The Mind Is Not a Camera, The Brain Is Not a VCR

Some **psychological guidelines** for designing charts and graphs

BY STEPHEN M. KOSSLYN, PH.D., AND CHRISTOPHER CHABRIS

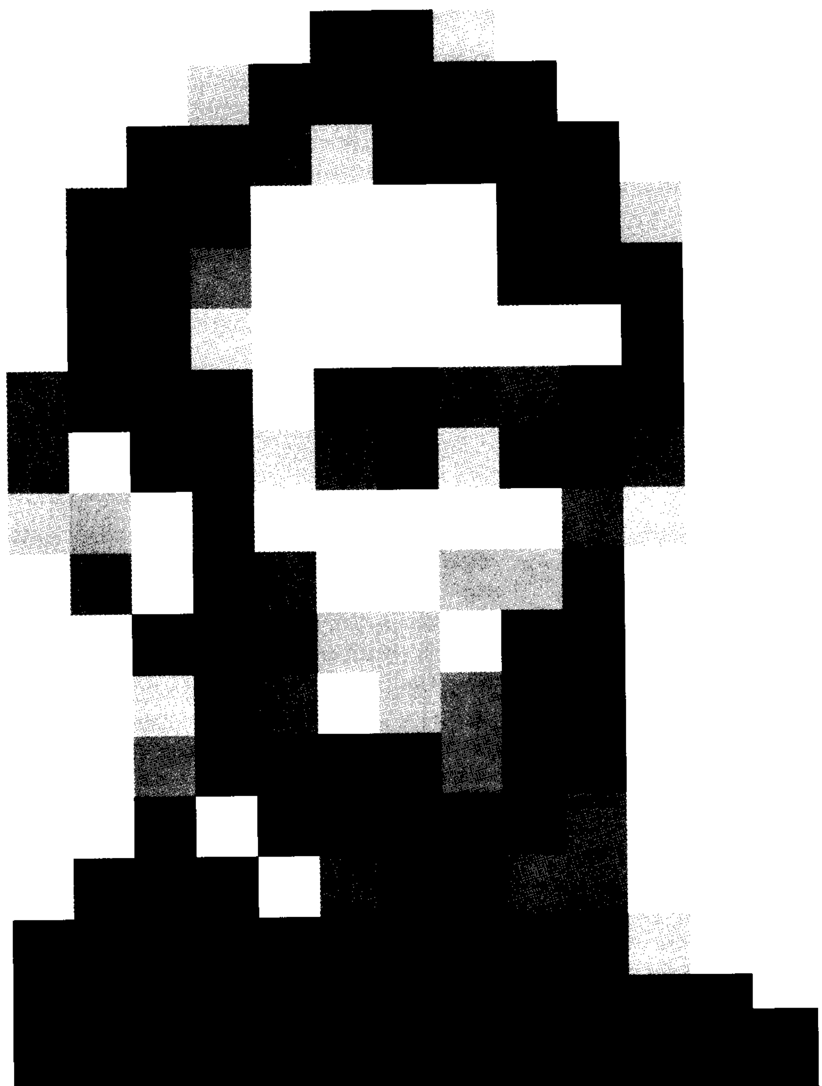
The emblem of the information age is the information graphic. The use of snappy color charts and graphs in newsmagazines, an innovation often ascribed to *Time* magazine's Nigel Holmes, has spread to special-interest magazines, journals, national newspapers (*USA Today* and a host of imitators), local dailies, television news, even Ross Perot's "infomercials" and Jay Leno's sketches. This accelerating trend has been fueled in the past decade by technological developments such as PostScript, desktop publishing, color prepress, and graphical user interfaces. Today, more than anything else, the multicolor bar graph is a symbol of a publication's membership in the big leagues.

If you catch a designer or editor in a moment of candor and ask why he uses information graphics, you might hear him admit to simply following the fashion of the day. More likely, though, you'll hear one or more of these answers: Infographics are eye-catching, they have "instant impact," they simplify complex ideas, they give information an aura of "scientific" credibility, they are easier to digest, or that a picture is worth a thousand words (and usually takes up less space).

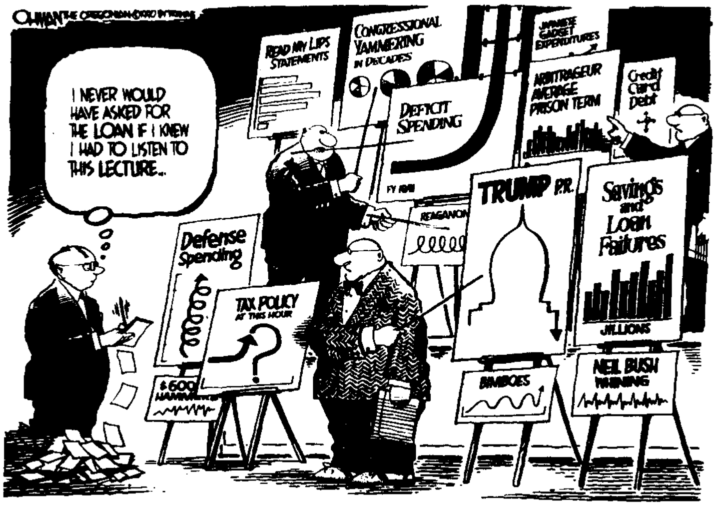
In fact, the Chinese adage places a value of *ten* thousand words on a single picture, but it does not take great insight to realize that only a well-drawn picture is truly worth its ink in words. After all, text has proven its power to express ideas over several millennia, whereas the modern information graphic was invented about two centuries ago, and its full possibilities have yet to be realized. At times, our prodigious ability to produce attractive graphics outstrips our knowledge of how to design and use them well. The result is a glut of beautiful ciphers—incomprehensible images clogging the information stream and *impairing* our understanding of the world and the issues that matter to us.

Some ways of preventing the medium from obscuring the message can be found in experimental psychology, the scientific study of perception, memory, and thought. The experimental approach to understanding behavior is a multifaceted enterprise, but some of its findings can be distilled into principles that are easy to understand and can be applied to your own work every time you set out to produce a new infographic—whether it is a chart, graph, map, diagram, table, or any other visual display of information.

Some of these recommendations will seem intuitive and commonsensical, whereas others may strike you as a bit strange until you see them demonstrated and use them yourself. Let's focus on what may be the most common misconception in infographic design, the idea that the human mind is a passive recorder of what it sees, a sort of information sponge that simply soaks up whatever we show it—once we have grabbed its attention in the first place, of course. This is simply wrong.



Why is this image easier to make out when it's blurred? See the section on "Texture channels," on page 37.



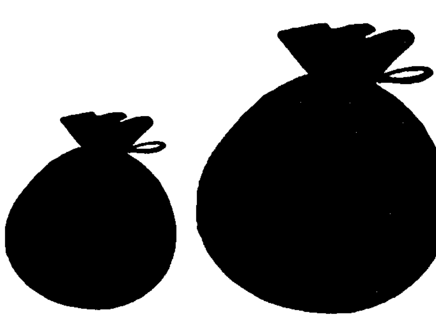
Although its topical references are dated, this 1990 cartoon portrays well the overwhelming profusion of graphs and charts in contemporary life.

The mind is not a camera, the brain is not a VCR—and a moment's reflection on your own experiences should convince you that human visual perception is a more subtle process than record, rewind, play back.

Ask yourself why, although you readily notice a gain of five pounds on a thin person, you normally overlook it on someone who is overweight. Or why you see reflectors on a dim highway or geese flying overhead as connected rows or formations, even though they're really isolated objects. And how it is that former athletes literally "see" much more when watching the Olympics than do people who are seeing a sport for the first time. Like breathing or walking, these phenomena are so natural that we normally give them no thought. But they are direct consequences of the way our eyes and brains work. Unlike cameras and VCRs, our minds are constantly and actively organizing and making sense of the visual world. Effective information graphics will take advantage of the strengths and avoid the weaknesses of human cognitive abilities.

Here are a few specific principles that should be useful in your work.

To most people, the moneybag on the right doesn't look twice the size of the one on the left—but it is. Beware of using area to display the precise relationship between quantities.



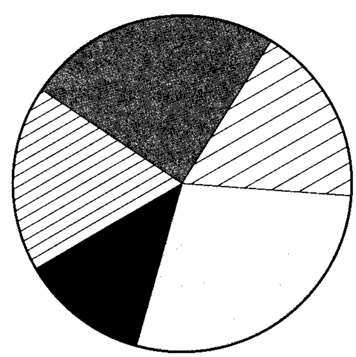
The eye is automatically drawn to change.

Brain cells are "difference detectors." What excites our neurons is not the *absolute* magnitude of a stimulus but its *relative* magnitude—that is, the *difference* between visual elements is what stands out. Our attention is automatically drawn to the parts of a visual display that are different, and our minds reflexively assume that these most salient aspects of a display have special significance. So, when designing charts and graphs, be careful to make changes mean something.

For example, in a pie graph of mostly black and white slices, a single red slice will command our notice and memory, so it had better correspond to the most important information you want to present. This principle helps to explain why gaudily decorated graphs are difficult to understand: our attention is constantly being pulled away from the information towards the content-free parts of the display—which, ironically, were put there to attract our gaze in the first place.

Our minds aren't good at precisely comparing areas.

The basic principle of a bar graph is to use the relative lengths of straight lines to represent quantities. This works well because our minds perceive the lengths of lines quite accurately; if you show someone a one-inch line next to a two-inch line, she will say that it is about half as long as its neighbor. But what works for length fails for area: people perceive areas as being smaller than they actually are, and this tendency is greater as the size of the area increases. So, if you present two circles, one twice the area of the other, the large one will seem to be less than twice as large as the small one. The same is true with volume, except that the distortions are even greater. Therefore, use area or volume to show quantity only when what you want is rough ordering (that is, to show that one thing is larger or smaller than another). If you want your viewers to receive an accurate impression of the differences, use length instead.



The frequencies of these two diagonal-line fills differ by less than 2 to 1, so they're processed by the same "channel." As a result, they're hard to distinguish, and it's hard to focus on one without the other intruding.

Perception works in "channels."

One of the most important ways in which the visual system differs from a camera is in the number of "lenses." A camera normally has one, but the brain operates as if it has several lenses, known in the literature as *channels*. In each aspect of visual perception—such as color, shape, or texture—the brain perceives information through several channels. The most important fact about these channels is that we are compelled to pay attention to all the information processed by a single channel, and can only untangle it with effort. This has several important implications for graphing.

Texture channels. Let's begin with a demonstration. Look at the illustration on page 35. If you wear glasses, try taking them off first; if you do not wear glasses, try standing about ten feet back from the picture. It may help to squint. In either case, it should be easier to identify Abraham Lincoln in the picture when it is out of focus! Why?

When you look around, it seems that you see everything at roughly one level of visual "sharpness." But in fact, our visual impressions are built up from a set of channels with different levels of sensitivity. Some are sensitive only to relatively large changes in a pattern, whereas others are tuned to fine details. The Lincoln figure was created by taking a digitized picture and averaging the lightness values within each large square. This averaging process masks fine variations in the pattern (such as Lincoln's nostrils, the hairs of his beard, and so on). At the same time, the edges of the squares introduce sharp changes where none should be.

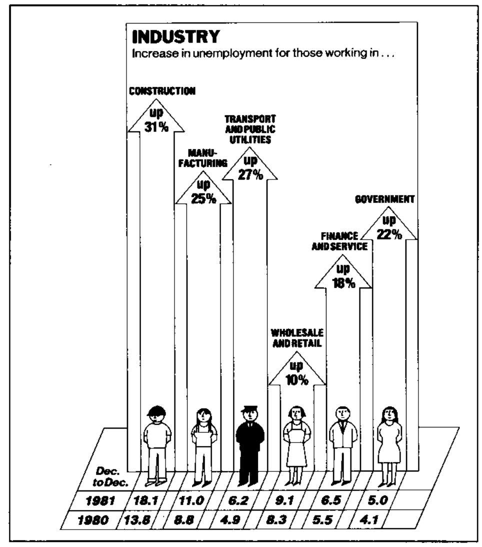
Defocusing the picture does not restore any of the actual details, which are gone forever. But defocusing removes the spurious details caused by the edges of the squares. The useful information from the coarse visual input channels was being obstructed by inappropriate information from the fine channels; blurring the picture prevents these channels from operating—unmasking the information from the coarser channels.

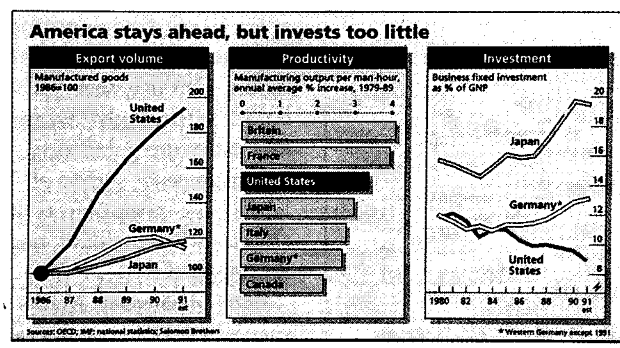
Each visual channel responds to a range of spatial variations, and the difference in fineness from one channel to the next is about 2 to 1. And remember, we are *compelled* to pay attention to all the information coming in through a given channel.

This means that whenever you're using a repeating pattern to distinguish elements—such as a series of patterned fills in a bar chart, or of dotted lines in a line graph—make sure the patterns differ in frequency by at least 2 to 1. As viewers, when we look at a patterned fill of diagonal lines that are 8 to the inch, we will also mentally take in, like it or not, any other similarly oriented lines that are up to twice as frequent (fewer than 16 to the inch) and any that are down to half as frequent (more than 4 to the inch). The closer the spacing is to the one we are paying attention to, the harder it is to ignore. Likewise, if one line has 6 dashes to the inch, another should have either 3 or fewer dashes to the inch, or else 12 or more.

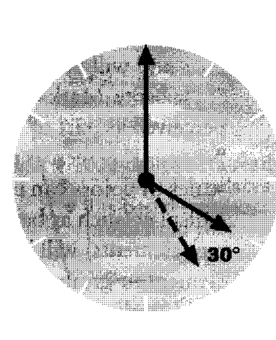
Orientation channels. Another area where the concept of channels applies is line orientation. Various studies have shown that when lines differ in angle by at least 30 degrees, we can distinguish among them without having to pay close attention. (It may be no accident that clock faces are divided into 12 equal increments, which are 30 degrees apart.) This means that, if you use differently oriented hatchings to distinguish elements in a chart or graph, their orientations should be at least 30 degrees apart. Likewise, if you're plotting a simple line chart, be aware that slopes differing by less than 30 degrees are harder to distinguish; conversely, if all but one of the lines are within 30 degrees of one another, the one that is not will "pop out" perceptually to your audience.

Salience: Highlighting what's important



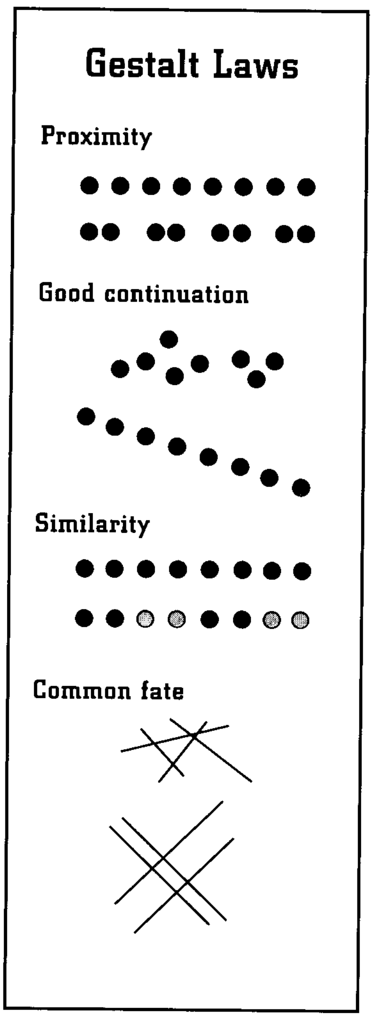


***Time* magazine's Nigel Holmes originally designed the chart at top in full color. But when he reused it in his book *Designer's Guide to Creating Charts and Diagrams,* he ran only the black plate (as shown here), and was tripped up by the principle of salience: the black-uniformed figure stands out, but the graph has nothing special to say about him. In contrast, the bottom example from *The Economist* uses salience well: the red lines and bars stand out in all three graphs, as they're intended to, and correspond consistently to the same category.**



Studies have shown that the eye can quickly distinguish lines whose angles differ by 30 degrees or more—which may be why the numbers on a clock are 30 degrees apart.

Making use of the Gestalt Laws.
Our minds don't perceive the elements of a visual display as separate, isolated marks; rather, we group marks together in specific, predictable ways, described by *principles of perceptual organization.* These regularities—often referred to as the Gestalt Laws, since many of them were first elucidated by the Gestalt psychologists in the 1920s and '30s—cause us to associate certain pieces of text, lines, and regions with one another, both within a single graphic and between separate graphics. Applying the four most important principles—*proximity, good continuation, similarity,* and *common fate*—is an easy way to exert more control over your audience's reaction to your message.



Proximity. Marks that are proximal, or near to each other, will appear to be grouped together in our minds. For example, "xxx xxx" is seen as two groups, whereas "xx xx xx" is seen as three groups, even though in each case there are six individual marks. This may seem obvious, but it's surprisingly easy to overlook when designing a chart. For instance, be sure to place labels close to the objects they refer to; when in doubt, nudge them a bit closer.

Good continuation. Marks that suggest a continuous line, even a dashed or dotted one, will tend to be grouped together. For example, "– – – – – –" is seen as comprising a single unit, not six separate ones, whereas "– – – _ _ _" is seen as comprising two units. If patterns overlap, ensure that they do not accidentally misgroup because of this principle. Similarly, if you place the labels on a line graph at the ends of the lines they mark, rather than in a separate legend, they will naturally seem to "extend" from the lines and will be easily seen as referring to them.

Similarity. Marks that are alike in some way will be perceived as part of a single group. For example, "– – – | | |" is seen as two groups. Consistent use of gray scales or colors can ensure that corresponding parts of a display (such as bars in a bar graph, or labels and content elements) will be seen as representing the same element or group, and that unrelated elements are not accidentally perceived together.

Common fate. Lines or marks that seem to be headed in the same direction are said to have "common fate," and will be grouped together. Thus, a graph containing parallel lines is far easier to understand than one containing the same number of crisscrossing lines; the parallel lines are seen as a single unit, whereas the crisscrossing lines are seen as several individual units, causing greater stress on memory and comprehension.

Indeed, the Gestalt Laws are so powerful because their influence extends beyond our perception of displays. When items are grouped together, they actually take up less "space" in short-term memory and are processed faster by the mind; thus, careful exploitation of visual grouping can pay sizable dividends.

A new perspective
The approach demonstrated here provides a new perspective on recent developments in infographics, beginning in the 1980s with Yale University's Edward Tufte. Tufte launched a counterrevolution against the trend towards gaudy, overdecorated, low-data infographics that began in the 1970s. Almost alone, Tufte preached the antithesis—a Spartan design philosophy of simplicity, even minimalism, with a zeal to eliminate from the page all marks that do not actually represent data, coupled with exhortations to include more, not less, data. But both the revolution and the reaction took the issue to extremes. Not all ways of decorating data are bad, neither simplicity nor complexity is an unalloyed virtue, and having less ink for more data can often confuse readers rather than stimulate them.

We know this because research in psychology can provide concrete solutions to some of the abstract debates of design philosophy. It cannot supplant traditional design principles, but it can augment them. And most importantly, it can help designers influence how viewers will perceive the elements of information graphics and how those elements relate to each other in meaningful patterns.

We have discussed only a few of the many techniques designers can use (without even touching on the vast subject of color), all based on research that had nothing to do with graphic design and everything to do with understanding how the mind and brain work. When it comes to information graphics, experimental psychology is of more than just academic interest.

This article is based in part on material in Elements of Graph Design, *by Stephen M. Kosslyn, to be published this year by W.H. Freeman. Kosslyn is Professor and Chabris is Artificial Intelligence Program Manager in the Psychology Department at Harvard University, and they have done consulting work on the psychology of effective visual communication.*

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