Confusion and clutter are failures of design, not attributes of information. And so the point is to find design strategies that reveal detail and complexity—rather than to fault the data for an excess of complication. Or, worse, to fault viewers for a lack of understanding. Among the most powerful devices for reducing noise and enriching the content of displays is the technique of layering and separation, visually stratifying various aspects of the data.

Effective layering of information is often difficult; for every excellent performance, a hundred clunky spectacles arise. An omnipresent, yet subtle, design issue is involved: the various elements collected together on flatland interact, creating non-information patterns and texture simply through their combined presence. Josef Albers described this visual effect as $1 + 1 = 3$ or more, when two elements show themselves along with assorted incidental by-products of their partnership—occasionally a basis for pleasing aesthetic effects but always a continuing danger to data exhibits.¹ Such patterns become dynamically obtrusive when our displays leave the relative constancy of paper and move to the changing video flatland of computer terminals. There, all sorts of unplanned and lushly cluttered interacting combinations turn up, with changing layers of information arrayed in miscellaneous windows surrounded by a frame of system commands and other computer administrative debris.


At left a second color annotates the brush strokes of the calligrapher, Uboku Nishitani. By creating a distinct layer, the red commentary maintains detail, coherence, and serenity, in a crisp precision side-by-side with a gestural and expressive black line in this marriage of color and information. The saturated quality of the red partially offsets its lighter value and finer line (appropriate to meticulous annotation). Alone, each color makes a strong statement; together, a stronger one.

Similarly, color effortlessly differentiates between annotation and annotated, in this skillful industrial-strength diagram separating 300 small parts and their identifying numbers.

What matters—inevitably, unrelentingly—is the proper relationship among information layers. These visual relationships must be in relevant proportion and in harmony to the substance of the ideas, evidence, and data conveyed. “Proportion and harmony” need not be vague counsel; their meanings are revealed in the practice of detailed visual editing of data displays. For example, in this train timetable a heavy-handed grid interacts with the type, generating a stripy texture and fighting with the scheduled times. The prominent top position in the table shows the least important information, a four-digit train identifier used by railroad personnel and nobody else:

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<tr>
<td>New York, N.Y.</td>
<td>A.M.</td>
<td>7:40</td>
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<td>A.M.</td>
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<td>A.M.</td>
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<td>Edison</td>
<td>12:52</td>
<td>12:53</td>
<td>12:54</td>
<td>12:55</td>
<td>12:56</td>
<td>12:57</td>
<td>12:58</td>
<td>12:59</td>
<td>1:00</td>
<td>1:01</td>
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<td>New Brunswick</td>
<td>1:02</td>
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<td>1:09</td>
<td>1:10</td>
<td>1:11</td>
<td>1:12</td>
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</table>

New Jersey Transit, Northeast Corridor Timetable (Newark, 1985).
A redesign calms the dominating grid, moves the New York departure times to the very top, de-emphasizes less important data, and adds new information. A separating line is formed by tiny leader dots, which read as gray, making a distinction but not a barricade:

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<tr>
<td>North Riverway</td>
<td>7:03</td>
<td>7:39</td>
<td>8:20</td>
<td>8:33</td>
<td>8:54</td>
<td></td>
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<tr>
<td>Jersey Avenue</td>
<td>1:02</td>
<td>2:18</td>
<td>7:36</td>
<td>9:21</td>
<td></td>
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The focus is now given over to information, transparently organized by an implicit typographical grid, defined simply by the absence of type. Nevertheless, data-imprisonment spans centuries of information-design struggles. At right is a touchingly ramshackle grid from a 1535 edition of *Cosmographia*. But, from the virtuoso of typographic design: "Tables should not be set to look like nets with every number enclosed," wrote Jan Tschichold in *Asymmetric Typography*:

The setting of tables, often approached with gloom, may with careful thought be turned into work of great pleasure. First, try to do without rules altogether. They should be used only when they are absolutely necessary. Vertical rules are needed only when the space between columns is so narrow that mistakes will occur in reading without rules. Tables without vertical rules look better; thin rules are better than thick ones.

Even quite small changes in line can have significant visual effects. For Paul Klee's sketch, the easy and graceful separation of black line and red commentary collapses into a mishmash when color and light/dark differences are minimized.

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Separate macro-annotation explains the micro-detail of hospital costs in this 26-day narrative of one person passing through an intensive care unit. The design is transparent to the disturbing information, as a layered polyphony of voices—time sequence, accounting data, commentary—weave together to trace out days, hours, minutes, dollars.

Mrs. K. has been taken to the emergency room of a renowned hospital on Manhattan’s Upper East Side. The doctors “work her up.” More than $200 worth of blood tests are ordered (“emr lab,” “lab serology out”). $232 worth of X-rays taken, $97.50 worth of drugs administered. I never saw Mrs. K. in my hospital, I don’t know her medical history. But I am a doctor, and can reconstruct from her hospital bill what is going on, more or less.

She is sick, very sick.

Mrs. K. has been moved to the Intensive Care Unit (“room ICU”). It costs $500 a day to stay in the ICU, base rate. California has the highest average ICU rates in the country: $632 a day. In Mississippi, the average is $265. ICUs were developed in the 1960s. They provide technological life-support systems and allow for extraordinary patient monitoring. An inhalation blood-gas monitor (“inhaled blood gas meter”) is being used to keep a close check on the amount of oxygen in her blood. Without the attention she is receiving in the ICU, Mrs. K. might already be dead.

Mrs. K. has been running a high fever. The doctors have sent cultures of her blood, urine, and sputum to the lab to find out why. She is put on gentamicin ("lab gentamycin trough"), a powerful antibiotic. Such strong drugs can have toxic side effects. Gentamicin kills bacteria, but can also cause kidney failure.

It is Mrs. K.’s fifth day at the hospital, and she is slipping closer to death: her lungs begin to fail. She is put on a respirator ("inhaled respirator"), which costs $119 a day to rent and requires a special technician to operate. A hospital can buy the machine for about $15,000.

Mrs. K. ’s first week in Intensive Care ends in a flourish of blood tests. She has five Chem-8s ("lab chem-8")—tests that measure the levels of sodium, potassium, and six other chemicals in her blood. The hospital charges Mrs. K. $531 for each Chem-8. Most independent labs charge about half as much; some hospitals charge up to $60. The New England Journal of Medicine has said: “The clinical laboratory is a convenient profit center that can be used to support unrelated deficit-producing hospital operations.” The Annals of Internal Medicine estimates that the number of clinical lab tests being done is rising 15 percent a year.

Mrs. K. has started peritoneal dialysis ("dial-per-kit 87101"). Her kidneys are failing. She is still hooked up to the respirator. She is being kept alive by what Lewis Thomas calls “halfway technologies”—”halfway" because kidney dialysis machines and respirators can support organ systems for long periods of time, but can’t cure the underlying disease. Some doctors are beginning to question this practice. A recent study at the George Washington University Medical Center concluded: “Substantial medical resources are now being used in aggressive but frequently futile attempts to avoid death.”

Mrs. K. has been put in a vest restraint. Restraints are used in Intensive Care to keep patients from thrashing about or pulling their tubes out. Many ICU patients develop what is called “ICU psychosis.” They become disoriented, begin hallucinating. The condition is brought on by lack of sleep, toxic drugs, the noise of the ICU staff and machines, and pain.
Mrs. K has been on the respirator for six days. It is breathing for her. But there has been a problem. The tube running from the machine into her mouth and down her throat was not bringing enough oxygen to her lungs. She needed a tracheotomy ("trache care set"). The tube from the respirator is now attached directly to her trachea, through a hole cut into her neck.

This change—for a blood product ("NSA 250MU proc fee")—is not covered by Mrs. K’s Blue Cross policy. The policy also does not cover the cost of fresh blood plasma ("fish f pla proc fee"). These charges have been mounting. Mrs. K is bleeding internally.

Mrs. K has been in Intensive Care for two weeks. She is still running a very high fever. The doctors are still testing. Mrs. K has been placed on a special blanket; it is hopped up to a machine that functions like a refrigerator ("hypothermia machine"). The machine cools the blanket, and the blanket helps lower Mrs. K’s body temperature. Should her temperature rise too high, she may suffer permanent brain damage.

Mrs. K has undergone a gated blood-pool study ("nuc med pool stv"). The doctors have "tagged" her red blood cells with a radioactive isotope. Using a camera that picks up the isotope, the doctors can watch the passage of blood through her heart. In this way, they see firsthand whether the ventricles are functioning properly—whether enough blood is getting pumped, enough oxygen is being sent through the body. First her lungs, then her kidneys. Now Mrs. K’s heart seems to be going.

Mrs. K’s fourth week in the hospital begins with a spinal tap. Using a long needle, a doctor drains fluid from her spinal cord. The fluid is sent to the lab for about a dozen tests ("lab s p f cell ct"). A spinal tap is performed when a patient has what are called "neurological signs." Partial paralysis is one such sign, loss of consciousness another. When doctors order a spinal tap, they suspect brain disease.

Weeks of halfway technology have given the doctors time for testing. The doctors may even have diagnosed what is wrong with Mrs. K; it is hard to say. But the ICU and its technology have not given them the ability to cure her. Now the heart, which has been failing, gives out. Cardiac arrest. There is a burst of activity. Bicarbonate, epinephrine, and other drugs ("pharmacy") are administered. Thirteen bottles of intravenous solution ("ph iv solutions") are poured in.

Mrs. K’s last minutes are recorded on the various ICU monitors. The level of oxygen in her blood falls. She dies.

Mrs. K’s bottom line. Total cost of twenty-six days in the hospital, nearly all this time in Intensive Care: $47,311.20. Of this, Blue Cross will pay $41,933.87. The doctors’ bills, not covered by hospitalization insurance, probably come to thousands of dollars more. Perhaps Mrs. K had Blue Shield, which covers doctors’ fees. In 1982, the last year for which figures are available, Americans spent $322 billion on health care. Of this, $135.3 billion was spent on hospital care. There were 56,241 ICU beds in 1982 like the one Mrs. K was kept alive in, and about $7.2 billion was spent for their use. That represented nearly one percent of the gross national product.
All elements in the map at right—contours, rivers, roads, names—are at the same visual level with equal values, equal texture, equal color, and even nearly equal shape. An undifferentiated, unlayered surface results, jumbled up, blurry, incoherent, chaotic with unintentional optical art. What we have here is a failure to communicate.

Far more detailed than the perfect jumble, this map below separates and layers information by means of distinctions in shape, value (light to dark), size, and especially color. The negative areas are also informative; light strips formed by the grid of buildings identify roads and paths. The water symbol is a blue field, further differentiated from other color fields by a gentle fading away from each outlined edge. Shown against a dull background rather than bright white, these colors remain both calm and distinctive, avoiding clutter. The map exemplifies the "first rule of color composition" of the illustrious Swiss cartographer, Eduard Imhof:

Pure, bright or very strong colors have loud, unbearable effects when they stand unrelieved over large areas adjacent to each other, but extraordinary effects can be achieved when they are used sparingly on or between dull background tones. "Noise is not music . . . only on a quiet background can a colorful theme be constructed," claims Windisch.³

Signal and background compete above, as electrocardiogram trace line becomes caught up in a thick grid. Below, the screened-down grid stays behind traces from each of 12 monitoring leads.\(^4\)

Similarly for music notation, some staff paper is better than others:

In Stravinsky’s sketchbook for *Sacre du printemps*, a grid quietly but clearly and precisely locates the music. Gray grids almost always work well and, with a delicate line, may promote more accurate data reading and reconstruction than a heavy grid. Dark grid lines are chartjunk. When a graphic serves as a look-up table (rare indeed), then a grid may help with reading and interpolation. But even then the grid should be muted relative to the data. Often ready-made graph paper comes with darkly printed lines. The reverse unprinted side should be used, for then lines show through faintly and do not clutter the data. If the paper is heavily gridded on both sides, throw it out.

\(^4\) The preferred example is redrawn from J. Marcus Wharton and Nora Goldschlager, *Interpreting Cardiac Dysrhythmias* (Oradell, New Jersey, 1987), 123. Color also layers, as a gray grid calibrates this signal of ventricular fibrillation, a final collapse of the heart, with only a disorganized rhythm remaining. A similar trace can result from recording artifacts such as a loose monitoring wire; however, one textbook dryly notes, "As the patient will usually have lost consciousness by the time you have realized that it is not just due to a loose connection, diagnosis is easy." John R. Hampton, *The ECG Made Easy* (Edinburgh, 1986), 66.

In the masterly 1748 Nolli map of Rome, the river's heavy inking activates what should be a visually tranquil area, causing bridge names and a little boat to vibrate in a moiré prison, albeit a quiet one. Muting the river encoding calms vibration and brings names and other details forward, while retaining a symbolism of rippling water. This redesign and others that we have seen are visual equivalents of Italo Calvino's approach to writing:

My working method has more often than not involved the subtraction of weight. I have tried to remove weight, sometimes from people, sometimes from heavenly bodies, sometimes from cities; above all I have tried to remove weight from the structure of stories and from language. . . . Maybe I was only then becoming aware of the weight, the inertia, the opacity of the world—qualities that stick to writing from the start, unless one finds some way of evading them.

Layering of data, often achieved by felicitous subtraction of weight, enhances representation of both data dimensionality and density on flatland. Usually this involves creating a hierarchy of visual effects, possibly matching an ordering of information content. Small, modest design moves can yield decisive visual results, as in these intriguing demonstrations of the illusory borders of subjective contours:

5 Giambattista Nolli, Pianta Grande di Roma (Rome, 1748; from a facsimile edition by J. H. Aronson, Highmount, New York, 1984). Note the seemingly English word "or" in the names under the bridge, a result of the 18th-century custom of contracting the Italian ora, meaning now, at this time, currently. On his map, Nolli cites first the old name Ponte Gianicolo or[a] Ponte Sisto (the bridge's new name). Ironically, the English "or" works in this context, although the meaning is not quite right. See Barbara Reynolds, The Cambridge Italian Dictionary, Italian-English (Cambridge, 1962), 524.


Visual activation of negative areas of white space in these exhibits illustrates the endlessly contextual and interactive nature of visual elements. This idea is captured in a fundamental principle of information design: \(1 + 1 = 3 \text{ or more.}\) In the simplest case, when we draw two black lines, a third visual activity results, a bright white path between the lines (note that this path appears even to have an angled end). And a complexity of marks generates an exponential complexity of negative shapes. Most of the time, that surplus visual activity is non-information, noise, and clutter. This two-step logic—recognition of \(1 + 1 = 3\) effects and the consideration that they generate noise—provides a valuable guide for refining and editing designs, for graphical reasoning, for subtraction of weight.

In a little-known essay on \(1 + 1 = 3\) effects, Josef Albers conducts the demonstrations below, a visually sensitive and artistic approach to the cognitive contours of perceptual psychologists. Albers, seeing area and surface rather than border and edge, escapes the preoccupying magic of optical illusions to conceive a broad idea of negative space activation:

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Here I have 2 equal strips of cardboard (1" x 6")

Here is one (vertical), here another (also vertical).
Seeing one strip plus one strip, we count 2 strips:
\(1 + 1 = 2.\)
We recognize the equal width of the strips.
Now, 1 width + 1 width (strips touching) equals 2 widths: \(1 + 1 = 2.\)
But now, separating them (both remain vertical) by 1 width — we count 3 widths (one of them negative): \(1 + 1 = 3.\)

Of the 2 vertical strips, one crosses the other horizontally in their centers.
Result: 2 lines form a crossing, thus producing 4 arms, as 4 extensions, to be read inward as well as outward.
We also see 4 rectangles, and with some imagination, 4 triangles, 4 squares.
By shifting centers and angles, arms and the in-between figures become unequal.

All together: one line plus one line results in many meanings — *Quod erat demonstrandum.*

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7 Rare exceptions are the Turgot-Bretez map of Paris and the Nolli map of Rome: streets, absent of ink, are defined—tersely, clearly, and precisely—by the surrounding ink of blocks and buildings, creating subjective contours.

8 Note the additional \(1 + 1 = 3\) effects, on this page, as the interaction between the examples and the surrounding type enlivens the white space, forming shapes, profiles, and paths. These reverberations are vivid because our examples are printed in black; strong light/dark contrasts accentuate the clutter of \(1 + 1 = 3\) or more.

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Stumbling over $1 + 1 = 3$ has produced perhaps the worst index ever designed, a rare perfect failure. The preface to this guide for flying small aircraft says, “This manual is primarily intended for use during actual flight instruction.” Imagine now noisy vibration in a plane as we search through this visually vibrating list, looking for, say, an entry on “forced landing” ... and the index turns out to have no page numbers. Only a small segment of the unbearable original is shown.

The noise of $1 + 1 = 3$ is directly proportional to the contrast in value (light/dark) between figure and ground. On white backgrounds, therefore, a varying range of lighter colors will minimize incidental clutter. Three maps at right show these tactics in action. In the first, the bold shapes promote vibration all over; and with only nameless streets down on paper, this map is already in visual trouble. At center, thinning two sides of each block results in every street bordered by one thick and one thin line, thus deflecting $1 + 1 = 3$ effects (the thin lines, like gray lines, are visually light in value). On the bottom map, gray establishes serene, motionless edges—an arrangement that will easily accommodate additional geographic detail.

Careful visual editing diminishes $1 + 1 = 3$ clutter. These are not trivial cosmetic matters, for signal enhancement through noise reduction can reduce viewer fatigue as well as improve accuracy of readings from a computer interface, a flight-control display, or a medical instrument. Clarity is not everything, but there is little without it. Editing this statistical graph (showing variability about local averages) remedies the visual clutter induced by parallel lines and equal-width white bands. The redesign, at far right, sweeps the noise away, with color spots now smartly tracking the path of averages.

Harmonizing text and line-drawing requires sensitive appraisals of prolific interaction effects. Unless deliberate obscurity is sought, avoid surrounding words by little boxes, which activate negative white spaces between word and box. And below, the first three maps place the type poorly, with an awkward white stripe materializing between name and river. Type from above adjusts to graphics better, in part because most words have fewer descendents than ascenders (in map 3, a diverting white shape is formed by the ascending letters).9 These small local details will promptly accumulate on the entire map surface, deciding quality.

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This array above, an information prison, employs a narrow range of strong shapes. Grid, silhouette, and type compete at the same nervous visual level. Too loud and too similar. Thick bars of grid boxes generate little paths around both type and silhouette by exciting the negative white space: $1 + 1 = 3$, all over again. Why should the trivial task of dividing up the already free-standing elements become the dominant statement of the entire display?

To direct attention toward the information at hand, the revision below extends the light to dark range of color, separating and layering the data in rough proportion to their relevance. Gray calms a contrasty silhouette, bringing about in turn more emphasis on the lamps and their position and motion. Coloring these lights helps to separate the signals from all the rest. Some 260 lamp-whiskers were erased, whiskers which originally read in confusion as glowing light and also trembling motion. Note the effectiveness and elegance of small spots of intense, saturated color for carrying information—a design secret of classical cartography and, for that matter, of traffic lights. Finally, in our revised version, the type for the title (upper left corner) has emerged from its foggy closet. Also the labels, now set in Gill Sans, are no longer equal in visual weight to the motion arrows, among several typographical refinements.

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"If one limits strong, heavy, rich, and solid colors to the small areas of extremes, then expressive and beautiful colored area patterns occur... Large area background or base-colors do their work most quietly, allowing the smaller, bright areas to stand out most vividly, if the former are muted, grayish or neutral." Eduard Imhof, Cartographic Relief Presentation (Berlin, 1982), edited and translated by H. J. Steward from Imhof’s Kartographische Geländedarstellung (Berlin, 1965), 72. On visual issues and map-making, see essays by Samuel Y. Edgerton, Jr., Svetlana Alpers, Juergen Schultz, Ulla Ehrensvard, James A. Welu, and David Woodward, in Woodward, ed., Art and Cartography (Chicago, 1987).
In the statistical graphic at top, the visually most active elements are, of all things, glowing optical white dots that appear at each intersection of grid lines. (The arrangement of many computer interfaces is similarly overwrought.) The doubled-up, tremor-inducing lines consume 18 percent of this technically ingenious chart, a multi-window plot. Here the redrawing, in ungrid style, eliminates the visual noise, concentrating our viewer’s attention on data rather than data containers.

Too often epidemics of data-imprisonment and decorative gridding break out when contemporary commercial designers are faced with information. The aggressive visual presence of stylized grids, little boxes surrounding words here and there, and cadenced accents—all so empty of content, irrelevant—becomes the only way you can tell if something has been “designed”. At any rate, the self-important grid is for the birds, providing only a nice place to perch:


Information consists of differences that make a difference. A fruitful method for the enforcement of such differences is to layer and separate data, much as is done on a high-density map. In representing various layers of meaning and reading, the most economical of means can yield distinctions that make a difference: the small gestures of Calder’s pen easily separate the stag and his watery reflection. Failure to differentiate among layers of reading leads to cluttered and incoherent displays filled with disinformation, generated by the unrelenting interactive visual arithmetic of flatland, \(1 + 1 = 3\) or more.

All these ideas—figure and ground, interaction effects, \(1 + 1 = 3\) or more, layering and separation—have compelling consequences for information displays. Such concepts (operating under an assortment of names) are thoroughly tested, long familiar the world over in the flatlands of typographers, calligraphers, graphic designers, illustrators, artists, and, in three dimensions, architects:

In every clear concept of the nature of vision and in every healthy approach to the spatial world, this dynamic unity of figure and background has been clearly understood. Lao Tse showed such grasp when he said: “A vessel is useful only through its emptiness. It is the space opened in a wall that serves as a window. Thus it is the nonexistent in things which makes them serviceable.” Eastern visual culture has a deep understanding of the role of empty space in the image. Chinese and Japanese painters have the admirable courage to leave empty large paths of their picture-surface so that the surface is divided into unequal intervals which, through their spacing, force the eye of the spectator to movements of varying velocity in following up relationships, and thus create the unity by the greatest possible variation of surface. Chinese and Japanese calligraphy also have a sound respect for the white interval. Characters are written in imaginary squares, the blank areas of which are given as much consideration as the graphic units, the strokes. Written or printed communications are living or dead depending upon the organization of their blank spaces. A single character gains clarity and meaning by an orderly relationship of the space background which surrounds it. The greater the variety and distinction among respective background units, the clearer becomes the comprehension of a character as an individual expression or sign.¹¹

In this splendid 1659 drawing by Christiaan Huygens, the inner ellipse traces Earth’s yearly journey around the Sun; the larger ellipse shows Saturn’s orbit, viewed from the heavens. The outermost images depict Saturn as seen through telescopes located on Earth. All told, we have 32 Saturns, at different locations in three-space and from the perspective of two different observers—a superior small multiple design.

At the heart of quantitative reasoning is a single question: Compared to what? Small multiple designs, multivariate and data bountiful, answer directly by visually enforcing comparisons of changes, of the differences among objects, of the scope of alternatives. For a wide range of problems in data presentation, small multiples are the best design solution.

Illustrations of postage-stamp size are indexed by category or a label, sequenced over time like the frames of a movie, or ordered by a quantitative variable not used in the single image itself. Information slices are positioned within the eyespan, so that viewers make comparisons at a glance—uninterrupted visual reasoning. Constancy of design puts the emphasis on changes in data, not changes in data frames.


Small multiples reveal, all at once, a scope of alternatives, a range of options. Above, varying signal lights on the ends of a train are entailed in a rulebook for railroad employees. Our redrawing mutes the repeated train outline and brings forward differentiating colors.

At far right, these photographs capture pressure, direction, and speed of the calligraphic brush as it draws a single Kana character. Images are indexed by time (→) and by dual camera angle (↑). The paired series of photographs link hand, brush, and character (top row). The second row shows pressure and bend of the brush-tip—and the consequent width of line. The sequence has a magical quality, reflecting a remark of Garry Winogrand, the photographer: “There is nothing as mysterious as a fact clearly described.”

At right, Kayu Hirata, *Tsugi Shiki Shi*, volume 25 of *Shado Giho Koza* [Techniques in Calligraphy] (Tokyo, 1974), 30. Above, without the aid of film, Mercator shows a similar sequence, the proper ordering of strokes in the formation of capital letters. Gerardus Mercator, *Literarum Latinarum, quas Italicas cursiviasque vocant, scribendorum ratio* [The method of writing the Latin letters, which are called italic and cursive] (Louvain, 1540), chapter 6.
MURAL WITH BLUE BRUSHSTROKE

To make *Mural with Blue Brushstroke*, Lichtenstein drew on sources ranging from the most exalted to the most banal. Classical architecture (2, 14) provided inspiration, as did the site itself (8, where painted windows align with real ones). Homages to twentieth-century masters abound: Léger's people (1), Kelly's color fields (6), Matisse's split philodendron form (9), Arp's silhouettes (10, echoed in a piece of Swiss cheese), De Kooning's brushstrokes (12), Stella's triangles and French curves (15), Johns's flagstones (16), and Braque's balusters (20). Art styles—like Abstract Expressionism (11, 12, and 13, the latter with its "perfect painting"), Cubism (20), and Art Deco (21)—and artist's tools (4, 5, and 15) appear. And bustling around amid all this high culture are images of everyday modern life, those perennial sources of fascination to Lichtenstein: sunbursts (3), copy books (17), advertisements (7), food and drink (10, 18), and, of course, comic strips (19).

Roy Lichtenstein created "Mural with Blue Brushstroke" for the lobby of a building in New York. The large painting contains allusions to other works by Lichtenstein as well as many quotations (some a bit vapidous) from other artists. For a book describing the mural, Samuel
Antupit (who was also responsible for the annotated invoice from the hospital) crafted this superb double-page spread, linking 21 small images from various sources to the mural at center. This design both isolates detail and places it in context.
With figures and pictographs chipped into stone, the Dighton Writing Rock sits near the Taunton River in southeastern Massachusetts. From 1680 onwards, observers sketched the inscriptions, with divergent results. Same rock, different views, arrayed here in a comparative small multiple. Some of these uncertain drawings, when sent off to European scholars, were then converted into far-reaching historical discoveries of startling visits to the New World. One researcher "triumphantly established" the marks as Scythian; a distinguished Orientalist detected the word melek (king) on the rock; others thought they saw Phoenician or Runic script. A Scandinavian antiquary translated the drawings into an account of a pre-Columbian sojourn to America by a party of Thorfinn the Hopeful. Since the writing resembles that on the Indian God Rock hundreds of miles southwest, such logic places the Vikings far inland, deep into what is now West Virginia and Ohio. All this scholarship of wishful thinking denies priority to the original Native-American residents; local experts conclude that the marks are Algonquin.¹

During the last 1,260 years in China, where did poets flourish? How many poets? And have their birthplaces changed over the years? Four maps, based on an inherently imperfect historical record, address these prominent questions.


Birthplaces of the 2,625 Tang poets, 618–907

Birthplaces of the 2,377 Sung poets, 969–1279
Shown is the geographic distribution of poets (grand total 10,086) during four dynasties, with their birthplaces shifting through centuries toward southeast China and concentrating—as is the case for so much human activity—in a relatively few areas.

Birthplaces of the 3,005 Ming poets, 1368-1644

Birthplaces of the 2,079 Ching poets, 1644-1911
And, finally, a map of distribution of temples of Matsu (T’ien Hou), the most famous sea goddess of China. With a sterling reputation for miracles, she receives prayers of fishermen and sailors during stormy weather; and when the sea is as dark as ink, she provides a torch on the top of the mast to guide small boats to safety. In recent times, the story goes, one mother (an alleged descendant of the goddess) left her child at a temple while going to work on the farm, saying “Sea Goddess, please take heed.” Matsu’s reaction to supervising a day-care facility was not recorded. Our display here, growing from surpassingly incomplete data, marks prefectures with a temple honoring Matsu. But we are unable to make the long-awaited comparisons among geographic distributions of sea-goddess temples and birthplaces of Tang, Sung, Ming, and Ching poets—because the poets are stranded over on the two preceding pages. *Comparisons must be enforced within the scope of the eyespan*, a fundamental point occasionally forgotten in practice.

The struggle between maintenance of context and enforcement of comparison is reflected in a 19th-century topographic diagram at right. Surveying lengths of the world’s rivers, the chart hangs them out, in parallel more or less, while still retaining specifics of place-names, lakes, and river branches. Note the various sequences of lakes, here linearly arranged. Without such detail, this is just another decorated bar chart. Some ardent typography sets oceans rippling at top. The juxtaposed mountains are less successful, too arbitrary in their relocation, and too stylized and lacking the nice local particulars of the rivers.


Simultaneous two-dimensional indexing of the multiplied image, flatland within flatland, significantly deepens displays, with little added complication in reading. These neurometric maps record distributions of brain electrical activity, arraying data over a matrix of color images—with frequency bands (delta, theta, alpha, and beta) sorting the columns, and individual diagnosis forming the rows. The contour lines depict only the average differences (normalized z-scores) of the row group compared to a healthy reference group, and thus do not show overlaps or extreme outlying values of all the individual members of each group. Graphically, this recursive design resembles the Los Angeles smog chart that we saw in Chapter 1, where maps were themselves spread on two dimensions, type of pollution and time of day.

3 E. R. John, L. S. Prichep, J. Fridman, and P. Easton, “Neurometrics: Computer-Assisted Differential Diagnosis of Brain Dysfunctions,” *Science*, 239 (January 8, 1988), 162–169. The authors conclude: “Healthy persons display only chance deviations beyond the predicted ranges. . . . Patients with neurological impairments, subtle cognitive dysfunctions, or psychiatric disorders show a high incidence of abnormal values. The magnitude of the deviations increases with clinical severity. Different disorders are characterized by distinctive profiles of abnormal brain electrical features. . . . These methods may provide independent criteria for diagnostic validity, evaluations of treatment efficacy, and more individualized therapy.”
In our neurometric example at left, the dark colors surrounding each image generate disruptive white stripes. Locations can be signaled by nearly silent methods, as above, where an implicit grid pairs each insect with its fly-fishing simulation. And the limited but focused color here is more effective than strong rainbow colors, for reasons now to be revealed.

In representing and communicating information, how are we to benefit from color's great dominion? Human eyes are exquisitely sensitive to color variations: a trained colorist can distinguish among 1,000,000 colors, at least when tested under contrived conditions of pairwise comparison. Some 20,000 colors are accessible to many viewers, with the constraints for practical applications set by the early limits of human visual memory rather than the capacity to discriminate locally among adjacent tints. For encoding abstract information, however, more than 20 or 30 colors frequently produce not diminishing but negative returns.

Tying color to information is as elementary and straightforward as color technique in art, “To paint well is simply this: to put the right color in the right place,” in Paul Klee’s ironic prescription. The often scant benefits derived from coloring data indicate that even putting a good color in a good place is a complex matter. Indeed, so difficult and subtle that avoiding catastrophe becomes the first principle in bringing color to information: Above all, do no harm.

At work in this fine Swiss mountain map are the fundamental uses of color in information design: to label (color as noun), to measure (color as quantity), to represent or imitate reality (color as representation), and to enliven or decorate (color as beauty). Here color labels by distinguishing water from stone and glacier from field, measures by indicating altitude with contour and rate of change by darkening, imitates reality with river blues and shadow hachures, and visually enlivens the topography quite beyond what could be done in black and white alone.

Note the many finely crafted details: changes in the color of contour lines as the background shifts, interplay of light and shadow in areas of glacial activity, and color typography. The black-ink-only area at the bottom, though not an optimized monochrome design, gives a sense of the overwhelming informational benefits of color, when it is at its best.
The Swiss maps are excellent because they are governed by good ideas and executed with superb craft. Ideas not only guide work, but also help defend our designs (by providing reasons for choices) against arbitrary taste preferences. Strategies for how color can serve information are set out in Eduard Imhof’s classic Cartographic Relief Presentation, which describes the design practices for the Swiss maps. The first two principles seek to minimize color damage:

*First rule:* Pure, bright or very strong colors have loud, unbearable effects when they stand unrelieved over large areas adjacent to each other, but extraordinary effects can be achieved when they are used sparingly on or between dull background tones. “Noise is not music. Only a piano allows a crescendo and then a forte, and only on a quiet background can a colorful theme be constructed.” The organization of the earth’s surface facilitates graphic solutions of this type in maps. Extremes of any type—such as highest land zones and deepest sea troughs, temperature maxima and minima—generally enclose small areas only. If one limits strong, heavy, rich, and solid colors to the small areas of extremes, then expressive and beautiful patterns occur. If one gives all, especially large areas, glaring, rich colors, the pictures have brilliant, disordered, confusing and unpleasant effects.

*Second rule:* The placing of light, bright colors mixed with white next to each other usually produces unpleasant results, especially if the colors are used for large areas.²

Violation of this counsel yields the exuberantly bad example below. All this strong color, especially the surrounding blue, generates a strange puffy white band, making it the map’s dominant visual statement, with some alarming shapes at lower left. These colors are dark in value, and inevitably we have significant $1 + 1 = 3$ effects again, at visual war with the heavily encoded information.

² Note the after-images and vibration resulting from these strong colors (complementary, equal in value), an example from Josef Albers, *The Interaction of Color* (New Haven, 1963), “Vibrating Boundaries,” folder XXII.1. The quotation is part of a longer list of color principles in Eduard Imhof, *Cartographic Relief Presentation* (Berlin, 1982), edited and translated by H. J. Steward from Imhof’s *Kartographische Geländedarstellung* (Berlin, 1965), 72. The internal quotation is from H. Windisch, *Schule der Farbenphotographie* (Seebruck, 6th edition, 1938). The color logic is similar to that for emphasis in music: “Without accent there is no life. The beat becomes monotonous and wearisome. Music without accent lacks coherence, and movement becomes aimless where there is no impulse. Conversely, if every note, word or movement is stressed, the result has even less meaning.” Ann Driver, *Music and Movement* (London, 1936), 34.
Along with its critique of color-clutter, Imhof's first rule contains an important constructive idea: *color spots against a light gray or muted field highlight and italicize data, and also help to weave an overall harmony*. Daniel Burnham's architectural drawing shows the vitality of small color spots on large muted backgrounds: coherent, vivid and textured but without clutter, the right color in the right place. The 1909 *Plan of Chicago* contains several other drawings the equal of that shown here—with skillful color illuminating architectural drawings and maps.

Applying a single mark, a strong but transparent spot, Jan Tschichold labels his rejection of the classical central axis typography and design, in favor of the asymmetric layout at right.


Color serves as a label most nobly of all in Oliver Byrne’s 1847 edition of Euclid’s *Geometry*. This truly visual Euclid discards the letter-coding native to geometry texts. In a proof, each element names itself by consistent shape, color, and orientation; instead of talking about angle DEF, the angle is *shown*—appropriately enough for geometry. Below, we see an orthodox march through the Pythagorean theorem; too much time must be spent puzzling over an alphabetic macaroni of 63 encoded links between diagram and proof. At far right, the visual Pythagoras. Ruari McLean described Byrne’s book as “one of the oddest and most beautiful books of the whole [19th] century... a decided complication of Euclid, but a triumph for Charles Whittingham [the printer].” A close look, however, indicates that Byrne’s design clarifies the overly indirect and complicated Euclid, at least for certain readers.

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**THEOREM 27.** (Pythagoras’ Theorem.)

In any right-angled triangle, the square on the hypotenuse is equal to the sum of the squares on the sides containing the right angle.

*Given* $\triangle ABC$ is a right angle.

*To prove* the square on $BC = \triangle ABC$ is equal to the square on $BA + \triangle ACD$ on $AC$.

Let $ABHK$, $ACMN$, $BCPQ$ be the squares on $AB$, $AC$, $BC$.

Join $CH$, $AQ$. Through $A$, draw $AXY$ parallel to $BQ$, cutting $BC$, $QX$ at $X$, $Y$.

Since $\angle BAC$ and $\angle BAK$ are right angles, $KA$ and $AC$ are in the same straight line.

Again $\angle HAQ = 90^\circ = \angle BQC$.

Add to each $\triangle ABC, \triangle HBC = \triangle ABQ$.

In the $\triangle ABC$, $\triangle HBC$.

$\triangle HBC$ and $\triangle ABC$ are on the same base $HB$ and between the same parallels $HB$, $KA$.

$\therefore \triangle HBC = \frac{1}{2}$ square $HA$.

Also $\triangle ABQ$ and rectangle $BQXY$ are on the same base $BQ$ and between the same parallels $BQ$, $AXY$.

$\therefore \triangle ABQ = \frac{1}{2}$ rect. $BQXY$.

$\therefore$ square $HA = \triangle ABQ$.

Similarly, by joining $AP$, $BM$, it can be shown that square $MA = \triangle CPYX$;

$\therefore$ square $HA + square MA = \triangle BQXY + \triangle CPYX = \triangle BQYX$.

Q.E.D.

---

In a right angled triangle

the square on the hypotenuse is equal to
the sum of the squares of the sides, ( and ).

On , and describe squares,

Draw \( \parallel \) also draw \( \parallel \) and \( \parallel \).

\[
\begin{align*}
\triangle &= \square, & \text{To each add } \triangle & = \square, \\
\square &= \square & \text{and } \square &= \square;
\end{align*}
\]

Again, because \( \parallel \)

\[
\begin{align*}
\square &= \text{twice } \triangle, & \text{and } \square &= \text{twice } \triangle; \\
\therefore \quad \square &= \square.
\end{align*}
\]

In the same manner it may be shown

that \( \square = \square \);

hence \( \square = \square \).

Redrawn from Oliver Byrne, The First Six Books of the Elements of Euclid in which coloured diagrams and symbols are used instead of letters for the greater ease of learners (London, 1847), 48-49.
Below, instructions for circumscribing a square on a circle, with a typically roundabout Euclidean proof verifying that □ really is square. Byrne's colors keep in mind the knowledge to be communicated, color for information. Use of the primary colors and black provides maximum differentiation (no four colors differ more). The yellow, broken with orange, is darkened in value, sharpening the definition of its edge against white paper; and the blue is relatively light (on a value scale of blues), reinforcing its distance from black. In the diagrams, the least-used color is black, and it is carefully avoided for large, solid elements—adding to the overall coherence of the proofs by muting unnecessary contrasts. Spacious leading of type assists integration of text and figure, and also unifies the page by creating lines of type (instead of the solid masses usually formed by bodies of straight text) similar in visual presence to the geometric lines and shapes.

![Diagram of a circle circumscribed by a square]

\[ \text{About a given circle to circumscribe a square.} \]

Draw two diameters of the given circle perpendicular to each other, and through their extremities draw \( \overline{a}, \overline{b}, \overline{c}, \) and \( \overline{d} \) tangents to the circle;

and \( \square \) is a square.

\[ \angle \text{ a right angle, (B. 3. pr. 18.)} \]

Also \( \angle \) (conf.),

\[ \therefore \overline{a} \parallel \overline{c} \quad \text{in the same manner it can be demonstrated that} \quad \overline{b} \parallel \overline{d} \quad \text{and also that} \quad \overline{a} \parallel \overline{d} ; \]

\[ \therefore \square \text{ is a parallelogram, and} \]

because \( \square \) they are all right angles (B. 1. pr. 34):

it is also evident that \( \overline{a}, \overline{b}, \overline{c}, \overline{d} \) and \( \overline{a} \) are equal.

\[ \therefore \square \text{ is a square.} \]

Q. E. D.
Design of these 292 pages of Euclid—drawn in 1847 by Her Majesty’s surveyor of the Falkland Islands and also school mathematics teacher, Oliver Byrne—anticipates the pure primary colors, asymmetrical layout, angularity, lightness of plentiful empty space, and non-representational (abstract, “denaturalized”) shapes characteristic of 20th-century Neo-Plasticism and De Stijl painting. And it is Euclid, too. Only the decorative initial capital letters (wood-engraved by Mary Byfield) appear now as pre-modern... or, for that matter, post-modern.

This redrawing below of part of Pythagoras couples Byrne’s visual method with conventional letter-encoding. Deflecting the fussiness that often results from redundant signals, the intermingling here of two labeling techniques seems to speed recognition of geometric elements as the eye moves between diagram and proof. Such a combination allows viewers to choose how they link up the text with the diagram, and it is likely that both methods will be used together.

8 Piet Mondrian presented principles of Neo-Plasticism in 1926: “(1) The plastic medium should be the flat plane or the rectangular prism in primary colors (red, blue, and yellow) and in non-color (white, black, and gray)... (2) There must be an equivalence of plastic means. Different in size and color, they should nevertheless have equal value. In general, equilibrium involves a large uncolored surface or an empty space, and a rather small colored surface... (4) Abiding equilibrium is achieved through opposition and is expressed by the straight line (limit of the plastic means) in its principal opposition, i.e., the right angle... (6) All symmetry shall be excluded.” One version of this essay, “Home—Street—City,” is found in Michel Seuphor, Piet Mondrian: Life and Work (New York, 1956), 166–168; see also The New Art—The New Life: The Collected Writings of Piet Mondrian, edited and translated by Harry Holtzman and Martin S. James (Boston, 1986), 205–212. 

Piet Mondrian, Composition with Red, Yellow and Blue, 1930.

Theo van Doesburg, Simultaneous Counter-Composition, 1929–1930.
In all 50 or so systems of color organization, every color is located in three space: described by hue, saturation, and value in Munsell and other spatial–perceptual classifications; by red, green, and blue components in various additive methods for video displays; and by cyan, magenta, and yellow components in subtractive methods for printing inks. A variety of color systems, but always three dimensions.

Can color's inherently multidimensional quality be used to express multidimensional information? And can viewers understand, or learn to understand, such displays? A good place to start on a video display terminal is to spread data points over flatland for two dimensions and then light up each point by red, green, and blue (RGB) components, in proportion to values taken by three additional variables. At right, a five by five scatterplot matrix shows all X–Y pairs. Note color clusters of data, assemblies of three-dimensional similarity (on RGB variables) spread on the X–Y plane, an obvious improvement over black–only dots. Color's multidimensionality can also enliven and inform what users must face at computer terminals, although some color applied to display screens has made what should be a straight–forward tool into something that looks like a grim parody of a video game.
Shown above are conventional graphical interfaces, with scroll bars, multiple windows, and computer administrative debris. Closely-spaced, dark grid lines generate $1 + 1 = 3$ clutter, with noise growing from the overscan borders (the surrounding dead area of a video tube). Noise is costly, since computer displays are low-resolution devices, working at extremely thin data densities, $1/10$ to $1/1000$ of a map or book page. This reflects the essential dilemma of a computer display: at every screen are two powerful information-processing capabilities, human and computer. Yet all communication between the two must pass through the low-resolution, narrow-band video display terminal, which chokes off fast, precise, and complex communication.

Color can improve the information resolution of a computer screen. First, by softening the bright-white background, color calms video glare, the effect of staring at a light bulb. Below, color defines edges and allows a simple and elegant de-gridded design. For framing fields, the appropriate color should be light in value (muting $1 + 1 = 3$ effects), and, at the same time, relatively intense and saturated (to give a strong visual signal for an active window). Yellow is the only color that satisfies this joint requirement. Thus a two-dimensional display task is handled by two visual dimensions of a single color:

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What palette of colors should we choose to represent and illuminate information? A grand strategy is to use colors found in nature, especially those on the lighter side, such as blues, yellows, and grays of sky and shadow. Nature’s colors are familiar and coherent, possessing a widely accepted harmony to the human eye—and their source has a certain definitive authority. A palette of nature’s colors helps suppress production of garish and content-empty color junk. Local emphasis for data is then given by means of spot highlights of strong color woven through the serene background. Eduard Imhof develops this theme, with his characteristic mix of cartographic science and art:

Third rule: Large area background or base-colors should do their work most quietly, allowing the smaller, bright areas to stand out most vividly, if the former are muted, grayish or neutral. For this very good reason, gray is regarded in painting to be one of the prettiest, most important and most versatile of colors. Strongly muted colors, mixed with gray, provide the best background for the colored theme. This philosophy applies equally to map design.

Fourth rule: If a picture is composed of two or more large, enclosed areas in different colors, then the picture falls apart. Unity will be maintained, however, if the colors of one area are repeatedly intermingled in the other, if the colors are interwoven carpet-fashion throughout the other. All colors of the main theme should be scattered like islands in the background color. The complex nature of the earth’s surface leads to enclosed colored areas, all over maps. They are the islands in the sea, the lakes on continents, they are lowlands, highlands, etc., which often also appear in thematic maps, and provide a desirable amount of disaggregation, interpretation and reiteration within the image.7


7 Eduard Imhof, Cartographic Relief Presentation (Berlin, 1982), edited and translated by H. J. Steward from Imhof’s Kartographische Geländedarstellung (Berlin, 1965), 72. Here what should be strictly cartographic and information design arguments are pushed too far toward a general theory of aesthetics. Mondrian, Malevich, and many others routinely violate the fourth rule; the problem is with the rule not Mondrian.
Of course color brings to information more than just codes naming visual nouns—color is a natural quantifier, with a perceptually continuous (in value and saturation) span of incredible fineness of distinction, at a precision comparable to most measurement. For data then as for art: "And what tremendous possibilities for the variation of meaning are offered by the combination of colors... What variations from the smallest shading to the glowing symphony of color. What perspectives in the dimension of meaning!" wrote Paul Klee. In practice everything is not this wonderful, given the frequently uneasy translations from number to corresponding color and thence to human readings and interpretations.

The General Bathymetric Chart of the Oceans records ocean depth (bathymetric tints) and land height (hypsometric tints) in 21 steps—with "the deeper or higher, the darker" serving as the visual metaphor for coloring. Shown are the great ocean trenches of the western Pacific and Japan Sea. Numbered contours outline color fields, improving accuracy of reading. Nearly transparent gray tracks, on a visual plane apart from the bathymetric tints, trace paths of sounding lines (outside those areas of extremely detailed surveys, such as ports and along coast lines). Every color mark on this map signals four variables: latitude, longitude, sea or land, and depth or altitude measured in meters.
In the ocean map, quantities are shown by a *value* scale, progressing from light to dark blue. Although easy to learn and remember, value scales may be vulnerable to the inaccuracies of reading provoked by disturbing contextual effects, shown above, of edge fluting and simultaneous contrast. A widely-used alternative is a scale of rainbow colors, replacing the clear visual sequence of light to dark with the disorderly red, orange, yellow, green, blue, indigo, and violet—an encoding that now and then reduces perplexed viewers to mumbling color names and the numbers they represent, perversely contrary to Paul Valéry’s axiom, “To see is to forget the name of the thing one sees.” Despite our experiences with the spectrum in science textbooks and rainbows, the mind’s eye does not readily give an order to *ROYGBIV*. In the face of this rainbow encipherment, viewers must turn to other cues (contour, edge, labels) in order to see and interpret data.

Any color coding of quantity (whether based on variations in hue, value, or saturation) is potentially sensitive to interactive contextual effects. These perceived color shifts, while an infrequent threat to accuracy of reading in day-to-day information design, are surprising and vivid—suggesting that color differences should not be relied upon as the sole method for sending a message amidst a mosaic of complex and variable data. Here the same color (in the central squares) looks quite different when placed in slightly different circumstances. The small squares are shifted so as to match the opposite surround—a fine

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9 Controlled variations in hue, however, help extend value scales, increasing fineness of differentiation and yet still giving viewers a sense of natural visual sequence.
visual touch. Perhaps even more stunning are arrangements of color fields that make two different colors look alike. Albers describes this as a *subtraction* of color: "Repeated ... experiments with adjacent colors will show that any ground subtracts its own hue from colors which it carries and therefore influences."¹⁰ How different the colors of the small squares above look against a uniform white field:

Can these interactions of color *benefit* information displays? Not often, but, in this conventional road map, the perceived visual palette used for labels is extended, without the expense of printing an additional flat color. The thin red line (smaller roads) changes to a deeper red when flanked by parallel blue stripes in the code for larger roads.

Color itself is subtle and exacting. And, furthermore, the process of translating perceived color marks on paper into quantitative data residing in the viewer’s mind is beset by uncertainties and complexities.¹¹ These translations are nonlinear (thus gamma curves), often noisy and idiosyncratic, with plenty of differences in perception found among viewers (including several percent who are color-deficient).¹²,¹³

*Multiple* signals will help escape from the swamp of perceptual shifts and other ambiguities in reading. Redundant and partially overlapping methods of data representation can yield a sturdy design, responding in one way or another to potential visual complications—with, however, a resulting danger of fussy, cluttered, insecure, committee-style design. A crystalline, lucid redundancy will do.

¹⁰ Josef Albers, *Interaction of Color* (New Haven, 1963), 28. In reading these color comparisons, Albers suggests "For a proper comparison, we must see them simultaneously, not alternatingly. The latter way, a repeated looking forth and back, produces changing and disturbing after-images which make a comparison under equal conditions impossible. For a simultaneous comparison, therefore, we must focus at a center between the 2 rectangles, and for a sufficient length of time." (*Interaction of Color: Commentary*, 16, italics added.) Students of printing may wish to note that reproduction of the various examples here required 23 separate flat colors for this signature.


¹² Because of color-deficient vision, it is best to avoid making crucial data distinctions depend on the difference between red and green. See Leo M. Hurvich, *Color Vision* (Sunderland, Massachusetts, 1980).

¹³ Also, the specific details of linking color to number must be decided in relation to the information itself, taking into account the frequency distribution of the data, what aspects of the data are to come forward, and the delineation of important cutpoints. For a good analysis of these issues, see Eduard Imhof, *Cartographic Relief Presentation* (Berlin, 1982), translated by H. J. Steward from Imhof’s *Kartographische Geländedarstellung* (Berlin, 1965), 312–324.
Transparent and effective deployment of redundant signals requires, first, the need—an ambiguity or confusion in seeing a data display that can in fact be diminished by multiplicity—and, second, the appropriate choice of design technique (from among all the various methods of signal reinforcement) that will work to minimize the ambiguity of reading. Disregard of these conspicuous distinctions will propagate a gratuitous multiplicity. Several examples, illustrating mutual interplay of color and contour, give our verbal pronouncements a visual reality.

The ocean map exemplifies a sensitive multiplicity: the color fields which encode depth are in turn delineated by contours labeled with depth measurements. These lines eliminate edge fluting and make each field a more coherent whole, minimizing within-field visual variation and maximizing between-field differences. Edge lines allow very fine value distinctions, increasing scale precision. Between fields, only the presence of an edge is needed, a thin line of a color not too distant in value from the scale itself (at left, 3% and 7% screen tints for ground and for building; at right, exactly the same tints with edges). Note the dramatic effect of the contour here, visually shifting color within the outlined form, sharply distinguishing the building from the surrounding ground. This technique of cartography and graphic design is confirmed by theories of vision, which point out that human cognitive processing gives considerable and often decisive weight to contour information.

In this map, the color merely delineates what is already obvious. Laid down in broad unrefined bands, the strong colors induce a loss of focus of detail on the entire map, making it something to be read only at poster distance. So much visual excitement, so little data, merely to outline a shape.
already familiar to most viewers of the map. Boundary lines should be
drawn so as to show clearly what falls on which side, essential details lost
here in color cross-hatching. The color misses the point.

The map at left is an unsuccessful imitation of the beautiful original
above, translucently aglow with delicate light. Outer areas are given
less emphasis, with color gently defining roads, boundaries, and cities.
City symbols are marked by red stars indicating how many members
each place sent to Parliament in 1724. At any rate, a clear statement
about geography, rather than a statement about color.

“All things are always on the move simultaneously,” as Winston
Churchill once described military strategy. So it is also for design and
color; even simple visual effects can involve a simultaneous complexity
of design issues. For this Japanese textile pattern, white dots produce a
slight contextual color shift nearby, as in the Albers examples of color in-
teractions. Surrounding the dots and the narrow band of shifted color
are cognitive contours. And these contours in turn produce a homogeneous
edged field, a result we have seen both in the ocean map and in the gray
tints of the building planviews.

Thomas Badeslade, A Compleat sett of Mapps
of England and Wales in General, and of each
County in particular . . . (1724), pen and ink,
and watercolor on vellum, leaf 35 (recto).