168.3	168.3	166.6
2000	168.8	169.8	171.2	171.3	171.5	172.4	172.8	172.8	173.7	174.0	174.1	174.0	172.2
2001	175.1	175.8	176.2	176.9	177.7	178.0	177.5	177.5	178.3	177.7	177.4	176.7	177.1
2002	177.1	177.8	178.8	179.8	179.8	179.9	180.1	180.7	181.0	181.3	181.3	180.9	179.9

- Used to look up individual values
- Used to compare individual values
- Data must be precise
- You must include multiple units of measure

What do graphs do best?

Graphs show relationships between values by giving them shape.



The old saying, “A picture is worth a thousand words,” applies quite literally to quantitative graphs. By displaying quantitative information in visual form, graphs efficiently reveal information that would otherwise require a thousand words or more to adequately describe.

“[When] we visualize the data effectively and suddenly, there is what Joseph Berkson called ‘interocular traumatic impact’: a conclusion that hits us between the eyes.” William S. Cleveland, *Visualizing Data*, Hobart Press, 1993.

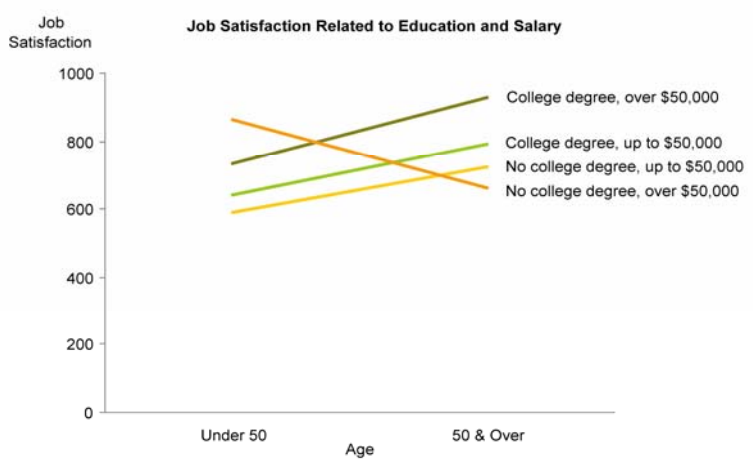
Take a moment to identify the various types of information that are revealed by the shape of the data in this graph.

Graphs bring relationships to light

What's the message?

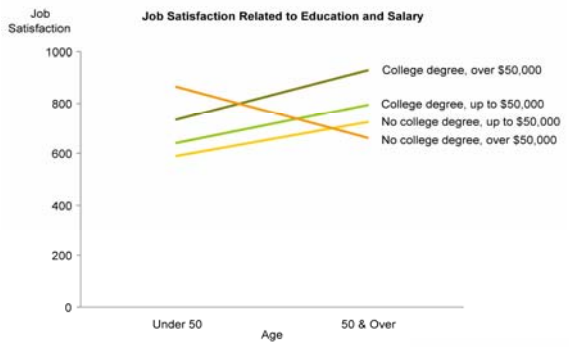
Job Satisfaction By Income, Education & Age

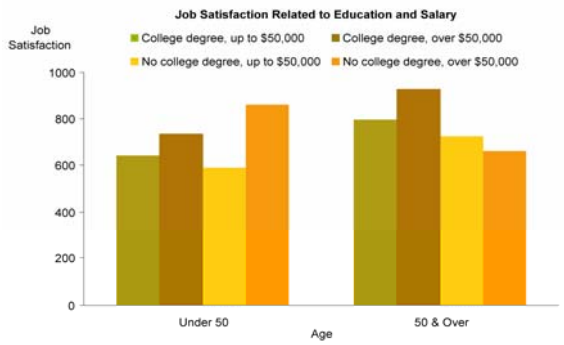
	College Degrees		No College Degrees	
Income	Under 50	50 & over	Under 50	50 & over
Up to $50,000	643	793	590	724
Over $50,000	735	928	863	662



The fact that job satisfaction for employees without a college degree decreases significantly in their later years doesn't jump out at you when you examine the table, but it is immediately obvious when you examine the graph.

But only if you design them correctly





The type of graph that is selected and the way it's designed also have great impact on the message that is communicated. By simply switching from a line graph to a bar graph, the decrease in job satisfaction among those without college degrees in their later years is no longer as obvious.

Quantitative information always consists of two types of data

1. Quantitative values (a.k.a. measures)
2. Categorical labels (a.k.a. dimensions)

Department	Exempt	Non-Exempt
Sales	950,003	1,309,846
Operations	648,763	2,039,927
Manufacturing	568,543	2,367,303
Total	$2,167,309	$5,717,076

Department	Exempt	Non-Exempt
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Manufacturing	568,543	2,367,303
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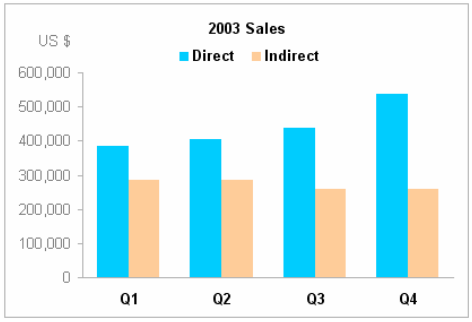
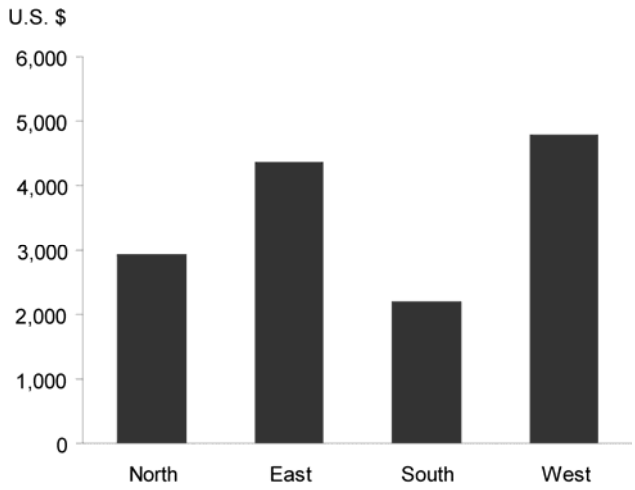


Quantitative values are numbers – measures of something related to the business (number of orders, amount of profit, rating of customer satisfaction, etc.). Categorical subdivisions break the measures down into meaningful groups and give them meaningful labels.

A scale on a graph is either quantitative or categorical

Quantitative

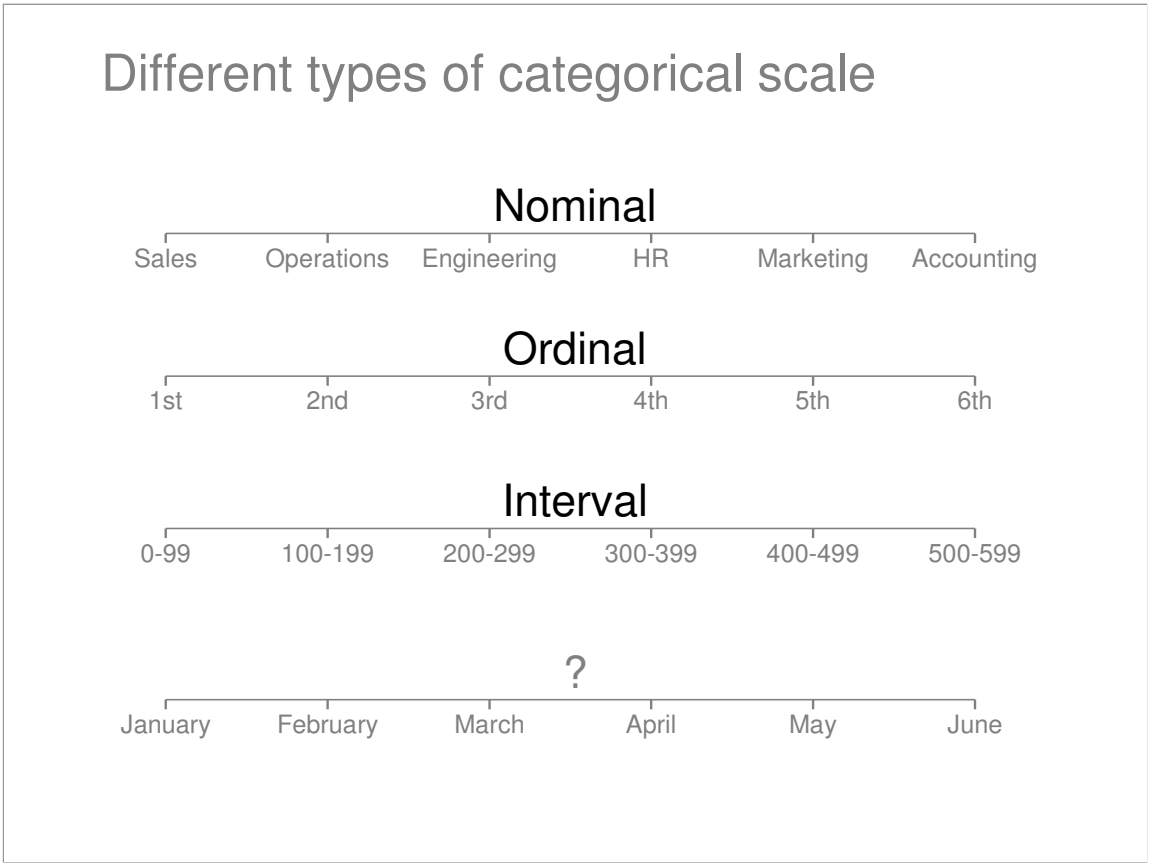
How much?



Categorical

What?

A quantitative scales consists of a range of values that is used to measure something. A categorical scale identifies what is being measured, listing the separate instances of a variable, the items in a category.

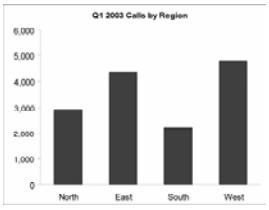


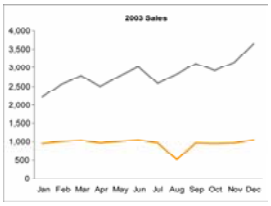
Categorical scales come in several types, three of which are common in graphs:

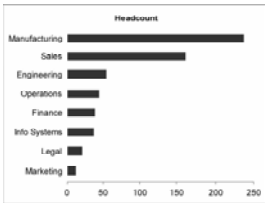
- Nominal: The individual items along the scale differ in name only. They have no particular order and represent no quantitative values.
- Ordinal: The individual items along the scale have an intrinsic order of rank, but also do not represent quantitative values.
- Interval: The individual items along the scale have an intrinsic order, which in this case does correspond to quantitative values. Interval scales begin as a range of quantitative values, but are converted into a categorical scale by subdividing the range into small ranges of equal size, each of which is given a label (e.g., “0-99” or “>= 0 and <100”).

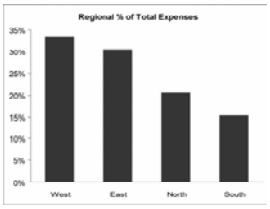
The last scale above, consisting of January through June, is an interval scale. It is ordinal, in that the months have an intrinsic order, but it is an interval scale because months are equal subdivisions of time, and time is quantitative in that units of time can be added, subtracted, and so on.

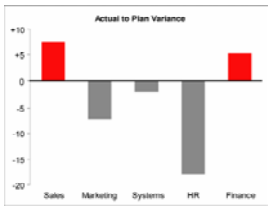
Quantitative messages always involve relationships.

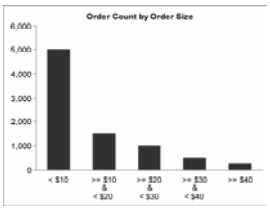


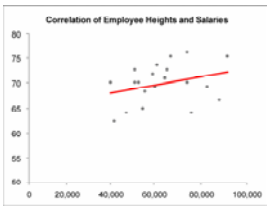






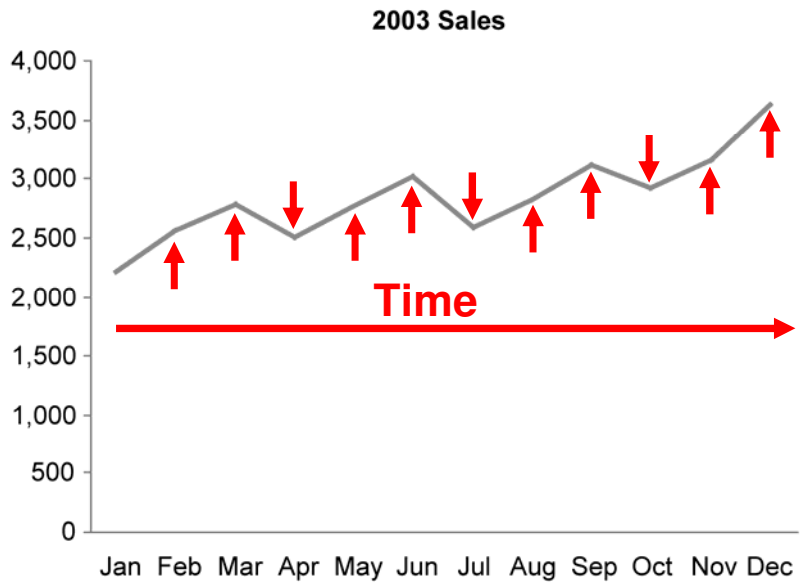




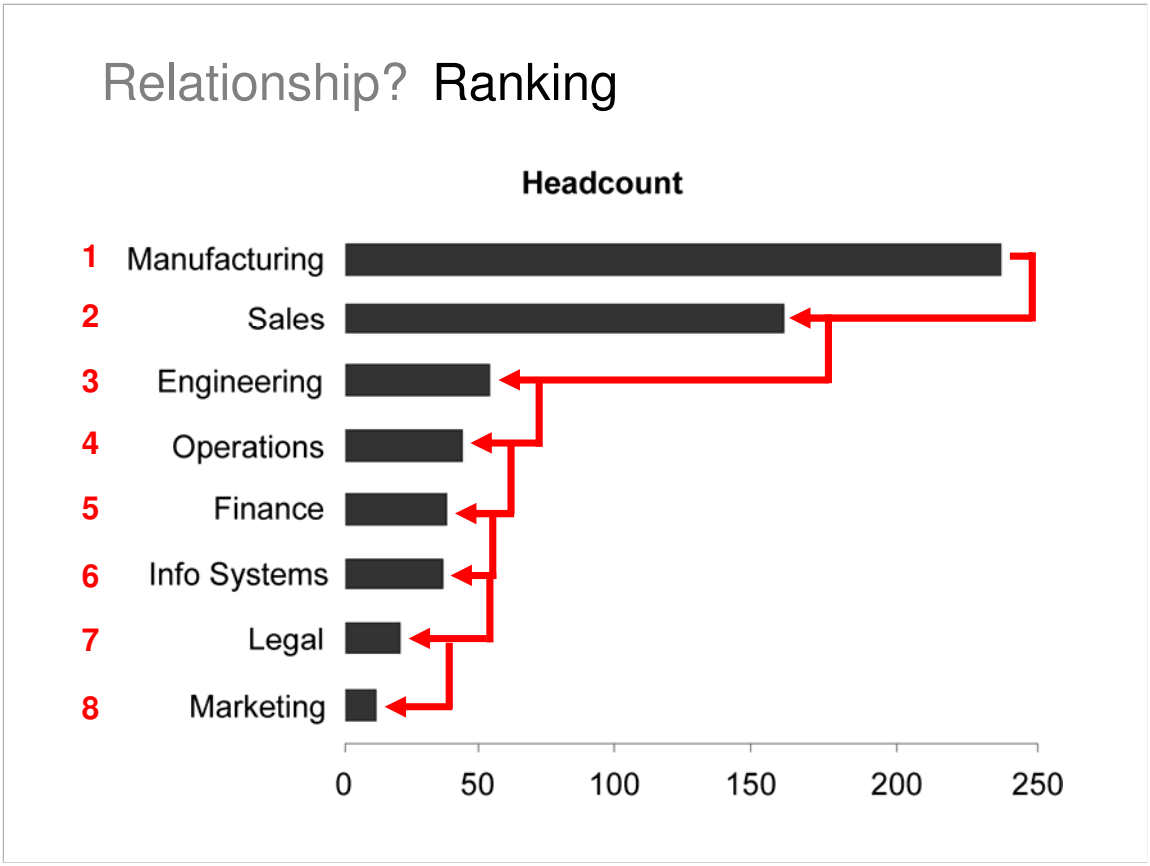


Each of these graphs illustrates a different type of quantitative relationship. Just as in life in general, the interesting and important content of a graph always involves relationships.

Relationship? Time-Series

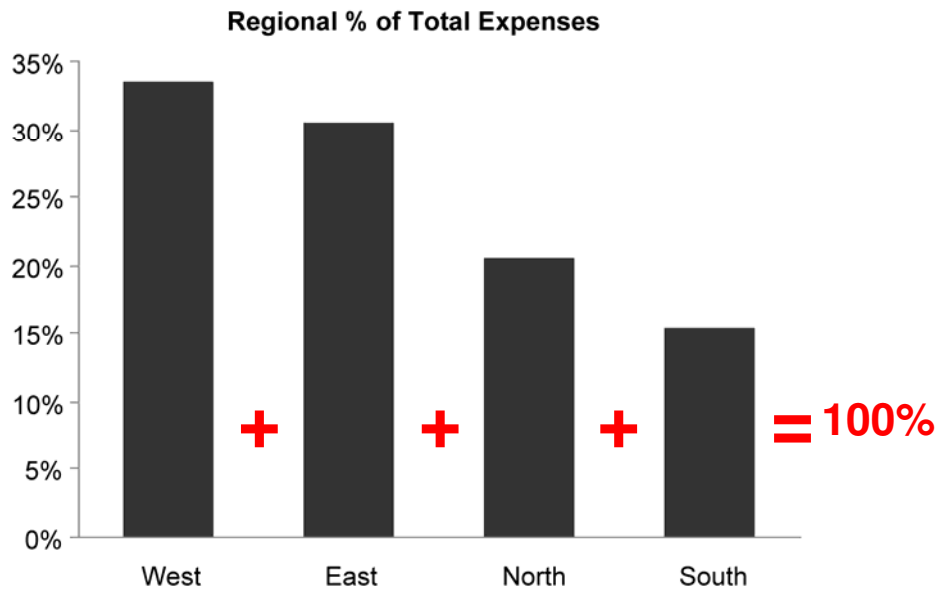


A time-series graph has a categorical scale that represents time, subdivided into a particular unit of time, such as years, quarters, months, days, or even hours. These graphs provide a powerful means to see patterns in the values as they march through time.



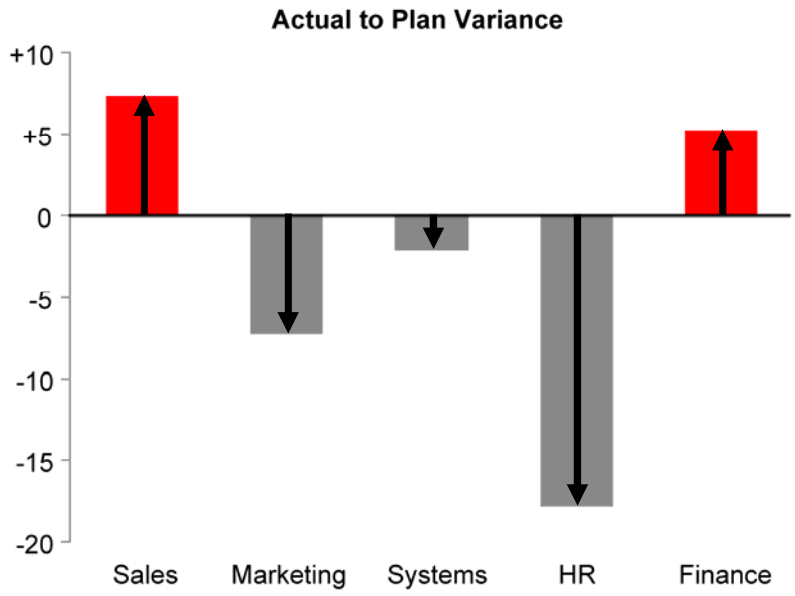
Ranking graphs show the sequence of a series of categorical subdivisions, based on the measures associated with them.

Relationship? Part-to-Whole



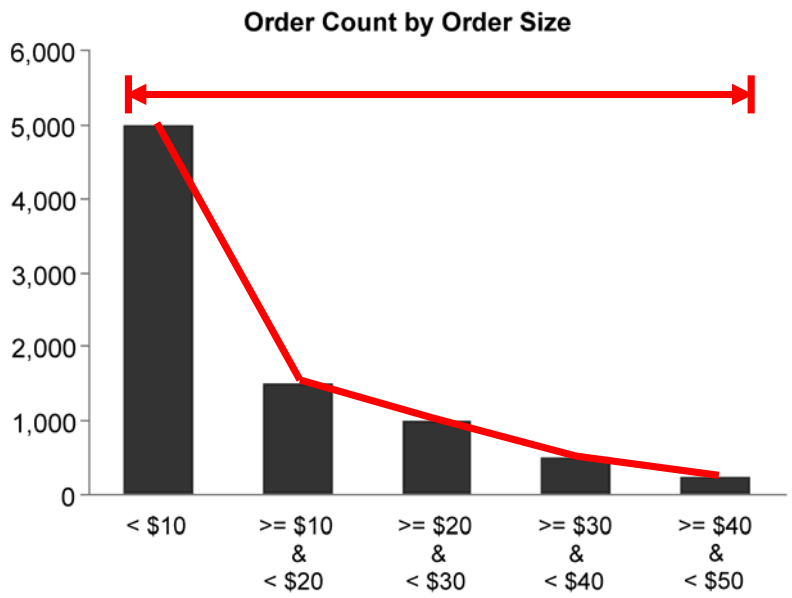
A part-to-whole graph shows how the measures associated with the individual categorical subdivisions of a full set relate to the whole and to one another.

Relationship? Deviation



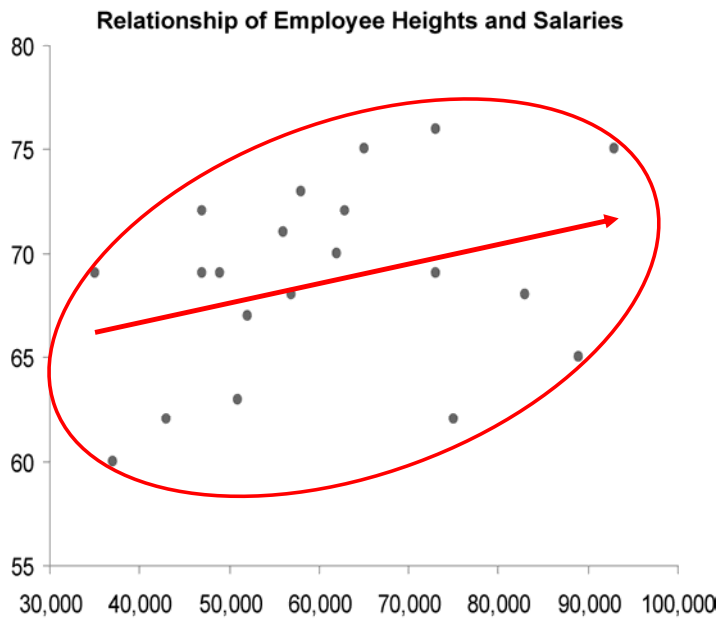
A deviation graph shows how the measures associated with one or more sets of categorical subdivision differ from a set of reference measures.

Relationship? Distribution



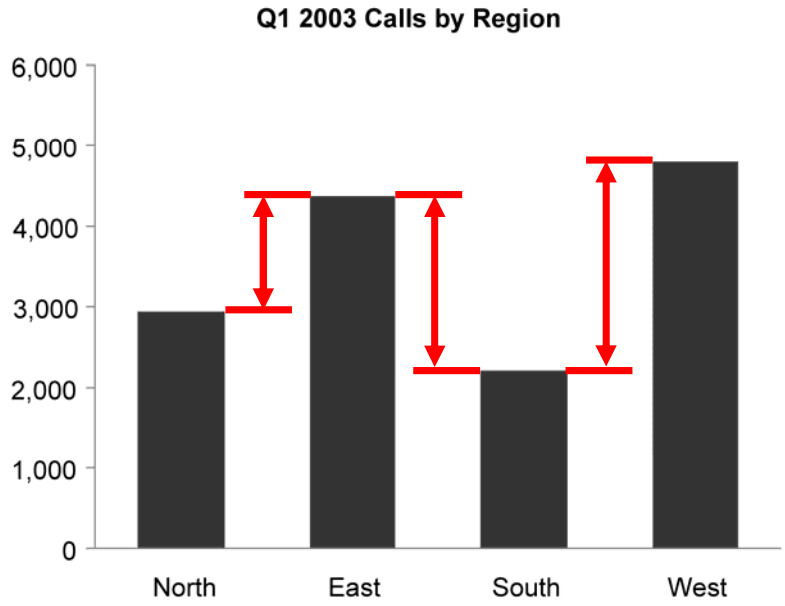
This type of distribution graph, called a frequency distribution, shows the number of times something occurs across consecutive intervals of a larger quantitative range. In a frequency distribution, a quantitative scale (in this case the range of dollar values of orders) is converted to a categorical scale by subdividing the range and giving each of the subdivisions a categorical label ("< $10", and so on).

Relationship? Correlation



A correlation graph shows whether two paired sets of measures vary in relation to one another, and if so, in which direction (positive or negative) and to what degree (strong or weak). If the trend line moves upwards, the correlation is positive; if it moves downwards, it is negative. A positive correlation indicates that as the values in one data set increase, so do the values in the other data set. A negative correlation indicates that as the values in one data set increase, the values in the other data set decrease. In a scatter plot like this, the more tightly the data points are grouped around the trend line, the stronger the correlation.

Relationship? Nominal Comparison



The term nominal means “in name only.” When items relate to one another nominally, they have no particular order. Whenever you find yourself creating a graph with only a nominal relationship, ask yourself if you could improve it by showing another relationship as well, such as a ranking or a part-to-whole.

The seven common relationships in graphs

- Nominal comparison
- Time-series
- Ranking
- Part-to-whole
- Deviation
- Distribution
- Correlation

Without reviewing the last few slides, unless you must as a reminder, try to describe a real-world example of each type of relationship.

Selecting the right medium is half the battle.

What's the other half?

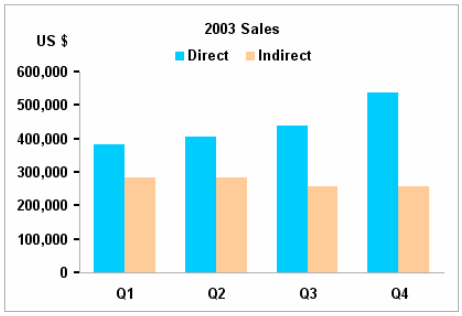
Designing each component to speak clearly.

Once you've selected the best means to display your data and message, the next big challenge is to design the visual components of the display to state your message clearly, without distraction, and to highlight what's most important.

The Data-Ink Ratio

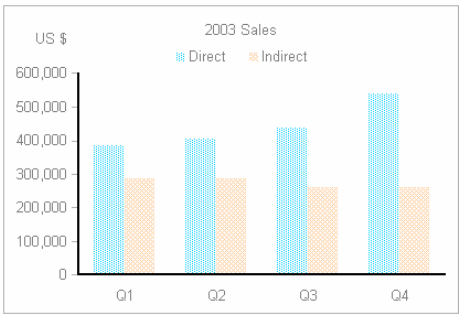
Data Ink

Department	Exempt	Non-Exempt
Sales	950,003	1,309,846
Operations	648,763	2,039,927
Manufacturing	568,543	2,367,303
Total	$2,167,309	$5,717,076



Non-Data Ink

Department	Exempt	Non-Exempt
Sales	950,003	1,309,846
Operations	648,763	2,039,927
Manufacturing	568,543	2,367,303
Total	$2,167,309	$5,717,076



But besides the data, what else is there? According to Edward Tufte, tables and graphs consist of two types of ink: data ink and non-data ink. He introduced the concept of the “data-ink ratio” in his 1983 classic *The Visual Display of Quantitative Data*. He argued that the ratio of ink used to display data to the total ink should be high. In other words, ink that is used to display anything that isn’t data should be reduced to a minimum.

Steps in the design process

1. Reduce the non-data ink.

Remove unnecessary non-data ink.

De-emphasize and regularize the remaining non-data ink.

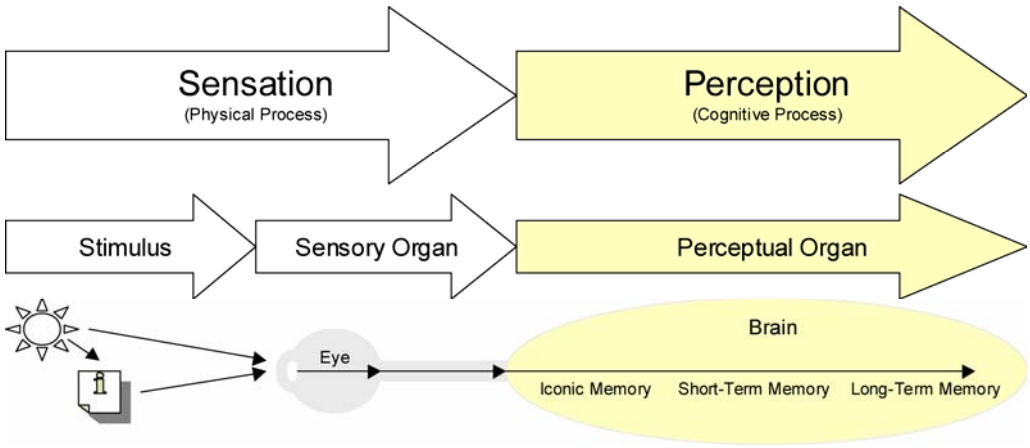
2. Enhance the data ink.

Remove unnecessary data ink.

Emphasize the most important data ink.

“In anything at all, perfection is finally attained not when there is no longer anything to add, but when there is no longer anything to take away.” Antoine de St. Exupery

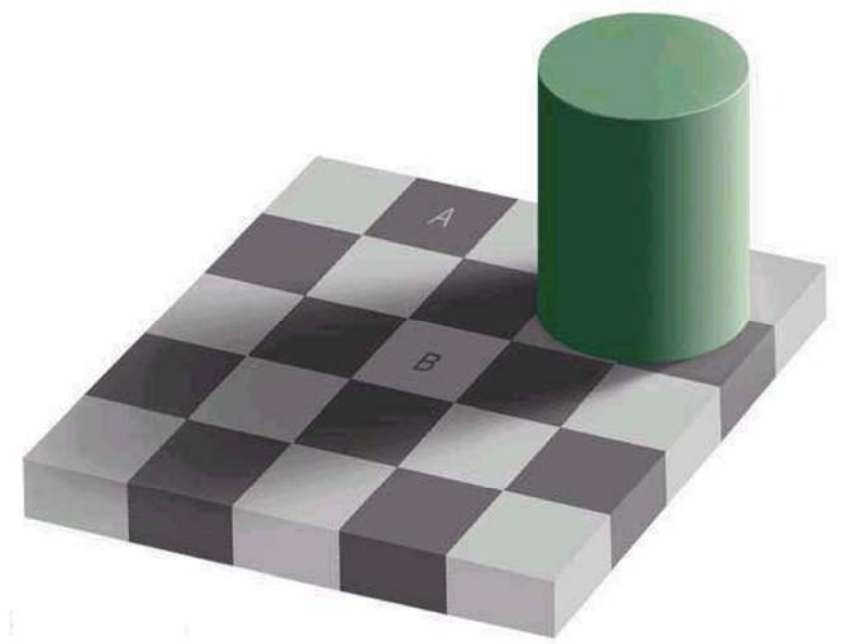
Effective data presentation is rooted in an understanding of visual perception



To know how to present information visually in an effective way, you must understand a little about visual perception – what works, what doesn't, and why.

"Why should we be interested in visualization? Because the human visual system is a pattern seeker of enormous power and subtlety. The eye and the visual cortex of the brain form a massively parallel processor that provides the highest-bandwidth channel into human cognitive centers… However, the visual system has its own rules. We can easily see patterns presented in certain ways, but if they are presented in other ways, they become invisible…If we can understand how perception works, our knowledge can be translated into rules for displaying information… If we disobey the rules, our data will be incomprehensible or misleading." Colin Ware, *Information Visualization: Perception for Design*, 2nd Edition, Morgan Kaufmann Publishers, San Francisco, 2004.

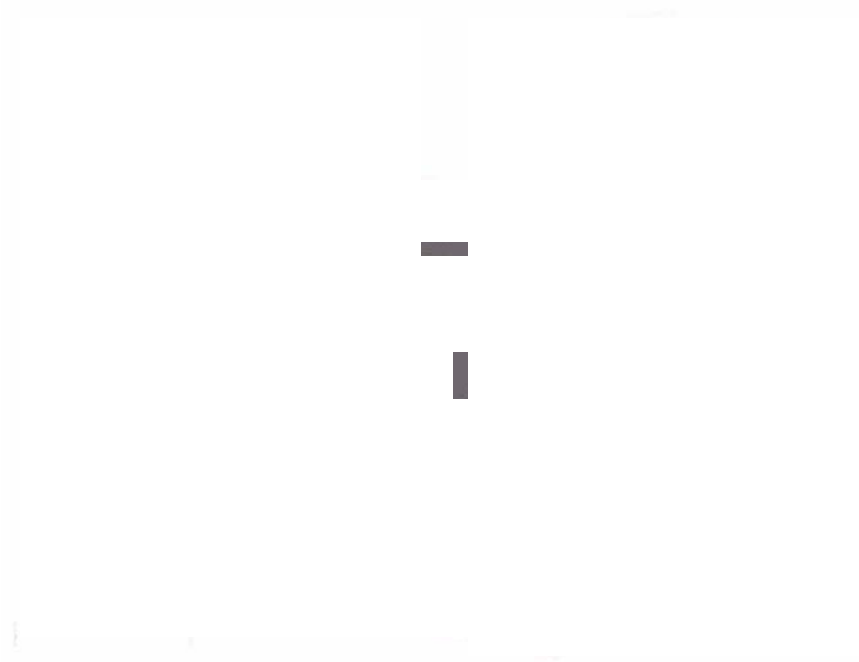
Visual perception is not just camera work



Square A is darker than B, right?

Actually, squares A and B are exactly the same color.

We perceive differences, not absolutes

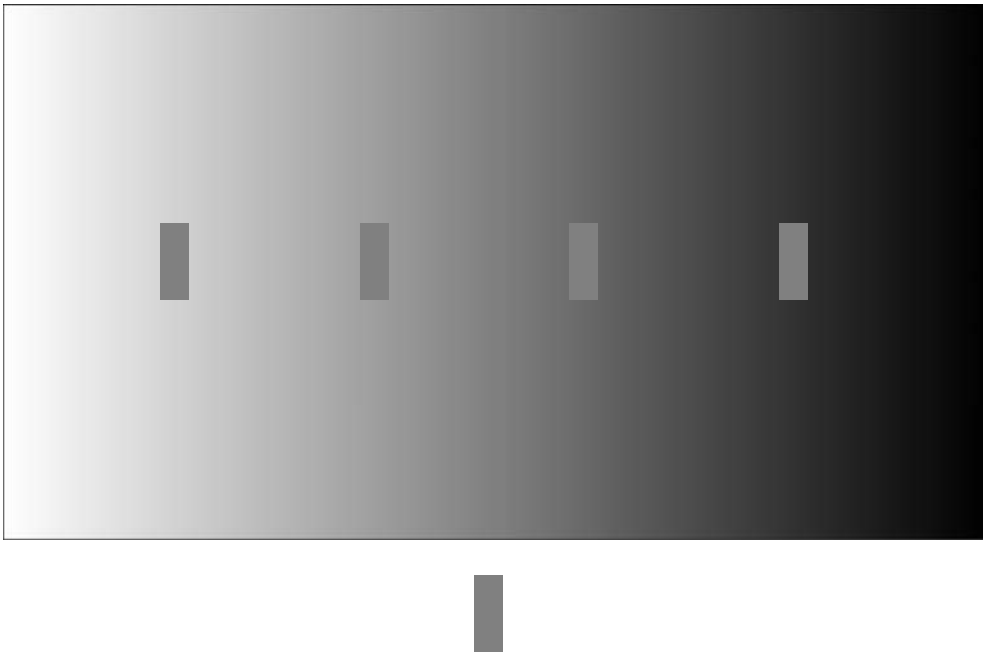


Take a closer look

What we see is not a simple recording of what is actually out there. Seeing is an active process that involves interpretations by our brains of data that is sensed by our eyes in an effort to make sense of it in context. The presence of the cylinder and its shadow in the image of the checkerboard triggers an adjustment in our minds to perceive the square labeled B as lighter than it actually is. The illusion is also created by the fact that the sensors in our eyes do not register actual color but rather the difference in color between something and what's nearby. The contrast between square A and the light squares that surround it and square B and the dark squares that surround it cause us to perceive squares A and B quite differently, even though they are actually the same color.

The ability to use graphs effectively requires a basic understanding of how we unconsciously interpret what we see.

Context affects visual perception



This image illustrates the surprising affect that a simple change in the lightness of the background alone has on our perception of color. The large rectangle displays a simple color gradient of a gray-scale from fully light to fully dark.The small rectangle is the same exact color everywhere it appears, but it doesn't look that way because our brains perceive visual differences rather than absolute values, in this case between the color of the small rectangle and the color that immediately surrounds it.

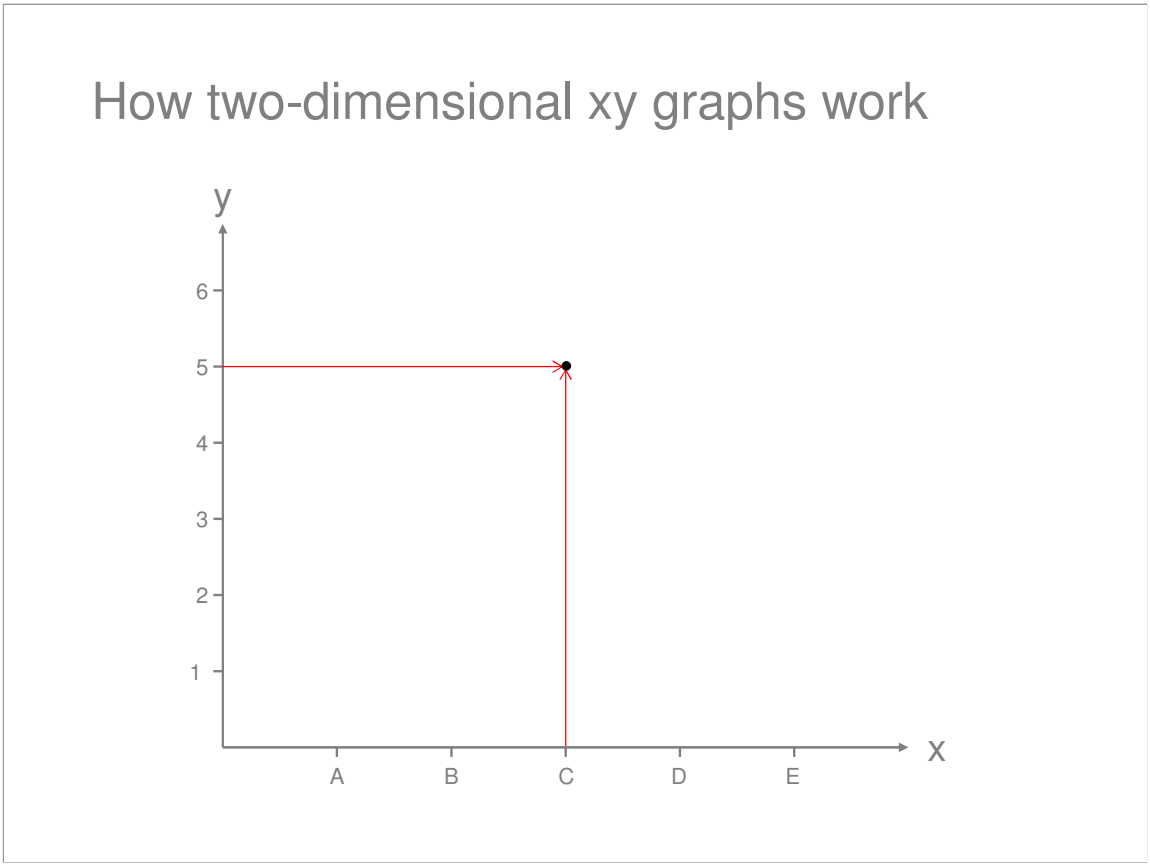
Among other things, understanding this should tell us that using a color gradient as the background of a graph should be avoided.

We even perceive the written word differently than you probably think

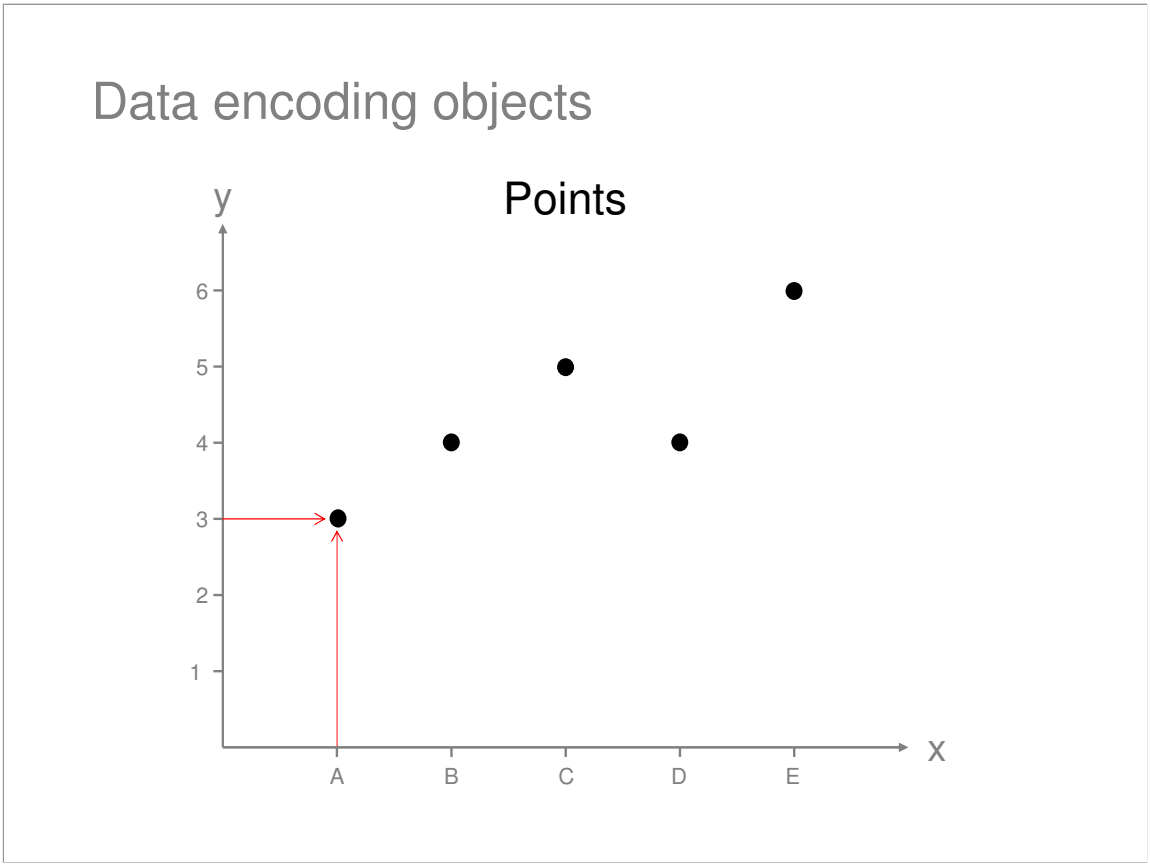
Aoccdrnig to rscheearch at Cmabridge Uinervtisy, it deosn't mttaer In what oredr the ltteers in a word are, the olny iprmoatnt tihng is that the frist and lsat ltteer be at the rghit pclae. The rset can be a Total mses and you can still raed it wouthit problem. This is bcuseae the huamn mnid deos not raed ervey lteter by istlef, but the word as a wlohe.

amzanig huh?

Even our perception of written language works much differently than we assume. To communicate effectively, we must present information in a way that matches how people perceive and think.

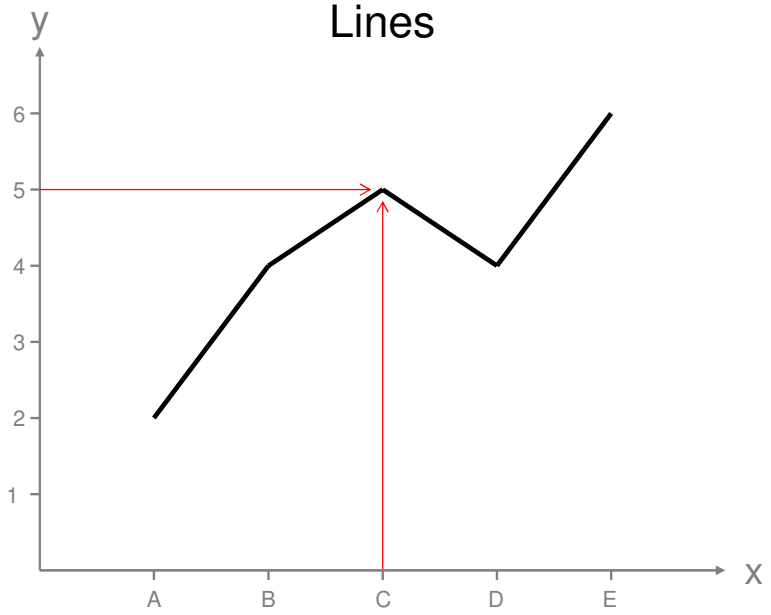


Most 2-D graphs work by means of a system of coordinates, encoding each value as a coordinate along two perpendicular axes, X (horizontal) and Y (vertical). Rene Descartes, the 17th century mathematician and philosopher ("I think, therefore I am.") invented this XY coordinate system for use in mathematics, not for communicating quantitative data.

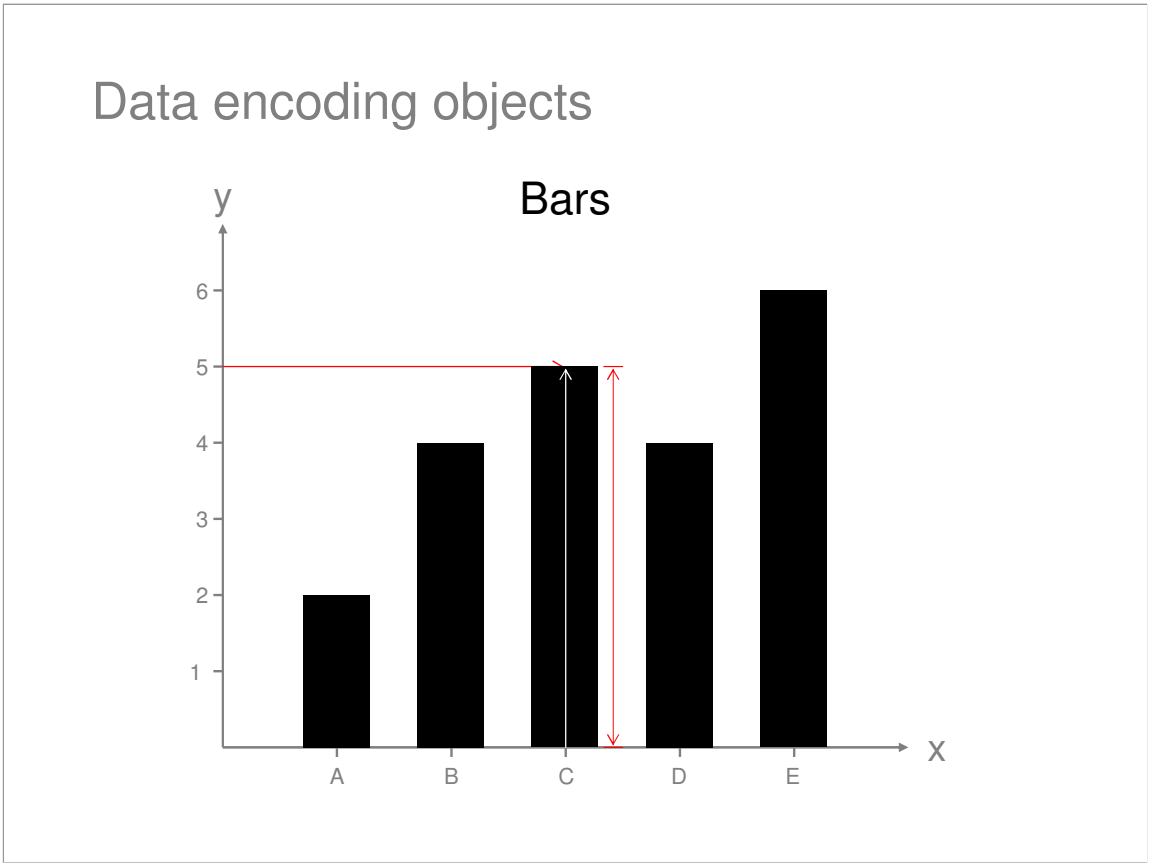


Points encode individual values as 2-D position.

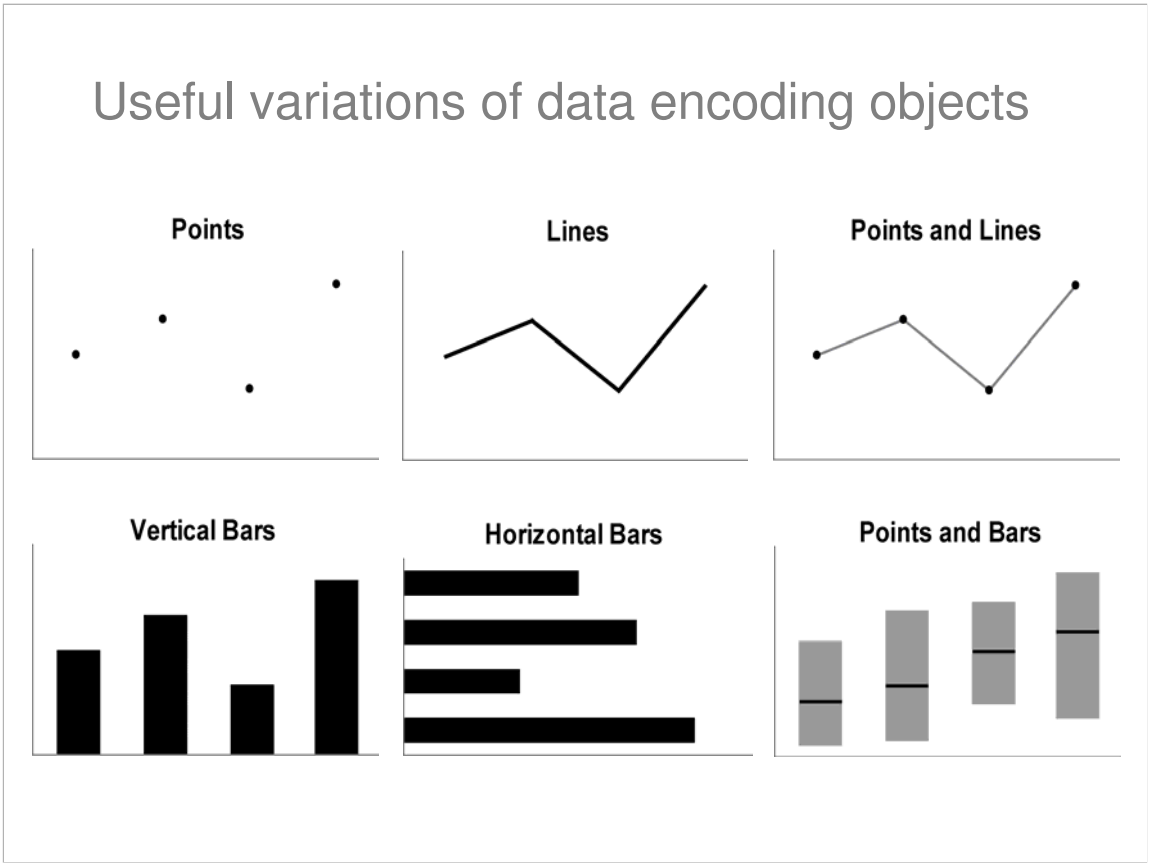
Data encoding objects



Line encode individual values as 2-D position (at each data point connected by the line), but by connecting the data values the added characteristics of slope and direction also carry information.

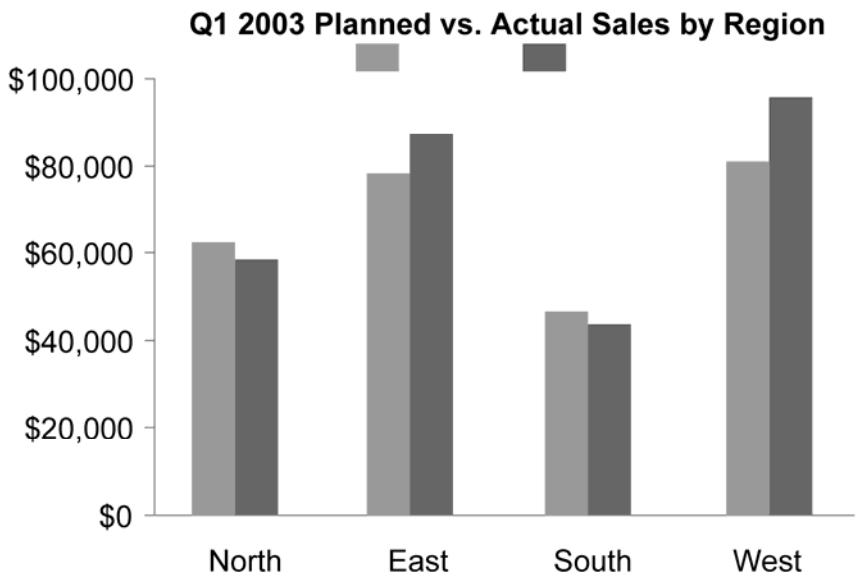


Bars encode individual values as 2-D position at the endpoint of the bar, and also as line length.



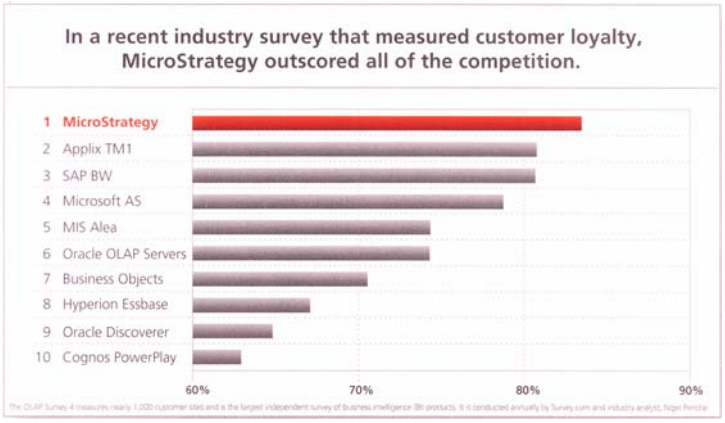
Six variations of these three data encoding objects work well in XY graphs. Each has its own strengths and weaknesses.

The strengths of bars



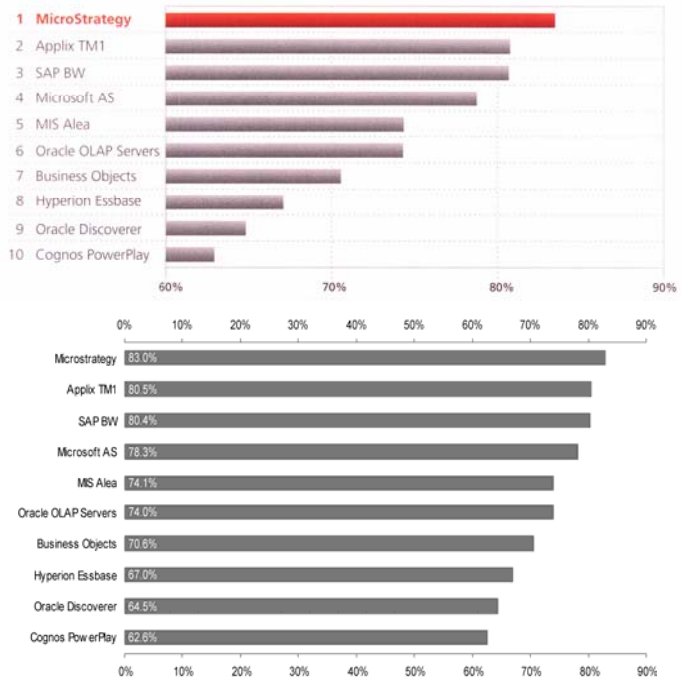
The strength of bars, because they have such great visual weight, like great column rising into the sky, is their ability to emphasize individual discrete values. Because bars encode quantitative values in part as line length, they must always begin at a value of zero, otherwise their length does not correspond accurately to their quantitative value.

What's wrong with this bar graph?



Something is terrible wrong with this graph. Can you see the problem?

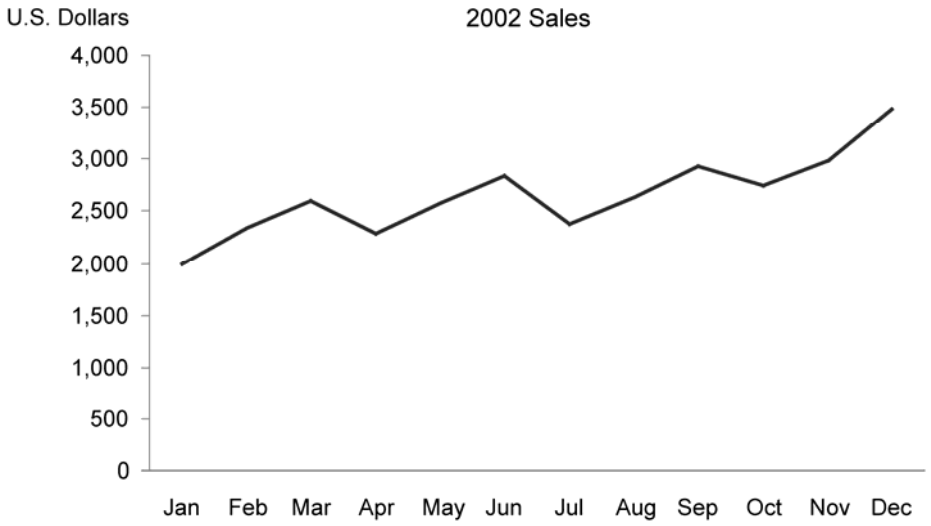
Bar values should always start at zero



Because bars encode quantitative values in part as line length, they must always begin at a value of zero, otherwise their length does not correspond accurately to their quantitative value.

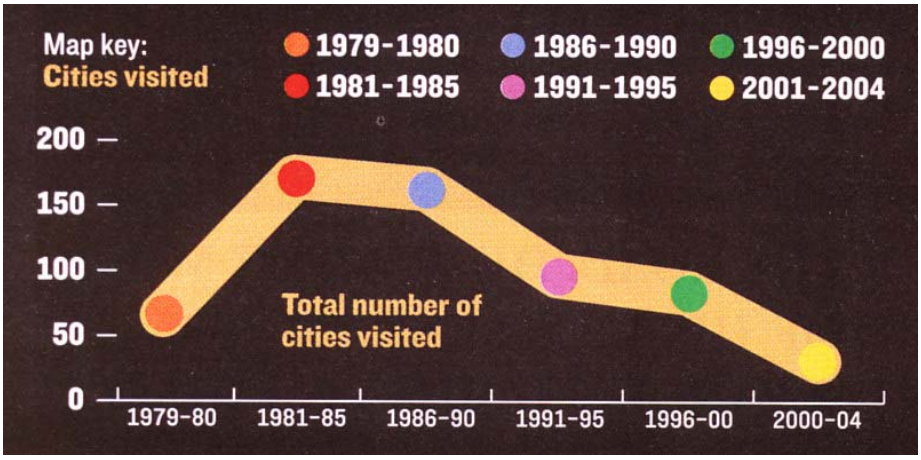
MicroStrategy's customer service score is only 33% greater than the lowest scoring product, Cognos PowerPlay, but the difference is bar lengths in MicroStrategy's graph is 750% greater. That's a lie factor of 2,301% (33%/750%=2,301%). Notice how different the data looks when encoded accurately in the bottom graph.

The strengths of lines

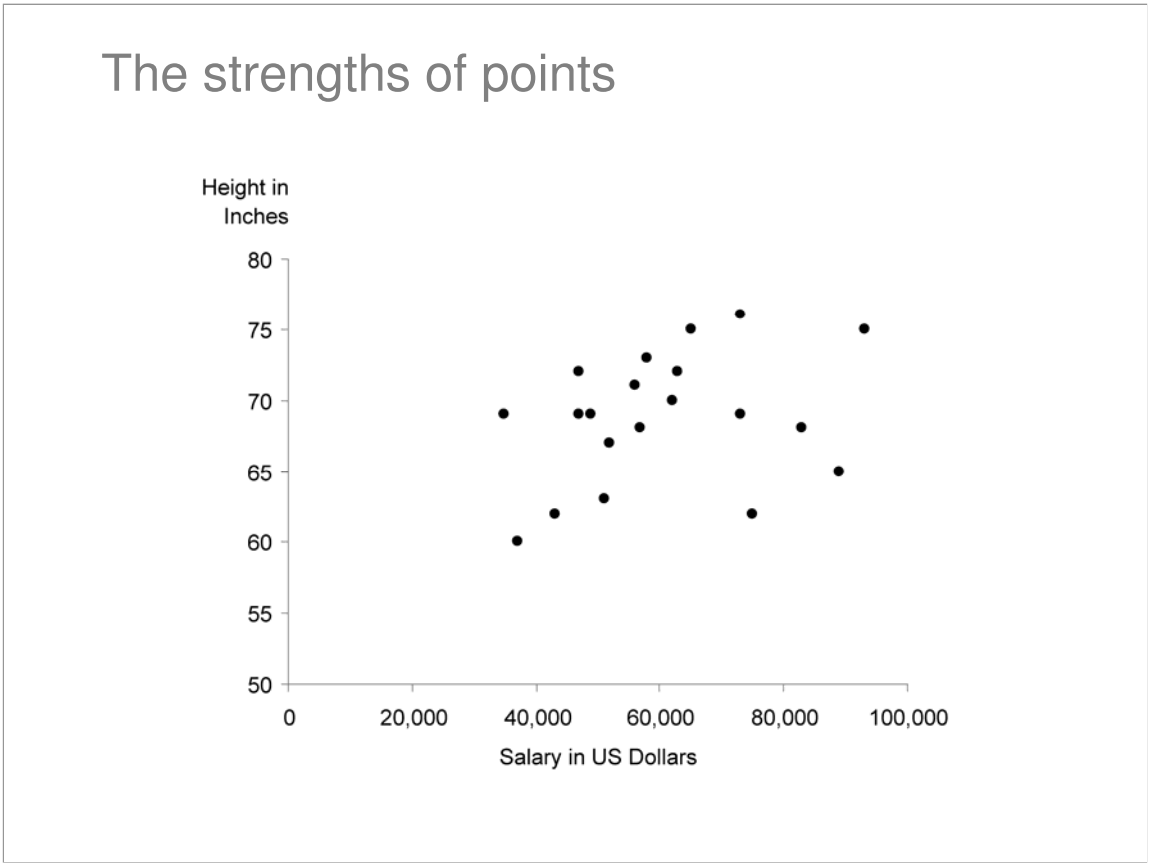


The strength of lines is their ability to emphasize the overall trend of the values and the nature of change from one value to the next. They should only be used to encode continuous variables along an interval scale, never discrete variables. The most common examples of continuous variables are those corresponding to a time series (continuous units of time) or a frequency distribution (contiguous ranges of quantity, such as 0-5, 6-10, 11-15, and so on).

What's wrong with this graph?



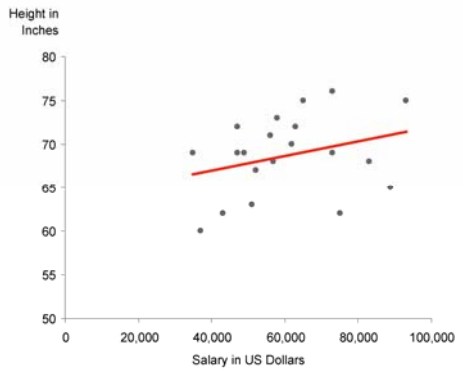
This graph appeared in the November 11, 2005 issue of Newsweek magazine. It displays the frequency of travel done by Pope John Paul II during his many years of service. The scale along the horizontal axis is an interval scale, but it has a problem: the intervals aren't equal. Notice that the first interval only covers two years, while each of the others covers five years. This causes the distribution to look as if the pope traveled relatively little during the first few years and then increase his travels dramatically in the next few. Another problem in this graph is the unnecessary dual labeling of the intervals, both along the horizontal axis and in the legend using color coding. This is not only unnecessary, it is also distracting.



The unique strength of points is their ability to encode values along two quantitative scales aligned with two axes simultaneously.

(Note: Points can also be used when you would normally use bars if there is a significant advantage to narrowing the quantitative scale such that zero is not included. When bars are used, the quantitative scale must include zero as the base for the bars, because otherwise the lengths of the bars would not accurately encode their values.)

The strength of points and lines together

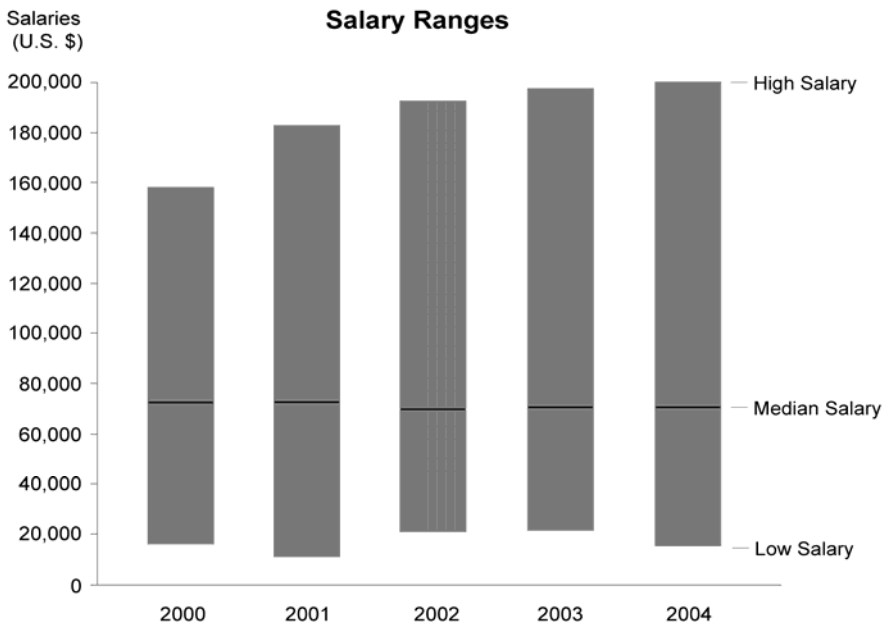


Point and lines can be combined in a single graph in two ways:

- Lines connect the individual points.
- Lines encode the overall shape of the points in the form of a trend line.

The strength of using them together in these ways is the ability to simultaneously emphasize individual values and their overall shape.

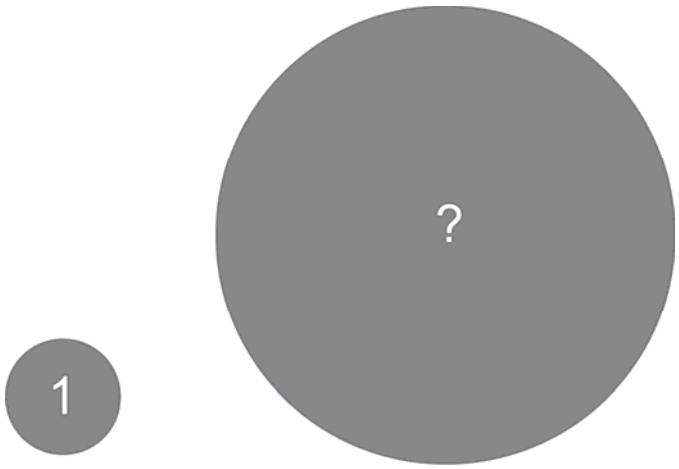
The strength of points and bars together



Because bars have a two ends that can both be used to mark a position along a quantitative scale, they can be used to encode the range from lowest to highest of a full set of values. A data point in some form, such as the short line on the examples above, can be used to mark the center of the range such as the median of the full set of values. This combination of points and bars provides a powerful way of summarizing the distributions of multiple sets of values.

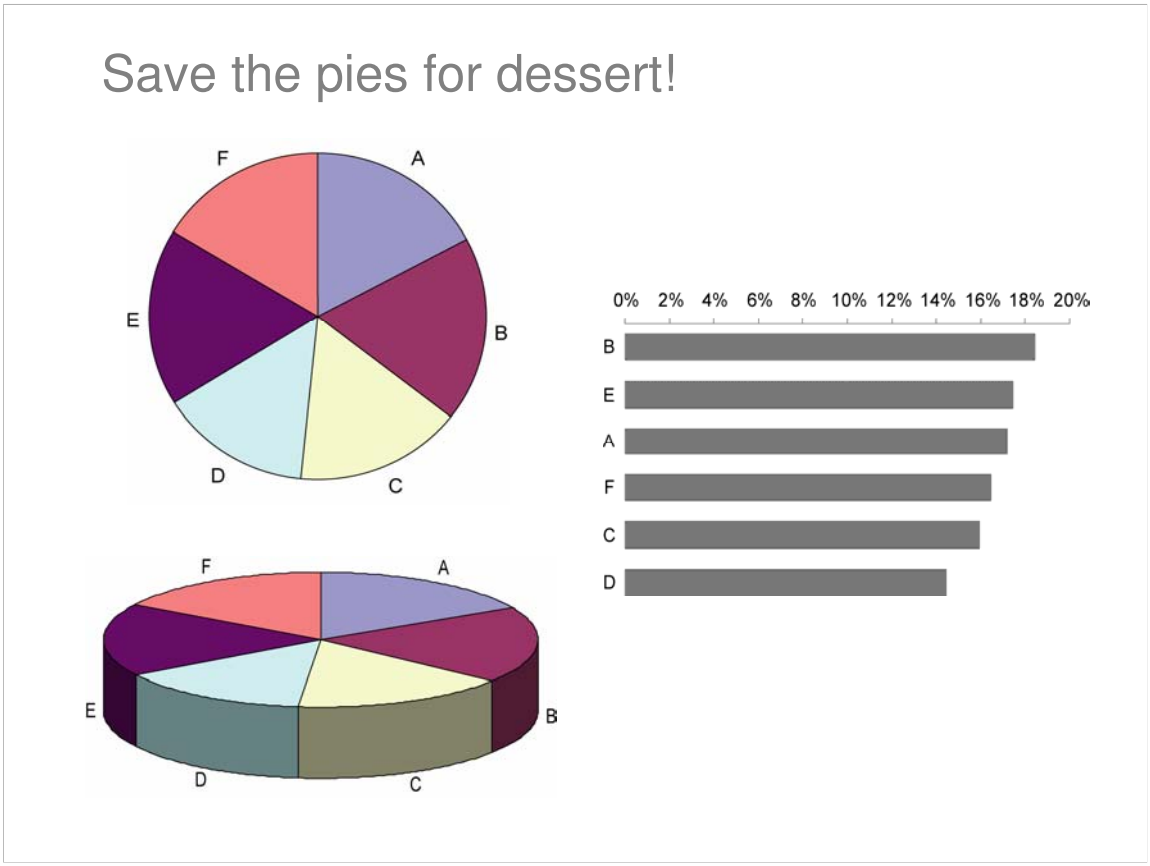
When bars and points are combined in this or similar ways to encode a distribution of values, it is called a *box plot*.

Why not encode data as 2-D areas, such as slices of a pie?



How big is the large circle? 16

Our visual perception of 2-D area is poor. It is difficult for us to accurately compare the sizes of 2-D areas.



Pie charts use 2-D areas and the angles formed by slices to encode quantitative values. Unfortunately, our perception of these visual attributes as measures of quantity is poor.

Since all graphs have one or more axes with scales, there must be one on a pie chart, but where is it? The circumference of the circle is where its quantitative scale would appear, but it is rarely shown.

Try using either one of the pie graphs to put the slices in order by size. Can't do it, can you? Now see how easy this is to do when the same data is encoded in a bar graph.

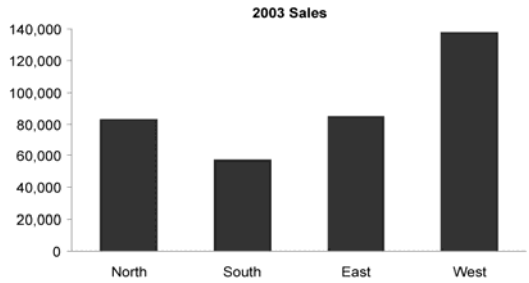
Which visual encoding objects display each relationship best?

	Points	Lines	Points & lines	Bars
Nominal comparison				
Time-series				
Ranking				
Part-to-whole				
Deviation				
Distribution				
Correlation				

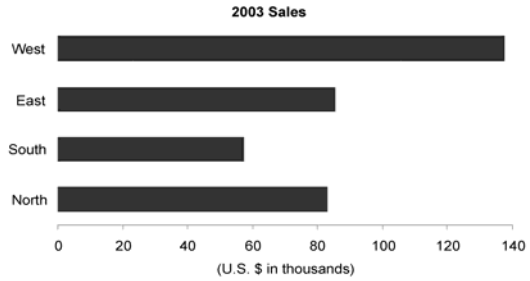
During the course of the next few slides we are going to identify which visual objects (points, lines, points and lines, and bars) do the best job of encoding each type of quantitative relationship.

Nominal Comparison

Nominal Comparison



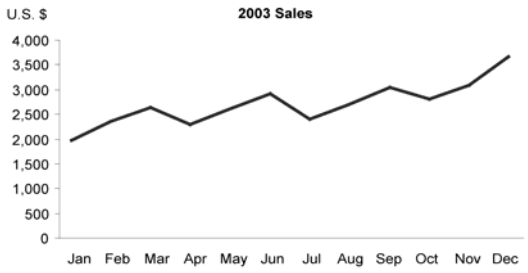
Bars
(vertical or horizontal)



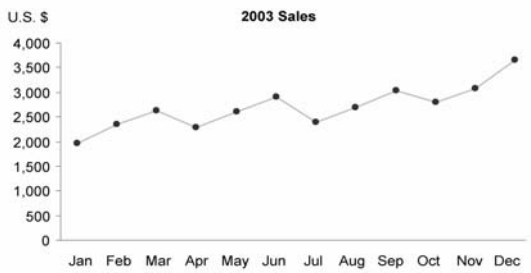
Why isn't it appropriate to use a line to encode a nominal comparison? Because the slope of the line as it moves from data point to data point would suggest change between different instances of the same measure. The difference between each region's sales is meaningful, but the movement from one region's sales to the next does not represent a change. Bars work best because they emphasize the independent nature of each region's sales.

Time-Series

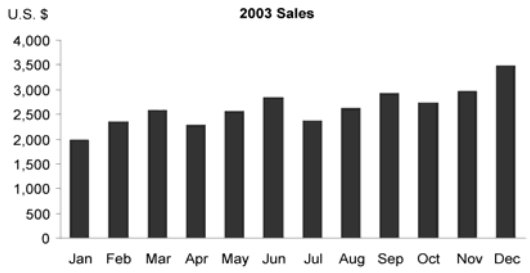
Time-Series



Lines



Points and Lines

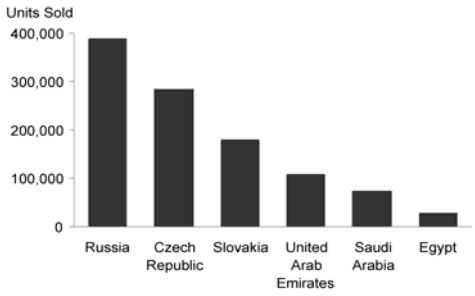


Bars (vertical only)

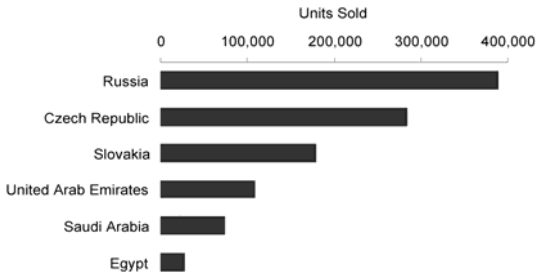
Lines do a great job of showing the flow of values across time, such as consecutive months of a year. The movement from one value to the next in this case represents change, giving meaning to the slope of the line: the steeper the slope, the more dramatic the change. If you want your message to emphasize individual values, such as the value for each month, however, bars do the job nicely. This is especially true when you graph multiple data sets, such as revenue and expenses, and you want to make it easy to compare these values for individual units of time, such as the month of September.

Ranking

Ranking



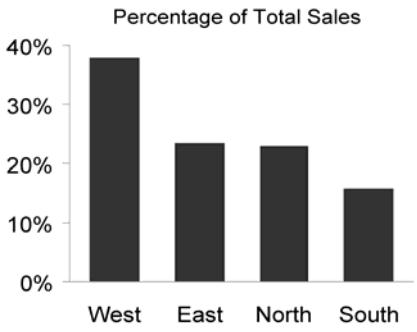
Bars
(vertical or horizontal)



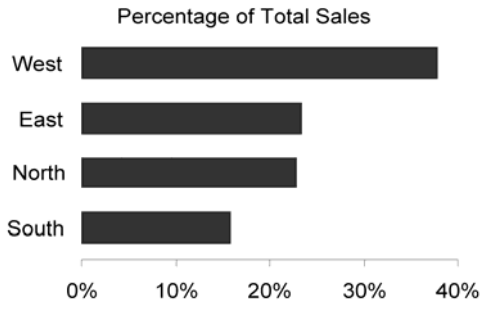
To emphasize the high values, sort the values in descending order from left to right or top to bottom; to emphasize the low values, sort the values in ascending order from left to right or top to bottom.

Part-to-Whole

Part-to-Whole

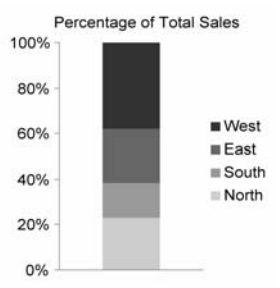


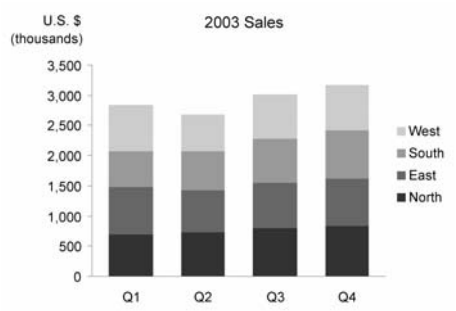
Bars
(vertical or horizontal)

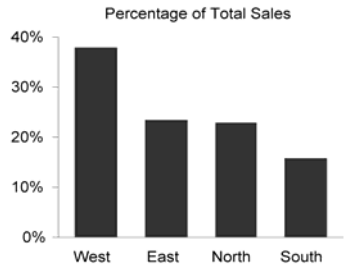


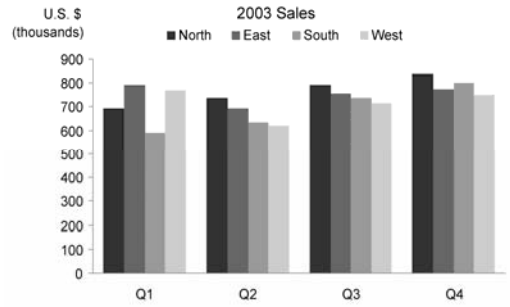
You will no doubt notice that the graph that is generally used to display part-to-whole relationships, the ubiquitous pie chart, has been left out. Despite the problems inherent in all forms of area graphs, the one useful characteristic of a pie chart is the fact that everyone immediately knows that the individual slices combine to make up a whole pie. When bars are used to encode part-to-whole relationships, the fact that the bars add up to 100% – a whole – is not as obvious, even though percentage is the unit of measure. To alleviate this problem, be sure to make the part-to-whole nature of the data obvious in the graph's title. In the above examples, the fact that the individual bars, which represent regional sales, add up to total sales, is stated explicitly in the title.

What about stacked bars?



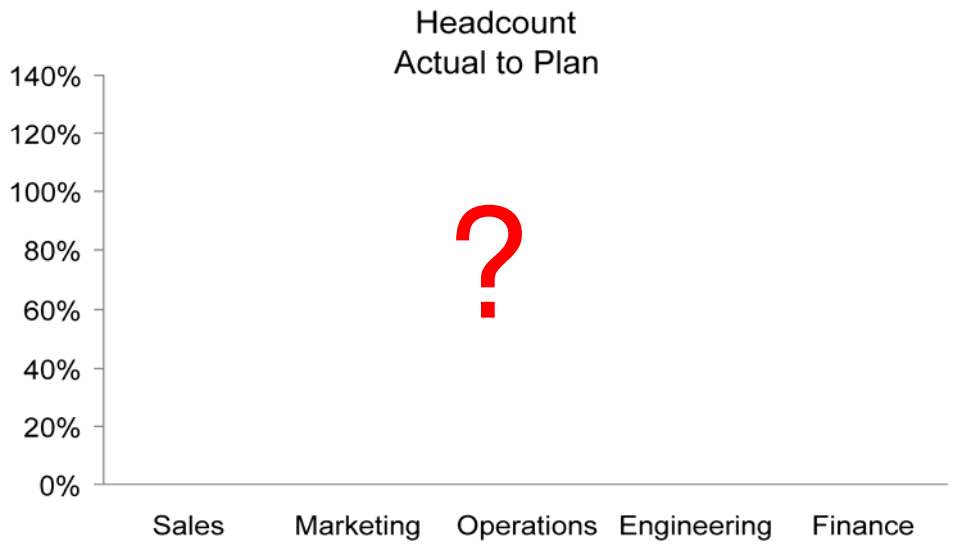


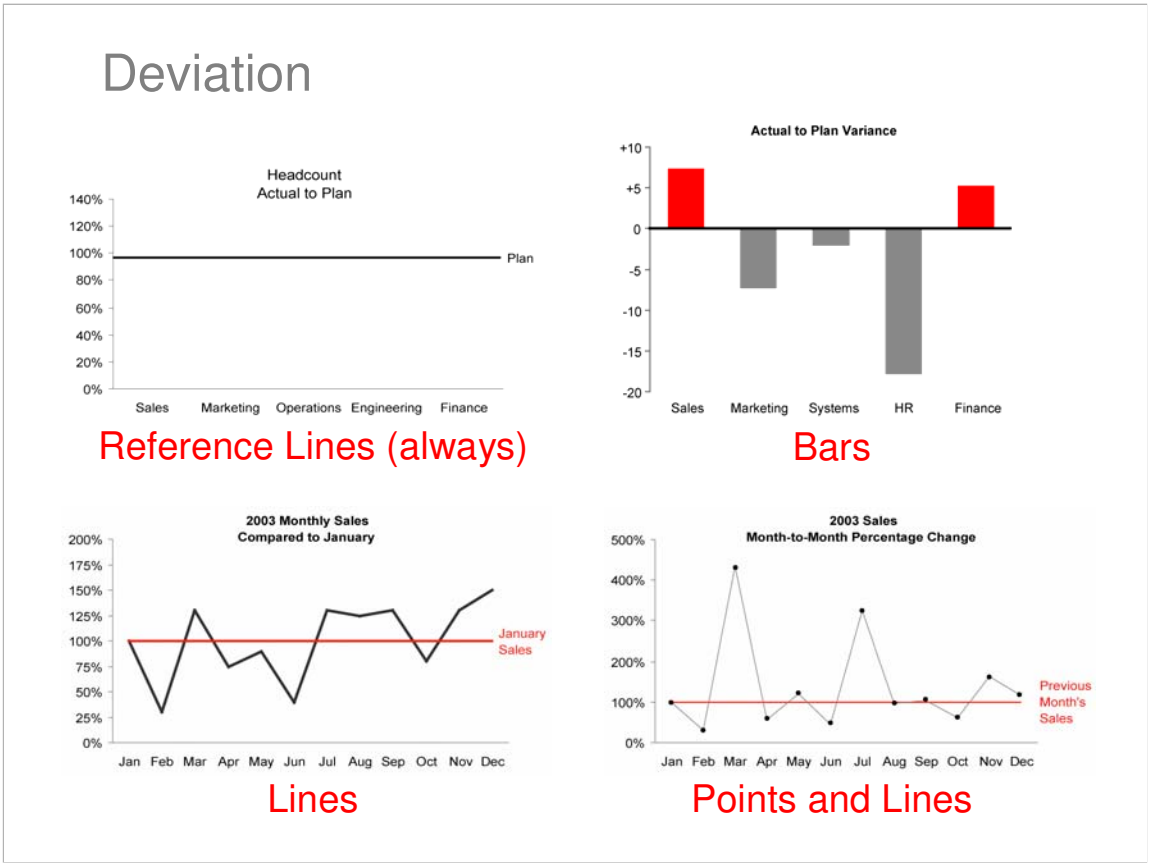




It is harder to compare and assign values to bars that are stacked, rather than side by side. Use stacked bars only when you need to display a measure of the whole as well as its parts.

Deviation





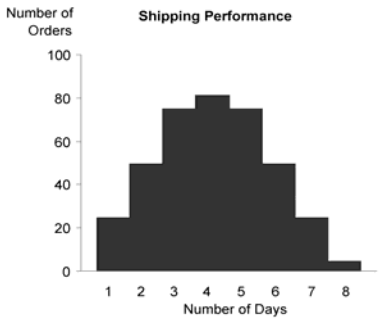
The use of a reference line makes it clear that the main point of graphs like those pictured above is to display how one or more measures deviate from some point of reference. Although deviations need not be expressed as percentages, when they are, especially as plus or minus percentages, the intention of the graph to focus on deviation becomes crystal clear. When bars are used to encode deviations, the reference line should always be set to a value of zero with the bars extending up (positive) or down (negative) from there.

Distribution

Single distribution

(a.k.a. frequency distribution)

Histogram



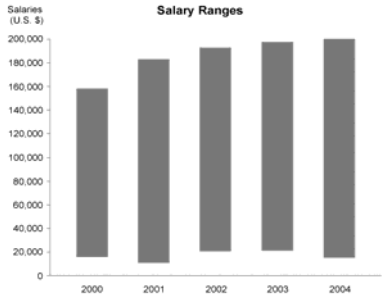
Bars (vertical only)

Frequency Polygon

Lines

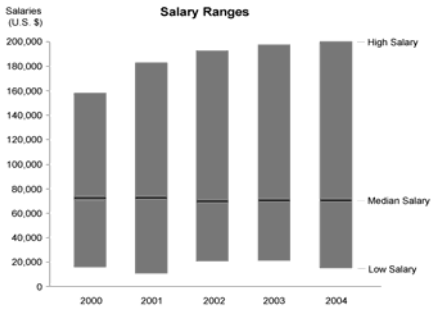
Histograms and frequency polygons both do a wonderful job of displaying frequency distributions; the only difference is whether you intend to emphasize the values of individual intervals or to emphasize the overall shape of the distribution.

Multiple distributions



Range Bars

Bars (vertical or horizontal)



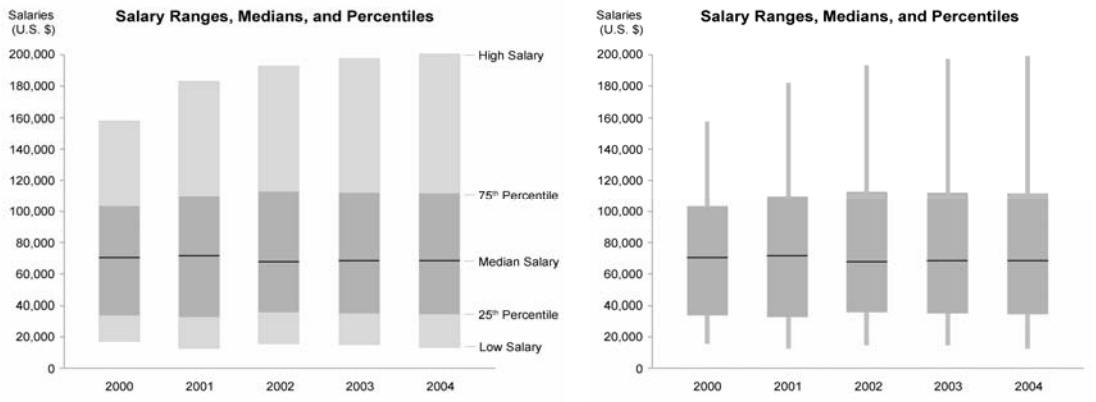
Bars and Points

Box Plot

Bars and Lines

Range bars provide the simplest means to display the full distribution of values from high to low, but by themselves too little information about a distribution of values is revealed. The simple addition of data points to mark measures of the center – averages, such as means and medians – provides much more insight. Box plots can become very sophisticated, with boxes (or bars) that encode measures of distribution other than the full range, such as quartiles, and individual data points to display outliers.

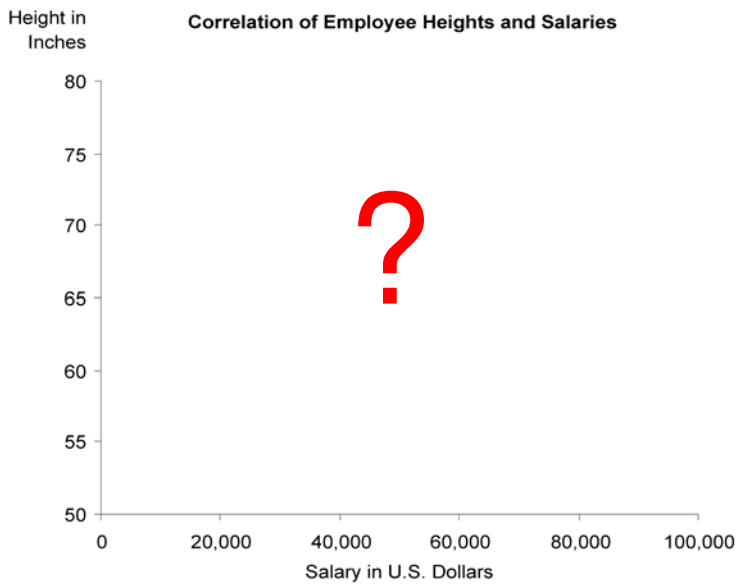
5-point distributions



There are many ways to visualize multiple distributions. Some provide more insight than others. The best approach depends on how much detail you want to communicate.

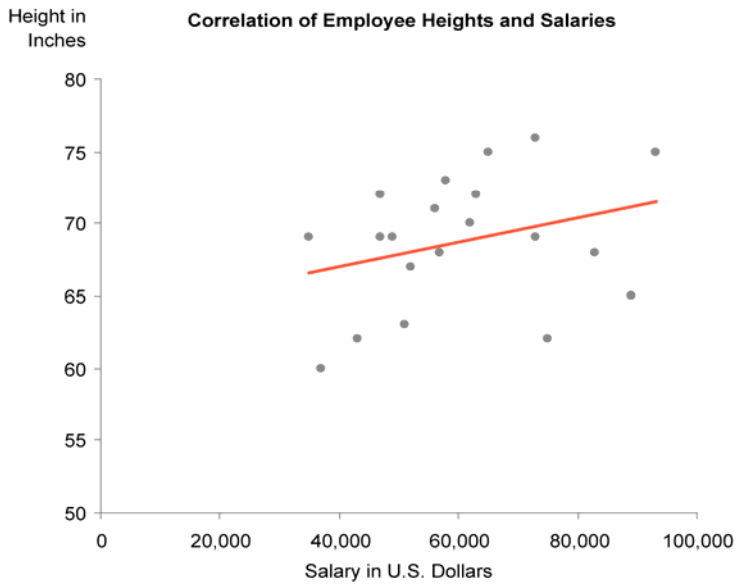
In a 5-point distribution, the full range of values is subdivided into quartiles to display the distribution of the top 25%, upper mid 25%, lower mid 25%, and bottom 25% provide the most insight of these three approaches.

Correlation



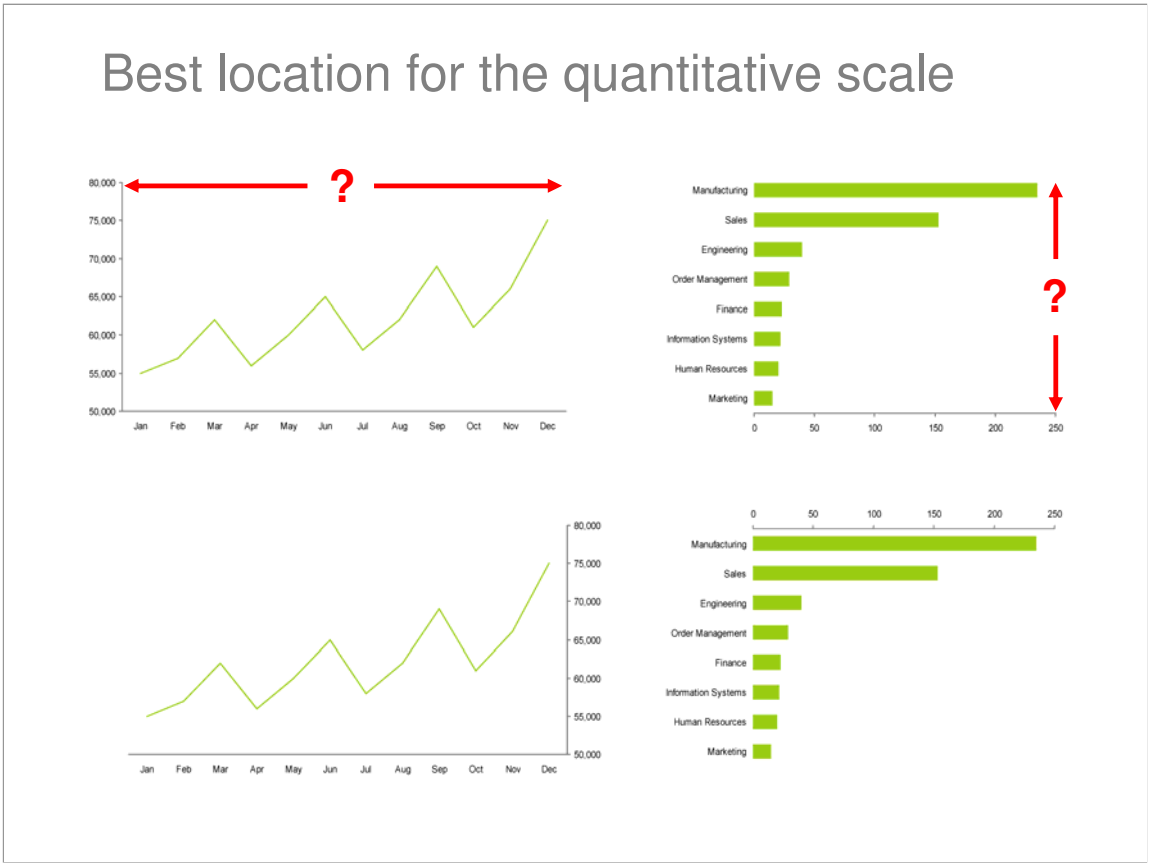
Correlation

Scatter Plot



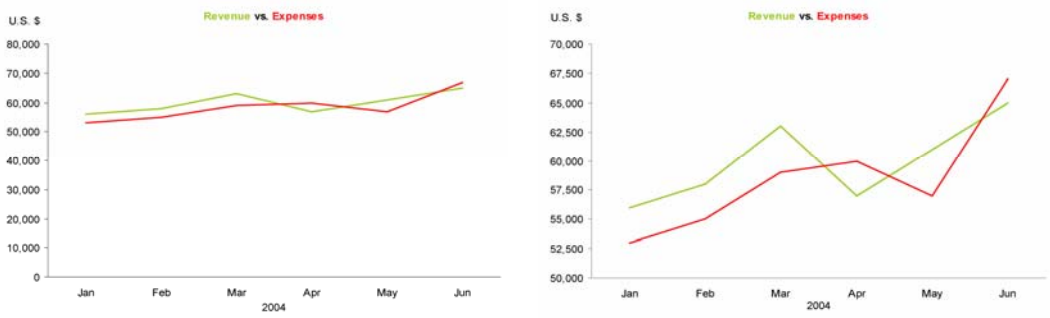
Points and Trend Lines

When you must display correlations to folks who aren't familiar with scatter plots, and you don't have the time nor opportunity to provide the instruction that they need, there are effective ways that you can use bars to encode the correlation of two data sets, especially if you have a relatively small set of values. For an introduction to paired bar charts and correlation bar charts, please refer to *Show Me the Numbers: Designing Tables and Graphs to Enlighten*.



Quantitative scales are usually placed on the left or bottom axis, but there is no reason that they can't be placed on the right or top axis if that offers an advantage. As a general rule, place the quantitative scale on the axis that is closest to the most important data in the graph. For instance, in the time-series graph above, if you want to make it easier to read the December value because where the year ended is more important than where it began, then the scale belongs on the right axis. If both ends of the graph are equally important and the graph it is particularly wide or tall such that some data would be far from the quantitative scale if you had to pick a side, you can place the quantitative scale on both sides (left and right or top and bottom).

Best range for the quantitative scale

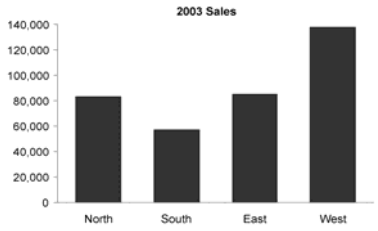


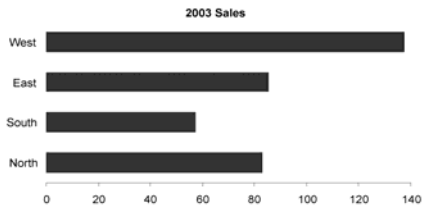
Whenever bars are used to encode values, the range of the quantitative scale must include zero. This is because the length of the bar encodes its quantity, which won't work without zero. Bars that encode positive values extend up (vertical bars) or to the right (horizontal bars) and those that encode negative values extend either down or to the left.

When lines or points are used to encode the values, however, the quantitative scale can be narrowed, for zero isn't required. Often, there is an advantage to setting the range of the quantitative scale to start just below the lowest value and end just above the highest value, thereby filling the data region of the graph with values without wasted space where no values exist. When this is done, however, you must make sure that people know it.

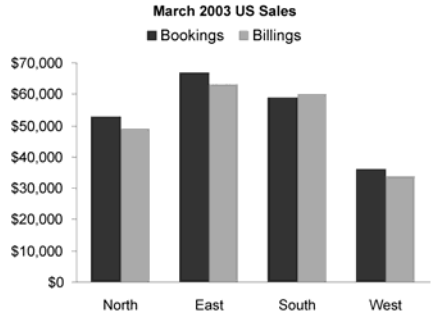
Best sequence for visual encoding choices

2 variables: 1 categorical and 1 quantitative?





3 variables: 2 categorical and 1 quantitative?



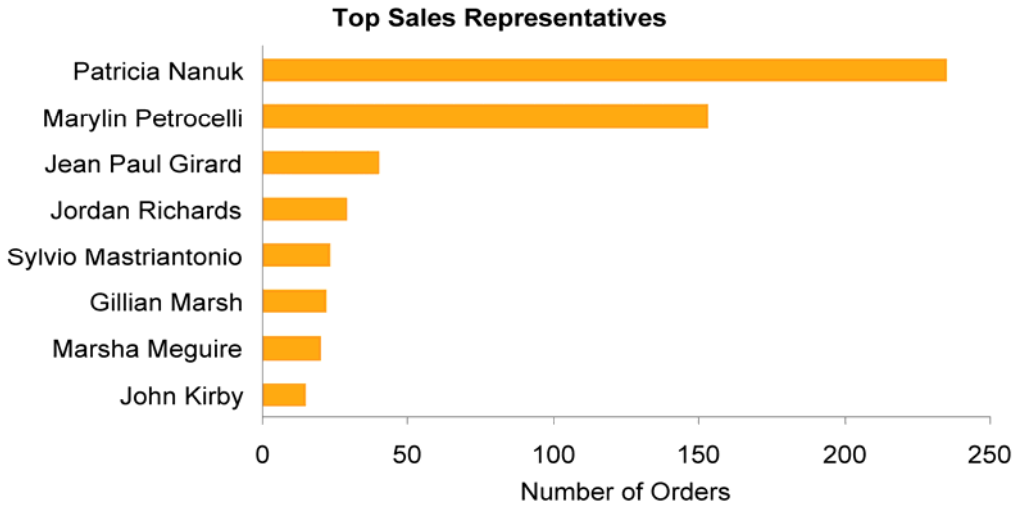
Two variables: one categorical and one quantitative

- The categorical variable should almost always go on the X axis.
- The categorical variable should only go on the Y axis when horizontal bars are used.

Three variables: two categorical and one quantitative

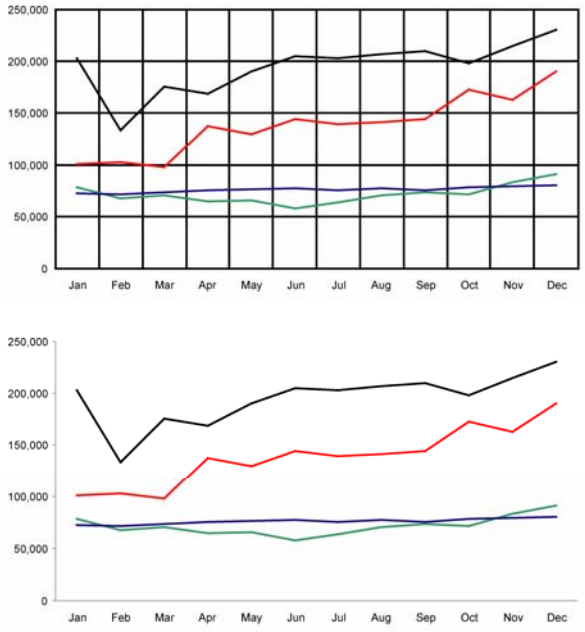
- With two categorical variables, only one can go on an axis (X axis, except with horizontal bars).
- The variable that contains the values that should be made the easiest to compare should *not* be associated with the X axis. Notice in the example above how much easier it is to compare bookings and billings within regions than it is to compare regions.
- Exception: When an interval variable like time is one of the two categorical variables, it should always appear on the X axis. If the other categorical variable is more important to your message than the interval variable, break the display into multiple graphs with the interval variable on the X axes and a separate graph for each item of the other variable.

Why bother with horizontal bars?



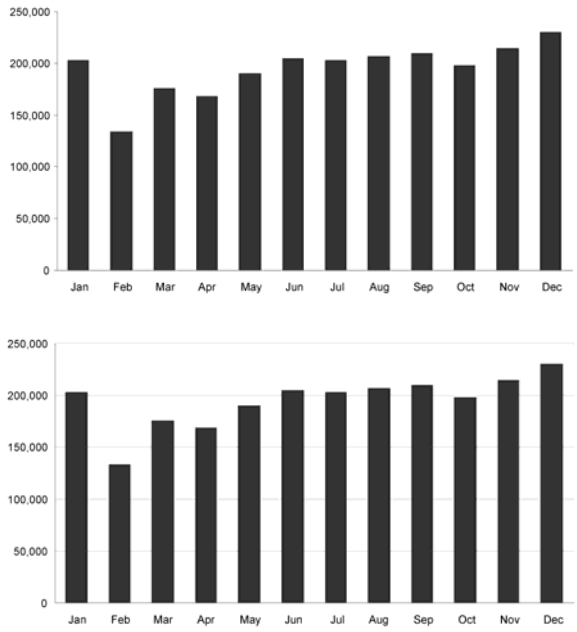
Long and/or large numbers of categorical labels fit better along the vertical axis.

What about grid lines in graphs?



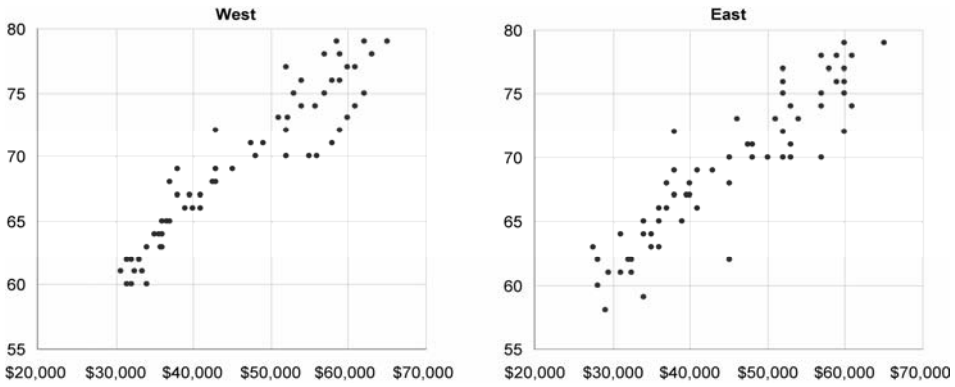
Grid lines are rarely useful and dark grid lines are never useful. They make it very difficult to pick out the shape of the data imprisoned behind the grid lines.

Grid lines clarify subtle differences



Light lines along the quantitative scale assist in making subtle distinctions.

Grid lines delineate sections

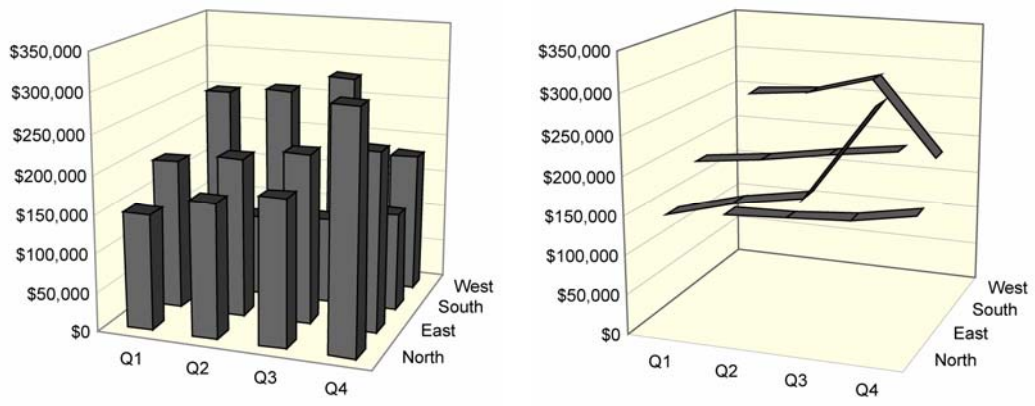


Light grids assist in reading and comparing subsections of graphs.

What about 3-D? It's so cute!!!

A 3rd dimension without a corresponding variable is meaningless.

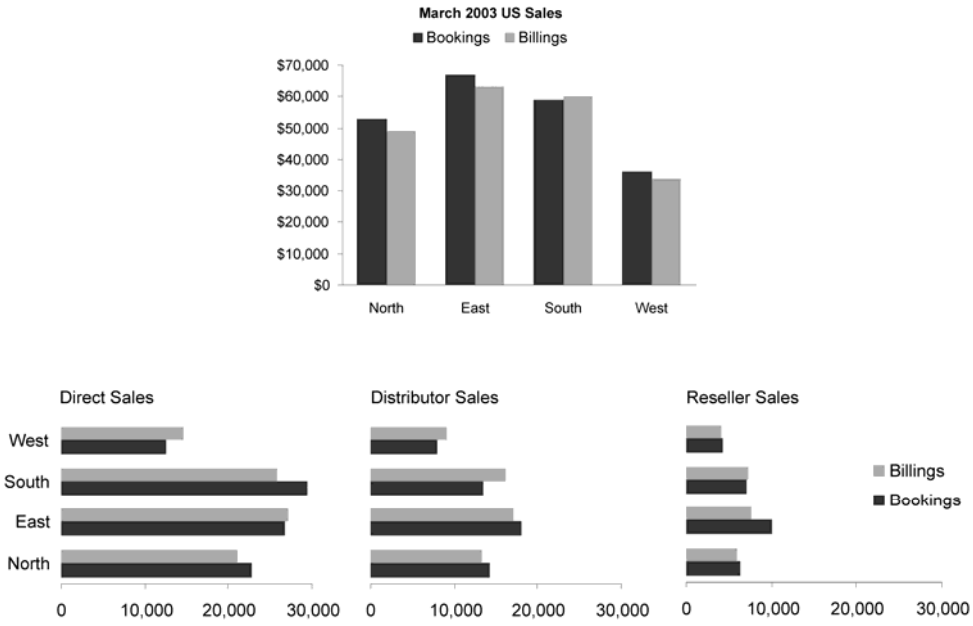
But what if there's a 3rd variable?



Can you determine which of the lines in the graph on the right represents the East region? Are you sure?

A 3rd dimension with a corresponding variable is too hard to read.

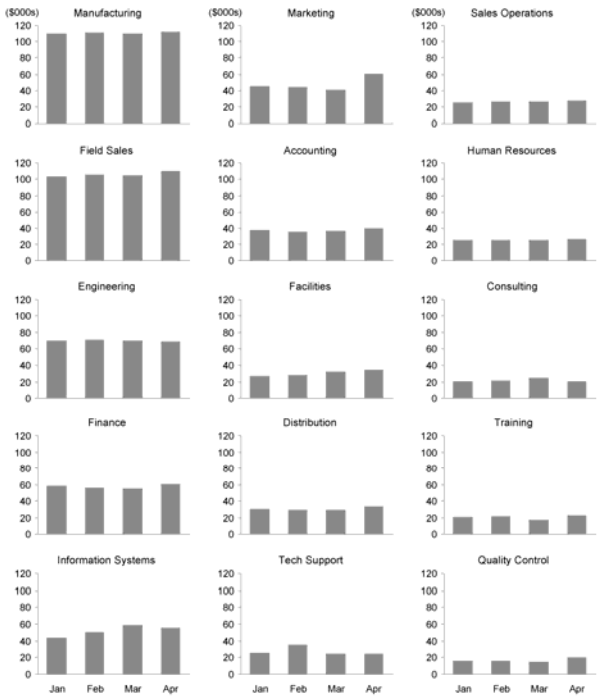
How can you display additional variables?



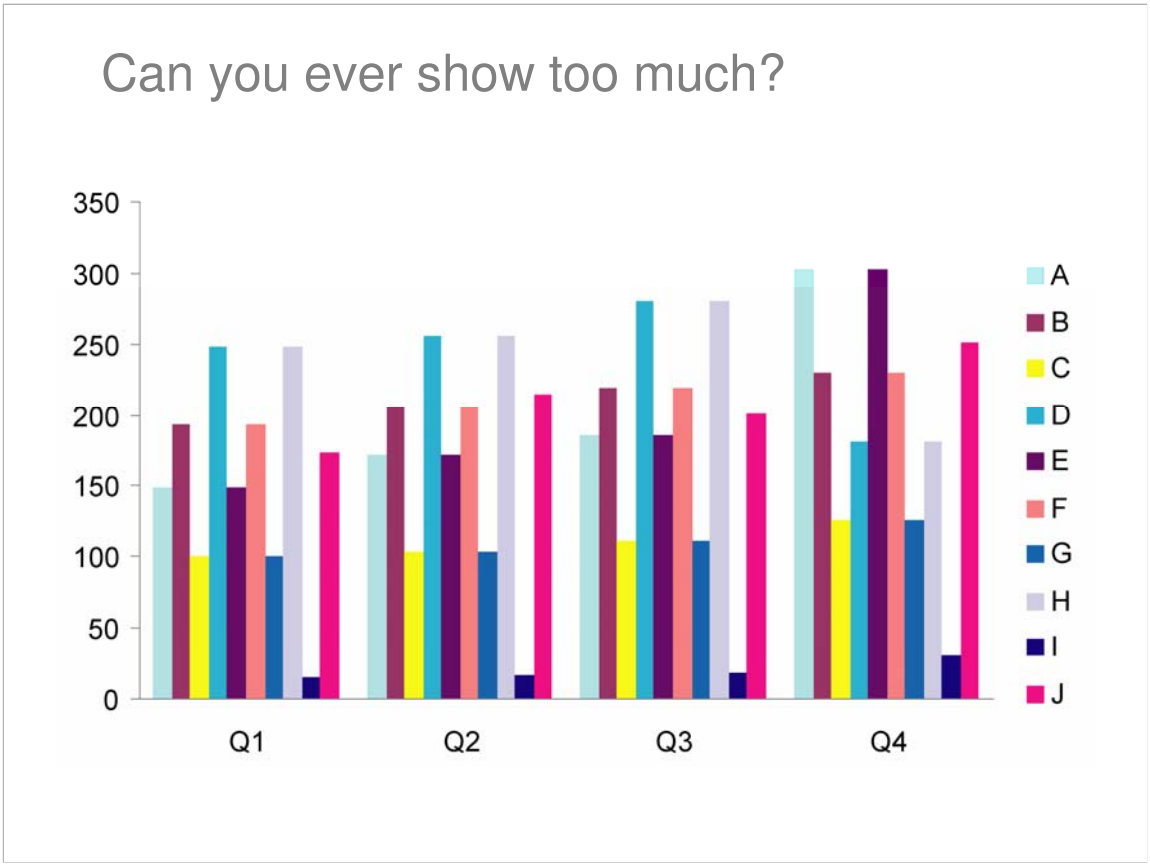
For instance, let's say you want to break the data in the top graph into three sales channels per region. You can do this by displaying a series of related graphs, each representing a different instance of the variable.

You can display many graphs within a single eyespan.

- Vary nothing but a single variable
- Arrange graphs in a logical sequence



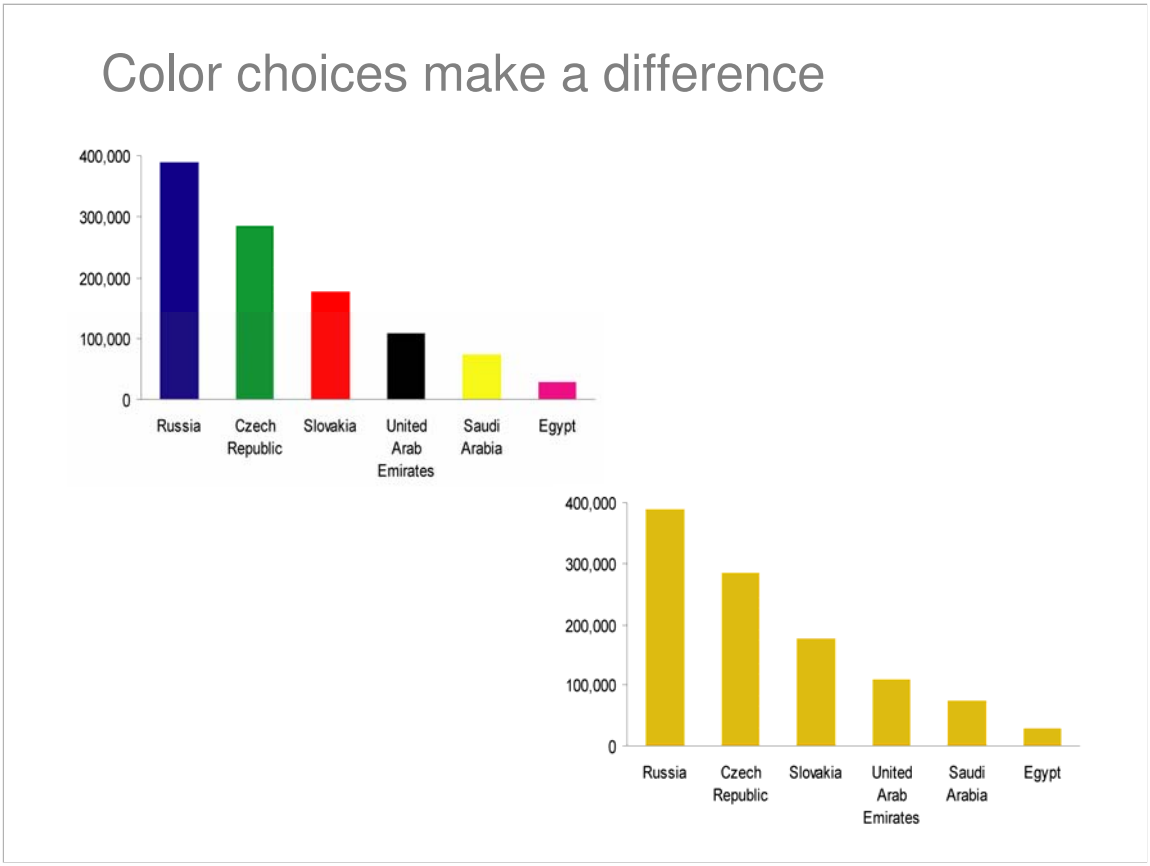
A series of related graphs arranged in a row, column, or matrix is what Edward Tufte calls “small multiples.”



Limit the number of categorical subdivisions to around five, except when encoded by position along an axis. Short-term memory can only maintain from five to eight chunks of information at a time.

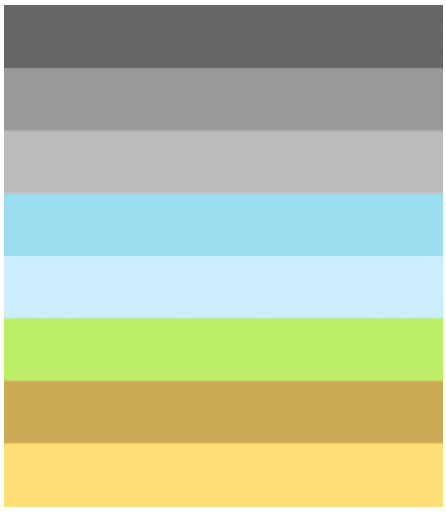
Is more color always better?

Lots of bright color is great is you're a preschooler. For adults, frequent use of bright colors accosts visual perception. Pastels and earth tones are much easier to look at. Use bright colors only to make particular data stand out above the rest.

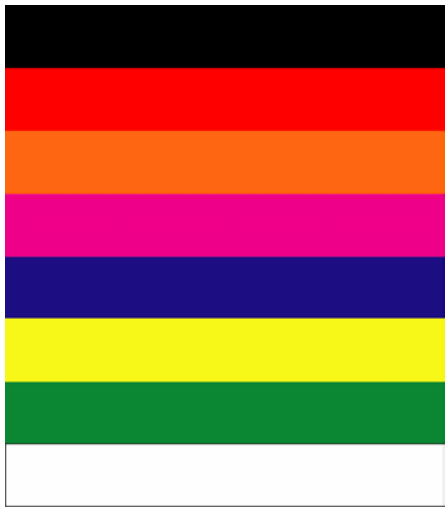


The top graph varies the colors of the bars unnecessarily. We already know that the individual bars represent different countries. Varying the colors creates emphasizes the distinctness of each bar when we want them to look alike to make it easy to see their shape as a whole.

Standardize on a good palette of colors



Soft, natural colors



Bright or dark colors
for emphasis only

Soft, natural earth tones work best for everything except data that needs to stand out above the rest. Use bright, dark colors only for highlighting data. If your software allows you to customize your color palette, it will definitely save you time to do this once, then rely on those colors for all of your displays.

You have a choice to make!

To communicate

or not to communicate,

that is the question!

The good news is, although the skills required to present data effectively are not all intuitive, they are easy to learn. The resources are available, but it won't happen unless you recognize the seriousness of the problem and commit yourself to solving it. It is up to you.