Special Issue

Diagrams as Tools for Worldmaking

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Visible Language is concerned with research and ideas that help define the unique role and properties of written language. It is a basic premise of the journal that writing/reading form an autonomous system of language expression which must be defined and developed on its own terms.

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Diagrams as Tools for Worldmaking

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Reliance on diagrams as quick, cut to the bone communications has become a commonplace in our most public of media, the newspaper and television. In the former we have diagram "bites" enhanced (or trivialized depending on one's viewpoint) with some icon or presented conventionally as a line, bar or pie chart. In the latter, we have Ross Perot with his ubiquitous flip-chart, abstracting the details of economic life and projecting trends. Today, computer software makes comparison, chronology or trend easy to accomplish. It is from this context that we seek to question the diagram as a tool. The purpose of this article is to step aside from conventional ideas about diagrams and to examine how they work, to look beneath the surface of these admittedly powerful tools which bring to its audience the possibility of a common understanding on some issue or relationship.

Ideas from a perceptual psychologist, J.J. Gibson, a communication theorist, W. Barnett Pearce and a philosopher, Nelson Goodman, are brought to bear, like can-openers, to smoothly cut or more forcefully crunch open the closed surface of the diagram. The papers are introduced in the three divisions of this issue: Examining the Past, Questioning the Present and Working Toward the Future.

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Sharon Helmer Poggenpohl,
and Dietmar R. Winkler, pp. 252-269,

1
J.J. Gibson. 1979. *The Ecological Approach to Visual Perception.* Boston: Houghton-Mifflin.

2.
Claude Shannon's model of communication from 1948 is redrawn in figure 1.

3.
For more detail on this see Herbert Franke's article in *Visible Language* 11:2, 22.

4.
J.J. Gibson was a distinguished American dissident in the field of perceptual psychology. For more background on him see Edward S. Reed's *James J. Gibson and the Psychology of Perception.* New Haven: Yale University Press, 1988.

Diagrams as Tools for Worldmaking

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In the introduction to J.J. Gibson's The Ecological Approach to Visual Perception, the author asks the reader ". . . to suppose that the concept of space has nothing to do with perception. Geometrical space is a pure abstraction. Outer space can be visualized but cannot be seen. The cues for depth refer only to paintings, nothing more. The visual third dimension is a misapplication of Descarte's notion of three axes for a coordinate system."[1] With this statement, Gibson challenges his readers to put aside the commonplace convention of space in order to better follow his argument. Likewise, this special issue of *Visible Language* on diagrams asks the reader to step aside from their conventional ideas about diagrams and to look beneath the surface.

Perceptual fundamentals: gains and losses

If we set aside an inventory of diagrams, any attempt to classify them or an analysis of their conventions, what is left? Where should we begin? It is tempting to begin with human physiology and cite the facts of foveal excitation, angle of vision or thresholds for contrast. After all the human system for visual reception of information is a given – it provides the constraints for what can be received. But this quickly becomes a reductive approach that remains on the diagrammatic surface and becomes a checklist of the obvious all the while slighting the dynamic nature of human perception. It also sets the stage for a stimulus-response approach that we know is limited.

Another model of more recent origin, the Shannon model of communication,[2] also needs to be side-stepped (*see figure 1*). Acceptance of this model returns us to the problem of limited channel capaciity and facts such as that the eyes can processs 10^7 bits/second while the ears process 1.5×10^6 bits/second.[3] Despite the external factual appearance of such information, the actual processing of data remains a black box.

Returning to Gibson,[4] we are reminded that we do not perceive or think with binary processes. He stated that there is a significant difference between ambient light reflected off surfaces in our environment – the stuff of perception yielding visual information – and radiant light, which at most transmits information about the atoms from which it originates. Gibson returns us to concepts that may seem obvious.

Man and the environment in which he lives are complementary with the components and events of the environment falling into natural units which are

Figure 1 Claude Shannon's 1948 model of communication.

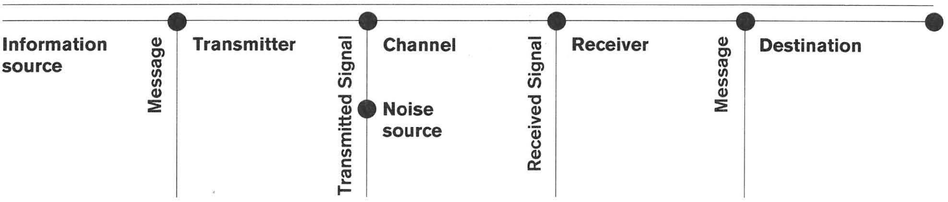
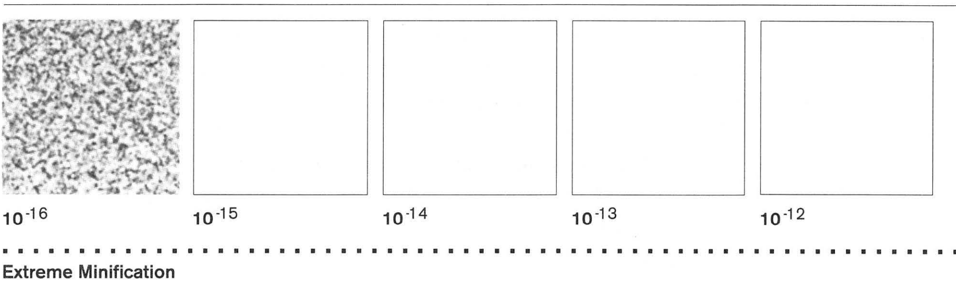


Figure 2 Expanding frames of perceptual reference.



The photographic material is from *The Powers of Ten* by Philip and Phylis Morrison and The Office of Charlesand Ray Eames.

5
Gibson, *Ecological Approach to Visual Perception*, 64.

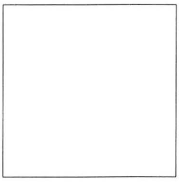
6
Gibson, *Ecological Approach to Visual Perception*, 110.

7
Philip Morrison et al. 1982. *Powers of Ten.* New York: Scientific American Library.

nested – leaves on a tree in a forest in a geographical region, for example. The environment persists in some respects and changes in others.

- Man lives in a medium – the gaseous atmosphere – not in space. The surfaces within this medium persist or change in terms of texture, layout, property of being in light or shadow, for example.
- Man sees the unformalized, familiar geometry of surfaces – a surface is seen rather than the plane of a formal geometry. The fundamental ways surfaces are laid out have intrinsic meaning for behavior unlike the abstract, intellectual concepts of mathematical space.
- Man sees by virtue of ambient light. "The orthodox theory of the formation of an image on a screen, based on the correspondence between radiating points and focus points, is rejected as the basis for an explanation of ecological vision . . .The information that can be extracted from ambient light is not the kind of information that is transmitted over a channel. There is no sender outside the head and no receiver inside the head."[5]

With these observations, Gibson carefully provided the groundwork for what he called an ecological optics. It is interesting to note that Gibson was an advisor on the training of aircraft carrier pilots whose task was to precisely land a fast plane in a small space. This seems to have led him to his notion of perception as a flow of information rather than as a frozen "image." He defined perception as an act of attention. We attend to various events by observing changing optical information that disturbs the local structure of the array. He went on to tentatively state that the following indicate the visual changes to which we are most sensitive: deletion – accretion, shearing, transformation, magnification – minification, deformation, nullification and substitution.[6]



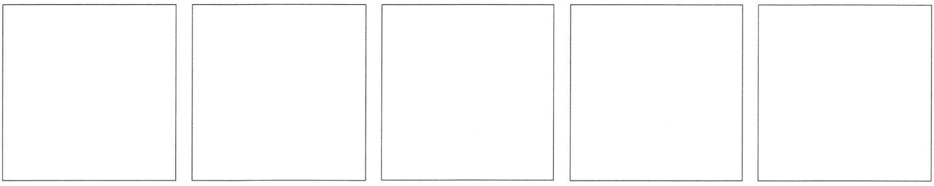
10^{-11}

Returning to the previously noted complimentary relationship between people and their environment, this idea merits closer examination. Figure 2, which borrows heavily from the book *Powers of Ten*,[7] shows how perceptual frames of reference have expanded from: the range of direct human interaction and experience (10^{-2} to about 10^{3}), to the world of minification (10^{-3} to 10^{-4}), to extreme minification (10^{-5} to 10^{-16}) and in the opposite direction they have expanded by human flight (10^{3} to 10^{7}), and through magnification (10^{3} to 10^{25}). Parallel to these changing scale relationships between people and the irvisible, kinesthetically experienced environment and the abstract and remote environment unavailable to the unaided eye, is the exploration of electromagnetic radiation far beyond the visible spectrum. This will not be developed further, but it serves as a reminder that the relationship between man and environment has shifted during the past five centuries from the tangible to the intangible with a concommitant expression in abstract language. This idea will be expanded upon later.

Gibson's theory of information pick-up emphasizes the dynamic qualities of an environment in a state of flux, with features that are variant or invariant, to which an active perceptual system attends through its own dynamic adjustments for orientation, exploration, optimization and extraction. We attend to change, the variant aspects of our environment and we attend to them directly rather than through the commonly supposed, highly mediated sequence of stages in figure 3. Information pick-up is the term favored by Gibson, it is the means by which direct knowledge of the world is obtained. This model side-steps such problematic terms as memory, a priori categories, sensory inputs and others.

Figure 3 **Commonly understood stages in the act of perceiving an object,** redrawn from *The Ecological Approach to Visual Perception.*

Object	Retinal image	Image in the brain	Various operations on the sensory image	Full consciousness of the object and its meaning



10^{-10} 10^{-9} 10^{-8} 10^{-7} 10^{-6}

Extreme Minification

Figure 2, continued.

8
Gibson, *Ecological Approach to Visual Perception*, 253.

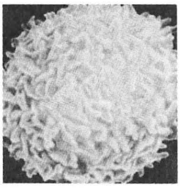
9
Gibson, *Ecological Approach to Visual Perception*, 244

10
Gibson, *Ecological Approach to Visual Perception*, 258.

11
Gibson, *Ecological Approach to Visual Perception*, 272, 273.

"Knowledge of the environment, surely, develops as perception develops, extends as the observers travel, gets finer as they learn to scrutinize, gets longer as they apprehend more events, gets fuller as they see more objects, and gets richer as they notice more affordances. Knowledge of this sort does not 'come from' anywhere; it is got by looking along with listening, feeling, smelling, and tasting."[8]

By afforances, Gibson means the usefulness, pleasure or aesthetic value that are the property of an interaction between an observer and an object — affordances are neither physical nor phenomenal. The relationship between perceiving and knowing are in a much closer and direct relationship in Gibson's theory than most philosophers would acknowledge. Gibson does make a distinction between direct perception and the facilitation of knowing mediated by some tool, such as instruments to extend our sight, the use of verbal descriptions and the use of pictures. He goes on specifically about picture-making: "Consider the human habit of picture-making, which I take to be the devising and displaying of optical information for perception by others. It is thus a means of communication, giving rise to mediated apprehension, but it is more like direct pick-up than word-making is... it can be pointed out here that picture-makers have been experimenting on us for centuries with artificial displays of information in a special form."[9]



10^{-5}

"Knowing is an extension of perceiving... Toys, pictures, and words are aids to perceiving... They transmit to the next generation the tricks of the human trade... The extracting and abstracting of the invariants that specify the environment are made vastly easier with these aids to comprehension. But they are not in themselves knowledge, as we are tempted to think. All they can do is facilitate knowing by the young."[10] And later, Gibson carefully develops a definition of a picture: "... a picture is a surface so treated that it makes available an optic array of arrested structures with underlying invariants of structure... A picture can only be seen in a context of other non-pictorial surfaces... A picture is a surface that always specifies something other than what it is."[11] Pictures record what its maker has noticed and considers worth noticing. This is done with invariants that have been observed in learning information pick-up.

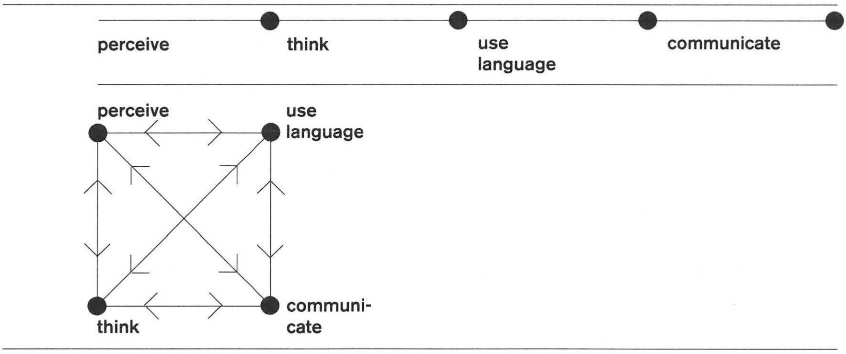
In order to round out this relationship, a review of one of Gibson's examples puts perception and picture-making into a clear context. Of several examples, a simple one discussed a child's ability to identify the graphic presentation of a man in silhouette, as a paper doll or even as a stick figure. Gibson theorized that what the child identified were the invariants of head-body-arms-legs and that consequently images with these elements in the right relationships signaled "man." He went on to stress that pictures do not present sense data but present information. In his examination of children's scribbles and their early drawings, he saw the invariants of the visual world: straights, curves, angles, apexes, intersections, connections, parallels, coincidences, etc. These, in fact, are exactly the concerns of abstract art.

Communication theory revisited

A contemporary communication theorist, W. Barnett Pearce, reexamined communication and produced three insights:

- we live in communication
- communication is more complex than we imagined

Figure 4 **Comparison of linear and actively linked structures.**



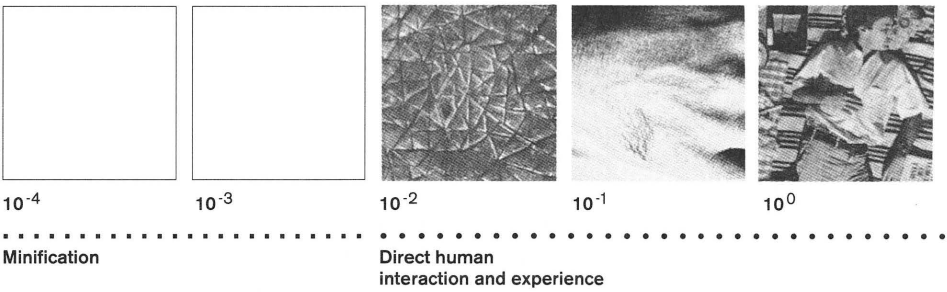


Figure 2, continued.

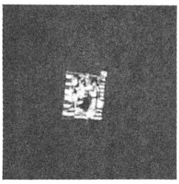
12
W. Barnett Pearce. 1989. *Communication and the Human Condition.* Carbondale, Illinois: Southern Illinois University Press.

13
George Miller. 1986. "What We Say and What we Mean." *New York Times Book Review,* January 26, 37.

14
Pearce, *Communication and the Human Condition,* 23.

- communication is more a way of thinking than an artifact to be produced or transmitted.[12]

This prompts us to question what diagrams are really about. Pulling back from the specifics of statistics, relational models or flow charts, for example, diagrams are about perception, framing thought in certain ways in relation to language and communication. These terms look deceptively simple, particularly printed on the page in linear fashion. It is easy to assume that these terms define four sequential steps: perceive, think, use appropriate language, communicate. Perhaps this sequence is an artifact of "reading" with its incessant linear structure (*see figure 4*). Communication theorists now look on earlier notions of how communication works as simplistic. Communication is usually taken as the transfer of meaning from one mind to another. Even theorists such as George Miller who early on embraced the engineering model of communication and was himself interested in channel capacity ("The Magic Number Seven Plus or Minus Two"), now believes the "post office" model to be in error. In this model communication involves ". . . wrapping an idea in words and sending it off to the other person, who unwraps the words and discovers the idea."[13] Miller observes that this model does not account for emotion, an ecologically important human attribute. Passing along the word happiness does not elicit the emotion of happiness in the recipient even though the message is clearly received. Three individuals reading a newspaper account of a political speech may become angry, amused or bored as they read the message.



10[1]

Pearce's reconstruction of communication concentrates on three terms: coordination, coherence and mystery.

- "Coordination names those practices in which persons attempt to call into being conjoint ennactment of their vision of the good. . . and to prevent conjoint ennactments of what they envision as bad. . . "
- "Coherence refers to the process by which we tell ourselves (and others) stories in order to interpret the world around us and our place in it. It specifically does not assume that these stories are an accurate description. . . "
- "Mystery stands in opposition to those who would attempt to impose an overrestrictive 'rationality' on the stories and the coordinated patterns of action in which we live. . . Mystery is at once a reminder of the fallability of the process of the social construction of reality, and of our emancipation from any particular set of stories and practices."[14]

All forms of communication practice involve the re(construction) and expression of resources. The resources are the various languages we use, verbal, visual, mathematical. It includes the pragmatics of use that we have observed as well as insight into extended or altered uses. Meta-systems with elements and relationships and rules also come into play. A major shift occurs when communication is not seen as a subset of human activity, but is conceived as a way of thinking about human action. We are, of course, limited by our own reference point. Gibson insists that we see ourselves in the environment – we see our hands and limbs, the shape made by our brow, nose and cheek – our personal frame for seeing the environment. In physics, an "exact" science, wave and particle theories of light co-exist, each anchors a subset of problems. Some contemporary physicists would propose that the physical world has a structure incomprehensible to our minds. "We are now approaching a boundary beyond which we are forever

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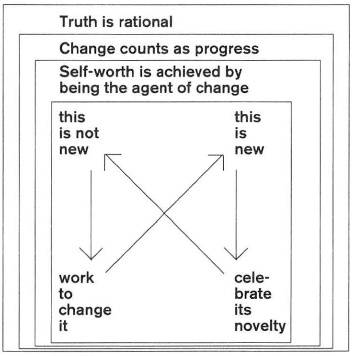
Figure 5 Pearce's "strange loop of modernity," redrawn from *Communication and Human Condition.*



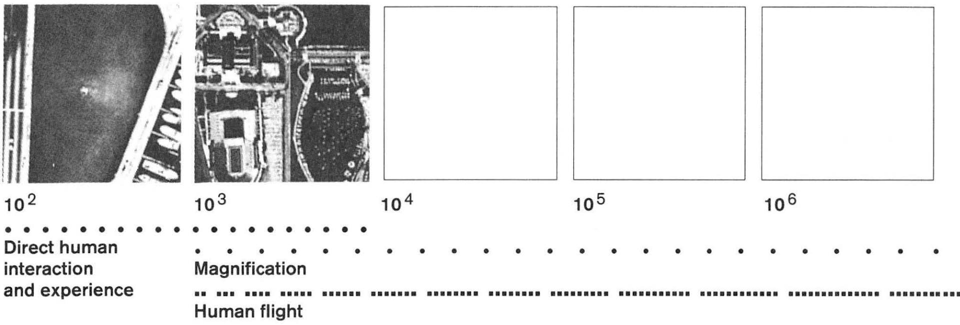


Figure 2, continued.

15
Jame B. Conant. 1962. *The Changing Scientific Scene 1900-1950.* Ed. Walker Gibson. *The Limits of Language.* New York: Hill and Wang, 15-28.

16
Pearce, *Communication and the Human Condition,* 133.

17
Pearce, *Communication and the Human Condition,* 145.

stopped from pursuing our inquiries, not by the construction of the world, but by the construction of ourselves."[15]

Because we are deeply enmeshed in specific forms of communication that are often both pervasive and invisible, models that present the cultural presumptions regarding communication are useful. Pearce presents four such models:

1. monocultural communication which concerns itself with communication within a homogeneous and closed culture (this need not concern us here);
2. ethnocentric communications, which make explicit distinctions between "us" and "them" and do concern us in the construction of diagrams;
3. modern communication practices that put resources and coordination at risk as the only constant is the expectation of change – these practices concern us for this is the prevalent context for diagram communication today; and
4. cosmopolitan communication which is a practice to which we might aspire – it stresses coordination through social eloquence.

Ethnocentric communication practices stem from unacknowledged constraints such as stereotypes and often lead to unanticipated results. A common theme in this model exalts the superiority of one's group and dismisses other groups as subhuman or barbarian. "Ethnocentric communication is robust, enabling particular patterns of resources and practices to perpetuate themselves in a complex, pluralistic world. The way of being human that it creates may include many types of artifacts and belief, some of which have great beauty and some considerable ugliness."[16]

10[7]

Modern communication celebrates change. In figure 5, Pearce's "strange loop of modernity" is presented. "Coherence is stressed more than coordination. The primary moral injunction is to change resources and practices... this injunction is grounded in the notion of both truth and personal worth... the largest contextualization is foundationalism, here expressed as the belief that 'truth is rational.' Within this context, 'change' counts as 'progress' because it is assumed to make successive approximations of truth. Engaged in a collective quest for truth and control of the environment, individual worth is produced by being the agent of change . . . in which the individual is forever engaged in a process of creating 'new things'."[17]

There is a common feature in monocultural, ethnocentric and modern communication, it is that the goal of coordination is achieved by attention to coherence and mystery. Cosmopolitan communication shifts attention to coordination itself. Pearce cites three conditions that serve to propel the change from modern to cosmopolitan communication. They are: democratization, the communication revolution and disillusionment with modernity. While the first and last of these may seem self-evident, the reference to communication revolution requires expansion. The communication revolution is characterized by: the expanding technological means for producing cultural symbols, global communication and migration which puts into contact people who would previously have been oblivious of or blindly ignored each other – they are forced to acknowledge or even actively coordinate with people they perceive as foreign or exotic. Recent world events as reported by paper or television serve to underscore the increasing need for cosmopolitan communication. "The necessity for coordination has been made overwhelmingly clear by the history of this century. The result is a set of

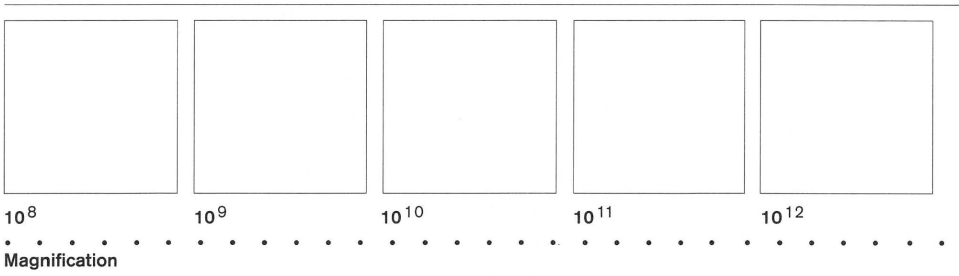


Figure 2, continued.

18
Pearce, *Communication and the Human Condition*, 171.

19
From a discussion with Dennis Livingston in Baltimore, August, 1989. Livingston frames his life and work as a social activist first, his role as a communicator creating diagrams is secondary.

20
Lupton, Ellen. 1990. Dennis Livingston: Social Graphics. New York: The Herb Lubalin Study Center of Design and Typography, 1.

social and material conditions that call for a way of communicating unlike any of those based on 'rhetorical eloquence.' They demand 'social eloquence'."[18] In practical terms what does cosmopolitan communication mean? Pearce describes a process he calls interpretive/critical research which is characterized by the following steps:

1. select an interesting set of practices characterized by conflict between groups,
2. describe the events in a neutral way,
3. learn to speak like a native to both groups,
4. describe the emerging logic of the interaction,
5. describe the interaction in the context of the resources of all participants as a system,
6. assess the opportunities for critique and intervention. This process allows for a transformation to occur in which the researcher does not take sides but achieves a suspension of belief, opening the way to entertain other communication options.

There is at least one person creating diagrams within the cosmopolitan context, Dennis Livingston, a social activist in Baltimore. He is an anathema to statisticians who carefully observe the logic and consistency of data collection and presentation. Livingston has stepped into the ambiguous arena of multiple data frames in his attempt to present the inter-relationships between larger cultural problems.[19] He found: "His ability to visualize abstract problems could be used to communicate ideas to people in an engaging manner, bringing life and urgency to stastistical figures. Visualization is a mode of understanding, of thinking as well as a mode of communicating: Livingston uses graphics to think through problems, to discover relationships within the data. The act of plotting figures on a graph or diagramming a process not only 'explains' what is already known but reveals new knowledge."[20]

10 13

Two of his charts demonstrate the power of his synthesis and the clarity he achieves regarding particular social problems. In the "Weatherization in Maryland" chart (*see figure 6*), he relates income, home-ownership, weatherization status of the dwelling unit and receipt of three forms of energy assistance: energy audit, energy loan or weatherization. The chart shows how few low-income households have benefited from any form of assistance, demonstrating the fact that too often well intentioned programs are established that never reach the intended constituency. "Social Stratification in The United States" also manages to chart many variables in a telling way: race, marital status, labor classification and income (*see figure 7, page 268*). It is clear from these two examples that Livingston advances his political interests in demonstrable ways. He seeks a larger conception of social and economic context rather than searching for satisfaction or utility in iso-lated fragments. Jeremy Campbell in *Gramatical Man*, identifies an important attribute of language that Livingston is taking full advantage of: "One important property of language is that, while its symbols may be used to bring about physical results in the real world of substance, they need not be used for that pur-pose. Symbols can be decoupled from physical reality to a greater or lesser extent. Words are not deeds, though they often lead to deeds. Symbols can be manipulated more freely than substance, and they can be

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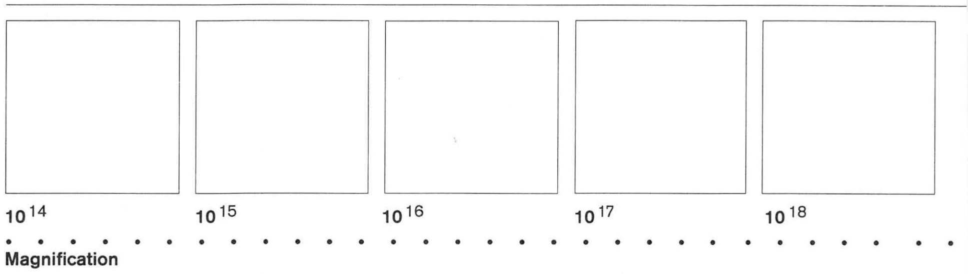

Figure 2, continued.

21
Jeremy Campbell. 1982. *Grammatical Man.* New York: Simon and Schuster, 91.

22
Nelson Goodman. 1978. *Ways of Worldmaking.* Indianapolis: Hackett Publishing Company.

23
Goodman, *Ways of Worldmaking,* 7.

24
Goodman, *Ways of Worldmaking,* 17.

manipulated to form new statements and expression which are only tentative, playful, figurative. Symbols are at liberty to be a little irresponsible and experimental."[21]

From a theoretical perspective, Campbell proposes that we explore with language – that we be wary of conventions that are not challenged. Livingston, from a social activist perspective, knows that the isolated context within which social and economic problems are addressed is senseless. He steps pragmatically into diagrammatic situations in order to challenge the conventions and the scholarly constraints that fail to provide insight into these problems. Both Campbell and Livingston know that we create worlds with diagrams and language. And sometimes we trap ourselves.

Worldmaking itself

Nelson Goodman in *Ways of Worldmaking*[22] describes two complimentary methods for constructing a world: composition, which involves assembling wholes and parts and subclasses, conjoining features into complexes and making connections, and decomposition, which involves separating wholes into parts, analyzing complexes into component features and making ever finer distinctions. Identification and repetition depend on specific organization. How information is classified as relevant or irrelevant depends on emphasis or weighting. The information is not neutral as it is presented. Order is yet another aspect under our control, including both proximity and periodicity and even value. Measurement is based on order – we are able to deal with vast quantities perceptually or cognitively only if they are carefully and clearly ordered. The time of years, months, days, hours, minutes, seconds is not built into the world but is a form of order superimposed on the world. It is a constructed frame of reference.

10[19]

Instead of sharing a stable body of knowledge, we find ourselves in a dynamic situation. We can reframe, supplement, reduce and reroute information. Goodman observes: "Much but by no means all worldmaking consists of taking apart and putting together, often conjointly: on the one hand of dividing the whole into parts and partitioning kinds into sub-species, analyzing complexes into component features, drawing distinctions; on the other hand, of composing whole and kinds out of parts and members and subclasses, combining features into complexes and making connections. Such composition or decomposition is normally effected or assisted or consolidated by the application of labels: names, predicates, gestures, pictures, etc."[23]

The conventional version of worldmaking with diagrams may no longer be appropriate. It may be necessary to reconfigure the process by developing a better fit between the way information is structured and the way information is searched for and used. This is shifting ground. How do we know if a schema is useful? Truth has been a traditional measure applied to information. Goodman states: "... [a] version is taken to be true when it offers no unyielding beliefs and none of its own precepts. Among beliefs unyielding at a given time may be long-lived reflections of laws of logic, short-lived reflections of recent observations ... Among precepts, for example, may be choices among alternative frames of reference, weightings and derivational bases."[24] Somewhat further on he offers measures other than truth for consideration including: compactness, comprehensiveness, informativeness and organizing power.

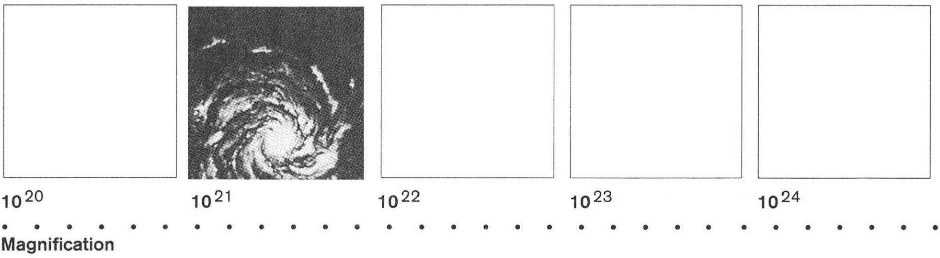

Figure 2, continued.

Gibson, Pearce and Goodman, a perceptual psychologist, a communication theorist and a philosopher, all underscore the mutability of our conventions and suggest that we construct alternative worlds through the synergy of attention, classification and language. They set the stage for this issue.

Examining the Past

There is more to presenting a diagram than technically translating data, or an idea or a set of relationships into the appropriate language whether in a list, a table, a chart or a diagram. It is more than an issue of aesthetic mediation or the tendering of a symbolic invitation to the reader to pay attention. The problem is one of communication – how will the user best understand the information – which approach is the clearest. Lenk and Kahn in their article "To Show and Explain. . ." take us back three and four centuries to the work of Simon Stevin and Amos Comenius. Stevins anchored abstract mathematics by visual reference to the commonsense experience of the student. Comenius developed language primers to both show and tell in a direct and memorable way by grouping related ideas into a clear context. Both Stevin and Comenius are masters of didactic function with diagrams.

McArthur's "Sign Function and the Potential of the Printed Word" shows with historical and contemporary examples a kind of diagrammatic impulse with language that transcends its usual linear sequence. He suggests that editors and designers might actively use this concept as we seek to encapsulate large ideas while maintaining inter-relationships and as we seek to abbreviate and streamline statements for quick delivery.

10^{25}

Early in this century, Otto Neurath took a very specific approach to the audience for isotype diagrams. He developed a logical set of icons representing fixed quantities to present a clear, rational message to his sometimes semi-literate audience. This iconic, statistical approach has spread round the world into very different languages and cultures. (It is not our purpose here to question its utility – the ease with which the reading of these diagrams is taught.) Chizlett in his article "Damned Lies. And Statistics" examines the philosophical and historic context in which Neurath operated. He opens for us the concept of truth – what the statistician knows about the manipulation of numbers – what responsibility the designer of a chart has to truth and his audience. Diagrams are no more value-free or objective than any other form of communication. They have an inherent point of view by virtue of what they include or exclude, how they count, what method is used to display the information and even how the proportional attributes of space are used. Returning to Goodman's observation that there can be other measures than truth (compactness, comprehensiveness, informativeness and organizing power) does not eliminate the author's fundamental concern with the ethical responsibility of the diagram designer.

Questioning the Present

Diagrams reveal thought processes – they are a way of thinking. Sims-Knight in her article "To Picture or Not to Picture. . ." draws our attention to common difficulties in thinking clearly and using statistics. Psychological studies that demonstrate common errors in thinking in divergent contexts are carefully presented in support of her argument. She proposes a more rigorous performance

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Figure 6 Dennis Livingston's "Weatherization in Maryland."
(Reproduced by permission of the author.)

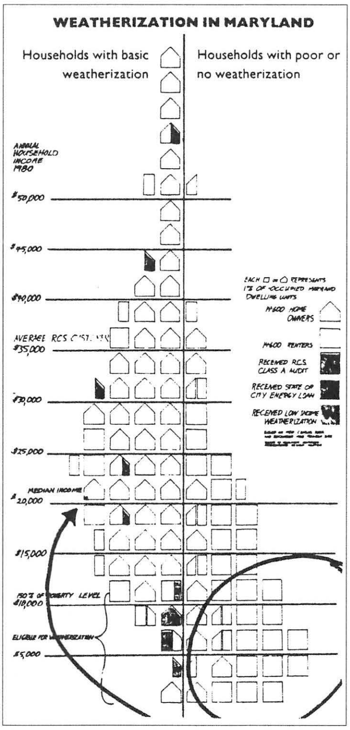
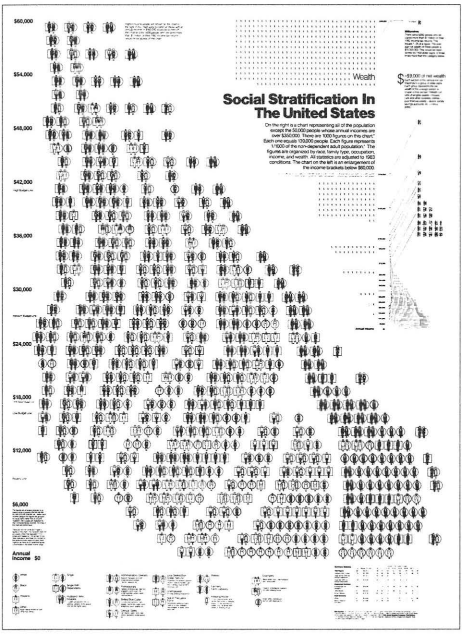


Figure 7 Dennis Livingston's "Social Stratification in the United States."
(Reproduced by permission of the author.)



criteria for assessing the design of communications. She cautions against paying too much attention to aesthetics and warns against decoration. Conversely, she encourages the designer to develop revealing structure, to attend to the content and its inter-relationships and overall meaning. The antidote to over-used intuition is scientific experimentation or user-based, interative design. While designers may not applaud her careful argument, pointing out the practical issue of the cost of scientific study to its incremental benefit in predictable communication, they may, however, be more receptive to user-based design.

Also in this section, we encounter Storkerson, who like Pearce asks broad questions concerning communication strategies. He asks us to reconsider the usual typologies of diagram presentation — to question accepted taxonomies — to alter the frame of inquiry in "Explicit and Implicit Graphs. . ." He examines diagrammatic structures. His method reveals some hardened categories and his discussion suggests that we can make new discoveries if we carefully question how information is framed.

Working toward the Future

Both articles in this section explore the syntax of diagram presentation. Cohen in "Blush and Zebrackets. . ." takes the problem of writing computer code and describes two ways to structure program detail in order to enhance clarity. Both are methods that catch our eye and insist on discrimination. They may appear to be small incremental steps in clarifying code, but in a larger sense, like McArthur, Cohen is looking to break the linear convention and insist on the nesting characteristics of language.

The syntax of diagrams on the computer is the focus of Sivasankaran and Owen's article "Data Exploration. . ." Here syntactic possibilities extend into time and space as they define transposition operations that facilitate the dynamic exploration of information. Information is entered or played against time. The analyst enters the diagrammatic space, and what was formerly a snapshot, now becomes in almost Gibsonian terms, a flow of information. The data puzzle becomes a more compelling resource which can be reconfigured without loosing essential relationships, in which insight is gained through active observation.

Running here and there throughout the issue is an article titled "The Kamikaze Photon". . . by Greg Stone, a science writer. He invites us with his compelling demonstration of light and space to stretch our understanding of reality. The writing is poetic but also clear in its patient description of events.

This special issue on diagrams is edited and designed with a view to opening discussion. The typographic design is diagrammatic in its use of the double page spread as the screen for the information. The text runs on the right hand page with illustrations and notes on the left page. The Kamikaze Photon weaves through the open left pages and some diagram demonstrations, such as figure 2 in this article, Expanding frames of perceptual reference, are developed as a sequence over several pages. As our ability to collect and store information expands, we need to develop tools for analysis and synthesis that address a changing more inter-related sense of worldmaking. The expanding syntax for diagrams is clear, but effective change in framing and meaning is less obvious. What is revealing and what is true or what is comprehensive, compact and informative is open to question.

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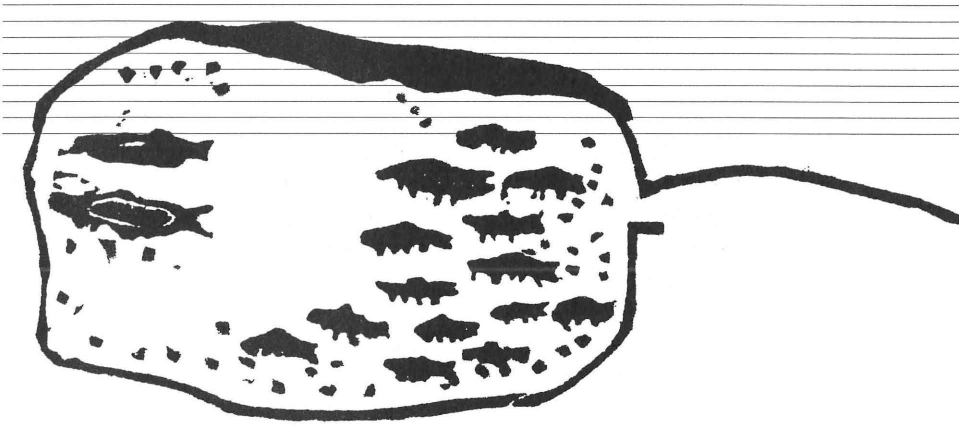
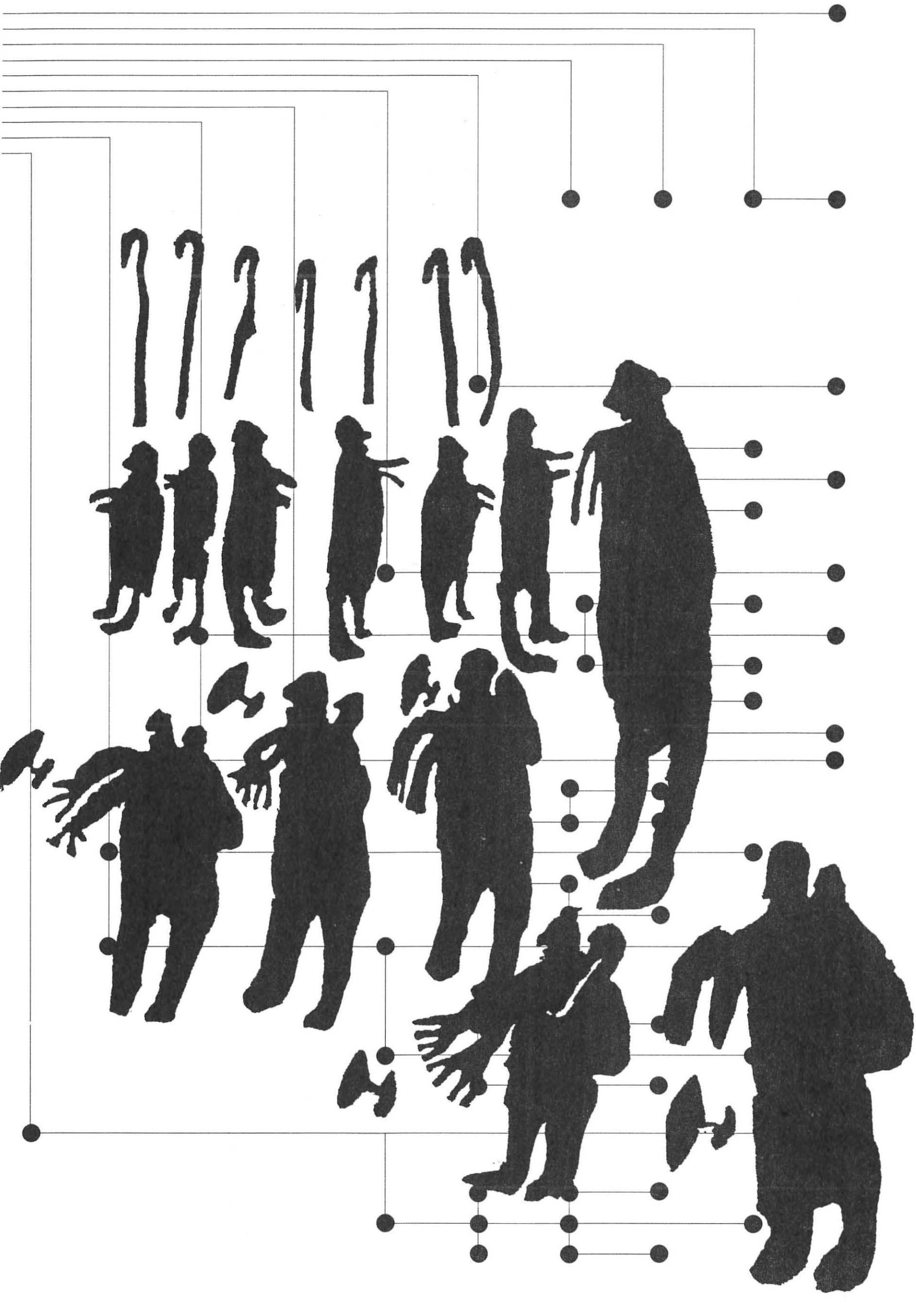


Examining the Past
or
looking at conventions



The development of diagrammatic presentation during the sixteenth and seventeenth centuries is briefly examined with particular emphasis on the work of Simon Stevin and Johann Amos Comenius. Stevin juxtaposed abstract mathematical notation with concrete examples from life. Comenius joined languages including Latin, a vernacular language, numbering systems and diagrammatic representation into experiential chunks for effective teaching. The authors believe study of these early visual pedagogical constructs offer renewed insight into diagrammatic possibilities for contemporary education.

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Paul Kahn, a native of New York City, took a degree in English Literature at Kenyon College, Ohio. Since 1985 he has been with the Institute for Research in Information and Scholarship at Brown University where he now serves as director. He works with a variety of hypermedia systems in education.

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Visible Language 26:3/4,
Krzysztof Lenk and Paul Kahn,
pp. 272-281,

1
Lenk, Krzysztof and
Paul Kahn.
How They Used
Circles.
High Quality
19/1991:18-25.

To Show and Explain: The Information Graphics of Stevin and Comenius

Krzysztof Lenk and **Paul Kahn**

As both educators and practitioners in the field of information graphics, we are constantly on the lookout for interesting and positive examples of visual logic and syntax. Again and again we return to the work of Simon Stevin and Johann Amos Comenius, two prominent European scholars and educators who were extremely effective in their use of visual material to compliment their texts.

Background

Simon Stevin (1548-1620) was a Dutchman active in the courts of both the Netherlands and Poland. He was a mathematician, a civil and military engineer, author of textbooks in each of these fields and a professor at the University of Leyden. Johann Amos Comenius (1592-1670) left his native Bohemia and lived as an exile in Poland, the Netherlands and for a brief time in both England and Sweden. He was famous as a leading protestant theologian, an innovative theoretician of education, a successful schoolmaster and the author of vocabulary textbooks.

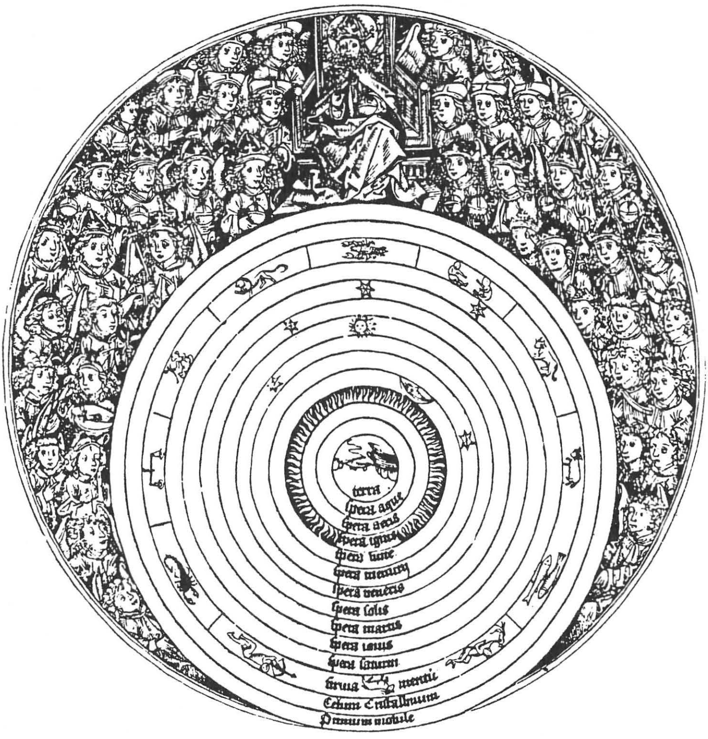
In the period when Stevin and Comenius began their innovations, the European language of diagrammatical notation had been well developed. The medieval period had produced a large body of diagrams in the manuscript book tradition. Diagrams were widely used to provide visual support for the description of universal order according to various philosophers and theologians. Such diagrams strove to represent a unified model of the physical and metaphysical aspects of the world. Diagrams in circular form were particularly common during this period because the circle clearly represented an abstract model.[1] Examples of this medieval style are visible in Ramon Llull's (d.1315) logical models of Divinity (*see figure 1*) and the diagrams of the Seven Days of Creation by the illustrators of *The Nüremburg Chronicle* of 1493 (*see figure 2*).

The Renaissance of the fifteenth and sixteenth centuries changed the focus of intellectual discourse from the macroscopic to the microscopic. It was a time of retreat from medieval general models of the universe. The thinkers of the time were driven by the need for a more precise understanding of the physical world. That understanding had to include all details, the links between the details, as well as the

Figure 1 **An abstract circular diagram** from the *Enciclopedia universal ilustrada*, Barcelona, 1923

Figure 2 **The Sanctification of the Seventh Day**, Latin edition of *The Nuremberg Chronicle*, 1493.

The sphere surrounding the earth are labeled from the smallest: water, air, fire, the moon, Mecury, Venus, Mars, Jupiter, Saturn, ring of the Zodiac, Crystalline ceiling and prime force by which the universe is kept in motion.



structures and mechanisms that made the pieces work as a whole. There was a need to develop new forms of visual notation to compliment known methods of verbal description and to support this new intellectual exploration.

Some of the most interesting achievements in the field of visual investigation are worthy of summarizing here:

- The development of geometric perspective by Giotto (1266-1337), Alberti (1404-1472) and Paccioli (d. 1514) helped to develop a presentation of the world whose visual order was more "realistic," e.g., closer to the visual distortions of the world as we see it (*see figure 3*). All elements were well coordinated according to their position in relation to the line of the horizon.
- An intensification of curiosity toward the world of nature, in particular the studies of human anatomy by Leonardo da Vinci (1452-1519) and Andreas Vesalis (1514-1564), resulted in the development of precise methods of visual recording (*see figure 4*).
- The unprecedented conceptual studies of nature by Albrecht Dürer (1471-1528) changed the way the natural world was represented. Dürer sketched from nature, did a thorough investigation of the relation of all natural elements and their proportions and finished by formulating general rules of presentation. His diagrams, developed by applying sophisticated grids, led him to search for a method by which he could objectively record the difference between the general rule models (the "ideal") and the particularities of what is actually found in nature (*see figure 5*). By the middle of the sixteenth century, developments of this methodology allowed illustrators to be not only descriptive, but also to explain particular details and structures with a higher degree of sophistication than was previously possible.

Simon Stevin.

Stevin's *Weeghconst* (Art of Weighing), which appeared in 1586, described in precise mathematical detail the principles of gravity and methods for determining centers of gravity. His achievement preceded Galileo's theory of gravitation by half a century. But it was Stevin's visual pedagogy that is most interesting. He relied on the fact that a reader of his book carried in his conscious mind a practical experience of weighing different objects. A reader was also familiar with the hand-held scale, together with its arms, point of support and small counterweight used to measure the object being weighed. Stevin's educational mission was to explain the rules by which such a mechanism operated. Convention would have him present the results of his investigation into the physical principles of weight and gravity in the form of a table of numbers. These numbers might be illustrated with purely geometric diagrams. Such visual notation would be understandable to someone who, like the author, had already absorbed the key to their meaning – a student who already understood the principles being

Figure 3 **Proportional system for the head**
from Luca Pacioli's
De divina proportione,
Venice, 1509.

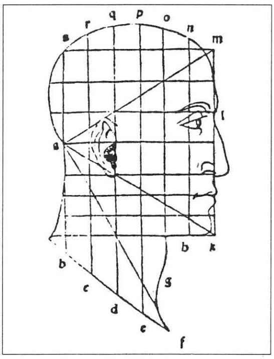
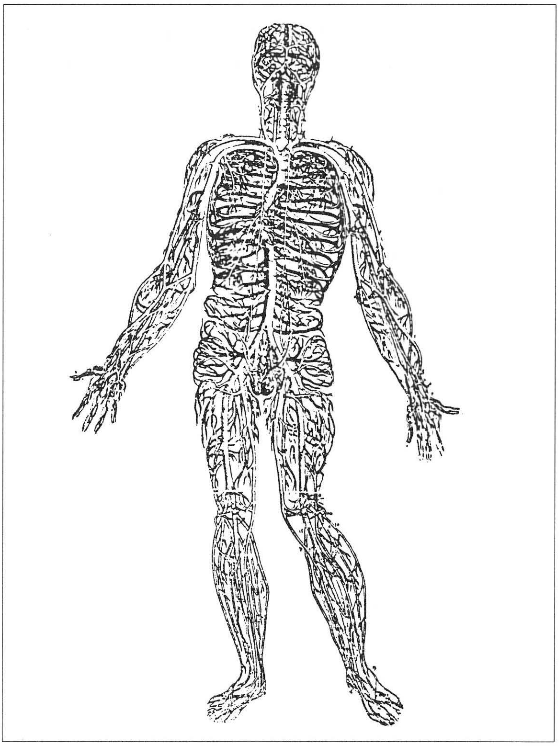


Figure 4 **Diagram from Andreas Vesalius,**
Fabric of the Human Body, 1543.



2
Struik, Dirk Jan. 1981. *The Land of Stevin and Huygens: a Sketch of Science and Technology in the Dutch Republic during the Golden Century.* Dordrecht, Holland: D. Reidel.

explained. But explaining to the student who already understands is not the challenge of education. What of the student who does not yet understand the abstract principles? Such a student cannot get past the barrier of a visual reference that remains unconnected to the world he sees. This is the barrier that all educators must confront: new information can be perceived and absorbed by the mind of the receiver only when it can be connected with some other information already existing in the receiver's store of experience. The structure or framework must be there before the new information can take its place.

It was Stevin's unique contribution to place his visually abstract, geometric explanations in the context of objects already known to the reader from his everyday experience (*see figures 6.1, 6.2 and 6.3*). The horse pulling a heavy wagon up the hypotenuse of a triangle, two men carrying a rectangle with a visible center of gravity first along a flat surface and then up a hill: these are a few of the many fine illustrations Stevin created to accompany his treatise (*see figures 6.4 and 6.5*).

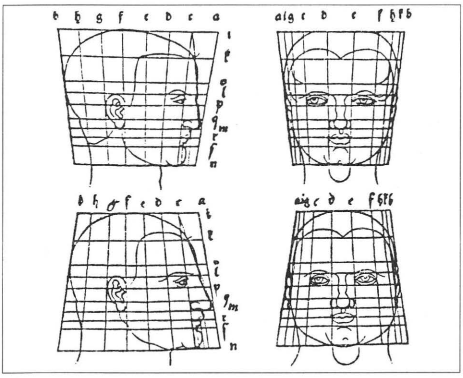
By doing this, Stevin exploits the student's ability to associate thoughts on several different levels at the same time. In this way the author sends pieces of diverse information on several simultaneous levels, mixing realistic and abstract conventions, expecting that the reader will connect the pieces of the puzzle in an appropriate fashion. His technique of overlapping conventions produced information graphics that instructed the engineers and explorers of his time and four hundred years later still fascinate us. In this era of electronic media, when the manipulation of visual elements through technology has become so facile, Stevin's method should be an inspiration. Many of his diagrams beg for animation and the kind of multi-window presentation made possible by today's hypertext and multimedia software applications.

Stevin, a proud practitioner of vernacular language, wrote his books in Dutch rather than Latin. He did this not only to reach his countrymen, many of whom had all but abandoned the Latin of the Spanish court they had rebelled against, but also because he believed his native language was the best one in which to express scientific thought.[2] This movement away from the universal Latin as the means of intellectual expression toward the developing vernacular languages of Europe went hand-in-hand with the other intellectual currents of the Reformation and Counter-Reformation. This attitude toward the importance and value of vernacular is an interesting point of overlap between Stevin, the Dutch engineer, and Comenius, the Moravian minister, who flourished during the next generation. For as much as any other educator, Comenius helped establish vernacular as the language of universal education.

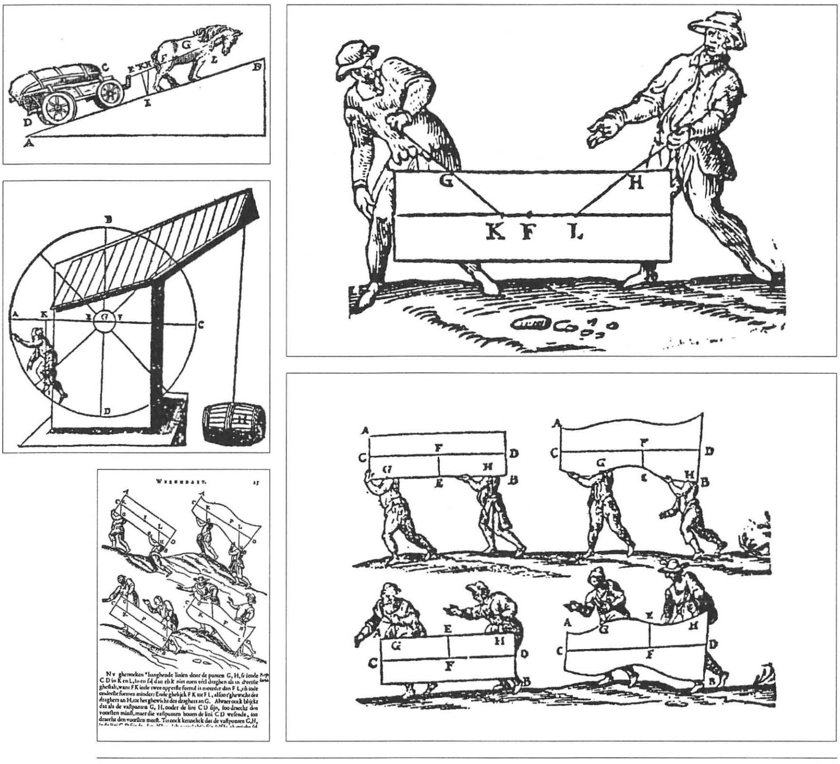
Johann Amos Comenius

Comenius was a schoolmaster by profession and a minister of the protestant church known as the Unity of Brethren. In the 1620s, hostility between the Bohemian protestants and the Hapsburg catholics

Figure 5 **Diagram from Albrecht Dürer,**
Die vier Bücher von menschlicher Proportion, 1528.



Figures 6.1-6.5 **Diagrams from Simon Stevin's *Weeghconst*, 1586,**
reprinted in *Principal Works*, Vol. I.
Amsterdam: C.V. Swets & Zeitlinger, 1955.



3
McArthur, Tom. 1986.
Worlds of Reference: Lexicography, Learning and Language from the Clay Tablet to the Computer.
United Kingdom: Cambridge University Press.

4
Sadler, John Edward. 1966.
J.A. Comenius and the Concept of Universal Education.
London: Allen & Unwin.

forced him to flee with his congregation into Poland. He had already developed a radical educational philosophy, believing in universal education and something close to what we today call child-centered learning. He believed students should learn about the world around them in their own spoken language. However, there were no textbooks that reflected this philosophy. The textbooks of the time relied on abstract word lists and declensions rather than Comenius' methodology of teaching language by associating words with things grouped in categories.

While studying at the university, Comenius had read Francis Bacon's *Novum organum* (1620) in which the English philosopher proposed science as the best way to understand the world. He later adapted Bacon's secular organization of knowledge and joined it with the developing tradition of phrase books, such as William Bathe's *Ianua linguarum* (The Gate of Tongues) which matched Latin with vernacular vocabularies.[3] The result was *Janua linguarum reserata* (The Gate of Tongues Unlocked), a textbook first published in 1631 in Lesno, Poland on the printing press carried there from Bohemia. After the first Czech-Latin edition, the book was quickly translated into every language of the day and reprinted in dozens of editions. A second vocabulary book using a similar methodology, *Orbus pictus* (Picture of the World) was produced in 1653 and aimed at a younger audience.

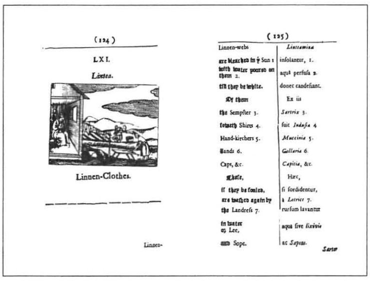
The success of both these books is difficult to exaggerate. Its acceptance as a teaching text throughout Europe in Comenius's own lifetime was nearly universal. It was translated into Turkish and Arabic by missionaries. Harvard College still holds copies of an early English edition inscribed with the names of the first Native American students who used the book to study Latin and English within a decade of its publication. Editions in German, French and English continued to appear well into the late nineteenth century.[4]

The books were organized along several new principles. First, language was taught in relation to things. Second, things were grouped into "natural" categories. Third, all things were illustrated. The connection between an illustration of a "thing" and the word for it in Latin and the vernacular language was made through number coding (*see figures 7.1 and 7.2*).

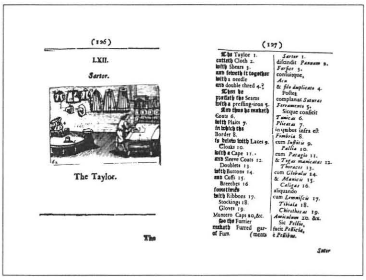
The *Orbus pictus* intended for the youngest pupils introduces words in thematic groups. The student experiences the world as an ordered collection of utilitarian things and the textbook reflects and reinforces this experience while introducing new words to express what the student already knows. Illustration is an important part of this pedagogy. Each plate shows objects grouped according to category or the process in which they participate. "The dressing of line" shows the outdoor drying of beaten hemp along with its indoor preparation. Realistic elements in the illustration have numbers connecting them with appropriate vocabulary in Latin and the vernacular language (*see figure 7.3*). The student experiences the composite illustration and the bilingual text simultaneously as parts of a single message. This is the

Figures 7.1-7.5

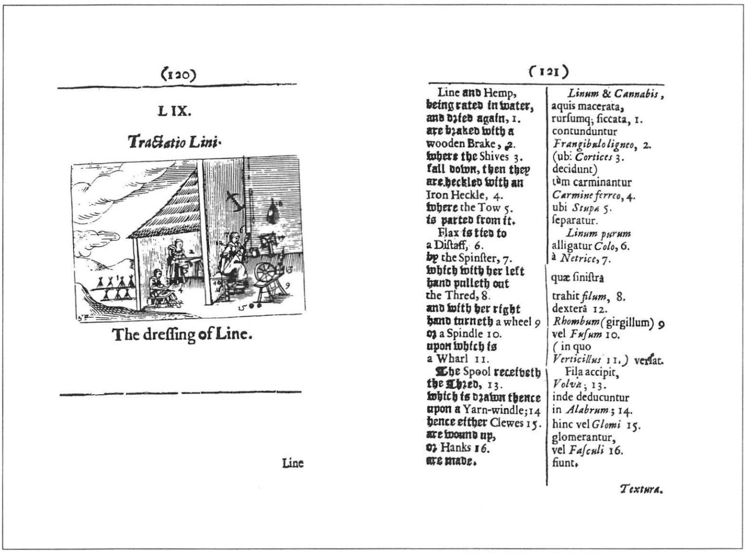
Spreads from Johann Amos Comenius' *Orbus sensualium pictus*,
translated by Charles Hoole, London, 1659.


(124)
LXI.
Lintea.
Linnen-Clothes.
Linnen-

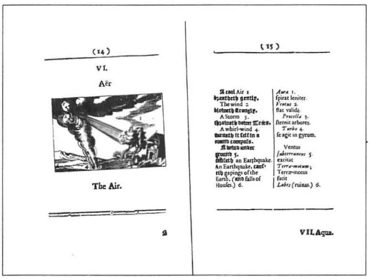
(125)
Linnen-webs | *Linteamina*
are bleached in ỹ Sun 1 | insolantur, 1.
with water poured on them 2. | aquâ perfusa 2.
till they be white. | donec candefiant.
Of them | Ex iis
the Sempster 3. | *Sartrix* 3.
soweth Shirts 4. | suit *Indusia* 4
Hand-kirchers 5. | *Muccinia* 5.
Bands 6. | *Collaria* 6.
Caps, &c. | *Capitia*, &c.
These, | Hæc,
if they be fouled, | si sordidentur,
are washed again by | à *Lotrice* 7.
the Landress 7. | rursum lavantur
in water or Lee, | aquâ sive *lixivio*
and Sope. | ac *Sapone*.
Sartor


(126)
LXII.
Sartor.
The Taylor.
The

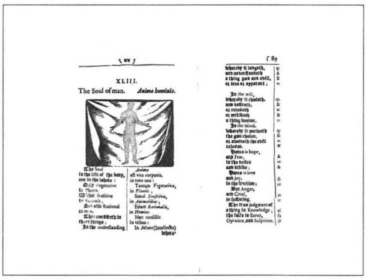
(127)
The Taylor 1. | *Sartor* 1.
cutteth Cloth 2. | discindit *Pannum* 2.
with Shears 3. | *Forfice* 3.
and soweth it together | consuitque,
with a needle | *Acu*
and double thred 4. | & *filo duplicato* 4.
Then he | Postea
presseth the Seams | complanat *Suturas*
with a pressing-iron 5. | *Ferramento* 5.
And thus he maketh | Sicque conficit
Coats 6. | *Tunicas* 6.
with Plaits 7. | *Plicatas* 7.
in which the | in quibus infra est
Border 8. | *Fimbria* 8.
is below with Laces 9. | cum *Institis* 9.
Cloaks 10. | *Pallia* 10.
with a Cape 11. | cum *Patagio* 11.
and Sleeve Coats 12. | & *Togas manicatas* 12.
Doublets 13. | *Thoraces* 13.
with Buttons 14. | cum *Globulis* 14.
and Cuffs 15. | & *Manicis* 15.
Breeches 16 | *Caligas* 16.
sometimes | aliquando
with Ribbons 17. | cum *Lemniscis* 17.
Stockings 18. | *Tibialia* 18.
Gloves 19. | *Chirothecas* 19.
Muntero Caps 20, &c. | *Amiculum* 20. &c.
So the Furrier | Sic *Pellio*,
maketh Furred garments of Furs. | facit *Pellicia*, è *Pellibus*.
Sartor


(120)
LIX.
Tractatio Lini.
The dressing of Line.
Line

(121)
Line and Hemp, | *Linum* & *Cannabis*,
being rated in water, | aquis macerata,
and dried again, 1. | rursumq; siccata, 1.
are braked with a | contunduntur
wooden Brake, 2. | *Frangibulo ligneo*, 2.
where the Shives 3. | (ubi *Cortices* 3.
fall down, then they | decidunt)
are heckled with an | tùm carminantur
Iron Heckle, 4. | *Carmine ferreo*, 4.
where the Tow 5. | ubi *Stupa* 5.
is parted from it. | separatur.
Flax is tied to | *Linum purum*
a Distaff, 6. | alligatur *Colo*, 6.
by the Spinster, 7. | à *Netrice*, 7.
which with her left hand pulleth out | quæ sinistrâ
the Thred, 8. | trahit *filum*, 8.
and with her right | dexterâ 12.
hand turneth a wheel 9 | *Rhombum* (girgillum) 9
or a Spindle 10. | vel *Fusum* 10.
upon which is | (in quo
a Wharl 11. | *Verticillus* 11.) versat.
The Spool receiveth | Fila accipit,
the Thred, 13. | *Volvæ*; 13.
which is drawn thence | inde deducuntur
upon a Yarn-windle; 14 | in *Alabrum*; 14.
hence either Clewes 15. | hinc vel *Glomi* 15.
are wound up, | glomerantur,
or Hanks 16. | vel *Fasculi* 16.
are made. | fiunt.
Textura.


(14)
VI.
Aër
The Air.
A

(15)
A cool Air 1 | *Aura* 1.
breatheth gently. | spirat leniter.
The wind 2 | *Ventus* 2.
bloweth strongly. | flat validè.
A Storm 3. | *Procella* 3.
throweth down Trees. | sternit arbores.
A whirl-wind 4. | *Turbo* 4.
turneth it self in a round compass. | se agit in gyrum.
A wind under ground 5. | Ventus *subterraneus* 5.
raiseth an Earthquake. | excitat *Terræ-motum*;
An Earthquake, causeth gapings of the Earth, (and falls of Houses.) 6. | Terræ-motus facit *Labes* (ruinas.) 6.
VII. Aqua.


XLIII.
The Soul of man. *Anima hominis.*
The Soul | *Anima*
is the life of the body, | est vita corporis,
one in the whole : | in toto una :
Tantum *Vegetativa*,
Simul *Sensitiva*,
in *Animalibus*;
Etiam *Rationalis*,
in *Homine*.
Hæc consistit
in tribus :
In the understanding | In *Mente* (Intellectu) where-

(89)
whereby it judgeth,
and understandeth
a thing good and evil,
or true or apparent ;
In the will,
whereby it chuseth,
Hence is hope,
and Fear,
in the desire
and dislike ;
Hence is love
and joy,
in the fruition ;
But Anger,
and Grief,
in suffering.
The true judgment of
a thing is Knowledge ,
the false is Error,
Opinion, and Suspition.

same methodology employed today in the many "visual dictionaries" and word books found throughout Europe.

On reflection, the illustrations in Comenius' books only appear to be realistic representations of the world as we see it. In fact they are collections of elements that are carefully and artifically composed. To see the process by which flax becomes line we must see the inside and outside of a building at the same time, so a wall is cut away. The symbol of the wind (a face in a cloud) is combined with a realistic image of a tree being torn from the ground (*see figure 7.4*). Reality is distorted in the service of pedagogy, but enough of the world as we see it remains so that we can recognize the context in which to understand the new information being presented. If I have seen wool spun I can recognize the spinning of flax. I know how much physical strength it takes to rip a tree from the ground, and so I can associate that strength with the symbol for wind. The reader recognizes particular elements in each illustration and can now name them with the help of the text. But the world of the illustration has a minimum of direct correspondence with the world as we see it. The visual manipulation by Comenius – or better his visual editing – eliminates from the display everything that does not correspond to words. We see only the world we can name, even when the subject is the soul represented as a human shape (*see figure 7.5*).

Conclusion

The activity of Stevin and Comenius came at a time of rapid change in the European world. The foundations of Latin education were shaken. Development of vernacular languages and their acceptance for education created a strong demand for printed books, spurring the further development of the printing industry. Protestantism had initiated a movement toward mass education and broken down the intellectual monopoly of the old university system. Geographical discoveries and a new scientific understanding of the natural world helped to develop a new methodology of seeing the world in more realistic terms.

All this demanded change in the methods of visual notation. The contributions of Stevin and Comenius were important steps along this path. Their work, so innovative in their own day, looks obvious and natural to use today. The work of both men continues to be an inspiration to the contemporary designer of information graphics.

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Diagrams as Tools for Worldmaking

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His research interests
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human expression and
the relationship
between expression
(and particular forms
of expression)
and epistemology.

Semiology provides a broad perspective for analyzing the range of signs, their differences in form and function, along with the relative efficiency of different signs for different purposes and situations. Some general semiological notions are applied to the printed page.

Acknowledgement: Extracts from Jeremy Bentham's *Chrestomathia* and Richard Owen's *Palaeontology* are reproduced by courtesy of the Director and Librarian of the John Rylands University Library of Manchester.

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Visible Language 26:3/4,
D. McArthur, pp. 282-297,

Sign Function and Potential of the Printed Word

Douglas McArthur

Semiology is usually presented as "the science of signs," but semiology is as yet far from being an agreed upon body of knowledge and method, partly because there is no agreement on a basic definition of the term *sign.* It is more appropriate to think of semiology as *the study of signs and related phenomena.* But even if the bases of the subject are not firm, and the domain of the subject is not yet clear, much progress has been made in understanding a range of forms of communication and expression. In particular, the semiological perspective is productive in that it encourages analysis of the similarities and differences between kinds of sign, and analysis of the relative efficiency of different kinds of sign in various situations. At a time when the forms of expression and communication are multiplying, a semiological approach keeps changing forms in perspective.

The Sign

Here is a working definition of the sign:

the sign is a tangible form (something that registers on the senses) which, in the mind of the user, is associated with a particular meaning (the meaning may be another tangible form, an abstract idea, an emotion or something else). According to Saussure, the sign is a combination of the sign-form (or signifier) and the sign-meaning (or signified). The gratuitous (or arbitrary, in one sense of the term) relationship between form and meaning can be contrasted with: cause-and-effect relationships, for example, heat melts butter; and part-whole relationships, for example, branch:tree. (Note, however, that through conditioning, sign-form and sign-meaning may become very closely linked in the mind of the user.)

The following, along with many other examples, may be considered signs:

speech, writing, mathematical symbols, choreographic and musical notations, calendars, maps, graphs, flow-charts and logic-charts, heraldic symbols, flags, uniforms and other styles of clothing, body-decoration, toys and dolls, money and tickets, photographs and films, statues, objects used for prophecy, color-codes in wiring, the sign-language of

1
See McArthur, D. 1987. Le langage considéré comme une technologie. *Cahiers de Lexicologie,* 50, 157-164. Also McArthur, D. 1991b. Language as Technology and skill. *Deafness and Development,* 2:1, 15-20.

2
The taxonomic principle is applied systematically in artificial languages like Esperanto and Interglossa and in many forms of notation. See also, McArthur, 1991b.

the deaf, etc. On later analysis, one might choose not to include some of these in the category of signs. (Note, too, that I include speech in the above list – some semiologists would give speech a special status, related to a special human faculty. Signs and sign-systems are human inventions.)[1]

Sign examination yields many variables including:

Physical form:
the sense-mode (visual, acoustic or tactile, for example); whether the form is permanent, semi-permanent or ephemeral; whether the form is static or dynamic.

Relationship between the form and the meaning:
stable or casual (for instance: "Let x = 20 [in this sum]."); iconic (or representational), iconic in relationship to a metaphor (for instance: "high" notes are shown high on the musical staff), or purely arbitrary; whether the form is an economical presentation of the meaning or not.

Nature of the meaning:
whether the meaning is vague or precise, concrete or abstract, public or private.

Sign is part of a system of signs, a code, or not:
if there is a system, how extensive is it? If there is a system, is the taxonomic principle in evidence? (According to the taxonomic principle, signs with a common element of meaning, should have a common element of form, as in "nation" and "national," for example.)[2]

Other variables include the relative ease of production of a particular form of sign, whether the particular sign is private or communal (for communication to take place, a sign must be "shared"), the intertranslatability of signs and historical relationships between sign-systems.

Functions of Signs

A major variable which requires longer comment is that of the function of the sign (in the sense of the purpose to which the sign is put). It is common to think of communication as the normal function – and perhaps even as the sole function of signs – but this is a false view. While it is true to say that the normal function, but not the only function, of spoken language is communication, written language and the act of writing, along with numerous other signs, can have a range of functions, and communication is not necessarily the most important of these. In this paper I emphasize the *non*-communicative functions of signs precisely in order to counterbalance the prevailing view.

Certain points must precede discussion of the range of functions. A given sign or group of signs may have different functions at different times: for example, a text written originally as a private diary (where the function is to record for personal use) may be subsequently published to communicate autobiography. Further, a given sign or groups of signs may have more than one function at a given time (probably with one

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Diagrams as Tools for Worldmaking

Figure 1 The Taxonomic Principle in Semiology

The generic divisions in common use for these shells are founded upon the plan of growth, or mode of numerical increase of the chambers. The following are the primary groups of *Rhizopoda* in the system of d'Orbigny:—

1. *Monostega.*—Body consisting of a single segment: shell of one chamber.
2. *Stichostega.*—Body composed of segments disposed in a single line: shell consisting of a linear series of chambers.
3. *Helicostega.*—Body consisting of a spiral series of segments: shell made up of a number of convolutions.
4. *Entomostega.*—Body consisting of alternate segments spirally arranged: shell chambers disposed on two alternating axes forming a spiral.
5. *Enallostega.*—Body composed of alternate segments not forming a spiral: chambers arranged on two or three axes which do not form a spiral.
6. *Agathistega.*—Body consisting of segments wound round an axis: chambers arranged in a similar manner, each investing half the entire circumference.

According to the taxonomic principle, signs of similar meaning should have similar form. (Compare the representation of relative duration of notes in music, and the symbols for relative wind-speed on weather-maps.) Taxonomies are a form of mapping

Reconstructed from Richard Owen's *Palaeontology* 1861, p.12.

3
See Knowlson, J. 1975. *Universal Language Schemes in England and France 1600-1800.* Toronto: Toronto UniversityPress. Also Slaughter, M.M. 1982. *Universal Languages and Scientific Taxonomy in the Seventeenth Century.* Cambridge, United Kingdom: Cambridge University Press.

dominant function): for example, on a particular occasion a writer may be more concerned with clarifying his or her own ideas than with communicating them to others. It should be noted that communication includes various sub-functions like informing, asking for information, persuasion, giving orders, etc. The analysis and naming of the various functions is not always easy: in many situations a number of different things are happening simultaneously and it is not always clear whether these things are discrete or different aspects of one basic function.

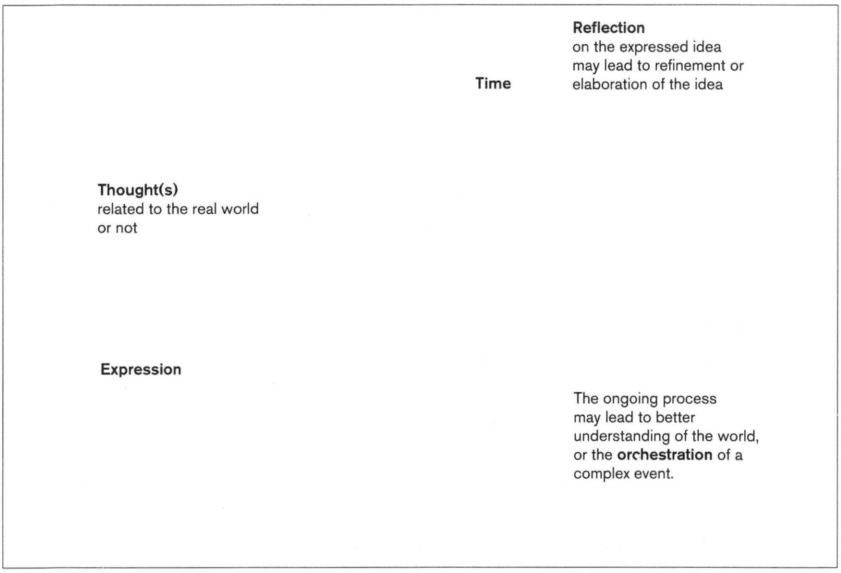
Consider some of the non-communicative functions of signs. It is probable that the very tangibility of the sign-form, and the fact that the form is finite (is an entity), help us to isolate and focus the meaning (or concept) expressed. Thinking or ideas may be imprecise, subtle or ephemeral, but if ideas can be closely associated with a particular tangible form, they are stabilized – they come under control. (Note that I do not accept the view held by some that concepts cannot exist before words and other signs.) Different concepts can be represented with different forms or groups of forms, for example, words in patterned phrases and clauses. Thus, there is the possibility of "mapping" all conceptual space; all experience, all ideas can be represented, in one sense of the term, in signs. When a standard expression is not available, one can create a new sign, posssibly by adapting established sign stock, as in *private* + *ize*, or use standard signs in new ways, as in a metaphor, or use circumlocution. At the same time, it should be remembered that concepts are, in a sense, interpretations, and there may be considerable variation in concepts between individuals and between communities. If one takes language, for instance, there are differences in thinking and usage between members of a given language-community, and between different language-communities – translation always involves more than a one-to-one correspondence. The situation is even more dynamic as individual and communal interpretations tend to evolve through time – the map is redrawn.

Mapping

Scientific taxonomies provide an interesting example of mapping. Systematic knowledge of a given domain of experience, plants, animals or chemistry, for example, is represented in a systematic terminology, corresponding to phenomena interpreted as being related in some precise way. The terminology or names themselves are informative in a particular sense. In the seventeenth and eighteenth centuries, philosophers and scientists were deeply concerned with the relationship between taxonomy expressed in words or other signs and the advancement of knowledge (*see figure 1*).[3]

The process of mapping, and perhaps the mere activity of expressing in sign-forms, gives the user a sense of control. Any aspect of the real or the imagined seems to be more manageable when reduced to signs. We can often assimilate the vague and/or problematic into the

Figure 2 Conceptual Absence of a Final Form



4
For discussion of the personal diary as a form of therapy see Field, J. 1952. *A Life of One's Own.* Harmondsworth. United Kingdom: Penguin Books.
For discussion of drawing and painting as therapy, see Hudson, L. 1978. *Human Beings.* St. Albans, United Kingdom: Triad/Paladin, 51-56.
See also Ulman, E. and P. Dachinger. 1975. *Art Therapy.* New York: Schocken.

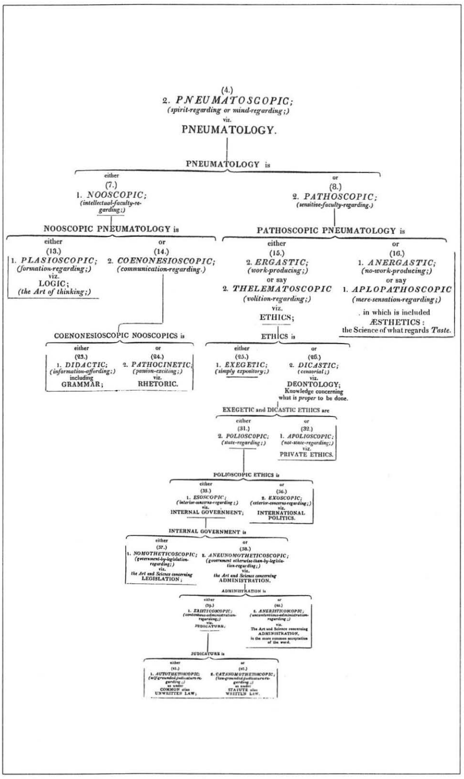
established categories of thought expressed in traditional words or other signs. Perhaps it is in the nature of any sign-system to designate entities and relationships between entities and to distinguish qualities. The process of expression necessitates an effort of analysis and therefore a sense of understanding. Examples quickly come to mind, self-expression is often encouraged as a form of therapy for the emotionally disturbed, likewise professional writers and artists often comment on the unburdening function of expression.[4] It is very likely that certain kinds of thinking are a sub-tangible signing (recall the usual expression, sub-vocal talking) and involve a similar ordering and clarifing of ideas.

When a concept (or group of concepts) is expressed, and particularly when it is expressed in a permanent or semi-permanent form, there is the possibility of reflecting on the concept, modifying it in one way or another, building upon it. In the process of producing the sign-forms, and in the process of reflection on the forms, concepts are likely to become more precise or more subtle. Unlike spontaneous face-to-face communication, there is time to think about the ideas or material with which one is involved. One may forget altogether any potential receiver of the message. For example, the decision to use one word rather than another is likely to become much more conscious. Too often writing and other sign activities are thought of as involving exclusively the expression of already formed thoughts, but initial thoughts are often modified or elaborated upon during the process of expression. When ideas are perfectly clear and final in the mind and are readily encodable in standard words or other signs, there is not the same difficulty in expression. In many different fields of human activity, however, it is common to make preliminary sketches or rough drafts along with many further drafts before the final stage. It is much more apt to think in terms of construction or process or gradual formation, than in terms of the expression of something precisely blue-printed in the mind, especially when the matter in hand is one of some complexity. Here are some examples from different fields. In the case of writing a computer program, there may be many revisions before the final successful form is produced. Or in the case of representational drawing, it has been said that drawing is discovery. In the process of drawing the likeness of anything but the simplest object we have to make many decisions and the need to make decisions obliges us to look again and again at the object, thus discovering the details of its form. In the case of programming and drawing, there is a notion of working towards a final form, but in many situations where signs are used, there may be no true final form because there is no limit to human imagination (*see figure 2*).

Abstract thought is aided by the use of signs, the tangible form gives a certain permanence and definition to any idea. With signs it is possible to elaborate on our thinking, to carry on complex thinking, and to maintain coherence in thought. Consider, as just one example, arithmetical calculation: the average person cannot carry out elaborate calculations without the help of visual symbols or some mechanical aid such as a calculator or abacus. Literacy and the use of other notations is likely

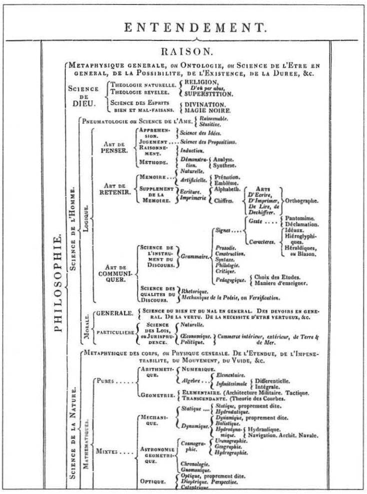
Figure 3 **The sign helps maintain coherence in abstract space.**

Figure 3.1 Part of D'Alembert's *Analysis of Human Understanding,* 1767.



Reprinted in Jeremy Bentham's *Chrestomathia.*

Figure 3.2 Part of Bentham's *Analysis of Human Understanding, 1816.*



Chrestomathia, Appendix.

5
See Goody, J. 1977. *The Domestication of the Savage Mind.* Cambridge, United Kingdom: Cambridge University Press; Havelock, E.A. 1963. *Preface to Plato.* Cambridge, United Kingdom: Cambridge University Press; and Ong, W.J. 1982. *Orality and Literacy– The Technologizing of the Word.* London and New York: Methuen.

to favor the development of more elaborate and more complex philosophy, theology, science and literature.[5] The terms elaboration and complexity can be understood in two different ways (at least). They can be applied to the overall structure of a work, for example, *The Divine Comedy* and Proust's *Remembrance of Things Past* have more complex narrative structures than the *Odyssey* and *The Song of Roland*. We can also apply them at the level of sentence structure, the poetry of Hopkins and Cummings and the prose of legal documents display a complexity which probably could not exist without writing.

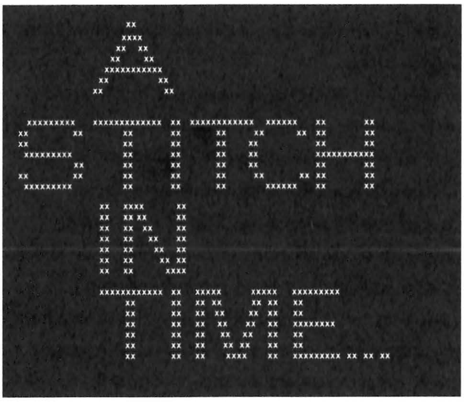
The elaboration of conceptual structures can lead to the realization of elaborate material structures or events (*see figure 3*). Consider the planning of symphonies, ballets, military operations, moon-shots, architecture and town planning. One could use the term orchestration in a metaphorical way for such a process of planning. The signs used in these projects might be words, mathematical or musical notation or scale models, but in every case they externalize and materialize concepts.

As demonstrated, signs can be used to record and develop ideas, but they can also record an event or a particular state of things. A note can serve as a reminder at a later date, it preserves information for reference. Calendars, diaries and logbooks locate people, ideas and events in space and time. Some written records are given special status as in the case of contracts and holy scriptures. The recording of information results in an accumulation of information over time which may be used for particular analyses and syntheses. From these, correlations can be made or conclusions can be drawn. Much science is the product of analysis and synthesis of observations recorded and maintained over time. Accumulated data is also important in the efficient administration and decision-making of any large organization whether a corporation or an empire.

Two aspects of sign use deserve particular attention: operations on sign-forms and memorability. Sign-forms are manipulated or processed as forms, in very precise ways. Consider how words are arranged alphabetically in dictionairies or directories. Where there are clearly definable and limited operations to be performed upon forms, the operations may be mechanized, allowing the task to be done quickly and efficiently by computer, for example. Modern methods of information storage and processing facilitate the task of administration. It is very important to note that machines process forms, not meanings (hence, inter alia, the difficulties in realizing machine translation).

There is also the question of memorability (or aesthetic character) in sign-forms. Memorability is a quality that one might attribute to abstract art, to music or to natural phenomena like rock formations. Memorability might be a product of features like repetition or regularity, contrast, balance, symmetry or pattern and variations on pattern. The forms of signs may be intrinsically memorable or may be modified in some way to be memorable or may be placed in memorable arrangements. The sounds of spoken words may be chosen and organized to make rhymes and patterns of rhymes, assonances, alliterations, and

Figures 4 The sign may have *dimensions* of information



patterns of syllables or stresses. Similarly, written or printed words may be chosen, arranged or modified in form and color to give memorable visual effects (*see figure 4*). Theoretically, any kind of sign-form might be modified to enhance its memorable effect, or might be used with other sign-forms to increase its memorable effect. (Note, by the way, that iconic signs are not necessarily memorable in this sense, galleries and museums are full of pictures and sculptures that are highly forgettable, except that they provide historical or other useful information.)

Pragmatics

Making an informed decision about the best form of sign to use on a given occasion requires consideration of a number of factors:
the physical circumstances of sign use,
the subject matter,
the function of the sign(s), and so on.

Here are some of the general factors operating in the case of communication:

Physical situation:
depending on the relative proximity of the sender and receiver or the various forms of transmission available, one may speak, write or use some other form of sign;

Code sharing:
sender and receiver must share a code, use the same language or the same symbols;

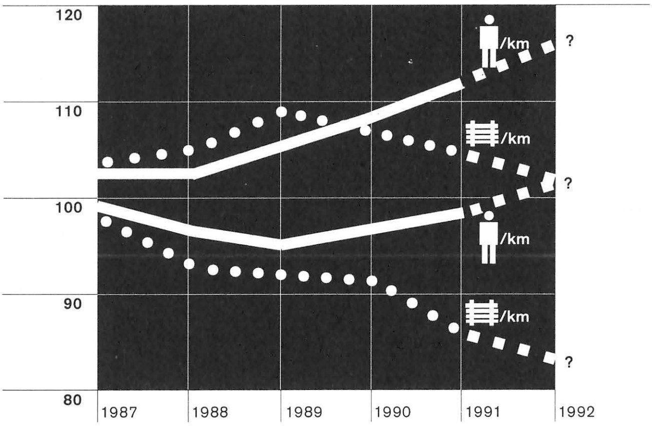
Unambiguous signs:
the sender should strive for clarity.

However, if one takes a more specific view and considers the question of the presentation of meaning (or information) and how best to present it, a large range of factors could be mentioned.

The Printed Page

As the discussion becomes more specific, focusing on information in a non-dynamic, two-dimensional, visual medium, one must keep in mind the possibilities of variation of form within the medium and the use to which these variations might be put for the expression of information. There may be dimensions of variation in form which can be correlated with different dimensions of information. Because the elements are familiar, the vocal medium of speech can serve as a preliminary analogical example. Words and their occurence in a construction (a sentence, for example) may be considered a dimension of information, the linguistic dimension; but when a person speaks, their voice identifies them as a child or adult, as a male or female; their mood and perhaps the state of their health may also be evident; there may also be rhetorical and/or aesthetic features in their particular utterance. These different

Figure 5 **This graph shows a hypothetical situation – the relative increase or decrease of transportation of passengers and goods by rail and road.**



Graphs are economical presentations of information (of certain kinds).

Some of the signs here are "iconic" (or representational). The relative "height" of the curves is a metaphorical way of showing numbers, or "volume".

The function of the squares here is purely esthetic – one could have used rectangles.

6
Compare ideas of the French philosopher Condillac. See also, Aarsleff, H. 1982. *From Locke to Saussure.* London: Athlone Press,157-158.

7
The desire for visual symmetry, balance, regularity of pattern(s), etc., may well interfere with the process of analysis. See Ong, W.J. 1958. *Ramus, Method and the Decay of Dialogue.* Cambridge, Massachusetts: Harvard University Press, figures IV and V, 80-81. The general Ramist principle of binary divisions reflects the same tendency. Compare also, C.S. Peirce's triadic analysis of signs.

aspects may be considered different dimensions of information. The medium has the potential for modulation and variation – we perceive and respond to differences–we process simultaneously the different aspects of the sign.

Likewise, the printed page offers a range of possibilities, and the possible variations in form can express not only a range of information but different dimensions of information. The medium allows text, image, graph, table and other hybrid forms. The text may be presented in linear, line-by-line form, or in other ways, such as lists. There is the possibility of different shapes and sizes of letters. There may be sub-codes within the text such as punctuation or numerals, or changes in color or in spatial orientation of the text to signal position in a hierarchy. The printed page is based on many conventions some of which involve motivated forms or the insistence on certain dimensions of information:

Taxonomic motivation:

similar meanings are expressed in similar forms, for example, capital letters at the beginning of names, italics for technical terms or foreign words, use of rows or columns or similar indentation for related information – the result is a structural consistency;

Aesthetic motivation:

the search is for pleasing and/or memorable form and may involve, for example, a concern for symmetry or asymmetry or regularity or surprise;

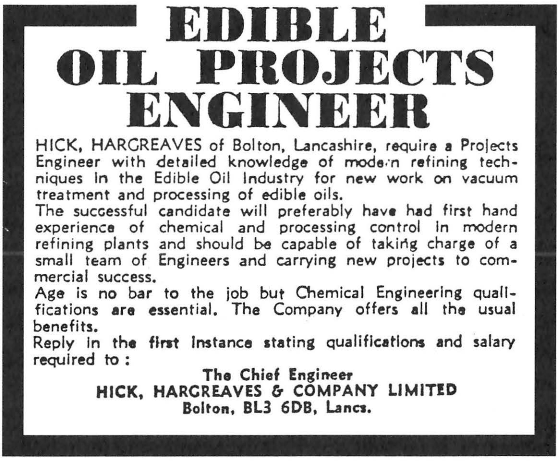
Iconic (or representational) expression:

size or position can be used to express importance or hierarchy, for example (*see figure 5*).

A general distinction can be made between signs of linear form and signs of non-linear form. Spoken words are produced and perceived as a sequence (even if our understanding, for instance, of grammatical and other relationships is not perfectly sequential); written words are basically produced and perceived as a sequence (but the writer and the reader may depart from the sequence in various ways). It is in the nature of the medium of sound that there is sequence, but vision does not necessitate sequence – a visual form of some degree of complexity can be perceived immediately. Consider the relationship between different kinds of thinking and the form of the sign. Linear signs like writing may be appropriate for narrative or for presenting the steps of an argument (as in a geometric proof), but if our ideas and knowledge exist in the mind rather as a structure (perhaps an untidy and sometimes incoherent structure),[6] there is a good case for presenting ideas in non-linear ways: with conceptual "maps," graphs, etc. (Note that individual words, not prose, are used on such occasions, *see figure 3*.) Distance and location in space can be used to show relationships between ideas, such as strength of association. There is, however, always a danger that aesthetic motives may unduly influence analytical thought.[7]

Many writers tend to produce text that can be read aloud and which, in a general way, can be understood like speech. Even Proust's 15-25 line sentences and the long, complex sentences of legal documents

Figure 6 Interruption of Grammatical Relationships



8
See Ong, 1982.
See also *Visible Language,* 22:2/3.

9
See Jennings, S. 1987. *The Complete Guide to Advanced Illustration and Design.* New Jersey: Chartwell Books, Inc. See also Simmonds, D. and L. Reynolds. 1989. *Computer Presentation of Data in Science.* Boston: Kluwer Academic Publishers.

can be read aloud (and understood, but with difficulty in many instances). Perhaps we limit ourselves by generally believing that a text should lend itself to reading aloud. (The term *residual orality* has been proposed for features of written language carried over – perhaps unnecessarily – from the speech communication situation.)[8]

A potential strategy that is not commonly used is the display of syntactic structure. It is possible to present text in such a way as to indicate main clause and subordinate clause, coordination between noun or verb and modifier.

For example:	words		
	and		could be presented
	word groups		
			to show grammatical relationships
		and thus	
			facilitate comprehension.

This kind of strategy is often used in posters and newspaper advertisement when similar form is used for similar information.

For example:	Product X is	new,
		efficient,
		and cheap.

Editors and designers should at least be aware of this dimension of information. In particular, the narrow columns of many newspapers and magazines, which entail the frequent interruption of syntactic groups and word forms, actually frustrate the reader. Ignorance of this aspect has, on occasion, humorous or ironic consequences as in figure 6. The grammatical relationships are (edible-oil) + / = (projects-engineer). The desire for a certain kind of symmetry (aesthetic motivation) outweighed the concern for meaning. Where different dimensions of information are present or potentially present, the basic aim should be coherence or harmony between the different dimensions.

Conclusion

At this time, computers and other machines have made it easier to present information in a variety of ways.[9] It is easier than ever before for those involved with communication to mix media and to use a variety of codes and forms within a given medium. The range of possibilities should be actively explored with a sensitivity to the potential dimensions of information, and if one is concerned with communication, with attention to established strategies.

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Tools for Worldmaking

There are lies.
There are damned lies.
And statistics.

Attributed to
Benjamin Disraeli,
nineteenth century
British prime minister

Clive Chizlett is a typographic designer and typesetter who has retired from full-time teaching and administration. He is active as a consultant in the publishing industry and is working on several parallel programs of research under the generic title Signs of Meaning. Among the completed programs is an objective algorithm for describing and planning the form, content and layout of sign-posting networks.

The life and times of Otto Neurath are briefly outlined. The principles of his Isotype Picture Language are reviewed and are critically examined in the light of descriptive statistics. The pre-history and origins of Isotype are traced to the United States, ultimately to the pragmatist philsosopher and pioneer semiotician, Charles Sanders Peirce, but more directly to the statistician, Willard Brinton and to Neurath's friend and associate, Charles W. Morris. Neurath's views of analytical philosophy and the social sciences are summarized and contrasted with ideas put forward by Popper and Wittgenstein. Finally, Neurath's personal credibility and scientific integrity are tested by looking at his contributions to Soviet propaganda in the early 1930s.

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Visible Language, 26:3/4,
Clive Chizlett, pp. 298-321,

Damned Lies. And Statistics.
Otto Neurath and Soviet Propaganda in the 1930s

Clive Chizlett

For more than three years, I have been inquiring into the use of ideographs for inter-cultural communication from the Late Stone and Early Bronze Ages to the present day. Studies of ideographic writing systems based largely on pictographs such as Sino-Japanese and Bliss Semantography have been particularly interesting and valuable to this study. Closed systems of pictographic symbols used for cartography, signposting and such inter-cultural events as the Olympic Games are also fields for study. Turning to diagrams, as though they were compound, annotated ideographs, I have been comparing the types and principles of diagrams which exist to convey descriptive and comparative statistics. Among the most prominent cases in this connection is the work of Otto Neurath and his associates.

When I examined for the first time Neurath's Isotype Picture Language in the context of statistics, I got the feeling of something odd, bogus, tinny; of things that did not really make sense. It was, at first, a disturbing sensation because Neurath is a major figure in the evolution of twentieth-century visual communication. My investigation of Neurath confirmed that initial instinct. It is timely and necessary to demonstrate that Neurath is, at best, over-rated by many historians of design.

Life and Times

A superficial outline of Neurath's career reveals he was a professional philosopher, political revolutionary, museum-director and descriptive statistician. A brief and selective review of important aspects of Neurath's disputes with some of the philosophers of his time indicates that these disputes were significant of Neurath's approach to education, propaganda and statistics and to his notions about the underlying unity of the exact and social sciences. In the early 1930s, he was heavily engaged in promoting his personal variations of analytical philosophy and theory of truth. It is particularly important to look at Neurath and his formulation and actual uses of the Isotype Picture Language against the background of his purported philosophy – his theory of truth. This paper examines in some detail what is the single

1
Neurath, Otto. 1936. *International Picture Language.* London: Kegan Paul, Trench and Trubner, Psyche Miniature Series No. 83 (1980 facsimile reprint, University of Reading, United Kingdom), 7-11.

2
Edwards, J. and M. Twyman. 1975. *Graphic Communication through Isotype.* Reading, United Kingdom: University of Reading, 18.

3
Bartley III, William Warren. 1974. *Wittgenstein.* London: Quartet, 33.

4
Edwards and Twyman, *Graphic Communication through Isotype*, 18.

5
Arntz, Gerd and Kees Broos. 1979. *Symbols for Education and Statistics.* The Hague: Mart Sprujit, introductory essay.

most revealing episode in Neurath's remarkable career: the period in the early 1930s when he was a consultative descriptive statistician to the Soviet authorities during the implementation of Stalin's first Five Year Plan.

The Austro-German Connection

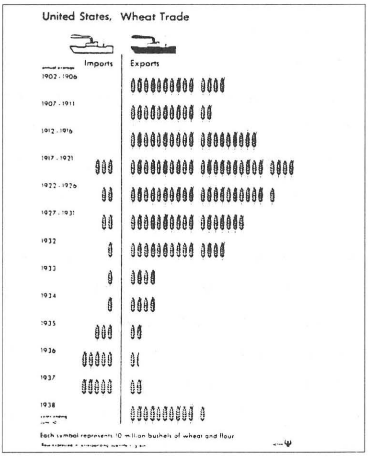
Dr. Otto Neurath (1882-1945), the principal formulator of the Isotype Picture Language,[1] received his higher education in Vienna and Berlin (1901-1905). His first degree related to mathematics and physics. His postgraduate work in Berlin was directed towards history, sociology and economics. From 1907 to 1914, Neurath taught at a trades college in Vienna. Between the years 1911 to 1913, he was also commissioned by the Carnegie Foundation to examine the prospects for peace in the Balkans.[2]

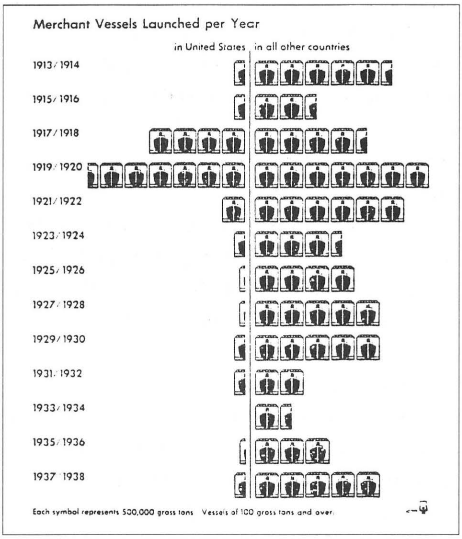
During the latter half of World War I, Neurath was employed by the German government as the director of the Leipzig War Economy Museum. Thematic museums with an ideological mission and a propagandistic function are phenomena which are unique to Austro-German cultural life and history. Neurath's first experience as a museum-director in war-time Germany greatly helped him when he subsequently set out to establish a museum dedicated to the social sciences in Vienna in the mid-1920s. Following his military and government service in World War I, Neurath was, for a short time, an active member of the revolutionary Spartacist Party which governed Munich for a few months during the year 1919.[3] Post-war politics in the Bavarian capital were fast moving and strong flavored. When the execution squads of the counter-revolutionary Freikorps swept into action, the practice of far-left politics in Munich and elsewhere in Germany became a distinctly lethal occupation. Neurath went home to Vienna to work for three years on municipal planning and housing in that city. From 1924 to 1934, between the ages of forty-one and fifty-two, Neurath was the founder-director of the Vienna Social & Economic Museum.[4]

A Museum of Social Science

Neurath's idea of an educational resource – a museum – dedicated to social and economic matters easily attracted civic and government funding. The museum was developed by Neurath as a medium of political propaganda rather than public education. (Bear in mind that public education and political propaganda are the same thing to totalitarian ideologists. The semantic distinction between a political museum and a museum of politics is subtle but very important to distinguish.) During his time at the museum, Neurath and his associates began to work on what was to become the Isotype Picture Language. In the processs, Neurath established one of the first graphic design group-practices. He worked with Alois Fischer, a consultant statistician, on the compilation and interpretation of data. He commissioned Gerd Arntz and Augustin Tschinkel and several other artists, to design picture-symbols for the museum's collaged statistical displays, printed wallcharts and pamphlets.[5]

Figures 1-2 Examples of Isotype comparative presentations.





6
Arntz and Broos, *Symbols for Education and Statistics*, illustrations of Isotype pictographs organized into sections. The introductory essay describes the systematic approach to design of the figurative symbols. The essay also describes the processes of tranformation from raw statistics into Isotype charts. The principal transformer was Marie Reidemeister.

7
Neurath, *International Picture Language.* Seven colors are stipulated, see page 42. For worldmaps, Molleweide's equal-area projection was normally used.

8
Passmore, John. 1968. *A Hundred Years of Philosophy.* London: Pelican, 579.

The Isotype System

The Isotype Picture Language is a method of preparing and graphically displaying descriptive and comparative statistics. Strictly speaking, Isotype is not a language but a system of signification. Isotype relies on the use of unit-pictographs, each of which stands for two variables. The first variable is a nominal category such as persons or things. The second variable is numerical so that each of the individual pictographs may have a value such as a percentage, or some multiple of tens or units per thousand households. When displayed as exhibits in a museum or as illustrations in a book, Isotype charts are the frozen display of an abacus-setting or abacus-reading. Each of the unit-pictographs within an array of pictographs functions in exactly the same way as an abacus-bead. Each chart, therefore, claims to be an objective statement – a verifiable proposition – a sum (*see figures 1 and 2*).

Each Isotype pictograph is normally a metonymic symbol exploiting a stylized and figurative representation of a human being, animal or thing.[6] The Isotype system provides for overall layout of charts and for the typography of chart titles and annotations; it provides for keys to the nominal categories and numerical values of individual pictographs; it provides for systematic use of up to seven colors; and it provides for the use of equal-area maps.[7] The principle of Isotype abacus charts is widely applied today and has become commonplace in all kinds of publication and exhibition. However, in the mid-1920s, the charts were novel and their social or economic significance was clearly and simply intelligible. Their impact on the Viennese public would have been considerable.

Validity and Reliability

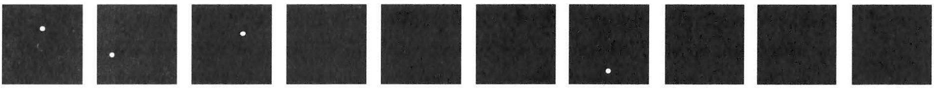
The statistical charts published by Neurath do not normally give the identities of the first-hand or second-hand sources of the data represented in pictographic arrays. The omission of sources from so many of those early abacus charts signalled the possible invalidity and unreliability of the content of those charts for purposes of inference. Descriptive and comparative statistics, which refer to social and economic phenomena, cannot be validly and reliably used for purposes of inference unless the sources of the statistics are properly and clearly identified. A further weakness of many of the early charts was their general failure to make clear whether or not the statistics were originally derived from systematic observations of whole populations, from genuinely random samples or from representative batches of the appropriate size and proportion. In short, the charts are unscientific. It is no use generating descriptive statistics as *objets d'art.* The only purpose of descriptive statistics is to provide a useful and useable basis for inferential statistics. It follows that many of the charts published by Neurath and his associates in the 1920s and 1930s are either inept or their purpose is merely to function as *objets d'art* or propaganda.

Neurath and The Vienna Circle

During the middle to late 1920s, Neurath was a member of the informal association of intellectuals known as The Vienna Circle (*Der Wiener Kreis*). He was directly and indirectly associated through the Circle with such outstanding thinkers as Ludwig Wittgenstein, Moritz Schlick, Rudolf Carnap and Karl Popper.[8] Among the many activities and concerns of the Circle, up to the time of its dis-

Greg Stone

The Journey of the Kamikaze Photon



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Instructions

Watch carefully. There will be two things happening at once. Read what is here. That's one thing; the message, the content. But just as important, watch how it is said. Watch the process. That's the second thing and perhaps the most important.

Continued on page 306.

9
Passmore, *A Hundred Years of Philosophy*, chapter 16.

10
Bartley, III, *Wittgenstein*, 33.

11
Passmore, *A Hundred Years of Philosophy*, 375-379.

12
Bartley, III, *Wittgenstein*, 36.

13
Passmore, *A Hundred Years of Philosophy*, 581.

bandment in 1938, was the critical study and development of a branch of logic-based analytical philosophy – logical positivism.[9] Neurath, who functioned as "the unofficial commissar and self-appointed political secretary" of the Circle, visited Moscow in 1930-31 to try to persuade Stalin to adopt physicalism (Neurath's personal variant of logical positivism) as the official form of scientific, materialist, analytical philosophy to be followed by all straight-thinking Marxists-Leninists.[10]

Physicalism and The Unity of Science Movement

As an offshoot of analytical philosophy in general, and of logical positivism in particular, Neurath's physicalism is realist in principle and is opposed to idealist, empiricist, metaphysical and existential approaches to philosophy. Physicalism is an attempt to join logical positivism to behaviorist psychology. As shown above, Neurath believed his theory of physicalism to be in perfect harmony with Marxist-Leninist doctrine. In the context of physicalism, Neurath claimed that all statements about so-called experiences are invalid unless they are expressed in the language of physics and are invalid unless they refer to processes which only occur in a particular space (such as this room) and a particular time (such as June 10, 1992).[11] Science supplies the criteria (the protocols) by which the validity and meaningfulness of a statement can be tested. If a statement, in the form of a sentence or a proposition, or an equation or a set of statistics can not be expressed in the language of science, in the reductionist language of physics, then that statement is effectively useless for objective purposes. It is either tautologous or nonsensical. In all this, we have no reference to such bourgeois notions as falsity or truth (or banality).

At some point during the mid-1920s, Wittgenstein expressed a view that Neurath's philosophical notions were naive, simplistic and materialist without being objective and vulgar.[12] A historian of modern philosophy writes that Neurath's "philosophical position was never worked out in detail: agitation was his forte."[13]

Physicalism eventually led Neurath to promote and encourage, in all sorts of ways, what he claimed to be the underlying unity between the exact and social sciences. During the 1930s, he worked with others to promote the Unity of Science Movement, chiefly through his organization of five international congresses, whose theme was the unification of the exact and social sciences.

The Soviet Connection

Throughout the late 1920s, Soviet diplomats, publicists and other agents operating in Vienna would have been monitoring Neurath's work as party-member, museum-director and exhibition-planner. Neurath's novel uses of illustrated statistics for purposes of ideological propaganda, or as he would have it, public information, would have interested the officers of Soviet agencies in Vienna, and through those agencies, the authorities in Moscow. Between 1931 and 1934 inclusively, and concurrently with his direction of the Social & Economic

Continued from page 304.

To begin with

Open
a single packet of sugar,
such as you find
in restaurants,
and pour the contents
on a plate.
What you have
before you are 6×10^{23}
carbon atoms –
whatever the hell that is.
John Gribbing, writing
In Search of Schrodinger's Cat - Quantum Physics and Reality,
gives us a way to get this
into perspective.
He suggests
that if we create a super being
with a super small pair
of tweezers, we could give
that person this plate of sugar
and tell her to start
removing atoms one at a time –
one every second.
If she began this task
at the time of the Big Bang
some 15 billion years ago –
the beginning of our Universe
as we think we know it –
she will have removed 5×10^{17}
atoms by today.

Now that might sound
like quite a few atoms. If you
removed one atom every second,
just for a single day,
you would discard 86,400 atoms.
Look at your plate of
sugar.
Try to imagine
for a moment
sitting there with your
super tweezers
and every second for
the next 24 hours,
picking out an atom
and discarding it.
Look at it.
Try – in the next two minutes
you could remove 120.
Now keep going, all day,
all week, all year.
Keep removing them all your life.
Live for thousands of years,
millions of years,
thousands of millions –
15 billion years,
doing nothing but this and
you will remove 5×10^{17} atoms.

Continued on page 308.

14
Arntz and Broos, *Symbols for Education and Statistics,* introductory essay. Neurath's team at the Institute from 1931 to 1934 operated under the name of Isostat. The Isostat team included Gerd Arntz as symbol-designer and Marie Reidemeister as the person responsible for selecting and tranforming Soviet statistics into the material for Isostat charts

15
Arntz and Broos, *Symbols for Education and Statistics,* Chart 6.

16
Conquest, Robert. 1986. *The Harvest of Sorrow.* London: Hutchinson, 265.

Museum in Vienna, Neurath, and some of his principal associates, were invited to serve, under the team name Isostat, as designers, consultants and visiting instructors within the Moscow Institute for the Visual Representation of Statistics. Among the media used for official publication of the Institute's statistics were *Pravda* and *Izvestia*.[14] The statistical institute and the Isostat team would have been directly responsible to the Soviet directorate for agitation and propaganda, Cominform. One might speculate as to the degree to which Neurath, and some of his colleagues within the Isostat team, found credible the raw data supplied to them by Soviet officials.

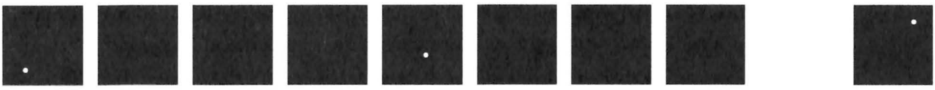
Descriptive Statistics and Governmental Propaganda

"When I use a word,"
Humpty Dumpty said in rather a scornful tone,
"it means just what I choose it to mean–
neither more nor less."
"The question is,"
said Alice,
"whether you can make words mean
so many different things."
"The question is,"
said Humpty Dumpty,
"which is to be master – that's all."
Lewis Carroll's *Alice Through the Looking Glass*, 1872

The period 1929-33 is noted for Stalin's first Five Year Plan, including the imposition of collectivized agriculture upon the whole of the Soviet Union. Among many statisticals charts published in support of the first Soviet Five Year Plan, in late 1933 or early 1934, is a particular Isostat chart which claims to deal with statistics of insecticidal crop-spraying.[15] Based on the same principles as the proto-Isotype charts, it shows a fivefold increase in crop-spraying by aircraft across the Soviet Union over a span of four years from 1931 to 1934 inclusively, but with the exception of the year 1932. There are no intelligible criteria given on the chart for quantifying the amounts of insecticidal chemicals used for the areas crop-sprayed. No clear distinction is made between areas sprayed in past years (1931 and 1933) and areas planned to be sprayed in the coming year (1934). Each unit-area represented on the chart might be as small as a tennis court or as large as a whole region. The chart is superficially impressive and pretty, but it is statistically meaningless and mendacious. With regard to its mendacity, why is the year 1932 missing from the record? Is that year missing because it was the year of the first and worst in a continual series of man-made famines?

It was the explicit duty of Cominform and its agencies, including Isostat, to prove, in contradiction of the plain and brutal reality, that Stalin's policy of collectivized agriculture worked well. The policy was actually a vast and lethal catastrophe for millions of Soviet citizens,

Continued from page 306.



A little hard to get a grip on?
What's harder still
is to understand
how many atoms *are still left.*
Let's see
if we can approach
that point
systematically.
Approximations are fine
for this next step.
Do your best
to discard half the sugar
onto the second plate.
Done It? Good.
Now discard half
of what remains.
We're down to just one-fourth
of what we started with,
but we still have a way to go.
Do it again.
We're down to an 8th.
Not bad.
But we have to go to one millionth.
If we kept dividing this in half
17 more times,
we would eventually get down to
just one-millionth
the amount of sugar we started with.
(1/2; 1/4; 1/8; 1/16; 1/32;
1/64; 1/128; 1/256;
1/512; 1/1,024;
1/2,048; 1/4,096; 1/8,192;
1/16,384; 1/32,768,
1/65,536; 1/131,072; 1/ 262,144;
1/524,288, 1/1,048,576.)
If you actually did this,
you might begin to get an
intuitive picture
of how small an atom is.

For the sugar you've been discarding –
the sugar that's on the plate
that looks nearly full –
that sugar represents the atoms
that our mythical being
has not removed even though
he has been working
tirelessly at this task since
the beginning of time.
All of this is preliminary.
I'm trying to get you
somewhere close
to our starting point,
which is not the atom,
but something far smaller,
the atomic nucleus
of an atom of hydrogen –
the simplest,
and most plentiful atom
in the universe.

Continued on page 310.

17
Conquest, *The Harvest of Sorrow,* 169.

18
Edwards and Twyman, *Graphic Communication through Isotype,* list of quotations from the writings of Otto Neurath.

19
Holmes, Nigel with Rose de Neve. 1985. *Designing Pictorial Symbols.* New York: Watson-Guptill, 7.

20
Arntz and Broos, *Symbols for Education and Statistics,* introductory essay. Gerd Arntz reports that the reason for Neurath's and his associates' departure from Moscow in 1934 was the Soviet government's declared preference for socialist-realist aesthetics in the fields of art and design. Such first-hand testimony is important because it discounts any claim which might be made that Neurath and his associates gave up their work in Moscow for reasons of disgust or scruple.

21
Neurath. *International Picture Language.* The facsimile reprint of Neurath's illustrated text is augmented by a translation from the original English edition into German and an editorial introduction by Robin Kinross. The English-German translation is by Marie Neurath.

a catastrophe designed to enable the consequent surplus of grain to be sold abroad in 1933.[16] The money obtained from these grain exports was used to buy the machine tools and other capital goods that Stalin needed for his policy of large scale and rapid industrialization.[17] As was the case with his malevolent and disastrous agricultural program, Stalin's chaotic industrialization schemes needed to generate fictional statistics for purposes of propaganda.

In September 1933, Neurath wrote, in terms that are truly worthy of Humpty Dumpty, "to remember simplified pictures is better than to forget accurate figures."[18] It all depends upon what you mean by the word simplified. In the case of the crop-spraying chart, and all the other Isostat charts published by the Soviet authorities in the early 1930s, did Neurath mean simplified pictures or did he mean simplified fictions?

The Chicago Connection

At some period in the mid-1920s, probably by way of the Vienna Circle, Neurath established a long-term friendship, exchange of correspondence and professional association with the American philosopher and semiotician, Charles W. Morris, of the University of Chicago. In 1938, and again for a period during World War II, Neurath worked with Morris as a principal editor of the University Press' serial publication, *The Enclyclopedia of Unified Science.* As a pragmatist philosopher with an interest in building bridges between the analytical and pragmatic schools of philosophy, Morris may have introduced Neurath to the thought of the American logician, Charles Sanders Peirce (1839-1914), the earliest formulator of pragmatist philosophy and of a scientific approach to semiotics.

It is also possible that at some period during the mid-1920s, Morris may have drawn Neurath's attention to the work of the American statistician, Willard Brinton. In 1914, Brinton had published his illustrated manual, *Graphic Methods for Presenting Facts* (New York: McGraw-Hill). Brinton's book describes charts which exploit arrays of unit-ideographs, with each ideograph having a dual significance: membership in a class and representation of a prescribed quantity.[19] Brinton's work preceded the Viennese proto-Isotype by about ten years and may well have provided Neurath and his associates with inspiration and example.

The Dutch and British Connections

In 1934 Neurath and some of his associates, including his principal symbol-designer, Gerd Arntz, moved their work from Vienna and Moscow to The Hague for six years until the invasion of Holland by the Germany Army in 1940.[20] While based in Holland, Neurath established the International Foundation for the Promotion of Visual Education, and in 1936 he formulated the Isotype system in his book, *International Picture Language,* published in London.[21] Neurath came to Britain in 1940 and was among the hundreds of Austrian, German and Italian citizens

Continued from page 308.

Most stars
consist mostly of hydrogen,
and that's
where we want to go now,
is into the center of a star
much like our sun.
There's a lot of company here.
Hydrogen atoms
are compressed close together
by the force of gravity.
But don't worry,
there's still plenty of
breathing room
because the atom itself
is mostly empty space.
One way to visualize
a hydrogen atom
is as a huge balloon.
The surface –
the part you see –
really isn't solid.
It consists of an incredibly
small particle called an electron
which is whirling around so quickly,
it's appearing to be everywhere
at once.
We can never identify exactly
where it is,
but we're sure it's there.
In the center of this balloon
is the nucleus.
It contains about 2,000 times
the mass of the electron
in the form of another particle,
a proton.
As large as this is,
this mass occupies just
10^{-15} of the total volume
of the atom.

At any rate,
these protons
in the center
of hydrogen atoms
collide and fuse
together,
and in so doing,
some of their mass
is converted to
high energy photons.
The process gets quite complex,
but the net result is
that photons created near
the stars' surface
escape.
It is one of these photons
that is the subject of this paper.
I call it the Kamikaze Photon,
for it fascinates me
that this object
that is only a very small part
of a very small part of an atom
can span incredible time
and distance
only to "die" in my eye.
Let me take you back
to the spring of 1991 and
to my backyard
in Westport, Massachusetts.
It is a clear Saturday night and
I have hunkered down
in the comfort of my star chair
with a small telescope
pointed towards a distant galaxy.
I am star dreaming.
I am relaxed, comfortable,
and totally transfixed
by a hazy patch of light
that appears in my telescope
as an oval blur. There are also some bright
pinpoints of light nearby,
but they don't interest me
on this evening.
Tonight I'm focusing on this blur
known as M-104,
or more poetically,
the Sombrero Galaxy.

Continued on page 312.

22
Edwards and Twyman, *Graphic Communication through Isotype*, Principles of Isotype, 23, and Working Methods, 25.

23
Passmore, *A Hundred Years of Philosophy*, 375.

24
Hamlyn, D.W. 1988. *A History of Western Philosophy*. London: Pelican, 281-83.

25
Hamlyn, *A History of Western Philosophy*, 375.

interned in prison camps as 'enemy aliens.' In 1941 he was released and he settled in Oxford. With his wife, Marie Reidemeister (born 1898, married 1941), he founded the Isotype Institute at Oxford in 1942. Between 1941 and 1944, Neurath worked with director, Paul Rotha, on eight documentary films for British government agencies. These films incorporate the earliest uses of *animated* Isotype picture-symbols. The themes of the films range from public health to aspects of prospective post-war reconstruction.

Marie Neurath and the Isotype Institute

Marie Neurath and her associates constructively developed the work of the Isotype Institute in Britain and Holland for some thirty years after Otto Neurath's death in 1945. The Institute turned away from ideological propaganda and statistics to specialize in preparing and publishing books, wallcharts, maps, filmstrips, animated film sequences, animated models and kits for educational purposes. The material was planned and designed for use in Britain and overseas. Starting in the mid-1950s, Marie Neurath produced a wide range of material in support of public welfare projects for the governments of Ghana, Nigeria and Sierra Leone. Her work had to take into account the various languages and tribal cultures of the West African states. Picture-symbols were extensively employed on the charts and posters so that information could be visually conveyed or orally presented to villagers whose culture was still in transition from pre-literacy to literacy. Marie Neurath's illustrated books, pamphlets, articles and charts on a vast range of topics, have been produced for use in schools in many languages: Anglo-American English, French, Dutch, German, Swedish, Italian, Portuguese, Japanese and the West African language, Yoruba (which uses the Latin alphabet for associated typography). All such material was developed on the basis of the first principles established by Otto Neurath in Vienna, Moscow and The Hague during the late 1920s and early 1930s.[22]

Science and Truth

During the period 1931-34, Neurath was regularly associated with the Moscow Institute and directing his Vienna Museum. He was also developing and publishing important philosophical ideas. For example, in 1932 (the year of the great famine in the Soviet Union), he published a paper on the topics of the coherence-theory of truth and protocol-sentences.[23] Coherence-theory had been earlier developed by the Oxford absolute-idealist and empiricist philosopher, F.H. Bradley (1846-1924) in his book, *Essays on Truth and Reality* (Oxford University Press, 1914).[24] Bradley, and later Neurath, argued that any coherent, comprehensive, well-knit, clear and consistent set of beliefs may be used contingently to supply the criteria for measuring the truth of a given statement. It would naturally follow that a statement which is found true by one set of criteria or set of protocols may be found true or false or non-proven

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Continued from page 310.

I have seen this before
in my much larger 16-inch telescope
and know that it deserves
the name Sombrero
because cutting across the center of the blur
is a thin, black dust line
that makes the galaxy look like
a Mexican hat.
That kind of detail is beyond the means
of the little 3-inch telescope I'm using now.
But I don't have to be able to see the dust line
to know it's there,
for there is so much
that I know about this little blur
that doesn't meet the eye,
but resides in the brain.
And it is this connection
between eye and brain –
between light and knowledge,
between photons and imagination,
between the physical and the abstract,
between the temporal and the eternal,
that I am trying to make
on this particular night
in the spring of 1991.
For the unknowing eye,
there is not much to see.
For the mind,
working in conjunction with the eye,
there is far more to see in this one blur of light
than a lifetime of observing will reveal.

What I see now
(in my eye and in my mind)
is that Kamikaze Photon –
that little dust mote of energy –
weaving its way across the boundless universe
to my backyard.
I lean back in my chair a little more; I
work the crick out of my neck;
I let my eye and mind relax –
and there is the photon,
emerging from a star within M-104.
Like our star, the sun,
it is a relatively ordinary star
and an ordinary photon.
Like other photons
it is moving at a constant speed,
about
186,200 miles per second.

Sure it is.

Continued on page 314.

26
Haack, Susan. 1976. *Philosophy of Logics.* United Kingdom: Cambridge University Press. See the chapter discussing and comparing coherence-theories and correspondence-theories of truth.

27
"Schlick thought that one had in the end to compare propositions directly with experience, but that what was being ascertained in that comparison could not be put into words. Neurath rejected that idea, asserting that one could only compare statements with statements. Hence the acceptability of any empirical proposition, basic or not, is a mat-ter of whether or not it fits into the system of propositions. Neurath thus accepted a coherence theory of truth and a notion of system which is more like that of the idealists. This did not please all members of the group [The Vienna Circle], although Carnap too was eventually driven in that direction." Hamlyn, *A History of Western Philosophy,* 308.

28
Passmore, *A Hundred Years of Philosophy,* 375.

29
Passmore, *A Hundred Years of Philosophy,* 407.

30
Passmore, *A Hundred Years of Philosophy,* 587.

by a different set.[25] The matter is not trivial: the effect upon ethics and aesthetics, for example, is vital.

Correspondence-Theories of Truth

Coherence-theories of truth are fundamentally different from the correspondence-theories of truth put forward by Bertrand Russell in 1918 and Ludwig Wittgenstein in 1921-22.[26] Correspondence-theory is universal in its scope and looks for direct mappings between the fact and the related statement of the fact. Such an approach to truth puts a major premium on the meaning of statements. We can largely replace Is it true? by What does it mean? To test the meaningful mapping of a fact by its related statement requires an examination of the methods that are used to test the mapping. Thus, we can agree with the conclusion of logical positivists, generally, that the truth of a statement is governed by the method of its verification. If, and only if, there is correspondence between fact and statement, is there meaning.[27] Neurath claimed that such an idea was metaphysical and therefore invalid in the context of analytical philosophy.[28]

Philosophy of Science

Karl Popper, who was particularly concerned with developing a philosophy of science, suggested to his colleagues in the Vienna Circle that the truth and reliability of scientific propositions, including hypotheses, are tested by refutation as much as by verification. According to Popper, refutation exists to distinguish science from its simulacra. He suggested that the social sciences and economics are merely simulacra of the exact sciences because, unlike the exact sciences, they do not and can not generate irrefutable laws. The social sciences and economics do not reliably explain “why things work out in one way rather than another.”[29] Neurath recognized with bitterness and hostility that Popper’s suggestions not only discounted the social sciences and economics as fields of objective inquiry, but also discredited Marxist-Leninist analyses of history, economics and societies.[30]

Language-Games and System-Codes

Correspondence-theory of the truth and the meaningfulness of terms relate naturally to scientific and logical discourse and to mathematics, particularly statistics. However, correspondence-theory can be generally and universally extended beyond scientific discourse to account for any proposition. Only within a coherent set of well-formed protocols, such as the rigorous language of science and physics, would Neurath accept a proposition as truly pertinent. Coherence-theory can not be generally and universally extended beyond formal protocols to account for any proposition (except to describe such a proposition as one to be excluded from consideration).

It was during the early 1930s, strangely enough, that Wittgenstein began to move away from the severe correspondence-theory of the *Tractatus* towards an almost open-ended theory of language-

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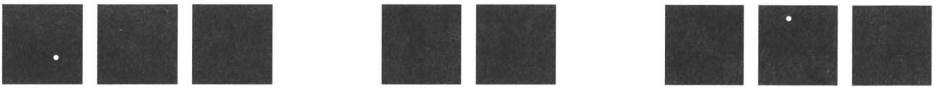


Just wrap your mind around that
for a moment.
You want weirdness?
Think of something that moves
at 186,200 miles a second.
How fast have you gone?
Sixty miles an hour?
That's a mile a minute.
Eighty-eight feet in a second.
Or maybe you have flown in a jet
faster than the speed of sound –
about 700 miles an hour.
Eight hundred and eighty feet per second.
Or if you happen to be an astronaut,
you've orbited the Earth
at 18,000 miles an hour.
That's fast.
But at that speed,
it would take you an hour and a half
to go around the Earth.
Light –
our little photon –
travels around the Earth
seven and a half times
each second.

So our Kamikaze Photon is no laggard.
It's not dragging its heels.
But it has an awful long way to go.
Just to get out of its galaxy –
to break out of this little Island Universe
of another 1.3 trillion suns –
and begin to cross intergalactic space,
our photon will travel about 40,000 years.
How do I know this?
The truth is,
the star I'm talking about
is too distant
to see as a single star,
so I've taken a little poetic license
and I'm imagining
that this particular photon
is leaving from a star
that's in one of the spiral arms
of the galaxy
at about the same distance
from the edge of M-104
as we are from the edge of the
Milky Way Galaxy
that we inhabit.

Continued on page 316.

31
Eco, Umberto. 1976. *A Theory of Semiotics.* Bloomington: Indiana University Press, 36.

32
Bartley, III, *Wittgenstein*, 36.

33
Eco, *A Theory of Semiotics*, 7.

34
Conquest, *The Harvest of Sorrow*, 111.

games (as eventually published in his *Blue and Brown Books* and *Philosophical Investigations*). Neurath's work on coherence-theory and protocol-sentences reminds one, in some ways of Wittgenstein's ideas about language-games and also of Eco's and other semioticians' more recent descriptions of system-codes.[31] Incidentally, Neurath purported to believe that the picture-theory of thought proposed in Wittgenstein's book, *Tractatus*, endorsed the picture-based internationality of the Isotype system. Wittgenstein discounted such a belief, observing that representational thought alone is the common language of humanity. In other words, pictures are not intrinsically means of inter-cultural communication.[32]

The Conflict between Truth and Ideology

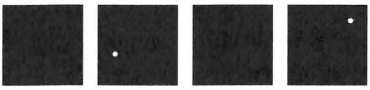
It is curious that Neurath was developing Bradley's coherence-theory of truth at a time when he was also advising Soviet authorities on the abuses of Isotype principles or how to deliver lies for the purpose of political propaganda. It is one thing to have made a contribution to the theory of language-games, but quite a different thing to play games with language itself. Clearly, Marxism-Leninism is a language-game or system-code which incorporates a "coherent, well-knit, clear and consistent set of beliefs" by which to test a truth. If the Party says that black is white, then black is white. Similarly, if it says that crop-spraying took place on that scale, it did.

However, even though Neurath allowed or engaged in dishonest use of Isotype principles, there is no need to invalidate his claims for Isotype as a means of conveying information. After all, one can tell truth as well as lie with a natural language. According to Eco, "semiotics (the science of the life of signs in the life of society) is in principle the discipline studying everything which can be used in order to lie."[33] Exactly.

The Statistics of Genocide

A closer examination of Neurath's contributions to the work of Isostat and the Moscow Institute for the Visual Representation of Statistics during the implementation of Stalin's first Five Year Plan is in order. The materials published by the Institute between 1929 and 1934 particularly, including its quasi-Isotype charts, describe remarkably successful developments in agriculture, industry, power-generation, mining, forestry, civil engineering and communications. The publishing program for the charts relating to the first Five Year Plan broadly coincide with the period of Neurath's consultative and instructional activities at the Moscow Institute. The data upon which the Institute's charts were based is a matter of critical importance when we examine Neurath's positive and perhaps negative contributions to the discipline and practice of descriptive and comparative statistics.

Continued from page 314.



The Journey **The first 40,000 Years**

The Kamikaze Photon
leaves its star, and
possibly a family of planets,
behind in a day or two.
It passes other stars and nebulae
and clusters of stars.
Some of these it comes quite near –
perhaps as close as half a light year.
But most
it misses by several light years,
and as it moves toward the edges,
"close" encounters with other stars become rare.
It also misses the tremendous cloud
of cosmic dust
that gives this galaxy its nickname.
Then it is in intergalactic space.
Ahead lies apparent nothingness –
roughly 40 million years
of nothingness.

As the Kamikaze Photon
departs its home galaxy,
there is no observatory at 1346 Drift Road,
Westport, Massachusetts, U.S. of A.
There is no 1346 Drift Road,
no United States,
and no creature on this planet
who even knows
how to build a telescope.
The land itself
is periodically part of the ocean,
then land again.
On it remain the bones of dinosaurs,
wiped out some 25 million years before this.
Some version of the early horse
might have been roaming it
as the photon began its journey.
Cats and dogs
have yet to make their appearance
even in primitive form.
Preprimates have appeared,
but the separate evolutionary path
for apes and monkeys
had not begun yet.

Continued on page 320.

35
Conquest,
The Harvest of Sorrow,
88.

36
Conquest,
The Harvest of Sorrow,
see chapter 18.

37
Conquest,
The Harvest of Sorrow,
311.

38
Conquest,
The Harvest of Sorrow,
311.

Soviet Statistics

A brief review of the history of a typical set of data from which the Moscow charts were derived is revealing. The Institute's immediate source of statistical data would have been Gosplan (the Soviet State Planning Commission) and its central statistical office.[34] Gosplan was the principal agency of the Soviet authorities for implementing the economic policy within the Five Year Plan: prescribing goals and establishing the interim objectives but also measuring actual economic performance. Gosplan collected its own raw data from statistical bureaus based on economic sectors, geographic regions and republics of the Soviet Union. Such bureaus gathered their data from local officials and line managers. We may assume that some of these officials and managers understood some of the forms and questionnaires which they were required to complete and return. We may also assume that some senior officials and managers knew how to draft a questionnaire (not an easy thing to do well without training). Finally, we may assume that some officials and managers ignored their prescribed quotas or deadlines within the Five Year Plan and told the truth.[35]

But What Shall We Tell the Children?

When Gosplan at last acquired data to be compiled into nationwide statistics, what did they do with the material? The facts as relayed to Stalin and his closest associates were rarely suitable for the consumption of the Soviet people and the world-at-large. The facts had to be hidden. Something had to be published, and if the real facts were politically unacceptable, fictions had to be devised by Cominform and its agencies for news, propaganda and agitation. The fictions were published and broadcast to occupy the place of the real facts.[36] In the contexts of governmental, ideological, political and corporate propaganda, the compilation, interpretation, selection and transmission of data are not, and can not be, scientifically objective. However, when groups or individuals exploit an apparently scientific medium such as descriptive statistics to convey data which are merely fictional or corrupt or banal, then we are in serious difficulty. No cause justifies the uttering of forged statistics.

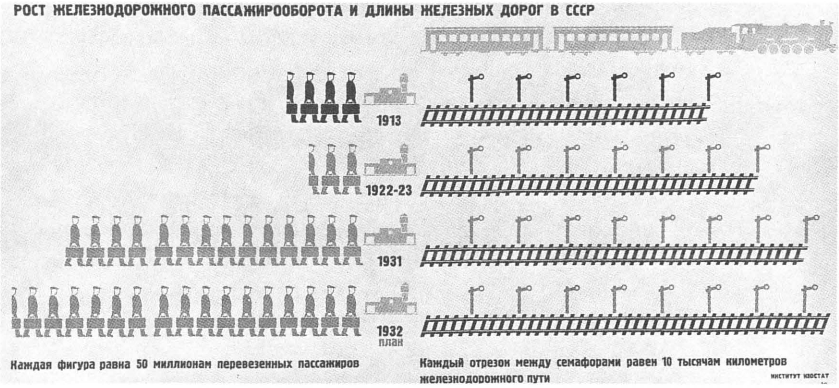
News of the Great Famines

Reports of the several genocidal famines imposed upon the Ukraine and elsewhere in the Soviet Union by Stalin during the early 1930s were widely published and broadcast in the West. The facts were also well known within all the major Russian centers of population such as Moscow. Reports of the famines circulated among foreign nationals living and working in Russia at that time. In December 1932, Stalin's second wife, Nadezhda Alliluyeva, was intensely distressed by reports of the Ukrainian famines, reports which she had been given by fellow students in Moscow.[37]

In Vienna, Neurath's home city and work base in between his operations in Moscow, the newspaper *Reichpost* continually reported

Figure 3 **Isotype comparison of passenger traffic and railroad construction in the Soviet Union.**
Each figure represents fifty million passengers transported. Each segment between semaphores represents ten million kilometers of train track.
(*Translated by Tim Jucovy*)

Reproduced courtesy of the Otto & Marie Neurath Collection in the Department of Typography & Graphic Communication, University of Reading, England.



39
Conquest,
The Harvest of Sorrow,
317.

40
Edwards and Twyman,
Graphic Communication through Isotype,
33.

41
Conquest,
The Harvest of Sorrow,
306.

the famines in the Ukraine from late 1932 onwards until the middle of 1934. In 1933, an International Relief Commission, with its headquarters in Vienna, was established under the chairmanship of the Cardinal Archbishop of Vienna. That commission was explicitly concerned with attempting to alleviate the effects of the famines in the Soviet Union.[38]

Know-Nothing or Stand-Patter?

It is remotely possible that Neurath was unaware of the widespread famines which were in full spate throughout the latter half of his work at the Moscow Institute. Rail journeys between Moscow and Vienna may have skirted the worst affected regions of the Ukraine and Byelorussia. While he was in Moscow and in Vienna between 1932 and 1934, it is even possible that he heard and read but honestly and honorably discounted all reports of the famines. What chills the blood, particularly in the light of history, reason and common sense, is the possibility that Neurath knew the purposes, locations and extent of the famines. Perhaps, in common with the British economists, Sidney and Beatrice Webb, he recognized and accepted the underlying political goals of the man-made famines.[39]

The Missing Chart?

The classical period of the Isostat work does not include any chart which conveys the brutal facts of the first Five Year Plan. We do have some very pretty charts such as the ones produced in Moscow in 1932 under Neurath's direction and dedicated to celebrating the first fifteen years of Soviet power following the revolution (*see figure 3*). There are other attractive charts which describe the phenomenal progress in various sectors of the Soviet economy (particularly in heavy industry and agriculture).[40] We can, however, imagine a chart for the famine years 1932-37 in the Ukraine, Byelorussia, the Caucasus, the Crimea and Kazahkstan. We might choose the human skull as the appropriate metonymic symbol, printed in off-white on a black background. Given the impact on the census-figures of more than twelve millions *extra* deaths in the Soviet Union between 1932 and 1937,[41] we might allocate 100,000 deaths to each skull. With photo-prints of 120 skulls, we should have enough images to patch together the artwork for printing an accurate array based on the principles of the classical Viennese abacus-charts. It would not be appropriate to use the Cross instead of the skull. The famines were inflicted upon the Ukrainian Jews and Kazahk Muslims in addition to whole populations of Orthodox, Catholic and Protestant Christians.

Continued from page 316.

The first 30 million years

The space it is traveling
through is unbelievably empty –
more so than the best laboratory vacuum
we can produce on earth,
and yet there are occasional atoms even here,
but our photon doesn't encounter any of them.
It does come relatively near other galaxies,
for its home galaxy is part of a cluster of star systems
known as the Virgo cluster.
There are about 2,500 galaxies in this cluster,
each containing on average 100,000 million stars.
But the distances between galaxies
is truly beyond the ability of our imagination to grasp.
Sometimes, on a dark morning
when I have been alone under the stars for hours
and I have given my mind free reign –
sometimes, I believe I understand those distances
just a little better.
Sometimes I think I understand them too well,
and I abandon my telescope and the stars
for the safety of my bed and sleep.
Sometimes they scare the hell out of me.

And onward
our Kamikaze Photon
rushes.

Continued on page 326.

Conclusion and Summation

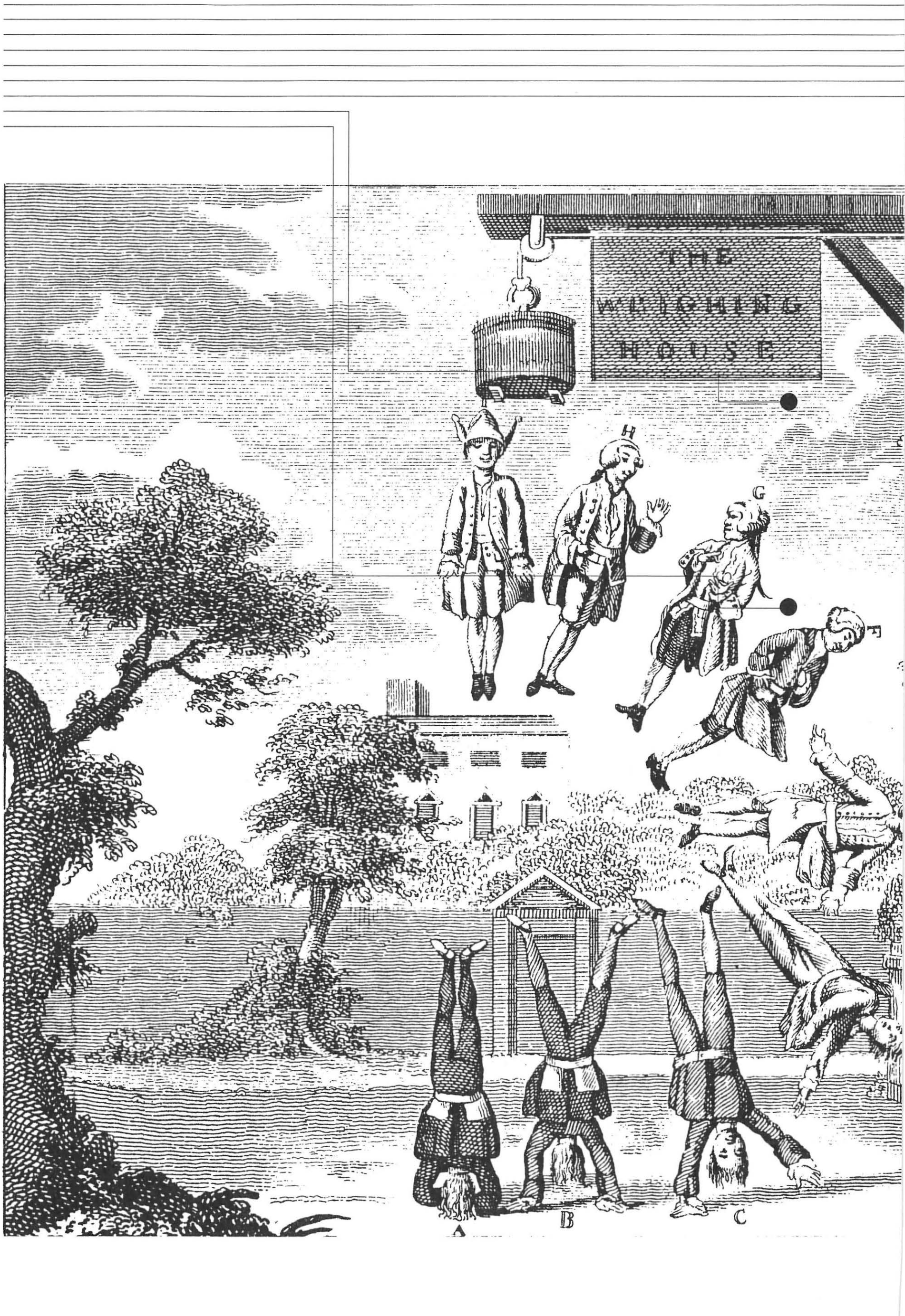
"A natural consequence of the upheaval was the death of millions of peasants in the rural famine of 1932-33 . . .To discourage the starving peasants from stealing their own grain, intended for the towns or for export, the death penalty was extended to "pilfering". . . For three decades after 1929 the Russian diet remained deficient in protein."

Endurance and Endeavor.

J.N. Westwood, Oxford University Press, 1987.

Each Isostat chart is the graphic expression of statistical content, content which we normally think of as real in its origin. The authority of an Isostat chart is endorsed by the disciplined regularity of its arrays of repetitive pictographs. The attractiveness of an Isostat chart is reminiscent of the attractiveness and simplicity of toys and tabletop games from childhood. The authority and attractiveness of Isostat and Isotype charts were exploited positively, but also negatively, by Neurath in the years from 1925 to 1934. But what is the objective value of a chart which is attractive but also banal or mendacious? Does the prettiness absolve the banality and the lying?

It can be shown that Otto Neurath helped the Soviet authorities in the early 1930s to compile and publish false statistics for the purposes of propaganda. To be fair to Neurath, we must consider the context of those times – the baleful and terrifying menace from Nazi Germany, particularly after December 1933 when Hitler became Chancellor. Neurath certainly deserves to be read against the background to his life and times during and between the two World Wars. He was, morally and ethically, neither better nor worse than the hundreds of other artists, writers, broadcasters, editors, journalists, film-makers, photographers, teachers and designers who worked to further the interests of Hitler, Mussolini, Franco and Stalin. Neurath is a major figure in the development of persuasive uses and abuses of media and statistical diagrams. He is also a political propagandist and campaigner of formidable ability and tenacious commitment. He has original things to say about the nature of truth. I rest my case.


THE
WEIGHING
HOUSE
H
G
F
A
B
C

Questioning the Present
or
questioning conventions

Judith E. Sims-Knight, professor of psychology at University of Massachusetts Dartmouth, has been studying the development of reasoning for twenty years. Her interest is the development of mature reasoning and problem solving skills in adolescents and adults. She is interested not only in the nature of reasoning and how it develops, but also, and especially, the environmental conditions under which such development can occur. This interest has led her to investigate the role of visual representations in promoting understanding of complex concepts and the role of user-based design in overcoming the difficulties of creating visuals that communicate. She has conducted research on development of logical reasoning and of algebraic reasoning and is currently engaged in a National Science Foundation project that employs user-based design to develop procedures using visual representations to teach nonprogramming students how to design computer software.

This paper proposes that to create visual designs that effectively communicate their information it is necessary to supplement the intuitions of the designer with empirical research. The first part of the paper gives the reasons why intuitions – of designers or anyone else – are inadequate. It describes the habits of human reasoning that distort designers' ability to intuit how users will understand and respond to graphics. The second part of the paper gives two alternative solutions to these problems, both of which are based on observing how people actually behave in response to visuals. One solution is to investigate scientifically whether and how visuals communicate to viewers. From such investigations general principles can be developed and examples of research-based principles for educational visual representations are given. When such general principles are not available or appear to be inappropriate for the given situation, designers can use a second solution, that of user-based iterative design. This strategy provides procedures by which designers can explore users' reactions at the same time they are developing prototypes of their designs. In this way user-based errors can be corrected while designs are still being developed.

University of Massachusetts Dartmouth, Psychology Department, North Dartmouth, Massachusetts 02747.

Visible Language, 26:3/4, Judith E. Sims-Knight, pp. 324-387,

1
Bertin, J. 1983. *Semiology of Graphics: Diagrams, Networks, Maps.* (W.J. Berg, trans). Madison, Wisconsin: University of Wisconsin Press.

2
Cox, D.J. 1988. Using the super-computer to visualize higher dimensions: An artist's contribution to scientific visualization. *Leonardo*, 21, 233-242. Also Cox, D.J. 1990 The Art of Scientific Visualization. *Academic Computing* 4, 20-22, 32-40, 58.

3
Tufte, E.R.1990. *Envisioning Information.* Cheshire, Connecticut: Graphics Press.

4
Personal communication, Dietmar Winkler, 1988.

To Picture or Not to Picture: How to Decide

Judith E. Sims-Knight

Graphics can be startlingly effective, as Bertin,[1] Cox,[2], and Tufte[3] have illustrated. They can also be costly failures. One good example of graphic design failure is the development of the signage for the Washington, DC subway system.[4] The signs for the stops were arranged vertically letter-by-letter on the subway platforms. The readers were unable to read them in the brief time the subway's speed allowed. The malfunctioning signage system had to be redesigned at an additional cost of nearly one million dollars. The costs from ineffective use of graphics in education may be harder to calculate, but they are undoubtedly substantial. On the one hand, the failure to use graphics, when they are the best – or even the only – way to communicate results in many lost opportunities to educate. On the other hand, the use of visuals in circumstances in which they are ineffective or even interfere with learning, may result in persistent misconceptions that hinder future learning.

Obviously, both designers and their audiences would prefer effective graphics. Why are so many visual representations ineffective or worse? The answer proposed in this paper is that the process of conceptualizing and creating visual representations rarely is grounded in knowledge that goes beyond the intuitions of the designer. To create effective graphics, one needs to understand how the audience (users) of the product understand cognitive material and how they will use the product. This knowledge can be gathered only by direct research that tests the effectiveness of the material with the appropriate audience. Thus, this paper has three central arguments:

1 Intuitions of the designer are not sufficient to understand how users will process and learn from graphics. All humans, no matter how bright, creative and experienced, suffer from certain habits of reasoning that distort their ability to intuit how users will understand and respond to graphics. Some of the large body of research documenting these reasoning tendencies will be described.

2 To develop general principles that can guide a more effective design process, it is necessary to conduct scientific research on how people understand and learn from graphics. Examples of research on the effectiveness of using visual diagrams and pictures to supplement educational texts will be reviewed. Although, as is typical of research with

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30 million years and counting

After the photon has made
three-fourths of its journey,
it gets to about the same range as M-82,
a galaxy near the Big Dipper
which I find fascinating
because we know
there is an incredible explosion
in progress here
and we can watch it
in the most exquisite slow motion.
In reality,
the explosion is rushing through the galaxy
at the speed of light,
but at this great distance
even that seems slow.
Meanwhile,
on our own little planet,
things are taking shape
as we now know them.
Grass has appeared.
The atmosphere has assumed
its modern composition.
Grazing animals are common.
But we are still several million years
from the point where apemen
diverge from the Chimpanzee family
and begin to walk upright.

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5
Tufte, E.R. 1983. *The Visual Display of Quantitative Information.* Cheshire, Connecticut: Graphics Press.

6
Winn, W.D. 1987. Charts, graphs and diagrams in educational material. In D.M. Willows and H.A. Houghton, eds, *The Psychology of Illustration* (volume 1 Basic Research). New York: Springer-Verlag, 152-198.

7
Neurath, M. 1974. Isotype. *Instructional Science*, 3, 127-150.

8
Macdonald-Ross, M. 1977a. How numbers are shown: A review of research on the presentation of quantitative data in texts. *AV Communication Review*, 25, 359-410.

9
Schutz, H.G. 1961. An evaluation of methods for presentation of graphic multiple trends. *Human Factors*, 3, 108-119.

10
Cuff, D.J. 1973. Colour on temperature maps. *The Cartographic Journal*, 10, 17-21.

11
Szlichcinski, K.P. 1980. The syntax of pictorial instructions. In P.A. Kolers, M.E. Wrolstad and N. Bouma, eds. *Processing of Visible Language* (volume 2). New York: Plenum, 113-124.

humans, there are more questions than answers in this research, the body of literature does yield a few principles that are adequately established to be applied to the design process. The research also suggests promising leads for the future.

3 The situations in which designers must design are far more disparate than the principles currently established. When scientific research fails to help, designers need not rely entirely on intuition. Rather, they can apply the user-based prototyping model of design development that has been applied successfully in computer software design. The nature and requirements of this process will be described.

What is wrong with the intuitive approach?

Today much design is based on intuitive skills developed by immersing oneself in the practice of design. In one sense this obviously works – one develops a grab bag of techniques and intuitively picks the one that seems best for the occasion. Some practitioners take it one step further and develop sets of principles based on their personal experience or on exploring the extant literature of others' work. This permits them to influence other practitioners and to teach student designers.

If the intuitions of experienced designers were sufficient to produce designs that communicate effectively, the history of various design fields would not be littered with sad tales of failed designs. In addition, intuitions often clash. For example, Tufte[5] argues that effective statistical graphs should present many numbers in a small space and argues that small data sets are better represented by tables. Yet Winn[6] and predecessors such as Neurath[7] and Macdonald-Ross[8] consider Neurath's isotype chart very effective and isotype charts typically chart only a few pieces of data (much as the bar graph). Schutz[9] found that single graphs with multiple lines led to fewer errors than the small multiple graphs recommended by Tufte. Whom should we believe?

Some design mistakes may be the result of designers being so focused on aesthetic issues that they don't pay adequate attention to issues of effective communication. Even if this is true, simply convincing designers that effective communication should be central in their design considerations is not sufficient to ensure that the resulting designs will be informationally effective. Why, then, are there still so many ineffective designs?

The answer, I believe, is that designers typically rely on only two sources of information. First, they attend to their own reactions and assume that the audience will have similar reactions – we're all human, right? Wrong. It is quite clear that the differences among humans, even in their reactions to graphics, is immense and it is impossible to generalize accurately from one's own reactions, no matter how typical one considers oneself. This was demonstrated by Cuff[10] with maps and Szlichcinski[11] with visual instructions. In addition, designers are experts in interpreting graphics, so their reactions are likely to be quite differ-

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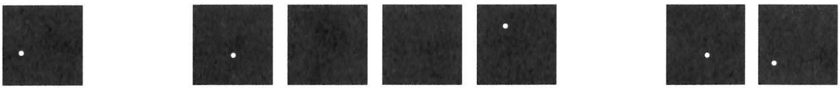

37.8 million years

At 2.2 million years away,
it is inside the "local" group of galaxies
to which our own Milky Way belongs.
The great M-31,
one of the largest galaxies known,
is in this region.
Visible to the naked eye
as a hazy patch on a clear summer evening,
M-31 contains more than
300 billion individual stars.
Spread over 180,000 light years,
this vast star system
is about twice the size of our own galaxy.

Continued on page 330.

12
Hartley, J. 1982. Designing Instructional Text. In D. Jonassen, ed. *The Technology of Text* (volume 1). Englewood Cliffs, New Jersey: Educational Technology Publications, 193-213.

13
Gauron, E.F. and Dickinson, J.K. 1969. The influence of seeing the patient first on diagnostic decision-making in psychiatry. *American Journal of Psychiatry*, 126, 199-205.
See also Sandifer, M.G., A. Hordern and L.M. Green. 1970. The psychiatric interview: The impact of the first three minutes. *American Journal of Psychiatry*, 126, 968-973.

14
Taylor, S.E. and S.C. Thompson. 1982. Stalking the elusive "vividness" effect. *Psychological Review*, 89, 155-181.

15
Anderson, C.H. 1983. Abstract and concrete data in the perseverance of social theories: When weak data lead to unshakable beliefs. *Journal of Experimental Social Psychology*, 19, 93-108.

ent from those of the naive consumers of their graphics. Furthermore, as Hartley[12] pointed out, it is easy to assume that because you have done something, it must be an improvement over earlier versions, whereas in actuality the change may not be for the better.

The second source of information is informal observation of the reactions of others to graphics. This approach is also doomed to failure. Humans are wonderfully creative, intuitively perceptive, and naturally theoretical, but we are by our very nature egocentric, biased and overconfident when we have to form opinions based on our impressions of others' behaviors. The next section describes some of the research that has demonstrated how humans misjudge the kinds of information that they need to assess whether designs communicate to their audience. Although this research has not been done in the context of designers designing, studies have been done in a variety of situations, which makes them likely to be generally applicable. Thus, the goal of this section is to demonstrate that people can not trust their informal impressions.

Initial opinions are formed rapidly and are based on inadequate evidence

The starting point in forming impressions of the reactions of others is the initial hypothesis. In visual communication it is the initial assessment of the needs and capabilities of the audience and/or the initial impression of the effectiveness of a particular representation (e.g., the designer's decision to make the DC subway stop signs read vertically). In clinical psychology and psychiatry this initial hypothesis is the diagnosis of the client. Social psychologists often study the formation of people's first impressions of others. In science it is formulating the initial belief about causal relations. Both experts and novices form opinions quickly and on the basis of remarkably little and weak evidence. For example, mental health professionals form their initial diagnostic impressions within the first five minutes of contact with the patient.[13]

The bases on which people form their initial impressions is consistent with the speed of their formation. They rely on snippets of knowledge that "stick in their minds" rather than systematically considering alternative hypotheses and the widest range of data that might differentially support these alternative hypotheses, a more time-consuming but less error ridden process. To make matters worse, these snippets are often inadequate or misleading. Some of the important types of information that attract people's attention follow.

Knowledge of individual cases

When people know (or know about) one or two people who epitomize a particular belief, they will consider that belief supported without even asking whether those cases are typical or atypical (cf. review by Taylor and Thompson[14]). Anderson's study[15] is a particularly nice

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38.2 million

And as the photon leaves
the Andromeda galaxy behind,
interesting things
are starting to happen on earth.
Interesting, at least,
from our parochial perspective,
for when the photon
is a mere 1.8 million light years away,
Homo erectus, the first true man,
arises in China.
Homo sapiens –
the wise guy –
has to wait another million years.

Continued on page 332.

16
Manstead, A.S.R., C. Proffitt and J.L. Smart. 1983. Predicting and understanding mothers' infant-feeding intentions and behavior: Testing the theory of reasoned action. *Journal of Personality and Social Psychology*, 44, 657-671.

17
Smith, R.E. and W.R. Swinyard. 1983. Attitude-behavior consistency: The impact of product trial versus advertising. *Journal of Marketing Research*, 20, 257-267. For additional examples, see Fazio, R.H. and M.P. Zanna. 1981. Direct experience and attitude-behavior consistency. In L. Berkowitz, ed. *Advances in Experimental Social Psychology* (volume 14). New York: Academic Press, 161-202.

18
Temerlin, M.K. 1968. Suggestion effects in psychiatric diagnosis. *Journal of Nervous and Mental Disease*, 147, 349-353.
Langer, E.J. and R.P. Abelson. 1974. A patient by any other name . . . : Clinician group difference in labeling bias. *Journal of Consulting and Clinical Psychology*, 442, 4-9.

example of this phenomenon. One group of undergraduates read two case studies exemplifying the hypothesis that good firefighters are high risk-takers. In one case the firefighter was good at his job and was also a high risk-taker, and in the other case, the firefighter was poor at his job and was a low risk-taker. Another group of undergraduates were given comparable case studies exemplifying the opposite relation (good firefighters are low risk-takers). Most subjects had no difficulty forming a causal hypothesis on the basis of the two case studies. The subjects were then informed that the case studies were fictitious and subsequently asked about their true beliefs about the relationship. The subjects acted as if the causal relationship they had been exposed to was true – they used it to make predictions about five additional case studies, for example – and they still held that belief a week later.

Personal experiences

One's own personal experiences are perhaps a specific type of case study. At least some studies have found the same strong influence of personal experience that has been found for case studies. For example, women who have nursed a previous baby respond more strongly and consistently to the prospect of nursing a new baby than do women who have not yet nursed a baby.[16] People who taste a new product are more likely than people who have simply read an ad to commit to buying the product.[17] It is not clear that direct experience has a particular impact beyond that provided by a case study of another (cf. Taylor and Thompson[14]), but it is important to note that one's own experience can have at least a comparable effect. For example, designers who have received rave reviews from one design may easily become convinced that this type of design is generally effective and superior to another of their designs that did not receive such rave reviews. Of course, those two experiences may be just as fortuitous as the firefighter case studies in the Anderson study. Likewise, writers on design principles, such as Bertin and Tufte, illustrate their points with particularly nice examples of particular kinds of designs – case studies – but they do not provide any evidence that principles so derived are what differentiates effective from ineffective graphics.

The influence of expert opinion

The influence of an expert or authority has been documented in a variety of settings. For example, Temerlin[18] found that psychiatrists, psychologists and graduate students in clinical psychology were likely to diagnose a patient (who actually was normal) as psychotic if they were told that a high-prestige colleague believed the patient was psychotic even though he looked neurotic (by 60, 28, and 11 percent, respectively). None of the experts without access to this biasing information diagnosed him as psychotic (cf. also Langer and Abelson, 1974).[18] In the world of design, certainly the design principles developed by experts would be expected to serve a similar role in forming impressions of goodness of designs.

Continued from page 330.

39.5 million

Now our photon
is really getting near.
There is a dwarf galaxy in Ursa Minor
near the Little Dipper
that's about half a million light years from us.
That's how far out our photon is
when Homo sapiens first puts in an appearance.
Thirty-nine and a half million years
of a 40-million-year journey is behind it
before modern man even emerges from the mist.
It will cut the distance in half again
before this wise animal learns
to control the use of fire.

Continued on page 334.

19
Lichtenstein, S., P. Slovic, B. Fischhoff, M. Layman and B. Combs. 1978. Judged frequency of lethal events. *Journal of Experimental Psychology: Human Learning and Memory*, 4, 551-578.

20
Higgins, E.T. and G. King. 1981. Accessibility of social constructs: Information processing consequences of individual and contextual variability. In N. Cantor and J.F. Kihlstrom, eds. *Personality, Cognition and Social Interaction.* Hillsdale, New Jersey: Erlbaum, 69-121.

21
Wason, P.C. 1960. On the failure to eliminate hypotheses in a conceptual task. *Quarterly Journal of Experimental Psychology*, 12, 129-140.
Wason, P.C. and P.N. Johnson-Laird. 1972. *Psychology of Reasoning: Structure and Content.* Cambridge,Massachusetts: Harvard University Press, 204-214.

22
Mahoney, M.J.. and B.G. DeMonbreun. 1977. Psychology of the scientist: An analysis of problem-solving bias. *Cognitive Therapy and Research*, 1, 229-238.

Availability (accessibility)

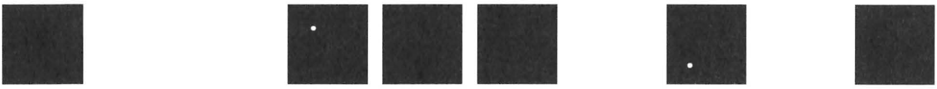
Another influence is that of availability (or accessibility). This describes people's tendency to form impressions or hypotheses based on what is easily accessible to their memory rather than on the basis of consideration of all the information. For example, when people are asked to estimate the probability of dying from various causes, they overestimate the probability of dying from causes with which they are familiar.[19] For example, people overestimate the frequency of deaths from causes typically reported in newspapers, which tend to be relatively rare but spectacular forms of deaths. Newspapers report homicides nine times more frequently than they report suicides and spend fifteen times the space even though suicides are twenty-three percent more frequent.

Differential familiarity is not the only basis for accessibility – expectations, motivation, recency of activation, frequency of activation, salience (prominence and/or distinctiveness), and relation to other accessible constructs also make information more or less accessible.[20] It is clear that we will use whatever constructs happen to be available to us at the time, whether or not they are appropriate.

Once initial impressions are formed we act to conserve them

To summarize the research described so far, people tend to form initial impressions very rapidly and typically on the basis of inadequate evidence. That in and of itself is not such a bad thing, if only they would then search for additional evidence and keep their minds open to changing their opinion. Unfortunately, the opposite appears to be true. After forming an initial impression, people tend to seek evidence to support that belief rather than seeking evidence in an unbiased fashion. Wason[21] demonstrated this phenomenon very clearly and it has been replicated and extended frequently since (cf. Wason and Johnson-Laird)[21] Subjects were told that the three numbers 2, 4, 6 conformed to a simple relational rule. Their job was to discover this rule by generating triads of numbers. After each triad they were told whether the triad conformed to the rule. They were allowed to keep records on paper and were to show the rule to the experimenter only when they were highly confident that they had discovered it. Very few people get the rule correct on the first try. Of forty-five scientists and ministers in Mahoney and DeMonbreun's study,[22] only two discovered the rule on their first guess. Fewer than half ever found the right rule. Why is this task so difficult? It is because people are likely to form an initial hypothesis very quickly – that the rule is "increasing by twos" or "even numbers." They then spend their time creating tests that would confirm their hypothesis, e.g., 100, 102, 104. Other rules are, of course, possible, including the correct rule: "numbers increasing in order of magnitude." To test whether this alternative

Continued from page 332.



39 million 840,000

Now the photon
is on the outskirts of our galaxy
near a dwarf companion.
Three years before our photon gets
to this little irregular galaxy
known as the Large Magellanic Cloud,
a star in it explodes.
Billions of neutrinos
rush with billions of photons
toward earth,
creating for modern astronomers
one of the most exciting and
scientifically fruitful events of the century.

There will be a few seconds
on February 23, 1987
when billions of neutrinos
pass through our bodies –
many more than is normal –
so many more
that some of the neutrinos
may actually collide
with the atoms in some of us,
an almost unheard of event.

Continued on page 336.

23
Mynatt, J.C., M.E. Doherty and R.D. Tweney. 1977. Confirmation bias in a simulated research environment: An experimental study of scientific interference. *Quarterly Journal of Experimental Psychology*, 29, 85-95. See also Mynatt, J.C., M.E. Doherty and R.D. Tweney. 1978. Consequences of confirmation and disconfirmation in a simulated research environment. *Quarterly of Experimental Psychology*, 30, 395-406. See also Wason and Johnson-Laird, 1972, cited in 21.

24
Snyder, M. and W.B. Swann. 1978. Hypothesis-testing processes in social interaction, *Journal of Personality and Social Psychology*, 36. 1202-1212.

25
M.J. Mahoney. 1977. Publication prejudices: An experimental study of confirmatory bias in the peer review system. *Cognitive Therapy and Research*, 1, 161-175. See also Mahoney and DeMonbreun, 1977, previously cited in 22. Also Mitroff, I.I. 1974. Norms and counter-norms in a select group of Apollo moon scientists: A case study of the ambivalence of scientists. *American Sociological Review*, 39, 579-495.

26
See Snyder and Swann, 1978 (Experiment 3), previously cited in 24.

27
Snyder, M. and B. Campbell. 1980. Testing hypotheses about other people: The role of the hypothesis. *Personality and Social Psychology Bulletin*, 6, 421-426.

28
Mynatt, Doherty and Tweney, 1978, previously cited in 22.

29
Anderson, 1983, previously cited in 15. Also Anderson, C.A., M.R. Lepper and L. Ross. 1980. Perseverance of social theories: The role of explanation in the persistence of discredited information. *Journal of Personality and Social Psychology*, 39, 1037-1049.

30
Chapman, L.J. and J.P. Chapman. 1967. Genesis of popular but erroneous psychodiagnostic observations. *Journal of Abnormal Psychology*, 72, 193-204. Chapman, L.J. and J.P. Chapman. 1969. Illusory correlation as an obstacle to the use of valid psychodiagnostic signs. *Journal of Abnormal Psychology*, 74, 271-280.

31
For an extensive overview, see Lichtenstein, S., B. Fischhoff and L.D. Phillips. 1982. Calibration of probabilities: The state of the art to 1980. In D. Kahneman, P. Slovic and A. Tversky, eds. *Judgment under uncertainty: Heuristics and biases.* Cambridge, Massachusetts: Cambridge University Press, 306-334.

32
Kahneman, D. and A. Tversky. 1973. On the psychology of prediction. *Psychological Review*, 80, 237-251. Also Oskamp, S. 1965. Overconfidence in case-study judgments. *Journal of Consulting Psychology*, 29, 261-265. Sines, L.K. 1959. The relative contribution of four kinds of data to accuracy in personality assessment. *Journal of Consulting Psychology*, 23, 483-492.

rule might be correct, subjects would have to use a disconfirmation strategy, e.g., seeing if the sequence 10, 11, 12 conformed to the rule. People rarely do this. Even when they are told "even numbers" is incorrect, the majority persevere in their error by reconfirming their previously falsified hypothesis.

The Wason research may seem like a "straw-man task," because it was selected to mislead, that is, the rule most obvious to most people is incorrect and a less obvious rule is correct. This argument should give us little comfort, however, for two reasons. First, many situations in the real world are misleading in the same way. Second, other research has shown the same phenomenon in other situations as well.[23] For example, Snyder and Swann's Experiment 1[24] asked college students to test the hypothesis that a target person was either an extrovert or an introvert. The subjects tested the hypothesis by selecting questions to ask the target person. Those who were asked to test the target person's extroversion selected questions that solicited evidence of extroverted behavior. Those testing the target person's introversion tended to ask questions that probed for introverted behavior. Thus, the subjects had no preexisting tendency to favor extrovert or introvert, yet they probed only for information that would support the hypothesis, ignoring the possibility that alternative hypotheses might be true.

This tendency to seek confirmatory evidence and not disconfirmatory evidence has been demonstrated even among research scientists, who ought to know better.[25] Furthermore, variables that one would expect to reduce the confirmatory bias have been shown to have little effect. For example, the phenomenon occurs even when the expected accuracy of the hypothesis is low,[26] when the initial hypothesis contains information about disconfirming as well as confirming attributes,[27] and even when the subjects have been trained to use disconfirmation.[28]

The confirmatory bias is so strong that

a *initial impressions last even if people are told that the data they had just studied were false*[29] *and*

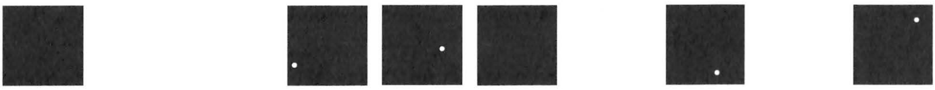
b *people find data that support their hypotheses even when the data provided contains no systematic support for that hypothesis.*[30]

We can not even rely on our sense of confidence

To make matters worse, it appears that these errors of reasoning are accompanied by a remarkable overconfidence in their validity, particularly when the judgment is difficult.[31] Not only do humans show a general tendency toward overconfidence, that overconfidence can be increased by invalid factors:

- Additional, redundant information makes people more confident even when it does not increase the actual probability of being correct[32]

Continued from page 334.



39 million 975,000

(Neutrinos are so close
to being nothing at all
that they usually
pass through things –
even millions of miles of lead
without any collisions.)
Where were you February 23, 1987?
Did you feel anything different?
But back to our photon's journey.
There are no astronomers on earth now,
but there are woolly mammoths.
And in just 50,000 years or so,
the stars will arrange themselves
into the familiar constellations
that man has known
throughout the time
when he has built
a collective memory
through writing and pictures
and stories.

The universe
the photon now passes through
is more crowded.
It occasionally comes near star cities
that while smaller than galaxies
are no less dramatic.
These are the globular clusters,
such as M-13 in Hercules.
This is one of the most spectacular objects
I can see in my telescope
and pictures can't do it justice,
for in the pictures,
you miss the dimension
of varying brightness –
of dozens of bright jewels
scattered over a glistening background
of fainter ones.

Continued on page 338.

33
Langer, E.J. and J. Roth. 1975. The effect of sequence of outcomes on a chance task on the illusion of control. *Journal of Personality and Social Psychology*, 32, 951-955.

34
Fischhoff, B. 1977. Perceived informativeness of facts. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 349-358.

35
Fischhoff, B. 1982a. For those condemned to study the past: Heuristics and biases in hindsight. In D. Kahneman, P. Slovic and A. Tversky, eds. *Judgment under uncertainty.* New York, New York: Cambridge University Press, 335-351.
Fischhoff, B. 1975. Hindsight ≠ foresight: The effect of outcome knowledge on judgment under uncertainty. *Journal of Experimental Psychology: Human Perception and Performance*, 1, 288-299.
Fischhoff, B. and R. Beyth. 1975. "I knew it would happen" – remembered probabilities of once – future things. *Organizational Behavior and Human Performance*, 13, 1-16.

36
Slovic, P. and B. Fischhoff. 1977. On the psychology of experimental surprises. *Journal of Experimental Psychology: Human Perception and Performance*, 3, 544-551.

37
Einhorn, H.J. and R.M. Hogarth. 1978. Confidence in judgment: Persistence of the illusion of validity. *Psychological Review*, 85, 395-415.

- Early success on a task increases overconfidence whereas early failure leads to more accurate prediction[33]

This overconfidence also affects even our memories of what we believed before we discovered an answer. For example, Fischhoff[34] asked people to rate the probabilities of two alternatives to factual questions (e.g., Was Aladdin of the magic lamp a) Chinese or b) Persian?). Then they were told the answer (Aladdin was Chinese). Finally, they were asked to remember what their initial probabilities were. For those questions with surprising answers (i.e., those most subjects had wrong), subjects misremembered how wrong they were. Fischhoff and his colleagues have demonstrated the same "I knew it all along" tendencies with historical events[35] and with learning of experimental results.[36]

Why should we be so overconfident? Part of the reason seems clearly to be because we are focusing on the evidence in our favor and not considering inconsistent or missing data.[37] A classic example is in personnel decisions. Say, for example, one hires new college graduates on the basis of their grade point average. Two years later one discovers that most of the people hired on that basis are performing well and the personnel office concludes that grade point average is a good criterion for hiring. One problem with this conclusion is that no information is available for those whose grade point averages were below the cutoff. If a higher proportion of people with low grade point averages would have succeeded than the proportion of those with high grade point averages, the personnel office would surely change its criteria. Yet, lacking half the evidence, the personnel department people become more confident.

We make causal connections impressionistically

Impressionistic reasoning also leads to errors in causal analysis. As an example, consider Designer A who creates graphic X, which is shown to result in all twenty-five college students in class C understanding the principle (notice that the typicality problem of case studies is solved in this example). Designer A then concludes that the effectiveness of design is due to the way he used color. This conclusion may reflect Designer A's intentions for this graphic and his beliefs about the effectiveness of design, but it may not reflect reality. Even asking the students may be ineffective, because people are not always aware of their own thought processes. The only way to find out whether it is really the use of color that makes the design effective is to compare the effectiveness of A's design with a comparable design that uses colors in other ways. Although this may seem like nit-picking to practitioners who would rather get on with their work of designing, it is an important issue. Without such knowledge, Designer A will continue to produce designs that use color comparably and may or may not continue to use the factors that really made the design effective. He is bound to meet with mixed success.

Continued from page 336.

M-13

No fewer than a million stars
are packed into a sphere
with about one star per
cubic light meter.
That's far closer than the stars are
around us,
yet you must understand
that while this is close for stars,
it is not really very close.
Robert Burnham, Jr.,
in his wonderful
Celestial Handbook,
describes this scale model
of M-13.
Take a million grains of sand
to represent the million stars in the cluster.
Let them occupy a volume of space,
roughly 300 miles on a side.
Each grain, just 3/100ths
of an inch in diameter,
is separated from
the next nearest grain
by three miles!

So these clusters,
which appear to be
the most densely packed mass of stars
in the universe to us,
are separated
by unimaginable distance.
A globular cluster
is mostly empty space
and our photon
could easily pass through one
without encountering
anything.
Neanderthal man has
disappeared.
The first musical instruments
have been crafted.
Farming will start soon,
and in a few thousand years,
people will begin
to populate America.

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38
Nisbett, R.E. and E. Borgida. 1975. Attribution and the psychology of prediction. *Journal of Personality and Social Psychology*, 32, 932-943.

39
Further examples include diagnosis and prognosis in mental patients, see Dawes, R.M., D. Faust and P.E. Meehl. 1989 Clinical versus actuarial judgment. *Science*, 243, 1663-1674. See also Sawyer, J. 1966. Measure and Prediction: Clinical and Statistical, Psychological Bulletin, 66, 178-200. Turk, D.C. and P. Salovey. 1988. *Reasoning, Inference and Judgment in Clinical Psychology.* New York: Free Press. In medical science, see Eddy, D.M. 1982. Probabilistic reasoning in clinical medicine: Problems and opportunities. In D. Kahnemman, P. Slovic and A. Tversky, eds. *Judgment Under Uncertainty: Heuristics and Biases.* Cambridge, Massachusetts: Cambridge University Press, 249-267. Kleinmuntz, B. 1984. The scientific study of clinical judgment in psychology and medicine. *Clinical Psychology Review*, 4, 111-126. Regarding making decisions or judgments about oneself, see Nisbett, R.E., E. Borgida, R. Crandall and H. Reed. 1976. Popular induction: Information is not necessarily informative. In J.S. Carroll and J.W. Payne, eds. *Cognition and Social Behavior*, 113-133. Hillsdale, New Jersey: Erlbaum.

Statistical evidence is often ignored and misunderstood

Much of the research described so far has involved designs that contrasted impressionistic data (representativeness, available memories, stereotypes, case studies) to statistical data. These studies have shown that when people have access to both impressionistic data and statistical data, most ignore the statistical data and form their predictions or conclusions on the basis of the impressionistic data.

A particularly nice example of this is a study by Nisbett and Borgida.[38] They asked college students to predict how people would act in a psychology experiment in which the subjects would be subjected to painful electric shock. Some subjects were provided with a table of the following data about people's behavior in this experiment: two refused to participate, one stopped the shock at tingling fingers, six stopped the shock at a jolt felt through the whole hand, nine stopped the shock at a jolt causing hand and forearm to jerk, and sixteen went all the way to a jolt causing entire arm to jerk. When later asked to predict how thirty-two new people would respond, they produced a distribution that was quite similar to the data they had been given and was quite unlike the guesses of other subjects who had not been given the table of data. This shows that they did understand the statistical information and could remember and use it appropriately. In contrast, when they were asked to predict the behavior of individuals whom they had seen on videotape or about whom they had read descriptions, they did not make use of the tabled information – they did not guess that the person would accept the most severe shock. In fact, their responses were no different than the responses of people who had not seen the tabled data. Thus, these subjects did not use the statistical information they clearly had assimilated.
In contrast, in the same study subjects who were given two case studies of people who took the extreme shock *did* predict that target individuals would take the extreme shock. Thus, the subjects in this study used case study data to predict behavior, but did not use tabled data to make predictions even though they remembered the data.

Similar tendencies to disregard statistical evidence have been found in hundreds of studies in a wide range of situations – predicting people's behavior, as the Nisbett and Borgida study did,[38] assigning people to categories, as the Kahneman and Tversky study did,[32] forming causal hypotheses, as Anderson's study[15] of the causal relation between being a good firefighter and a risk-taker did.[39] Even when they know better, people prefer to base their judgments on impressions rather than statistical evidence.

Why is Statistical Information Superior?

Although reasoning on the basis of impressionistic data has its place, that place is decidedly *not* when statistical evidence is available. To see how reasoning from impressionistic rather than statistical data can

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Table 1 **Firefighters and Risk**

Case	Job excellence	Risk taking	Case is consistent with hypothesis that good firefighters are:
1	Poor	High	Low risk takers
2	Poor	High	Low risk takers
3	Poor	High	Low risk takers
4	Good	High	High risk takers
5	Good	Low	Low risk takers
6	Good	Low	Low risk takers
7	Good	High	High risk takers
8	Poor	Low	High risk takers
9	Poor	Low	High risk takers
10	Poor	High	Low risk takers

40
Tversky, A. and D. Kahneman. 1971. Belief in the law of small numbers. *Psychological Bulletin*, 76, 105-110.

lead us to error, consider the example of Anderson's firefighter case studies, described earlier. Recall that one of the firefighters was both good in his job and a high risk-taker and the second firefighter was both weak in his job and a low risk-taker, thus suggesting that good firefighters are high risk-takers. The problem with the case studies is that they may be typical or atypical cases. It may be much more common for a good firefighter to be a low risk-taker, but we have no way of telling that from the two case studies. There is no reason to believe and no way to predict whether two case studies will be typical of the population or not. Thus, for any two case studies that suggest a particular relation (e.g., that good firefighters are high risk-takers) the true relation may be

a *the one illustrated by the case studies,*
b *opposite to the case studies,*
(i.e., that good firefighters are low risk-takers) or
c *that there is no relation between risk-taking*
and excellence in fire fighting.

Because research has made it clear that even scientists steeped in statistical knowledge make this mistake,[40] I will demonstrate it with an example. I have created a sample of ten purported case studies of risk-taking in firefighters (*see table 1*). It shows, for example, that Case 1 was a poor firefighter who was a high risk-taker, and Case 5 was a good firefighter who was a low risk-taker. A person who knows only these two cases would likely believe the hypothesis that good firefighters are low risk-takers, because both cases are consistent with that hypothesis. A person who is exposed only to Cases 4 and 8, would be likely to conclude the opposite (that good firefighters are high risk-takers). A person who see only Cases 1 and 4 would probably conclude that there is no relation.

In this "manufactured" example, in fact, the true situation is that there is no relation between risk-taking and fire fighting job performance. The case studies were generated by tossing coins. The first toss came up tails and so Case 1 became a poor firefighter. The second toss came up heads and so Case 1 was a high risk-taker. The third toss was tails and so Case 2 was a poor firefighter, etc. Thus, the data were completely random.

What can we conclude from this example? If we reason from only a few case studies, the conclusion we reach will depend on the particular cases we see. If, in contrast, we pay attention to the entire set of ten case studies, we would be much more likely to reach the correct conclusion that there is no relation, because six case studies suggest the first and four, the second.

Note, however, that the appropriate conclusion may not be clear even if the kind of data in table 1 is available. In the situation given, which was created by chance, the lack of a relationship was fairly obvious, but what if seven cases supported one hypothesis and three, the other. Would you be willing to conclude that the hypothesis was supported, or would you want to conclude that it was just random variation? It is to answer such questions that statistical techniques were developed (and the

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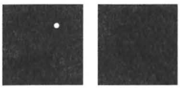
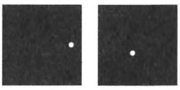


39 million 994,000

The photon now passes
the remnants of an exploded star.
Many know this ragged gas cloud
as the Crab Nebulae, or M-1.
Roughly 7,000 years ago,
it exploded. The light from the explosion
reached us about 1,000 years
ahead of our Kamikaze Photon.
The cloud of gas and dust
is expanding at the rate
of about 600 miles a second.
Moving at 186,200 miles a second,
our photon easily leaves
the remnant of the exploded star
behind.

39 million 998,000

Soon
the Kamikaze Photon
passes the Great Orion Nebulae.
On Earth men in the Near East
are writing about the birth of a savior
in Bethlehem.
Another type of birth
is taking place
in the gas and dust
of the great Orion nebulae,
for there we have seen stars being formed.
In even the smallest telescope,
this nebulae is a spectacular sight
and it is not hard to imagine
from these views
that it is a seething mass
of activity.
The truth is,
that while matter here
is relatively densely packed,
a small sampling of it
would show that it is really
closer to a vacuum
than anything
we've been able to create
in the laboratory
on Earth.



Continued on page 344.

41
Fischhoff, 1977; previously cited in 34. Also Kurtz, R.M. and S.L. Garfield. 1978. Illusory correlation: A further exploration of Chapman's paradigm. *Journal of Consulting and Clinical Psychology*, 46, 1009-1015. Wood, G. 1978. The knew-it-all-along effect. *Journal of Experimental Psychology: Human Perception and Performance*, 4, 345-353.

42
Fischhoff, B. 1982b. Debiasing. In D. Kahneman, P. Slovic and A. Tversky, eds. *Judgment Under Uncertainty.* New York: Cambridge University Press, 422-444. Lichtenstein, Fischhoff and Phillips, 1982, previously cited in 31. Calibration of probabilities: The state of the art to 1980, previously cited in 31.

43
Fischhoff, 1982 b, just cited, and Lichtenstein, Fischhoff and Phillips, 1982, previously cited in 31.

44
Koriat, A., S. Lichtenstein and B. Fischhoff. 1980. Reasons for confidence. *Journal of Experimental Psychology: Human Learning and Memory*, 6, 107-118.

45
Fazio and Zanna, 1981, previously cited in 17. Also Zanna, M.P., J.M. Olson and R.H. Fazio. 1981. Attitude-behavior consistency: An individual difference perspective. *Journal of Personality and Social Psychology*, 38, 432-440.

answer in this case is that seven of ten trials is most likely to be due to chance variation, not a true relation).

The relevance of this to the situation of creating visual designs is obvious. Most designers have only case study information – the opinions of oneself plus a few colleagues or target individuals. Their opinions may be typical of the larger audience or they may be atypical – the designer has no way of knowing.

Biases in reasoning are not easy to overcome

People can not overcome their judgmental errors simply by becoming aware of them. Studies in which errors were explained to individuals and they were warned against them have been ineffective in correcting errors.[41] Nor does education nor expertise per se overcome these biases in reasoning. Physicians, clinical psychologists and stock analysts have all been shown to make grave errors in judgmental reasoning. The only professionals who have been found to be accurate predictors are weather forecasters and horse-racing columnists.[42] Unlike therapists, personnel officers and designers, these forecasters have available to them feedback about their predictions. Weather forecasters find out if their prediction of rain was correct and horse-racing columnists find out how the race turned out. Most practitioners do not get such consistent feedback.

Experimental studies have delineated exactly what kinds of information effectively curb biases:

- consistent and specific feedback[43]
- searching for counterevidence or alternative hypotheses, that is, exceptions to one's beliefs[44]
- searching for a complete picture of the situation by attending to a variety of instances (e.g., ten designs in different contexts rather than just one).[45]

This research suggests that if designers are drawing on their entire experience to form a conclusion (for example, whether in their experience asymmetrical designs are truly more aesthetically pleasing), it might help to make a list of all the times they've made such designs and whether the designs were pleasing to them and effective with their audience. It is particularly important to look specifically for contrary examples – designs in which the asymmetrical design is less aesthetically pleasing. Such a list will help to correct for many biasing factors – the first and last cases, extreme cases, and cases that confirm one's preconceptions.

Making a list of one's past experiences will, of course, not solve the problem of not knowing the thoughts and reactions of consumers of graphics. The unbiased, accurate way of forming judgments about people, about causal relationships (such as the comprehensibility or emotional impact of a graphic on people) is to use quantitative information about large groups of individuals. Humans are naturally capable

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39 million 999,500

About the time
that Columbus was rediscovering
America for the Europeans,
the Kamikaze Photon
was passing Antares,
a red giant and
one of the brightest stars
in our sky.
This also happens to be the distance –
about 500 light years –
where our distance measurements
become much more accurate.
From this point,
inward careful observation
and simple trigonometry
can tell us
how far away a star is
with some measure
of precision.
Of course,
it will still be another 100 years
before anyone turns a telescope to the sky.
People still believe
that the Earth is the center
of the universe
and that the stars are out
just beyond the planets
which are, themselves,
believed to be quite close.
With Copernicus, Galileo,
and Kepler,
that will change
and with the new knowledge
will come dramatic changes in philosophy,
art, and religion,
not to mention exploration
and mechanics.

39 million 999,933

Photos taken
through the new 100-inch telescope
on Mt. Wilson in California
convince scientists
that the so-called "spiral nebulae"
are really distant galaxies.
In another decade or so,
they will be studying
a phenomena known as the "red shift"
and will use this to discover
that the spiral known as M-104,
the Sombrero,
is 40 million light years away,
give or take a million or two.

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46
With scientists,
see Tversky and
Kahneman, 1971,
previously cited in 40;
with physicians,
see Eddy, 1982,
previously cited in 39.

of learning to reason statistically – after all, humans developed the various quantitative techniques – but, even highly trained and experienced people[46] will take every opportunity to ignore the statistical information and resort to their impressionistic, rule-of-thumb judgmental processes. The inescapable conclusion is that one can not trust one's own intuitions about the graphic's effectiveness, one can not rely on expert opinion (since the expert is also biased), and one can not even depend on trying out the graphic with a few individuals, because that amounts to reliance on case study evidence.

Conclusions: Human Reasoning

The research on human reasoning is quite clear. People form beliefs very quickly, on the basis of

a *their own limited experience,*
b *their understanding of expert opinion,*
c *their acquaintance with a few relevant individual cases and*
d *whatever melange of these various kinds of information is uppermost in their minds.*

Once such a belief is formed, people assimilate additional information to it and with each new piece of information they become more confident in that belief. They show a profound lack of ability to differentiate between more or less valid data and show a remarkable tendency to ignore statistical data even though it is almost always more accurate. They tend neither to seek nor accept disconfirming evidence, even when it is hammered at them. It should come as no surprise that there are so many instances of major errors in all walks of life – business, engineering, science, parenting, etc.

Note that the use of these heuristics is not evidence that human minds are disordered or irrational. These are typically human cognitive processes and they are quite effective in situations that call for rapid, common sense judgments. In our evolutionary past, such judgments – deciding whether a sound or sight was, for example, prey or predator, friend or foe – could be life-saving. This same reasoning, however, becomes biasing when we need to make judgments about frequency of events, covariation or cause in situations in which one case varies from others. Judging (or predicting) the effectiveness of designs is one of these situations, because it always involves a target audience of a large number of people who will react in varying fashions. Reasoning on the basis of only partial data – one or two individuals or only one aspect of their behavior – will in most cases lead to error. In such judgment situations reasoning on the basis of judgmental heuristics will always be inferior to reasoning on the basis of statistical principles.

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39 million 999,950

And still the photon moves on.
It is 1941 and the photon
is now near Castor,
a bright star
in the constellation Gemini,
the heavenly twins.
And in a hospital
in Baltimore, Maryland,
I open my eyes and become aware.
These two seemingly unrelated events
will eventually come together
and in the end
annihilate the photon,
stopping at last
its 40 million year
odyssey.

39 million 999,989

Ronald Reagan comes to power
as one of America 's
most popular presidents.
The photon
is approaching the
neighborhood of Sirius,
the brightest star
in our winter sky.

39 million 999,995

As Ronald Reagan makes deals or
doesn't make deals with Iran
to free hostages
and Ollie North does his thing
with the Contras,
the photon
reaches the distance
of our nearest stellar neighbor,
Alpha Centauri.
This double-star system
is just 4.3 light years away.
That may seem awfully close
in terms of what we've been discussing
and it is from the perspective
of our long-traveling photon.
But the photon still has
roughly 25,000 billion miles
to go!

Continued on page 348.

What can be done?

Simply becoming aware that one's reasoning is flawed is not sufficient to overcome the tendency to make faulty judgments. How then can designers increase the likelihood that they will avoid mistakes such as the DC metro signage and increase the probability of effective design? It is possible to take corrective measures, but only by collecting information systematically and using all of the data thus collected. Two methods – scientific investigation and user-based design – provide frameworks by which human errors in reasoning can be addressed. I will first discuss why designers should learn about scientific research concerning visual representations and then describe illustrative research on using visual representations to promote learning. Last I will discuss the use of user-based design techniques, which allow practitioners to incorporate systematic exploration of the users into the development of the design.

Scientific investigation

The discussion on human reasoning should have made it clear that scientists are human and thereby vulnerable to all the same reasoning tendencies as the rest of humankind. This does not mean, however, that conclusions made on the basis of scientific evidence are no better than those made by humans – scientist or other – in their normal functioning. The scientific method has, in fact, developed as a means of correcting for human error by building in constraints against such error. For example, conclusions considered scientifically valid are based on the responses of large and representative samples of individuals; the use of such samples guards against errors likely to result from reasoning on the basis of a few individuals.

Nonetheless, the scientific method is not infallible. The scientific study of human behavior has a number of characteristics that should be understood if one is to be able to interpret the research results appropriately. It is beyond the scope of this article to review all of the issues of validity, although it behooves those who wish to evaluate the evidence for themselves to learn about these issues. For the purpose of this paper, I will focus on general characteristics of scientific research that need to be understood to interpret a group of related studies:

- The resulting knowledge is probabilistic – when describing psychological responses relevant to design issues there is very little that can be said to be true of all humans and so hypotheses must be tested in terms of what is true of most people. Finding one person who does not conform to the hypothesis does not disprove the hypothesis.
- The method of study of human behavior is probabilistic – the statistical test that determines whether a particular hypothesis is supported by a specific set of data returns a probability of the hypothesis being valid. This means that even when a particular study is well done, its conclusions may be wrong. This is why scientists insist on replication of studies. Results from one study may be simply a chance phenom-

Continued from page 346.

39 million 999,997 **39 million 999,999** Years 365 days 21 hours

When Governor Michael Dukakis
was perched at his apex –
just before one of the steepest,
longest, most dramatic slides
in American political history –
our photon was entering
the outer region
of the solar system.
It's a region known as the Oort Cloud
after the astronomer
who postulated
its most likely existence.
This is a dark area
of interstellar space
where dark comets swarm.
Every once in a while
the orbit of one of these comets
carries it in from the Cloud
and it burns a path
across our night skies
on its way to a close encounter
with our sun.
It is still a long way
from what we generally consider
the outer bounds of our solar system,
the orbit of Pluto.

In fact, it wasn't until
the spring Saturday in 1991
during the time I was having supper
that our Kamikaze Photon
passed the orbit of Pluto.
At 7:30 pm
some friends came out
to look through
the 16-inch telescope.

Continued on page 376.

47
Personal communication, Herbert Feigl, 1968.

48
See Tufte, 1990, 92-95, previously cited in 3.

49
For example, see Marr, D. 1985. *Vision*. San Francisco: W.H. Freemon, 215-233.

50
Marr, 1985, 94.

enon, but if two or three studies find the same results, the likelihood that the results are simply a chance phenomenon becomes vanishingly small.

- Although the scientific method builds in corrective factors, experimenter biases can still affect the results. Thus, replications that are done by different researchers in different laboratories are particularly desirable.
- In all studies of human behavior one may wish to test a general hypothesis, such as diagrams facilitate learning. To test such a hypothesis, one must, however, implement a specific situation. One must use a particular diagram (e.g., a representation of a "machine,") in a particular learning setting (e.g., the study of mechanics) and one must use a particular test of learning (e.g., solving a problem). Even if the specific experiment is replicated several times in two or more laboratories, it may only be true within the narrow confines of its particular features. The hypothesis may not be supported when a different kind of diagram (e.g., a graph) in a different learning situation (e.g., mathematics) with a different kind of learning (e.g., generating algebraic equations) is used.
- Scientific knowledge develops by the discovery of new data. At any point our beliefs may be shown to be incorrect by new information. As Herbert Feigl was fond of saying, scientific knowledge is only true until further notice.[47]

Thus, conclusions based on scientific studies are preferable to conclusions based without such research, but the development of useful principles requires a body of carefully executed, broad-ranging studies. Three examples of the kind of research evidence available follow.

Indirect Evidence: Studies of Perception

Psychologists have been studying how people perceive visual stimuli for one hundred years. One might expect it to be a rich source of information about the effectiveness of graphics. In one sense, that is quite true, but its evidence is indirect and thus insufficient by itself. An example will illustrate this.

Tufte[48] effectively used basic research on color perception to produce guidelines for use of color and contour. He warned against the use of value scales of color (e.g., progressing from light to dark blue) to represent differences in quantities, as is often done in topographic maps. He argues that because of color context effects, viewers may perceive particular colors inaccurately and thus interpret the quantitative information inaccurately. He then suggests that this problem might be solved by drawing light contour lines coincidental with color changes. His reasoning here is that, because humans are apparently wired to perceive contour edges preeminently,[49] drawing in contour lines makes each color code a coherent whole, "minimizing within-field visual variation and maximizing between-field differences."[50]

There are two problems with Tufte's use of perception research here. First, Tufte was not consistent in his use of perceptual prin-

51
For example, see Rosenblith, J.F. and J.E. Sims-Knight. 1984. *In the Beginning: Development in the First Two Years of Life.* Monterey, California: Brooks/Cole.

52
For extensive examples of this, see Macdonald-Ross, M. 1977b. Graphics in Text. In L.S. Shulman, ed. *Review of Research in Education* (volume 5), Itasca, Illinois: Peacock, 45-85.

ciples. He used the color contrast phenomena effectively, but recommends using light, thin contour lines even though perceptual principles suggest that darker, more prominent contours would be more easily perceived.[51]

If perceptual principles are an appropriate basis for design decisions in one instance, why are they inappropriate in another instance?

The second problem is that the perception literature permits us to generate hypotheses about effective design, but it does not permit us to assume that such hypotheses are valid without conducting direct experimental tests. In the Tufte example, drawing light contour lines might not be sufficient to counteract successfully the color context effects. Worse, contour lines may be sufficient with some color combinations and not with others.

This illustrative example is decidedly not meant to argue against the value of perception research in guiding design research.[52] Rather, it only argues that indirect application of scientific evidence is just a start, not a final goal.

Direct evidence: Research on visuals in texts

Scientific research has also directly tested the effectiveness of particular kinds of visual representations. For example, there is a large body of research concerned with the role of graphics in helping children to learn in school – to learn to read, to remember textbook material, to understand math concepts, etc. Most of this research is atheoretical. It typically starts with a study that compares a text with a visual to a text without. The second step is to find if the study was valid – subsequent researchers correct flaws in its methodology and repeat the study to see if they get the same results. If so, the study is said to replicate. The third step is to see how widely appropriate the conclusion is. Is it true for a variety of pictures? Is it true for both introductory and more advanced texts, both with and without a text, at the beginning, middle or end of the text? Is it true for both concrete illustrations and diagrams, for memory and for problem solving, for all children or just some (good readers, poor readers, high ability, etc.), is it true for all content areas (e.g., social studies, mathematics) or only for some? Confident conclusions require that the preponderance of studies of a particular sort (specified types of graphics, content areas, etc.) reach the same conclusion. Often the answer is complex – what is true for one kind of visual is not true for another, etc. Sometimes these complexities lead to the formulation of theoretical principles that describe why and when visuals will be effective.

The scientific study of the effect of visuals on learning is following this course. Some of the possible situations have been extensively studied and have yielded consistent findings from different laboratories with different instantiations. Thus, one can have some confidence in the validity of the resulting conclusions. This is true for research on the effect of pictures on memory. The other research areas described here

Figure 1 **A comparison of organizational and interpretational illustrations.**

Example from Levin, Anglin, and Carney, 1987.
Reprinted with permission from *Alive and well: Decisions in health.* by A. Eisenberg and H. Eisenberg, 1979, New York: McGraw-Hill.

Figure 1.1 **An organizational illustration:** Notice that it separates the procedures into discrete units and then puts them together in an ordered sequence.

Open the airways by placing one hand under victim's neck and the other on his or her forehead, tilting back the head to lift the tongue from the back of the throat. Remove any obstructions - solids, liquids, vomitus. If the victim is not breathing, proceed to step 2.

If no pulse can be felt strike a sharp, quick single blow to the mid-chest with the fleshy portion of your fist, starting 8 to 12 inches above the chest. This must be done within 60 seconds of cessation of heartbeat.

To restart breathing, pinch nostrils closed, put your mouth over victim's to form tight seal, and inflate lungs with four quick, full breaths, without waiting between breaths. If no pulse is felt, proceed to step 4. Otherwise continue rescue breathing 12 times a minute until breathing resumes or help arrives.

Begin CPR. If alone, use 15 chest compressions (80 per minute) as shown in drawing 6, followed by 2 very quick inflations of victim's lungs as shown in drawing 3.

If you have help, begin CPR in a 5 to 1 ratio - 5 chest compressions to 1 lung inflation, without pause.

Effective cardiac compression in adult requires enough pressure to depress sternum (breast bone) at least 1 1/2 inches. Hold fingers free of chest wall.

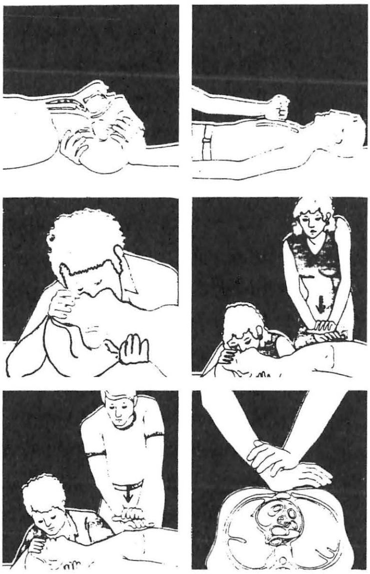
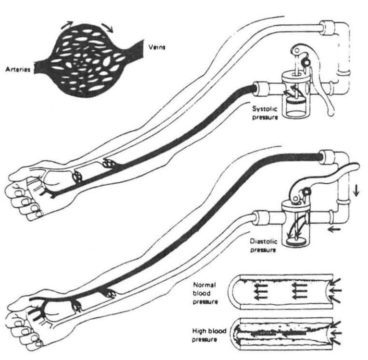


Figure 1.2 **An interpretational illustration:** It makes the abstract concepts of heart functioning concrete and visual by superimposing the analogy of a pump onto the circulatory system.

The mechanics of blood pressure. When the heart is pumping blood into the circulatory system, blood pressure is at its highest point and is called systolic pressure. When the heart is at rest and filling between pumping beats, blood pressure is at its lowest point and is called diastolic pressure.

High blood pressure (over 150 systolic and 95 diastolic in most people) occurs when the arteries become partially blocked, inflexible, or both, thereby increasing pressure in the arteries and making the heart work harder to pump blood through the system.



have been much less studied, but have still yielded consistent results and sometimes across laboratories and so deserve some commendation.

Pictures and memory

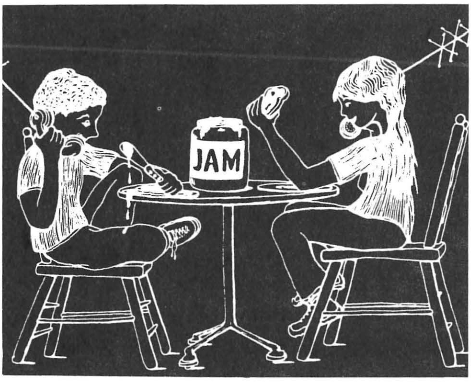
One of the most widely studied areas of visual representation is that of exploring the impact of adding pictures to text. Much of the motivation for this research stems from research done in the 1960s that suggested that the pictures that accompany learning-to-read texts can interfere rather than facilitate children's learning to read.[53] At that time there were few studies that assessed the impact of pictures on older students' comprehension of text – so-called reading to learn – and so many people concluded that pictures in text are never beneficial.[54] Since that time hundreds of studies have addressed this issue and we can now reach some fairly clear conclusions.

As described above, to form conclusions one must honor differences in kinds of illustrations, in the proposed effect, and in the type of individual for whom a conclusion is appropriate. I will begin with the largest body of research – the effects of adding pictures to prose on students' ability to remember what they have read. Several reviews using a statistical summarizing technique called meta-analysis[55] have found that when pictures or diagrams relevant to a prose passage are presented, students are more likely to remember what they have read. In contrast, there appears to be equally consistent evidence that pictures that are merely decorative do *not* facilitate memory. The difference between a merely decorative picture and a representational picture is that the decorative picture may be connected to the text loosely (e.g., a picture of a sailing ship in a story about a sailor), but it does not represent anything that is happening in the story. It is the kind of picture an illustrator might produce if told to create a picture that piques student interest or increases sales. Representational pictures illustrate a major narrative event, that is, "they tell the story," at least in part. Illustrations of stories would clearly be representational if artists were told to draw a picture that depicts the gist of the story or a scene from the story. Such representational pictures help to organize into one integrated whole disparate pieces of information contained in sequential sentences in the prose. They further clarify spatial and other relational information, such as where various objects and people appear in a scene. Representational pictures may accompany expository prose as well as stories; they then serve to make the textual material more concrete.

Illustrations that make the text more coherent or more comprehensible rather than just more concrete are organizational or interpretational.[56] Both types integrate or organize various elements of the text, but they differ in that interpretative figures deal with unfamiliar, difficult concepts whereas organizational ones deal with simple or familiar concepts. Examples of organizational pictures are "how-to-do-it" diagrams (*see figure 1.1*) and illustrated maps.[57] Interpretational pictures clarify difficult-to-understand passages and abstract concepts and often serve as advance organizers (*see figure 1.2*). Levin, Anglin, and

Figure 2 An example of a transformational illustration.

The critical information to be learned is Karl Jansky invented an antenna for improving the quality of telecommunications. The visual recodes the unfamiliar name Jansky into the more concrete jam and then integrates jam, antenna and telephone (telecommunications) into a scene.



Reproduced from Levin, J.R., G.J. Anglin and R.N. Carney. 1987. On empirically validating functions of pictures in prose. In D.M. Willows and H.A. Houghton, eds. *The Psychology of Illustration* (volume 1, Basic Research). New York: Springer-Verlag, 51-85.

53
Samuels, S.J. 1970. Effects of pictures on learning to read, comprehension, and attitude. *Review of Educational Research*, 40, 398-407. Also see Rusted, J. 1984. Differential facilitation by pictures of children's retention of written texts: A review. *Current Psychological Research and Reviews*, 3, 61-71.

54
Levin, J.R., G.J. Anglin and R.N. Carney. 1987. On empirically validating functions of pictures in prose. In D.M. Willows and H.A. Houghton, eds. *The Psychology of Illustration* (volume 1, Basic Research). New York: Springer-Verlag, 51-85.

55
See Levin, Anglin and Carney, 1987, just cited. Levie, W.H. and R. Lentz. 1982. Effects of text illustrations: A review of research. *Educational Communication and Technology Journal*, 30, 195-232.

56
See Levin, Anglin and Carney, 1987.

57
For How-to-do-it diagrams, see Kieras, D.E. and S. Bovair. 1984. The role of a mental model in learning to operate a device. *Cognitive Science*, 8, 255-273. Also Stone, D.W. and M.D. Glock. 1981. How do young adults read directions with and without pictures? *Journal of Educational Psychology*, 73, 419-426. For illustrated maps, see Dean, R.S. and R.W. Kulhavy. 1981. Influence of spatial organization on prose learning. *Journal of Educational Psychology*, 73, 57-64.

Carney's meta-analysis showed that all three of these text-relevant visuals (representational, organizational, interpretational) improve memory compared to no pictures (the effect size for each is around .75, a moderate but real improvement) whereas decorative pictures did not facilitate memory.

Levin, Anglin, and Carney identified a final type of text-relevant illustration – the transformational picture (*see figure 3*). This type of picture, not usually found in texts, is designed to impact students' memory directly. They target the critical information to be learned and

a *recode it into a more concrete and memorable (i.e., vivid and salient) form,*

b *relate the separate pieces of that information in a well-organized context and*

c *provide the student with a systematic means of retrieving the critical information when later asked for it.*

This type of picture was more effective than all other picture types in improving memory. The effect was strongest for children (effect size of 1.43, a very large effect) but was also substantial and greater than other types of pictures for adults (effect size of 1.04, still an impressively substantial effect).

Why should transformational pictures facilitate memory? To improve memory of otherwise unrelated ideas, two good techniques are to link the ideas together by

a *providing an elaborative context and*

b *making the unit salient and distinctive.*

It may also be that transformational pictures are particularly effective when the elements that have to be remembered are not easily integrated. The example in figure 2 would not be effectively illustrated by an organizational or interpretational figure.

One of the hidden issues in the study of effects of pictures is the relation between pictures and the viewer's own cognitive processes. One way we explore that is to have people produce their own images or pictures and compare its effect to that of pictures produced by others. When we do this, we find that transformational pictures (1.25) and interpretational pictures (almost 1.00) are still quite effective, but that the effectiveness of creating one's own representational and organizational pictures is less than when illustrations are provided. Nonetheless, only the representational effect is so small (effect size = .30) as to be possibly of little practical value. This pattern of results suggests that these types of illustrations do capture something real in terms of the viewer's own cognitions. It further suggests that providing pictures is a good idea, because

a *it ensures that visual representations will be available and*

b *viewers may encode something additional from the picture that they would not have put into their own image.*

58
Mayer, R.E. 1989. Models for understanding. *Review of Educational Research*, 59, 43-64.

59
Beveridge, M. and E. Parkins. 1987. Visual representation in analogical problem solving. *Memory and Cognition*, 15, 230-237. Also Kieras, D.E. and S. Bovair, 1984, cited in 57. Mayer, 1989, just cited. Moyer, J.C., L. Sowder, J. Threadgill-Sowder and M.B. Moyer. 1984. Story problem formats: Drawn versus verbal versus telegraphic. *Journal for Research in Mathematics Education*, 15, 342-351. See also Winn, 1987, cited in 6.

60
Gick, M.L. and K.J. Holyoak. 1980. Analogical problem solving. *Cognitive Psychology*, 12, 306-355; also their 1983, Schema induction and analogical transfer. *Cognitive Psychology*, 15, 1-38; Kulm, G., J.F. Lewis, I. Omari and H. Cook. 1974, January. The effectiveness of textbook, student-generated, and pictorial versions of presenting mathematical problems in ninth-grade algebra. *Journal for Research in Mathematics Education*, 5, 28-35. Mayer, R.E. 1976a. Comprehension as affected by the structure of problem representation. *Memory & Cognition*, 4, 249-255. Sims-Knight, J.E. and J.J. Kaput. 1983. Effects of natural language and image-based representation on translating between the symbol systems of natural language and algebra. In D.R. Rogers and J.A. Sloboda, eds. *Acquisition of Symbolic Skills*. New York: Plenum Press, 561-570.

61
Hayes, J.R. and H.A. Simon. 1974. Understanding written task instructions. In L.W. Gregg, ed. *Knowledge and Cognition*. Hillsdale, New Jersey: Erlbaum. Kaplan, C.A. and H.A. Simon. 1990. In search of insight. *Cognitive Psychology*, 22, 374-419. Larkin, J.H. and H.A. Simon. 1987. Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65-99. Simon, H.A. and J.R. Hayes. 1976. The understanding process: Problem isomorphs. *Cognitive Psychology*, 8, 165-190.

62
Hayes and Simon,1974; Kaplan and Simon, 1990; and Simon and Hayes, 1976, all just cited.

63
Kaplan and Simon, 1990, just cited.

64
Larkin and Simon, 1987, just cited.

Diagrams and problem solving

The research on the memory effect of graphics in instructional text is quite extensive and yields rather clear results. It has fulfilled many of the criteria for good scientific research described above – a number of methodologically good studies using a variety of different specific pictures and texts studied by a variety of different investigators. Still, it is limited in that the studies all measure memory. Thus, we know that visuals of certain types help children remember material, but that isn't all there is to learning. We also need to be able to apply what we know and to solve problems with the materials we use. In some sense these are the really critical questions, at least when we think beyond the narrow confines of school tests. Moreover, it is not necessarily true that what helps one remember will help one learn to apply the material. In fact, Mayer has shown in a number of studies[58] that visual models (organizational and interpretational pictures) help students to understand and to apply what they know, even while they interfere with verbatim recall (i.e., remembering exactly what was presented). Thus, it would be inappropriate to assume that if visuals of certain types facilitate memory, they will facilitate all positive outcomes.

Fortunately, a number of research studies have addressed the issue of whether visual representations facilitate problem solving, usually using diagrams of some sort. Many have shown that when visual diagrams accompany text, problem solving is facilitated[59] but some studies have found no facilitative effect.[60] When scientific studies yield inconsistent results, it suggests that additional factors lurk behind the scenes.

Luckily, some research offers insight into when a visual will work. Simon and his collaborators[61] have developed a description both of the typical problem solving process and of the role visual representations can play in facilitating finding a solution. He argues that discovering an effective problem representation is the key to creative problem solving (that type of problem solving in which we gain a feeling of "Aha" when we finally understand how to solve it). When first confronted by difficult problem situations (one in which the solution is not obvious), individuals do not initially identify alternative problem representations and choose the best one. Rather they almost always adopt the representation suggested by the verbal problem statement.[62] If that representation is inappropriate, they must then find an appropriate problem representation to solve the problem. Once they find this alternative representation, they can solve the problem.[63] Obviously, then, a visual can help when it helps the individual formulate that better representation.

Diagrams as guides for search. Larkin and Simon[64] used a computational analysis to identify when and why a diagram would be a better representation of a problem than a verbal description. They identified two situations in which visual diagrams are superior. One is when search for the appropriate aspect of the problem is made easier by a visualization. They give an example of a physics problem (*see figure 3*)

Figure 3 A demonstration of the value of a diagram as a guide for search.

Verbal Problem:

We have three pulleys, two weights and some ropes, arranged as follows.

1
The first weight is suspended from the left end of a rope over Pulley **A**. The right end of this rope is attached to, and partially supports, the second weight.

2
Pulley **A** is suspended from the left end of a rope that runs over Pulley **B**, and under Pulley **C**. Pulley **B** is suspended from the ceiling. The right end of the rope that runs under Pulley **C** is attached to the ceiling.

3
Pulley **C** is attached to the second weight, supporting it jointly with the right end of the first rope.

The pulleys and ropes are weightless; the pulleys are frictionless; and the rope segments are all vertical, except where they run over or under the pulley wheels. Find the ratio of the second to the first weight, if the system is in equilibrium.

Schematic diagram:
(figure 2 in Larkin and Simon)

The subject solves the problem by going up from **a** to **b** to **d**, etc., e.g.:

1
A weight at **a**, with associated value **1**, hangs from something at **b**, which is a rope. Therefore the rope at **b** has associated value **1** (by the single-string support rule that says that if there is a single support, it will have tension equal to the value of the weight). Attention is now at **b**.

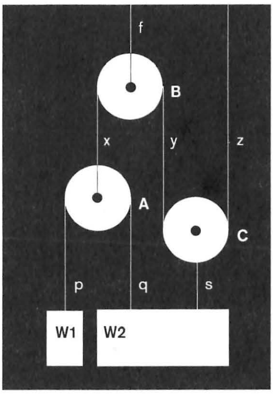
2
The rope at **b** is in the pulley-system at **d** which also contains the thing at **c** which is a rope. Therefore the rope at **c** has associated value **1**. (By Ropes over Pulley rule, which says that if a pulley system has two ropes over it, and we know the value of one rope, the value of the other rope is the same.)

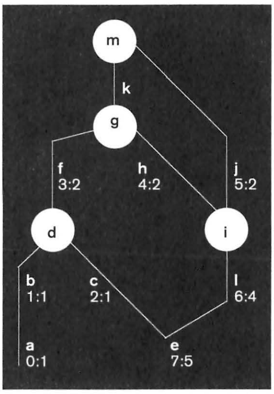
3
The rope at **c** (value **1**) is in the pulley-system of **d** which hangs from the thing at **f** which is a rope. The pulley-system at **d** also contains the thing at **b** which is a rope with value **1**. . . Attention is now at **f**.

4
The rope at **f** (value **2**) is the pulley system at **g**. . .

Visual Representation:

(the diagram of a concrete problem)

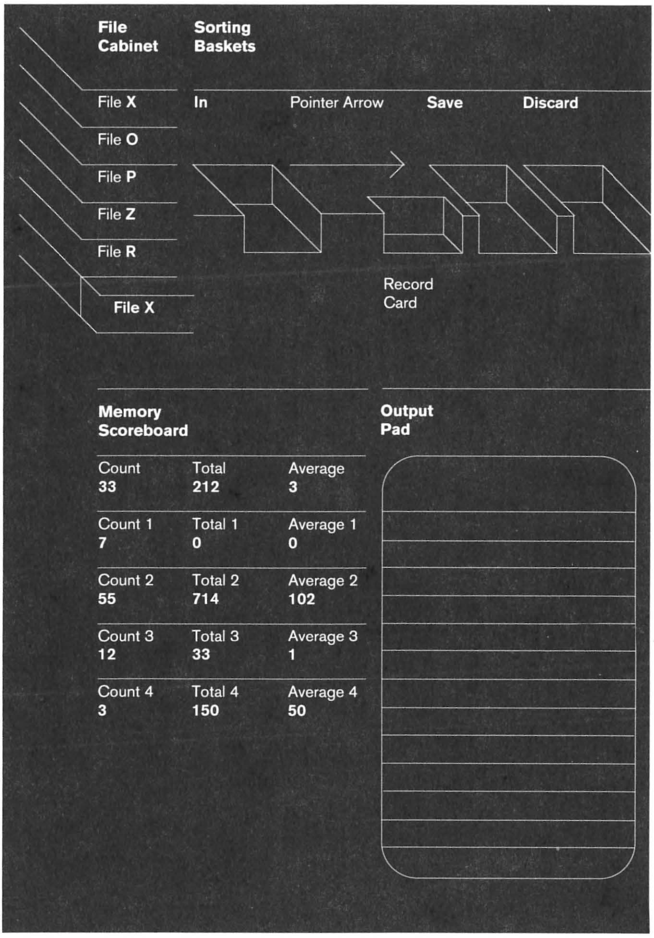




Adapted with permission from Larkin, J. H., & Simon, H. A. 1987. Why a diagram is (sometimes) worth ten thousand words. *Cognitive Science*, 11, 65-99.

Figure 4 A model for understanding a data base.

(Mayer Fig. 7.) A model for understanding data base programming. Students can follow the program as it moves from one element to the next by following through the images.



Adapted with permission from Mayer, R. E. 1976b. Some conditions of meaningful learning for computer programming: Advance organizers and subject control of frame order. *Journal of Educational Psychology*, 68, 143-150.

Figure 5 **Constrasting verbal and visual presentations of a geometry problem.**

Adapted with permission from Larkin, J. H., & Simon, H. A. 1987. Why a diagram is (some-times) worth ten thousand words. *Cognitive Science*, 11, 65-99.

Verbal Statement of Problem:

1
Two transversals intersect two parallel lines and intersect with each other at a point X between the two parallel lines.
2
One of the transversals bisects the segment of the other that is between the two parallel lines.
3
Prove that the two triangles formed by the transversals are congruent.

The diagram makes explicit the points, segments, angles and triangles implied in the verbal statement of the problem.

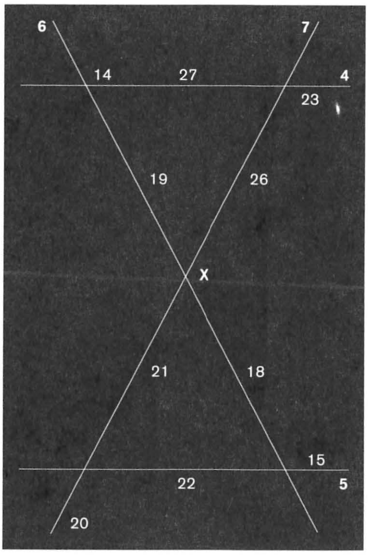


Figure 6 **The mutilated checkerboard with and without contrast versus a verbal description.**

Adapted with permission from Kaplan, C. A., & Simon, H. A. 1990. In search of insight. *Cognitive Psychology*, 22, 374-419.

Verbal description:

Consider a standard 8 x 8 checkerboard, two of whose diagonally opposite corners have been removed. Imagine placing dominos on the board so that one domino covers two horizontally or vertically (but not diagonally) adjacent squares. The problem is either to show how 31 dominos would cover the 62 remaining squares, or to prove logically that a complete covering is impossible.

The solution requires representing the problem as one of parity between the black and white squares. Once the problem solver notices that there are two fewer white squares than black, it becomes apparent that a complete covering is impossible.

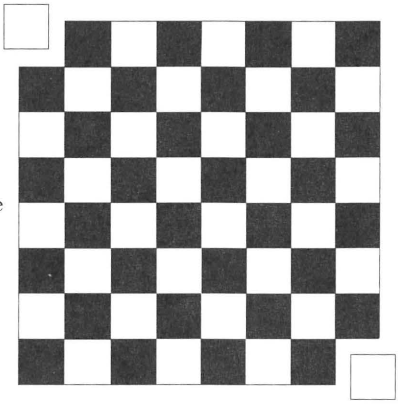


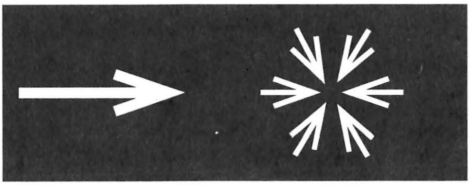
Figure 7 **Contrasting diagrams developed to help individuals solve a problem.**

Adapted with permission from Gick, M. L., and Holyoak, K. J. 1983. Schema induction and analogical transfer. *Cognitive Psychology*, 15, 1-38; and with permission from Beveridge, M., and Parkins, E. 1987. Visual representation in analogical problem solving. *Memory & Cognition*, 15, 230-237.

The problem:

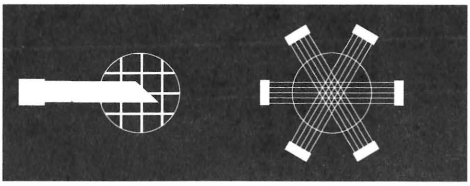
Suppose you are a doctor faced with a patient who has a malignant tumor in his stomach. It is impossible to operate on the patient, but unless the tumor is destroyed the patient will die. There is a kind of ray that can be used to destroy the tumor. If the rays reach it all at once at a sufficiently high intensity, the tumor will be destroyed. Unfortunately, at this intensity the healthy tissue that the rays pass through on the way to the tumor will also be destroyed. At lower intensities the rays are harmless to healthy tissue, but they will not affect the tumor either. What type of procedure might be used to destroy the tumor with the rays, and at the same time avoid destroying the healthy tissue?

Figure 7.1



Unsuccessful diagram representing the dispersion solution used by Gick and Holyoak. It represents the necessity to break one large X-ray into a number of small X-rays all pointing to the tumor, but it does not represent the differential intensity between the single large X-ray and the many small X-rays.

Figure 7.2



Successful diagram used by Beveridge and Parkins. It not only represents the difference in the number of X-rays, but it shows the essence of the solution – that the many small X-rays are less intense, but then combine their intensities at the site of the tumor.

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Figure 8 **Contrasting verbal and visual versions of a math problem.**

Adapted with permission from Moyer, J. C., Sowder, L., Threadgill-Sowder, J., and Moyer, M. B. 1984.

Story problem formats: Drawn versus verbal versus telegraphic. *Journal for Research in Mathematics Education*, 15, 342-351.

Figure 8.1 **Verbal description:**

There are 6 boxes of crayons. There are 24 crayons in each box. Each box costs 90 cents. How much do the 6 boxes cost?

Note that the picture gives all the information in an ordered – and simultaneous – form. Thus all the problem solver needs to do is to figure out which are the relevant quantities and what operation to apply.

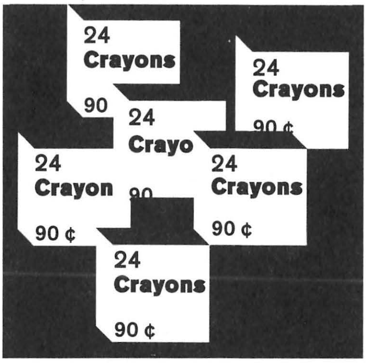
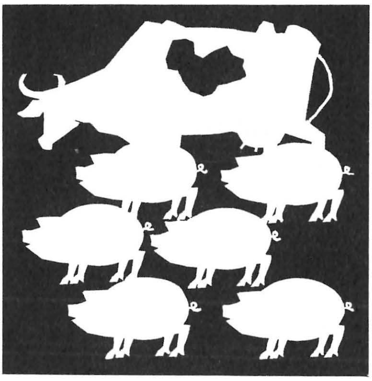


Figure 8.2 **Verbal description:**

Farmer Smith has 6 pigs for every cow. Let **P** stand for the number of pigs and **C** stand for the number of cows. Write an equation relating the number of pigs to the number of cows...

Try to use the visual to solve the problem. Does it help? It doesn't help most students, probably because the "trick" to the problem is to understand how ratios and algebraic symbolization work, not to understand the relative quantities.



65
Mayer, R.E., 1976b. Some conditions of meaningful learning for computer programming: Advance organizers and subject control of frame order. *Journal of Educational Psychology*, 68, 143-150; and Mayer, R.E. and B.K. Bromage. 1980. Different recall protocols for technical texts due to advance organizers. *Journal of Educational Psychology*, 72, 209-225.

66
For example, see Polich, J.M. and S.H. Schwartz. 1974. The effect of problem size on representation in deductive reasoning. *Memory & Cognition*, 30, 683-686. Schwartz, S.H. 1971. Modes of representation and problem solving: Well evolved is half solved. *Journal of Experimental Psychology*, 91, 347-350.

67
Beveridge, M. and E. Parkins, 1987, previously cited at 59.

68
Gick, M.L. and K.J. Holyoak, 1980, previously cited at 60.

69
Duncker, K. 1945. On problem solving. *Psychological Monographs*, 58 (5, Whole No. 270).

70
Moyer, Sowder, Threadgill-Sowder et al., 1984, previously cited at 59. Threadgill-Sowder, J., L. Sowder, J.C. Moyer and M.B. Moyer. 1985. Cognitive variables and performance on mathematical story problems. *Journal of Experimental Education*, 54, 56-62.

71
Kulm, Lewis et al., 1974; and Sims-Knight and Kaput, 1983; both previously cited at 60.

in which the problem can be solved by going from place to place in the diagram. To solve the problem using only the verbal description of the problem, one has to read repeatedly through the problem to find the next step. In other words, the visual diagram has structured the problem into local regions that represent steps in the problem.

Organizational and interpretational diagrams also facilitate search in noncomputational domains, such as understanding the steps through a biological or chemical cycle, or moving through a computer program. For example, Mayer[65] created a model for understanding data base programming that included pictures of a file cabinet, sorting baskets, memory scoreboard, and output pad (*see figure 4*). A data base program moves from one to another of these elements. Thus, students can follow the program through by moving from one picture to the next – the visual image may help them hold the concept in mind. Two-dimensional matrices that systematically record the values of variables (numerical or otherwise) also facilitate searches for communalities, relations, missing cells, etc.[66]

Making the implicit explicit. The second circumstance in which Larkin and Simon identify superiority for visual diagrams is when the visual representation makes explicit crucial aspects of a problem that are implicit in the verbal representation. They give the example of a geometry problem (*see figure 5*) in which the points, segments, angles and triangles are not mentioned specifically in the verbal description, but are made explicit in the drawing. In Kaplan and Simon's 1990 paper, they explored a problem called the mutilated checkerboard problem in which a picture of the checkerboard made explicit that there were black and white squares where such information was only implicit in a verbal description of the mutilated checkerboard. The patterning of black and white gave the clue to the solution (*see figure 6*).

Larkin and Simon's second factor – that visual representations sometimes make crucial elements of the problem representation explicit has been supported in several quite different contexts. Beveridge and Parkins[67] improved on a graphic developed by Gick and Holyoak[68] (*see figure 7.1*) that had failed to help individuals solve the radiation problem developed by Duncker.[69] The difference between their figures and those of Gick and Holyoak was that theirs (*figure 7.2*) made explicit that the small, less intense rays would combine at the site of the tumor to become sufficiently intense to destroy the tumor. Thus only figure 7.2 makes explicit the crux of the problem, which is only implicit in the verbal problem.

Studies of visuals in mathematical problem solving also suggest that only visuals that represent the essential components of the solution will facilitate finding the answer. Pictures have been found to facilitate solving arithmetic problems, particularly for low readers,[70] whereas they have been found to provide little help with algebraic story problems.[71] In the studies of arithmetic problems (*see figure 8.1*) they facilitate because they show both the quantities and the relations among the quantities, which is what one needs to know to solve the arithmetic

Figure 9 **Four representations of a problem to be programmed.**

Adapted with permission from Mayer, R.E.1976a. Comprehension as affected by the structure of problem representation. *Memory & Cognition*, 4, 249-255.

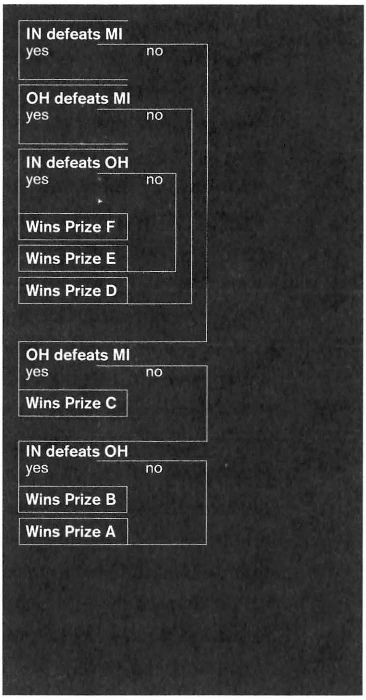
Verbal and diagrammatic forms of four different structures were presented. The most successful was the Example structure regardless of whether it was presented verbally or visually.

9.1 **Jump**

Verbal

1	If **Indiana** defeats **Michigan** go on to next step, otherwise go to step **7**.
2	If **Ohio** defeats **Michigan** go on to next step, otherwise go to step **6**.
3	If **Indiana** defeats **Ohio** go on to next step, otherwise go to step **5**.
4	You win prize **F**.
5	You win prize **E**.
6	You win prize **D**.
7	If **Ohio** defeats **Michigan** go on to next step, otherwise go to step **9**.
8	You win prize **C**.
9	If **Indiana** defeats **Ohio** go on to next step, otherwise go to step **11**.
10	You win prize **B**.
11	You win prize **A**.

Diagram (Flow)



72
Mayer, 1976a, previously cited at 60.

73
Mayer, 1989, previously cited at 58.

problem. In algebraic story problems the pictures capture the arithmetic representation of the problem (*see figure 8.2*) but do not help the student translate that quantitative representation into the algebraic symbol system. In support of this interpretation, Kulm et al. found that the picture helped students remember the words in the problem and helped them draw a sketch (create the representation given by the problem), but it did not help them create the solution representation necessary to solving the problem. Thus, such visuals, like the one developed by Gick and Holyoak in their 1980 and 1983 studies, fail to capture the essence of the solution.

A third example of the facilitative effect of making the implicit essence of a problem explicit is a study by Mayer[72] that also demonstrated that the best representation is not always the pictorial diagram. The problem was a logical one – there was a three-team tournament with six prizes obtained for various outcomes of the tournament. The subjects had to answer eight questions that gave either antecedents or consequences and asked for possible deductions (e.g., If team 1 defeats team 2, then could you possibly win prize X? If you won prize X, which is the best team?). Mayer devised four different problem representations and implemented them either verbally or pictorially (*see figure 9*). Two representations – Jump and Short-Jump – were a series of if-then propositions with the outcomes specified as GO-TO steps (the only difference between them was that Jump had eleven steps with intermixed "You win prize X" and "Who defeats whom?" statements, and Short-Jump integrated the eleven steps into five steps with both possible outcomes declared in each step). Mayer's third structure used if ... then ... else propositions structured into an indented, more integrated form. The fourth representation (called Example) was a contingency table that set up an advance organizer of all three games and then in each of six steps listed all possible winners; the diagram version was set up like a tournament sheet with alternative outcomes. There were clear differences in performance among the eight conditions (range of performance was 51 percent correct to 82 percent correct in the first experiment and 70 to 96 percent in the second experiment). There was, however, no clear superiority of diagrams over the verbal representations. In fact, in both experiments the best performance was the verbal version of Example, which made clearest the logical relations necessary to answer the questions.

Diagrams as organizational structures. Mayer, in a review of twenty studies involving thirty-one separate tests,[73] has also addressed the issue of the relation between visuals and problem solving. This research involved organizational and interpretational diagrams (*see figure 1*) in science and computer education and the subjects were tested on what they remembered (exact or verbatim memory), what they understood (conceptual memory) and whether they could apply what they learned to solve problems (problem-solving). The diagrams were consistently effective in facilitating conceptual memory and problem solving, but interfered with verbatim recall. This pattern of results is consistent with

9.2 Nest

Verbal | **Diagram** (Flow)

If **Indiana** defeats **Michigan** then

If **Ohio** defeats **Michigan** then

If **Indiana** defeats **Ohio** then
you win prize **F.**

Otherwise you win prize **E.**

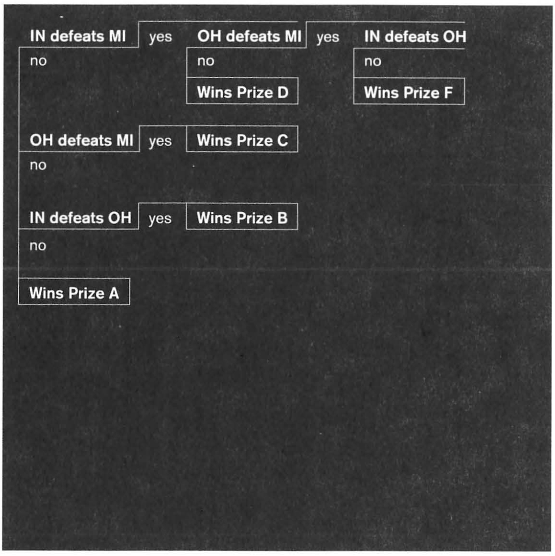
Otherwise you win prize **D.**

Otherwise
If **Ohio** defeats **Michigan**
then you win prize **C.**

Otherwise
If **Ohio** defeats **Michigan**
then you win prize **C.**

Otherwise,
If **Indiana** defeats **Ohio**
then you win prize **B.**

Otherwise
you win prize **B.**



9.3 Short-Jump

Verbal | **Diagram** (Flow)

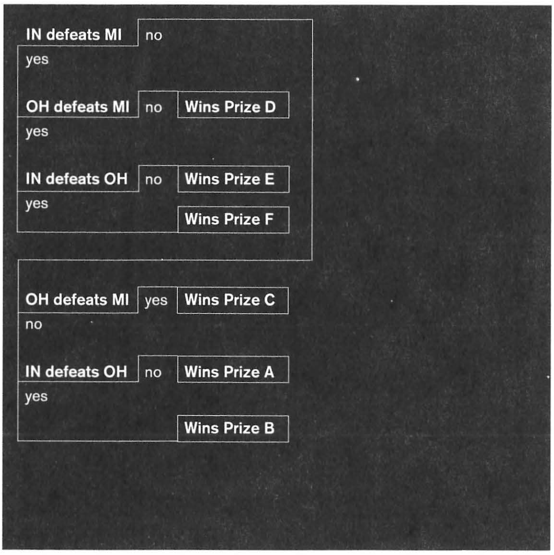
1 If **Indiana** defeats **Michigan**
go on to step **2**,
otherwise go to step **4**.

2 If **Ohio** defeats **Michigan**
go on to step **3**,
otherwise you win prize **D.**

3 If **Indiana** defeats **Ohio**
you win prize **F**,
otherwise you win prize **E.**

4 If **Ohio** defeats **Michigan**
you win prize **D**,
otherwise go to step **5.**

5 If **Indiana** defeats **Ohio**
you win prize **B**,
otherwise you win prize **E.**



9.4 **Example**

Verbal — **Diagram** (Flow)

There are three games:

1 **Indiana** vs. **Michigan**,
2 **Ohio** vs. **Michigan**, 3 **Indiana** vs.**Ohio**.

If the winners are
1 **Indiana**, 2 **Ohio**, 3 **Indiana**,
then you can win prize **F**.

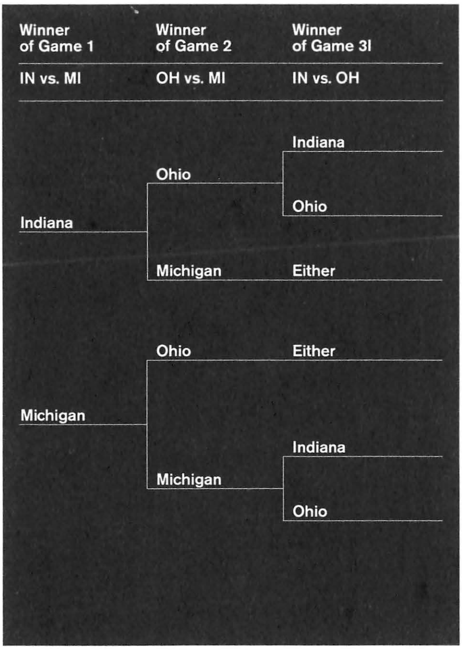
If the winners are
1 **Indiana**, 2 **Ohio**, 3 **Ohio**,
then you can win prize **E**.

If the winners are
1 **Indiana**, 2 **Michigan**, 3 **either team**,
then you can win prize **D**.

If the winners are
1 **Michigan**, 2 **Ohio**, 3 **either team**,
then you can win prize **C**.

If the winners are
1 **Michigan**, 2 **Michigan**, 3 **Indiana**,
then you can win prize **B**.

If the winners are
1 **Michigan**, 2 **Michigan**, 3 **Ohio**,
then you can win prize **A**.



74
Levin, Anglin and Carney, 1987, previously cited at 54.

75
Kieras and Bovair, 1984, previously cited at 57.

76
Holliday, W.G., L.L. Brunner and E.L. Donais. 1977. Differential cognitive and affective responses to flow diagrams in science. *Journal of Research in Science Teaching*, 14, 129-138.
Kulhavy, R.W., N.H. Schwartz and S.H. Shaha. 1983. Spatial representation of maps. *American Journal of Psychology*, 96, 337-351.
Taylor and Thompson, 1982, previously cited in 14.
Winn, W.D. 1981. The effect of attribute highlighting and spatial organization on identification and classification. *Journal of Research in Science Teaching*, 18, 23-32.
Winn, W.D. 1982. The role of diagrammatic representation in learning sequences, identification and classification as a function of verbal and spatial ability. *Journal of Research in Science Teaching*, 19, 79-89.

the explanation that the visuals help students create a conceptual model and reorganize what they have read to fit that model. Insofar as the model is effective, it should – and does – help students understand the material and use the material to solve problems. Because the visuals encourage reorganization of the textual material, students in such conditions would be expected to show worse straight recall.

What is it about Mayer's visual models that makes them effective? Simon's two principles are certainly involved – Mayer's visual models often do organize students' search through elements of a concept and they do make explicit that which is implicit in the text (e.g., showing sparse versus dense dispersion of molecules as differing numbers of circles with downward pointing arrows in same-sized containers to show the difference in gravitational pull). Some of his diagrams, however, derive their power from their organizing and integrating nature; that is, they abstract the essential properties from the text, organize them, and show the relations among the concepts. The spatial layout characteristics of a visual permit those elements and their relations to be represented simultaneously – something text can never do. This integrative function is, of course, making the organization of a topic explicit, so it may not be different than Simon's second principle, particularly since the current state of research has not shown that it operates independent of the explicit visual/implicit textual principle. It may be, for example, that the capacity of the visual diagram to denote the conceptual structure of a topic (i.e., the parts and their relation to the whole) may still facilitate relative to text, even when the text explicitly describes that structure.

Noninformational aspects of visuals

Research on the effectiveness of visuals has demonstrated clearly that visuals that clarify text promote learning. Does that mean that the only differences among visuals that affect their effectiveness is their informational content? If so, their aesthetic values, their vividness, their concreteness would be irrelevant. There is little research exploring these issues, but what is available suggests that other variables are largely irrelevant.

The research described earlier found that pictures that serve only a decorative function do not facilitate memory.[74] Nonetheless, it might be that visuals that have both informational content and are vivid or aesthetically pleasing might be more memorable than those with the same informational content but dull, unappealing presentation. There are remarkably few studies that address this issue in any way and the few that have done so have not provided strong support for a vividness effect. Kieras and Bovair[75] compared two models of an electronic device. One was incorporated into a Star Trek fantasy – certainly vivid – whereas the other was a straightforward technical diagram. There was no difference in effectiveness. Several studies have compared diagrams with elements identified by words (dull) or pictures (vivid), but the findings have been inconsistent.[76] Moreover, the pictures may have served an informational role in some of these studies (e.g., drawings of dinosaurs

77
Tufte, 1983, previously cited in 5.

78
For discussion of other principles, see Levie, W.H. 1987, previously cited in 55; Levin et al., 1987, Research on pictures: A guide to theliterature. In D.M. Willows and H.A. Houghton, eds. *The Psychology of Illustration* (volume 1, Basic Research). New York: Springer-Verlag, 1-50, previously cited in 54. Readence, J.E. and D.W. Moore. 1981. A meta-analysis of the effect of adjunct pictures on reading comprehension. *Psychology in the Schools*, 18, 218-224. See also Rusted, 1984, previously cited in 53; and Winn, 1987, previously cited in 6.

that cued the direction of the evolutionary sequence). Related to this point, attempts to make graphs and diagrams more aesthetically pleasing or more eyecatching often result in less effective or even misleading graphics.[77]

Thus, the importance of aesthetic or attention-getting properties of visuals is largely unexplored, but the available evidence suggests that, so long as the informational content is attended to, even dull or unappealing visuals will be effective in their educational function.

Practical implications of scientific studies of visuals with text

The research reviewed above, when considered as an integrated whole, suggests three principles for designers.

Principle 1:
One Picture Is Not Always Worth More Than 10,000 Words

It is a mistake to assume that, just because visuals often help learners to remember and understand information and to solve problems, that visual presentation is always effective. In general we can conclude that visuals will not help or will actually interfere with learning in the following circumstances:

- when pictures are merely decorative
- when the essence of the problem is made as clear or clearer by a verbal presentation than by a visual presentation
- when visuals fail to elucidate the phenomenon, as explicated in Principle 2.

This list of circumstances in which visuals do not facilitate learning is not meant to be exhaustive, but rather to illustrate that such circumstances exist.[78]

Principle 2:
Designers' Primary Consideration Should be to Produce a Representation That Elucidates the Phenomenon

The clearest conclusion from this research is that visuals facilitate learning and problem solving if they help readers make sense of the material. Three ways in which visuals can do this have been identified:

- when the visual helps learners search through multifaceted information
- when the visual makes explicit crucial features of the solution that is implicit in the text
- when the visual organizes and integrates complex information.

In addition, visuals facilitate memory if they represent the text adequately even if they do not fulfill one of the above criteria.

To make visuals that meet this principle will require that designers' creativity be grounded firmly in an understanding of the content of the material.

79
Gould, J.D., S.J. Boies, S. Levy, J.T. Richards and J. Schoonard. 1987. The 1984 Olympic Messaging System: A test of behavioral principles of system design. *Communications of the Association for Computing Machinery*, 30, 758-769.

Principle 3:
Features Not in the Service of the Informational Content
Must be Used with Care

The research does not give clear guidance about how to make informational graphics decorative and attention-getting, but it does make it clear that purely decorative pictures will not facilitate textual learning. There apparently is a danger that decorative and attention-getting elements may make a visual less informative. A safer approach would be for designers to put their creativity into producing the best representation of the crucial informational content.

User-based Design

Clearly, when scientific research yields clear, consistent results, they can be used as guidelines for effective design. Nonetheless, as the previous section indicated, designers will often find themselves in situations in which the well-established scientific principles are not sufficient or applicable. In those instances, user-based design is the only answer.

User-based design starts with the premise that designs should be maximally effective for the users of the design. It accepts the limitations of our impressionistic reasoning and insists that users' cognitions and needs be incorporated from the beginning of the design process. This is typically done by creating "quick and dirty" scenarios, models or prototypes for the user to try rather than implementing the entire project and then testing its effectiveness. If the results are disappointing, changes can be made, a new prototype developed and tested before the time, effort and expense is put into the implementation of the entire project. The steps of redesign and testing can be repeated as often as needed. Implementation of the design is postponed as long as possible, because errors can be corrected more easily while still in prototype.

A nice example of user-based design in computer software development incorporated early focus on users and tasks, empirical measurement and iterative design into the design of the multilingual Olympic Messaging System (OMS) used at the 1984 Olympic Games in Los Angeles.[79] The OMS allowed Olympians (the main user group) to send and receive voice messages among themselves and to and from their family, friends, former coaches, etc. throughout the world. The design team started by developing written scenarios of simulated "conversations" on the proposed system – their first prototype – and gave them to people to comment upon. Users could understand the functions of the system because they saw their behavioral consequences. It also allowed users' input at a time when their comments could influence the design and before any programming was done. They found that many of the functions that the designers thought crucial were unimportant to users. In the same way, the design team tried out drafts of user guides before finalization – their second prototype. This also brought the system to potential users in a

80
For technical documentation, see Carroll, J.M., P.L. Smith-Kerker, J.R. Ford, and S.A. Mazur-Rimetz. 1988. The minimal manual. *Human-Computer Interaction*, 3, 123-153.

For product design, see Powell, E.N. 1989. *Designing for product success: Essays and case studies from the TRIAD design project exhibit.* Boston, Massachusetts: Design Management Institute.

Also Mantei, M.M. and T.J. Teorey. 1988. Cost/benefit analysis for incorporating human factors in the software lifecycle. *Communication of the Association for Computing Machinery*, 31, 428-439.

form that facilitated users' responses. It took two hundred iterations of the English version of the guide to produce the final version, which shows you how unanticipated the needs and issues of the audience can be. This "try-it" approach was used at every step of the development process – they simulated the push-button telephone keys, the interactions between user and system, and the kiosk in which the system was to be placed. After the working prototype was developed, it was subjected to a number of tests with about one hundred participants, which identified bugs, additional types of help needed, etc. Finally, they ran "try-to-destroy-it" tests plus several kinds of field tests with ten computer science students from a local college.

That the steps taken by the OMS designers were successful is demonstrated by two facts. First, the final form of the design was not anticipated by designers. Users did not want functions designers thought critical and designers' vision of an easy-to-use system was too difficult for the users. Second, the resulting system was unusually successful – forty percent of the Olympians used it at least once, and it was used an average of one to two times per minute, twenty-four hours per day, a record use of electronic mail by noncomputer users.

Although this example described the development of a software product, the same principles have been used in technical documentation and product design.[80] Clearly, the techniques are widely adaptable. As an example of how it would work in producing graphics, consider the DC subway signage project. If user-based design had been used in the DC subway project, prototypes of the signage would have been presented to users for brief periods of time (equaling the amount of time the average rider would have as her train passed through a station) and the users would have been asked to read the signs. The users' inability to read the signs would have been obvious. (Of course, we are dealing from hindsight here and so know exactly what to test to uncover the error. In the normal circumstance the designers would probably have had to discover the reading problem while testing scenarios.)

Principles

Prototyping, Iterativeness, and Postponement of Implementation

The essence of the prototype model is to create preliminary versions of the product to try before deciding on a final design. In the OMS project the prototypes included behavioral scenarios of how the system would work, the manuals, the keypad interactions and the kiosk. Notice that it often takes some imagination to develop these prototypes. Each prototype was tested and changes incorporated into a subsequent prototype, which was in turn tested. A working prototype was not created until the simulated prototypes had answered all the questions the designers and users could generate. The working prototype was also tested and changed as a result of that testing. Only after all aspects of the design had been

Continued from page 348.

39 million 999,999 Years

365 days
22 hours 40 minutes

One of the things
we looked at
was the planet Jupiter.
Huge by Earth standards,
it is still
a tiny fraction the size
of a star.
But it is an impressive object
in a small telescope,
and as we looked at its four bright moons
and bands on its surface,
our Kamikaze Photon
passed its orbit.

39 million 999,999 Years

365 days
22 hours 59 minutes

My friends went home,
I closed up the big telescope,
and settled down in my star chair.

Continued on page 378.

81
Powell, 1989, just cited.

82
Shriver, K.A. 1989. Document design from 1980 to 1989: Challenges that remain. *Technical Communication*, Fourth Quarter, 316-331; and Wright, P. 1989. Can research assist technical communication? *Proceedings of the 1989 International Technical Communication Conference (RT3-RT6).* Washington, D.C.: Society of Technical Communication.

tested by appropriate user groups did they actually implement their design and systematically test it.

User-based design is often criticized as too expensive. Its proponents, however, claim just the opposite. Their claim to economy is twofold. First, by creating prototypes and incorporating user testing from the first to last prototype, many errors can be detected and corrected before implementation; consequently fewer errors need be corrected after manufacturing has begun, development cost is lower and, often, development time is shortened.[81] Second, the resulting product is more usable and thus often is preferred by customers.

Exploration of users' behaviors and thoughts

In a user-based design strategy one finds out whether one's design is communicating by presenting prototypes to users. Note that in this strategy the designers do not describe their ideas and ask users whether they think a proposed design will work. Rather the designers present a concrete example of the product and have users use it (or at least put themselves in the role of using it). In the OMS example, they did not simply ask the users which of a list of functions the users wanted (which often does not work because users can't always understand what the designer is asking). Rather, they presented users with scenarios, which allowed users to experience the interface behaviorally.

User-based design is not equivalent to considering one's audience, because in the former designers actually interact with users and in the latter, they intuit what the audience is like. People's intuitions are informed and distorted by our impressionistic reasoning biases discussed earlier. Therefore, it should not be surprising that considering one's audience has been found to be inadequate.[82] Nor is user-based design equivalent to market research, which typically surveys people's needs and desires and is thereby limited to their conscious desires, based on their limited previous experiences and on their limited ability to understand the lingo of an unfamiliar area. Market research may sometimes be a useful adjunct to user-based design, but its goal – to find out what will sell – encourages a focus on easily advertisable functions rather than on ways to make a product truly more usable. Thus, to continue the software example, market research would determine whether a messaging system was desirable and would likely result in a long list of desired functions and a recommendation that it be user friendly. In contrast to user-based design, it would not yield the information that the system became usable for its naive users only when functionality was reduced to a bare minimum (e.g., the final version had no way the sender could find out if the message arrived and no way for the sender to insert text if s/he had forgotten something s/he wanted to say, both of which are standard features in many electronic mail systems).

User-based design encourages innovativeness in user-oriented features in two ways. First, observing and interacting with users working with prototypes teaches the designer how users think about – and misunderstand and get confused by – both the form and the content of

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Continued from page 376.

40 million years

And then it happened.
Forty million years,
untold trillions of miles,
came to an end in a single instant.
I pointed the aluminum tube
in the direction of the Sombrero galaxy;
I looked through the eyepiece.
Five hundred millimeters from my eye
the photon passed
through the beautifully curved glass lens
which changed
the final millimeters of its course
so that it passed
through the eyepiece
and into my eye.
There it collided
with a rod changing my chemistry.
The photon was destroyed.
Its mission complete.
The chemical changes
it generated in my eye caused
a small electrical impulse
to go to my brain,
and as that impulse combined
with many similar impulses
from many similar photons
which had also traveled
for 40 million years,
I breathed a sigh and thought,
"There it is.
That little blur of light
is the Sombrero Galaxy."

Continued on page 380.

the design. Second, designers are likely to dismiss their creative ideas for designs for fear that they would not be effective. In user-based design it is easy to get an idea of how such ideas might work by presenting them informally and it is possible to develop such ideas through iterative testing.

Thus, user-based design provides input concerning users in two ways that no other part of design can do. First, it solves the communication problem between designer and user by setting up situations in which users can provide behavioral evidence of their functioning within the system. No designer intuition, user survey or interview can do that. Second, it provides a unique opportunity for designers to come to understand the cognitive processes of others and to create innovative solutions to users' problems.

How user-based design controls impressionistic reasoning

The example of the development of OMS demonstrates ways in which user-based design decreases reasoning errors:

- The designers did not rely on their own experiences or on the accounts of the experiences of a few colleagues or friends. They collected systematic data from a broad spectrum of people, ranging from the naive eventual users to experts.
- They did not rely on their own expert opinion about the desirable characteristics of a messaging system, but rather tested users at each step of the design development.
- At critical steps substantial numbers of users were tested (and presumably their data considered as a whole). Thus, the designers could consider group data statistically rather than having to rely on multiple case studies.

These characteristics provide the opportunity for designers to control their impressionistic reasoning biases. By testing a variety of users in different ways, designers can create the conditions identified as effective at curbing biases. They can

a *provide for themselves consistent and specific feedback,*
b *think through alternative explanations for their particular design hypotheses and create some feedback for them and*
c *search for a complete picture of the situation by testing a variety of users on a variety of tasks.*

Note, however, that collecting these kinds of information is not inevitable in user-based design. Designers must consciously incorporate these into the process.

User-based Design versus Scientific Inquiry

It is important to understand that user-based design differs from traditional scientific research in many important ways beyond the obvious one of being done in the field. Designers have neither the time nor financial resources to test rigorously every aspect of their design, because the goal of user-based design is to solve design problems for the particu-

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Continued from page page 378.

Conclusion

Writing this all seems so pitifully inadequate to me.

I'm sure there will be physicists and astronomers out there who feel I have taken too much liberty with quantum mechanics as they now understand it when I speak of this journey as if we really could track a single photon and see it pass the objects mentioned. I trust they will allow for a certain amount of poetic license.

What I've tried to convey in the best way I know how is a perspective on time and distance. But in the final analysis, I know I have only scratched the surface. I cannot even adequately convey those things I think I know, and I certainly do not claim to know how far 40 million light years is.

How in the world can I know it? There is nothing in my experience to which I can compare it.

And that is the real message I want to communicate. I want to convey the incredible difficulty in even beginning to show someone the world that modern science is revealing. It is a world strange beyond belief and yet I think we all – scientists and non-scientists alike – are truly ignorant of it.

We're attempting to describe the indescribable. We kid ourselves by inventing words, such as infinity, eternity, light year, parsec, and mathematical notations, such as 10-to-the-23rd. These allow us to gather some sort of picture of the new reality. They roll off our tongues glibly.

And all the nice little analogies that the scientists and the science writers come up with can only nudge us in the direction of this reality; but they leave us so far short of it, it is pitiful.

And there are some things perhaps better left unsaid. Relativity theory, for example, tells us that from our perspective, that photon has been journeying for 40 million years. From the photon's perspective, it has been traveling at the speed of light and at that speed no time has passed. It is all one in the same instant. I have been journeying these 40 million years, and at last the atoms that currently make up me (I'm not sure if they're the same ones that were me on July 9, 1941) – these atoms have at last crossed the path of that photon which was here and at the Sombrero Galaxy all in the same instant.

It is mind boggling, of course. And in studying these things, I find that I renew a delightful sense of child-like wonder.

Albert Einstein once said:

"I want to know
how God created this world.
I am not interested in this
or that phenomenon,
in the spectrum of this
or that element.
I want to know His thoughts;
the rest are details."

What lovely arrogance!

83
Gould et al., 1987, 762, cited in 79.

84
Ericsson, K.A. and H.A. Simon. 1984. *Protocol Analysis: Verbal Reports as Data.* Cambridge, Massachusetts: The MIT Press.

lar project. That typically means that the experimental control necessary for the establishment of a scientific principle is not used. For example, Gould et al. found that four audio alternatives on an audio prompt was too many (e.g., "press 1, listen again; 2, listen to another new message; 3, send a message; 4, hang up.").[83] In their next prototype they reduced the alternatives to three, but they undoubtedly made other changes as well. Their subsequent version worked better (fewer problems, more satisfaction) than the previous one and that was sufficient for their purposes. If this had been a scientific inquiry, it would have been necessary to isolate the change in the number of possible options from other changes and to test the two versions systematically – with a substantial sized sample, statistical analyses, etc. What such a scientific inquiry permits that is impossible in the user-based design is the conclusion that one should not use more than three alternatives in a voice-messaging system. The danger in user-based design is that the designers may remember that principle as substantiated and use it blindly in their next design. This would be an error – the appropriate response would be to keep it on the list of things to be checked out in user testing in the next design, because the three-principle may have been a fluke of this particular situation.

In addition, the less rigorous qualitative techniques typical of protocol analysis are usually more appropriate to user-based design.[84] That means that many of the important controls of scientific research – appropriate and extensive sampling, experimental controls and statistical analyses – are not used.

Thus, it is crucial in user-based design that designers understand that the principles they discover in the development of a particular design are more tenuous than is true in scientific inquiry. They have not tested the influence of any one principle independent of other principles, they often have not tested enough users to have a scientifically valid sample, they have usually not tested statistically the effect of that principle, and they have certainly not tested the generality of the principle (by testing in different laboratories with different investigators and different content material, etc.).

While user-based design helps designers to overcome the biases of their impressionistic reasoning relative to no testing, it still allows impressionistic reasoning biases – the tendency to form strong beliefs on little evidence, the tendency to settle on the first hypothesis without considering alternatives, the tendency to look for confirmatory data and ignore disconfirmatory evidence, the failure to obtain or consider, when available, all the evidence or evidence from all the subjects.

This discussion should make it clear that user-based design can not replace scientific research. The development of scientifically valid general guidelines can help to narrow the range of possible prototypes. Furthermore, the more one understands about the perceptual and cognitive processing of humans, the better one's intuitions about effective ways to communicate are likely to be and the better one's initial prototypes will be. Finally, empirically-based guidelines, in the hands of

85
Clark, K. and T. Fujimoto. 1989. Overlapping problem solving and product development. In K. Ferdows, ed. *Managing International Manufacturing.* Amsterdam: Elsevier. See also Powell, 1989, cited in 80.

86
Gould et al., 1987, cited in 79.

87
Duffy, T.M., T. Post and G. Smith. 1987, May. An analysis of the process of developing military technical manuals. *Journal of the Society for Technical Communication,* 34, 70-78.

88
Sherwood, B.A. and J.H. Larkin. 1989, Spring. New tools for courseware production. *Journal of Computing in Higher Education,* 1, 3-20.

a designer who understands his own human biases and limitations, can help him or her to correct those biases.

Personnel issues in user-based design projects

User-based design requires that one unit maintains control over all aspects of the design. In the development of the OMS the design team developed all aspects of the project, the kiosk, the audio system, the computer implementation and the user documentation. In a traditional management scheme, a product is handed off from one department to another in a linear fashion, which discourages the use of iterative design and often results in less effective products.[85] Gould et al. pointed out that they would never have been able to rewrite the manual two hundred times if they had had to negotiate with another department.[86]

The use of a team approach can be very effective in many settings. For example, in the development of textbooks, the authors and designers need to work together from the start of the project. Much of the user feedback will apply to both text and visuals and iterating both together will likely build a stronger product. An alternative approach is to teach skills required in the user-based orientation to the expert, as Duffy, Post and Smith[87] argue with respect to documentation and Sherwood and Larkin[88] argue in reference to interactive computer software. It seems likely that both strategies can be effective. Specifically, I would predict that two variables determine whether a team or single designer approach will work better. Team design apparently works better in situations in which the necessary expertise is too wide to be held by one person, e.g., in complex manufacturing situations, and in situations in which group problem solving is particularly advantageous, e.g., in situations in which different perspectives may interact synergistically. Development of solutions by the individual designer will be effective when those conditions do not obtain, but only if the designer has the necessary array of expertise – s/he must understand the subject matter domain and user-based testing as well as design.

Summary

The problem addressed in this paper is how to ensure that visual representations will effectively communicate to their intended audience. Designs and design principles developed by expert designers sometimes promote effective communication and sometimes do not. Because presumably designers want their designs to communicate effectively, the failure must be one of judgment. A perusal of the psychological research on judgment makes it clear that the problem lies in the way humans typically reason when they make judgments. This research can be summarized by the following comparison:

When forming one's initial hypothesis:

- People *should* consider all possible positions, using all available information

- People *do* rapidly form initial impressions, based primarily on
  - a *their own personal experiences and those of one or a few individual cases (even when statistical data are available),*
  - b *the opinion of experts and*
  - c *whatever is salient, motivated, recent or expected.*

After one's initial hypothesis is formed

- People *should* consider systematically all information available, not just that which confirms their hypotheses. Special attention should be paid to finding disconfirmatory data and exploring alternative explanations. The most convincing evidence is statistical – similar information gathered on a large number of people.
- People *do* try to conserve their first impression by seeking only confirmatory evidence and by overevaluating that evidence. They ignore statistical data whenever any alternative is available.

Controlling these judgmental biases is not just a matter of becoming aware of the problem. Effective techniques for curbing biases are

- a *seeking and evaluating consistent and specific feedback,*
- b *explicitly working at debunking one's beliefs by searching for disconfirming evidence or alternative interpretations and*
- c *searching for a complete picture of the situation by attending to a variety of instances.*

Two methodologies have been developed that help people accomplish these goals – scientific research and user-based design.

Scientific research is the more powerful debunker and the more time-consuming. It has developed over the centuries as a set of techniques by which errors in reasoning about empirical phenomena can be corrected. Discussion of the basic method is beyond the scope of this paper, but guidelines for the evaluation of bodies of research were provided and exemplified in two areas of research on the effectiveness of visuals presented with text. Because the findings are consistent and extensive, practical principles could be derived from these areas:

- Visuals sometimes are ineffective or even interfere with learning. Examples of such situations are when pictures are merely decorative or when the visual fails to capture the essence of the situation.
- Visuals facilitate learning and problem solving when they
  - a *help learners search through multifaceted information,*
  - b *when the visual makes explicit crucial features of the problem that is implicit in the text and*
  - c *when the visual organizes and integrates complex information.*

In addition, visuals facilitate memory when they represent the text even if they do not fill the above criteria.

- Features not in the service of the informational content can be counterproductive.

When scientific principles are not available, designers can use the methodologies of user-based design to help guard against judgmental reasoning errors. In user-based design, the designers collect data (often by informal means rather than by the rigorous formal data collection techniques of science) from users at various stages as the design is developed. The designers develop a rough prototype, scenario or simulation that puts the user more or less in the position that they would be using the finished product and asks them to respond as if it were the finished product. This feedback provides the basis for subsequent revision of the prototype and the cycle is repeated until the designers have answered all their questions and those of the users. Although user-based design lacks the rigorous methodological control of scientific research and thereby is more prone to error, it can improve on typical human reasoning in that it seeks behavioral feedback from users (the more systematic and carefully this is done, the more likely the outcome will be valid) and provides an opportunity for designers to explore alternative hypotheses and alternative solutions.

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A view long venerated in philosophy and science separates image and word into separate worlds. Images resemble their referents or ideas of their referents. They present themselves all at once and lack clear linguistic procedures like syntax for ordering and decoding. Words, on the other hand, describe rather than resemble and are read linearly in time. Images are rich but diffuse in meanings, while words have less dense meaning and are more precise. The two do not translate directly into each other. These dichotomies reflect an ideological split between literal and metaphorical, true and fictional, scientific and artistic. Word and image often operate as unwitting stand-ins in this struggle. But the differences between word and image are smaller than they might seem. One area where the function of image is most like word is in graphs. The graph is a culturally given way of reading – a visual organization as language. It provides a means of systematically thinking about how we use such language without realizing it. Is there an understanding of how graphing as a technology functions? Investigation of this leads to considering ways of looking at and of understanding visual organization in order to put forward some alternative goals.

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Peter Storkerson, pp. 388-433,

1
Language is often described as either a verbal form, related by ear as distinct from eye, or if written, as an encrypted form. These distinctions cleave language to avoid recognition of the fact that written language is performed visually.

2
In this article, graph is the largest term, it contains map, chart and diagram.

Explicit and Implicit Graphs: Changing the Frame

Peter Storkerson

Graphing and Taxonomy

This article explores aspects of graphs and maps as forms of inquiry and discourse.[1] Recent concern with the quality and clarity of map and chart making, seen particularly in the work of Edward Tufte, focuses on presenting data and on understanding that information must tell a story. Such work uncovers some problems that lie beneath presentation, in the process of conceptualization upon which graph making is habitually based, both in terms of what constitutes knowledge, and in terms of expressive visual form. Graphs, as we use them, rely on strict rules of organization and of logic, which depend on a particular world view. That world view is dominated by a belief that the explicit propositional discourse of science is the valid model of language and thought.

Graphs[2] are abstract documents. In them certain characteristics of a complex object are carefully selected or emphasized in relation to a particular argument. Their ritual forms declare them as discourse – they provide distinct ways of reading and interpreting. Graphs, charts and maps abstract characteristics to provide models of their objects for analytical purposes: The United States becomes a line shape with a series of boxes and dots; an experiment investigating the conductivity of a metal as affected by temperature becomes a curve on paper; the buying and selling of goods becomes a series of bars placed next to each other. There are many forms of discourse: the novel, poetry, newspaper and journal articles. Some, for instance, are fictional, while others are informational. Graphs are formal, informational, propositional and explicit. They are used to present glosses of often large amounts of data in ways that give the data a unity of expression that can be quickly grasped. The graph can also precede or create what it describes.

Place and procedure

The chess board is a graph charting a configuration of pieces – each piece a bundle of moves with an implied structure, positions defined by the rules of the game (*see figure 1*). The game consists of all possible positions and moves. Any particular position consists of all possible subsequent moves and outcomes. Moving chess pieces mechanically

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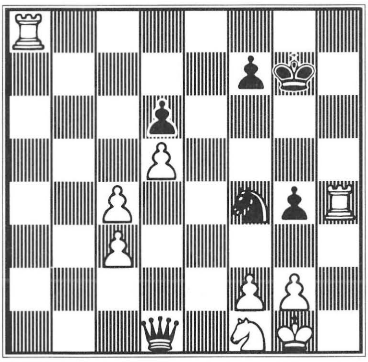
Figure 1 A diagrammatic presentation of chess.



explicates what is already implicit in the position. The apparent physical reality of the board and pieces and the procedures of the game merge. Graphs present concepts. Geographical maps present methods of getting from A to B. The resemblance is to an idea. But it takes for granted the typical geographical map that accepts the physical form as given, preceding the technology or rules of construction. (Does the United States really look like any map?) The rules have been so successful that they recede into the background. Like chess boards, maps and charts are conceptual or procedural documents, physical manifestations of logical constructs. A new method of travel radically alters the relationships between points as transportation maps often show. Where a train route is placed on top of a map of topography, topography remains the organizational principle. Increasingly, transportation maps disregard topography to simplify their statement.

Graphing and reportage

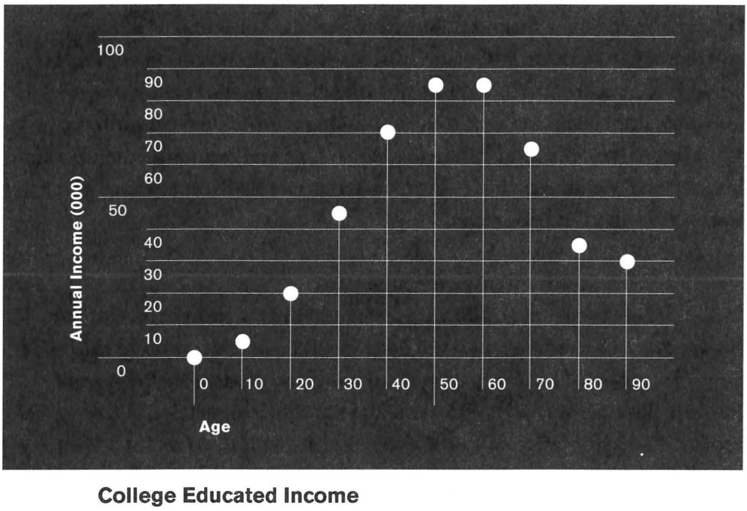
Reportage is graphing: a giving of form, a transportation and translation of experience into a matrix or plane of conceptually informed variables where it becomes data in an analysis. That plane forms and informs the structure of the inquiry, the resulting report and the reported reality. The experiences that form data are reconstituted as functioning elements in the conceptual structure of the inquiry or story. That structure functions not only as a conclusion, but more importantly as an organizing principle, a beginning – it is a way to select, locate and configure data into a coherent picture. It is a way of constructing a problem. The data serve as bricks in the hands of the architect-builder. But it is the structure of the building that is visible, a structure which the materials must be able to support, but which they do not imply.

Inquiry is a way of explaining things as if the things themselves were the focus of attention, but that is not the only point of view. In *Art as Experience*, John Dewey points out that we often mistake works of art for their tangible results, whereas the works lie in the ways they change how we see the world.

Point of view is well established in twentieth century thought from the phenomenologies of Husserl and Merleau-Ponty, and the philosophy of language that Wittgenstein founded to gestalt psychology and the semiotics of Umberto Eco and Roland Barthes. It argues that the world is experienced through the mediation of perception. Experience is possible through shaping it in specific forms. Point of view is fully constituted by perceptual rules. Questions about the outside world are also about the perceiving subjects (us), and the communication technologies for sensing as well as media that provide for culturally approved ways of looking.

But this point of view is foreign to the philosophical topology of factual inquiry at least as it is usually practiced. That practice seems to rely more on positivist principles. Inquiry emerges from the context of problems, not first as a way of knowing, but as a way of exploring. (It often emerges as a way of knowing from the standpoint of the specialist

Figure 2 A hypothetical chart.



whose professional life is given over to the maintenance and practice of a field of inquiry, who, thus, has a personal stake in that particular perspective.) The pragmatic bias of inquiry is toward a single or a clear set of interpretations which can be put into practice.

Ways of thinking are as much matters of form as of content. The chess board plays its part as context for the game played upon it and the rules for constructing graphs define the rules by which the knowledge they impart is constructed. Likewise, a printed page, with its rows of horizontal lines of text, frames its content. The printed page now in view, for instance, creates the possibility of the novel and its linearity bears very little relation to the structure of conversation.

Explicit discourse of viewing.

To summarize, the graph is a form of inquiry and of discourse: a way of asking and a way of speaking. The enquirer has selected this way of framing the question, while the map maker has chosen it as a way of communicating. Graphing has its most explicit expression in its physical or graphic form. But graphing is not just some sort of naive picture – it is an implicit set of directions from author to reader on how to read or interpret the page. It is also explicit, consider, for example, a legend which directs the reading. As a form of language, a graph is a ritual by which only certain aspects of presentation are considered relevant and certain ways for reading them are defined. The graph discloses its contents literally, not metaphorically. Within the graph, terms or variables define and enclose data with unequivocal, clear definitions. The graph defines the ways in which data are related to each other by their physical relationships.

Thus, the graph is explicit in two ways. There is a strict and known set of rules by which it is to be read, and it is read as a series of explicit statements. There are no metaphoric ambiguities or figurative entanglements within it. This explicit, positivist world is a major part of its *Weltanschauung*. Some rules are communicated by legends, but most are learned in school, like learning mathematics, or like learning to read street signs.

In the fictitious example at the left (*see figure 2*), we would say that there is a single clear reading. We expect to consider the physical relationships between income (the vertical axis with hash marks) and numbers as a depiction, reckoned against (the horizontal axis with hash marks) figures and age. The curve mediates them and relates them as orthogonals. Vertical and horizontal axes are obvious because it is identified as a graph. How is relevance defined? Income and age both have specific meanings: age is chronology not maturity and income (both earned and unearned) is dollars received. Any other meanings that might apply in other sentences are excluded. The constituents or variables of the graph have clear and unequivocal meanings. These meanings are sometimes defined, but more often they are customary understandings. They may be given specific definitions peculiar to the graph, or they may be equivocal outside it, but within the graph, they constitute rules for

the association of data. The rule of implicit justification forces the graph to project a compatible world.

What can be said about the terms brought together in the graph can also be said about its use of space. It is a ritual use of space implying a single interpretation of spatial organization. Type style, color, the texture of the paper and a range of levels of meaning used by the artist or designer are irrelevant here. This graph would mean the same whether hand drawn on paper or scratched into the dirt. It is a very specific reading – a ritual of intention and attention.

Contents and Form

Anything outside the box or visual area the graph occupies is outside its conceptual space. Even the characterization of what the graph is: i.e., career income history, is outside the graph, appearing as a title, it sets a context for how the graph is to be read. The title is the next level, the graph in a larger context, it is, perhaps, a conversation about the joys and advantages of education. Titles make a graph explicit by helping to indicate that it is a graph, not some sort of art, and by giving it a linguistic standing like monetary expectations of the college educated. In this way, graph findings are a phrase and they can be used in other sentences.

All elements within the graph are equal, and each can be independently varied. No information is hidden and nothing is modified or viewed as logically subsequent to anything else, at least not within the logic or taxonomy of the graph. In the case above, age and income can be varied independently. You can move back and forth on the line in any way you wish. The decisions may be irreversible in life, but they can be reversed here, as "what ifs." Moreover, the graph includes implicit relationships between its members. If I create a map in which Boston is 200 miles from New York, New York is 200 miles from Washington, and Washington is 200 miles from Boston, the three must form an equilateral triangle.

As far as visual simultaneity is concerned, we are not entirely free to rove over the page. There are certain discrete packets of information that get considered with respect to each other, some are logically prior to each other. On the other hand, the unity of gesture aids examination from many different angles to probe, question and extend. Like any good proposition or formula, a graph can teach us things we didn't know we knew. As we will see, this is a small subset of the possibilities, and it contrasts sharply with visual art in which each gesture is seen in the light of others.

Layout: a visual form of taxonomy

We may not usually look at pages as taxonomies, but, like other objects, pages are organizations of parts and parts of organizations. Advertising pages are carefully designed as taxonomies and arranged in a fashion which offers the reader a particular reading. Order in the visual

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Figure 3 An advertisement as diagram.

3
For an illustration of the complex meaning of text juxtaposition, see Spivak, G.C. in Derrida, Jacques, *Of Grammatology*, Baltimore: Johns Hopkins University Press, 1967, translator's preface, p. xii.

field attests to the existence of such taxonomies. Part of the mystery is that the meanings of many visual taxonomies remain obscure. The accounts of practitioners such as designers and typographers reveal some of their procedures, but the internal structures remain surprisingly implicit.

Pointing out the universality of taxonomy does not dilute or trivialize it. Any sentence, paragraph or block of text that can be glossed in a word, can function as a part of speech in a new syntactic structure made up of the other text units or blocks. The taxonomy or syntax of a page demonstrates clear relationships, whose description may be elusive. These relationships may mirror the relationships among words. They may also be as open to multiple interpretations as are words themselves.[3]

Graphs within graphs

In the concentric graphing (see figure 3), the three x-y graphs of curves, taken together with their titles and legend, are resolution comparisons, the headline "High Resolution" communicates this clearly. The two pages below top-rated speed are not of importance in themselves (even at full size, their texts are not readable) but together, as their head indicates, they are exhibits. The bottom chart is just a series of words which the headline indicates are fonts. Each of the three has a subscript specifying what is meant, e.g., 135 fonts are standard on all LaserMaster plain-paper typesetters. Together, the three form implicit histograms: one of printer resolution, one of speed, and one of font availability.

Taken as a group, they form a large chart that communicates that LaserMaster offers more value. Here the knowledge of comparison is so taken for granted that the real alternative, e.g., laser writer, is not even mentioned. Like any statement, it can be heard as the answer to an implicit question.

Additionally, the advertisement functions graphically. The eye does not follow each word and read it as if it were text, line-by-line down the left hand column. Discrete packets of information, each of which is self-sufficient as a meaningful statement, is visually apparent by hierarchy and organization through a variety of devices including color, size, border and shape. The text on the right, which is meant to be read linearly stands in sharp contrast, in size, type appearance, grammar and style. This example page stands as a testimony to the inadequacy of linear reading and the lack of a syntax for reading pictures.

The page as a whole functions as an implicit graph. Its rules and claims are unstated, and the relationships between elements are up to the interpretation of the reader though here the reader is primed to make certain choices. In implicit graphs, the relationships between elements, especially text blocks are often indeterminate or open to multiple interpretations.

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4
International Code of Botanical Nomenclature. Utrecht: International Bureau for Plant Taxonomy and Nomenclature of the International Association for Plant Taxonomy, 1956.

5
International Code of Botanical Nomenclature, 8-9.

6
We find this kind of alignment in poetic and dramatic forms as well. At one point in Oliver Stone's film J.F.K., a witness recalls where she was when Kennedy died. As she speaks, the picture fades to the bar where she was and we hear her voice-over saying, "I heard Kennedy was shot." We see her in the bar, as the television bulletin appears, the announcer says, "Kennedy has been shot." She repeats it, others in the bar repeat it and the bulletin flashes to a person on the street who talks about it. It reverberates and synchronizes everyone's experience.

Taxonomy: Organization and idea.

Graphs are visual taxonomies, used to communicate taxonomies of content. Taxonomies are organizations, ranks and files, categories and sub-categories. They are schemes for bringing items together to form new objects, both abstract and concrete. Social institutions, organizations of behavior, parents and children, chess boards and chairs are taxonomies. As such they are themselves organizations of qualities and constituents of larger organizations. These organizations express ideas by insisting on a certain relationship or set of relationships.

The problems of taxonomy reflect the problem of how to understand experience. Perhaps no one has faced the task of confronting unstructured diversity more than the botanists and zoologists developing theories of life out of empirical randomness. Their studies came out of increasing knowledge and exploration of similarity and difference in larger varieties of environments. Are two animals related? Which are the defining characteristics of groups or species?

Often different contexts and the informal nomenclatures of native populations offered different accounts of relationships or of significant characteristics. The challenge was to come up with a single system that worked across contexts yielding consistent results. *The International Code of Botanical Nomenclature*[4] was adopted in 1954 at the Eighth International Botanical Congress to provide a common way of naming across five major languages. It amounts to more than that. Its codes for naming read like a constitution with preamble, principles, rules, recommendations and accounts of exceptions.

The taxonomic rules include prescriptions that a taxon may have only one name and rules for the naming procedures including the uses and associations of prefixes. Typification, for example, presents a particularly interesting example. The type is often defined by exemplification, by a holotype. (What's a Rhesus monkey? Here it is.) Wherever it is living, it will, however, die, thus:

A lectotype is a specimen or other element selected from the original material to serve as a nomenclatural type when the holotype was not designated at the time of publication or for so long as it is missing. When two or more specimens have been designated as types by the author of a name (e.g., male and female, flowering and fruiting, etc.), one of them must be chosen as lectotype.

A neotype is a specimen selected to serve as nomenclatural type for so long as all of the material on which the name of the taxon was based is missing.[5] The nomenclatural system embodies within its grammatical rules the logical structure and problems of the objects (specimens and their taxa) themselves. In this way, the botanical taxa, the taxonomy, the taxonomies, rules for forming taxonomies and, it turns out, the rules for the administration of the body responsible for regulating the taxonomies are aligned as concentric ranks in a consistent taxonomic system.[6]

It is often not useful for a taxonomist to begin with local classifications and develop a general taxonomy from the bottom up. It is wiser to simply learn the international system and then apply it from the top down. Like the bricks of a building, the local flora and fauna do not project any single taxonomic structure. The field of cladistics, for example, claims to develop classifications of flora and fauna out of defining characteristics of species or genera. It is an objective system which seeks to trace ancestry of the defining characteristics that mark a genera or species like the opposed thumb. But cladists with the same data can build different cladograms. Some argue that the disagreement must be a matter of error. As usual, where the rules are internally consistent and logical, the bias is to resolve the cognitive dissonance of ambiguity, first by human error, and second, if necessary, by redesign of the taxonomy. Multiple interpretations remain taboo.

Taxonomy and Logic

Taxonomy is a form of logic as it is used in inquiry. The relationship is not merely one of similarity, in the way that the rules for distinguishing and using, and the items distinguished and used, merge. The emblematic textual expression of taxonomy is the outline, and its emblematic visual expression is the chart, map or diagram; its historical expression is the clockwork, and the concomitant sets of relations are cause and effect and whole-constituent parts. It can accommodate the relations of a truth table – it can provide for glosses, and glosses of glosses, etc., as each organizational object or rank provides a gloss of its constituents for use in the next one.

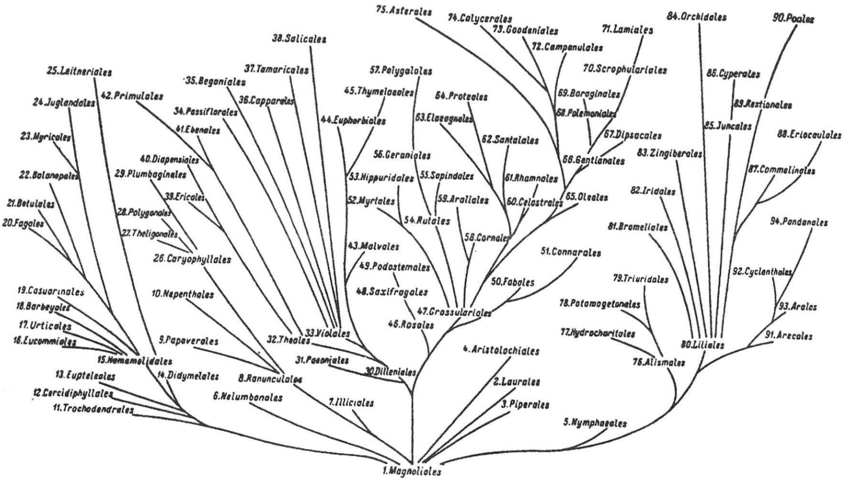
Clive Stace in *Plant Taxonomy and Biosystematics* has described the problem of taxonomy as follows: The need for some system of classification is absolute, for it is only by first naming organisms and then grouping them in recognizable categories that one can begin to sort out and understand the vast array which exists. This requirement is not confined to taxonomists or even to biologists, for living organisms are a part of the everyday life of all humans. Thus it is not surprising that classification is a process which mankind naturally and instinctively carries out ... for the accurate recognition (identification) of food, predators, mates, fuel, building materials, etc., is essential for his survival.

Taxonomists agree that their field is both the goal of the pursuit and its prerequisite, because one cannot build a taxonomy without the units. It is only at the end of the process that one knows what the units are.

Taxonomy and perception

In a sense, taxonomy is prior to perception in that to perceive is to perceive as, as a member of a class. It is not just the organization of parts into wholes, but the recognitions of parts of wholes. But we are rarely aware of that process. New items, are often seen in terms of old models that no longer fit. We start with the given, i.e., that the characteris-

Figure 4 **Cladogram of the orders of angio-sperms**
taken from the 1966 version of Takhtajan's scheme of classification.



7
See
Langer, Suzanne. 1951. *Philosophy in a New Key*. Cambridge: Harvard University Press.

8
See
Mitchell, William J. *The Logic of Architecture*. Camridge: The MIT Press, 1990, 85-108.

tics of objects are within the objects and are not a part of our way of looking. But we soon discover that the question: Is Fred a man? is as much about man-ness, as distinct from boy-ness, or woman-ness (what is connoted), as it is about Fred (who is denoted). For the taxonomist, the questions are about the taxonomy. For example, how does one draw the line between race and species? Ornithologists, for example, are often concerned with these distinctions. Are different races of a bird to be considered different species if they could mate, but almost never do because they are almost never in contact? Is the answer about them or about how the taxonomy is constructed? A taxonomy is a truly conceptual and insubstantial thing. It is a web of connotations, and whether in zoology, psychology or everyday usage, it is just where taxonomy ends that empirical reality comes into existence. Fred may be approached as man, gender or race, but Fred himself, as a whole, is always beyond grasp.[7] For some philosophers, names function as symbols reflecting not objects but ideas of objects and their significance lies in connotation rather than denotation.

Visible taxonomy

Figure 4 is a tree of life, actually, it is a cladogram of angiosperms (for our purposes it could be almost anything with limbs and branches). They take substantial form on the pages of a book, but they are immaterial: nothing other than concepts. Not one of them is visible or can even pretend to be a description – they are criteria and their relevance is to each other as nodes in a taxonomy. In effect, while they are describing something else they are more powerfully being themselves. On the chart they are hypostatized by their physical, printed form.

The world of plants begins when they are recognized as belonging to categories, each tree or shrub as a member of a species – one of many within which it may be compared – as a member of a category. Here the taxonomy begins. Moreover, the taxonomy does not reveal them in their totalities, only in relation to the structure of the taxonomy. (Within the context of this article, neither author nor reader are particularized. Each is an intention, a writing and a reading in a context of critical curiosity that structures the article. Neither needs to actually feel it, but both need to understand its language well enough to fulfill their respective roles.)

Taxonomy, text and organizational object

Taxonomies are limited by practical terms, but as a matter of inquiry, each taxonomic constituent is potentially infinitely divisible. The process is open ended: a function not of the objects but of the stock of knowledge. In short, there are no objects that are not divisible into qualities, so all objects are organizations – they are themselves taxonomies. Wherever two schemata include a given constituent, it links them, claiming similarity and demonstrating their mutual consonances and contradictions. The entwining and entangling of taxonomies is inevitable. But the sources of the various sorts of knowledge collected under the

9
Porter, C.L.
Taxonomy of Flowering Plants.
San Francisco:
W.H. Freeman and Co.,
1959.

entangled taxonomies are disparate, and it is entirely possible, in fact inevitable, that there will be incompatibilities or incomparabilities among them. Thus, seemingly minor problems may force reconsiderations of the whole. This is the designer's or engineer's problem as much as it is the problem of the taxonomist.

Another statement of this issue comes from the notion of contrasting sets.[8] Any object, a temple, for example, is a collection of qualities. It is brown, unpainted, marble, a religious place, a seat of power, etc. Each of these descriptors is a quality, and all qualities collectively comprise the object. The contrasting set for brown includes all colors, for paint includes painted, unpainted, stained and so on. Each contrasting set is a sort of axis of mutually exclusive alternatives upon which one can be located. What can apply to the temple can apply equally to any of its constituents, e.g., columns. Moreover, the qualities, e.g., painted, are also made up of contrasting sets, e.g., lead, latex, etc.

The term "temple" refers to a specific building, this links it to other buildings which share some, but not all, of its characteristics. The term simultaneously invokes all of its constituents, present, past and those to be created in the future. As such "temple" is a collection of collections, each of which is one of its constituent parts or qualities. It is an organizational object.

The pragmatics of human behavior are consistent – Parmenides said that perception is possible only when there is a category. What if, for instance, there were only one cup in the universe. How would it be possible to know of what its cup-ness consists. Is it its color, size, weight, material, glaze or something else? Comparison makes categorization possible and categorization allows membership to be recognized. (One might call this the rule of non-uniqueness.) To posit is to claim as existing and to position, to categorize: the two functions are inseparable.

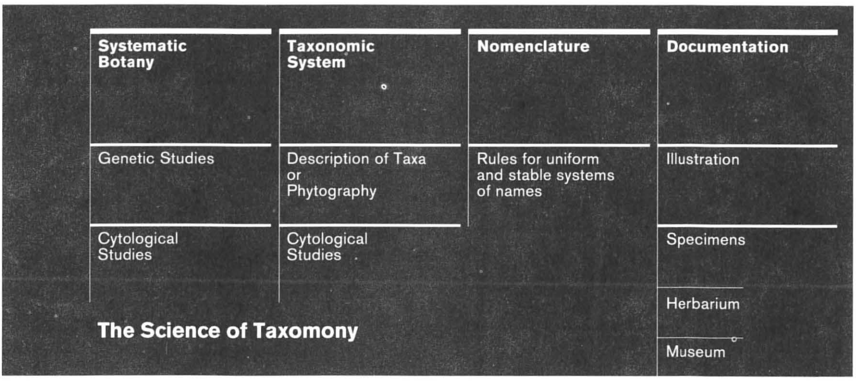
The sources of the various sorts of knowledge collected under the rubric of any word or phrase are disparate. Maintenance of contextual boundaries often become a major preoccupation. As a result, one important practical problem of constructing taxonomies is the regulation of their endogenous and exogenous boundaries: what elements are excluded as environment and what characteristics of constituents are excluded as irrelevant (or dangerous because they bring contradiction with them.) The structure provides for a relationship between inside and outside. If the taxonomy as a whole is an institution e.g., a corporate organization chart or a machine of some sort, its internal structure is its operationalization. It provides for asking and answering questions like: How can that set of parts do what that machine is purported to do?

Functioning of taxonomy

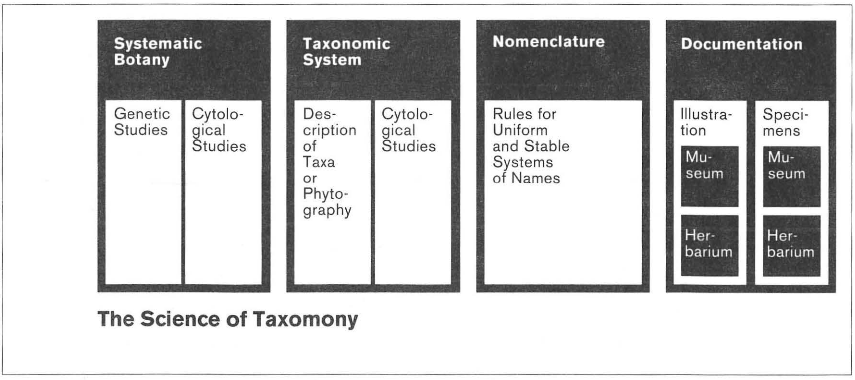
Here is a view of taxonomy taken from C. L. Porter's *Taxonomy of Flowering Plants.*[9] As is often the case, the structure of the account is so correlated with that of the field that it is not entirely clear which is which. The two often seem to end up the same.

Figure 5 Three graphic structures containing the same information.

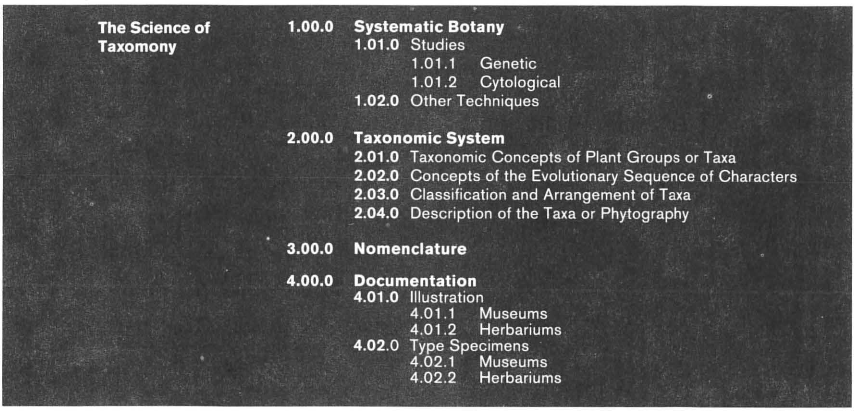
5.1



5.2



5.3



The science of taxonomy may be thought of as a synthesis of four interrelated fields:

1 ***Systematic botany:*** the fact-finding field, which includes genetic and cytological studies as well as any other techniques applicable to the problem.

2 ***The taxonomic system:*** based on the facts that were found and including

a *Taxonomic concepts of plant groups, or taxa.*

b *Concepts of the evolutionary sequence of characters.*

c *Classification and arrangement of taxa.*

d *Description of taxa, or phytography.*

3 ***Nomenclature:*** a method of naming plants based on international rules that botanists have agreed upon in order to promote a uniform and reasonably stable system. This permits only a single valid scientifc name for each plant, discarded names being known as synonyms.

4 ***Documentation:*** which includes the preservation of living or fossil floras in a museum or herbarium, including type specimens, (those on which names and concepts of species and lesser taxa were originally based) and illustrations (which may sometimes be used in lieu of type materials).

It is remarkable how much alike most graphs are. Here are three representations, all graphs (*see figure 5*). The second could be seen as an overhead view of the first. The third translates the other two into a method of procedure or explanation. The first two present a simultaneous form, an immediate perceivable whole. The third transforms it into a procedure extended in time as a verbal or written form. The second graph contains an interesting contradiction. Any division which has further subdivisions has an empty space with its name or title in it. Logically, systematic botany should be fully comprised by studies and other techniques, and a complete description of both of these subdivisions should exhaust all that could be said about systematic botany. The same holds for genetic and cytological studies. Titles that name a category do not belong to that category or within it, but to the next level up and in comparison with its sisters, e.g., systematic botany's sisters are taxonomic system, nomenclature and documentation. Those titles indicate how data about their constituents are to be read.

Text, Image and Narrative

An outline translates between two forms of intelligibility–image and reading text. The visual form has a mimetic relationship not primarily to what it is expressing, but to how it is being ordered. The procedure of reading reveals the sense of the order. In so doing, it collaterally presents a commentary on mimesis; that mimesis is a recognized resemblance to a logical structure or linearity. That linearity may be visual, logical in the vernacular sense, or narrative such as to a normative procedure through which a story unfolds. Similarly, the classifications

Figure 6.1 Cladogram of angio-sperms.

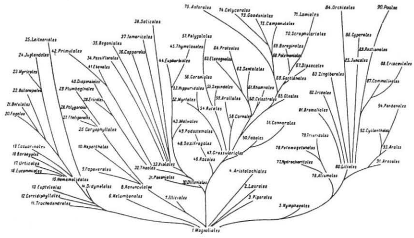


Figure 6.2 Elevation dendrogram.

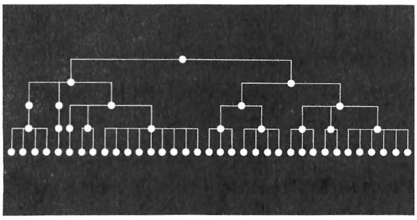


Figure 6.3 Elevation dendrogram from above.

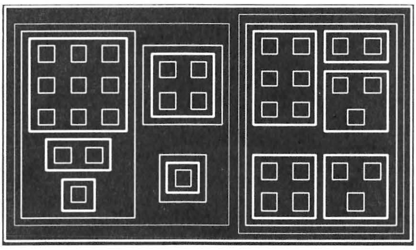


Figure 6.4 Cladogram as a "transection of an imaginary phylogenetic tree."

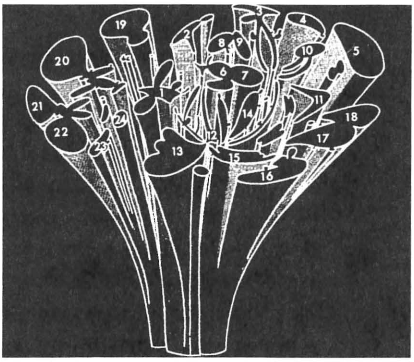


Figure 6.5 Circular graphing of a phylogenetic classification.

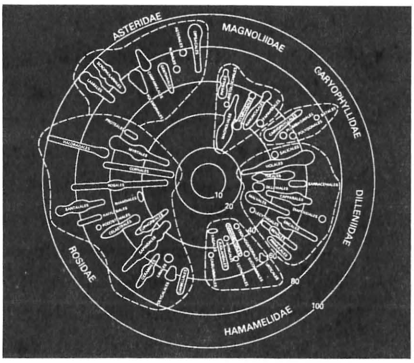
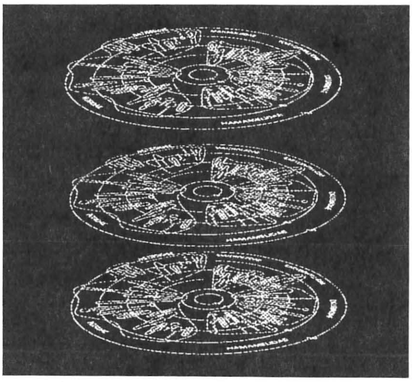


Figure 6.6 Multiple circular graphs projected like the leaves of a book.



of animals which were first based on physical resemblance and difference, are now based on genetic resemblance. As mimesis is displaced, the idea of genetics becomes a way of seeing literally.

The graphs present a bureaucratic view of the process of discovering and understanding plant species. It is not a narrative of discovery, but a sort of post-fact "if I knew then what I know now...." The pragmatic functioning of the system including the questions it answers and way it evolved are often given in accompanying text. The reading of the text requires readers to immerse themselves in the writer's culture. Very often the teacher translates, but generally not with the goal of bringing the writer's culture to the student but enabling the student to inhabit the culture of the writer.

Six logically equivalent graphs

One might presume the dendrogram, number 1, to be the logical or historical origin or precedent (*see figures 6.1-6.6*). The tree of life motif provides a mimetic image for what is a logical statement.
Graph number 2 removes some mimetic aspects to disclose a logical structure. Number 1 reads first as a tree, then as a graph, while number 2 reads first as a graph, then if inverted, as a tree. Or, it could be seen as a mimesis of outline: a 90 degree rotation would yield an outline.
Graph number 3 presents a Boolean form, a set of nesting categories.
Graph number 4 returns to the form of number 1, but as a transection of branching seen from an oblique angle. Graph number 5 provides a wafer thin horizontal slice, and Graph number 6 projects a series of possible slices at different heights. It becomes obvious that apparently illustrative or mimetic representational gestures may have taxonomic consequences or origins, they can present ways of thinking clothed in decoration. They function digitally with something approaching grammatical and syntactic structure. In short, the tree of life appears to be a metaphor, but it is more importantly an organizing principle of branching that underlies both the tree and the taxonomy. Organization is disguised as illustration.

Empirical researchers, whether in the life sciences or social sciences, have long been aware of the problems of conceptually mandated or a priori taxonomies. They would prefer the data to create their own taxonomic frame. That would satisfy the positivist model. With the modern computer it is possible to provide for more detailed communication between contents and taxonomic frame – to provide for a better affinity. In systematic zoology the method is called numerical taxonomy, and in social science, it is called factor analysis. Such methods tease out the strength of correlations. Relationships can be considered through separation or associatation. These methods may aid the creative leap that invents a taxonomic frame or a story that can account for the phenomena presented, but they cannot effect it. No procedure seems adequate to do that.

Likewise, the gulf between the structure of item or phenomenon, and the rules for making the account of it, is well known in the social

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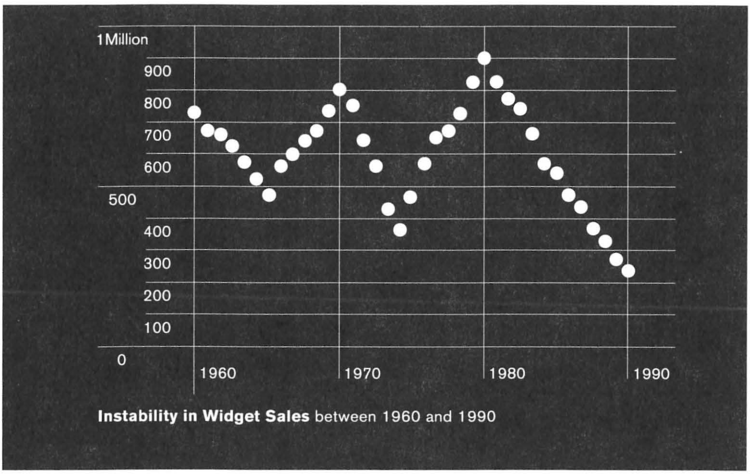
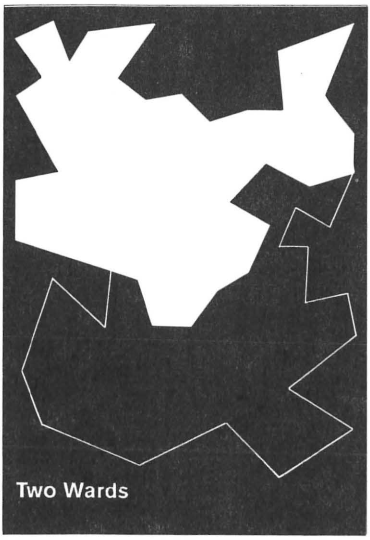
Figure 7 A hypothetical chart.



Units Sold

Figure 8 A hypothetical chart.



10
Paintings, though they are still, often express motion through the implications of position. More generally what they are about is the sort of story a viewer constructs by inference from what is and is not depicted.

11
This summarizing has conceptual verbal and visual aspects: a single idea, a word or phrase, short enough to be heard as a sound, small enough to be seen clearly without moving the eyes. The visual term is foveal, what is perceived within the retinal fovea where vision is most acute. Larger objects must be assembled by scanning. Sound patterns beyond a certain duration and verbal patterns beyond a certain complexity must also be assembled or read.

sciences. Accounts provide for the intelligibility of stories, intelligibilities that belong to the taxonomies in which they are placed: the lives of peoples are placed within a particular context–sociologists or economists' accounts reflect the structure of their fields and their formal inquiry. The results could be ones the people studied would find utterly alien. This is a particular issue where the researcher visits a foreign or primitive culture and comes back with a report. Does the report resemble the lives or do the lives come to resemble the report? It seems that like charts stories impose their structures on their contents.

Frame for taxonomy

The charts on the left demonstrate the graphical and categorical relationship of the subject of charts and the charts themselves (*see figures 7 and 8*). Units Sold appears as a title. "Wards 1 and 2" may seem to be an exception, but on closer inspection, the visible intelligible subject is the ensemble of wards 1 and 2. Each is marked individually as 1, and 2, but the whole exists outside the chart and the chart is finally about gerrymandering. It also does not exist in the chart, but is inferred by the viewer the way motion or narrative can be inferred in some images.[10]

Returning again to the second graph of *The Science of Taxonomy*, it models information location. Each of the titles is a gloss for the total of the information which comprise it such as a model for a book or page layout in which text blocks were allocated space simultaneously on each page. The spatial allocation could be extended to succeeding pages by the same rule, making each block of information a three dimensional prism and each page a slice through all of them. It would be like having a series of books open simultaneously, the front page of a newspaper or the display windows of adjacent shops.

The hierarchies of graphic display could be defined by size of text, typestyle and location. Viewed at a distance, only the headlines would be seen. Headlines compose a next higher level; the units that the texts below are meant to comprise and the components of the overall story into which the individual articles may be woven by the reader form the next level. This disjuncture between title and contents is in the nature of the gloss. It summarizes its contents in a single word or phrase making it a unit to be used in different syntactic contexts.[11]

Titles putatively report the contents, but actually they determine how the reader experiences the material. The reader reads the articles as articles "about" with the headline delivering the clue. The headline provokes the selection of contrasting sets and the contours of the taxonomic boundaries of the articles that follow beneath them. If the redistricting graph were entitled not gerrymandering, but language, or topography or Abstract Number One, the maps would be seen in entirely different ways. This aspect will be discussed further in terms of the logical disjuncture between the whole and its constituents.

In the newspaper, items provide discrete packets of information, not to be read linearly, but to be construed like components of an image, each in light of the others. Articles are written in such a way that the

Figure 9 A hypothetical chart.

Inflation

reader could stop reading any article at the end of a paragraph and have it still make sense. In this context, the images function equally as implicit charts which the headlines narrate. There are few fixed rules that overdetermine a single reading. The "what it means" presents itself as a speculation or conclusion made by the reader.

Taxonomy as inevitable myth

The disparity between content and taxonomy reveals the taxonomy as a social construct. The power of a taxonomy is not just in the propositional demonstration that something is true, i.e., that there is a denoted object which is a member of the defined class, but in the creation of the class itself – the connotation – independent of any of its constituents. Constructs are the tools by which experience is made intelligible. One could pick any of many different ones, but one cannot avoid picking one any more than we can speak without using a language. Money is a construct – money has value as long as it is believed to have value.

Overdetermination

The tendency is to see the constituents of taxonomies in terms of atoms and to resist the view that the atoms, themselves, are tightly defined by their taxonomies. While watching a television program about animal behavior patterns, pecking order or submission-dominance behavior among wolves is shown, you flip the channel and see Humphrey Bogart (Sam Spade) approaching Sidney Greenstreet (Gutman) with his henchman (Wilmer). (Gutman has sent Wilmer to kill Spade.) Spade is polite, usurping Wilmers position and displaying a willingness to cooperate with Gutman, his real adversary. In the context of the movie, this is a turn in the sleuthing, but after watching animal behavior you see it as pack behavior, human style. Seen this way, the scene cuts have a new rhythm and it elicits a very different set of feelings. The juxtaposition of diverse sets of information develops a rich context. This is why observing contextual boundaries is important and why sciences proliferate. If the constituents were the same across context, one science could collect all knowledge.

Inflation in the future

The customary language of graphing focuses on truth-falsehood in terms of the agreement between the scheme and its constituents. In the example at right, the symbol is halved to indicate fifty-percent inflation, but in so doing, its area is quartered and its perceived size is altered by a different factor. The visual ambiguity arises from the question of which rule is intended for use (*see figure 9*).

Another question of truth or falsehood which presents itself is in the matter of context, or meaning: the taxonomy within which the chart, graph or statement functions as an item. Newspaper reporters and advertisements are often cited for taking things out of context, which really means contextually transforming them. Any narrative alters mean-

ing by altering context. Both printing and writing allow statements to be transported. Statements can be taken across boundaries of context. The form of the statement often displays its context and its intended meaning. The competence of any viewer is limited by their knowledge of contexts seen in terms of cultures, periods, pursuits or professions. Transportability and its reciprocal contextual competence make the statement that we encounter not so much: Is it true? but what does it mean?

Framing in reverse

A truth is normalized to a frame. What is empirical and what is conceptual is simply a matter of point of view. The theoretical question of whether a particular being belongs within a given species or genus appears to be an analytical question to the person digging up his bones, but it is an empirical question to the taxonomist, i.e., does my taxonomy (as an empirical object) work? That which is backward in terms of explicit presentation, e.g., here it is – what does it mean? is the way most experiences in life are presented. It is explicit discourse which is backward. Likewise, any declarative statement can be seen as a response to a question, stated or unstated, which forms its frame. In the larger context, the logical space occupied by the explicit discourse of the graph is vanishingly small. The universe of applicable meaning has been collapsed to a single or discrete set of points of absolute precision in which all terms have precise and unequivocal meanings, and alternative contrasting sets have been eliminated. It is a construct – a certain way of seeing.

Graphs without rules

Most of life is spent in the larger universe of meaning, with things or events that do not insist on a particular interpretation. Without narration, items project themselves as potential information, as texts to be decoded and as segments from larger contexts. Newspapers present that sort of challenge. The introductions and framing that were part of early television and radio sound dated, as increasingly, items are juxtaposed and montaged together. Whether there is an implicit juxtaposition of image and text, text and text or of any other statement, the receiver is concerned with finding a universe of discourse, the placement of that statement in a frame in which it makes sense. In short, we have graphs without rules that reinforce any one reading. Writing and publishing have transported these words from a then and a there to the here and now. It is they that are real while the author is ephemeral. The ritual structure of the journal article is a taxonomic frame that regulates the reading. It is one of many particular forms.

Digital versus Analog

Nelson Goodman has developed a taxonomy of symbolic systems according to criteria that contrast richness against precision

which he terms analog versus digital. An archetypal analog system is an image, photograph or painting, while a typical digital system is the word. Analog systems are rich, diffuse and dense. A brush stroke can have infinite variations in weight, angle, curvature, any and all of its characteristics. Each centimeter is perceptible and any of its perceivable aspects contain potential information. It may, on the other hand, be difficult to determine precisely what is being expressed in a drawing. Every aspect of every gesture is there in its fullness and the associations are potentially infinite. To be more precise, number is in some sense irrelevant to analog systems because they are not made up of discrete units.

Conversely, the digital world is discrete and precise in its symbols. A digital symbol has a precisely definable, and repeatable meaning. The number 100 means exactly that. Twenty-four, 24, and 24 all mean the same thing. Words refer to discrete meanings (or sets of meanings) as well as locations or uses in syntactic systems. Like the notes of a piano, there are always spaces in between them. The multiplicity of specific meanings or uses of any word and the variety of contexts or sentences into which any word can be placed provide webs of meaning. The closest digital similarity to analog density is in the multiple ways in which statements can be interpreted. It is just that aspect that is exploited in poetry. There remains, nevertheless, a gulf between multiple, inderminate meaning and continuous shift. Graphs and charts live in the digital world by glossing, by abstracting only specific, discrete meanings and by applying strict rules for reading. Graphs trade richness for precision, they capitalize on the agility that precision yields.

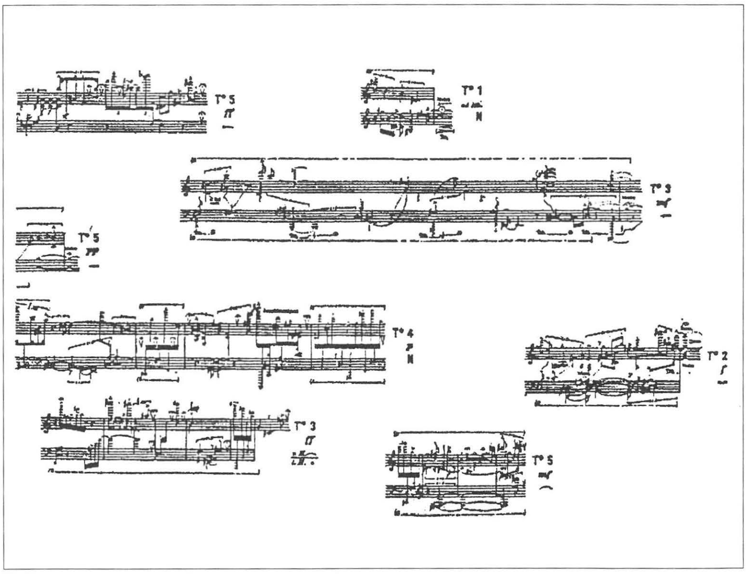
What is easy to do in the analog world approaches impossibility in the digital world: a freehand curve, the variability of hand printing and subtleties that are difficult to define. What is easy in the digital world is impossible in the analog world: absolute precision, repeatability, clarity and certainty.

The analog world is one of gradual growth and continuous change. Its essence is continuity. The digital world is one of contrast, change by increment or by comparison.

The Implicit Graph

Graphing can be explicit or implicit. The previous discussion concentrated on explicit graphs, those which ideally approach a notational precision and a carefully directed reading. Newspapers, for example, can be looked at as implicit graphs, often with carefully worked out taxonomies for headline size and placement of various kinds of stories. The visual resources of size and placement provide procedures for assembling readings. The front page delivers a snapshot of the day, with its hierarchy of headlines. This kind of graphing lacks the title to claim a univocal interpretation – it is a graph without a title – it is an implicit graph. We associate words according to generally understood conventions of page reading: line-by-line, column-by-column, page-by-page, but that

Figure 10 Karlheinz Stockhausen.
Klavierstücke XI, excerpt.



12
Eco, Umberto.
The Open Work.
Cambridge:
Harvard University
Press, 1989, 1.

13
Eco, *The Open Work,*
3-4.

is rarely how we read. Newspapers, advertisements, any walk down an urban street present us with multiple, simultaneous texts which we often read like an implicit graph. The taxonomy also functions associatively, its building blocks remain digital but the interpretive freedoms provide structured choices. If the question asked of a chart is: is it true? The question asked of the implicit graph is: What does it mean? How many things?

In *Klavierstücke XI*, Karlheinz Stockhausen makes freedom of choice part of the procedure of performance (*see figure 10*). He presents to the performer a sheet of music paper with a series of note groupings. The performer must choose among the groupings, first for the one to start the piece, and next, for the successive units in the order in which he selects to present the piece. In this type of performance, the instrumentalists' freedom is a function of the narrative structure of the piece, the performer determines the sequence of musical units by the order he chooses.[12]

According to french composer Henri Pousseur, " ...the poetics of this 'open' work tends to encourage acts of conscious freedom on the part of the performer and place him at the focal point of a network of limitless [but we can see not random] interrelations, among which he chooses to set up his own form without being influenced by an external necessity which definitely prescribes the organization of the work in hand."[13] The performer is free to interact with an already structured text and make it into an intelligibility that follows his own sense of structure, in the full expectation that it will not be one which was specifically predicted or projected by the composition as he received it. This is often the characteristic of aleatoric works. Aleatoric methods are somewhat like what happens whenever there is a large display or exhibition through which one may wander, or a collection of writings among which a reader may sample. For example, in John Cage compositions, pop art painting, automatic writing or quasi-mechanically produced work, the relationship between writer and reader is occluded or specifically made an issue. The otherness of the work is one of its themes. When Cage creates music out of apparent chance, he concerns himself with the role of intention in art, asking if there was a creator in any meaningful sense at all. Is the receiver receiving noise? If he perceives an order, is it an order of his own creation or some version of the natural order? Such works often actually exhibit a high degree of intention in their authorship, but the intention may be hidden as when a very carefully chosen group of words are shuffled. The works may be also about something other than what their form would lead one to presume at the outset. Clearly, in either case, the receiver's expectations are an integral part of the works, either to be presumed and furthered or to be challenged. These are more fully open texts. Rather than telling us how to read them, they ask us to discover how to read them.

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14
Eco, *The Open Work*, 53.

15
Eco, *The Open Work*, 58.

Information v. æsthetics

In The Open Text, Umberto Eco considers the problem of information according to Norbert Wiener's theories–a noninformative datum may specify a likely situation, while a highly informative datum specifies an existentially unlikely situation. For example, this apartment rents for $1,001.50 per month versus this apartment does not rent for $1,001.50 per month. The latter is highly likely, but the former is unlikely and can be counted as informative.

If no assumptions or projections about the receiver is made, the information content belongs to the data, but if there is any presumption about the receiver, the information content must be assigned to a receiver-message nexus. In order to contribute to the general information of a community, a piece of information must say something substantially different from the community's previous common stock of information.[14] Additionally, the degree of informative content is related to its degree of organization. This could be seen as the relation of a number of unlikely events taken together and made interdependent. This contrasts with random, independent atoms, which like grains of sand form a uniform pile or plane – a visual form of entropy. Indeed the most powerful arguments are those that encompass large amounts of complex (already highly articulated) information in a clear structure.

What is the likelihood that the message will be received over noise. Redundancy, for example, counteracts noise. About fifty percent of the English language consists of redundancy and the other fifty percent is determined by the statistical nature of the language and functions as a supplementary means of clarification. In written and visual texts, it is possible to re-read, to read nonlinearly, to build that aspect of performance into the medium rather than the message. (Terms like redundancy and repetition are biased toward meaninglessness.) When contexts are never identical, no exact repetition is possible. Moreover it is only by repetition that a pattern becomes perceivable. An unrepeated refrain is not a refrain. Redundancy may be essential and repetition may be better called reference.

From the point of view of communication, I have information when

1 I have been able to establish an order (that is a code) as a system of probability within an original disorder; and

2 within this new system, I introduce through the elaboration of a message that violates the rules of the code elements of disorder in dialectical tension with the order that supports them (the message challenges the code.)... Such communication is disorder only in relation to a previous order.[15]

Art as enriched information

The situation above is classic Hegelian dialectic, the opposition of a pair in contradiction with each other, resolved by a more adequate frame of meaning. In the closed or univocal work, the dialectical aspects have been banished. Without contradiction, new information

Figure 11 Poetic/typographic development of a text.

It may
rain tomorrow,

As pregnant droplets fall
from the eves
of the temple roof
onto the mats below,

Or it may not rain
At all

cannot modify or comment upon existing information except by either extension or refutation of the given. Comment upon what is given has the power to transform it by showing and altering its limiting frame, its presumptions and its meanings. Such comment is often banished as speculative. Information and meaning are indeed canonically conjugate. They are denotation and connotation, two halves of the same whole. Open text, the text of expression or art, is not the opposite of science but its enlarged version institutionalized. John Cage causes us to face the same questions as other taxonomists by creating the situation in which we must give form to experience.

Consider the following: It may rain tomorrow, as pregnant droplets fall from the eaves of the temple roof onto mats below, or it may not rain at all. By definition, no information has been transmitted. But something has happened. Something has been named, and it has become a focus of intention which cannot be undone (*see figure 11*). The work of much fiction, poetry, the limits of physics or neurology and other works of art is to propose just this sort of reality for the receiver to consider, perhaps as "what ifs" or as ways of seeing the world. Such proposals may appear to be worked out systems or to be an indeterminate or clearly open work.

The open work is a system of multiple intelligibilities, consisting of possible meanings, their interrelationships, what can be inferred from them and so forth. None of the meanings are diffuse or analog, but there are degrees of freedom in interpretation and rationality that allow multiple interpretive procedures. The intelligibility is, in part, for the receiver to construct. One sees in art the same process that one sees in the speculative sciences. In Western culture, art is expected to say something new. It is something new because the "work" is something that cannot be specified in known frames. Its purpose is to open new avenues. It is information outside the accepted bounds of information. Such works often include the systematic breaking of rules.

Going back to Wiener's statement regarding probability or expectancy, it appears that a breaking of rules may be necessary for the transmission and acquisition of new information or knowledge. Indeed such knowledge may be constituted by breaking the known rules–breaking the rules reveals them. To exclude this breaking is to limit the possibility of learning.

The open work exists within the digital domain, it expands through choice and decision. It returns us, in a sense, to the chess board. Texts can be juxtaposed in the same ways as words or objects. They can be above, below, in front, behind or form progressions or mazes. The juxtapositions may be used to indicate foreground, background, relative importance or centrality-peripherality. It is tempting to speculate that there may be an obvious visual unity when there is also a taxonomic unity. Certainly, where a visual orderliness is perceived, relationships are sought out.

Figure 12 Two spatial variations in presenting text.

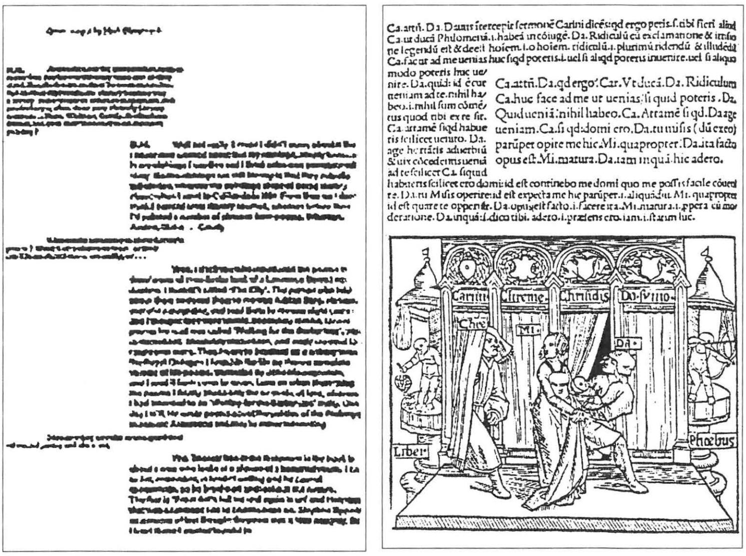

Figure 13 A newspaper front page as a chart.

16
Steinsalz, Adin.
The Talmud, the Steinsaltz Edition,
volume 1. New York: Random House, 43.

Implicit graph, open text

Here are two layouts using contrasting texts (*see figure 12*). The first uses contrast of placement to indicate interviewer and interviewee. In the other, one text is an inset. They serve as independent voices, but they also invite comparison to each other. The visual distinctions point to relationships between the texts, but these differences are not made explicit, the texts will have to be read to determine what the relationships are.

The front page of the newspaper provides an intricate layout (*see figure 13*). The style books which specify typefaces and placements, rules and other conventions for front and editorial pages are often over two-hundred pages in length. The front page, itself, has typically between thirty and fifty modulations of typeface, size and style alone. But the style books written to enable typesetters to execute design rules are not useful for understanding the relationship between visual display and meaning. The front page of a newspaper remains, itself, a text to be interpreted.

Open text graphically realized

The Talmud uses a visual form based on discussion. It displays sections of civil and canonical law along with the commentary of the rabbis. That commentary consists not only of exegesis, but of debate and discussion between rabbis and the text and between each other. Each text relates forward and backward as the continuity of the laws or the continuity that presents the character of a rabbi (*see figure 14*). That rabbi's commentary may be considered next to the law or against the language of any other rabbi. The commentaries often present themes or threads that can lead outside of the Talmud, but there is no authoritative outside text or narrator to interpret the page for the reader. The result is an open indeterminacy of ensemble – each part of which interacts with the others as each modifies and is modified by the others.

"Viewed superficially, the Talmud seems to lack inner order. The order of the Talmud is not that commonly found in standard textbooks. The arrangement of the Talmud is not systematic, nor does it follow familiar didactic principles. It does not proceed from the simple to the complex, or from the general to the particular. Nevertheless, the Talmud does have an inner order, different from the kind with which we are familiar. Textbooks deal with specific material, and it is therefore easy to present that material in a clearly defined order. The Talmud, by contrast, deals with an overwhelmingly broad subject, the nature of all things according to the Torah. Its contours are a reflection of life itself. It has no formal external order, but is bound by a strong inner connection between its many diverse subjects."[16]

The talmud realizes conversations in print. Unlike the Platonic dialogues, which are often tracts written as if conversational, the voices of the Talmud are independent, raising independent meanings and questions, each providing a separate context through which to look at the whole. For any given speaker's statement, you may look in terms of any one or all of the other speakers on that page, the law they are discussing, the speaker's statement in comparison to his statements on

Figure 14 The Talmud

2B | BAVA METZIA | ב ע״ב

TERMINOLOGY

הַאי מַאי What is this? A term used to express astonishment at the previous statement, often with the significance "How can you make such a comparison?!"

בִּשְׁלָמָא In peace [i.e., granted that...] This term introduces a question in which the element that is understood and acceptable is placed first and the difficulty is placed second. Its structure here indicates that a Halakhah is understandable according to the viewpoint of one scholar, but is difficult to understand according to the viewpoint of another scholar: "אִי אָמְרַתְּ בִּשְׁלָמָא רַבָּנַן... אֶלָּא אִי אָמְרַתְּ סוּמָכוֹס..." — "If you accept the viewpoint of the Sages it is all right, but if you accept the viewpoint of Summakhos the following dif-, ficulty arises..."

TRANSLATION AND COMMENTARY

וְאֶלָּא מַאי [1]The Gemara now attacks the basis of this question, and objects. **Then what** would you **rather say** instead — that the Mishnah follows the view of the **Sages** who disagree with Summakhos?! [2]Surely not, for in a case where ownership of property cannot be decided **they say**: "**The burden of proof rests on whoever seeks to take** money or property **away from someone else**." Yet in our Mishnah, even though each claimant seeks to take the garment away from the other one, and neither brings proof that he is telling the truth (by bringing witnesses, for example), nevertheless the Mishnah rules that the claimants take oaths and divide the article. Our Mishnah would seem, therefore, to be in accordance neither with Summakhos nor with the Sages! (In this comparison of cases, three rulings have been quoted: [1] Our Mishnah, where the object is divided after the claimants have each taken an oath; [2] the ruling of Summakhos, that in a case of doubt the object is divided between the claimants without recourse to an oath; [3] the ruling of the Sages in that case that the burden of proof rests on the person seeking to exact payment. Since these three rulings seem to be mutually exclusive, we are seemingly forced to the conclusion that our Mishnah is in accordance neither with Summakhos nor with the Sages!)

הַאי מַאי [3]The Gemara now rejects this objection: **What** sort of comparison **is this** that you have just made? [4]There is no problem **if you say** that our Mishnah follows the view of **the Sages**. It is possible to distinguish between the two cases and to justify the different rulings. [5]**There**, in the case brought in tractate *Bava Kamma* where the responsibility for the death of the calf is in doubt, the two litigants **are not both holding on to** (in physical possession of) a disputed item. The money demanded in compensation for the damage done to the calf is in the possession of the owner of the ox. Therefore **the Sages say: Whoever seeks to take** property **away from someone else** (in this case the owner of the calf from the owner of the ox), **must bring proof** that the property is his, because, in principle, possession of money or an article does confer a presumptive advantage on its possessor. Therefore the owner of the calf must bring proof that the ox was responsible for the death of the calf. [6]But **here**, in our Mishnah, **where both** claimants **are holding on** to the garment, and neither is in exclusive possession of it, the claimants are not considered to be "extracting" property from each other, and hence **they divide** the garment between them **after taking an oath.**

[1]וְאֶלָּא מַאי, רַבָּנַן?! [2]הָא אָמְרִי: "הַמּוֹצִיא מֵחֲבֵירוֹ עָלָיו הָרְאָיָה"!
[3]הַאי מַאי?! [4]אִי אָמְרַתְּ בִּשְׁלָמָא רַבָּנַן: [5]הָתָם דְּלָא תָּפְסֵי תַּרְוַיְיהוּ, אָמְרוּ רַבָּנַן: "הַמּוֹצִיא מֵחֲבֵירוֹ עָלָיו הָרְאָיָה". [6]הָכָא, דְּתַרְוַיְיהוּ תָּפְסֵי, פָּלְגִי לַהּ בִּשְׁבוּעָה.

LITERAL TRANSLATION

[1]But what [do you say, that our Mishnah follows] the Sages?! [2]Surely they say: "Whoever seeks to take [property] away from his fellow, upon him is the [burden of] proof"!

[3]What [comparison] is this?! [4]It is well if you say [that our Mishnah is in accordance with] the Sages: [5]There, where both of them are not holding on, the Sages say: "Whoever seeks to take [property] away from his fellow, upon him is the [burden of] proof." [6][But] here, where both are holding on [to the garment], they divide it with an oath.

RASHI

עליו הראיה — בעדים, ואי לא — לא גבי מידי, והכא חולקין [בשבועה]. הכי גרסינן: אי אמרת בשלמא רבנן, התם דלא תפסי תרוייהו אמור רבנן כו׳, הכא דתפסי תרוייהו פלגי בשבועה, אלא אי אמרת סומכוס, ומה התם דלא תפסי תרוייהו אמר סומכוס פלגי בלא שבועה — הכא דתפסי תרוייהו לא כל שכן. תרוייהו תפסי — ואין כאן מוציא מחבירו. בשבועה פלגי לה — כיון דתמסר גוביינא במה שחבירו תופס, דהאי תפיס נכולה והאי תפיס [נכולה], לא קים להו לרבנן להוציא מתוך מחזקתו נכדי, כדאמרינן התם: לרבנן דבעי ראיה הנריטום שבועה.

NOTES

dead before the goring (in which case the owner of the ox could not be held responsible for the loss of the calf) or after the goring (in which case the miscarriage of the calf could be attributed to the goring). The Mishnah requires the owner of the ox to pay half the damages that he would have had to pay for the calf if it had been certain that the ox had caused its death. In discussing this Mishnah the Talmud asserts that the viewpoint expressed in it is that of Summakhos, who maintains that, where the ownership of property or money is in doubt, the property or money is divided equally between the claimants. The majority viewpoint of the Sages is, however, that the burden of proof rests on the person seeking to extract money from another person. In the case discussed in that Mishnah, therefore, the Sages would exempt the owner of the ox from making any payment for the loss of the calf, because the ox cannot be proved to have been responsible for its death.

דְּלָא תָּפְסֵי תַּרְוַיְיהוּ Where both are holding on to the disputed object. Absolute ownership of an object depends on judicial proof that the object belongs to its possessor (through inheritance, purchase, or gift). But there are also presumptions (חֲזָקָה) regarding ownership, which although not absolute proof nevertheless create a situation of apparent proof. One of these presumptions, as in the case of the owner of the bull, is חֲזָקַת מָרָא קַמָּא — prior ownership other pages, to the continuity of the whole book. Each look from a new angle will alter all of the others, like a painting or game of chess, but with more elements and more moves. It will be both orderly and varied: a potentially endless exploration which, through its external references, can snare the rest of the universe in its own peculiar way. Add to that the temporal/cultural remoteness of its readers, and its willingness to conspire with them to form new meanings and a living tradition emerges.

A second feature of Talmudic organization is that subjects are arranged to stimulate interest. Tracts usually open with a somewhat puzzling introduction, taken from the very depths of the subject, and only afterwards does the discussion return to them. Sometimes too, the Talmud passes from one subject to another in an associative way. After the statement of a certain scholar is cited, a whole series of his statements may be presented. Hence the Talmud may drift away from the first, central topic. Sometimes in discussions of this kind the focus of attention may shift from subject to subject until we find ourselves far from the original starting point. However, not only does the Talmud ultimately return to the original subject, but it is also guided by an inner connection, sometimes very subtle but often very strong, between all the subjects discussed. This connection is never superficial, and the seemingly wayward digressions in fact add substance and interest to the central theme.

The Talmud provides for almost free association, for a dialectic of meaning and context for various interests. It at first appears discursive, but its discursions add a richness that a specific, discipline often fails to bring. There is no forced hierarchy of ideas. Most items outside the Mishna or Gemara condition each other. These are the ways we perceive images – as many elements as possible are simultaneously available – it also describes hypertext in the ability of the receiver to interact and actively construct a particular document.

The Talmud does not have to be read in order, in fact there might be some question of what "in order" means. The various texts can always be seen next to each other for potential juxtaposition. All of these tendencies run toward fragmentation, separation, specialization of vocabulary and montage – the unmediated confrontation of texts. Talmudic confrontation is more a matter of debate in which the voices are placed together in direct communication with each other. The document may seem prolix or unfocused at times, but that is perhaps because it is carrying a number of types of truth at once and leaving them all open for examination, regardless of whether they might or might not be convenient. Like the newspaper, the text arrangement encourages the reader to become aware of the many aspects that form a comprehensive understanding.

This ancient model shows one methodological approach to the modern problem of information fragmentation. It does not build a

17
This would be an analog to the speech act; it might pretend some external basis, but it would have created that basis. We report the news. The news is what we report. We already conditionally accord that authority to the printed word, as constituted by the writing style, page layout, binding and presentation rituals of scholarly publication.

grand scheme, but presents an open montage in which each utterance provides a packet of information which is sensible in itself and which can be juxtaposed with others. Multiple and comparative contexts are built into the structure of the work itself. Rather than an encyclopædia with separate bits of information, it is like an unending conundrum of expanding meaning. Like Stockhausen's composition, the participant assembles the work as he chooses.

Finally, what about the analog. Both images and printed language are visual forms. They differ merely in the rules for reading them. I understand Goodman's position to be that images become analog in that there are no a priori rules by which characteristics are excluded. Thus each image is unique because every characteristic, even the ones we are not yet aware of, is potentially important. That does not mean that every characteristic is actually important. In drawing, where two lines meet is critical. If one ends, while the other continues, it indicates distance. Thus in some Giacometti drawings, the figure recedes into the ground provoking taxonomic questions. We know that drawings are full of lines that we do not actually see. Those lines encode information in ways that we have learned so thoroughly that if we want to draw, we study them so we can draw them as well as read them. It may be that drawings are digital like language but made up of many more decisions.

An image may be more like a book than a proposition. The idea is that a picture is also digital, just more, much more complicated, and with more freedom to include various aspects and define them differently. Modern publication of information in textual and multimedia formats will increasingly beg this question. Information is meaningful when its form is a matter of conscious choice – when it is evidence of an expressed intention. Traditional publication placed practical limits on the dimensions of expression. Now, the individual can have control over many aspects of visual and auditory performance. It will be less and less possible to mark off any of these aspects as irrelevant or to separate the word from the way it appears on the page or the screen.

Conclusion

Widespread verbal literacy began when Gutenberg made it possible for printed publications to be mass produced and disseminated. Modern society is built upon the text: book, newspaper, broadside and sign. Printed text dominates and redefines previous forms of communication, it takes a supremely authoritative position. Modern technologies, such as computer printing, television and video animation are changing the form of mass culture fundamentally and rapidly. In the short run for the masses, the future of literacy seems uncertain, if not for intellectuals. Television is not yet fully authoritative because it has not yet crystallized ritual forms by which it can declaim[17] or create its objectivity. The comments of interviewed pundits are somewhere between conversation and thesis, while documentaries are somewhere

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Tools for Worldmaking

between drama and fact, but television continues to evolve and gain authority.

Moreover, daily life confronts us with montage, disparate messages coexisting in space and time, which we weave together by a process of understanding how they relate to each other. Who sent them, to whom, why, what do they mean to me? These are ways to create relationship among the messages. The history of the computer as a scientific device gives computer generated or processed information a leg up in the objectivity game, and as we know, computers, television, still photography and sound are all in the process of merging to form a new unified environment of intersubjective creation sufficient to displace written communication from its privileged position.

Current ways of thinking about communication media reflect the past – the printed text environment of apparently linear reading for discrete fact, and art and other images for associative looking. Both views operate as normative broadsides as much as descriptions. Not only are these forms essentially different; they have been kept apart – forcibly if necessary. Their differences are understood as sequence versus simultaneous, or eye versus ear, or directly given versus encoded. It is possible to collapse some of those distinctions and to call both image and written text spatio-temporal – even to displace the distinction to digital versus analog. Even so, echoes of the essential distinction remain.

What we take to be paradigmatic of text or word interpretation is formal discourse (simply one of its forms) and that in doing so, we limit our understanding of the word. It is as if we believed normal conversation to be an imperfect form of oration. The difference between images and text seem less matters of essential differences, than matters of the rules by which we read them or our belief in these rules. Both texts and images come in small intelligible packets such as objects and sentences which can be combined in various ways.

Once the sacred linearity of text, and the rules of strict univocal interpretation are overcome, it is apparent that written text and image present similar problems of interpretation and that those problems are far less concerned with whether it is true than what the "it" is. Further, it is less a matter of explanation rather than explication.

The problems of taxonomy demonstrate that the "what is it?" question is in the relationship of classification which appears as category, item or constituent. This question often appears directly in an image, but context must be identified. The question appears in explicit, univocal text, as the probing of intertext – the multiple meanings of words.

The proposition defines its constituents but its definitions hold only as long as it remains hermetically sealed in an unproblematical context. The graph title defines its contents. Once we step outside that contextual box, when we apply that graph to a new problem, or reapply it to an old one, or see it near another graph, that certainty has been destroyed and we again find ourselves back at the beginning asking what the image, graph, text refers to: what does it mean.

Bibliography

Arnheim, Rudolf. 1969. *Visual Thinking.* Berkeley: University of California Press.

Benson, Lyman. *Plant Taxonomy: Methods and Principles.* New York: The Ronald Press.

Dennett, Daniel. 1991. *Consciousness Explained.* Boston: Little, Brown.

Derrida, Jacques. 1967. *Of Grammatology.* Baltimore: Johns Hopkins University Press.

Eco, Umberto. 1980. *The Open Work.* Cambridge: Harvard University Press.

Goodman, Nelson. 1978. *Ways of Worldmaking.* Indianapolis: Hackett Publishing Co.

Harvey, Jonathan. 1975. *The Music of Karlheinz Stockhausen.* Berkeley: University of California Press.

Ihde, Don. 1973. *Sense and Significance.* Pittsburgh: Dusquesne University Press.

Ihde, Don. 1990. *Technology and the Life World.* Bloomington: University of Indiana.

International Code of Botanical Nomenclature. 1956. Utrecht: International Bureau for Plant Taxonomy and Nomenclature of the International Association for Plant Taxonomy.

Mitchell, W.T.J. 1986. *Iconology.* Chicago: University of Chicago Press.

Mitchell, William J. 1990. *The Logic of Architecture.* Cambridge: The MIT Press.

Langer, Suzanne. 1942. *Philosophy in a New Key.* Cambridge: Harvard University Press.

Neisser, Ulric. 1976. *Cognition and Reality.* London: Freeman and Co.

Porter, C.L. 1959. *Taxonomy of Flowering Plants.* San Francisco: W.H. Freeman and Co.

Ruder, Emil. 1967. *Typographie.* Niederteufen, Switzerland: Arthur Niggli, Ltd.

Sontag, Susan. 1977. *On Photography.* New York: Anchor Books.

Stace, Clive. 1980. *Plant Taxonomy and Biosystematics.* Baltimore: Edward Arnold.

Wittgenstein, Ludwig. 1981. *Tractatus Logico-Philosophicus.* London: Routledge and Kegan Paul.

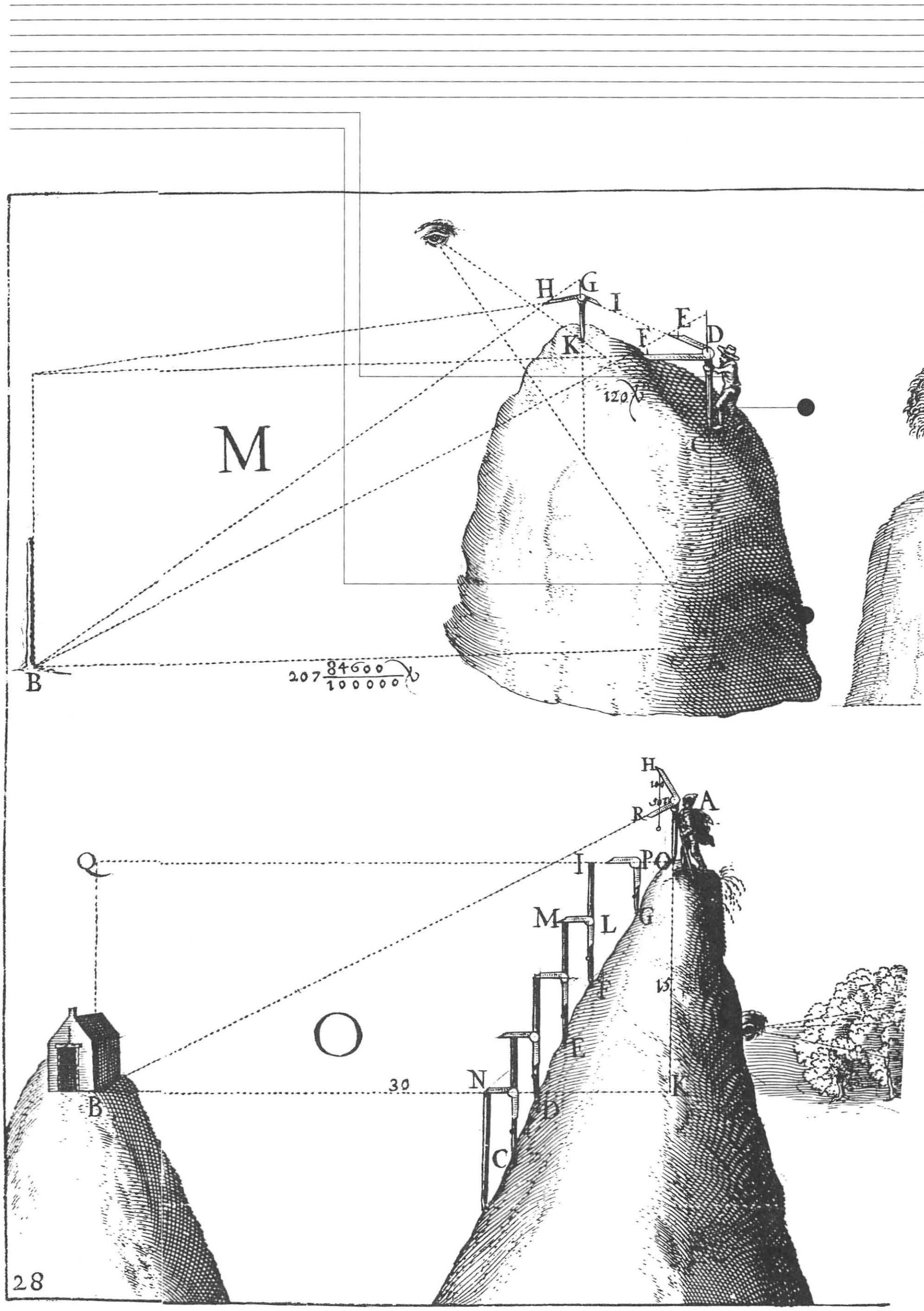
Wittgenstein, Ludwig. 1979. *Wittgenstein's Lectures Cambridge,* 1932-35. Chicago: University of Chicago Press.

18
For an interesting discussion on this aspect, see Dennett, Daniel. *Consciousness Explained.* Boston: Little, Brown, 1991, 152.

Meaning transports us from what we take to be its qualities, to the recognition that they are qualities to us, that the item is a nexus of a something out there and the form of what we see. This process takes place so automatically that we are hardly aware of it. When I write, or say something, you know that it has been written or said and you normalize it to the ritual (journal article–author). In this approach, reasoning carries with it some enormously complex machinery by which all aspects of experience are recorded and bundled with it, as a sort of postmark.[18] This aspect seems to have confounded artificially intelligent computer programs. To grossly oversimplify, or perhaps to put it backward, the computer doesn't know where it is, so it does not know how to frame its input.

Because our habitual language strives for context-free knowledge we are sometimes confounded when efforts to create crossdisciplinary knowledge result not in integration but in further division as new disciplines arise at the margins of previously existing ones. Put simply, information must tell a surprising story. The story is the taxonomic structure which allows the information to exist. The facts may tell the story, but they are not the story. The story is created by us as a pattern of intelligibility that mediates between us and the phenomena we observe. Each discipline or disciplinary shift, context of use, social class or cultural origin, presents new taxonomic frames in which existing knowledge is incompatible, or at the least, in terms of which it must be interpreted or postmarked.

In an era of exploding information and cultural diversity, we need fresh ways of taking in information. We need to use or develop the information more quickly and fully. The new media technology performs the same functions already performed by print. The new graphic capability to combine image and text freely and to treat text as image, opens new practical possibilities in terms of liberating text from linear reading. The language of visual juxtaposition includes logical proposition but is also far richer. It includes things above, below, in front of or behind; things that are bigger, smaller, opaque or transparent. We have some awareness that these visual structures mean something. We can create the kind of montage that better enables information use in various contexts. This is the beginning of thinking about what visual interpretation of text can mean. Graphs, which look like pictures but read more like words, give us the opportunity to test traditional views.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207 84600/100000
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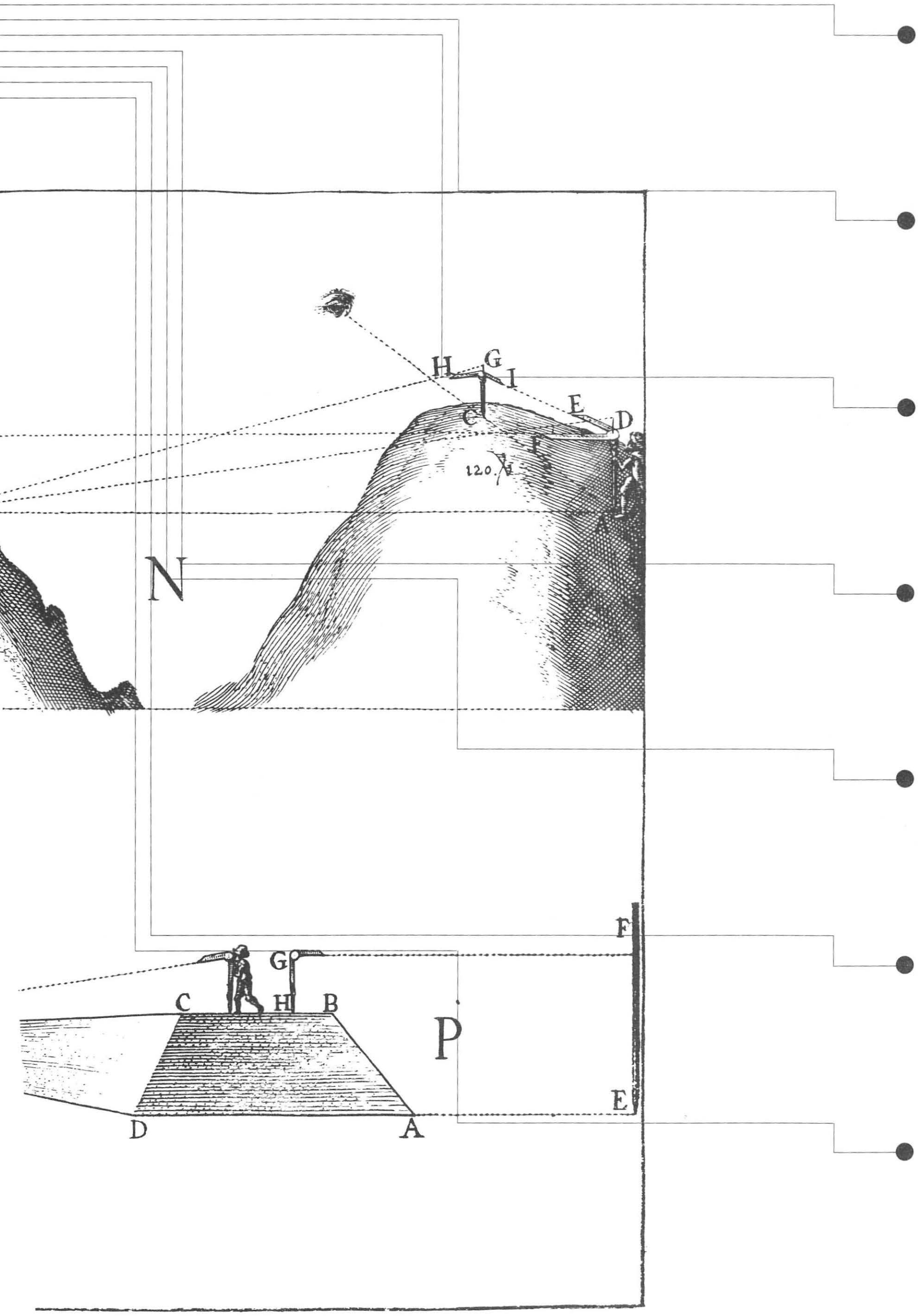
28

Working toward the Future
or
extending conventions



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Two systems are introduced that increase the information density of textual presentation by reconsidering text as pictures, expanding the range of written expression. Both schemes indicate nested associativity, and both employ stripes, but in different styles: Blush uses large-scale vertical gutters, superimposed as reverse-fielding on indented outlines or computer programs; Zebrackets uses small-scale horizontal striations, superimposed on parenthetical delimiters. These systems are implemented as computer programs, active filters that represent textual information graphically.

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1
Unix is a trademark of AT&T Bell Laboratories.

2
Rubenstein, R. 1988. *Digital Typography: An Introduction to Type and Composition for Computer System Design.* Reading, Massachusetts: Addison-Wesley.

3
Lamport, L. 1986. *LATEX: A Document Preparation System.* Reading, Massachusetts: Addison-Wesley.

4
As extreme examples, the programming languages Occam and Miranda use white-space directly to represent scoping information, without any explicit begin-end pairs.

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Japan.

Visible Language, 26:3/4,
Michael Cohen, pp. 436-449,

Blush and Zebrackets: Two Schemes for Typographic Representation of Nested Associativity

Michael Cohen

Introduction

The notion of a hierarchical (de)composition of a structure or action, often conveyed by a graph tree, is universal. A related concept is a stack, a LIFO (last in, first out) protocol, which can be used to track tree traversal. (For example, a single-threaded computer program execution relies on a stack to reflect invocation and return from subroutines.) While trees are graphical and inherently two-dimensional, streams of characters are one-dimensional. Graph trees can be mapped to nested expressions (sets) or outlines, which use delimiters and indentation, respectively, to denote the tree structure. Delimiters (usually paired parentheses) and indentation (usually carriage returns, linefeeds, tabs, and spaces – "whitespace" in Unix[1] parlance) associate items that belong to nodes of the tree, while showing their context in the overall scheme. Left parentheses and deeper indentation represent a "push" onto a stack, and right parentheses and shallower indentation map to a "pop."

Bit-mapped terminals and high-resolution printers suggest the possibility of more elaborate presentations[2] which exploit underutilized human visual acuity. Figure 1 shows some simple axes of variation (under LATEX/TEX,[3] the document formatter with which the examples were prepared). Combining a computer filter (to analyze the text) with an extra coding dimension, orthogonal to standard techniques (to display it), can algorithmically (systematically) vary the way documents look.

Blush

Motivation

Procedural computer languages often have many blocks of code (program statements) nested logically inside enclosing envelopes of code (which in turn are nested...). In the programming language C, for example, these blocks might be alternative (*switch...case*), conditional (*if...else*), or iterative (*for, repeat,* or *while*). Pairwise delimiters scope the ranges of blocks of code, but with even properly indented code fragments, it is difficult to determine what exactly is enclosing which, resolving the extent of the various sections, especially if there are many lines between the delimiters.[4] *Blush* addresses this visual ambiguity by "reverse fielding" (a.k.a. "reverse videoing") nested blocks of

Figure 1 Some traditional and non-traditional ways of typographically indicating nested associativity.

Delimiter		Shape
		Explicit tag
Indention		
Frames		
Parenthesis		
Color/shading		
Dynamic effects		Momentary highlight (during editing)
		Synchronous flashing
Rules		Overlines and underlines
Braces		Superscripted overbraces and / or
		Superscripted underbraces
Type	Style	Serif, sans serif
		Roman, italicized
		Condensed, regular, extended
	Weight	Light, regular, medium, bold, extra-bold
	Size	Small, medium, large
	Spacing	Proportional or variable-spaced
		Fixed pitch or mono-spaced

5
NeXT is a trademark of NeXT Computer, Inc.

6
Reynolds, L. 1988. Legibility of type. *Baseline*, (Cassandre):26-29.

code, alternating between black-on-white and black-on-gray. The patterns introduced by *Blush* are like variable-sized parentheses; successively highlighted blocks of code, enveloping inner blocks, suggest the structure of the underlying program or text.

Examples

Computer Program A particularly complicated and deeply nested section of an (Objective-C) computer program is shown in figure 2, after having been automatically indented. (For the purposes of illustration, the exact meaning of the segment is unimportant.) In figure 3, *Blush* has been run on this program (under Unix), turning the indentations into "gutters." Typically, *blush* ("standard") input is precomposed with *indent*, to align the code, and expand, to normalize tabs and spaces. An indentation quantum of two characters' width ("*-i2*") seems aesthetic, perhaps since it makes the gutters' width about the height of a line. For the example, a reasonably sized section is extracted with *head* and *tail* in order to display the invocation and the output on a single page.

Along with the command line invoking *Blush*, the frame around the program fragment shows the context as it would be presented on a computer monitor, including buttons, scrollers, titles and windowing tools. For hardcopy output, these would not normally be printed, as in the presentation of the following examples.

Outline

Although *Blush* was originally developed as a programming tool to macroscopically display nesting levels in computer programs, it works equally well on any indented outline. Figure 4 is an outline illustrating a concert's hierarchical decomposition; in figure 5, this outline has been "piped through" *Blush*.

Implementation

Blush was written as an active filter in C on a NeXT[5] workstation, but works on any Unix machine. It augments an input stream, using a program's indentation as an indication of block depth, inserting forward/reverse fielding display style escape sequences to distinguish successively nested blocks. This highlighting, in which blocks of code "blush," is the origin of the name. The examples are set in Letter Gothic, a monospaced sans serif typeface. Constant pitch allows display via normal computer terminals (or emulators); sans serif faces are thought to be more robust in reverse-fielded displays.[6]

One complication is that indentation levels in documents, unlike pure stacks, often don't exhaustively pop back (inside-)out, instead skipping some number of frames. Output of a non-interpolating blushing filter is shown in figure 6, exhibiting the (perhaps arguably) confusing bleeding of the *second violins* into the *brass*, the *kettledrums* into *other* and the elision of wrappers at the end. To allow clean display of the frames, therefore, *Blush* inserts blank, but appropriately shaded, lines into the output stream (*see figure 5*).

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Figure 2 A section of a computer program.

```
if (!gotHit)
  do {
    if (!g) {
      i = 0;
      g = [glist objectAt:i++];
    }
    if (![g isSelected] && [g hit:&p]) {
      gotHit = YES;
      if (!shift) {
        [self deselectAll:self];
        [slist addObject:g];
        gvFlags.groupInSlist = [g isKindOf:[Group class]];
        gvFlags.clusterInSlist = [g isKindOf:[Cluster class]];
      }
      [g select];
      [conferenceSpeaker gbUser:conferenceID
       selectObjectAt:[glist indexOf:g]];   /* <jf> individ */
      DIRTY(YES);
      if (shift)
        [self getSelection];
      if (deepHit ||
          !(([slist count] == 1 &&
             [[slist lastObject] isKindOf:[SourceSinkIcon class]]) ?
            [self translateRotate : event] :[self translate:event])) {
        [self cache:[g getExtendedBounds:&eb]];
      }
    } else {
      g = [glist objectAt:i++];
    }
  } while (!gotHit && g != startg);
```

A similar work-around is required for a more subtle pathology: if the indentation levels of the source are inconsistent, such that the nesting pops out to a previously unpushed indentation, then lines of different hierarchical depth would be both adjacent and similarly shaded. This problem typically arises because a previous line, as a continuation of a still earlier line, was indented according to where the line break was, to align logically parallel elements.

This situation is observed towards the bottom of figure 2, around "[self translateRotate:event] : [self translate:event])) {". Again, the inappropriate juxtaposition is resolved with the interpolation of blank blushed lines *(see figure 3)*.

Discussion

Blush offers a seamless way to extend "pretty printers" for ASCII documents. *Blush* has an option that skips an arbitrary number of columns, making it suitable for formatting FORTRAN, SPSS and other languages with label fields or sequence numbers. Further, *Blush* is compatible with outline processors, since the shading scheme is invariant under hierarchical expansion/contraction.

Properly presented, the shape of a document or program's text suggests its meaning or flow-of-control, and *Blush* helps highlight that shape. The gutters and interpolated lines introduced by *Blush* allow thinner indentation increments and deeper nesting than would otherwise be perspicuous, and make explicit the alignment at which whitespace indentation only hints.

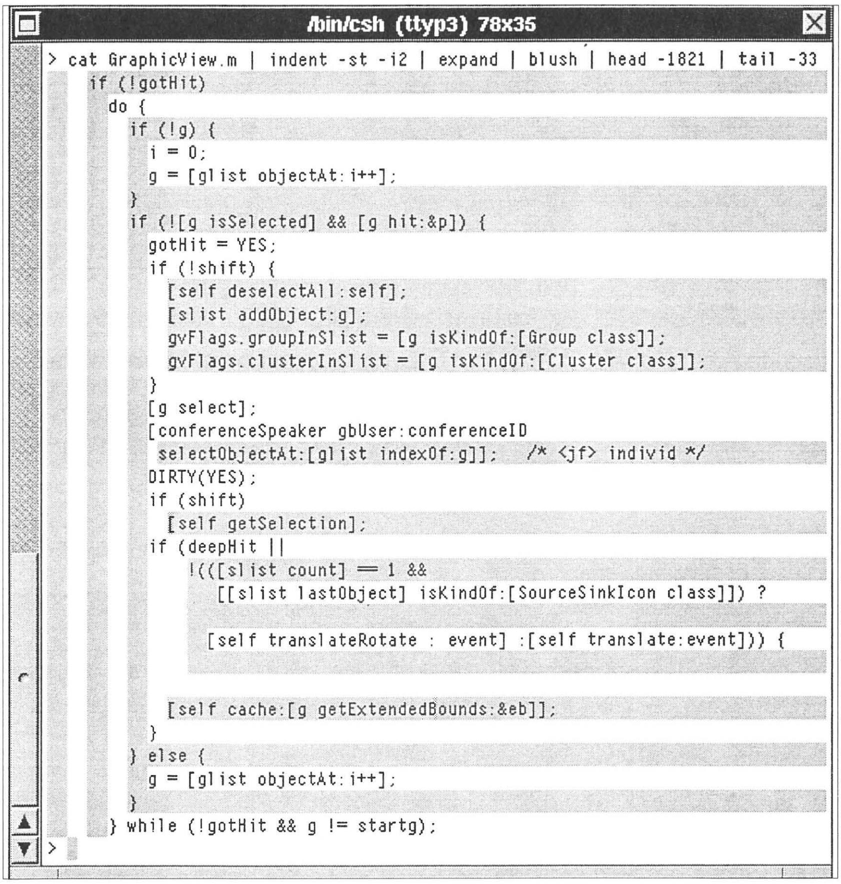
Zebrackets

Motivation

While *Blush* provides an extension to indentation-based hierarchical representation, a large-scale approach to textual presentation, *Zebrackets* takes a small-scale approach, focusing on in-line representation of nested associativity.

To represent parenthetical expressions, traditionally typewritten documents use parentheses, "( )", for first-level subphrases, extended by (square) brackets, "[ ]", for doubly nested phrases (parentheses within parentheses), and alternating the two sets of delimiters for the rare more deeply nested phrases. Parentheses and brackets are overloaded; they are used in prose for delimiting subordinate expressions, appositives, citations and cross-references, and in mathematical formulae and computer programs for associative precedence, array subscripts, numeric ranges, function parameters and arguments, as well as special interpretations (like "((n))m" denoting "n mod[ulo] m"). Editors also use brackets to set off editorial substitution and interpolation ("[sic]"), ellipsis ("[...]"), elision ("[expletives deleted]"), etymology ("[MF *braguette* codpiece, fr. dim. of *brague* breeches, fr. OProv *braga*, fr. L *braca*, fr. Gaulish *brāca*, of Gmc origin; akin to OHG *bruoh* breeches – more at breech]"), etc. For

Figure 3 Output of *Blush* on computer program.



```
/bin/csh (ttyp3) 78x35
> cat GraphicView.m | indent -st -i2 | expand | blush | head -1821 | tail -33
    if (!gotHit)
      do {
        if (!g) {
          i = 0;
          g = [glist objectAt:i++];
        }
        if (![g isSelected] && [g hit:&p]) {
          gotHit = YES;
          if (!shift) {
            [self deselectAll:self];
            [slist addObject:g];
            gvFlags.groupInSlist = [g isKindOf:[Group class]];
            gvFlags.clusterInSlist = [g isKindOf:[Cluster class]];
          }
          [g select];
          [conferenceSpeaker gbUser:conferenceID
           selectObjectAt:[glist indexOf:g]];   /* <jf> individ */
          DIRTY(YES);
          if (shift)
            [self getSelection];
          if (deepHit ||
              !(([slist count] == 1 &&
                 [[slist lastObject] isKindOf:[SourceSinkIcon class]]) ?

                [self translateRotate : event] :[self translate:event])) {


            [self cache:[g getExtendedBounds:&eb]];
          }
        } else {
          g = [glist objectAt:i++];
        }
      } while (!gotHit && g != startg);
>
```

Figure 4 An outline (decomposition) of an instrumental concert.

```
concert
  chorus
    soprano
    alto
    tenor
    bass
  orchestra
    strings
      basses
      cellos
      violas
      violins
        G-string
        D-string
        A-string
        E-string
    brass
      horns
      trumpets
      trombones
      tuba
    woodwinds
      bassoons
      clarinets
      flutes
      oboes
    percussion
      bass drum
      cymbals
      snare drum
      triangle
      tubular bells
      wood block
      xylophone
      timpani
    other
      harp
```

Figure 5 Output of *Blush* on instrumental concert outline.

```
concert
  chorus
    soprano
    alto
    tenor
    bass
  orchestra
    strings
      basses
      cellos
      violas
      violins
        G-string
        D-string
        A-string
        E-string
    brass
      horns
      trumpets
      trombones
      tuba
    woodwinds
      bassoons
      clarinets
      flutes
      oboes
    percussion
      bass drum
      cymbals
      snare drum
      triangle
      tubular bells
      wood block
      xylophone
      timpani
    other
      harp
      piano
```

Figure 6 Output of non-interpolating *Blush*.

```
concert
  chorus
    soprano
    alto
    tenor
    bass
  orchestra
    strings
      basses
      cellos
      violas
      violins
        G-string
        D-string
        A-string
        E-string
    brass
      horns
      trumpets
      trombones
      tuba
    woodwinds
      bassoons
      clarinets
      flutes
      oboes
    percussion
      bass drum
      cymbals
      snare drum
      triangle
      tubular bells
      wood block
      xylophone
      timpani
    other
      harp
      piano
```

Figure 7 **Chemical Compound, before and after *Zebrackets.***

ACTIVE INGREDIENT: Hydramethylnon [tetrahydro-5, 5-dimethyl-2(1$\underline{H}$)-pyrimidinone(3-[4-(trifluoromethyl)phenyl]-1-(2-[4-(trifluoro-methyl) phenyl]ethenyl)-2-propenylidene)hydrazone]

ACTIVE INGREDIENT: Hydramethylnon [tetrahydro-5, 5-dimethyl-2(1$\underline{H}$)-pyrimidinone(3-[4-(trifluoromethyl)phenyl]-1-(2-[4-(trifluoro-methyl) phenyl]ethenyl)-2-propenylidene)hydrazone]

Figure 8 **LISP code, before and after *Zebrackets.***

```
(DEFUN ANY (LST)
 (COND ((NULL LST) NIL)
       ((CAR LST) T)
       (T (ANY (CDR LST))) ) )

(DEFUN ANY (LST)
 (COND ((NULL LST) NIL)
       ((CAR LST) T)
       (T (ANY (CDR LST))) ) )
```

Figure 9 **Objective-C code, before and after applying *Zebrackets.***

```
[inspectorPanel setAccessoryView:[[[[accessory contentView] subviews]
                                   objectAt:0] removeFromSuperview]];

[inspectorPanel setAccessoryView:[[[[accessory contentView] subviews]
                                   objectAt:0] removeFromSuperview]];
```

Figure 10 **First order predicate calculus, before and after applying *Zebrackets.***

$\forall P\ \forall v\ \forall w\ \forall x\ \forall y\ \forall z\ ((P(v,w) \Rightarrow P(w,v)) \wedge ((P(x,y) \wedge P(y,z)) \Rightarrow P(x,z)) \Rightarrow$

$\forall P\ \forall v\ \forall w\ \forall x\ \forall y\ \forall z\ ((P(v,w) \Rightarrow P(w,v)) \wedge ((P(x,y) \wedge P(y,z)) \Rightarrow P(x,z)) \Rightarrow$

7
Traditionally precise LISP punctuation puts a space before parentheses that close an association begun on another line. Many LISP interpreters also have a super parenthesis, "]", that closes any pendant associations.

literature and journalism, these conventions have been adequate, since the reader could usually parse the subphrases. Extended schemes have used (curly or set) braces (a.k.a. "bracelets"), "{}", and angle brackets (a.k.a. "inequality signs"), "<>", to indicate more deeply nested phrases. But especially for non-natural languages, in which stacks of association are not only comprehensible but necessary and encouraged, a more extensible scheme is needed.

Using size to denote nesting (or any other kind of) level doesn't work, since juxtaposed expressions, at the same parenthetical depth, might require different sized delimiters for aesthetic (lexicographical) reasons. "$\big(A * (B+C)\big)$" suffices, but expressions that span use or over- and under-lines or braces break down across line boundaries.

Zebrackets extends parentheses, square brackets (and other pairwise delimiters) by systematically striping them according to an index reflecting their order in the text. Each index of the respective delimiter pairs is cast into a binary pattern, which is superimposed on the characters as striations. Alternate encoding schemes are also possible, but informal experiments suggest that users tend to look only for matching delimiters. Some of these special-purpose modes are mentioned later in the discussion.

Examples

Chemical Compound Figure 7 shows the chemical formula for a popular roach control system, as shown on its box. The top version is without brackets and the bottom version is zebracketed. What is the "matching bookend" to the parenthesis before "3-" in the second line? A quick scan of the zebracketed version finds the parenthesis closing the association in question.

LISP The LISP programming language relies on parentheses for delimiting lists,[7] the language's basic data structure. The function shown in figure 8 performs a generalized "inclusive or." As in the previous example, the top version is without zebrackets, while the bottom version with zebrackets performs the same function and elucidates the associations.

Objective-C Figure 9 shows a line from an Objective-C program, with and without zebrackets as before.

Logic Figure 10 shows the first order predicate calculus notation indicating that symmetry and transitivity imply reflexivity. *Zebrackets* illuminates the precedence.

Association beyond single parenthetical pairs Just as pairs of identically valued parentheses point at each other, like matching bookends, so do multiple sets of same-valued delimiters associate beyond the scope of a single pair of parentheses. In figure 11, the zebrackets are not just reinforcing patterns already present, but are adding new information.

Implementation

The implementation of *Zebrackets* comprises two aspects: a filter to generate permuted invocations of the underlying parentheses

Figure 11 **Association beyond single parenthetical pairs**

$$(\ln|(\ln|(x^2-2)|)|)' = (\ln|(x^2-2)|)^{-1}\,(x^2-2)^{-1}\,(x^2-2)'$$

8
Knuth, D.E. 1986.
The Metafont Book.
Reading, Massachusetts: Addison-Wesley.

9
Tufte, E.R. 1983.
The Visual Display of Quantitative Information.
Cheshire, Connecticut: Graphics Press.

10
Tufte, E.R. 1990.
Envisioning Information.
Cheshire, Connecticut: Graphics Press.

and brackets, and the delimiter fonts themselves. A filter was written to intelligently parse expressions, substituting zebrackets for ordinary delimiters. *Zebrackets* glyphs are implemented with METAFONT,[8] an algorithmic typographic computer language, as extension fonts in the Computer Modern typeface. Unlike *Blush*, *Zebrackets* adopts a minimalist "less (ink) is more (data)" philosophy,[9] adding information to regular parentheses and brackets by resetting some pixels in the characters.

Because of the tendency of white features to bleed out into a black background, the striations need not be terribly thick to be perceivable. In the examples shown, the stripes are 1 pt. (1/72.27 inches) thick on 12 pt. type, subsuming about 2.6 arc-minutes (≈ 0.044 degrees ≈ 0.77 milliradians) of visual angle (assuming a reading distance of 18 inches). This is greater than the accepted (if heuristic) industrial minimum for visual acuity, 1 arc-minute.

Since there are usually more ascending than descending characters, readers (of English) tend to look slightly above the line of print, deriving meaning from the "top coastline"(upper half) of the text. Therefore, the index of the parenthetical pair is encoded with the LSB (least significant bit) at the top of the parenthesis or bracket. Further, for even curved parentheses, the stripes are drawn horizontally (rather than radially), so that the reader might imagine an invisible line drawn through the intermediate text. Since the delimiter pairs are horizontally symmetrical, they can be conceptually associated, and since the bands are aligning, they can also be visually associated, like toothpicks holding bread around a thick sandwich.

Discussion

For single levels of nesting, the extended parentheses and brackets are identical to the unenhanced, since an index of zero leaves the delimiters unbanded in *Zebrackets'* default positively-coded scheme, chosen to preserve the backwards compatibility of the curve substrate.

For deeper levels, *Zebrackets* tries to maintain this backwards compatibility by being non-distracting to users who don't know about it. It is, by design, "just noticeable," right over the limen, or edge of perceptibility. The added information is meant to be clear to the user actively seeking it and transparent to any user not actively seeking it. (Such an effect is like making something a little smaller to call attention to it.) By designing a scheme that is both noticeable and ignorable, one is obtained that is unambiguous but unobtrusive, unmistakable but unassuming. In practice, however, *Zebrackets* has two problems: For linear reading without searching, zebrackets can actually be distracting, introducing high-frequency noise (that looks like printer spotting). On the other hand, zebracket striations can be difficult to see, especially for readers with less sharp eyes and zebracketed documents are not robust under (perhaps repeated) copying by low-resolution devices (like most faxes).

Figure 12 **Foreground stripes.**

```
(DEFUN ANY (LST)
 (COND ((NULL LST) NIL)
       ((CAR LST) T)
       (T (ANY (CDR LST))) ) )
```

Figure 13 **Different encoding modes**

Indexing the streaks "inside-out," (so that the outer delimiters pairs have a higher index (than inner)), orders the evaluation of expression trees. Displaying breadth (or depth (or both)), instead of an incremental index, is useful for visualizing expression complexity. Striping the delimiters "upside-down," from the bottom, might be better for languages (like Hebrew) that carry more information in the "lower coastline."

Variations that overcome these limitations are possible. For instance, grayscale striations (not yet implemented) might disappear at normal reading speed, but be visible when doing a detailed search. Alternatively, using black stripes to tick the parentheses, instead of dropping out (white) segments, is more legible, if less inconspicuous (*see figure 12*).

For too-deeply parenthesized expressions, *Zebrackets* degrades, but gracefully. The filter maintains a stack, wrapping around (repeating) the indexing scheme if the delimiters exhaust the range of uniquely encodable depths. Most of the *Zebrackets* fonts in this paper use four bands (allowing $2^4 = 16$ different versions of each pair of delimiters), but denser representations are possible (perhaps adaptively chosen, so that the maximum depth of the expression determines the fineness of the striations, or tuned by the user, to match visual acuity). Further, invocation of different encoding modes, perhaps for special purposes, is straight-forward (*see figure 13*).

Conclusion

These utilities recall the counter-intuitive advice "To clarify, add detail."[10] *Blush* and *Zebrackets* are tools in a suite of prettyprinters (like Unix's *vgrind*) that start to treat words and documents as pictures, with attendant increases in information/ink value: denser data without loss of legibility.

Documents should look like what they mean: context after content, form after function, process after product and style after substance. Creative orthography frees words from traditional (technologically imposed) constraints, allowing textual re-presentation of multidimensional concepts by projecting multilayered structure into linear text. Extended electronic typography, as manifested by tools like *Blush* and *Zebrackets*, provides additional parsing cues and differentiates between heretofore duplicate symbols.

The handwritten "publishing" of pre-Gutenberg scribes was arbitrarily subtle, with its attendant human caprice (and mistakes). Printing can be thought of as having rigidified this information transmission. The research described here loosens some of that determinism, not by randomizing the presented information, but by softening the digitized boundaries, thereby expanding the range of expression. *Blush* and *Zebrackets* indicate evolving modes of written representation, algorithmic descriptions driving adaptive displays, as style catches up to technology.

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Diagramming, in the age of fast computer graphics, has been revitalized as a tool for finding and communicating patterns. What is new is the ability for a diagram on a computer screen to be dimensionally manipulated in real time. Instead of the two dimensions of a piece of paper, dynamic diagrams have four: three spatial dimensions and an active time dimension.

Operations for working with dynamic diagrams deal with both structure and observation. Tools for describing and altering the model are transformations; tools for changing the way its behavior is viewed are transpositions. Transpositions, the subject of this paper, change the way the display of the model proceeds, letting the viewer look at the unfolding results in different ways. These may be spatial, allowing the viewer to move the point of view or the point viewed; procedural, allowing the viewer to change the flow of time; or organizational, allowing the viewer to arrange multiple simultaneous views and to interject auxiliary measuring tools.

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Data Exploration: Transposition Operations in Dynamic Diagrams

Vijay K. Sivasankaran and Charles L. Owen

Introduction

Visualization and formative processes go hand-in-hand in design and other design-related disciplines. It is commonplace – and expected – to see drawings, diagrams, blueprints, photographs and other visual aids among the working paraphernalia of designers. Less obviously, visualization also can play a key role in the processes of *understanding* that take place before *form making* begins.

Typically, the first step of the design process is the assembly and analysis of pertinent data. This is generally true also of any creative process, whether it is a process of discovery in the sciences or humanities, or a process of invention in design, engineering or architecture. The critical role of analysis is the distillation of insight from the relevant data. Analysis proceeds with selecting, organizing, structuring and otherwise recasting the data to reveal meaningful patterns.

With the coming of real-time computing, this analysis can be conducted with new kinds of tools. The new tools use computer graphics to display relationships dynamically, directly revealing patterns that heretofore required multiple passes of data processing, interpretation and visualization. Because of their ability to involve the user interactively with the process of inquiry, the new tools have great potential as investigative and communicative instruments. The key to this new potential is the diagram. Developed to meet economic needs first encountered in the industrial revolution, diagrams have evolved from simple visual aids for comparing two variables, or tracing the progress of a variable over time, to sophisticated means for examining and explaining complex relationships. Essentially, diagramming holds the middle ground in the spectrum of visual language. Diagramming is both real enough to employ concepts of position, scale, direction, proportion and other visual constructs from real life experience – and abstract enough to attach meaning to visual elements, just as symbols are assigned values in writing and number systems.

Dynamic Patterns in Diagrams

Using a select visual vocabulary and grammar, a diagram freezes data about entities and their relationships into a specific visual pattern. It is this visual pattern that a viewer analyzes to gain insight about the data.

As valuable as traditional diagrams are for communicating information, however, they are only marginally effective as investigative tools. This is because it is difficult to understand the relationships among parts in a complex information structure without viewing the relationships from many vantage points. The restrictions of the conventional diagram's static, two-dimensional format make it impossible for the viewer to examine more than a few simple relationships at a time. The addition of a usable third spatial dimension and time as a separate fourth dimension greatly enhances the usefulness of diagramming as a tool.

In the dynamic diagram, the presentation of the data is continually updated as variables change in value. Pattern is recognized as much by the rhythm of changes in time as by changes in space. The possibility of manipulating the diagram interactively adds further power to the exploration process because it enables the viewer/analyst to discover patterns using the natural ability of human perception to search and recognize.

As the recognition of pattern is fundamental to the attainment of insight, the communication of pattern is key to the sharing of insight. The same dynamic mechanisms that make the dynamic diagram so effective in discovering pattern contribute to the success of the dynamic diagram as a tool for communicating abstract information. Once discovered, significant patterns can be isolated and stored in dynamic diagrams that can be shown as animated presentations or manipulated interactively by those who need to understand.

Structure

The structure underlying the dynamic diagramming model represents reality in terms of entities and relations. In this model, the elements "in view" at any time are entities, and associations among them are expressed by relations. Attributes, both for entities and relations, provide detail and variation. Long employed by systems engineers, this modeling concept is now commonplace in computer science and other disciplines; it is referred to as the *entity/relation*, or *ER model.*

Two extensions to the general ER model add great power for dynamic diagramming. The first is a role for context as a hierarchical concept. Context is always the level above what is focused upon. If the ER model is expressed hierarchically, there will be a progression of entities from those of grand scope to those which are highly specific or fundamental; entities will belong to higher level entities and will have their

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Some sources for exploring diagram structure are included in the bibliography. See, for example, entries for P. P. Chen, H. F. Korth and A. Silberschatz, C.L. Owen (1986 entries) and T. J. Teorey et al.

own member entities at levels below. At any level in such a structure, the next higher level entity is the context for its member entities. The second extension is that of processes as specialized attributes. Borrowed from object-oriented programming, the concept of processes associated with entities and relations (and context) supplies a major dynamic capability useful for modeling. A process may be a set of rules that are applied, a production system that is initiated, an algorithm that is executed or some other form of activity prescription.

More than this basic introduction to structure requires its own presentation. Some additional reading may be of use for this purpose.[1] How dynamic diagramming can be used for data exploration is the subject of this paper, and the focus for that is the operations that can be performed on a dynamic diagram.

Operations

Using the dynamic system requires tools for developing the model and tools for observing its working. Tools for describing and altering the model are operations called *transformations*; tools for changing the way its performance is viewed are *transpositions*. Both are best conceptualized as processes operating on the model or on its display in diagram form, and both should be thought of as being applied by the analyst actively working at the display.

Transformations

Transformations operate on the structure of the model, changing any or all of its components. Transformations on entites change the model at a macro level. They may create entities, add or remove entities of a given kind, change entities from one kind to another, consolidate or differentiate them. Attribute transformations change the local characteristics of entities. They may add or remove attributes, consolidate or differentiate among them; change attribute types, values or ranges of values. Because transformations deal exclusively with structure, they will not be discussed further in this paper.

Transpositions

Transpositions change the diagrammatic display of the model, letting the viewer look at the model in different ways. They are conceived as operations that control how the display proceeds in space, time and domain. With state-of-the-art computer technology, it is possible to design a number of fundamental operations for this purpose. By combining these operations in different ways, the analyst can examine the model's performance in intricate detail.

Transpositional operations that operate on spatial relationships let the analyst study a diagram from different spatial viewpoints, helping him to comprehend complexity without resorting to reductionist methods. For instance, instead of generating another diagram to view

an obscured portion of a static two-dimensional diagram of three variables, the analyst working with a dynamic diagram simply rotates it to see the region of interest.

Time-related changes in attributes require temporal transpositions. For example, to study changing attributes and processes in an ER model, the analyst should have at his disposal ways to view these temporal changes with different time frames.

Shifting emphasis from one context or domain to another requires transpositional operations to change the focus of study. Among other actions, these transpositions allow the analyst to traverse the model hierarchically, using depth-first or breadth-first traversal methods, or combinations of both.

An effective analysis of information primarily involves understanding relationships. Comparisons of pattern are critical. To compare, the analyst must have the capacity to organize images in all of the different ways discussed. For this purpose, a number of operations can be constructed under the classifications of *spatial, procedural* and *organizational* transpositions.

Some general control characteristics are established for these transpositions to assist the analyst with maximum interactivity. A user is given the option for manual or automatic control. The manual option, in which a diagram is subjected to controlled manipulations, allows the analyst to look at the diagram with precision. By automating operations according to a predetermined plan, the analyst is able to view changes from an optimal viewpoint. Options are also provided to effect changes in a continuous manner or in discrete steps. In many cases, making the changes cyclic in nature offers an advantage – the repetitive study of patterns in motion. Accordingly, there are options for toggling between cyclic and acyclic transpositions as desired.

The effectiveness of an analyst's interactivity is also increased by assigning control variables to appropriate hardware devices. A control variable that changes continuously is assigned to a knob or a similar device; a control requiring random access to any location on the screen is assigned to a pointer device such as a mouse.

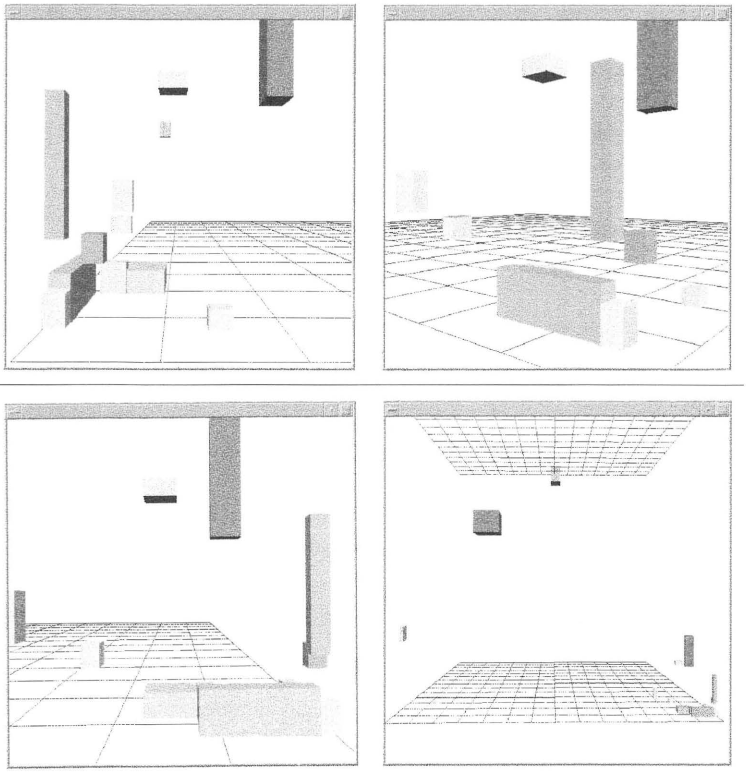
Spatial Transpositions Spatial transpositions are operations that permit changes in the "geographic" viewpoint of the observer with respect to the diagram. They are executed by either moving the diagram relative to the observer or vice versa. The use of these transpositions is modeled on the familiar movement of three-dimensional objects.

1 ***Rotation.*** This transposition moves the diagram around a point. *Object rotation* is one method to achieve this; the diagram is simply moved about a point treated as a rotation origin. *View point* rotation changes the display by moving the viewpoint in relation to the diagram. This is comparable to a camera movement, in which the observer looks at an object through the view-finder and moves around while focusing on a static reference point. Effectively, for the display, the reference point is the rotation origin. In the case of a three-dimensional diagram, object rotation and viewpoint rotation both may occur around the

Figure 1 Screen snapshots during rotation transposition around the Y axis show an initial front local view of the diagram (1.1), a view from the front left corner after 60 degree rotation (1.2), a view from the left side after 90 degree rotation (1.3) and a global view from the left side after zooming out (1.4).

1.1-1.2

1.3-1.4



three spatial axes X, Y and Z. For the rotation transposition, the analyst controls the selection of the axes around which rotation is to be performed, individually or in combinations. Also under the analyst's control is the placement of the rotation origin – not necessarily within the limits of the diagram space. Locating the origin near the center of the diagram ensures that it will remain visible within the viewing window during transposition. Selecting a point outside the diagram space causes the diagram to move in a circular path, continuously changing position in relation to the screen and, during some period, passing out of sight.

The angle of rotation for every successive frame of a changing display is also under the control of the analyst, allowing movement resolution and the speed of rotation to be precisely specified. An obvious use of this transposition is for finding views in which entities cluster in patterns, revealing close associations and "strangers" (*see figure 1*).

2 ***Pan.*** This transposition two-dimensionally translates the diagram. Simplified, the movements are categorized as left/right and up/down translations. Combinations of these movements let the analyst position his viewpoint anywhere on the field of view.

The transposition is executed by either translating the two-dimensional screen image with respect to the viewer or by translating the view axis. The former can be referred to as *image pan*, the latter as *view-axis pan.*

When a detail of interest is being displayed on the screen, the analyst will need to keep track of its relationship to the rest of the diagram. The pan transposition helps accomplish this by supporting movement anywhere in the field of the diagram. Conversely, when a large diagram is being studied, panning across the field introduces a series of local views, helping in the search for interesting details.

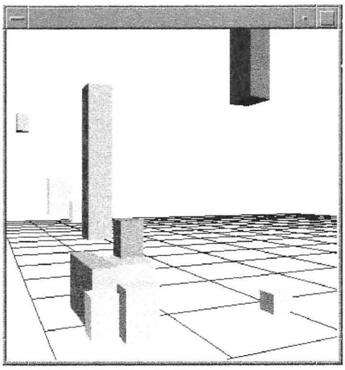
3 ***Zoom.*** This is movement into or out of the diagram. In execution, the process either moves the diagram toward the viewpoint or moves the viewpoint toward the diagram – the former method is referred to as *image zoom*; the latter, *viewpoint zoom.* Selection of the zoom center is made by clicking the mouse at a point on the screen. Zoom motion, continuous or discrete and zooming speed are also under the control of the user. An extension of this transposition is *zoom through*; in this case, zooming-in proceeds along the zoom axis beyond the zoom center, revealing the view of the diagram from the back (*see figure 2*).

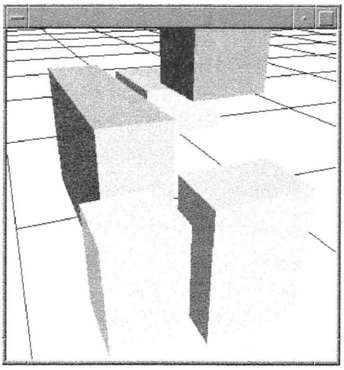
The zoom transposition can be quite effective in extracting detail from a global view of the diagram. In contrast, when a local pattern is under study, zooming out reveals a bird's eye view for better understanding of contextual relationships.

4 ***Translation.*** Using this transposition, the analyst can move the diagram along the spatial coordinate axes, individually or in combinations (a special case occurs when the translation axis coincides with the view axis; in this instance, the transposition functions as a zoom along that axis). Normally, translation causes the diagram simply to change in two-dimensional position on the screen. When spatial coordinates are

Figure 2 From an initial global view (2.1), the zoom-in transposition reveals details (2.2).

2.1-2.2





assigned to attribute values, translation changes the diagram in accordance with the changing values of the associated attributes.

5 ***Scaling.*** Here the diagram is treated as a two-dimensional image and is enlarged or reduced in size. Like other basic operations, scaling is executed by changing and applying the transformation matrix that controls the repositioning of element coordinates on the screen. Scaling up or down can be done continuously or in discrete steps with a user-selected scale factor. The center for scaling is selected with the pointer device. Like the zoom transposition, scaling gives the user the ability to look at the diagram locally or globally. Because it is a simple enlargement or reduction of the image, however, scaling (unlike zooming) does not produce changes in perspective.

6 ***Sectioning.*** In this operation, a plane is interactively moved across the diagram. Since spatial coordinates may be associated with the diagram's attributes, a sectioning plane perpendicular to a coordinate axis can be considered, at any instant during the sectioning, to be a reference plane having the value of the associated attribute. In the case of a three-dimensional diagram, three sectioning planes can be established, each perpendicular to one of the coordinate axes and parallel to the other two. Inclined or oblique sectioning planes can also be introduced by the user for more complex referencing. Movement of the sectioning planes is assigned to individual control knobs to enable the analyst to undertake combined sectioning transpositions with precision (*see figure3*).

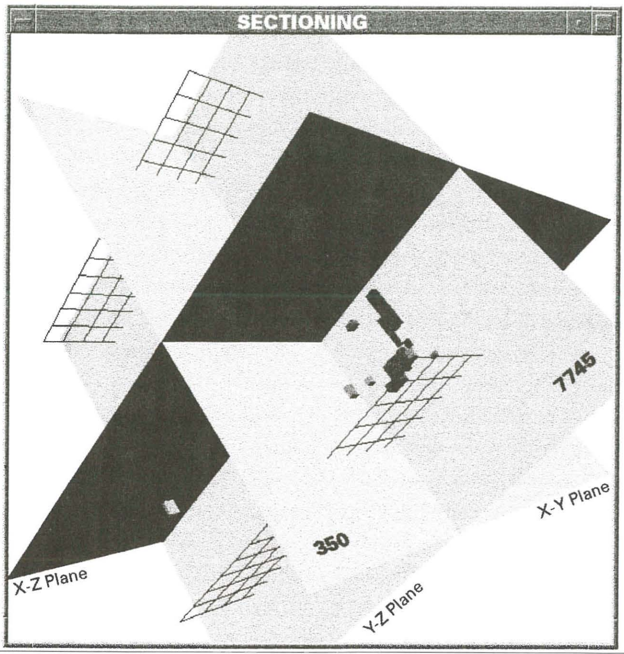
In addition to simply moving the sectioning plane across the diagram, the user can clip the diagram on one side (*unilateral clipping*) or on both sides(*bilateral clipping*). In the first case, the view shows only that portion of the diagram with values beyond the axis value assigned to the sectioning plane. In the second case, the display is, effectively, a two-dimensional view of the diagram for the axis value of the sectioning plane. The thickness of the sectioning plane can also be controlled. In this case, the portion of the diagram within the thickness of the plane contains just those entities whose values for the attributes are marked by the plane.

7 ***Navigation.*** Borrowed from concepts associated with aircraft movements, navigation is used when the analyst wishes to enter the diagram. For control purposes, the diagram is conceived to be stationary while the view axis undergoes yaw, pitch and roll. These capabilities, combined with forward motion and speed control, enable the analyst to fly or "navigate" through the diagram (*see figure 4*). Serendipitous navigation is often a good way to gain insight. As interesting events are explored in an ad hoc manner, the patterns that are observed may lead to the inference of critical relationships.

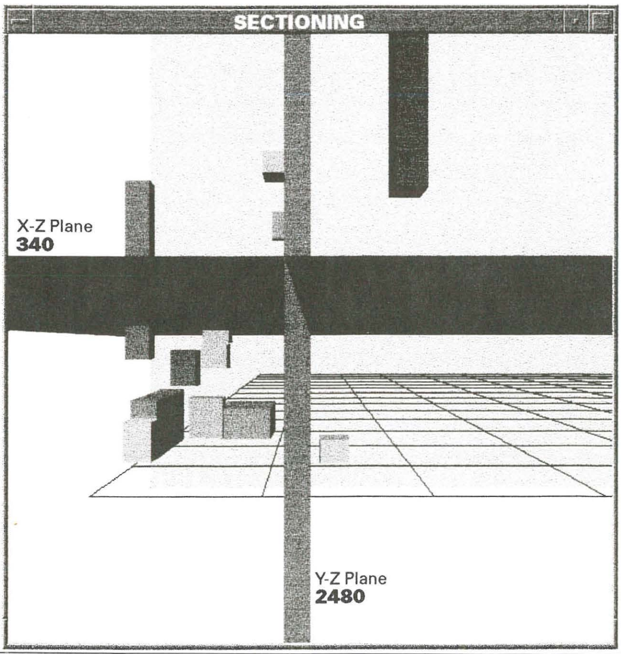
8 ***Slit Scan.*** Here, the screen image is viewed through a slit, or thin window, that can be interactively translated anywhere on the screen. The image bounded by the slit is highlighted as the focus of attention for selective pattern recognition. Dimensions of the slit can be set by the analyst and its movement can be independently controlled along the X and Y coordinates of the screen, or along a combination of both. By assigning the movement of the slit during scanning to a function of changing

Figure 3 A sectioning transposition involves interactive placement of sectioning planes to divide the diagram into sub-spaces. A global view of the sectioned diagram (3.1) and a local view from the front (3.2) are shown.

3.1



3.2



attribute values, the scanned images can reveal useful clues relating to continuity or sample diversity.

9 ***Flip.*** Flip can be considered a special case of rotation. The diagram's image on the two-dimensional screen is rotated in three dimensions around an axis perpendicular to the viewer's line of sight. The image (as a two-dimensional projection) progressively condenses, becomes a thin line and returns to a full-frame image as seen from behind.

Procedural Transpositions Procedural transpositions manipulate the time flow of the display. Here, time is considered to have two connotations. *Viewing time* pertains to the intervals between the display of successive images, in other words, the length of time that an image is seen before the next image is displayed. *Data time* refers to intervals between changes in the attribute values of the data set; it is measured in the time units of the data (e.g., years, microseconds, light-years). By manipulating the viewing time, the analyst is able to temporally view changing spatial patterns. Patterns of growth, decay, steady-state, etc. for the entities of the model are analyzed through the control of data time.

1 ***Time Run.*** The time run is a basic transposition applied to data time. Changes in attribute values for a period of time are displayed as entity changes over the selected time run. Execution of the transposition is made by displaying image frames (associated with each time unit) at a speed governed by the persistence of human vision and by the system's processing speed. For repeated viewing of the patterns, the sequential display of frames can be made cyclic. Options are also available to execute the time run in forward or reverse order.

2 ***Time Lapse.*** Time lapse can be considered a special case of time run in which frames are displayed in an artificial continuum whose time intervals are not those of the given data time, but longer, preselected intervals that collapse time for the real-time analysis of otherwise slow processes. Selection of the time interval is done either through external control devices or by entering the interval in discrete time units. The transposition lets the analyst look at changes at a quickened pace, much as would be seen with time-lapse photography.

3 ***Time Scan – Forward/Backward.*** The time scan transposition presents frames rapidly in succession to help the analyst to scan through many to find an exact time frame. It is executed by operating a step knob assigned three operations–forward, stop and backward motion.

4 ***Sequence Replay – Forward/Backward.*** Sequence replay allows the analyst to replay sequences of frames forward or backward. A sequence can be selected from a list of sequences marked by the analyst and saved by the program; alternatively, it can be specified directly by indicating beginning and ending times in data time. Repeated viewing of a sequence of interest is possible by making the transposition cyclic.

5 ***Flash Back – Flash Forward.*** During a viewing session, an analyst can instantaneously flash to a desired time frame in past or future data time relative to the current frame. An extension of this transposition

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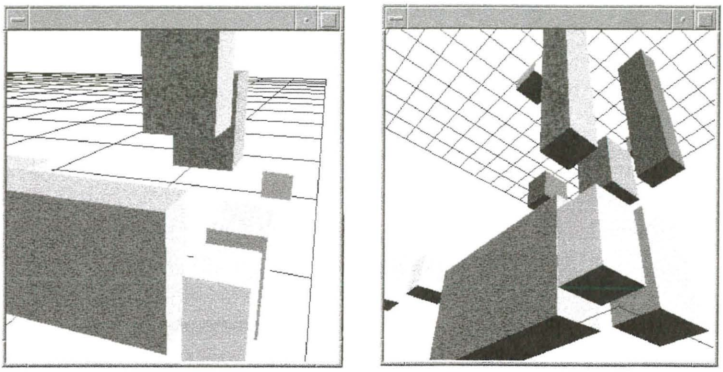
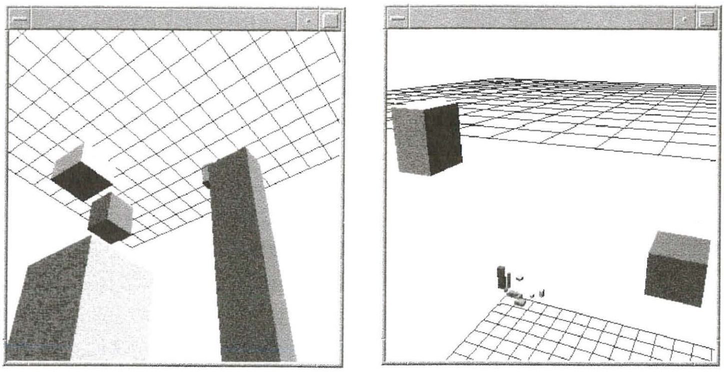
Figure 4 Screen snapshots during navigation transposition show an initial local view of the diagram (4.1), a view after lowering altitude and pitching up (4.2), a view after continued movement forward (4.3) and a view after reaching the top of the diagram and looking backward (4.4).

4.1 - 4.2



4.3 - 4.4



allows the analyst to flash to a past or future sequence. This supports comparison of a just seen pattern with that of a previously noticed pattern or with that of an expected one.

6 ***Freeze/Resume.*** During animated display of a diagram, the ability to freeze a desired image faciltiates detailed study of a stage in an unfolding pattern. The resulting snap-shot is a single frame in viewing time. The resume transposition restarts the display process.

7 ***Altered Speed.*** This is a general operation that can be applied to any temporal process. Using interactive controls, the analyst can decrease or increase the rate of display to any desired level within the capabilties of the computer hardware. Adapted from techniques used in animation, control is realized by varying the number of frames generated and displayed per unit time. In slow motion, detailed entity movements within the diagram space are revealed. General patterns of motion are evident at high speed.

8 ***Stroboscopic Time Run.*** In a stroboscopic time run, entities' images are allowed to remain on the screen as the time run proceeds. The screen is not erased, and current images are drawn over previous ones. The analyst sees not only the progression of an event, but its "frozen" history with the positions of all entities over the time period shown simultaneously. Paths of progression are clearly shown (*see figure 5*). Forward or backward progression may be selected.

9 ***Time Path.*** With the help of a time path, changes in attribute values associated with spatial position can be displayed as a continuous progressive path. During execution, lines are drawn between entity positions as viewing time progresses. The resulting image unambiguously reveals the path traversed by the entities within the period being studied. These paths may then be examined independently or comparatively as new artifacts.

As a useful extension to this transposition, *history cues* may be added. History cues help to reduce confusion about the order of steps in a path, this is sometimes a problem in determining beginnings and endings, and always a problem when an entity changes spatial position radically as it moves in time. For cueing, the images of entities are progressively altered in brightness or value with each succeeding time frame. The result is an unambiguous path with a clear indication of beginning and ending.

Organization Transpositions Both spatial and temporal patterns can be studied more easily if images can be seen together optimally on the screen. Supporting this are *organizational transpositions* for flexibly creating and arranging multiple diagrams. These operations are designed to support interactive comparison, aiding the analyst to draw meaningful inferences from the study material. Organizational transpositions work with relationships between diagrams, between segments of a diagram and between diagrams and other elements added to the display.

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Figure 5 **A stroboscopic time run transposition** displays entities' movement paths over time in a single view. In an entity's movement sequence, the darkest and lightest blocks represent beginning and ending locations respectively.

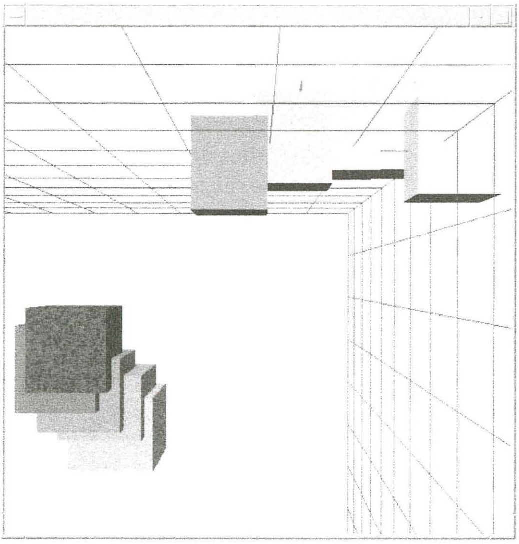
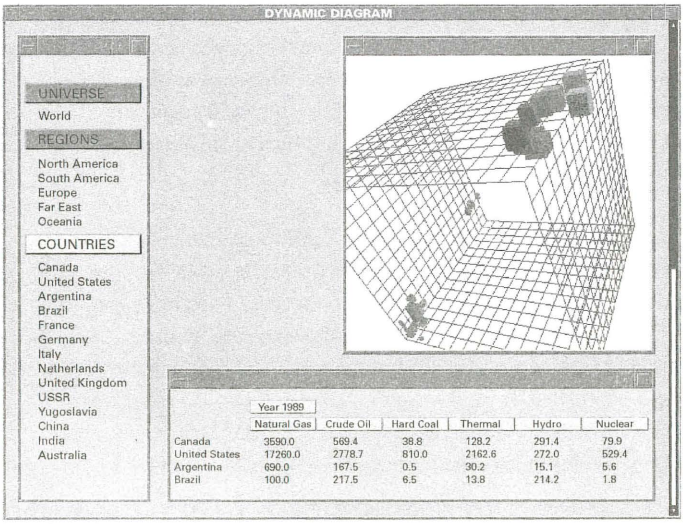


Figure 6 **Three simultaneously displayed windows,** during a stroboscopic time run, show the changing diagram (top right window), a table in which numerically displayed attribute values change in synchronization (bottom window) and names of displayed entities as text (left window).



1 ***Simultaneous Windowing.*** This allows the analyst to open multiple windows showing different views of a diagram at one time. Selection of the views to be displayed depends on the user's intent. The images can be static or dynamic or both. Some of the possibilities are:

- Views of the same space at diferent times.
- Views at the same time of different spaces.
- Views of different diagram representations of the same context or model.
- Views of different contexts or models with the same diagram representation.
- Views of different segments of the same diagram.

For pattern finding, explorations proceed most conveniently if a model can be studied alternately (or simultaneously) in diagram form, in tabular form and in structural form (to institute *"what if"* transformational changes). The tabular form of a model is a table consisting of text, numbers or other symbols. It has particular value as a detailed reference when animated in synchronization with the diagram form of the model. As a time-run proceeds, for example, one window can show the changing diagram while another shows a table in which the actual attribute values, displayed numerically, change in synchronization (*see figure 6*).

Priorities can also be assigned to windows. If two or more views have the same significance in terms of comparison of patterns, they probably will be the same size. If one view has primary importance, however, it can be given size priority and status as a *focus* window. Secondary windows, then, can be smaller (and more of them can exist simultaneously). In such a case, an additional operation is available to the user: the capacity to switch the focus of study by interchanging views among windows.

A frequently valuable simultaneous windowing strategy is the display of a three-dimensional diagram and its two-dimensional projections. Normal orientation in three-dimensional space is maintained and attribute values can be directly determined graphically.

2 ***Image Overlay.*** Overlaying other images on a diagram permits immediate comparisons; the patterns are visible on a single image. The images overlaid can be space frames (frozen images in viewing time), time frames (stroboscopic paths of entities, for example) or diagrams of different models. Images to be overlaid can be selectively recalled from a set of already-saved frames or can be progressively generated, along with the diagram under study and overlaid as the operational sequence proceeds.

3 ***Reference Element Overlay.*** To assist the analyst in establishing attribute values for entities in a diagram, reference elements can be overlaid. Some of these are:

- *Grids.* Selection of grid size (as a function of attribute value) and the choice to put the grid on any or all the principal projection planes is controllable by the analyst. Three-dimensional as well as two-dimensional grids are possible.

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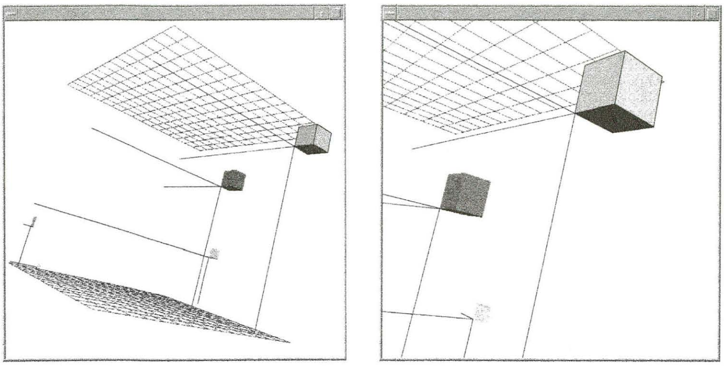
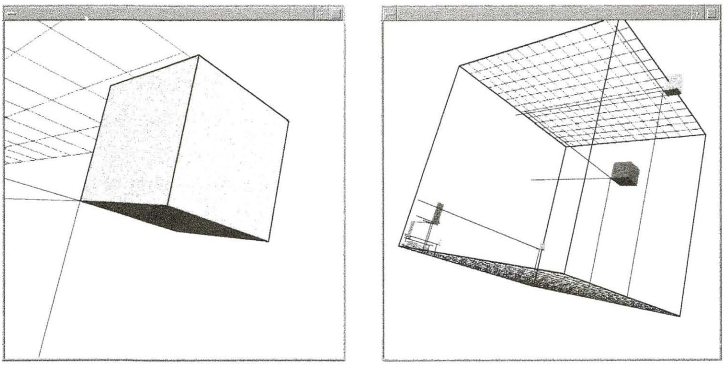
Figure 7 **A hierarchical zoom-in transposition** involves zooming into a member entity (7.1, 7.2, 7.3) to reveal its sub-entities at a lower entity level (7.4).

7.1-7.2



7.3-7.4



- *Coordinate Axes.* The spatial location of entities under study can be perceived better when lines parallel to the major diagram axes (representing the global spatial coordinates) are drawn from the major axis planes to the location of the entity in space. In a time run, the varying lengths of these lines visually record the changing attribute values. Coordinate axes can be put on one, some or all the entities under study.

4 ***Identification Elements Overlay.*** As an aid to interpretation, a wide variety of identification markers can be overlaid on a diagram. Some typical examples are:

- Attribute name text elements written on the global spatial coordinate axes.
- Entity name text, numeric or symbolic elements drawn directly on the entities.
- Attribute names and/or values displayed on the sectioning planes. (This is useful during interactive sectioning transpositions.)

5 ***Superimposition.*** Elements useful for obtaining feedback on the state of transpositions during an interactive session can be superimposed on the display. Some of these feedback elements are:

- *Speedometers.* These might show the current speed during a spatial or procedural transposition.
- *Rotation/Pan/Translation/Scaling/Zooming Maps.* Maps show the current local status in relation to the global diagram during a spatial transposition.
- *Yaw, Pitch and Roll Indicators.* These show current status relative to initial condition during navigation transpositions.
- *Clocks.* These show viewing time, data time or time relative to an arbitrary event.
- *Tracks.* These record movement paths over a sequence of transpositions.

6 ***Highlighting.*** This is used for the purpose of visually focusing attention on selected elements of the diagram. It is accomplished by increasing the contrast between the selected element(s) and the background through a change in hue, intensity, saturation, tone or transparency. Some useful possibilities are:

- Highlighting of entities, singly or in groups.
- Highlighting of selected space or time frames.
- Highlighting of sectioned entities during sectioning.
- Highlighting of entity movement paths.

7 ***Hierarchical Zoom.*** This is a very important transposition in which context and domain are traversed hierarchically, exposing associated super-set and sub-set diagrams progressively. While at a specific context level, zooming into a member entity brings that entity to the context level and reveals its sub-entities and their relationships on the display. Zooming out shrinks the current context from its frame state to its state as a member entity of a newly revealed higher-level entity, now the context entity at the window level (*see figure 7*).

Combining Transpositions An analyst's control over a dynamic diagram can be enhanced by applying transpositions in combinations. The fundamental transpositions described above (spatial, procedural and organizational) are conceived as modules. Complex manipulations are possible by combining them for specialized operations. Many combinations can be constructed from these modules; some examples are discussed below.

By combining *rotation, pan* and *zoom*, analysts can position themselves anywhere in the diagram's space, locally or globally. Adding *sectioning* to this combination, enables analysts to observe the diagram being sliced from any viewpoint. If time related changes in patterns are being viewed, *time run* can be integrated with this combination of spatial transpositions. By placing sectioning planes at selected values of attributes, growth or decay patterns with reference to these threshold values can be studied from different viewpoints as the time run proceeds. If the path of the entities is the main concern of study, time run transposition can be switched to a *stroboscopic* or *time path* transposition. By using the *freeze/resume* transposition with this process, the analyst can study a snapshot of an interesting pattern (noticed while examining the diagram from different viewpoints) and then continue the exploration.

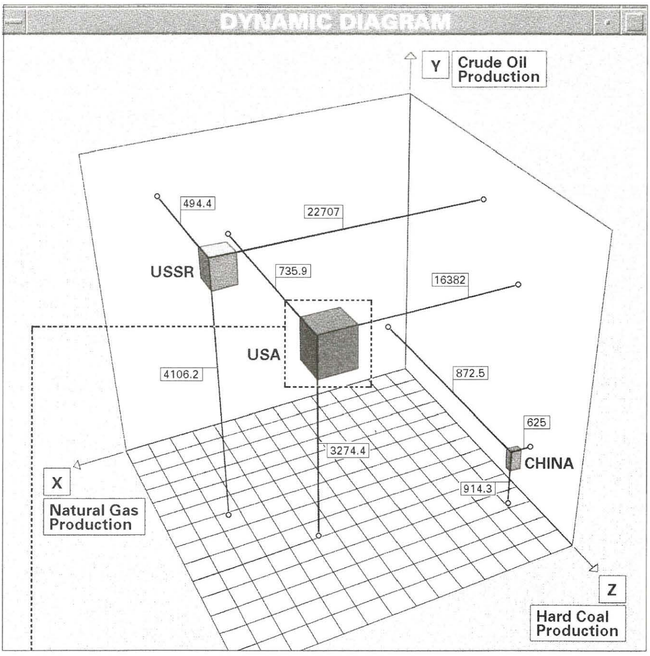
Combining transpositions is made easier with knobs. For controlling the speed and direction of a time run, for example, a knob is considered to have a neutral position at which quantity and direction are zero. Turning the knob clockwise increases quantity (speed) in the forward direction (future); turning it counter-clockwise increases quantity (speed) backward (past).

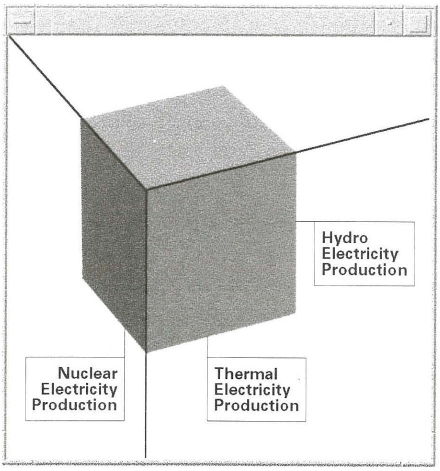
At any point the analyst can automate a transposition for recurrent viewing. For instance, making the rotation transposition automatic causes the diagram to revolve continuously around a chosen axis or axes at a selected speed and direction. The analyst may then study the recurring views for interesting relationships with hands free to apply other operations as appropriate.

Navigation is a transposition that combines *rotation, pan* and *zoom* and enables a user to fly through the diagram space looking at dynamically changing time-related and sectioned patterns and focusing at will on events of interest.

While a combination of spatial and procedural transpositions is running, organizational transpositions can also be applied. As examples, multiple windows can be opened for comparisons; images, reference elements or identification elements can be overlaid and selected entities or images can be highlighted. Combined transpositions, readily constructed as needed, powerfully enhance the versatility of the exploration process.

Figure 8 A six-variable model of world energy production is used as an experimental vehicle to illustrate transpositions. Natural gas, crude oil and hard coal production are plotted along the X, Y and Z spatial coordinates of the three-dimensional diagram. Thermal, hydroelectric and nuclear production are plotted as the width, height and depth of the blocks representing entities.





2
As part of his thesis development at the Institute of Design, Vijay Sivasankaran created a library of transpositions written in the C computer language on a Hewlett-Packard 9000/835 turbo SRX workstation. An ER model was used for the data structure and the simple three-dimensional diagrams shown in the figures were produced to illustrate the transpositions. Figure 8 shows the six-variable model of world energy use that served as the experimental vehicle.

3
Major work on the problem of modeling structure has been completed by Greg T.H. Chien in *Dynamic System Modeling and Simulation in Product Design*, a master's thesis at the Institute of Design. Work on diagrams appropriate for dynamic diagramming is the subject of a thesis in progress by Fatma Sanli-Korbut.

Conclusions

Experience with the working model illustrated and discussed here has demonstrated the effectiveness of transpositional operations for working on dynamic diagrams (*see figure 8*).[2] Further work is needed in two areas: the development of equally powerful transformational operations to build and modify models and the exploration of new forms of diagrams especially suited to the potential of dynamic diagramming.[3]

Diagramming is in the process of being reinvented – a natural outcome of new technology being applied to previously manual processes. Real-time computing means that diagrams can use three spatial dimensions as effectively as two and that time, the fourth dimension, can also be active. The capacity for representation has increased substantially and the potential for interpretation has expanded.

Dynamic diagramming is much more than diagramming. The ease with which the dynamic diagram can be manipulated in time and space gives real meaning to the concept of exploration. The dynamic diagram can formally represent large sets of data – even ultra-large data sets. Because the dynamic diagram can selectively use any portion of the data in space and/or time, it can become the visual "vehicle" for traversing and studying the entire data field.

Since the first serious use of diagrams as tools for analysis, interest and development have been noticeably periodic. In the past, periods of activity have usually been associated with wars, when the need for efficient understanding and communication of complex information was more than normally critical. Now, the driving force is technological. The availability of fast, large memory computers at low prices has made dynamic diagramming both possible and practical for business and science. The result is already evident in the creation of "scientific visualization" as a new field of computer science. Dynamic diagramming, the generalization of the concept, will influence many fields. It is visual statistics.

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By Title, continued.

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Volume 26: 3/4, a special issue, *Diagrams as Tools for Worldmaking*, pages 249-473.

New Perspectives: Critical Histories of Graphic Design
A special issue of *Visible Language*

Call for Papers

New Perspectives: Critical Histories of Graphic Design is a special issue of *Visible Language*. This project seeks to identify problematic aspects of current historical methods and models and to offer alternative approaches to the interpretation of graphic design. An essential element of that endeavor includes the critical examination of current practices including major texts, canons and presentation techniques as well as a reassessment of theoretical assumptions and conventions guiding the study of graphic design history. In addition, an expanded range of interpretations and historiographic methods is sought which broaden the understanding of graphic design as a cultural practice and attempt to locate it within the context of other social, political and cultural activities.

Individuals are invited to submit abstracts for the development of papers concerning the evolving field of graphic design history. *New Perspectives* seeks previously unpublished writing utilizing alternative methods of historical interpretation of graphic design. The project welcomes a broad range of writing which bridges the areas of criticism, theory and praxis. The following suggests the potential scope of papers but it is neither exhaustive nor definitive:

• critical analysis of current approaches to the study and presentation of graphic design history including issues of canon formation, stylistic succession, heroicism, typologies, etc.

• theoretical propositions which offer alternative paradigms for the articulation of graphic design history or models of alternative approaches to interpretation drawn from other disciplines.

• application of alternative methods or perspectives (e.g., Marxist, semiotic, feminist, poststructuralist, etc.) in the interpretation and reassessment of specific subjects of graphic design history including case studies of graphic design which enlarge the scope of current canons through greater cultural diversity and representation.

In keeping with the spirit of the journal, individuals are strongly encouraged to make use of visual demonstrations (photographs, diagrams, sketches, etc.) in their papers including experimental presentations of material.

This project serves as a venue for the publication of alternative material and scholarship for individuals engaged in the study of graphic design history. The project seeks to foster cross-disciplinary inquiry in the practice of graphic design through the examination of the larger social and cultural contexts from which the historical enterprise emerges.

Interested individuals should forward an abstract of no more than 500 words no later than November 1, 1993 to:
Professor Andrew Blauvelt
North Carolina State University
School of Design
Brooks Hall Box 7701
Raleigh, NC 27695-7701
(919) 515-2202 (telephone)
(919) 515-7330 (facsimile)

Individuals will be notified of their acceptance and will have approximately six months for the development of papers. For more information please write or call the guest editor at the address listed above.