IV

INSTRUCTIONAL MESSAGE DESIGN RESEARCH

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26. VISUAL MESSAGE DESIGN AND LEARNING: THE ROLE OF STATIC AND DYNAMIC ILLUSTRATIONS

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The use of illustrations in instructional materials is pervasive (Feaver, 1977; Slythe, 1970). With the proliferation of illustrations in instructional materials, it becomes increasingly important to investigate their effects on student learning. A substantial research literature has already accumulated concerning the role of illustrations in instructional materials. The purpose of this chapter is to introduce researchers in instructional message design to the primary theories of picture perception and to provide a survey and critique of the visual message design research that incorporates static and dynamic (animated) illustrations.

26.1 SCOPE

The effective use of illustrations (pictures, charts, graphs, and diagrams) in instructional materials is an important facet of instructional message design (see 9.7, 16.4.2). Fleming (1993) defines a message as "a pattern of signs (words, pictures, gestures) produced for the purpose of modifying the psychomotor, cognitive, or affective behavior of one or more persons" (p. x). We define pictures as illustrations that have some resemblance to the entity that they stand for, while nonrepresentational graphics, including charts, graphs, and diagrams, are more abstract but do use spatial layout in a consequential way (Knowlton, 1966; Levie & Dickie, 1973; Rieber, 1994; Winn, 1987). Levie (1987) has suggested that there are at least four lines of research on illustrations: (a) picture perception, (b) memory for pictures, (c) learning and cognition, and (d) affective responses to pictures. In this chapter we will first present several theories of picture perception and a brief discussion of selected memory models that have been used to describe how words and pictures are encoded. Next, knowledge acquisition studies incorporating static and dynamic pictures will be reviewed. Finally, we will critically analyze the literature and offer suggestions for future research and practice based on results of primary research and all literature reviews discussed in the chapter. Given the magnitude of the literature, our own expertise, and the economics of publishing, we have only reviewed comparative-experimental research studies (see Chapter 39). Visual message design studies completed using other research methods are certainly reasonable and appropriate. There are many variables to consider when designing visual instructional messages. Our system of classification represents only one perspective on the literature. We have reviewed a wide range of studies, but we do not claim that the review is exhaustive (see 5.2).

26.2 PICTURE PERCEPTION

26.2.1 Theories of Picture Perception

When is a surface with marks on it a "picture?" How do pictures carry meaning? What kinds of meaning can pictures carry (see 8.8.2, 15.8)? Is there a grammar of picturing? Is picture perception essentially innate, or is it a skill that must be learned?

Questions such as these have provoked conjecture from philosophers, psychologists, art historians, semioticians, and computer scientists. It is a fascinating, disputatious literature, one with implications for researchers in educational communication and technology—although widely neglected.

This section of the chapter provides a concise introduction to the major scientific theories of picture perception. To set the discussion of modern theories in historical context, the article begins with a description of the theory of linear perspective developed during the Italian Renaissance. Then two major conflicting theories are introduced: James J. Gibson's resemblance theory, in which meaning is

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based on the picture's resemblance to the visual environment, and E. H. Gombrich's constructivist theory, in which meaning is based on pictorial conventions. Next, a compromise position by Margaret Hagen is described. Then a third major theory is presented: Rudolph Arnheim's Gestalt approach, followed by the views of Julian Hochberg, who is in opposition to Arnheim, and John M. Kennedy, who supports Arnheim.

Next the discussion shifts to two approaches from the field of semiotics: James Knowlton's analysis of the iconic sign, and Nelson Goodman's theory of symbol systems. Finally, some emerging approaches from cognitive science are noted, exemplified by David Marr's computational theory of vision.

Only the gist of each approach is presented, but suggestions for further reading are provided. Overviews to the area can be found in several edited books containing chapters on a wide range of issues: Crozier and Chapman (1984), Hagen (1980b, 1980c), Mitchell (1980), Nodine and Fisher (1979), Olson (1974), and Perkins and Leondar (1977).

26.2.2 Renaissance Perspective Theory: Brunelleschi

The technique of linear perspective by which three-dimensional scenes are represented on two-dimensional surfaces has its origins in ancient Greek architecture and scene design. It was not until 1420, however, that a theoretical basis for the technique was elucidated by Filippo Brunelleschi of Florence. The technique involves using the pattern of light rays emanating from a natural scene. The artists draws the composition that is projected onto a picture plane—a cross section of the straight lines connecting the artist's viewpoint with the objects in the scene. Accordingly, our ability to understand pictures is due to the optical equivalence between pictures and their real-world referents. Because the picture is an optical surrogate for the scene, picture perception is thought to be straightforward and essentially automatic.

But there are problems with this theory. According to the theory, a picture will be perceived accurately only when the person viewing the picture assumes the point of observation taken by the artist. Viewing the picture from a different position should result in distorted perception—an outcome that does not occur in practice. For example, when we look at a portrait from an oblique angle we do not conclude that the person portrayed actually has an elongated head. We take notice of our orientation to the picture surface and judge shapes as though our viewpoint were perpendicular to the picture [although modest distortion due to oblique viewing may occur (Goldstein, 1987)].

Another problem is that successful pictures often violate perspective theory. For example, artists rarely obey the rules of perspective in the vertical dimension. When a tall building is seen from ground level, the rules of three-point perspective stipulate that the sides of the building should be drawn as converging lines. Such drawings are usually judged to look unnatural. On the other hand, when artists violate perspective in the third dimension, the "error" is visually noticed only by those few who are attuned to watch for it. Another violation is that artists often use more than one station point. Often each major figure in a picture is drawn from a different station point, a fact that goes unnoticed by most viewers. On the other hand, pictures drawn from a single station point can look distorted if the station point is very close to the subject. Yet another problem—and there are several more—is that the shapes on the picture plane are ambiguous since they can be the result of the projections of more than one three-dimensional object.

Thus the techniques of pictorial composition used in post-Renaissance Western culture often disobey the geometric rules of perspective. In practice, pictures are very rarely the optical equivalence of the sense they represent, and Renaissance perspective theory cannot serve as an adequate explanation of picture perception.

Detailed treatments of the geometry of perspective are provided by Hagen (1986) and Kubovy (1986). Other commentary on this topic can be found in Greene (1983), Haber (1979), Penrice (1980), and Pirenne (1970).

26.2.3 Resemblance Theory: James J. Gibson

The laws of linear perspective were the starting point for Gibson's resemblance theory of picture perception (sometimes called *projective theory* or the "*direct perception* approach). Although modified somewhat by his final position on the status of pictures (Gibson, 1979), Gibson's best known definition of *picture* is: "A picture is a surface so treated that a delimited optic array to a point of observation is made available that contains the same kind of information that is found in the ambient optic arrays of an ordinary environment" (Gibson, 1971, p. 31).

But what is this "kind of information" that is found in both the picture and environment? According to Gibson it is something beyond the static lines and shapes in the picture; it is a higher-order kind of information consisting of formless, timeless invariants. The concept of an invariant is described by Gibson:

> When a young child sees the family cat at play, the front view, side view, rear view, top view, and so on are not seen, and what gets perceived is the invariant cat. Hence, when the child first sees a picture of a cat, he is prepared to pick up the invariants, and he pays no attention to the frozen cartoon. It is not that he sees an abstract cat, or a conceptual cat, or the common features of the class of cats; what he gets is the information for the persistence of that peculiar, furry, mobile layout of surfaces (Gibson, 1979, p. 271).

These stable, enduring structures that are picked up from the environment are also present in the optic array provided by a picture, and are used to interpret the picture. An example of an invariant is the texture of surfaces such as sand or fur. Such textures are represented in photographs, and act as optical gradients that guide judgments of distances (Gibson & Bridgeman, 1987). Although it is not equally clear how we are able to perceive the invariant shapes of the objects in a picture (e.g., what does an "invariant cat" look like?), Gibson uses the concept to avoid some of the problems of perspective theory (e.g., how can we identify an object in a picture if it is depicted from a point of view we have never seen?). Nevertheless, Gibson's theory of pictorial representation is based primarily on the optical correspondence of the picture and the environment, and it is the structure of the stimulus that is the driving force in picture perception.

For recent discussions of Gibson's work see Cutting (1982, 1987), Fodor and Pylyshyn (1981), Natsoulas (1983), Reed and Jones (1982), Rogers and Costall (1983), and Wilcox and Edwards (1982).

26.2.4 Constructivism: E. H. Gombrich

Perception, as Neisser (1976) puts it, is where reality and cognition meet. Whereas Gibson assigns the major role in this meeting to reality, constructivists such as Gombrich emphasize the role of cognition. Pictures do not "tell their own story," Gombrich argues, the viewer must *construct* a meaning (see also 7.3.1).

Pictures will be interpreted differently depending on the attitude taken by the eye of the beholder. What we see, or think we see, is filtered through a variety of mental sets and expectations. For example, briefly shown playing cards in which hearts are colored black are sometime seen as purple (Bruner & Postman, 1949).

One special class of expectations consists of the artistic conventions in common use. Gombrich (1969) traces the history of Western art, showing how cultural and technological changes have altered the criteria for pictorial realism. What is judged to be a "good likeness" is a function of the conventions and drawing techniques that now look "wrong" and amateurish to our modern eye.

A more pervasive example of a system of pictorial convention in use today is the outline drawing. The use of lines to represent the edges of objects is a substantial departure from nature. The objects in the world are not bounded by lines, and it is due to convention that we perceive outline drawings as depicting shapes rather than arrangements of wires. Whereas the convention that shapes can be represented by outlines is a rapidly acquired understanding, the ability to interpret some conventions such as implied motion cues may require extensive experience or even direct instruction (Levie, 1978).

Such conventions are not arbitrary. Artists are not free to adopt any technique they choose. In fact, the history of naturalistic art can be thought of as a series of innovations in the technique of approximating what is seen by viewing the environment. But Gombrich argues that realism in art is more than just an effort to record the optical data present in nature. The artists must produce an "illusion of reality" that matches the viewer's concept (schema) of what a picture of a given kind *should* look like. And how are these schemata acquired? By repeated exposure to the art of the day. These schemata then function as the standards for judging reality in subsequent picture viewing.

Such schemata can also affect our perceptions of nature. "We not only believe what we see: to some extent we see what we believe" (Gregory, 1970, p. 86). Our experience with art may lead us to look at the natural environment in new ways. For example, the sensitive museum visitor may note that the pastel patches of impressionist paintings can be observed in nature as well. So the ways of representing nature can become ways of seeing nature. Similarly, artists vacillate between painting what they see in nature and seeing in nature what they paint on canvas.

One controversial claim by Gombrich (1972) is that pictures lack the "statement function" of words. For example, he argues that the statement "The cat sits on the mat" cannot be directly pictured. A picture of a cat on a mat depicts a particular cat in a particular environment as seen from a particular viewpoint. An equivalent verbal message would be something like: "There is a cat seen from behind." Gombrich would not, however, propose that pictures are a poor source of ideas. Indeed, the conceptual richness of pictorial representation is a central theme of his work.

For further comment on this approach, see Blinder (1983), Carrier (1983), Gregory (1973, 1981), Heffernan (1985), and Katz (1983).

26.2.5 A Generative Theory: Margaret Hagen

Is picture perception primarily a bottom-up process as Gibson claims, or a top-down process as Gombrich claims? Hagen (1978, 1980a) provides a generative theory of representation that suggests a reconciliation: "Meaning is not given by the head to the unstructured stimulus, nor is it given by the stimulus to the unstructured head. The relation between the two is reciprocal and symmetrical" (1980a, p. 45).

In developing her thesis, Hagen describes differences between how we perceive the natural world and how we perceive "the world within the picture." For example, as compared to natural perception, picture perception compresses the perceived third dimension and increases the awareness of the angle among objects (the spread). Thus, picture perception has a special character that is based partly on ecological geometry (the natural perspective of the visual environment), and partly on the creativity or generativity of the perceiver.

Recently Hagen (1986) has provided a category system for describing the geometrical foundations of many styles of representational art: early Egyptian art, Roman murals, Northwest Coast Indian art, Japanese art, Mayan art, and ice age cave art, to name just a few. For example, there are several options for the location of the artist's station point. It can be close to the subject of the picture, at a moderate distance, or at optical infinity, in which case vanishing points and the convergence of parallel lines (e.g., railroad tracks meeting at the horizon) are obviated. Also, the system can involve the use of a single station point or multiple station points. Hagen observes that each system of depiction is "correct" when judged according to its assumptions. Thus in evaluating the art of other times and cultures, we must reject the premise that the prevailing post-Renaissance system of Western art is the only valid system for representing reality, a position also taken by Arnheim.

26.2.6 A Gestalt Approach: Rudolf Arnheim

According to Arnheim, picture perception is not primarily an act of direct perception as Gibson claims, nor is it a response to changing conventions as Gombrich claims. Picture perception is primarily a matter of organizing the lines and other elements of a picture into shapes and patterns according to innate laws of structure. Arnheim (1954) applies the principles of Gestalt psychology to the study of art. He shows how the laws of organization (e.g., the rules of grouping, the laws of simplicity and good continuation) can be found in the art of many periods. Meaning, he argues, has always been embodied in the Gestalt, the whole which is greater than the sum of its parts. Picture making is also derived from Gestalt principles:

> The urge to create simple shapes . . . cannot be explained as an urge to copy nature; it can be understood only when one realizes that perceiving is not passive recording but understanding, that understanding can take place only through the conception of definable shapes. For this reason art begins not with attempts to duplicate nature, but with highly abstract general principles that take the form of elementary shapes (Arnheim, 1986, pp. 161–162).

Arnheim observes that our judgment of the art of other times and cultures suffers from "a prejudice generated by the particular conventions of Western art since the Renaissance" (Arnheim, 1986, p. 159). Furthermore, current technique is so pervasive that we assume that it is the only correct way to make pictures. But the techniques of unfamiliar art styles are not, as sometimes supposed, due to lack of skill or accidentally acquired convention; nor are they deliberate distortions devised for some artistic purpose. Each style is based on an internally consistent system of solutions to visual problems, solutions that are no more in need of justification than contemporary technique.

Arnheim (1969) is also known for his advocacy of "visual thinking." He rejects the belief that reasoning occurs only through the use of language. In fact, he argues that thinking occurs primarily through abstract imagery. Arnheim champions the role of art in education and stresses the importance of teaching students to become fluent in thinking with shapes.

Another recurrent theme in Arnheim's work is the nature of abstraction. Representational art involves one kind of abstraction. Portraits, for example, are more abstract than their real-world referents. In such cases, "abstractness is a means by which a picture interprets what it portrays" (Arnheim, 1969, p. 137). On the other hand, pictures may be less abstract than the concepts they symbolize. For example, the silhouette of a cow on a roadside sign, although quite abstract, is still less abstract than the concept "cattle crossing." Arnheim (1974) discusses some of the problems faced by educators in determining the most effective kind and level of abstraction to use in instructional illustrations.

Although Gestalt ideas have been eschewed by cognitive psychologists, recent discoveries in visual anatomy and physiology and the study of perceptual organization have attracted some renewed interest in the area (Hoffman & Dodwell, 1985; Kubovy, 1981, #1056).

26.2.7 Picture Perception as Purposive Behavior: Julian Hochberg

Hochberg opposes the Gestalt approach, arguing that "the whole stimulus configuration cannot in general be taken as the effective determinant for perception" (Peterson & Hochberg, 1983, p. 192). Here is why: All aspects of a picture cannot be perceived in a single glance. Vision is sharp only in a small central area of the visual field—an area about the size of your thumbnail when held at arm's length. On the retina of the eye, acuity falls off rapidly from this area (the fovea). Since detailed discriminations are possible only on the fovea, it is necessary to scan pictures in order to take in all the details. Scanning does not occur in smooth sweeps but rather as a series of very rapid jumps called *saccades* and brief stops called *fixations*—normally about one-third second each. The information obtained from these separate fixations must be integrated into a mental map. Thus "at any given time most of the picture as we perceive it is not only the retina of the eye, nor on the plane of the picture—it is in the mind's eye" (Hochberg, 1972). So the whole is not perceived directly, as Arnheim claims; it is the result of synthesis based on the analysis of parts. These interactions between the picture, eye movements, and cognitions, are "highly skilled sequential purposive behaviors" that are, according to Hochberg, the keys to understanding picture perception.

Hochberg (1979, 1980) describes how certain techniques used in painting can be thought to mimic the workings of the visual system. For example, in some of Rembrandt's paintings most of the canvas is blurred; only a few areas are rendered in sharp detail, simulating what is registered by the eye in a series of fixations. Similarly, techniques used in impressionistic paintings (which Hochberg calls "painting for parafoveal viewing"), pointillist paintings, and Op Art (Vitz & Glimcher, 1984) mirror processes of the human perceptual system.

Another issue discussed by Hochberg concerns the question of which picture of an object is the "best" picture. Hochberg uses the term *canonical form* to refer to "the most readily recognized and remembered view or 'clean up' version of some form or object" (Hochberg, 1980, p. 76). Canonical form preserves the most distinctive features of an object and eliminates noninformative features. Another factor in determining canonical form is the point of view from which an object is depicted.

26.2.8 A Mentalistic Approach: John M. Kennedy

Kennedy is supportive of Arnheim's approach and opposed to Gibson and Gombrich. He argues that we will learn very little about how pictures are perceived by studying the optical geometry of naturalistic art. Understanding picture perception should begin with the realization that pictures are made by people trying to communicate to receivers who are themselves intelligent perceivers striving to grasp the sender's intent. Pictures are made to communicate ideas, not just show scenes. To exemplify his approach, Kennedy discusses the pictorial metaphor:

> Imagine a picture of a businessman with as many arms as an octopus, each hand holding a telephone. Or imagine a picture of a bride looking into a mirror and seeing a harried housewife. These pictures violate the laws of physics; they break the rules that Gibson called on. . . . And they do so precisely because the artist wants to put across ideas: that business men are overworked; that present bliss gives rise to future stress (Kennedy, 1985, p. 38).

Metaphoric pictures present two meanings, one false, the other intended. Understanding the perception of such pictures requires a "mentalistic analysis" in which assumptions are made about the experience and mental processes of the sender and the receiver. "The person who makes the metaphor expects the recipient to notice both meanings, and expects the recipient to know which was intended, and expects the recipient to know what the maker expected from the recipient" (Kennedy, 1984b, p. 901). Kennedy also argues that pictorial cues such as implied motion cues can be conceived of as metaphor rather than as pictorial convention.

As a historical footnote, Kennedy was Gibson's student at Cornell, and at one time followed in his footsteps, writing a survey of the field that was based largely on Gibsonian ideas (1974). But a decade later, Kennedy would write: "Regrettably scientific psychology as found in our universities can never be anything more than a trivial pursuit. By its very nature it is incapable of profound insights into humankind" (Kennedy, 1984a, p. 30). Although this represents a dramatic change in philosophy on Kennedy's part, the attack on a competing approach is by no means unusual. The picture perception literature is an intellectual battlefield delightfully seasoned with charge and countercharge. Theorists are robustly combative in attacking opposing views while defending their own.

26.2.9 A Semiotic Approach: James Knowlton

The theories discussed so far approach the topic from points of view related to visual perception, either by way of perceptual psychology or through the analysis of visual art. The next two theories have a different starting point; they derive from a concern with symbol using in general, thus placing the discussion of picture perception in a broader context.

The boundaries of semiotics—the science of signs—are wide and indistinct. The domain includes questions of the meaning of as well as the communication of meaning. Among the central figures in this field are Cassirer (1944), Morris (1946), Pierce (1960), and Sebeok (1976). For further commentary on the contribution of semiotics to picture perception see Cassidy (1982), Eco (1976), Holowka (1981), Langer (1976), Sless (1986), and Veltrusky (1976).

Here, however, we will focus on the theorist in this tradition who speaks most directly to our present concerns with visual message design research: James Knowlton. Knowlton (1964, 1966) develops a metalanguage for talking about pictures beginning with the term *sign.* A sign is a stimulus intentionally produced for the purpose of making reference to some other object or concept. A key distinction is that between digital signs and iconic signs. Digital signs bear no resemblance to their referents. For example, the physical appearance of the signs "man" and "hombre" do not in any way look like their referent. Examples of digital signs are words, numbers, Morse code, Braille, and semaphore. Iconic signs, on the other hand, are not arbitrary in their appearance. In some way, iconic signs include drawings, photographs, maps, and blueprints.

Usually pictures are thought to resemble their referents in terms of visual appearance. Resemblance can, however, take other forms. Knowlton broadens the concept of "picture" to include "logical pictures" and "analogical pictures." Logical pictures resemble their referents in terms of the relationships between elements. An electrical writing schematic, for example, bears no visual resemblance to the piece of apparatus it represents; it is a picture of the pattern of connections between elements. Flowcharts and diagrams are other examples of logical pictures. In analogical pictures, the intent is to portray a resemblance in function. For example, a pictorial analogy could be made between a suit of armor and an insect's exoskeleton. Thus Knowlton's definition of "resemblance" goes far beyond Gibson's concept in which resemblance is based on the optical equivalence of pictures and their referents. And, even when resemblance is based on physical appearance, the resemblance of a picture to its referent can, according to Knowlton, be slight. Sometimes a simple silhouette will do the job. Additionally, the ways in which resemblance functions in pictorial communication often depend on factors that are extrinsic to the picture itself:

> Resemblance does not designate a single relation between pictures and their subjects; it designates the members of a fairly comprehensive class of relations—a class whose boundaries are not clear. And relations of resemblance are not always immediately evident to the uneducated eye. Knowing how to look at a picture is required to discern the ways it resembles its subject. Knowledge of other matters may be required as well—pictorial conventions, referential connections, historical, scientific, or mythical lore that sets the context of the work. Such matters are not taken in at a glance (Elgin, 1984, p. 919).

The most extreme and controversial position on the role of resemblance is taken by Goodman. He asserts that resemblance between picture and nature is not necessary, and that "A picture is realistic to the extent that it is correct under the accustomed system of representation" (Goodman, 1978, p. 130).

26.2.10 Symbol Systems Theory: Nelson Goodman

Goodman (1976) has devised a detailed theory of symbol systems. A symbol system consists of a set of inscriptions (e.g., phonemes, numbers) organized into a scheme that correlates with a field of reference. For example, musical staff notation consists of five horizontal lines on which notes and other marks are placed that correlate with a musical performance. As another example, maps consist of lines, shapes, and symbols that correlate with a musical performance. Also, maps consist of lines, shapes, and symbols that correlate with roads, boundaries, and landmarks. Thus the analysis of a symbol system involves an examination of (1) the scheme of representation, (2) the field of reference, and (3) the rules of correspondence between the two.

Goodman provides several conceptual tools that can be used for analyzing symbol systems. One key concept is *notationality.* Notationality is the degree to which the elements of a symbol system are distinct and are combined according to precise rules. Music is high in notationality. The notes on the scale are distinct in terms of pitch and duration, and the rules for combining them are clear. Mathematics systems are also high in notationality; each number is distinct and the rules for "making statements" are precise. Pictures, on the other hand, are nonnotational. The "elements" of picturing are overlapping, confusable, and lacking in syntax. The lines and shadings that pictures are built from are without limit, and the ways they are combined to produce a symbol are undefined.

Notationality is an aspect of symbol using that may have implications for human information processing. Gardner (1982) speculates that "a case can be made that the left hemisphere of the human brain is relatively more effective than the right at dealing with notational symbol systems, . . . while the right hemisphere is more at ease in dealing with . . . nonnotational systems" (p. 59).

Another key concept in Goodman's theory is repleteness. Some symbol schemes, such as most pictures, are replete (or dense), whereas other schemes, such as printed words, are lacking in repleteness. The degree of repleteness is an index of how many aspects of a scheme are significant. In printed text, changes in the typeface, boldness, ink color, and other physical parameters do not necessarily alter meaning in any significant way. Drawings, on the other hand, are relatively replete, since several aspects of the marks in a drawing are often critical. Paintings are very high in repleteness. "Everything about a painting is part of it—design, coloration, brush stroke, texture, and so on. A painting is unrepeatable in the strict sense of the term" (Kolers, 1983, p. 146).

Goodman distinguishes three primary functions of symbol systems. Symbols can represent concepts by denoting or depicting them. Symbols can *exemplify* ideas or qualities by providing a sample of the concept. And symbols can *express* affective meaning (emotions).

Symbol systems differ in respect to the ease with which they can perform the functions of representation, exemplification, and expression. For example, music, although richly expressive, has no literal denotation. Music in the absence of a title or lyrics is not "about" anything. Number systems are limited in a different way. Numbers represent quantities, but they normally have no expressive function. Most pictorial systems are versatile. Line drawings, photographs, and representational paintings can depict, exemplify, and express forcefully.

Pictures exemplify qualities such as color and shape through the possession and presentation of them. The qualities exemplified are properties of the picture. Pictures express through "metaphorical exemplification", the figurative possession and presentation of emotion. For example, when a picture expresses sorrow, the feeling can be said to be "in the picture." We must, however, learn how to decode the expressive features of pictorial systems. "Emotions are everywhere the same; but the artistic expression of them varies from age to age and from one country to another" (Goodman, 1976, p. 90).

For other comments on Goodman's theory see Coldron (1982), Gardner, Howard, and Perkins (1974), Roupas (1977), Salomon (1979a, 1979b), and Scruton (1974).

26.2.11 Cognitive Science: David Marr

Artificial-intelligence research on computer vision is a rapidly developing area that may contribute to understanding picture perception by humans. One focus of this work involves determining the computations that are required in order to program a computer to see. To do this, it is necessary to specify the nature of the visual input, to describe how this input is transformed into data that can be handled by a computer, and to enumerate the computations that are carried out on-line to produce solutions to visual problems. Such problems include the detection of shape contours and surface textures.

A central figure in this area is David Marr. Marr's (1982) theory of vision involves the analysis of visual input through a series of stages that culminates the meaningful interpretation of an image. In Marr's theory, an initial analysis involves the detection of features such as boundaries. These determinations are used to construct a "primal sketch" that distinguishes the sections of the display. From these sections, surface data such as shading are used to define the simple three-dimensional shapes in the scene. Finally, "generalized cones" form the basis for the representation and recognition of complex shapes such as animals.

Marr (1982) asserts that since the early days of the Gestalt school "students of the psychology of perception have made no serious attempts at an overall understanding of what perception is" (p. 9). Some psychologists are equally skeptical of the reciprocal value of Marr's work. Kolers (1983), for example, comments that "Although the study of human perceiving may continue to inform the study of machine vision, it remains to be seen whether students of computer vision will teach us much about human perceiving" (p. 160). For comments on Marr's work and other recent approaches to computer vision, see Connell and Brady (1987), Fischler and Firschein (1987), Gregory (1981), Jackendoff (1987), Kitcher (1988), Kolers and Smythe (1984), Lowe (1987), and Rosenfeld (1986).

A theory that is closely related to Marr's approach has been proposed by Biederman (1985, 1987). Biederman describes a process by which an object in a two-dimensional image can be recognized. The process uses a set of primitive elements: 36 generalized-cone components called *geons*. These geons are derived from the combination of only five aspects of the edges of objects (e.g., curvature and symmetry). The process of interpreting a picture involves detecting the edge elements in an image, generating the resulting geons, combining these geons to produce meaningful forms, and matching them to known forms in the visual environment. Only 36 geons are needed for the perception of all possible images, a situation that is analogous to speech perception in which only 44 phonemes are needed to encode all the words in the English language. Biederman invokes evidence showing that the recognition of objects is robust across a wide range of viewing conditions (e.g., occluded views) and viewpoints (e.g., rotations in depth). Biederman's theory would appear to be in opposition to most other theorists who contend that it makes little sense to talk of a "vocabulary" and "grammar" of picturing.

Another area that should be mentioned is neurophysiology. Kosslyn (1986, 1987) suggests how neurophysiology might be combined with AI computational theory to yield a more complete understanding of vision. After all, Kosslyn observes, perception and cognition are something the brain does. The extreme belief regarding the potential importance of neurophysiology is expressed by Kitcher (1988): "Ultimately, all phenomena currently regarded as psychological will either be explained by neurophysiology or not at all" (p. 10).

26.2.12 Implications for Media Researchers: An Example

Picture perception theorists have challenged many of our orthodox beliefs about pictures. For example, consider the question of what constitutes "realism" in pictures. In the media research literature, realism is generally defined as a matter of faithfully copying nature. A picture is said to be "realistic" to the degree that it mirrors the visual information provided by the real-world referent, and researchers studying the effects of pictorial realism have manipulated "realism cues" such as amount of detail, color, and motion. The outcomes of this research have been frequently disappointing.

Picture perception theorists have offered alternatives to the simple "copy theory" of realism. Although Gibson's approach stresses the fidelity of picture to referent, he adds the qualification that a successful picture copies the *invariant* visual information in nature—the optical data about reality that remains constant across time and across different views of an object. Goodman (1976) contends that realism is ". . . not a matter of copying but of conveying. It is more a matter of 'catching a likeness' than of duplicating—in the sense that a likeness lost in a photograph may be caught in a caricature" (p. 14). For Gombrich, the criteria for realism are not in nature, but in the perceiver's head in the form of expectations for what pictures of a given type "should" look like. These expectations are built up during extensive experience with the prevailing pictorial system and function as the standards for judging realism. Arnheim argues that perceptions of realism are relative to pictorial style, and are particularly influenced by how a style represents what we know about an object (conceptual reality) as compared to what the object looks like (perceptual reality). Marr and Biederman propose bottom-up theories that focus on the match between abstract elementary forms in pictures and their referents.

Thus contrasting the copy theory of pictorial realism with those of picture perception theorists, the copy theory emphasizes the exact visual match between pictures and referents, whereas theorists emphasize the nature of departures of picture from reality: surface level vs. deeper semantic, psychological, stimulus only vs. contribution of perceiver also.

26.3 MEMORY MODELS

There is significant evidence that generally memory for pictures is better than memory for words. This consistent finding is referred to as the *picture superiority effect.* At least three significant theoretical perspectives have been used to explain the "picture superiority effect," including: (1) the dual-code model (see 16.2.1, 29.2.3), (2) the single-code model, and (3) the sensory-semantic model (see Fig. 26-1).

Proponents of the dual-coding theory argue that there are two interdependent types of memory codes, verbal and nonverbal, for processing and storing information (Paivio, 1971, 1978, 1990, 1991).

The verbal code is a specialized system for processing and storing verbal information such as words and sentences. The nonverbal system "includes memory for all nonverbal phenomenon, including such things as emotional reactions. This system is most easily thought of as a code for images and other 'picture-like' representations (although it would be inaccurate to think of this as pictures stored in the head)" (Rieber, 1994, p. 111). If it is assumed, as Paivio does, that the dual coding of pictures in verbal and nonverbal memory is more likely to occur for pictures than words, then the "picture superiority effect" could be explained using dual-coding theory.

Proponents of a single-code model argue that visual information is transformed into abstract propositions stored

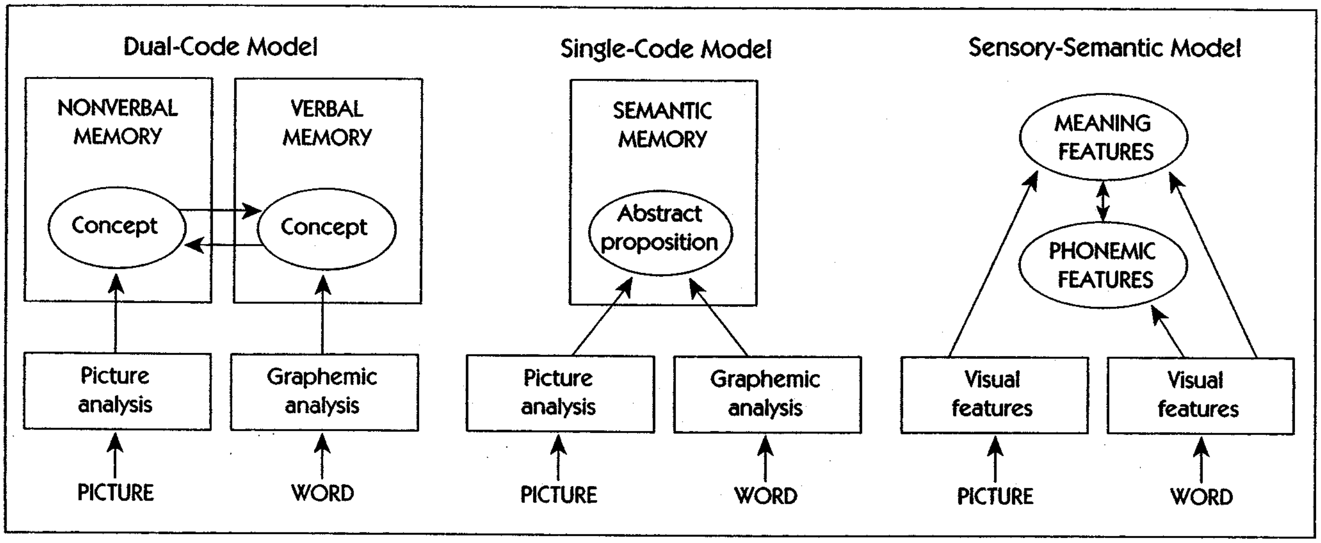

Figure 26-1. Three prominent models of encoding words and pictures. From "Picture-word differences in decision latency: a test of common-coding assumptions" by J. te Linde, 1982, *Journal of Experimental Psychology: Learning, Memory, and Cognition 8,* pp. 585, 586. Copyright 1982 by American Psychological Association. Adapted by permission. Also from "Learning to order pictures and words: a model of sensory and semantic encoding": by D. L. Nelson, V. S. Reed & C. L. McEvoy, 1977, *Journal of Experimental Psychology: Human Learning and Memory 3,* p. 486. Copyright 1977 by the American Psychological Association. Adapted by permission. Also from "Research on pictures: a guide to the literature" by W. Howard Levie, 1982. *In* D. M. Willows & H. A. Houghton, eds. *The psychology of illustration: basic research,* p. 1. Copyright 1982 by Springer-Verlag, New York. Reprinted by permission.

in semantic memory (Anderson, 1978; Kieras, 1978; Kosslyn, 1980, 1981; Pylyshyn, 1981; Rieber, 1994; Shepard, 1978). Advocates for a single-code model argue that pictures activate a single semantic memory system differently than do words. Individuals "provided with pictures just naturally spend more time and effort processing pictures" (Rieber, 1994, p. 114).

Picture superiority can also be explained using a sensory-semantic model (Nelson, 1979). There may be a more distinctive sensory code for pictures, or the probability that pictures will be processed semantically is greater than that for words (Levie, 1987; Nelson, Reed & Walling, 1976; Smith & Magee, 1980). In many cases researchers in educational communications and technology have neglected the work that has been done concerning memory models.

26.4 PICTURES AND KNOWLEDGE ACQUISITION

26.4.1 Literature Search and Reviews

Through various on-line and manual literature searches, 2,196 primary research studies, reviews, books, conceptual papers, and magazine articles were identified, collected, and catalogued. The literature search was limited to the categories of static and dynamic pictures and knowledge acquisition. Many of the documents collected were not appropriate for the current review. For example, numerous papers reported the results of memory recognition studies including pictures. In addition, several studies were not included because of methodological flaws such as failing to include a control group or appropriate statistics. Many of the papers identified were not primary research studies or theoretical in nature. A total of 132 primary research studies were included across the two categories (static illustrations, dynamic graphics) used for the review. We first report the results of earlier literature reviews. Then an abridged guide to the literature will be presented.

26.4.2 Static Pictures and Knowledge Acquisition

In this section, we first present a summary of earlier reviews of the literature concerning the role of static pictures in the acquisition of knowledge. Second, we discuss the results of our literature search and summary. A similar approach will be used for dynamic pictures and knowledge acquisition.

26.4.2.1. Static Pictures and Knowledge Acquisition: Literature Reviews. Spaulding (1955) reviewed 16 research studies using pictorial illustrations conducted between 1930 and 1953. Based on the findings of the 16 studies, Spaulding concluded that illustrations: (a) are effective interest-getting devices; (b) help the learner interpret and remember the content of the illustrated text; (c) are more effective in realistic color than black-and-white, but the amount of effectiveness might not always be significant; (d) will draw more attention if they are large; and (e) should conform to eye movement tendencies.

Samuels (1970) reviewed a series of 23 studies that investigated the effects of pictures on learning to read words, on reading comprehension, and on reader attitudes. Samuels's review covered a time span from 1938 to 1969. The studies reviewed included such treatments as: (a) learning to read words in isolation with and without pictures, (b) acquiring a sight-vocabulary with and without pictures, (c) using pictures as a response alternative in a reading program, and (d) using pictures as prompts. Samuels concluded that: (a) Most studies show that, for acquisition of a sight-vocabulary, pictures interfere with learning to read; (b) the majority of studies indicate that pictures used as adjuncts to printed text do not facilitate comprehension; and (c) pictures can influence attitudes. Many of the studies reviewed by Samuels were narrowly focused on the use of illustrations to learn to decode words in isolation. Illustrations used in the context of learning to read have generally not proved to facilitate learning.

An analysis of the pictorial research in science instruction has also been conducted (Holliday, 1973). The general conclusions reached by Holliday concerning the effect of pictures on science education were that: (a) Pictures used in conjunction with related verbal material can aid recall of a combination of verbal and pictorial information; (b) pictures will facilitate learning if they relate to relevant criterion test items; (c) pictorial variables such as embellishment, size, and preference are complex issues; and there are almost infinite interrelationships between picture types, presentation formats, subject content, and individual learner characteristics.

Concannon (1975) reviewed a number of studies on the effects of illustrations in children's texts (mainly basal readers). Concannon summarized the results of her review with the single conclusion that when pictures are used as motivating factors, they do not contribute significantly to helping a young reader decode the textual information.

Levin and Lesgold (1978, pp. 234–235) reviewed studies of prose learning with pictures and concluded that pictures do facilitate prose learning when five ground rules are adhered to, including:

1. Prose passages are presented orally.
2. The subjects are children.
3. The passages are fictional narratives.
4. The pictures overlap the story content.
5. Learning is demonstrated by factual recall.

While Levin and Lesgold (1978) focused on oral prose, they also suggest that pictures may benefit individuals reading for comprehension.

Schallert (1980) reviewed a number of research studies and presented the case for and against pictures in instructional materials. In the case against pictures, Shallert reviewed the work of Samuels (1967, 1970) and others. Shallert states that "the most convincing evidence against the use of illustrations in children's text has been marshaled by Samuels" (p. 505). Shallert noted that many of the early reviews completed by Samuels, Concannon, and others reported that the use of pictures serving as motivating factors do not facilitate a child's ability to decode text information. Shallert indicated that some of the reasons the pre-1970 studies did not identify picture effects were: (a) The primary emphasis in the word acquisition treatments were speed and efficiency; with the words being spoken aloud, pictures used in that context are of little value; (b) the illustrations used in many studies were not meant to convey new information and were only used as adjuncts to the text; (c) many illustrations used in basal readers vaguely relate to the contextual information in the text; and (d) the effects of illustrations on long-term memory were not measured in these earlier studies.

In the case supporting positive picture effects, Shallert (1980) reviewed a series of studies that covered the time period from 1972 to 1977. The general conclusions reached by Schallert were that pictures can help subjects: (a) learn and comprehend text when the pictures illustrate information central to the text, (b) when they represent new content important to the overall message being presented, (c) when they help depict the structural relationships covered by the text, and (d) if the illustrated information contributes more than a simple second rehearsal of the text.

Readence and Moore (1981) conducted a meta-analytic review of the literature on the effect of experimenter-provided adjunct pictures on reading comprehension. The 16 studies reviewed included 2,227 subjects and incorporated a total of 122 measures of association between the use of adjunct pictures and reading comprehension. The overall results across all studies revealed only minimal positive effects on reading text and subsequent reading comprehension when using adjunct pictures. The magnitude of picture effects were more substantial for university subjects who read text containing adjunct pictures.

One of the most comprehensive reviews of the effects of illustrated text on learning was done by Levie and Lentz (1982). The Levie and Lentz (1982) review compared three separate areas concerning the role of illustration in learning: (a) learning illustrated text information, (b) learning nonillustrated text information, and (c) learning using a combination of illustrated and nonillustrated text information. Studies included in the Levie and Lentz review cover a time period from 1938 to 1981. Levie and Lentz also present a functional perspective, which could be used to explain how illustrations might function to facilitate learning. Functional frameworks will be covered in detail in a later section of this chapter.

Summarizing the results across all studies included in their review, Levie and Lentz (1982) drew three primary conclusions: (a) Learning will be facilitated when the information in the written text is depicted in the illustrations; (b) learning of text material will not be helped nor necessarily hindered with illustrations that are not related to the text; and (c) when the criterion measure of learning includes both illustrated and nonillustrated text information, a modest improvement may often result from the addition of pictures.

Using Levin's (1981) framework to classify pictures according to the function they serve in prose learning, Levin, Anglin, and Carney (1987) conducted a meta-analysis of the pictures in prose studies. The reviewers concluded that for pictures (not mental images), serving a representation, organization, interpretation, or transformation function yielded at least moderate degrees of facilitation. A substantial effect size was identified for the transformation function.

One of the most significant programs of research on visual learning has been conducted by Dwyer and his associates (Dwyer, 1972, 1978, 1987; Levie & Lentz, 1982; Rieber, 1994). The research program is unique in several ways. The studies in the Dwyer series used similar stimulus materials. In particular, the stimulus materials included a 2,000-word prose passage describing the parts, locations, and functions of the human heart along with various types of visual materials including line drawings, shaded drawings, and photographs in black and white and in color. The materials were delivered in a number of formats and combinations including: written prose with illustrations, a slide-tape program with audio and television, and computer-based. In addition, a rationale was provided for the inclusion of visual illustrations in the treatments. If the information tested in a particular section of the text material was not difficult for the student (did not require external visualization), visual information would not be included and tested for this section of the text. Several types of criterion measure were developed by Dwyer and his associates, including a drawing test, an identification test, a terminology test, and a comprehension test. The research has been conducted with over 48,000 students (Dwyer, 1972, 1978, 1987).

Levie and Lentz (1982) conducted a meta-analysis using the treatments developed by Dwyer and presented in a text format or programmed booklet. All studies included in the meta-analysis included a text-only condition. Based on 41 comparisons of treatments with text-plus-prose, with text only using four criterion measures (drawing test, identification test, terminology test, comprehension test), Levie and Lentz (1982) report that 36 comparisons favor illustrated text, and 4 favor text alone (see Appendix Table 26-1).* As with other reviews of literature discussed, one conclusion that can be drawn from the work of Dwyer and his colleagues is that visuals are "effective some of the time under some conditions" (Rieber, 1994, p. 132). Space limitations do not permit a more detailed discussion of the Dwyer series (Dwyer, 1972, 1978, 1987).

26.4.2.2. Guide to the Literature: Static Illustrations. Based on our literature search, 90 studies investigating the role of static pictures in knowledge acquisition were identified (see 12.2). The 90 studies were conducted with more than 13,528 subjects ranging from elementary school children to adults (see Appendix Table 26-3.) All of the studies static visual illustrations of various types with a prose-only included at least one comparison of learning with prose and treatment. A number of the studies included written prose materials, while other included prose presented orally. It should be noted that many of the studies summarized included other comparisons irrelevant to this review, and they are not discussed. In the 118 experiments included in the 90 studies, 102 significant effects for treatments including text and visual illustrations vs. text only were identified. The results of the "box score" summary indicate that static visuals can have a positive effect on the acquisition of knowledge by students. The treatments used were varied, and many of the studies were not based on a particular theoretical perspective. In many of the studies, it was not possible to identify the role or function of the visual illustrations in the instructional treatments. Examples of visuals and criterion measure items should more regularly be included in published studies. It was also difficult to determine what type of information was tested using the criterion measures in many of the studies. The reliability coefficients of the criterion measures were infrequently reported in the studies reviewed. In addition, few of the studies have been replicated. Notable exceptions are the research programs of Dwyer and Levin. A more detailed summary of each study is reported in Appendix Table 26-2. The studies by Dwyer and his associates that are reported in Table 26-1 are not duplicated in Table 26-3.

Based on our review of reviews of the literature and our own literature summary concerning the role of visual illustrations and knowledge acquisition, we still agree with a conclusion stated by Levie (1987) that:

> It is clear that "research on pictures" is not a coherent field of inquiry. An aerial view of the picture research literature would look like a group of small topical islands with only a few connecting bridges in between. Most researchers refer to a narrow range of this literature in devising their hypotheses and in discussing their results. Similarly, authors of picture memory models, for example, take little notice of theories of picture perception (Levie, 1987, p. 26).

One of the primary reasons much of the research on the role of visual illustrations in knowledge acquisition is not easily integrated is that the role or function of the pictures and illustrations in the instructional treatments are not identified. We feel that it is critically important to determine, in advance of conducting research, the particular functions of the visual illustrations.

26.4.2.3. The Use of Functional Frameworks in Static Visual Research. In spite of the considerable amount of research concerning how static visuals facilitate learning, many empirical research studies reflect an unclear perception on the part of researchers of the manner in which illustrations function in facilitating learning. A number of researchers have provided a variety of functional frameworks that may provide assistance in classifying static visuals into meaningful functional categories (Alesandrini, 1984; Brody, 1984; Duchastel & Waller, 1979; Levie & Lentz, 1982; Levin, 1981; Levin et al., 1987). We will provide a brief summary of several functional frameworks.

*All tables are gathered in an appendix at the end of the chapter.

Two taxonomies have been proposed which take a morphological approach (what an illustration physically looks like) to picture classification (Fleming, 1967; Twyman, 1985). But classifying the role of pictures on the basis of "form" rather than "function" has not proved to be very useful (Duchastel & Waller, 1979). According to Duchastel and Waller, what is needed is not a taxonomy of illustrations but a grammar of illustrations that provides a functional set of principles that relate illustrations to the potential effects they may have on the learner.

Duchastel (1978) identified three general functional roles of illustrations in text: (a) an attentional role, (b) a retentional role, and (c) an explicative role. The attentional role relies on the fact that pictures naturally attract attention. The retentional role aids the learner in recalling information seen in an illustration, and the explicative role explains, in visual terms, information that would be hard to convey in verbal or written terms (Duchastel & Waller, 1979). Duchastel and Waller (1979) concluded that the explicative role of illustrations provides the most direct means with which to classify the role of illustrations in text. Seven subfunctions of explicative illustrations were identified by Duchastel and Waller (1979, pp. 21–24). These explicative subfunctions are:

1. *Descriptive.* The role of the descriptive function is to show what an object looks like physically.
2. *Expressive.* The expressive role is to make an impact on the reader beyond a simple description.
3. *Constructional.* The intent of the constructional role is to show how the parts of a system form the whole.
4. *Functional.* The functional role allows a learner to follow visually the unfolding of a process or the organization of a system.
5. *Logico-mathematical.* The purpose of this role is to show mathematical concepts through curves, graphs, etc.
6. *Algorithmic.* The algorithmic role is used to show action possibilities.
7. *Data display.* The functional role of data display is to allow quick visual comparison and easy access to data such as pie charts, histograms, dot maps, or bar graphs.

An alternative functional framework offered by Levie and Lentz (1982) suggests a functional framework that includes classifying illustrations in text based on how they impact a learner in attending, feeling, or thinking about the information being presented. Their framework contains four major functions: (a) attentional, (b) affective, (c) cognitive, and (d) compensatory. The attentional function attracts or directs attention to the material. The affective function enhances enjoyment or in some other way affects emotions and attitude. Illustrations serving a cognitive function facilitate learning text content through improving comprehension, improving retention, or providing additional information. The last functional role identified by Levie and Lentz is the compensatory role used to accommodate poor readers. Levie and Lentz, after reviewing a large number of studies containing 155 experimental comparisons of learning, have found much empirical support for the utility of their functional framework. Such a framework can help researchers sort out the functions that illustrations perform and can be used to identify the ways illustrations should be designed and used for specific cases (Levie & Lentz, 1982).

A functional framework that has proved to be useful in explaining differences in research studies concerning pictures and prose is provided by (Levin, 1981). Levin contended that different types of text-embedded pictures serve five prose learning functions. The five functions identified by Levin are: (a) decoration, (b) representation, (c) organization, (d) interpretive, and (e) transformation. The decoration function is associated with text-irrelevant pictures (e.g., pictures used to make a written text more attractive) and does not represent the actors, objects, and activities happening in the text. Representational pictures are associated with text-relevant pictures and do represent the actors, objects, and activities happening in the text. The role of organizational pictures is to provide an organizational structure giving the text more coherence. Interpretational pictures serve to clarify passages and abstract concepts or ideas that are hard to understand. Transformational pictures are first, unconventional, and not often found in traditional textbooks. Transformational pictures are designed to have a direct impact on a learner's memory (e.g., pictures used as a mnemonical aid serve a transformation function).

After reviewing the frameworks offered by Duchastel, Levin, Levie and Lentz, and others, Brody (1984) suggests that many of the specific functions identified within these frameworks do not clarify how pictures function in instructional settings. First, some functions are too broad or general in nature and add little to gaining an understanding of the instructional roles served by visuals. As an example, Brody contends that a single picture can increase comprehension in multiple ways such as gaining attention, repeating information, offering new information, and providing additional examples. A broad functional role such as increasing prose comprehension does not provide an adequate explanation of how a picture is to be used to affect prose comprehension (Brody, 1984). Brody (1984) also suggests that many previously defined functional roles of pictures are often too narrow in their view. In an effort to ameliorate the limitations of previously identified functional roles of pictures, Brody offers his own set of representative instructional functions served by illustrations. Brody's approach to creating a potentially more useful functional framework was to identify functions in terms of what occurs during the instructional process. Another prime objective was to make the functional framework as general as possible in scope, that is, to make the functions independent of the specific form of instruction, content area, or types of learning skills being taught. Brody identified 20 representative instructional functions served by pictures. A potential problem with Brody's classification system for determining the role of illustrations in instructional materials is that it already contains a large number of categories. To extend his classification scheme further would make it less practical for identifying the role of pictures in either research or instructional design practice.

Alesandrini (1984) states that some of the previous functional frameworks dealt only with representational pictures, that is, pictures that represent the actors, objects, and activities taking place in the text. Alesandrini notes that other frameworks also include arbitrary or nonrepresentational roles of pictures such as graphs and flowcharts in the functional mix. Alesandrini offers a functional framework based on how instructional pictures convey meaning. Based on previous work by Grooper and Knowlton, Alesandrini classifies the role of instructional pictures into three functions: (a) representational, (b) analogical, and (c) arbitrary. Representational pictures can convey information in a direct way through tangible objects or concepts, or indirectly by the portrayal of intangible concepts that have no physical existence. Photos and drawings, or models and manipulatives, are examples of representational illustrations. Analogical pictures convey meaning by acting as a substitute and then implying a similarity for the concept or topic being presented. Arbitrary pictures (sometimes referred to as *logical pictures*) are highly schematized visuals that do not look like the things they represent but are related in some conceptual or logical way. Arbitrary illustrations include schematized charts and diagrams, flowcharts, tree diagrams, maps, and networks.

26.4.2.4. Static Visuals and Knowledge Acquisition: Conclusions. Based on the conclusions of our review of earlier literature reviews and the studies we summarized in Tables 26-1 and 26-3, we conclude that static visual illustrations can facilitate the acquisition of knowledge when they are presented with text materials. However, the facilitative effects of illustrations are not present across all learning situations. It is very difficult to integrate the results across all studies due to the lack of connections (theoretical or functional) between many of them. We do offer the following broad conclusions regarding the effects of illustrated visuals on learning: (a) Illustrated visuals used in the context of learning to read are not very helpful; (b) illustrated visuals that contain text-redundant information can facilitate learning; (c) illustrated visuals that are not text-redundant neither help nor hinder learning; (d) illustration variables (cueing) such as size, page position, style, color, and degree of realism may direct attention but may not act as a significant aid in learning; and (e) there is a curvilinear relationship between the degree of realism in illustrations and the subsequent learning that takes place.

There has been substantial progress in understanding how static illustrations affect the learning process. However, much remains to be done. Validations for many of the functional frameworks summarized in this chapter need to be completed. Theory-based studies that are informed by both memory research and theories of picture perception are lacking. Specific studies incorporating a particular theory of picture perception and a particular memory model need to be conducted. Theory-based research will provide us with a deeper understanding of the mechanisms that contribute to the effectiveness or ineffectiveness of static illustrations in instructional materials. It is also not clear how students use illustrations in instructional materials or that they even know how to use them. A number of methods, including eye movement measurements, student surveys, and simply questioning students while they are using visual illustrations, will provide useful data on how students use or do not use illustrations. These data will be complimentary to the results of the recall and comprehension studies already completed. In addition, studies are needed that attempt to identify effective strategies for using illustrations included in instructional materials. Assuming that strategies for effectively using illustrations are identified, studies will then be needed that consider effective ways to train students to use these strategies. The issue of what constitutes "realism" in illustrations also needs to be reconsidered in light of the theories of picture perception discussed in this chapter. Many of the criterion measures (recall or comprehension tests) are administered immediately after the presentation of the instructional treatments. It is also important to determine if the illustration effects identified in many of the studies reviewed in this chapter are durable over time. Finally, few of the studies reviewed systematically controlled for the type of text or picture included. Perhaps the effects of illustrations on learning will vary according to the type of prose passage or picture used.

26.4.3 Dynamic Pictures and Knowledge Acquisition

In this section, we first review the early research on the effect of dynamic visuals on learning (see also 1.5, 16.11). Next we will summarize more recent reviews of the literature concerning the role of dynamic visual displays and knowledge acquisition. Finally, we present the results of our literature search and analysis.

26.4.3.1. Dynamic Pictures and Knowledge Acquisition: Literature Reviews. Early studies examining the effects of dynamic visuals on learning can be found in instructional film research. Freeman (1924) summarized 13 research studies that compared the effectiveness of various forms of visual instruction. The treatment formats used in the 13 studies included film, slides, lectures, still pictures, prints, live demonstrations, and stereographs. The motion treatments in these studies included the use of action pictures, animated drawings, and maps or cartoons. Based on the results of the 13 studies, it was concluded that motion or animated sequences in film are effective when (a) motion is a critical attribute of the concept being presented, and (b) motion is used to cue or draw the viewer's attention to the material being presented. It should be noted that the methodologies used in the 13 studies do not meet current standards for conducting comparative experimental research. A number of other investigators have conducted instructional film research that examined the effect of dynamic visuals on learning (Lumsdaine, Sultzer & Kopstein, 1961; May & Lumsdaine, 1958; Weber, 1926). Several conclusions can be drawn based on the early research on the role of dynamic visuals in instructional materials, including that (a) animation (motion) can lead to positive learning effects if it is a critical attribute of the concept(s) being presented, (b) animation (motion) can increase learning of a complex procedural task, and (c) motion or action used primarily to enhance the realism of the presentation does not appear to have a significant effect on learning. It should be noted that the conclusions drawn are based on a limited number of studies in which the motion variables were not usually tightly controlled.

Rieber (1990) summarized the results of 13 empirical studies investigating the role of animated graphics in computer-based instruction. Significant effects for animated treatments were found in 5 of the primary research studies reviewed. Based on the results of the 13 studies reviewed, Rieber presented three design recommendations for the use of animated visuals in instructional materials, including that: (a) "animation should be incorporated only when its attributes are congruent to the learning task" (Rieber, 1990, p. 79); (b) "evidence suggests that when learners are novices in the content area, they may not know how to attend to relevant cues or details provided by animation" (Rieber, 1990, p. 82); and (c) "animation's greatest contributions to CBI may lie in interactive graphic applications (e. g., interactive dynamics)" (Rieber, 1990, p. 82).

As discussed in the review of static visuals, a number of frameworks have been provided to classify static visual material. A similar functional approach would be appropriate for dynamic visual research. Rieber (1990) suggests that "generally, animation has been used in instruction to fulfill or assist one of three functions: attention-gaining, presentation, and practice" (p. 77).

More recently, Park and Hopkins (1993, p. 19) identified five important instructional roles of animated visuals:

1. As an attention guide, the animated visual can serve to guide and direct the subject's attention.
2. As an aid for illustration, dynamic visuals can be used as an effective aid to represent the structural and functional relations among components in a domain of knowledge.
3. As a representation of domain knowledge, movement and action can be used to effectively represent certain domain knowledge.
4. As a device model for forming a mental image, graphical animation can be used to represent system structures and functions that are not directly observable (e.g., blood flowing through the heart).
5. As a visual analogy or reasoning anchor for understanding abstract and symbolic concepts or processes, animation can make abstract and symbolic concepts (e.g., velocity) become more concrete and directly observable.

When both the characteristics of the domain knowledge and the characteristics of the subjects require one or more of the five instructional roles described above to be used, then animated visuals will most likely be effective (Park & Hopkins, 1993).

Using their functional framework, Park and Hopkins produced a research summary of 25 studies investigating the effects of dynamic versus static visual displays. The delivery medium for 17 of the studies was computer-based instruction, while the delivery medium for the remaining 8 studies was film or television. Fourteen of the studies yielded significant effects for dynamic visual displays. However:

> The research findings do not consistently support the superior effect of dynamic visual displays. The conflicting findings seem to be related to the different theoretical rationales and methodological approaches used in various studies (Park & Hopkins, 1993, p. 427).

One of the most interesting and rigorous programs of research on the effect of animation on learning has been conducted by Rieber (Rieber, 1989, 1994). The animation research conducted by Rieber included students across age groups, with realistic instructional content (Newton's laws of motion) and higher-level learning outcomes. As with the static visual research of Dwyer and his associates, the Rieber series of studies used animated graphics only when there was a need for external visualization. Results from the Rieber series are mixed and do not support the use of animated graphics across the board.

In summary, conclusions drawn from early reviews of the animation research literature are mixed. Rieber (1990) states that "the few serious attempts to study the instructional attributes of animation have reported inconsistent results.... CBI designers . . . must resist incorporating special effects, like animation, when no rationale exists" (p. 84).

26.4.3.2. Guide to the Literature. Forty-two studies were located which included at least one animation treatment. Information concerning the author, treatments, subjects, and results is reported in Table 26-5. Initially, we attempted to classify the animated treatments according to the function they performed (Park & Hopkins, 1993). However, we later abandoned the approach due to lack of specific information concerning the treatments. It was also difficult to classify many of the animated treatments as performing a single role using the classification system.

From the group of 42 studies, a total 45 comparisons were identified which included at least one animation treatment. Significant animation effects were identified in 21 of these comparisons. Animated treatments used by investigators have included various visual content such as animated illustrations, diagrams and visuals, real-time motion graphics, dynamic spatial visualization graphics, and animated interactive maps with blinking dots. General content areas covered by these studies include general science, physics, geometry, mathematics, statistics, and electronics. Subjects for these experiments ranged from mature adults to primary school children in the first, second, and third grade. A variety of tests were used to measure learning outcomes, including (a) learning of facts, concepts, and procedures; (b) problem solving and visual thinking; and (c) acquisition of cognitive skills that are primarily spatial or perceptual in nature.

How can the mixed results of the animation research be interpreted? Based on these "box score" results only, one could conclude that the use of animated graphics does not facilitate learning. However, methodological issues need to be considered. For example, in many of the studies it was not indicated if it was determined that there was a need for external visuals, static or dynamic. Perhaps reading text alone is adequate. In addition, many of the investigators did not provide a rationale for why motion is needed to either indicate changes over time or changes in direction. Text or text-plus-static graphics may be the optimal treatment if motion is not required. Many of the research reports reviewed did not specifically indicate that the animated sequences were text relevant or at least congruent with the text information presented. Also, both the information tested and the test type are critical considerations when investigating the learning effects for both static and animated graphic displays. It was not always possible to determine if the information tested was presented only in the animation, only in the animated sequence, or presented in both. It was also difficult to determine the function of the animated sequences. Using the lessons learned from static graphic research, more attention needs to be given to the functional role of animated sequences in research studies.

Such methodological problems call into question the results of these studies reporting insignificant animation effects. We believe that the comments of Rieber, and of Park and Hopkins, are still timely and appropriate. Rieber (1990) stated that "while speculative explanations for these studies which did not produce effects have been offered, many rival hypotheses linger rooted in general procedural flaws such as poor conceptualization of the research problem or inappropriate implementation of methods" (p. 84).

In a later review of the literature, Park and Hopkins (1993, p. 439) suggested that:

> Probably the most profound discrepancy separating the research is theoretical in nature. One important difference between studies which found significant effects of DVDs [dynamic visuals] and studies which found no such effects is that the former were guided by theoretical rationales which derived the appropriate uses for dynamic and static features of visual displays and their presumed effect. Accordingly, learner variables, the learning requirements in the task, and/or the medium characteristics were appropriately coordinated in most of the studies that found significant effects.

As is the case for static graphics, it is clear that facilitative effects are not present for animated treatments across all learning situations.

26.4.3.3. Dynamic Visuals and Knowledge Acquisition: Conclusions. Unlike research pertaining to static visuals, which encompass many additional studies and dozens of treatment conditions, research on the effects of dynamic visuals is very limited. The early research lacked appropriate controls, so that the specific effects of animation on learning cannot be determined. Results from the limited number of completed studies of the effect of dynamic visuals on learning are mixed. As discussed earlier, a number of the studies are methodologically flawed. Thus, the verdict is still out on the effect of animated treatments on student learning.

More work needs to be completed concerning the functions of animated visuals in learning materials. Contributions of Rieber, and of Park and Hopkins, have provided a starting point for further work. Refinement and validation of the functional frameworks suggested by Rieber, and by Park and Hopkins, are needed. In addition, it has not been demonstrated if or how learners use an animated sequence in the learning process. The effect of experience, prior knowledge, and aptitude patterns on the effective use of dynamic visual displays needs to be considered. Also, will students who are naive to specific instructional content be able to determine that an animated sequence indicates changes over time or changes in direction, and relate these changes to the specific content they are learning? Perhaps students need specific training on how to use animated sequences for learning. In almost all of the animation studies we reviewed, students in an animated treatment condition received visualized instruction (an animated sequence) and then were tested verbally. It is an open question whether a verbal test covering content displayed in a visual animated sequence measures the learning that has occurred. Also, many animated sequences particularly in simulations include a significant amount of information incidental to the particular purpose of the instructional package. Studies investigating the effect of such animated treatments on incidental learning are needed. Few of the animation studies we reviewed considered the effects of developmental level on learning. Animated treatments may differentially affect older vs. younger students. Finally, as discussed earlier, Rieber has suggested that animation may be most effective in computer-based instruction when used in interactive graphic applications. Much work needs to be done in this promising area of inquiry. In any case, future research investigating the effect of dynamic visual displays on learning should: (a) be based on a functional framework (i.e., Rieber, Park & Hopkins), (b) include content for which external visual information is needed and which requires the illustration of motion or the trajectory of an object, and (c) control for the effect of static graphics.

While some progress had been made, it is apparent that we know very little about the effect of dynamic visual displays on student learning. Given the proliferation of visual information in instructional material, it is imperative that the most effective strategies for using animated visuals be determined. Relative to the production of static visuals and text materials, the cost of producing animated sequences is high. Caraballo-Rios (1985) stated that "insisting on the use of computer animation in cases where it is not absolutely necessary should be considered an extravagance" (p. 4). Many additional theory-based studies, including a range of content areas, audiences, treatment conditions, and learner characteristics, are needed.

26.5 CONCLUSIONS

We have briefly reviewed theories of picture perception and memory models. Then a survey of existing studies and reviews concerning the effect of static and dynamic visuals on learning was presented. Significant progress has been made concerning our understanding of the effect of static and animated visuals on learning. Several problems are evident in the research reviewed. First, for both static and animated graphics, the research is fragmented and sporadic. Notable exceptions are the research programs of Dwyer, Levin, and Rieber. Second, the animation research is very limited in scope. Third, many of the researchers in instructional communication and technology have neglected the work on memory models and theories of picture perception. Future research related to visual learning should derive from theories of picture perception and incorporate memory models. Fourth, the functional roles of visuals in instructional materials need to be further clarified. There is much that we do not know about how to design effective visual messages. Future research strategies should be selected carefully to ensure that we continue to make significant progress.

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TABLE 26-1. SUMMARY MATRIX OF STUDIES BY DWYER AND HIS ASSOCIATES*

		Drawing Test			Identification Test			Terminology Test			Comprehension Test		
Study	Learners (N)	Better Version	Effect Size	Mean IT Mean TA	Better Version	Effect Size	Mean IT Mean TA	Better Version	Effect Size	Mean IT Mean TA	Better Version	Effect Size	Mean IT Mean TA
Dwyer (1967)	College (86)	IT	.35	1.14	IT	.34	1.09	IT	.23	1.06	IT	.02	1.00
Dwyer (1968)	9th grade (141)	IT	.82	1.28	IT	.57	1.24	TA	-.10	.96	TA	-.17	.94
Delayed retest	9th grade (129)	IT	.36	1.09	IT	.42	1.14	IT	.27	1.06	IT	.50	1.18
Dwyer (1969)	College (175)	IT	1.23	1.37	IT	.67	1.17	IT	.80	1.16	NSD	—	—
Dwyer (1972)	College (266)	IT	.43	1.12	IT	.26	1.07	IT	.16	1.04	IT	.11	1.03
Dwyer (1975)	College (587)	IT	.82	1.16	IT	.47	1.13	IT	.52	1.11	TA	-.04	.99
Arnold & Dwyer (1975)	10th grade (185)	—	—	—	—	—	—	IT	.77	1.27	IT	.90	1.22
Joseph (1978)	10th grade (414)	IT	.41	1.07	IT	.14	1.02	TA	-.12	.98	IT	.01	1.00
Delayed retest	10th grade	IT	.24	1.03	IT	.13	1.02	IT	.47	1.10	IT	.23	1.04
de Melo (1980)	High school (48)	—	—	—	IT	.23	1.11	IT	.34	1.18	IT	.36	1.15
Pictorial test	High school (48)	—	—	—	IT	1.42	1.72	IT	1.11	1.50	IT	.52	1.23

IT = illustrated text; TA = text alone; NSD = no significant difference; dashes indicate that the value was not provided in the published report.

TABLE 26-2. REFERENCE LIST FOR DWYER SERIES REVIEWED BY W. HOWARD LEVIE

Arnold, T.C. & Dwyer, F.M. (1975). Realism in visualized instruction. *Perceptual and Motor Skills 40*, 369–70.

de Melo, H.T. (1981). Visual self-paced instruction and visual testing in biological science at the secondary level. (Doctoral dissertation, Pennsylvania State University, 1980.) *Dissertation Abstracts International 41*, 4954A.

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TABLE 26-3. SUMMARY MATRIX OF RESEARCH RESULTS FOR STATIC VISUALS

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Alesandrini & Rigney (1981) Experiment 1.0	1. Verbal + interactive graphics expansion 2. Verbal + computer game 3. Verbal + verbal expansion 4. Verbal + game	Science (battery cell)	Undergraduate (98)	1. 37-item verbal test 2. 27-item picture recognition test	Written	SD
Experiment 2.0	1. Verbal + pictorial review 2. Verbal + verbal review	Same (50)	Undergraduate 2. 27-item	1. 60-item verbal test picture recognition test	Same (verbal)	NSD
Alesandrini (1981)	1. Pictorial + learning strategy (3) 2. Verbal + learning strategy (3) 3. Verbal (read twice)	Science (battery cell)	College (383)	A 60-item test of: (a) Knowledge (b) Comprehension (c) Application	Written	SD (picture) SD (holistic learning strategy
Anglin & Stevens (1986)	1. Prose + pictures 2. Prose only	Science (water clock)	Undergraduate (42)	12-item multiple-choice test Immediate and 28-day delay	Written	SD (immediate) NSD (delayed)
Anglin (1986) Experiment 1.0	1. Prose + picture 2. Prose only	3 human interest stories	Graduate (52)	Consisted of 15 short-answer paraphrase questions; immediate and 14-day delay	Written	SD (immediate & delayed)
Experiment 2.0	Same	Same	Graduate (47)	Same, except delay increased to 28 days	Same	SD (immediate & delayed)
Anglin (1987)	1. Prose + picture 2. Prose	3 human interest stories	Graduate (30)	Recall Test had 15 paraphrase questions on text-redundant information, 5 short-answer questions on text-only information (immediate & 55-day delayed recall)	Written	SD for text-redundant information on immediate & delayed NSD for text-only information
Arnold & Brooks (1976)	1. Verbal + pictorial integrated organizer 2. Verbal + pictorial nonintegrated organizer 3. Verbal + verbal integrated organizer 4. Verbal + verbal nonintegrated organizer	8 organizationally complex paragraphs about unusual situations	Elementary school (32)	1. Total responses 2. Inferential responses 3. Recall responses 4. Correct responses	Oral	SD dependent on age & organizer type
Beck (1984)	1. Prose + pictorial cues 2. Prose + textual cues 3. Prose + combinational cues 4. Prose + noncues	12 passages & pictures based on carnivorous plants	Elementary school (256)	Recall 1-day delayed multiple-choice test	Written	SD for combinational cueing only

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Bender & Levin (1978)	1. Story + illustrations 2. Story + generate visual images 3. Story (listen twice) 4. Story (listen once)	20-sentence fictitious story	Mental-retarded children (96)	Recall scores 10 verbatim + 10 paraphrase questions	Oral	SD (illustrations) NSD other 3 conditions
Bernard, Petterson & Ally (1981)	1. Verbal organizer 2. Contextual image (picture) 3. No organizer control 4. Placebo control	800-word passage about function of the brain	Undergraduate (104)	Recognition. 18 paraphrase & nonparaphrase questions Immediate & delayed testing (2 weeks)	Written	SD for both verbal & image organizers NSD between them
Bieger & Glock (1984)	1. Ten combinations of text + pictures by information type 2. Nothing control Information types: nonoperational, operational, contextual, spatial, operational + contextual, operational + spatial	2 assembly tasks (hand truck & wall hanging)	Undergraduate (120)	1. Mean assembly times 2. Mean number of assembly errors	Written	SD depending on information type
Bluth (1973)	1. Prose + illustrations 2. Prose only	2 different cloze passages of 126 words each	Elementary school (80)	Cloze test measure of comprehension	Written	SD (good readers)
Borges & Robins (1980)	1. Story + appropriate context picture 2. Story + partial context picture 3. Story + no picture	Character motivation story	Undergraduate (120)	1. Recall based on 14 idea units 2. Mean comprehension rating	Oral	SD Appropriate > Partial > No picture
Bransford & Johnson (1972) Experiment 1.0	1. No context 1 (heard prose passage) 2. No context 2 (heard prose passage twice) 3. Context after (picture after passage) 4. Partial context (partial picture before passage) 5. Context before (picture before passage)	Fictitious prose passage	High school (50)	1. Mean comprehension 2. Mean recall score	Oral	SD context picture before passage
Covey & Carroll (1985)	1. Text + line drawings 2. Text only	3 expository science passages of approximately 300 words each	Elementary school (132)	Recognition using 36-item multiple-choice test	Written	SD
Dean & Enemoh (1983)	1. Pictures before reading text 2. Pictures after reading text 3. Text only	Difficult geology passage containing 262 words	Undergraduate (90)	Total number of "idea units" recalled	Written	SD picture before passage

TABLE 26-3: *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
DeRose (1976)	1. Prose + experimenter-provided illustration 2. Prose + instructions to summarize 3. Prose + experimenter-provided summary 4. Prose + instructions to image 5. Prose-only control	A 490-word passage from a social studies textbook	Middle school (192)	14 short-answer questions	Written	SD for experimenter provided illustrations
Digdon, Pressley & Levin (1985)	1. Object picture + no imagery instruction 2. Partial picture + no imagery instruction 3. Object picture + imagery instruction 4. Partial picture + imagery instruction 5. Object picture + partial picture + imagery instruction 6. Object picture + partial picture + no imagery instruction 7. Prose + imagery instruction 8. Prose + no imagery instruction	Two 10-sentence prose stories	Young children (160)	Set of cued recall questions	Oral	SD for object + partial pictures with and without imagery instruction
Duchastel (1980)	1. Prose only 2. Prose + illustrations (Illustrations conveyed the topical ideas)	A 750-word prose passage on energy	High school (77)	Retention by: 1. summary 2. free recall 3. 30 short answers	Written	NSD
Duchastel (1981)	1. Prose + illustrations 2. Prose only	A 1,700-word history passage	High school (77)	1. Topical recall 2. Cued recall (36 questions) Immediate & 2-week delay	Written	SD on 2-week delay only (recall test)
Durso & Johnson (1980) Experiment 1.0	1. Words (verbal orienting task) 2. Pictures (verbal orienting task) 3. Words (imaging orienting task) 4. Pictures (imaging orienting task) 5. Words (referential orienting task) 6. Pictures (referential orienting task) (Pictures were line drawings of each of the 140-word concepts)	Contained 140 words, each a concept, chosen from Kucera & Francis word norms	Undergraduate (120)	A response of either a picture or word was taken as an indication that the item remembered as having been present during acquisition	Oral	SD for the verbal orienting tasks only
Experiment 2.0	Same	Same	Undergraduate (60)	Free recall of the items presented:	Same	Same
Gibbons et al. (1986)	1. Prose + visuals 2. Prose only	Dolls as actors performing in several settings	Young children (96)	1. Free recall 2. Reconstruction of story content	Oral	SD audiovisual condition
Goldberg (1974)	1. Prose (incidental information) + illustrations 2. Prose (incidental information)	Spelling and grammar exercise	Elementary school (216)	Incidental information: 12 recognition and 12 recall questions	Written	SD
Goldston & Richman (1985)	1. Prose + partial pictures during study 2. Prose + partial sentence repetition during study 3. Prose only	10-sentence narrative story	Elementary school (288)	Cued-recall measures	Oral	SD for partial pictorial cues

TABLE 26-3: *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Guttmann, Levin & Pressley (1977) Experiment 1.0	1. Imagery + prose 2. Partial pictures + prose 3. Complete pictures + prose 4. Prose only	2 short stories each with a person, object, and thing	Young children & elementary school (240)	Cued recall 20 questions	Oral	SD Kinder-garten for complete pictures only, SD 3d-graders for imagery = partial = complete SD 2d-graders for complete> partial> imagery> control
Hannafin (1988)	1. Pictures + oral 2. Pictures 3. Prose only	Fictitious children's story	Elementary school (168)	Recall test containing 24-item short answers of abstract and concrete items Immediate and 1-week delayed	Oral	SD oral + pictures immediate & delayed
Haring & Fry (1979)	1. Top-level + lower-level pictures + prose 2. Top-level pictures + prose 3. Prose only (text redundant line drawings)	A 360-word version of "Mercury and the Woodcutter"	Elementary school & middle school (150)	Free recall of both level of idea units Immediate and 5-day delayed	Written	SD for top-level idea units for both immediate and delayed
Hayes & Readence (1983)	1. Two line drawings + prose + no instructions 2. Two line drawings + prose + instructions to pay careful attention to pictures 3. Prose + instruction to form images 4. Prose + no instructions	Four 400-word prose passages from illustrated educational texts	Middle school (108)	1. Mean score on information recalled 2. Mean proportion of inferences per information unit recalled	Written	SD of both illustrated conditions NSD between illustrated conditions
Hayes & Readence (1982)	1. Two line drawings + prose + no instructions 2. Two line drawings + prose + instructions to pay careful attention to pictures 3. Prose + instruction to form images 4. Prose + no instructions	Four 300-word science texts about simple machines	Middle school (82)	Student success at working study problems with text available	Written	SD illustrated text with or without instructions

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Hayes & Henk (1986)	1. Pictures only 2. Pictures + prose 3. Prose only (5 simple line drawings)	How to tie a "bowline" knot	High school (102)	Nonverbal applied performance Immediate and 2-week delayed	Written	SD pictures + prose & pictures, immediate testing only NSD between them
Holliday (1975)	1. Textbook-like illustrations + verbal 2. verbal	Verbal prose (23 pages) about plant growth hormones	High school (80)	Verbal comprehension 30-item multiple choice administered orally	Oral	SD
Holliday & Harvey (1976)	1. Adjunct labeled line drawings + prose 2. Prose only	Biology lesson on density, pressure & Archimedes' principal	High school (61)	Verbal quantitative (nonpictorial), multiple-choice test	Written	SD
Holmes (1987)	1. Prose + picture 2. Pictures 3. Prose only	15 passages of 150–200 words each; material from popular magazines	Elementary school, middle school (116)	25 inferential questions	Written	SD Pictures + text > pictures > prose NSD Pictures vs. prose
Jagodzinska (1976)	1. Prose + schematic correspondent illustration 2. Prose + realistic correspondent illustration 3. Prose + schematic supplement illustration 4. Prose + realistic supplement illustration 5. Prose Note: Above instructional conditions crossed with two text types (essential & nonessential) giving 10 total conditions	2 versions of a biology lesson	Middle school (200)	1. Reproduction (amount of material reproduced) 2. Text organization. Both immediate & delayed 2-week testing	Written	SD depending on picture type and its relationship to the text type

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Jahoda et al. (1976) Experiment 1.0	1. Pictures + prose 2. Pictures 3. Prose only 4. Control	Expository text designed to be culturally free	Middle school, high school, (938) Scotland India Ghana Kenya	Recall scores 10 pictorial or verbal questions of picture & text-redundant information	Written	SD for pictures + text NSD pictures alone vs. text alone
Jonassen (1979)	1. Prose + 1-screen presentation 2. Prose + 3-screen presentation 3. Prose + 4-screen presentation 4. Prose only	Biology lesson on 4 plant types	Middle school (363)	Criterion test of a verbal and visual classification exercise Immediate & 2-week delay	Oral	SD 4-screen condition on visual classification Immediate & delayed
Koenke & Otto (1969)	1. Prose + illustrations (both specifically relevant and generally relevant to passage) 2. Prose only	Three 198-word passages from *Readers Digest*	Elementary school, middle school (60)	Comprehension of main ideas	Written	SD (both picture types) 6th-graders only
Koran & Koran (1980)	1. Picture before text 2. Picture after text 3. Text only	Science lesson on hydrologic cycle	Middle school (84)	23-item completion consisting of transformed and paraphrase questions	Written	SD for 7th-graders regardless of picture placement NSD for 8th-graders
Lesgold & DeGood & Levin (1977)	1. Prose + subject illustrated story using cutouts on a background 2. Prose + coloring simple figures in a booklet	16 prose stories, 4 of each type (50 vs. 100 words; 1 vs. 2 locations)	Elementary school (32)	Free and cued-recall scores	Oral	SD
Lesgold et al. (1975) Experiment 1.0	1. Prose + subjects made up illustrations from cutouts (some potentially interfering) 2. Prose + subjects copied or colored geometric forms during illustration phase	5 single episode stories of 30–50 words each	Elementary school (24)	Oral recall	Oral	NSD
Experiment 2.0a	1. Prose + subjects made up illustrations from fewer cutouts than experiment #1 2. Prose + subjects copied or colored geometric forms during illustration phase	3 stories of 5 sentences each	Elementary school (48)	Oral recall, both free and cued	Same	SD

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Experiment 2.0b	1. Prose + experimenter-provided pictures 2. Prose + subjects copied or colored geometric forms during illustration phase	Same as 2a	Elementary school (24)	Same as 2a	Same	SD for both picture conditions NSD between the 2 picture conditions
Experiment 3.0	1. Prose + experimenter-provided pictures 2. Prose + subjects made up illustrations from fewer cutouts than experiment #1 2. Prose + subjects copied or colored geometric forms during illustration phase	Same as 2a	Elementary school (36)	Same as 2a	Same	SD for experimenter-provided pictures only
Levin & Berry (1980) Experiment 1.0	1. Prose + 1-colored, main idea line drawing per passage 2. Prose only	5 human interest and novelty stories, from local newspapers, of approximately 100 words each	Elementary school (50)	6 short-answer paraphrase questions per passage (30 total). Half the questions about information in the pictures, the other half about information not in pictures.	Oral	SD for pictured information
Experiment 2.0	Same (change was in time of testing only)	A 6th passage added	Elementary school (37)	Same but testing took place on 3-day delayed basis	Same	SD
Experiment 3a	1. Single main idea picture + prose 2. Prose + prompt (verbal analog of main idea for each passage)	Same	Elementary school (36)	16 main-idea questions	Same	SD
Experiment 3b	1. One main idea picture/passage + prose 2. Prose + no prompting	Same as 3a	Elementary school (36)	16 main-idea questions plus 24 nonmain-idea questions	Same	SD (both question types)
Levin (1976) Experiment 2.0	1. Prose + experimenter-provided culminating pictures 2. Prose + experimenter-provided nonculminating pictures 3. Repetition condition (passage repeated once) 4. Activity control (passage + nonrelevant coloring activity) 5. Nonactivity control (passage only)	3 single-episode stories of 30 to 75 words each	Elementary school (61)	Cued-recall, 5 short-answer questions	Oral	SD
Experiment 3.0	Same (minus the activity control condition)	Two 10-sentence passages	Elementary school (64)	Cued-recall, 10 questions/story	Same	SD

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Levin et al. (1983) Experiment 1.0	1. Prose + colored mnemonic illustrations 2. Prose only	Learn the numerical order of 10 U.S. presidents	Middle school (46)	1. Total recall 2. Serial-position profile 3. Response latencies	Oral	NSD on total recall
Experiment 2.0	Same + additional study trials added	Same	Middle school (40)	Same + name recall added	Same	NSD on total recall
Experiment 3.0	Same + 3 study trials added	Same	High school (32)	Total recall scores only	Same	SD
Levin et al. (1982) Experiment 1.0	1. Keyword context (word list + contextually explicit colored "keyword" illustration) 2. Control condition (word list + experimenter read aloud + use own strategy)	Learn meanings of 12 challenging vocabulary words	Elementary school (30)	Total number of words defined correctly	Oral	SD
Experiment 2.0	1. Keyword context (word list + contextually explicit colored "keyword" illustration) 2. Picture context (colored illustration of words definition + read definition aloud) 3. Experiential context (read 3 sentences with definition + application question with word) 4. Control condition (word list + experimenter read aloud + use own strategy)	14 words to learn	Elementary school (64)	Same	Same	SD Keyword context best Picture better than experiential
Levin et al. (1983) Experiment 1a & 1b	1. Prose + organized mnemonic "keyword" picture 2. Prose + organized single picture 3. Prose + separate pictures 4. Prose + subjects use own learning strategy	Short prose passages about distinguishing attributes of fictitious towns	Middle school (178)	1. Total number of attributes remembered via matching questions 2. Clustering score	Oral	SD organized mnemonic "keyword" NSD separate picture
Experiment 2a & 2b	Same without organized separate picture condition (# 2 above)	Same	Middle school (113)	Subject responses of (a) verbatim correct (b) essence correct	Same	SD organized mnemonic NSD separate picture
Levin et al. (1986) Experiment 1.0	1. Text + mnemonic pictures 2. Text + summary using fact mapping 3. Text + free study instructions	A 540-word text about minerals organized around "names"	Middle school (53)	Names and attributes recall testing	Written	SD for mnemonic pictures
Experiment 2.0	Same	Same except text organized around "attributes"	Middle school (115)	Same	Same	SD for mnemonic pictures

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Mange & Parknas (1962) Experiment 1.0	1. Picture information slide + picture test slide 2. Picture information slide + word test slide 3. Word slide + picture test slide 4. Word slide + word test slide	Biology lesson on plant types	Middle school (228)	Retention of pictorial or verbal information	Written	SD When retention measured by pictorial testing
Experiment 2.0	Same	Same	College (81)	Same	Same	SD (same condition)
Experiment 3.0	1. Prose + filmstrip 2. Prose	Lesson on Greenland	Middle school (192)	Retention using both verbal and pictorial questions	Same	SD (same condition)
Main & Griffiths (1977)	1. Printed text + printed and pictorial supplement 2. Printed text + audio and pictorial supplement 3. Printed text + printed supplement 4. Printed text (control)	12 passages from a chapter on weather	Adult (120)	1. Vocabulary test 2. 100-item sentence completion part 3. 55-item multiple-choice section	Written Oral	SD all experimental group vs. control NSD between experimental groups
Mayer (1989) Experiment 1.0	1. Text + illustrations including labels 2. Text only	Vehicle braking systems	College (34)	95 idea units of both explanative and nonexplanative information	Written	SD on recall of explanative information
Experiment 2.0	1. Text + labeled illustrations 2. Text + nonlabeled illustrations 3. Text only	Same	College (44)	Same	Same	SD on recall of explanative information for labeled illustrations
McCormick et al. (1984)	1. Related text + separate mnemonic illustrations 2. Related text + integrated mnemonic illustration 3. Noninterference control (read 3 unrelated passages) 4. Interference control (read 3 related but potentially interfering passages)	3 fictitious biographical stories	College (160)	11 short-answer recall questions	Written	SD for integrated mnemonic illustrations

TABLE 26-3. ***Continued***

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
McCormick & Levin (1984) Experiment 1.0	1. Text + mnemonic pictures (keyword-paired) 2. Text + mnemonic pictures (keyword-chained) 3. Text + mnemonic pictures (keyword-integrated) 4. Simple control (text + additional study each sentence) 5. Cumulative control (text + cumulative study of all sentences)	4 fictitious biographies	Middle school (220)	20 cued-recall questions	Written	SD for all 3 mnemonic conditions but NSD between them
Experiment 2.0	Same except delete condition # 2 above	Same	Middle school (82)	Name-attribute recognition test both immediate and 2-day delayed	Same	SD for keyword conditions both immediate & delayed
Miller (1938)	1. Prose + illustrations 2. Prose only	3 stories from basal readers	Elementary school (600)	Comprehension	Written	NSD
Moore (1975)	1. Illustrations + prose together 2. Illustrations before prose 3. Illustrations after prose 4. Prose only	Text on learning time from a sundial	Elementary school (63)	Comprehension–20-item multiple choice	Written	NSD
Nugent (1982) Experiment 1.0	1. Visuals + print + audio 2. Visuals + print 3. Visuals + audio 4. Print + audio 5. Visuals 6. Print 7. Audio 8. Control	Film about factual life of a cheetah	Elementary school, middle school (201)	23 multiple-choice comprehension test	Oral	NSD single media SD dual media SD 3 media
O'Keefe & Solman (1987) Experiment 1.0 & 2.0	1. Complex pictures before prose 2. Complex pictures after prose 3. Normal pictures before prose 4. Normal pictures after prose	Stories about 470 words in length	Elementary school (118)	Recall of semantic & logical network of story information	Written	NSD
Peeck (1974)	1. Prose + pictures 2. Pictures 3. Prose only	Passage from "Rupert Bear" story	Elementary school (71)	40-item retention test Immediate, 1-day & 1-week delayed testing	Written	SD immediate & delayed testing
Peng & Levin (1979)	1. Prose + colored line drawings 2. Prose only	Two 10-sentence narrative stories	Elementary school (64) questions both immediate and 3-day delayed	Cued-recall using paraphrase & verbatim	Oral	SD immediate & delayed testing

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Popham (1969)	1. Cartoon embellished tape/slide version 2. Unembellished tape/slide version 3. Programmed text version	Program developed for public school administrators	College (175)	1. Cognitive achievement (58 items) 2. Anonymous response (4 items)	Written Oral	NSD
Pressley, Pigott & Bryant (1982) Experiment 1	1. Prose + completely matched picture 2. Prose + actor action picture 3. Prose + actor static picture 4. Prose + mismatched picture/ object incorrect 5. Prose + incorrect object picture 6. Prose only	2 lists of concrete sentences	Young children	Correct recall responses	Oral	SD
Experiment 2	1. Prose + completely matched picture 2. Prose + actor action/object correct picture 3. Prose + actor static/object picture 4. Prose only	Same	Young children (52)	Same	Same	SD Matched pictures > action object > prose only NSD action object & static object
Pressley et al. (1983) Collapsed experiments 1, 2, 2A, 3 & 3A	1. Prose + matched pictures 2. Prose + mismatched pictures 3. Prose only Note: Above basic conditions were combined with explicit or nonexplicit instructions regarding picture-text relationships	33 concrete sentences or 6 moderately difficult stories	Elementary school (414)	1. Cued-recall questions 2. Picture recognition in some instances	Written Oral	SD in all cases for matched pictures NSD for mismatched pictures vs. prose only
Rankin & Culhane (1970)	1. Typed format text with no illustrations 2. Printed format text with illustrations	A passage from "Pioneer Life in America"	Middle school (57) High school (22)	50-item cloze comprehension test	Written	NSD
Rasco et al. (1975) Experiment 1.0	1. Prose + drawings + instructional strategy 2. Prose + drawings 3. Prose + instructional strategy 4. Prose only	2,511-word prose passage	Undergraduate (91)	35-item test with 28-true/false, 1 constructed response & 6 multiple-choice questions on the verbal information in the text	Written	NSD
Experiment 2.0	Same	Same	High school (80)	Same	Same	NSD
Experiment 3.0	Same	2 shorter passages (429 words & 633 words)	Elementary school (93)	20 multiple-choice questions on verbal information	Same	SD Prose + strategy + pictures

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Reid, Briggs & Beveridge (1983)	1. Prose + colored illustrations 2. Prose + black & white illustrations 3. Prose only	Specifically written science topic "Structure and Function of the Mammalian Heart"	Middle school (338)	1. Cloze test immediately 2. Objective test items 15 minutes delayed	Written	SD for pictures on objective test NSD for pictures on cloze testing
Rice, Doan & Brown (1981)	1. Prose + pictures 2. Prose only	Prose story "Little Bear"	Elementary school (60)	Reading comprehension with a 11-item test	Written	SD
Riding & Shore (1974)	1. Prose + visuals 2. Prose only	Prose passage "A Story of Rhodpis" containing 185 words	High school (100)	Recall test with 43 questions	Oral	SD
Rohwer & Matz (1975)	1. Prose + pictures 2. Prose only	Prose containing 3 passages	Elementary school (128)	Total number of assertions correctly verified	Oral	SD
Rohwer & Harris (1975)	1. Oral prose + written prose + pictures 2. Written prose + pictures 3. Oral prose + pictures 4. Oral prose + written prose 5. Pictures only 6. Oral prose only 7. Written prose only	Passages about 2 types of monkeys	Elementary school (186)	1. Short answers 2. Free-recall 3. Verification of statements in text	Oral Written	SD oral + pictures was superior
Royer & Cable (1976)	1. Abstract passage + illustrations 2. Unembellished abstract passage 3. Abstract passage with analogues 4. Concrete passage 5. Unrelated prose (control)	Science lesson on heat flow & electrical conductivity	College (80)	Recall of "idea units"	Written	SD
Ruch & Levin (1977)	1. Partial test (partial pictures with each question) 2. Partial study (look at partial pictures during narrative) 3. Repetition (each sentence twice in succession) 4. Control (listened to text once)	Two 10-sentence narrative passages	Elementary school (112)	Cued-recall: 10 verbatim 10 paraphrase	Oral	SD (relative to other 3 conditions) for partial pictures during study on paraphrase questions only

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Ruch & Levin (1979) Experiment 1.0	1. Reinstated picture condition (prose + partial picture at onset of passage and at question time) 2. Partial picture condition (prose + partial picture at onset of each passage) 3. Prose only	2-sentence narrative passage that makes reference to an object	Elementary school (48)	Set of 10 "Wh" questions containing both paraphrase & verbatim information	Oral	SD for reinstated picture condition only
Experiment 2.0	1. Reinstated descriptions (prose + partial picture at onset of passage & 2-sentence verbal description prior to each question) 2. Reinstated pictures (prose + partial pictures both during story and questions) 3. Partial pictures only during story presentation 4. Prose only	Same plus 2-sentence verbal description developed for each picture added	Elementary school (42)	Same	Same	SD reinstated pictures > reinstated descriptions
Rusted & Coltheart (1979b)	1. Prose + simple line drawings 2. Prose only	2 sets of concrete nouns plus a short prose passage	Elementary school (32)	Mean recall, recognition & pronunciation scores	Written	SD
Rusted & Coltheart (1979a) Experiment 1.0	1. Prose + line drawings 2. Prose only	6 short factual passages of highly unusual plant or creatures	Elementary school (72)	Free recall both immediate and 5–7-minute delayed	Written	SD both immediate and delayed testing
Experiment 2.0	1-3. Prose + 3 picture types 4-6. 3 picture types alone 7. Prose Picture types: (a) line drawing, (b) colored drawing, (c) color & background	Same	Elementary school (100)	Number of features recalled both immediate & delayed testing	Same	SD independent of picture type both immediate and delayed testing
Rusted & Hodgson (1985)	1. Text + text-relevant and text-nonrelevant pictures 2. Text only	1 factual & 1 fictitious passage	Middle school (40)	Oral recall scores	Written	SD for factual/expository text
Scruggs, et al. (1985)	1. Mnemonic-instruction (10 interactive illustrations) 2. Direct-study (realistic colored illustration) 3. Free-study (text only)	Passage describing 8 North American minerals	High school + LD (56)	Recall of mineral attributes	Written	SD mnemonic condition

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Sewell, Jr. & Moore (1980)	1. Cartoon text (text + 43 cartoon embellishments) 2. Visual only (cartoons embellishment) 3. Audio/visual (audio + slides of cartoons) 4. Audio only 5. Printed text only	Cartoon strip used as passage	College (150)	Comprehension using 25-item multiple-choice test	Written Oral	SD audio/visual
Sherman (1976)	1. Graphic partial before passage 2. Graphic partial after passage 3. Graphic complete before passage 4. Graphic complete after passage 5. Verbal partial before passage 6. Verbal partial after passage 7. Verbal complete before passage 8. Verbal complete after passage	Eight, 70-word paragraphs (both concrete & abstract versions)	High school (144)	Free recall Total words, idea units, and thematic intrusions recalled	Written	SD for all graphics vs. all verbal conditions
Shriberg et al. (1892) Experiment 1.0	1. Prose + pictures plus (colored "keyword" line drawings + 2 additional pieces of incidental information) 2. Prose + pictures (colored "keyword" line drawings) 3. Prose (12 passages)	Twelve 3-sentence passages about famous people	Middle school (48)	12 sets test questions relating to passages	Written	SD for pictures NSD between picture conditions
Experiment 2.0	1. Prose + pictures plus (colored "keyword" line drawings + 4 additional pieces of incidental information) 2. Imagery + name & keyword pages 3. Prose (12 passages)	Same	Middle school (48)	Same	Same	SD
Silvern (1980)	1. Picture (listen + picture) 2. Play (listen + pretend in story) 3. Repetition (listen twice) 4. Control (listen once)	2 stories, each 10 sentences long	Young children (40)	Comprehension using 10 "Wh" questions	Oral	NSD
Snowman & Cunningham (1975)	1. Pictures before relevant text 2. Pictures after relevant text 3. Pictures & questions before relevant text 4. Pictures & questions after relevant text 5. Questions before relevant text 6. Questions after relevant text 7. Text with no adjunct aids	A 2,189-word fictitious passage	Undergraduate (63)	Recall of specific factual information for both practiced and nonpracticed items	Written	NSD (with respect to type of adjunct aid)
Stone & Glock (1981)	1. Prose + text redundant line drawings 2. Text redundant line drawings 3. Text only	Directs for assembly of a "hand truck" toy	Undergraduate (90)	1. Number of assembly errors 2. Comprehension of reading the instructions	Written	SD (drawing + text)

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Stromnes & Nyman (1974)	1. Prose + mnemonic illustrations preceding each sentence 2. Prose only	Two 30-sentence stories of connected discourse	High school (30)	Immediate paced recall with pictures or empty frames; paced and free recall 1-year delayed	Written	SD for immediate but NSD for delayed testing
Talley (1989)	1. Basal text + basal pictures 2. Story grammar + story grammar pictures 3. Literature + pictures 4. Basal text 5. Story grammar 6. Literature	4 stories from basal readers	Elementary school (72)	1. Comprehension questions 2. Recall measures	Written	SD for picture conditions
Thomas (1978)	1. Color photographs + text 2. Simplified line drawings + text 3. Text only	Prose from a science textbook	Elementary school (108)	1. Literal comprehension 2. Inferential comprehension	Written	NSD
Towers (1994) Experiment 1.0	1. Prose only 2. Prose + static visuals	Weather patterns	College (69)	10 short-answer paraphrase questions	Written	SD
Experiment 2.0	same Note: These 2 experiments also contained an animated treatment not included in this summary	Same	College (64)	13 short-answer paraphrase questions + 4 comprehension questions	Same	NSD
Vernon (1953) Series 1 & 2	1. Prose + photographs 2. Prose + graphs (series 1.0 only) 3. Prose only	Expository short stories of 700–800 words each	High school (62) (major points)	Oral recall of verbal information	Written	NSD
Vernon (1954) Experiment 1.0	1. Prose + pictures 2. Prose only	Text from 2 small books of 755 & 940 words in length	Elementary school & middle school (24)	6 fairly general questions related to text on recall measures	Written	NSD
Experiment 2.0	1. Prose + pictures cutout from book 2. Prose + 4 simple line drawings 3. Text + photographs	Text taken from book "The Shape of of Things"	Elementary school (60)	1. Number of items remembered 2. Question to test understanding	Oral	NSD
Vye et al. (1986)	1. Sentence + picture 2. Picture 3. Sentence Note: 1. Above instructional conditions crossed with elaboration type (precise, imprecise), crossed with retrieval cue (verbal, pictorial) yielding 12 total instructional conditions	20 precise-sentences & 20 imprecise sentences	Undergraduate (168)	Cued recall	Oral	SD for sentence + picture condition superior

TABLE 26-3. *Continued*

Appendix 3 Study	Treatments	Content	Subjects	Dependent Variable(s)	Prose Type	Results
Waddill, McDaniel & Einstein (1988) Experiment 1.0	1. Prose + detailed pictures 2. Prose + relational pictures 3. Prose only	2 text types, a narrative fairy tale & an expository text	College (172)	1. Comprehension 2. Free recall 3. Cued recall	Written	SD dependent on text type and picture type
Experiment 2.0	Same + subjects instructed to attend to the type of information not normally encoded from each text type	Same	College (72)	Same	Same	SD dependent on text type and picture type
Weintraub (1960)	1. Prose + pictures 2. Pictures only 3. Prose only	3 stories from selected basal readers	Elementary school (104)	Questions dealing with comprehension	Written	NSD
Weisberg (1970)	1. Prose + advanced organizer (graph) 2. Prose + advanced organizer (map) 3. Prose + advanced organizer (verbal) 4. Prose + no advanced organizer	Earth science concepts	Middle school (96)	40 questions, verbal multiple choice of knowledge content	Written	SD Map > graph > verbal > prose
Woolridge et al. (1982)	1. Partial pictures during prose & question phases 2. Partial pictures during question phase 3. Partial pictures during prose phase 4. Prose only	Two 10-sentence narrative paragraphs	Elementary school (80)	Two 10-sentence narrative paragraphs	Oral	SD

NSD = nonsignificant difference; SDS = significant static graphics effect

TABLE 26-4. STUDIES LISTED IN THE MATRIX FOR STATIC VISUALS

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TABLE 26-5. SUMMARY OF STUDY RESULTS FOR DYNAMIC VISUALS

Study	Treatment	Subjects	Results*
Alesandrini & Rigney (1981)	Exp. #1. mode (all-verbal vs. verbal-pictorial) × practice (review with dynamic graphics vs. no-review)	College (96)	DVD
	Exp. #2. mode (all-verbal) × practice (review with dynamic graphics vs. no-review)	College (50)	DVD
Avons (1983)	Graphic simulation (active vs. passive)	Middle school, & high school (108)	NSD
Baek & Layne (1988)	(Color vs. B/W) × (text vs. static vs. animation)	High school (119)	DVD
Beichner (1990)	Technique (videograph or traditional) vs. view (witnessed a real motion event or did not)	High school & college (237)	NSD
Blake (1977)	(Still slides) vs. (animated cueing arrows) vs. (full motion film)	College (84)	Mixed
Brasell (1987)	Standard -MBL (real time graphing) vs. delayed-MBL or (delayed graphing) vs. (paper only) vs. (test only)	High school (93)	DVD
Caputo (1982)	(Dynamic graphics enhanced CAI) vs. (verbal CAI) vs. (checklist CAI)	College (72)	DVD
Caraballo (1985)	(Control) vs. (text only) vs. (text + still) vs. (text + still + animation)	College (80)	NSD
Caraballo-Rios (1985)	(text) × (text + still) vs. (text + still + animation)	College (109)	NSD
Chien (1986)	(Hands on simulation) vs. (animated interactive graphics)	Elementary school (72)	NSD
Collins et. al. (1978)	(Unlabeled map) vs. (static labeled map) vs. (interactive dynamic map with blinking dots)	High school & college (18)	DVD
Hativa & Reingold (1987)	(Static graphics + no sound + monochrome) vs. (sound + animation + color)	Middle school (92)	DVD
Johnson (1985)	(Interactive dynamic computer graphics) vs. (static computer graphics)	High school (165)	DVD
King (1975)	(Text) vs. (text + still) vs. (text + still + dynamic)	Adult (45)	NSD
Kinzer et al. (1989)	(Expository text only) vs. (simulation using animation)	Elementary school (52)	SDT
Klein (1986)	Rule type (temporal vs. spatial) vs. mode (nonanimated graphics vs. animated graphics)	College (38)	Mixed

TABLE 26-5. ***Continued***

Study	Treatment	Subjects	Results*
Laner (1954)	(Static film strip) vs. (full motion picture film)	Adult (75)	NSD
Laner (1955)	(Text + static diagrams) vs. (full motion film)	Adult (50)	NSD
Lumsdaine et al. (1961)	(Nonanimated film) vs. (animated film)	Adult (1300)	DVD
Mayer & Anderson (1991)	Exp. #2. (words with animation) vs. (animation only) vs. (words only) vs. (no treatment)	College (48)	DVD
Mayton (1990)	(Static + no cueing) vs. (static + imagery cueing) vs. (animation + imagery cueing)	College (72)	DVD
McCloskey & Kohl (1983)	(No motion) vs. (dynamic rotations) vs. (dynamic trajectories)	College (90)	NSD
McCuistion (1990)	(Static visuals) vs. (dynamic visuals)	College (137)	NSD
Moore et al. (1979)	(Alphanumeric & schematics) vs. (line drawings) vs. (animation)	Adult (90)	NSD
Myers (1990)	(Traditional classroom) vs. (dynamic interactive graphics)	College (52)	DVD
Park & Gittelman (1992)	(Type of feedback) x (static vs. animated)	College (90)	DVD
Peters & Daiker (1982)	(Program with no animation) vs. (CAI program with animation)	College (35)	NSD
Ponick (1987)	(Nonanimated graphics) vs. (animated graphics)	College (71)	DVD
Reed (1985)	(Animated single dot) vs. (animated two dots)	College (180)	Mixed
Rieber & Hannafin (1988)	(Text) vs. (animation) vs. (text + animation) vs. (none) vs. (animation) vs. (text + animation)	Elementary school (111)	NSD
Rieber (1989)	Practice type × (no graphics) vs. (static graphics) vs. (animation)	SC (192)	NSD
Rieber (1990)	Practice type × (no graphics) vs. (static graphics) vs. (animated graphics)	Elementary school (119)	DVD
Rieber, Boyce & Assad (1990)	Visual elaboration × (no graphic) vs. (static graphics) vs. (animation) × (practice order)	College (141)	NSD
Rieber (1991)	(Static graphics) vs. (animation) × (practice order)	Elementary school (70)	DVD
Rigney & Lutz (1976)	(Written description only) vs. (verbal statement plus animation)	College (40)	DVD
Roshal (1961)	Motion (yes vs. no) × show hands (yes vs. no) × active participation (yes vs. no)	Adult (3314)	DVD
Spangenberg (1973)	Exp. #1. (motion sequence) vs. (set of still photo's)	Adult (40)	DVD
	Exp. #2. (motion sequence) vs. (motion sequence + cueing arrows) vs. (static) vs. (static + cueing arrows)	Adult (80)	DVD
Spangler (1994)	Traditional instruction vs. static graphics vs. animated graphics	College (57)	NSD
Swezey et al. (1991)	(Video motion) vs. (static 35-mm slides)	Children (120)	NSD
Thompson & Riding (1990)	(Static diagram no computer) vs. computer (static or animated diagrams)	College (108)	DVD
Towers (1994)	Exp. #1. prose only vs. prose + static vs. prose + animated	College (49)	SDS
	Exp. #2. prose only vs. prose + static vs. prose + animated	College (64)	NSD
Zavotka (1987)	(Tested only no snimation) vs. (3-D animated projection)	College (101)	Mixed

*NSD = nonsignificant differences; Mixed = mixed effects reported; DVD = significant differences for dynamic visual displays; SDT text = significant difference for static text treatment; SDS = significant differences for static graphics.

TABLE 26-6. STUDIES LISTED IN THE MATRIX FOR DYNAMIC VISUALS

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TABLE 26-7. SUMMARY TABLE FOR PRIMARY RESEARCH STUDIES INCLUDED IN THE LITERATURE SURVEY

	Total Number	Subjects*					Prose Type		Results†	
		Y	H	U	G	A	Written	Oral	SD	NSD
Static Pictures										
Studies	90	9217	1362	2700	129	120	61	34	81	33
Experiments	118						73	48	102	36
Animation										
Studies	42	690	429	1991	—	4994	42	0	19	18
Experiments	45						45	0	21	18

*Y = Young children, elementary, and middle school; H = High school; U = Undergraduate; G = Graduate; A = Adult

†SD = Significant differences; NSD = Nonsignificant differences.

Mixed effects were identified in four animation studies.