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VISUAL REPRESENTATIONS AND LEARNING: THE ROLE OF STATIC AND ANIMATED GRAPHICS

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With the proliferation of illustrations in instructional materials, it becomes increasingly important to investigate their effects on student learning. The use of illustrations in instructional materials has been pervasive for a considerable amount of time (Feaver, 1977; Slythe, 1970). 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 technology and others to the primary theories of picture perception and to provide a survey and critique of the visual representation research that incorporates static animated illustrations.

33.1 SCOPE

The effective use of illustrations (pictures, charts, graphs, and diagrams) in instructional materials is an important facet of instructional message design. 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, whereas 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 first present several theories of picture perception. We then present a brief discussion of selected memory models that have been used to describe how words and pictures are encoded and two related topics, cognitive load theory and multiple representations in multimedia. Next, knowledge acquisition studies incorporating static and animated pictures are reviewed. Finally, we 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 reviewed only comparative experimental research studies. 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 reviewed a wide range of studies but we do not claim that the review is exhaustive.

33.2 PICTURE PERCEPTION

33.2.1 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? 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 provides a concise introduction to the major scientific theories of picture perception. To set the discussion of modern theories in historical context, we begin 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 based on the picture's resemblance to the visual environment, and E. H. Gombrich's constructivist theory, in which meaning is based upon 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).

33.2.1.1 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 artist 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, as 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 is given by Greene (1983), Haber (1979), Penrice (1980), and Pirenne (1970).

33.2.1.2 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 (1971) 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" (p. 31).

But what is this "kind of information" that is found in both the picture and the 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 (1979):

> 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. (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 discussion 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).

33.2.1.3 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.

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).

33.2.1.4 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, 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.

33.2.1.5 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 that 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" (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).

33.2.1.6 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). Because detailed discriminations are possible only on the fovea, it is necessary to scan pictures 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 0.33 s 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 among 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 (1980) uses the term "canonical form" to refer to "the most readily recognized and remembered view or 'clean up' version of some form or object" (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.

33.2.1.7 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 (1985) 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. (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 which was intended, and expects the recipient to know the maker expected all this 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 (1984a) 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" (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 counter charge. Theorists are robustly combative in attacking opposing views while defending their own.

33.2.1.8 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 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 (1978). 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" (p. 130).

33.2.1.9 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 (a) the scheme of representation, (b) the field of reference, and (c) 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 . . . non-notational 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, as 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 with 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).

33.2.1.10 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 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 artificial intelligence 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).

33.2.2 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 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) 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.

33.3 MEMORY MODELS, COGNITIVE LOAD THEORY, AND MULTIPLE REPRESENTATIONS

33.3.1 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 (a) the dual-code model, (b) the single-code model, and (c) the sensory-semantic model.

Proponents of the dual-code 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 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.

33.3.1.1 Cognitive Load Theory. We believe that it is critical for instructional design researchers to be aware of the knowledge and breakthroughs that have been made by researchers in cognitive science concerning human cognitive architecture and a particular instructional theory based on current cognitive science research. In this section we provide a brief summary of a particular information processing view (IPV) of human cognitive architecture similar to the one presented in the learning and memory section. We then describe an instructional theory based on this IPV.

In our discussion of memory models we presented an IPV of human cognitive architecture. An IPV assumes that humans have a limited working (conscious) memory and a long-term memory (Miller, 1956). There is evidence that only seven elements can be stored in working memory at a given time (Miller). Individuals are not conscious of the information stored in long-term memory. On the other hand, there is evidence that humans have the ability to store almost unlimited amounts of information in long-term memory (Sweller, Van Merrienboer, & Pass, 1998). Sweller et al. suggest that individuals real intellectual power lies in their knowledge stored in long-term memory. The implications for instructional design are that we should not emphasize general reasoning strategies that use working memory but, rather, promote the acquisition of knowledge in specific domains.

An additional component of human cognitive architecture is that of schema. A schema is a network of information or classification of elements according to the way that they will be used. Schemas are stored in long-term memory. Consider the following example. If one asks an educational researcher to write a research paper using APA style, an experienced writer will already know what APA style is and will have knowledge of the following elements: order of presentation, heading structure, in-text citation format, and reference list. A schema has been developed and stored for "APA" style. Most researchers that are true experts at writing research papers using APA style will automatically be able to recall and use their schema for an APA-style paper without performing any means–ends analysis including the elements of APA style.

In summary, humans have limited working memory and almost-unlimited long-term memory, and they develop schemas that may become automated and used to solve particular problems. The result of schema development is a reduction in the load on working memoy. The goal of instruction should be to help learners develop and automate schemas.

Cognitive load refers to the resources used by working memory at a given point in time. Two types of cognitive load have been identified in particular: instrinsic cognitive load and extraneous cognitive load (Sweller et al., 1998). Intrinsic cognitive load refers to the load placed on working memory by "difficult-to-learn" content. Extraneous cognitive load is the working memory load resulting from poorly designed instructional message materials and poor instructional designs. In any case, if working memory is cognitively overloaded, the desired learning will not be accomplished. We believe that researchers investigating how pictures and animated graphics can help or hinder learning should consider the implications of cognitive load theory.

33.3.1.2 Multiple Representations. It is now common for multiple representations to be used in instructional programs and situations. For example, students can now learn how to solve quadratic equations algebraically, or they can learn to draw the "right" picture. Concepts and content can be represented using pictures, animations, spreadsheets, graphs, and a number of other external representations. Research on using multiple representations in instruction has yielded conflicting results (Ainsworth, 1999). Ainsworth suggests that one finding that is consistent across a number of studies investigating multiple representations in multimedia. It is difficult for students to see the relationship between the multiple representations used. The translation process may place a heavy demand on short-term memory and cognitive overload occurs. Ainsworth suggests that if we are to develop principles for incorporating effective multiple external representations (MERs) in learning situations, we must consider the functions of MERs.

Anisworth (1999) identifies three primary functions of MERs in learning environments, "to complement, constrain, and construct" (p. 134). The complimentary function involves using "representations that contain complementary information or support complementary cognitive processes"; when using the constrain function of MERs, "one representation is used to constrain possible (mis)interpretations in the use of another"; the construct function involves using MERs to "'construct deeper' understanding of a situation" (p. 134). For each of the functions of MERs Ainsworth has identified, she has also identified a number of subfunctions and discussed using MERs to support more than one function. We attempt to present only the gist of her perspective her. A detailed discussion can be found in Ainsworth (1999).

Ainsworth also suggests that the selection of particular MERs has implications for how learning will be measured when incorporating MERs in instructional situations. For example, when MREs are used to complement information or processes or to constrain interpretation, it is not critical for the learner to understand the relationship between the representations, so that measurement of performance on MERs in isolation is appropriate. In contrast, for MERs designed to facilitate deeper understanding, it is important to assess the relationship between MERs. As with cognitive load theory, the authors believe that Ainsworth's discussion of the functions of multiple representations can be very useful to researchers interested in the effect of static pictures and animated graphics on learning.

33.4 PICTURES AND KNOWLEDGE ACQUISITION

33.4.1 Literature Search and Reviews

Through various on-line and manual literature searches, 2,235 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 animated graphics 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 168 primary research studies was included across the two categories (static illustrations and animated graphics) used for the review. We first report the results of earlier literature reviews. Then an abridged guide to the literature is presented.

33.4.1.1 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. We then discuss the results of our literature search and summary. A similar approach is used for animated pictures and knowledge acquisition.

33.4.1.2 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 the 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 among 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) reviewed studies of prose learning with pictures and concluded that pictures do facilitate prose learning when five ground rules are adhered to.

1. Prose passages are presented orally;
2. The subjects are children;
3. The passages are fictional narratives;
4. The pictures overlap the story content; and
5. Learning is demonstrated by factual recall. (pp. 234–235)

Although 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 that (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 used only 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 learn and comprehend text (a) 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 metanalytic 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 was 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 the 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 are covered in detail in a later section.

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 or 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 metanalysis of the pictures in prose studies. The reviewers concluded that for pictures (not

TABLE 33.1. Summary of Primary Research Studies Included in the Literature Survey

Studies	Total Number	Audience by Experiment			Results by Study	
		Y	H	A	SD	NSD
Static pictures	90	75	16	29	81	33
Animation	78	15	5	72	43	27

Note. Subject classifications: Y—young children, elementary school, and middle school; H—high school; A—adult. SD, significant differences; NSD, nonsignificant differences. Mixed effects were identified in selected studies. Some studies included more than one experiment.

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, 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 measures 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 metanalysis using the treatments developed by Dwyer and presented in a text format or programmed booklet. All studies included in the metanalysis included a text-only condition. Based on 41 comparisons of treatments with text plus prose vs. with text only using four criterion measures (drawing test, identification test, terminology test, comprehension test), Levie and Lentz (1982) reported that 36 comparisons favored illustrated text and 4 favored text alone (see Appendix 33.1). 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 (1972, 1978, 1987) series.

33.4.1.3 Guide to the Literature: Static Illustrations. Based on our literature search, 90 studies investigating the role of static pictures in knowledge acquisition were identified. The 90 studies were conducted with more than 13,528 subjects ranging from elementary-school children to adults. (See Table 33.1.) All of the studies included at least one comparison of learning with prose and static visual illustrations of various types vs. with a prose-only treatment. A number of the studies included written prose materials, whereas others 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 be included more regularly 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 33.2. The studies by Dwyer and his associates that are reported in Appendix 33.1 are not duplicated in Appendix 33.2.

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):

> 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. (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 is not identified. We feel that it is critically important to determine, in advance of conducting research, the particular functions of the visual illustrations.

33.4.1.4 The Use of Functional Frameworks in Static Visual Research. Despite 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 provide a brief summary of several functional frameworks.

Two taxonomies have been proposed that 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 proven 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 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.

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 visually follow 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. (pp. 21–24)

An alternative functional framework, offered by Levie and Lentz (1982), suggests that a functional framework include 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, which is 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).

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: (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 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 serves 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). Brody 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.

33.4.1.5 Static Visuals and Knowledge Acquisition: Conclusions. Based on the conclusions of our review of earlier literature reviews and the studies we summarize in Appendixes 33.3 and 33.4, 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) among 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 complementary 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.

33.4.2 Animated Pictures and Knowledge Acquisition

In this section we first review the early research on the effect of animated visuals on learning. We then summarize more recent reviews of the literature concerning the role of animated visual displays and knowledge acquisition. Finally, we present the results of our literature search and analysis.

33.4.2.1 Animated Pictures and Knowledge Acquisition: Literature Reviews. Early studies examining the effects of animated 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 drew 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 animated 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 animated 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 where 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 five 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" (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" (p. 82), and (c) "animation's greatest contributions to CBI may lie in interactive graphic applications (e.g., interactive dynamics)" (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 animated 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) 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 which 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. (p. 19)

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

Using their functional framework, Park and Hopkins (1993) produced a research summary of 25 studies investigating the effects of animated versus static visual displays. The delivery medium for 17 of the studies was computer-based instruction, whereas the delivery medium for the remaining 8 studies was film or television. Fourteen of the studies yielded significant effects for animated visual displays. However, "the research findings do not consistently support the superior effect of animated visual displays. The conflicting findings seem to be related to the different theoretical rationales and methodological approaches used in various studies. . . " (p. 427).

One of the most interesting and rigorous programs of research on the effect of animation on learning has been conducted by 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).

33.4.2.2 Guide to the Literature. Forty-two studies were located that included at least one animation treatment. Information concerning the authors, treatments, subjects, and results is reported in Appendix 33.5 (see also Appendix 33.6). 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 of 45 comparisons was identified that 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, animated 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 was 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 animated. Perhaps reading text alone is adequate. In addition, many of the investigators did not provide a rationale for why motion is needed to indicate either 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 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) 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 [animated visuals] and studies which found no such effects is that the former were guided by theoretical rationales which derived the appropriate uses for animated 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. (p. 439)

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

33.4.2.3 Animated 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 animated 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 animated 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 research needs to be completed concerning the functions of animated visuals in learning materials. Rieber's and Park and Hopkins' contributions 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 animated 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 were then 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 animated visual displays on learning should (a) be based on a functional framework (i.e., Rieber or Park and Hopkins), (b) include content for which external visual information is needed and that requires the illustration of motion or the trajectory of an object, and (c) control for the effect of static graphics.

Whereas some progress had been made since the review by Anglin, Towers, and Levie (1996), it is apparent that we still know very little about the effect of animated 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 used 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.

33.4.3 The Role of Static and Animated Visuals: Conclusions

We have emphasized the need for future research on the effect of static and animated graphics on learning. Some of the studies we reviewed are theory based, whereas others are not. It is difficult to draw general conclusions across all studies given the wide variety of topics and perspectives represented in the studies. This is true particularly for the studies incorporating animated graphics. It was also pointed out that functional frameworks have been helpful when attempting to explain conflicting results identified across various studies. The functional frameworks developed for static graphics have been particularly useful. However, we think it is now time for researchers to revaluate the functional frameworks that they are using in light of what we know about human learning and cognition. Consideration of cognitive load theory in conjunction with Ainsworth's (1991) taxonomy of multiple representations could provide a perspective that incorporates recent breakthroughs in human cognitive science with a functional framework that could be used for various external representations of concepts and content in instructional materials, including static animated and graphics (Sweller et al., 1998). Consideration of cognitive load theory and taxonomy of multiple representations would lead to a new set of research questions related to the effectiveness of static and animated graphics. Do the static pictures or animated graphics we include in instructional materials overload working memory, or do such pictures help reduce cognitive load and help the learner develop automated schemas? When should pictures and animated graphics be used as external representations? How should pictures and animated graphics function when used with other forms or external representation or with each other? Should they complement information and processes, constrain interpretation, or promote deeper understanding (Ainsworth, 1999)? What strategies will be effective is helping the learner understand the relationships among multiple representations when appropriate? In addition to new research questions, the use of cognitive load theory and a taxonomy of multiple representations also has implications for the assessment method researchers would use. In some cases it would be appropriate to assess the effectiveness of a single external representation on learning; in other cases it would be necessary to assess weather learners understand the relationships between multiple representations. In conclusion, we think that it is critical that new research concerning the effectiveness of visual representations on learning be well grounded in theory and that the functions of external representations, including static pictures and animated graphics, be identified.

33.5 CONCLUSIONS

We have briefly reviewed theories of picture perception, memory models, and cognitive load theory and presented a taxonomy of multiple external representations in instructional materials. Then a survey of existing studies and reviews concerning the effect of static and animated 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. For both static and animated graphics, the research is fragmented and sporadic. Notable exceptions are the research programs of Dwyer, Levin, and Rieber. Over the last 6 years, the scope of animation research has broadened. In addition, many of the researchers in instructional communication and technology have neglected the work on human cognitive architecture, memory models, perspectives on multiple external representations, and theories of pictures perception. Future research related to visual learning should derive from theories of picture perception and incorporate memory models. We believe that consideration of cognitive load theory and Ainsworth's (1999) taxonomy of multiple external representations would be very useful to researchers interested in examining the effect of static and animated graphics on student learning. There is much that we do not know about how to design effective visual representations. Future research strategies should be selected carefully to assure that we continue to make significant progress.

APPENDIX 33.1

TABLE 33.A1. 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	0.35	1.14	IT	0.34	1.09	IT	0.23	1.06	IT	0.02	1.00
Dwyer (1968)	9th grade (141)	IT	0.82	1.28	IT	0.57	1.24	TA	−0.10	0.96	TA	−0.17	0.94
Delayed retest	9th grade (129)	IT	0.36	1.09	IT	0.42	1.14	IT	0.27	1.06	IT	0.50	1.18
Dwyer (1969)	College (175)	IT	1.23	1.37	IT	0.67	1.17	IT	0.80	1.16	NSD	—	—
Dwyer (1972)	College (266)	IT	0.43	1.12	IT	0.26	1.07	IT	0.16	1.04	IT	0.11	1.03
Dwyer (1975)	College (587)	IT	0.82	1.16	IT	0.47	1.13	IT	0.52	1.11	TA	−0.04	0.99
Arnold & Dwyer (1975)	10th Grade (185)	—	—	—	—	—	—	IT	0.77	1.27	IT	0.90	1.22
Joseph (1978)	10th Grade (414)	IT	0.41	1.07	IT	0.14	1.02	TA	−0.12	0.98	IT	0.01	1.00
Delayed retest	10th Grade	IT	0.24	1.03	IT	0.13	1.02	IT	0.47	1.10	IT	0.23	1.04
de Melo (1980)	High school (48)	—	—	—	IT	0.23	1.11	IT	0.34	1.18	IT	0.36	1.15
Pictorial test	High school (48)	—	—	—	IT	1.42	1.72	IT	1.11	1.50	IT	0.52	1.23

Note. IT, illustrated text; TA, text alone; NSD, no significant difference. Dashes indicate that the value was not provided in the published report. From "Effects of Text Illustrations: A Review of Research," by W. H. Levie and R. Lentz, 1982, *Educational Communication and Technology Journal*, *30*,30(4) p. 212, pp. 195–232. Copyright 1982 by the Association for Educational Communications and Technology. Reprinted by permission of the AECT.

APPENDIX 33.2 REFERENCE LIST OF DWYER SERIES REVIEWED BY W. HOWARD LEVIE (SEE APPENDIX 33.1)

Arnold, T. C., & Dwyer, F. M. (1975). Realism in visualized instruction. *Perceptual and Motor Skills, 40,* 369–370.

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.

Dwyer, F. M., Jr (1967). The relative effectiveness of varied visual illustrations in complementing programed instruction. *Journal of Experimental Education, 36,* 34–42.

Dwyer, F. M. (1968). The effectiveness of visual illustrations used to complement programed instruction. *Journal of Psychology, 70,* 157–162.

Dwyer, F. M. (1969). The effect of varying the amount of realistic detail in visual illustrations designed to complement programmed instruction. *Programmed Learning and Educational Technology, 6,* 147–153.

Dwyer, F. M. (1972). The effect of overt responses in improving visually programmed science instruction. *Journal of Research in Science Teaching, 9,* 47–55.

Dwyer, F. M. (1975). On visualized instruction effect of students' entering behavior. *Journal of Experimental Education, 43,* 78–83.

Joseph, J. H. (1979). The instructional effectiveness of integrating abstract and realistic visualization (Doctoral dissertation, Pennsylvania State University, 1978). *Dissertation Abstracts International, 39,* 5907A.

APPENDIX 33.3 (pp. 880–893)

TABLE 33.A3. Summary Matrix of Research Results for Static Visuals

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
Alesandrini & Rigney (1981)						
Experiment 1	1. Verbal + interactive graphics expansion 2. Verbal + computer game 3. Verbal + verbal expansion 4. Verbal + game	Science (battery cell)	Undergraduate (98)	1. A 37-item verbal test 2. A 27-item picture recognition test	Written	SD
Experiment 2	1. Verbal + pictorial review 2. Verbal + verbal review	Same	Undergraduate (50)	1. A 60-item verbal test 2. A 27-item picture recognition test	Same	NSD (verbal) SD (picture)
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 (holistic learning strategy)
Anglin & Stevens (1986)	1. Prose + pictures 2. Prose only	Science (water clock)	Undergraduate (42)	A 12-item multiple-choice test Immediate and 28 day delayed	Written	SD (immediate) NSD (delayed)
Anglin (1986)						
Experiment 1	1. Prose + picture 2. Prose only	Three human interest stories	Graduate (52)	15 short-answer paraphrase questions; immediate and 14 day delayed	Written	SD (immediate & delayed)
Experiment 2	Same	Same	Graduate (47)	Same, except delay increased to 28 days	Same	SD (immediate and delayed)
Anglin (1987)	1. Prose + picture 2. Prose	Three human interest stories	Graduate (30)	Recall test had 15 paraphrase questions on text-redundant information, 5 short-answer questions on text-only information (immediate and 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	Eight 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 and organizer type
Beck (1984)	1. Prose + pictorial cues 2. Prose + textual cues 3. Prose + combinational cues 4. Prose + noncues	12 passages and pictures based on carnivorous plants	Elementary school (256)	Recall 1-day-delayed multiple-choice test	Written	SD for combin-rational cueing only
Bender & Levin (1978)	1. Story + illustrations 2. Story + generate visual images 3. Story (listen twice) 4. Story (listen once)	20 sentence fictitious story	Mentally retarded children (96)	Recall scores 10 verbatim + 10 paraphrased 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	An 800-word passage about function of the brain	Undergraduate (104)	Recognition 18 paraphrase and nonparaphrase questions Immediate & delayed testing (2 weeks)	Written	SD for both verbal and 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	Two 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	Two 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)
Bransford & Johnson (1972)						
Experiment 1	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	Three 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
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	Two 10-sentence prose stories	Young children (160)	Set of cued recall questions	Oral	SD for object + partial pictures with and without imagery instruction

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
	5. Object picture + partial picture + imagery instruction 6. Object picture + partial picture + no imagery instruction 7. Prose + imagery instruction 8. Prose + no 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 delayed	Written	SD on 2- week- delayed only (recall test)
Durso & Johnson (1980)						
Experiment 1	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 a word was taken as an indication that the item was remembered as having been present during acquisition	Oral	SD for verbal orienting tasks only
Experiment 2	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
Guttmann, Levin, & Pressley (1977)						
Experiment 1	1. Imagery + prose 2. Partial pictures + prose 3. Complete pictures + prose 4. Prose only	Two short stories, each with a person, object, and thing	Young children & elementary school (240)	Cued recall, 20 questions	Oral	SD, kindergarten, for complete pictures only SD, third graders, for imagery = partial = complete SD, second 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 answer 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 levels of idea units Immediate and 5 day delayed	Written	SD for top-level idea units for both immediate & 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
Hayes & Henk (1986)	1. Pictures only 2. Pictures + prose 3. Prose only (five 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, and Archimedes' principle	High school (61)	Verbal quantitative (non-pictorial), multiple-choice test	Written	SD
Holmes (1987)	1. Prose + picture 2. Pictures 3. Prose only	Fifteen 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

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
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 2 text types (essential & nonessential), giving 10 total conditions	Two versions of a biology lesson	Middle school (200)	1. Reproduction (amount of material reproduced) 2. Text organization Both immediate and 2-week-delayed testing	Written	SD depending on picture type and its relationship to the text type
Jahoda et al. (1976)						
Experiment 1	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 and text-redundant information	Written	SD for pictures + text NSD, pictures alone vs. text alone
Jonassen (1979)	1. Prose + single-screen presentation 2. Prose + three-screen presentation 3. Prose + four-screen presentation 4. Prose only	Biology lesson on four plant types	Middle school (363)	Criterion test of a verbal and visual classification exercise Immediate and 2 week delayed	Oral	SD, Four-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), sixth 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 seventh graders regardless of picture placement NSD for eighth graders
Lesgold & DeGood & Levin (1977)	1. Prose + subject-illustrated story using cutouts on a background 2. Prose + coloring simple figures in a booklet	Sixteen prose stories, four of each type (50 vs. 100 words; one vs. two locations)	Elementary school (32)	Free and cued-recall scores	Oral	SD
Lesgold et al. (1975)						
Experiment 1	1. Prose + subjects made up illustrations from cutouts (some potentially interfering) 2. Prose + subjects copied or colored geometric forms during illustration phase	Five single-episode stories of 30–50 words each	Elementary school (24)	Oral recall	Oral	NSD

Experiment 2a	1. Prose + subjects made up illustrations from fewer cutouts than experiment 1 2. Prose + subjects copied or colored geometric forms during illustration phase	Three stories of 5 sentences each	Elementary school (48)	Oral recall, both free and cued	Same	SD
Experiment 2b	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 two picture conditions
Experiment 3	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	1. Prose + one colored, main-idea line drawing per passage 2. Prose only	Five human interest and novelty stories, from local newspapers, approximately 100 words each	Elementary school (50)	Six 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	Same (change was in time of testing only)	A sixth 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 analogue 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 non-main-idea questions	Same	SD (both question types)
Levin (1976)						
Experiment 2	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)	Three single-episode stories of 30 to 75 words each	Elementary school (61)	Cued-recall, 5 short-answer questions	Oral	SD
Experiment 3	Same (minus the activity control condition)	Two 10-sentence passages	Elementary school (64)	Cued recall, 10 questions/story	Same	SD

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
Levin et al. (1983)						
Experiment 1	1. Prose + colored mnemonic illustrations 2. Prose only	Learn 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	Same + additional study trials added	Same	Middle school (40)	Same + name recall added	Same	NSD on total recall
Experiment 3	Same + 3 study trials added	Same	High school (32)	Total recall scores only	Same	SD
Levin et al. (1982)						
Experiment 1	1. Key word context (word list + contextually explicit colored "key word" 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	1. Key word context (word list + contextually explicit colored "key word" 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, Key word context best Picture better than experiential
Levin et al. (1983)						
Experiments 1a & 1b	1. Prose + organized mnemonic "key word" 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 "key word" NSD, separate picture
Experiments 2a & 2b	Same without organized separate picture condition (No. 2 above)	Same	Middle school (113)	Subject responses of (a) Verbatim correct (b) Essence correct	Same	SD, organized mnemonic "key word" NSD, separate picture
Levin et al. (1986)						
Experiment 1	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)	Name and attribute recall testing	Written	SD for mnemonic pictures
Experiment 2	Same	Same except text organized around "attributes"	Middle school (115)	Same	Same	SD for mnemonic pictures

Mange & Parknas (1962)						
Experiment 1	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	Same	Same	College (81)	Same	Same	SD (same condition)
Experiment 3	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. A 100-item sentence completion part 3. A 55-item multiple-choice section	Written Oral	SD, all experimental groups vs. control NSD between experimental groups
Mayer (1989)						
Experiment 1	1. Text + illustrations including labels 2. Text only	Vehicle braking systems	College (34)	95 idea units of both explanatory and nonexplanatory information	Written	SD on recall of explanatory information
Experiment 2	1. Text + labeled illustrations 2. Text + nonlabeled illustrations 3. Text only	Same	College (44)	Same	Same	SD on recall of explanatory 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)	Three fictitious biographical stories	College (160)	11 short-answer recall questions	Written	SD for integrated mnemonic illustrations
McCormick & Levin (1984)						
Experiment 1	1. Text + mnemonic pictures (key word-paired) 2. Text + mnemonic pictures (key word-chained) 3. Text + mnemonic pictures (key word-integrated) 4. Simple control (text + additional study each sentence) 5. Cumulative control (text + cumulative study of all sentences)	Four fictitious biographies	Middle school (220)	20 cued-recall questions	Written	SD for all three mnemonic conditions NSD between them
Experiment 2	Same except delete condition 2 above	Same	Middle school (82)	Name–attribute recognition test, both immediate and 2 day delayed	Same	SD for key word conditions, both immediate and delayed

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
Miller (1938)	1. Prose + illustrations 2. Prose only	Three 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	1. Visuals + print + audio. 5. Visuals 2. Visuals + print. 6. Print 3. Visuals + audio. 7. Audio 4. Print + audio. 8. Control	Film about factual life of a cheetah	Elementary school & middle school (201)	23 multiple-choice comprehension test	Oral	NSD, single medium SD, dual media SD, three media
O'Keefe & Solman (1987)						
Experiments 1 & 2	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 and 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- and 1-week-delayed testing	Written	SD, immediate and delayed testing
Peng & Levin (1979)	1. Prose + colored line drawings 2. Prose only	Two 10 -sentence narrative stories	Elementary school (64)	Cued recall using paraphrase verbatim questions, both immediate and 3 day delayed	Oral	SD, immediate and delayed testing
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.	Two lists of concrete sentences	Young children (126)	Correct recall responses	Oral	SD, matched pictures > prose only, prose only > mismatched pictures
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 > static object > prose only NSD, action object and 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	1. Prose + drawings + Instructional strategy 2. Prose + drawings 3. Prose + instructional strategy 4. Prose only	A 2,511-word prose passage	Undergraduate (91)	35-item test with 28 true/false, 1 constructed response, and 6 multiple-choice questions on the verbal information in the text	Written	NSD
Experiment 2	Same	Same	High school (80)	Same	Same	NSD
Experiment 3	Same	Two shorter passages (429 words and 633 words)	Elementary school (93)	20 multiple-choice questions on verbal information	Same	SD, prose + strategy + pictures
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, delayed 15 min	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 an 11-item test	Written	SD
Riding & Shore (1974)	1. Prose + visuals 2. Prose only	Prose passage from "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 three 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 two 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 and electrical conductivity	College (80)	Recall of "idea units"	Written	SD

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Dependent Variable(s)	Prose Type	Result(s)
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
Ruch & Levin (1979)						
Experiment 1	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	Two-sentence narrative passage making reference to an object	Elementary school (48)	Set of 10 "Wh—" questions containing both paraphrase and verbatim information	Oral	SD for reinstated picture condition only
Experiment 2	1. Reinstated descriptions (prose + partial picture at onset of passage & two-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 two-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	Two sets of concrete nouns plus a short prose passage	Elementary school (32)	Mean recall, recognition and pronunciation scores	Written	SD
Rusted & Coltheart (1979a)						
Experiment 1	1. Prose + line drawings 2. Prose only	Six short factual passages of highly unusual plant or creatures	Elementary school (72)	Free recall, both immediate and 5–7 min delayed	Written	SD, both immediate and delayed testing
Experiment 2	1–3. Prose + three picture types 4–6. Three picture types alone 7. Prose Picture types: (a) line drawing, (b) colored drawing, (c) color and background	Same	Elementary school (100)	Number of features recalled, both immediate and 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	One factual and one 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

Sewell & Moore (1980)	1. Cartoon text (text + 43 cartoon embellishments) 2. Visual only (cartoon 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 and 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	1. Prose + pictures plus (colored "key word" line drawings + 2 additional pieces of incidental information) 2. Prose + pictures (colored "key word" line drawings) 3. Prose (12 passages	12 three-sentence passages about famous people	Middle school (48)	12 sets of test questions relating to passages	Written	SD for pictures NSD between picture conditions
Experiment 2	1. Prose + pictures plus (colored "key word" line drawings + 4 additional pieces of incidental information) 2. Imagery + name & key word 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)	Two 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)
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

Continues

TABLE 33.A3. (Continued)

Study	Treatment	Contents	Subjects (N)	Depedent Variable(s)	Prose Type	Result(s)
Talley (1989)	1. Basal text + basal pictures 2. Story grammar + story grammar pictures 3. Literature + pictures 4. Basal text 5. Story grammar 6. Literature	Four 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	1. Prose only 2. Prose + static visuals	Weather patterns	College (69)	10 short-answer paraphrase questions	Written	SD
Experiment 2	Same Note: These two experiments also contained an animated treatment that is 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 only) 3. Prose only	Expository short stories of 700–800 words each	High school (62)	Oral recall of verbal information (major points)	Written	NSD
Vernon (1954)						
Experiment 1	1. Prose + pictures 2. Prose only	Text from two small books 755 and 940 words in length	Elementary school & middle school (24)	Six fairly general questions related to text on recall measures	Written	NSD
Experiment 2	1. Prose + pictures cutout from book 2. Prose + four simple line drawings 3. Text + photographs	Text taken from book, *The Shape 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: Above instructional conditions crossed with elaboration type (precise, imprecise), crossed with retrieval cue (verbal, pictorial) , yielding 12 total instructional conditions	20 precise sentences and 20 imprecise sentences	Undergraduate (168)	Cued recall	Oral	SD for sentence + picture condition superior

Waddill, McDaniel, & Einstein (1988)						
Experiment 1	1. Prose + detailed pictures 2. Prose + relational pictures 3. Prose only	Two text types, a narrative fairy tale and an expository text	College (172)	1. Comprehension 2. Free recall 3. Cued recall	Written	SD dependent on text type and picture type
Experiment 2	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	Three 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

Note. NSD, nonsignificant difference; SD, significant static graphic effect.

APPENDIX 33.4. STUDIES LISTED IN THE MATRIX FOR STATIC VISUALS (SEE APPENDIX 33.3)

Alesandrini, K. L. (1981). Pictorial-verbal and analytic-holistic learning strategies in science learning. *Journal of Educational Psychology, 73,* 358–368.

Alesandrini, K. L., & Rigney, J. W. (1981). Pictorial presentation and review strategies in science learning. *Journal of Research in Science Teaching, 18*(5), 465–474.

Anglin, G. J. (1986). Prose-relevant pictures and older learners' recall of written prose. *Educational Communication and Technology Journal, 34*(3), 131–136.

Anglin, G. J. (1987). Effect of pictures on recall of written prose: How durable are picture effects? *Educational Communication and Technology Journal, 35*(1), 25–30.

Anglin, G. J., & Stevens, J. T. (1986). Prose-relevant pictures and recall from science text. *Perceptual and Motor Skills, 63*(3), 1143–1148.

Arnold, D. J., & Brooks, P. H. (1976). Influence of contextual organizing material on children's listening comprehension. *Journal of Educational Psychology, 68,* 711–716.

Beck, C. R. (1984). Visual cueing strategies: Pictorial, textual, and combinational effects. *Educational Communication and Technology Journal, 32,* 207–216.

Bender, B. G., & Levin, J. R. (1978). Pictures, imagery, and retarded children's prose learning. *Journal of Educational Psychology, 70,* 583–588.

Bernard, R. M., Petersen, C. H., & Ally, M. (1981). Can images provide contextual support for prose? *Educational Communication and Technology Journal, 29,* 101–108.

Bieger, G. R., & Glock, M. D. (1984). Comprehending spatial and contextual information in picture-text instructions. *Journal of Experimental Education,* 181–188.

Bluth, L. F. (1973). A comparison of the reading comprehension of good and poor readers in the second grade with and without illustration (Doctoral dissertation, University of Illinois at Urbana-Champaign, 1972). *Dissertations Abstracts International, 34,* 637A.

Borges, M. A., & Robins, S. L. (1980). Contextual and motivational cue effects on the comprehension and recall of prose. *Psychological Reports, 47,* 263–268.

Bransford, J. D., & Johnson, M. K. (1972). Contextual prerequisites for understanding: Some investigations of comprehension and recall. *Journal of Verbal Learning and Verbal Behavior, 11,* 717–726.

Covey, R. E., & Carroll, J. L. (1985, October). *Effects of adjunct pictures on comprehension of grade six science texts under three levels of text organization*. Paper presented at the annual meeting of the Evaluation Network/Evaluation Research Society, San Francisco, CA. (ERIC Document Reproduction Service No. 259-946)

Dean, R. S., & Enemoh, P. A. (1983). Pictorial organization in prose learning. *Contemporary Educational Psychology, 8,* 20–27.

DeRose, T. (1976). *The effects of verbally and pictorially induced and imposed strategies on children's memory for text*. Madison: Wisconsin Research and Development Center for Cognitive Learning, University of Wisconsin. (ERIC Document Reproduction Service No. 133–709).

Digdon, N., Pressley, M., & Levin, J. R. (1985). Preschoolers' learning when pictures do not tell the whole story. *Educational Communication and Technology Journal, 33,* 139–145.

Duchastel, P. C. (1980). Test of the role in retention of illustrations in text. *Psychological Reports, 47,* 204–206.

Duchastel, P. C. (1981). Illustrations in text: A retentional role. *Programmed Learning and Educational Technology, 18,* 11–15.

Durso, F. T., & Johnson, M. K. (1980). The effects of orienting tasks on recognition, recall, and modality confusion of pictures and words. *Journal of Verbal Learning and Verbal Behavior, 19,* 416–429.

Gibbons, J., et al. (1986). Young children's recall and reconstruction of audio and audiovisual narratives. *Child Development, 57*(4), 1014–1023.

Goldberg, F. (1974). Effects of imagery on learning incidental material in the classroom. *Journal of Educational Psychology, 66,* 233–237.

Goldston, D. B., & Richman, C. L. (1985). Imagery, encoding, specificity, and prose recall in 6-year-old children. *Journal of Experimental Child Psychology, 40,* 395–405.

Guttmann, J., Levin, J. R., & Pressley, M. (1977). Pictures, partial pictures, and young children's oral prose learning. *Journal of Educational Psychology, 69,* 473–480.

Hannafin, M. J. (1988). The effects of instructional explicitness on learning and error persistence. *Contemporary Educational Psychology, 13,* 126–132.

Haring, M. J., & Fry, M. A. (1979). Effect of pictures on children's comprehension of written text. *Educational Communication and Technology Journal, 27,* 185–190.

Hayes, D. A., & Henk, W. A. (1986). Understanding and remembering complex prose augmented by analogic and pictorial illustration. *Journal of Reading Behavior, 18*(1), 63–77.

Hayes, D. A., & Readance, J. E. (1983). Transfer of learning from illustration-dependent text. *Journal of Educational Research, 76,* 245–248.

Hayes, D. A., & Readence, J. E. (1982). Effects of cued attention to illustrations in text. In G. A. Niles & L. A. Harris (Eds.), *New inquiries in reading research and instruction* (pp. 60–63). *Thirty-first year book of the National Reading Conference*. Rochester NY: National Reading Conference.

Holliday, W. G. (1975). The effects of verbal and adjunct pictorial-verbal information in science instruction. *Journal of Research in Science Teaching, 12,* 77–83.

Holliday, W. G., & Harvey, D. A. (1976). Adjunct labeled drawings in teaching physics to junior high school students. *Journal of Research in Science Teaching, 13,* 37–43.

Holmes, B. C. (1987). Children's inferences with print and pictures. *Journal of Educational Psychology, 79*(1), 14–18.

Jagodzinska, M. (1976). The role of illustrations in verbal learning. *Polish Psychological Bulletin, 7,* 95–104.

Jahoda, G., Cheyne, W. M., Deregowski, J. B., Sinha, D., & Collingsbourne, R. (1976). Utilization of pictorial information in classroom learning: A cross cultural study. *AV Communication Review, 24,* 295–315.

Jonassen, D. H. (1979). Implications of multi-image for concept acqusition. *Educational Communication and Technology Journal, 27*(4), 291–302.

Koenke, K., & Otto, W. (1969). Contribution of pictures to children's comprehension of the main idea in reading. *Psychology in the Schools, 6,* 298–302.

Koran, M. L., & Koran, J. J. J. (1980). Interaction of learner characteristics with pictorial adjuncts in learning from science text. *Journal of Research in Science Teaching, 17*(5), 477–483.

Lesgold, A. M., DeGood, & Levin, J. R. (1977). Pictures and young children's prose learning: A supplementary report. *Journal of Reading Behavior, 9,* 353–360.

Lesgold, A. M., Levin, J. R., Shimron, J., & Guttmann, J. (1975). Pictures and young children's learning from oral prose. *Journal of Educational Psychology, 67,* 636–642.

Levin, J. R. (1976). What have we learned about maximizing what children learn? In J. R. L. & & V. L. Allen (Eds.), *Cognitive learning in* *children: Theories and strategies.* (pp. 105–134). New York: Academic Press.

Levin, J. R., & Berry, J. K. (1980). Children's learning of all the news that's fit to picture. *Educational Communication and Technology Journal, 28,* 177–185.

Levin, J. R., McCormick, C. B., Miller, G. E., Berry, J. K., & Pressley, M. (1982). Mnemonic versus nonmnemonic vocabulary-learning strategies for children. *American Educational Research Journal, 19,* 121–136.

Levin, J. R., Morrison, C. R., McGivern, J. E., Mastropieri, M. S., & Scruggs, T. E. (1986). Mnemonic facilitation of text-embedded science facts. *American Educational Research Journal, 23,* 489–506.

Levin, J. R., et al. (1983). Learning via mnemonic pictures: Analysis of presidential process. *Educational Communication and Technology Journal, 31*(3), 161–173.

Levin, J. R., Shriberg, L. K., & Berry, J. K. (1983). A concrete strategy for remembering abstract prose. *American Educational Research Journal, 20*(2), 277–290.

Magne, O., & Parknas, L. (1962). The learning effects of pictures. *British Journal of Educational Psychology, 33,* 265–275.

Main, R. E., & Griffiths, B. (1977). Evaluation of audio and pictorial instructional supplements. *AV Communication Review, 25*(2), 167–179.

Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology, 81*(2), 240–246.

McCormick, C. B., & Levin, J. R. (1984). A comparison of different prose-learning variations of the mnemoic keyword method. *American Education Research Journal, 21,* 379–398.

McCormick, C. B., Levin, J. R., Cykowski, F., & Danilovics, P. (1984). Mnemonic-strategy reduction of prose-learning interference. *Educational Communication and Technology Journal, 32,* 154–152.

Miller, W. A. (1938). Reading with and without pictures. *Elementary School Journal, 38,* 676–682.

Moore, A. M. (1975). Investigation of the effect of patterns of illustrations on third graders' comprehension of information (Doctoral dissertation, Kent State University, 1974). *Dissertation Abstracts International, 36,* 1275A.

Nugent, G. C. (1982). Pictures, audio, and print: Symbolic representation and effect on learning. *Educational Communications and Technology Journal, 30*(3), 163–174.

O'Keefe, E. J., & Solman, R. T. (1987). The influence of illustrations on children's comprehension of written stories. *Journal of Reading Behavior, 19*(4), 353–377.

Peeck, J. (1974). Retention of pictorial and verbal content of a text with illustrations. *Journal of Educational Psychology, 66,* 880–888.

Peng, C. Y., & Levin, J. R. (1979). Pictures and children's story recall: Some questions of durability. *Educational Communication and Technology Journal, 27,* 179–192.

Popham, W. J. (1969). Pictorial embellishments in a tape-slide instructional program. *AV Communication Review, 17*(1), 28–35.

Pressley, M., Levin, J. R., Pigott, S., LeComte, M., & Hope, D. J. (1983). Mismatched pictures and children's prose learning. *Educational Communication and Technology Journal, 31,* 131–143.

Pressley, M., Pigott, S., & Bryant, S. L. (1982). Picture content and preschoolers' learning from sentences. *Educational Communication and Technology Journal, 30,* 151–161.

Rankin, E. F., & Culhane, J. W. (1970). One picture equals 1,000 words? *Reading Improvement, 7,* 37–40.

Rasco, R. W., Tennyson, R. D., & Boutwell, R. C. (1975). Imagery instructions and drawings in learning prose. *Journal of Educational Psychology, 67,* 188–192.

Reid, D. J., Briggs, N., & Beveridge, M. (1983). The effect of pictures upon the readability of a school science topic. *British Journal of Educational Psychology, 53,* 327–335.

Rice, D. R., Doan, R. L., & Brown, S. J. (1981). The effects of pictures on reading comprehension, speed and interest of second grade students. *Reading Improvement, 18,* 308–312.

Riding, R. J., & Shore, J. M. (1974). A comparison of two methods of improving prose comprehension in educationally subnormal children. *British Journal of Educational Psychology, 44,* 300–303.

Rohwer, W. D., & Matz, R. D. (1975). Improving aural comprehension in white and in black children. *Journal of Experimental Child Psychology, 19,* 23–36.

Rohwer, W. D. J., & Harris, W. J. (1975). Media effects of prose learning in two populations of children. *Journal of Educational Psychology, 67,* 651–657.

Royer, J. M., & Cable, G. W. (1976). Illustrations, analogies, and facilitative transfer in prose learning. *Journal of Educational Psychology, 68,* 205–209.

Ruch, M. D., & Levin, J. R. (1977). Pictorial organization versus verbal repetition of children's prose: Evidence for processing differences. *AV Communication Review, 25,* 269–280.

Ruch, M. D., & Levin, J. R. (1979). Partial pictures as imagery-retrieval cues in young children's prose recall. *Journal of Experimental Child Psychology, 28,* 268–279.

Rusted, J., & Coltheart, M. (1979a). Facilitation of children's prose recall by the presence of pictures. *Memory and Cognition, 7*(5), 354–359.

Rusted, J., & Coltheart, V. (1979b). The effect of pictures on the retention of novel words and prose passages. *Journal of Experimental Child Psychology, 28,* 516–524.

Rusted, J., & Hodgson, S. (1985). Evaluating the picture facilitation effect in children's recall of written texts. *British Journal of Educational Psychology, 55*(3), 288–294.

Scruggs, T. E., Mastropieri, M. A., Levin, J. R., & Gaffney, J. S. (1985). Facilitating the acquisition of science facts in learning disabled students. *American Educational Research Journal, 22,* 575–586.

Sewell, E. H., & Moore, R. L. (1980). Cartoon embellishments in informative presentations. *Educational Communication and Technology Journal, 28,* 39–46.

Sherman, J. L. (1976). Contextual information and prose comprehension. *Journal of Reading Behavior, 8,* 369–379.

Shriberg, L. K., Levin, J. R., McCormick, C. B., & Pressley, M. (1982). Learning about "famous" people via the keyword method. *Journal of Educational Pscyhology, 74,* 238–247.

Silvern, S. B. (1980). Play, pictures, and repetition: Mediators in aural prose learning. *Educational Communication and Technology Journal, 28,* 134–139.

Snowman, J., & Cunningham, D. J. (1975). A comparison of pictorial and written adjunct aids in learning from text. *Journal of Educational Psychology, 67,* 307–311.

Stone, D. E., & Glock, M. D. (1981). How do young adults read directions with and without pictures? *Journal of Educational Psychology, 73,* 419–426.

Stromnes, F. J., & Nyman, J. (1974). Immediate and long-term retention of connected concrete discourse as a function of mnemonic picture-type sequence and context. *Scandinavian Journal of Psychology, 15,* 197–202.

Talley, J. E. (1989). The effect of pictures and story text structure on recall and comprehension. (Doctoral dissertation, Auburn University, 1988). *Dissertation Abstracts International, 49,* 2604A.

Thomas, J. L. (1978). The influence of pictorial illustrations with written text and previous achievement on the reading comprehension of fourth grade science students. *Journal of Research in Science Teaching, 15,* 401–405.

Towers, R. L. (1994). *The effects of animated graphics and static graphics on student learning in a computer-based instructional format*. Doctoral dissertation, University of Kentucky.

Vernon, M. D. (1953). The value of pictorial illustration. *British Journal of Educational Psychology, 23,* 180–187.

Vernon, M. D. (1954). The instruction of children by pictorial illustration. *British Journal of Educational Psychology, 24,* 171–179.

Vye, N. J., Bransford, J. D., Symons, S. E., & Acton, H. (1986, April). *Constraints on elaborations in visual domains*. Paper presented at the meeting of the American Educational Research Association, San Francisco.

Waddill, M. A., & McDaniel, M. A. (1988). Illustrations as adjuncts to prose: A text-appropriate processing approach. *Journal of Educational Psychology, 80*(4), 457–464.

Weintraub, S. (1960). The effect of pictures on the comprehension of a second grade basal reader (Doctoral dissertation, University of Illinois, 1960). *Dissertation Abstracts International, 21,* 1428.

Weisberg, J. S. (1970). The use of visual advance organizers for learning earth science concepts. *Journal of Research in Science Teaching, 7,* 161–165.

Woolridge, P., Nall, L., Hughes, L., Rauch, T., Stewart, G., & Richman, C. L. (1982). Prose recall in first-grade children using imagery, pictures, and questions. *Bulletin of the Psychonomic Society, 20,* 249–252.

APPENDIX 33.5 (pp. 898–912)

APPENDIX 33.6. STUDIES LISTED IN THE MATRIX FOR DYNAMIC VISUALS (SEE APPENDIX 33.5)

Al-Mulla, A. (1995). The influence of computer animation on learning (Doctoral dissertation, University of Kansas, 1995). *Dissertation Abstracts International, 57,* 0993A.

Alesandrini, K. L., & Rigney, J. (1981). Pictorial representation and review strategies in science learning. *Journal of Research in Science Teaching 1*(5), 465–474.

Atlas, R., Cornett, L., Lane, D. M., & Napier, A. (1977). The use of animation in software training: Pitfalls and benefits. In M. A. Quinones & A. Ehrenstein (Eds.), *Training for a Rapidly Changing Workplace* (pp. 281–302). Washington DC: American Psychological Association.

Avons, S. E., Beveridge, M. C., Hickman, A. T., & Hitch, G. J. (1983). Teaching journey graph with microcomputer animation. *Human Learning, 2,* 93–105.

Baek, Y. K., & Layne, B. H. (1988). Color, graphics, and animation in a computer-assisted learning tutorial lesson. *Journal of Computer-Based Instruction, 15*(4), 131–135.

Beichner, R. (1990). The effects of simultaneous motion presentation and graph generation in a kinematics lab. *Journal of Research in Science Teaching, 27*(8), 803–815.

Blake, T. (1977). Motion in instructional media: Some subject-display mode interactions. *Perceptual and Motor Skills, 44,* 975–985.

Brasell, H. (1987). The effects of real-time laboratory graphing on learning graphic representations of distance and velocity. *Journal of Research in Science Teaching, 24*(4), 385–395.

Caputo, D. J. (1982). An analysis of relative effectiveness of a graphic-enhanced microcomputer-based remedial system in a university basic mathematical skills deficiency removal plan. (Doctoral dissertation, University of Pittsburgh, 1981.) *Dissertation Abstracts International, 42,* 3482A.

Caraballo, J. N. (1985). The effect of various visual display modes in computer-based instruction and language background upon achievement of selected educational objectives (Doctoral dissertation, Pennsylvania State University, 1985). *Dissertation Abstracts International, 46*(6), 1494A.

Caraballo-Rios, A. (1985). An experimental study to investigate the effects of computer animation on the understanding and retention of selected levels of learning outcomes (Doctoral dissertation, Pennsylvania State University, 1985). *Dissertation Abstracts International, 46,* 1494A.

ChanLin, L. (1996). Enhancing computer graphics through metaphorical elaboration. *Journal of Instructional Psychology, 23*(3), 196.

ChanLin, L. (1998). Animation to teach students of different knowledge levels. *Journal of Instructional Psychology, 25*(3), 166.

ChanLin, L. (1999). Visual treatment for different prior knowledge. *International Journal of Instructional Media, 26*(2), 213–220.

ChanLin, L. (2000). Attributes of animation for learning scientific knowledge. *Journal of Instructional Psychology, 24*(4), 228–238.

Chien, S. C. (1986). The effectiveness of animated and interactive microcomputer graphics on children's development of spatial visualization ability/mental rotation skills (Doctoral dissertation, Ohio State University, 1986). *Dissertation Abstracts International, 46,* 1494A.

Collins, A., Adams, M. J., & Pew, R. W. (1978). Effectiveness of an interactive map display in tutoring geography. *Journal of Educational Psychology, 70*(1), 1–7.

Dwyer, F. (1969). The instructional effect of motion in varied visual illustrations. *Journal of Psychology, 73,* 167–172.

Dyck, J., L. (1995). Problem solving by Macintosh users: The effects of animated, self-paced written, and no instruction. *Educational Computing Research, 12*(1), 29–49.

Hativa, N., & Reingold, A. (1987). Effects of audiovisual stimuli on learning through microcomputer-based class presentation. *Instructional Science, 16,* 287–306.

Hays, T. A. (1996). Spatial abilities and the effects of computer animation on short-term and long-term comprehension. *Educational Computing Research, 14*(2), 139–155.

Houston, J. M., Joiner, C. L., Uddo, F., Harper, C., & Stroll, A. (1995). Computer animation in mock juries' decision making. *Psychological Reports, 76,* 987–993.

Johnson, N. C. (1985). Using a microcomputer to teach a statistical concept (Doctoral dissertation, University of Minnesota, 1986). *Dissertation Abstracts International, 47,* 455A.

Kann, C., Lindeman, R. W., & Heller, R. (1977). Integrating algorithm animation into a learning environment. *Computers Education, 28*(4), 223–228.

King, W. A. (1975). *A comparison of three combinations of text and graphics for concept learning.* Navy Personnel Research and Development Center, Report No. NPRDC-TR-76-16, San Diego, CA. (ERIC Document Reproduction Service No. ED 112936)

Kini, A. S. (1994). *Effects of cognitive style and verbal and visual presentation mode on concept learning in CBI*. Paper presented at the meeting of the American Educational Research Association, New Orleans, LA.

Kinzer, C. K., Sherwood, R. D., & Loofbourrow, M. C. (1989). Simulation software vs expository text: A comparison of retention across two instructional tools. *Reading Research and Instruction, 28*(2), 41–49.

Klein, D. (1986). Conditions influencing the effectiveness of animated and non-animated displays in computer assisted instruction (Doctoral dissertation, University of Illinois at Urbana–Champaign, 1985). *Dissertation Abstracts International, 46,* 1878A.

Lai, S. (1998). The effects of visual display on analogies using computer-based learning. *International Journal of Instructional Media, 25*(2), 151–161.

Lai, S. (2000). Influence of audio-visual presentations on learning of abstract concepts. *International Journal of Instructional Media, 27*(2), 199–207.

Laner, S. (1954). The impact of visual aid displays showing a manipulative task. *Quarterly Journal of Experimental Psychology, 6,* 95–106.

Laner, S. (1955). Some factors influencing the effectiveness of an instructional film. *British Journal of Psychology, 46,* 280–294.

Large, A., Beheshti, J., Breuleux, A., & Reneud, A. (1995). Multimedia and comprehension: The relationship among text, animation, and captions. *Journal of the American Society for Information Science, 46*(5), 340–347.

Lumsdaine, A. A., Sultzer, R. L. & Kopstein, F. F. (1961). The effect of animation cues and repetition of examples on learning from an instructional film. In A. A. Lumsdaine (Ed.), *Student response in programmed instruction* (pp. 241–269). Washington, DC: National Research Council.

Mayer, R. E., & Anderson, R. B. (1991). Animation needs narration: an experimental test of a dual-coding hypothesis. *Journal of Educational Psychology, 83*(4), 484–90.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology, 84*(4), 444–452.

Mayer, R. E., Moreno, R., Boire, M., & Vagge, S. (1999). Maximizing constructivist learning from multimedia communications by minimizing cognitive load. *Journal of Educational Psychology, 81*(4), 638–643.

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*(2), 312–320.

Mayer, R. E., & Sims, V. K. (1994). For whom is a picture worth a thousand words? Extensions of dual-coding theory of multimedia learning. *Journal of Educational Psychology, 86*(3), 389–401.

Mayton, G. B. (1990). The effects of the animation of visuals on the learning of dynamic progresses through microcomputer-based instruction (Doctoral dissertation, Ohio State University, 1990). *Dissertation Abstracts International, 51,* 4097A.

McCloskey, M., & Kohl, D. (1983). Naive physics: The curvilinear impetus principle and its role in interactions with moving objects. *Journal of Experimental Psychology: Learning Memory and Cognition, 9*(1), 146–156.

Mccuistion, P. J. (1990). Static vs dynamic visuals in computer-assisted instruction. (Doctoral dissertation, Texas A&M University, 1989). *Dissertation Abstracts International, 42,* 4409A.

Moore, M. V., Nawrocki, L. H., & Simutis, Z. M. (1979). The instructional effectiveness of three levels of graphic displays for computer-assisted instruction. *Army Research Center, ARI-TP-359,* 2–14. (ERIC, ED No. 178 057)

Myers, K. N. (1990). An exploratory study of the effectiveness of computer graphics and simulations in a computer-student interactive environment in illustrating random sampling and the central limit theorem (Doctoral dissertation, Florida State University, 1990). *Dissertation Abstracts International, 51,* 441A.

Nicholls, C., & Merkel, S. (1996). The effect of computer animation on students' understanding of microbiology. *Journal of Research on Computing in Education, 28*(3), 359–372.

Palmiter, S., Elkerton, J., & Baggett, P. (1991). Animated demonstrations vs written instructions for learning procedural tasks: A preliminary investigation. *Instructional Journal of Man-Machine Studies, 34,* 687–701.

Palmiter, S., & Elkerton, J. (1993). Animated demonstrations for learning procedural computer-based tasks. *Human-Computer Interaction, 8,* 193–216.

Park, O. (1998). Visual displays and contextual presentations in computer-based instruction. *Educational Technology Research and Development, 46*(3), 37–50.

Park, O., & Gittelman, S. (1992). Selective use of animation and feedback in computer-based instruction. *Educational Technology Research and Development, 40*(4), 27–38.

Payne, S. J., Chesworth, L., & Hill, E. (1992). Animated demonstrations for exploratory learners. *Interacting with Computers, 4*(1), 3–22.

Peters, H. J., & Daiker, K. C. (1982). Graphics and animations as instructional tools: A case study. *Pipeline, 7*(1), 11–13.

Ponick, D. A. (1986). Animation used as a logical organizer in visualization for concept learning (Doctoral dissertation, University of Minnesota, 1986). *Dissertation Abstracts International, 47,* 3300A.

Ram, S. P., & Phua, K. K. (1997). The effectiveness of a computer-aided instruction courseware developed using interactive multimedia concepts for teaching phase III MD students. *Medical Teacher, 19*(1), 51–53.

Reed, S. K. (1985). Effects of computer graphics on improving estimates to algebra word problems. *Journal of Educational Psychology, 77*(3), 285–298.

Rieber, L. P., & Hannafin, M. J. (1988). Effects of textual and animated orienting activities and practice on learning from computer-based instruction. *Computers in Schools, 5*(1/2), 77–89.

Rieber, L. P. (1989). The effects of computer animated elaboration strategies and practice on factual and application learning in an elementary science lesson. *Journal of Educational Computing Research, 5*(4), 431–444.

Rieber, L. P. (1990). Using computer animated graphics in science instruction with children. *Journal of Educational Psychology, 82*(1), 135–140.

Rieber, L. P., Boyce, M. J., & Assad, C. (1990). The effects of computer animation on adult learning and retrieval tasks. *Journal of Computer-Based Instruction, 17*(2), 46–52.

Rieber, L. P. (1991a). Animation, incidental learning, and continuing motivation. *Journal of Educational Psychology, 83*(3), 318–328.

Rieber, L. P. (1991b). Effects of visual grouping strategies of computer-animated presentations on selective attention in science. *Educational Technology Research and Development, 39*(4), 5–15.

Rieber, L. P. (1996a). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research and Development, 44*(1), 5–22.

Rieber, L. P. (1996b). Animation as a distractor to learning. *International Journal of Instructional Media, 23*(1), 53–57.

Rieber, L. P., Smith, M., Al-gharry, S., Strickland, B., Chu, G., & Spahi, F. (1996). The role of meaning in interpreting graphical and textual feedback during a computer-based simulation. *Computers & Education, 27*(1), 45–58.

Rigney, J. W., & Lutz, K. A. (1976). Effects of graphic analogies of concepts in chemistry on learning and attitude. *Journal of Educational Psychology, 68*(3), 305–311.

Roshal, S. M. (1961). Film mediated learning with varying representations of the task: Viewing angle, portrayal of demonstration, motion, and student participation. In A. A. Lumsdaine (Ed.), *Student response in programmed instruction* (pp. 155–175). Washington, DC: National Research Council.

Sanger, M. J., & Greenbowe, T. J. (2000). Addressing student misconceptions concerning electron flow in aqueous solutions with instruction including computer animations and conceptual change strategies. *International Journal of Science Education, 22*(5), 521–537.

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TABLE 33.A5. Summary Matrix of Research Results for Dynamic Visuals

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Al-Mulla (1995)	1. Static visuals 2. Animated visuals	Aerodynamic, air-conditioner, & joystick	50 adults	Immediate and delayed posttests	SD for animation on aerodynamic intellectual skills delayed posttest, overall intellectual skills delayed posttest, and immediate and delayed joystick intellectual skills
Alesandrini & Rigney (1981)					
Expt 1	1. Pictorial lesson & pictorial review 2. Pictorial lesson & no review 3. Verbal lesson & pictorial review 4. Verbal lesson & no review	Function of a battery	96 adults	Pictorial test & verbal test	SD for animation on picture recognition NSD among groups for verbal test
Expt 2	1. Verbal lesson & pictorial review 2. Verbal lesson & verbal review		50 adults		
Atlas, Cornett, Lane, & Napier (1997)					
Expt 1	1. Text 2. Animation 3. Animation plus verbal information	Training in HyperCard authoring tasks	39 adults	Immediate test & 7 day delayed test	Mixed results: Animated group performed better on immediate test but worse on delayed test
Expt 2	1. Text 2. Animation plus verbal information	22 adults			Training in animation plus verbal information led to greater improvement on delayed test
Avons, Beveridge, Hickman, & Hitch (1983)					
Expt 1	1. Active vertical 2. Active horizontal 3. Passive vertical 4. Passive horizontal 5. Optimal condition	Relationship between speed and corresponding slopes of the graph in an animated simulation of a moving car	60 children, 9 to 11 years old 48 children, 10 to 11 years old	Posttest measuring comprehension, production, and conceptual understanding	In both experiments, NSD were found among the groups for conceptual, comprehension, and production tests. However, children performed better on comprehension and production tests
Expt 2	1. Vertical label (VL) 2. Vertical (V) 3. Horizontal (H) 4. Label only (L)				

Baek & Layne (1988)	1. Animated group (color) 2. Graphics group (color) 3. Text group (color) 4. Animated group (B/W) 5. Graphics group (B/W) 6. Text group (B/W)	Tutorial lessons about the mathematical rules for calculating speed	119 high-school children	Score on performance test and time to finish computer module	SD among the groups for both performance test and completion time. Animated groups performed better than graphics and text groups, and graphics groups performed better than text groups on performance test. For completion time, animated groups had the slowest time. Color had no effects on learning
Beichner (1990)	1. Videograph technique, viewed the real motion 2. Videograph technique, did not view the real motion 3. Traditional technique, viewed the real motion 4. Traditional technique, did not view the real motion	MBL experiments showing the physical events along with their graphical representations	237 mixed subjects (165 high-school students and 72 adults)	Score on pretest and posttest (understanding graphs)	NSD among groups
Blake (1977)	1. Still condition (only slides) 2. Arrow condition (slides plus cueing arrows) 3. Motion condition showing standard motion video	Learning the movement of chess pieces	84 adults	Score on test consisting of 32 diagrams of chessboard	Mixed result. SD found among groups for low-spatial ability students. The still condition performed worse than either one of the motion conditions, which did not differ from each other. NSD found among groups for high-spatial ability students
Brasell (1987)	1. Standard (real-time graphing) 2. Delayed (delayed-graphing) 3. Test only 4. Control (paper only)	Experiments for learning graphing skills	93 high-school students	Score on pretest and posttest (understanding graphs)	SD found among groups in favor of animation (real-time graphing).
Caputo (1982)	1. Dynamic graphic CAI 2. Verbal CAI 3. Checklist CAI	Upgrading certain basic mathematical skills	109 adults	Score on basic mathematical skills retake test. Also, course grade average for computer science	SD among groups
Caraballo (1985)	1. No instruction 2. Text only 3. Text plus still graphics 4. Text plus still graphics plus animated graphics	Learner's achievement and language background	80 adults	Four criterion tests (terminology, identification, drawing, and comprehension) and total scores	NSD
Caraballo-Rios (1985)	1. Text 2. Text plus still pictures 3. Text plus still pictures plus animation	Concepts and rules in geometry	72 adults	Immediate and delayed posttests on performance	NSD among groups

Continues

33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
ChanLin (1996)	1. Nongraphic w/ metaphors 2. Static graphics w/ metaphors 3. Animated graphics w/ metaphors 4. Animated graphics w/o metaphors 5. Static graphics w/o metaphors 6. Nongraphics w/o metaphors	CAI explaining concepts of biotechnology	120 college students	Criterion referenced test, Keller's IMMS (Instructional Materials Motivational Survey)	SD for student performance metaphorical elaboration w/ animation treatment. NSD for no metaphors w/graphic representation. SD for student motivational scores w/ metaphors & animated graphics
ChanLin (1998)	1. No graphics 2. Still graphics 3. Animated graphics	Biotechnology	135 adults	Tests of procedural and descriptive facts	Mixed results
ChanLin (1999)	1. Text (control group) 2. Still graphics 3. Animated graphics	Biotechnology	135 adults	Criterion referenced test	SD among groups for animation
ChanLin (2000)	1. Text 2. Graphics with text 3. Animation with text	Physics lesson	357 children	Descriptive test and procedural knowledge test	Mixed results
Chien (1986)	1. Hands-on simulations 2. Animated interactive graphics	Spatial visualization	72 children, 1st, 2nd, and 3rd graders	Posttest on performance	NSD among groups
Collins, Adams, & Pew (1978)	1. SCHOLAR map system (interactive) condition 2. A labeled map condition 3. An unlabeled map condition	Learning geography	9 high-school students and 9 adults	Score on pretest and posttest (number of correct responses)	SD among groups in favor of animation. Scores on posttest showed that the SCHOLAR condition performed significantly better than the labeled map condition, which in turn scored significantly better than the unlabeled map condition
Dwyer (1969)	1. Control group (G1), text-only group 2. Simple line representations (G2) 3. Detailed shaded drawings (G3) 4. Photographs of the heart model (G4) 5. Realistic heart photographs (G5)	Function of human heart	139 adults	A pretest, a drawing test, an identification test, a terminology test, and a total criterion test	SD among groups for drawing tests. G2 performed better than G1. SD among groups for terminology test. G2 performed significantly better than G1 SD among groups for total criterion test. G2 & G5 performed significantly better than G1. NSD among groups for identification and comprehension tests
Dyck (1995)	1. No instruction 2. Mouse/icon manual 3. File manipulation manual 4. Animated instruction (Mac tour)	Macintosh operating system	48 adults	Posttest measuring the task completion time and proportion of tasks completed with familiar and unfamiliar tasks	NSD among groups for either completion time or proportion of tasks completed

Hativa & Reingold (1987)	1. Stimulus group with sound, animation, and color 2. Nonstimulus without sound, animation, or color	Learning Euclidean geometry	92 9th graders	Immediate and delayed posttests measuring the aptitude for learning and understanding of geometry	SD found for both understanding and aptitude on both immediate and delayed posttests. The stimulus group performed better. Animation was helpful in gaining attention, creating positive attitude, and helping students understand the subjects
Hays (1996)	1. Text alone 2. Text and static visuals 3. Text plus animation	Concepts involving time and motion (diffusion)	131 6th, 7th, and 8th graders	Two tests: 1. Sentence verification technique (SVT) to measure short-term comprehension for spatial ability, and presentation mode 2. Concept evaluation statement (CES) to measure long-term comprehension for spatial ability and presentation mode	Short-term comprehension: SD among groups for SVT test. Animation helped low-spatial ability students. NSD among groups for mode of presentation. Long-term comprehension: SD for CES test. Animation helped both low- and high-spatial ability students to gain higher score on conceptual understanding. However, low-spatial ability students benefited the most
Houston, Joiner, Uddo, Harper, & Stroll (1995)	1. Reading out loud group, listening to the transcript of the voice recorder 2. Voice recorder's written transcript & audiotape group 3. Animated group listening to the cockpit's voice and flight recorder	Plane crash investigation	72 adults	A questionnaire for rating the blame on the crew for the crash A questionnaire to measure the subject s recall of information about the crash	SD among groups. Subjects in the animated group put less of the blame on the flight crew NSD found among groups for recall of information and retention
Kann, Lindeman, & Heller (1977)	1. N group (no animation) 2. V group (viewed animation of the algorithm) 3. C group (control group, wrote programs without any instruction) 4. VC group (subjects wrote programs after viewing the animation)	Knapsack algorithm	28 adults	Posttest measuring students' ability to recognize the type of program (declarative, procedural, analytical, and recursion) Quality of the written codes	SD among groups for recognizing the recursive-type programs. The animated group performed better on the posttest. The animated group also performed better on the posttest than the others for the procedural- and declarative-type problem SD among groups for writing programs. The animated group performed much better than the other groups.
King (1975)	1. Text and animation 2. Text & still graphics 3. Text only	Sine-ratio concepts	45 adults	Posttest measuring students' understanding of the sine-ratio concepts	NSD among groups. However, the mean score of the animated group was the highest on the posttest

Continues

33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Kini (1994)	1. Text only 2. Text plus animated graphics 3. Field independence–field dependence 4. Preferred perceptual mode (verbal–visual)	Concepts of velocity and acceleration in one-dimensional space	192 adults	Concept test	NSD among groups
Kinzer, Sherwood, & Loofbourrow (1989)	1. Computer animation 2. Text	Understanding the food chain	52 children, 5th graders	Posttest measuring students' understanding of the food chain	SD among groups in favor of the text group
Klein (1986)	1. Temporal animated, easy 2. Temporal animated, difficult 3. Temporal nonanimated, easy 4. Temporal nonanimated, difficult 5. Spatial animated, easy 6. Spatial animated, difficult 7. Spatial nonanimated, easy 8. Spatial nonanimated, difficult	Problem solving	38 adults	Time between presenting the problem and receiving answers from students	Mixed results
Lai (1998)	1. Text only 2. Text with static graphics 3. Animation	Learning computer-based programming language through analogies	78 children and adults	A multiple-choice test measuring the understanding of programming concepts and functions	SD among groups in favor of text with static graphics
Lai (2000)	1. Text with audio instruction 2. Treatment 1 plus static graphics 3. Treatment 1 plus animated graphics	Computer programming languages	169 adults	A multiple-choice test measuring concepts; an attitude questionnaire (Likert type)	SD among groups for animation NSD among groups for attitude
Laner (1954)	1. Students' film group 2. RAF film group 3. RAF film strip	Moving film showing the repair of a sash-cord window	75 adults	Individual tests of performance	NSD among groups. However, students who viewed the film performed better than both RAF groups
Laner (1955)	1. Film 2. Text and two static pictures	Moving films about the Bren-Gun trigger mechanism	50 adults	Individual performance test for drawing the mechanism, naming parts, and performing the assembly	NSD among groups for performance. This means that moving film did not have any effects on performance
Large, Beheshti, Breuleux, & Reneud (1995)	1. Text-only group 2. Text plus animation 3. Text plus animation plus captions 4. Captions plus animation	Multimedia learning. The procedural task of "how to find south"	71 6th graders	Individual test for recall of information and performance of the procedure	NSD among groups for recall of information SD among groups for performance The animated group and the caption groups performed better than the text-only group

Lumsdaine et al. (1961)	1. Animated group given the prefilm test 2. Animated group given film with 6 examples 1. Animated group given film with 3 examples 2. Animated group with supplemental sound 3. Nonanimated group with prefilm test 4. Nonanimated group given film with 6 examples 5. Nonanimated group given film with 3 examples 6. Nonanimated group with supplemental sound	Instrument reading skills	1,300 Air Force basic trainees	Ability to read the value of the micrometer settings	SD among groups. The animated prefilm test group performed significantly better than the animated group not given the prefilm test. Animated group also performed better in the replication trials
Mayer & Anderson (1991)					
Expt 1	1. Words with pictures 2. Words before pictures	Operation of a bicycle pump	30 adults	A problem-solving test (four essay questions)	SD among groups in favor of words with picture group
Expt 2b	1. Control 2. Words only 3. Pictures only 4. Words with pictures	Same as above	48 adults	A problem-solving test and a verbal recall test	SD among groups for problem solving NSD among groups for recall
Mayer & Anderson (1992)					
Expt 1	1. Concurrent group, 3 (A+N) 2. Successive group, 3 (AN, NA, A, N, N, A) 3. Animation-alone group 4. Narration-alone group 5. No instruction group (control group)	Operation of a bicycle pump	136 adults	A posttest measuring recall of information and number of solutions generated to fix the given problems	SD among groups for retention and problem solving in favor of the experimental groups. The concurrent group performed better than any other group on problem solving. All experimental groups performed better than the control group, but their performance did not differ from each other.
Expt 2	Same treatment as Expt 1	Operation of an automobile braking system	144 adults	Same as Expt1	SD among the experimental groups and the control group for problem solving. All experimental groups, except AAA group performed significantly better than the control group.

Continues

33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Mayer, Moreno, Boire, & Vagge (1999)					
Expt 1	1. Concurrent presentation 2. Small bites of narration before animation 3. Small bites of animation before narration 4. Large bites of narration before animation 5. Large bites of animation before narration	How lightening forms, and how automobile breaking system operates	60 adults	Retention test, matching test, and transfer test (open response and open-ended questions)	SD among groups for both experiments, except NSD found for the matching test in Expt 2.
Expt 2, replication of Expt 1					
Mayer & Moreno (1998)					
Expt 1	1. Concurrent animation plus narration (AN group) 2. Concurrent animation plus text (AT group)	Process of lighting formation	78 adults	A matching test, to measure students' ability to match each animation frame to a particular sentence that describes it, a retention test, and a transfer test, to assess students' ability to apply the learned knowledge to a new situation	SD among groups. In both experiments; the AN group outperformed the AT group in all tests.
Expt 2	1. Concurrent animation plus narration (AN group) 2. Concurrent animation plus text (AT group)	Operation of an automobile braking system	68 adults		
Mayer & Sims (1994)					
Expt 1	1. Concurrent group, 3(A+N), consisted of 10 HSA & 12 LSA 2. Successive group, 3 (AN,NA), consisted of 21 HAS and 22 LSA 3. Control group (no instruction), consisted of 7 HAS and 14 LSA	Operation of an automobile breaking system	86 adults	A posttest measuring the number of solutions generated for the given problem by high- and low-spatial ability students	SD among groups for the number of solutions generated for each problem. The performance of the concurrent group was significantly better than that of the successive or no instruction groups, which did not differ from each other. SD among the spatial ability groups for problem solving. The high-spatial ability students who viewed concurrent animation generated twice as many solutions as the high-spatial ability students who received successive animation.

Expt 2	1. Concurrent group, 3 (A+N) 2. Successive group, 3 (N,A) 3. Control group (no instruction)	Operation of human respiratory system	97 adults	Posttest measuring the number of solutions generated by the high- and low-spatial ability students	The results were almost similar to experiment #1. SD was found for problem solving. The presentation of animation and narration generated 50% more solutions to the given problems.
Mayton (1990)	1. Static graphics 2. Static graphics with some imagery cues 3 Animated graphics & imagery cues	Functions of the human heart	72 adults	Five tests. T1 & T2 to identify the heart parts in both free and cued recall. T3 to identify parts of the human heart. T4 & T5 to measure the understanding of the heart's functions, with cued and free recall.	SD found among groups. Animated group outperformed the other groups
McCloskey & Kohl (1983)					
Expt 1	1. Computer animation 2. Computer animation showing the possible trajectories 3 Visual graphics with no motion	Perceiving trajectories in the ball-and-string problem	90 adults	Finding the correct trajectory for the ball	NSD found among the groups in each experiment
Expt 2	1. The no-motion group (chose the correct path without viewing animation 2. The trajectory group (Viewed an animation, then picked the correct path from the given six alternatives)		72 adults		
Expt 3	1. Same instructions for all on the task		50 adults		
Mccuistion (1990)	1. Static visual 2. Dynamic visual	Spatial abilities	137 adults	A performance test and a mental rotation test	NSD among groups
Moore, Nawrocki, & Simutis (1979)	1. Low-level graphic group, consisted of alphanumerics and schematics 2. Medium-level graphic group, consisted of line drawing 3. High-level graphic group, consisted of line drawing and animation	How the inner ear works	90 adults	Five tests were used: one test to measure the completion time of the lesson; other content tests used to measure terminology, facts, identification, and principles	NSD among groups for completion time NSD among groups for the other four tests
Myers (1990)	1. Traditional lecture 2. Interactive method	Learning statistical concepts	52 adults	A concept test and an application test	SD among groups for concept test NSD among the groups for application test

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33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Nicholls & Merkel (1996)	1. Animated tutorial 2. Text with still diagram	Nitrogen cycle	44 adults	10 multiple-choice questions and six short-answer questions	NSD among groups
Palmiter, Elkerton, and Baggett (1991)	1. Animated demonstration group 2. Written-text group	Performing authoring tasks in HyperCard on the Macintosh	28 adults	Immediate and delayed posttests on different, identical, and similar tasks measuring initial acquisition, retention, and transfer	NSD among groups. There was a trade-off between training performance and later speed and transfer. The animated group was 50% faster in the training session than the text group, but their performance was worse on both immediate and delayed posttest.
Palmiter & Elkerton (1993)	1. Text-only group 2. Animated demo-only group 3. Text plus animated demo group	Performing HyperCard tasks	48 adults	Immediate and delayed tests (7 days) measuring acquisition, retention, and transfer of HyperCard tasks	NSD among groups. The demo groups were faster and more accurate than the text group during the training session but became slower during the test sessions. There were NSD between the demo group and the demo plus text group.
Park (1998)	1. Animation 2. Static graphics w/ motion cues. 3. Static graphic w/o motion cues	Electronic circuits and troubleshooting procedures	96 adults	Test of performance and test of transfer (troubleshooting)	SD among groups for animated groups
Park & Gittelman (1992)	1. Animation with natural feedback 2. Animation with knowledge of results feedback 3. Animation with explanatory feedback 4. Static visuals with natural feedback 5. Static visuals with knowledge of results feedback 6. Static visuals with explanatory feedback	Problem solving, teaching electronics troubleshooting	90 adults	A test measuring number of trials attempted to fix the faulty circuits and time spent on the faulty circuit during practice and test sessions	SD among groups for number of trials and in favor of animation NSD among groups for time spent on circuit and feedback type
Payne, Chesworth, & Hill (1992)					
Expt 1	1. No instruction group 2. Cards-only instructions 3. Video-only instructions 4. Card and video instructions	Performing tasks on the MacDraw software package Understanding and performing different tasks in MacDraw	32 adults	Amount of time spent to complete all six tasks	SD among groups in favor of animation. The animated groups performed all tasks in 38 min less than the text group SD among groups in favor of animation for understanding and performance. The animated group finished all four tasks 15 min faster than the control group

Expt 2	1. Video (animated) group 2. Control (no instruction) group		16 adults	Amount of time spent to perform all four tasks	
Peters & Daiker (1982)	1. Animation-only group 2. Interaction-only group 3. Animation plus interaction group 4. Control group; played an unrelated game	Understanding organic chemistry	35 adults	Score on the posttest	NSD among groups
Ponick (1986)	1. Random selection with sequential presentation 2. Random selection with simultaneous presentation 3. Guided selection with sequential presentations 4. Guided selection with simultaneous presentation)	Concept learning in mathematical curve sketching	71 adults	Identifying the function that represented the given graph, from the set of six alternatives	SD among the animated group and static visual groups. Subjects assigned to animated treatment (No. 4) performed significantly better on learning concepts related to mathematical functions than subjects assigned to static graphics treatments
Ram & Phua (1997)	1. Conventional lecture 2. Animation courseware	Review of congenital heart disease.	64 adults	10 multiple-choice questions	SD among groups in favor of animation
Reed (1985)	1. Experimental group, viewing simulations with regard to speed estimation, filling tank estimation, and mixture estimation 2. Control group, receiving unrelated information	Teaching algebra word problems related to: 1. Speed simulation 2. Tank filling 3. Mixing of different concentrations	180 adults	Net gain in students estimate of the problem from the prequestionnaire to the posttest questionnaire	Mixed results were reported. Watching simulation (animation) was useful when feedback was provided (learning by doing). However, in most cases viewing alone (learning by seeing) was not enough. This means that graphics displays alone did not produce an increase in instructional effectiveness.
Rieber & Hannafin (1988)	1. Text group with practice 2. Text group without practice 3. Animation group with practice 4. Animation group without practice 5. Text plus animation group with practice 6. Text plus animation group without practice 7. No-activity group with practice 8. No-activity group without practice	Rule using and problem solving, Newton's laws of motion	111 4th, 5th, and 6th graders	A 24-item posttest measuring rule using and problem solving	NSD among groups for orienting activities. No main effect was found for practice. A significant interaction was found between practice and learning outcomes. These results suggests that "orienting activities whether text-based or animated do not exert influence on learning" (p. 85)

Continues

33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Rieber (1989)	1. Static graphics 2. Static graphics without relevant practice 3. Static graphics without text 4. Static graphics 5. Animated graphics with relevant practice 6. Animated graphics without relevant practice 7. Animated graphics without text 8. Animated graphics with text 9. No graphics with relevant practice 10. No graphics 11. No graphics without text 12. No graphics	Newton's laws of motion	192 4th, 5th and 6th graders	A posttest measuring learning outcomes and transfer	NSD among groups for learning outcomes. This means no animation effects.
Rieber (1990)	1. Static graphics with behavioral practice 2. Static graphics with cognitive practice 3. Static graphics with no practice 4. Animated graphics with behavioral practice 5. Animated graphics with cognitive practice 6. Animated graphics with no practice	Newton's laws of motion	119 4th and 5th graders	A posttest measuring six learning objectives (p. 137)	SD among groups for visual elaboration. Significant interaction between visual elaboration and practice. Students in the cognitive group scored higher than the other groups on the posttest. SD among groups for learning objectives in favor of animation
Rieber, Boyce, & Assad (1990)	This is the replication of the 1990b study using adult subjects.	Newton's laws of motion	141 adults	A posttest measuring six learning objectives (p. 48)	NSD among groups for visual elaboration Significant interaction between visual elaboration and practice. The practice had more effects on learning than the strategy. The animated group outperformed the other groups when there was no feedback. SD among groups for learning objectives and response latency in favor of animation
Rieber (1991a)	1. Animation with questions/simulations. 2. Animation with simulation/questions 3. Static graphics with questions/simulations	Newton's laws of motion	70 children, 4th graders	A 24-item posttest (immediate and 2 days delayed) measuring both types of rule learning: intentional and incidental	SD among groups for incidental learning in both immediate and delayed posttest in favor of animation SD among groups for intentional learning in favor of animation

	4. Static graphics with simulations/questions				SD among groups for time latency. The animated groups took significantly less time to answer the incidental questions. This was not the case for intentional learning.
Rieber (1991b)	1. Grouped animation (chunked) 2. Ungrouped animation (no chunking) 3. Grouped static graphics (chunked) 4. Ungrouped static graphics (no chunking)	Newton's laws of motion	39 children, 4th graders	A 24-item posttest measuring incidental and intentional learning	SD among groups in favor of animation. The chunked group scored significantly better on the posttest than the static groups. NSD between the ungrouped animated condition and any of the other three groups. SD among groups on incidental learning in favor of animation NSD among groups for intentional learning
Rieber (1996a) Expt 1	1. Animated feedback group 2. Textual feedback group 3. Textual plus animated feedback	Learning the relationship between speed & velocity of a ball	40 adults	A 12-item pretest and posttest to measure score (time/s), interactivity (No. of hits on keys), and frustration level	NSD among simulation versions for the performance test. SD for the game score. The animated feedback group had a lower score SD among simulation versions for interactivity. The animated feedback version had a lower interactivity level (understood the relationship between speed and velocity). NSD found among the simulation versions for the level of frustrations.
Expt 2	This is the replication of Expt 1. The only changes are the amount of practice and the number of subjects.		49 adults		SD among simulation versions. The animated feedback and animated feedback plus text groups performed significantly better than the textual group. SD among the simulation groups for score and interactivity. The animated feedback version had the lowest time and number of hits. SD found for frustration level in favor of the animated groups.
Rieber (1996b)	1. High-distraction condition (spaceship moved from L to R) 2. Medium-distraction condition (spaceship moved at top of page) 3. No-distraction condition (no spaceship)	Newton's laws of motion	364 5th graders	A posttest measuring performance and processing time (time needed by each student to process each instructional frame)	NSD among groups for performance test. The distracter did not affect students' performance on the posttest. SD among groups for processing time. The high- and medium-distraction groups paid attention to the distracters and took less time to view the instructional frames.

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33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Rieber et al. (1996)	1. Meaningful context group 2. Arbitrary context group	Understanding Newton's laws of motion through simulated games (miniature golf)	41 adults	A pretest and posttest measured students' performance; game score, interactivity, and frustration level also measured	NSD among groups for performance. NSD among groups for interactivity. However, subjects did better with animated feedback. NSD among groups for frustration level. SD among groups for score in favor of animation.
Rigney & Lutz (1976)	1. Verbal treatment group (verbal only) 2. Imagery group (verbal information plus animation)	Learning the concept of a simple battery	40 adults	One recognition (memory) test and three recall tests (knowledge, comprehension, and application)	SD among groups for recall and attitude in favor of animated group. NSD among groups for recognition test. However, the animated group performed better on the recognition test.
Roshal (1949)	1. Group 1 2. Group 2 3. Group 3 4. Group 4 5. Group 5 6. Group 6 7. Group 7 8. Group 8	Tying three types of knots	3314 adults (Navy recruit trainees)	Performing the task correctly (tying the knots)	SD among groups in favor of motion. Portraying continuous changes through movement was an effective learning strategy.
Sanger & Greenbowe (2000)	1. Animation 2. Conceptual change instruction	Chemical processes	135 adults	Eight multiple-choice questions and one essay	NSD among groups
Spangenberg (1973)					
Expt 1	1. Animated video group 2. Still-Sequence group	Learning the disassembly procedure for an M-85 machine gun	40 adults (Army soldiers)	Individual performance test	SD among groups. The percentage of subjects who correctly disassembled the procedure was 59% for the video group and 25% for the still-sequence group.
Expt 2	1. Animated video group 2. Animated video group plus cueing arrows 3. Still-sequence group 4. Still-sequence group plus cueing arrows		80 adults (enlisted soldiers)		SD among groups. The percentage of subjects who correctly disassembled the procedure was 43% for the video groups and 15% for the still-sequence groups.
Spangler (1994)	1. Traditional instruction 2. Animation with color 3. Animation without color 4. Static pictures with color 5. Static pictures without color	Depicting 2D and 3D objects	57 adults	A 2D & 3D test; mental rotation test	NSD among groups
Spotts & Dwyer (1996)	1. Text plus static graphics 2. Text plus animation 3. Text plus animation plus simulation	Learning parts and functions of human heart	63 adults	Four criterion tests: drawing, identification, terminology, and comprehension tests	SD among groups for drawing test in favor of the animation plus text group SD among groups for total criterion test (combination of the four criterion tests). The animation plus text group outperformed the simulation group. The addition of simulated blood flow did not affect learning.

Swezey, Prez, & Allen (1991)	1. Procedural group: (a) video presentation, (b) slide presentation 2. Generic system structure and function group: (a) video presentation, (b) slide presentation 3. Integrated group: combination of the above	Troubleshooting electromechanical systems in a diesel engine	120 adults	Four tests: a criterion-based reference task, a hands-on transfer task, an abstract transfer task, and a conceptual knowledge task	NSD among subjects who received static versus dynamic presentations of the training materials, regardless of the instructional strategy conditions employed
Szabo & Poohkay (1996)	1. Text only 2. Text plus static graphics 3. Text plus animated graphics	Construction of a triangle using a compass	173 adults	Construction problem test and Likert-type attitude test	NSD among groups
Thompson & Riding (1990)	1. No computerized illustration group 2. Pythagorean program with illustrations 3. Pythagorean program with computerized animation (experimental group)	Learning Pythogoras' theorem through mathematical demonstrations	108 children, 11 to 14 years old	Two tests given to measure students' understanding of the rotations and shears	SD among groups in favor of animation. The mean score of the animated group was significantly higher than the mean scores of the other two groups.
Todorov, Shadmehr, & Bizzi (1997)					
Expt 1	1. Viewed real performance plus verbal coaching 2. Viewed simulated performance and animated paddle (pilot group) 3. Viewed simulated performance showing animated paddle and ball (training group)	Learning difficult motor skills (hitting a ping-pong ball)	42 adults	Number of times to hit the target for two sets of 50-ball trials	Significant interaction reported. The performance of the pilot group was similar to that of the control group for the first 50 trials and worse for the second 50 trials. SD among groups in the second trial. The simulated training group performed significantly better than the other groups. SD for performance. The training group that practiced in the simulator performed better than the control group that practiced on the task in the real environment.
Expt 2	1. Control group (real practice) 2. Training group (simulating practice)		21 adults		
Towers (1994)					
Expt 1	1. Text only 2. Text plus static visuals 3. Text plus animated visuals	Prediction of weather pattern	49 adults	A 10-item recall test	SD among groups in favor of text

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33.A5. (Continued)

Study	Treatment	Content	Subjects	Dependent Variable (s)	Results
Expt 2	1. Text only 2. Text plus static visuals 3. Text plus animated visuals		64 adults	An immediate test and a 14-day-delayed test on recall and comprehension of information	NSD among groups
Vaez (2000)	1. Pure animation 2. Animation plus textual narration 3. Animation plus verbal narration	Operation of an internal combustion engine	60 adults	Immediate and delayed tests consisting of a 33-item retention test, an 11-item matching test, and a 7-item transfer test	SD among groups for treatment NSD among groups for exposure time to animation. NSD among groups for sequence of viewing
Westendorp (1996)	1. Text plus spatial information 2. Text only 3. Picture w/ spatial information only 4. Picture only 5. Animation with / spatial information 6. Animation only	Setting up a telephone system	Not given	Time spent reading instructions; time spent performing 13 tasks immediately after instruction and 1 week later	SD among groups for immediate test. In the delayed test NSD among groups for performance
Williams & Abraham (1995)					
Unit 5	1. Static visuals (control group) 2. Animation in lectures 3. Animation in lectures and laboratories	Understanding the molecular behavior of matters (PNM)	124 adults	For both units: Test of conceptual understanding (PNMET), course achievement test, reasoning ability test (TOLT), and attitude test (BAR)	For Units 5 and 7: SD among groups for conceptual understanding. Both animated groups performed 50% better than the control group (effect size of 0 .5). However, they did not differ from each other.
Unit 7	1. Static visuals (control group) 2. Animation in lectures 3. Animation in lectures and laboratories		124 adults		NSD among groups for reasoning abilities, attitude toward instruction, and course achievement
Zavotka (1987)	1. No animation (control group) 2. Animation order 1 3. Animation order 2 4. Animation order 3	Understanding 3D orthographic drawings	101 adults	A mental rotation pretest, an immediate mental rotation test, and a final identification test	Mixed results: NSD among groups for mental rotation test. Animation did not have any effect on the mental rotation test. SD among groups for identification test. One experimental order (natural 3D to natural 2D to a 3D wire frame to a 2D flat line drawing form) scored higher than the control group.

Note. Adult subjects are undergraduate and graduate students. Others are specified.

Spangenberg, R. W. (1973). The motion variable in procedural learning. *AV Communication Review, 21*(4), 419–436.

Spangler, R. D. (1994). *The effects of computer-based animated and static graphics on learning to visualize three-dimensional objects*. Unpublished doctoral dissertation, University of Kentucky.

Spotts, J., & Dwyer, F. (1996). The effects of computer-generated animation on student achievement of different types of educational objectives. *International Journal of Instructional Media, 23*(4), 365–375.

Swezey, R. W. (1991). Effects of instructional strategy and motion presentation conditions on the acquisition and transfer of electromechanical troubleshooting skill. *Human Factors, 33*(3), 309–323.

Szabo, M., & Poohkay, B. (1996). An experimental study of animation, mathematics achievement, and attitude toward computer-assisted instruction. *Journal of Research on Computing in Education, 28*(3), 390–403.

Thompson, S. V., & Riding, R. J. (1990). The effect of animated diagrams on the understanding of a mathematical demonstration in 11- to 14-year-old pupils. *British Journal of Educational Psychology, 60,* 93–98.

Todorov, E., Shadmehr, R., & Bizzi, E. (1997). Augmented feedback presented in virtual environment accelerates learning of a difficult motor task. *Journal of Motor Behavior, 29*(2), 147–158.

Towers, R. (1994). The effects of animated graphics and static graphics on student learning in a computer-based instructional format (Doctoral dissertation, University of Kentucky, 1994). *Dissertation Abstracts International, 55,* 1184A.

Vaez, H. (2000). Effects of narrated computer animation versus pure computer animation on understanding of the operation of an internal combustion engine (Doctoral dissertation, University of Kentucky, 2000). *Dissertation Abstracts International* 61, 4280A.

Westendorp, P. (1996). Learning efficiency with text, pictures, and animation in on-line help. *Journal of Technical Writing and Communication, 26*(4), 401–417.

Williamson, V. M., & Abraham, M. R. (1995). The effects of computer animation on the particulate mental models of college chemistry students. *Journal of Research in Science Teaching, 32*(5), 521–534.

Zavotka, S. L. (1987). Three-dimensional computer animated graphics: A tool for spatial skill instruction. *Educational Communication Technology Journal, 35*(3), 133–144.

References

Ainsworth, S. (1999). The functions of multiple representations. *Computers and Education, 33,* 131–152.

Alesandrini, K. L. (1984). Pictures and adult learning. *Instructional Science, 13,* 63–77.

Anderson, J. R. (1978). Arguments concerning representations for mental imagery. *Psychological Review, 85,* 249–277.

Anglin, G. J, Towers, R. L., & Levie, W. H. (1996). Visual message design and learning: The role of static and animated illustrations. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 755–794). New York: Simon & Schuster Macmillan.

Arnheim, R. (1954). *Art and visual perception: A psychology of the creative eye*. Berkeley: University of California Press.

Arnheim, R. (1969). *Visual thinking*. Berkeley: University of California Press.

Arnheim, R. (1974). Virtues and vices of the visual media. In D. R. Olsen (Ed.), *Media and symbols: The forms of expression, communication, and education. The 73 yearbook of the National Society for the Study of Education* (pp. 180–210). Chicago: University of Chicago Press.

Arnheim, R. (1986). *New essays on the psychology of art*. Berkeley: University of California Press.

Biederman, I. (1985). Human image understanding: Recent research and a theory. *Computer Vision, Graphics, and Image Processing, 32,* 29–73.

Biederman, I. (1987). Recognition-by components: A theory of human image understanding. *Psychological Review, 94,* 115–147.

Blinder, D. (1983). The controversy over conventionalism. *Journal of Aesthetics and Art Criticism, 41,* 253–264.

Brody, P. J. (1984). In search of instructional utility: A function-based approach to pictorial research. *Instructional Science, 13,* 47–61.

Bruner, J. S., & Postman, L. (1949). On the perception of incongruity: A paradigm. *Journal of Personality, 18,* 206–223.

Caraballo-Rios, A. L. (1985). An experimental study to investigate the effects of computer animation on the understanding and retention of selected levels of learning outcomes (Doctoral dissertation, Pennsylvania State University, 1985). *Dissertation Abstracts International, 46,* 1494A.

Carrier, D. (1983). Gombrich on art historical explanations. *Leonardo, 16,* 91–96.

Cassidy, M. F. (1982). Toward integration: Education, instructional technology, and semiotics. *Educational Communication and Technology Journal, 30,* 75–89.

Cassirer, E. (1944). *An essay on man*. New Haven, CT: Yale University Press.

Coldron, J. (1982). Peltz on Goodman on exemplification. *Journal of Aesthetic Education, 16,* 88–93.

Concannon, S. J. (1975). Illustrations in books for children: Review of research. *The Reading Teacher, 29,* 254–256.

Connell, J. H., & Brady, M. (1987). Generating and generalizing models of visual objects. *Artificial Intelligence, 31,* 159–183.

Crozier, W. R., & Chapman, A. J. (Eds.). (1984). *Cognitive processes in the perception of art*. Amsterdam: Elsevier Science.

Cutting, J. E. (1982). Two ecological perspectives: Gibson vs. Shaw and Turvey. *American Journal of Psychology, 95*(2), 199–222.

Cutting, J. E. (1987). Perception and information. *Annual Review of Psychology, 38,* 61–90.

Duchastel, P. C. (1978). Illustrating instructional texts. *Educational Technology, 11,* 36–39.

Duchastel, P., & Waller, R. (1979, November). Pictorial illustration in instructional texts. *Educational Technology,* 20–25.

Dwyer, F. M. (1972). *A guide for improving visualized instruction*. State College, PA: Learning Services.

Dwyer, F. M. (1978). *Strategies for improving visual learning*. State College, PA: Learning Services.

Dwyer, F. M. (Ed.). (1987). *Enhancing visualized instruction—Recommendations for practitioners*. State College, PA: Learning Services.

Eco, U. (1976). *A theory of semiotics*. Bloomington: Indiana University.

Elgin, C. Z. (1984). Representation, comprehension, and competence. *Social Research, 51*(4), 905–925.

Feaver, W. (1977). *When we were young: Two centuries of children's book illustration*. London: Thames & Hudson.

Fischler, M., & Firschein, O. (Eds.). (1987). *Readings in computer vision: Issues, problems, principles, and paradigms*. Palo Alto, CA: Morgan Kaufmann.

Fleming, M. (1967). Classification and analysis of instructional illustrations. *AV Communication Review, 15*(3), 246–258.

Fleming, M. (1993). Introduction. In M. Fleming & W. H. Levie (Eds.), *Instructional message design: Principles from the behavioral and cognitive sciences* (p. x). Englewood Cliffs, NJ: Educational Technology.

Fodor, J. H., & Pylyshyn, Z. W. (1981). How direct is visual perception? Some reflections on Gibson's "ecological approach." *Cognition, 9,* 139–196.

Freeman, F. N. (Ed.). (1924). *Visual education: A comparative study of motion pictures and other methods of instruction*. Chicago: University of Chicago Press.

Gardner, H. (1982). *Art, mind, and brain: A cognitive approach to creativity*. New York: Basic Books.

Gardner, H., Howard, V. A., & Perkins, D. (1974). Symbol systems: A philosophical, psychological, and educational investigation. In D. R. Olson (Ed.), *Media and symbols: the forms of expression, communication, and education. The 73 yearbook of the National Society for the Study of Education* (pp. 27–55). Chicago: University of Chicago Press.

Gibson, J. J. (1971). The information available in pictures. *Leonardo, 4,* 27–35.

Gibson, J. J. (1979). *The ecological approach to visual perception*. Boston, MA: Houghton Mifflin.

Gibson, J. J., & Bridgeman, B. (1987). The visual perception of surface texture in photographs. *Psychological Review, 49,* 1–5.

Goldstein, E. B. (1987). Spatial layout, orientation relative to the observer, and perceived projection in pictures viewed at an angle. *Journal of Experimental Psychology: Human Perception and Performance, 13*(2), 256–266.

Gombrich, E. H. (1969). *Art and illusion: A study in the psychology of pictorial representation*. Princeton, NJ: Princeton University Press.

Gombrich, E. H. (1972). The visual image. *Scientific American, 227*(3), 82–96.

Goodman, N. (Ed.). (1976). *Languages of art: An approach to a theory of symbols* (2nd ed.). Indianapolis, IN: Hackett.

Goodman, N. (1978). *Ways of worldmaking*. Indianapolis, IN: Hacket.

Greene, R. (1983). Determining the preferred viewpoint in linear perspective. *Leonardo, 16,* 97–102.

Gregory, R. L. (1970). *The intelligent eye*. New York: McGraw–Hill.

Gregory, R. L. (1973). *Eye and brain*. New York: McGraw–Hill.

Gregory, R. L. (1981). Questions of pattern and object perception by man and computer. In J. Long & A. Baddeley (Eds.), *Attention and performance IX* (pp. 97–116). Hillsdale, NJ: Lawrence Erlbaum.

Haber, R. N. (1979). Perceiving the layout of space in pictures: A perspective theory based upon Leonardo da Vinci. In C. F. Nodine & D. F. Fisher (Eds.), *Perception and pictorial representation* (pp. 84–99). New York: Praeger.

Hagen, M. A. (1978). An outline of an investigation into the special character of pictures. In H. L. J. Pick & E. Saltzman (Eds.), *Modes of perceiving and processing information* (pp. 23–38). New York: John Wiley.

Hagen, M. A. (1980a). Generative theory: A perceptual theory of pictorial representation. In M. A. Hagen (Ed.), *The perception of pictures, Vol. 2* (pp. 3–46). New York: Academic Press.

Hagen, M. A. (Ed.). (1980b). *The perception of pictures, Vol. 1. Alberti's window: The projective model of pictorial information*. New York: Academic Press.

Hagen, M. A. (Ed.). (1980c). *The perception of pictures, Vol. 2. Durer's devices: Beyond the projective model of pictures*. New York: Academic Press.

Hagen, M. A. (1986). *Varieties of realism: Geometries of representational art*. New York: Cambridge University Press.

Heffernan, J. A. (1985). Resemblance, signification, and metaphor in the visual arts. *Journal of Aesthetics and Arts Criticism, 44*(2), 167–180.

Hochberg, J. (1972). The representation of things and people. In E. H. Gombrich, J. Hochberg, & M. Black (Eds.), *Art, perception, and reality* (pp. 47–94). Baltimore: Johns Hopkins Press.

Hochberg, J. (1979). Some of the things that paintings are. In C. F. Nodine & D. F. Fisher (Eds.), *Perception and pictorial representation* (pp. 17–41). New York: Praeger.

Hochberg, J. (1980). Pictorial functions and perceptual structures. In M. A. Hagen (Ed.), *The perception of pictures, Vol. 2* (pp. 47–93). New York: Academic Press.

Hoffman, W. C., & Dodwell, P. C. (1985). Geometric psychology generates the visual Gestalt. *Canadian Journal of Psychology, 39,* 491–528.

Holliday, W. G. (1973). Critical analysis of pictorial research related to science education. *Science Education, 57*(2), 201–214.

Holowka, T. (1981). On conventionality of signs. *Semiotica, 33,* 79–86.

Jackendoff, R. (1987). On beyond zebra: The relation of linguistic and visual information. *Cognition, 26,* 89–114.

Katz, S. (1983). R. L. Gregory and others: The wrong picture of the picture theory of perception. *Perception, 12,* 269–279.

Kennedy, J. M. (1974). *A psychology of picture perception*. San Francisco: Jossey-Bass.

Kennedy, J. M. (1984a). Gombrich and Winner: Schema theories of perception in aesthetics. *Visual Arts Research, 10*(2), 30–36.

Kennedy, J. M. (1984b). How minds use pictures. *Social Research, 51*(4), 885–904.

Kennedy, J. M. (1985). Arnheim, Gestalt theory and pictures. *Visual Arts Research, 11,* 23–44.

Kieras, D. (1978). Beyond pictures and words: Alternative information processing models for imagery effects in verbal memory. *Psychological Bulletin, 85,* 532–554.

Kitcher, P. (1988). Marrs's computational theory of vision. *Philosophy of Science, 55,* 1–24.

Knowlton, J. Q. (1964). *A socio- and psycho-linguistic theory of pictorial communication*. Bloomington: Indiana University.

Knowlton, J. Q. (1966). On the definition of "picture." *AV Communication Review, 14,* 157–183.

Kolers, P. A. (1983). Perception and representation. *Annual Review of Psychology, 34,* 129–166.

Kolers, P. A., & Smythe, W. E. (1984). Symbol manipulation: Alternatives to the computational view of mind. *Journal of Verbal Learning and Verbal Behavior, 23,* 289–314.

Kosslyn, S. M. (1980). *Image and mind*. Cambridge, MA: Harvard University Press.

Kosslyn, S. M. (1981). The medium and the message in mental imagery: A theory. *Psychological Review, 88,* 46–66.

Kosslyn, S. M. (1986). Toward a computational neuropsychology of high-level vision. In T. J. Knapp & L. C. Robertson (Eds.), *Approaches to cognition: Contrasts and controversies* (pp. 223–242). Hillsdale, NJ: Lawrence Erlbaum.

Kosslyn, S. M. (1987). Seeing and imagining in the cerebral hemispheres: A computational approach. *Psychological Review, 94*(2), 148–175.

Kubovy, M. (1986). *The psychology of perspective and Renaissance art*. New York: Cambridge University Press.

Langer, S. (1976). *Philosophy in a new key* (3rd ed.). Cambridge, MA: Harvard University Press.

Levie, W. H. (1978). A prospectus for instructional research on visual literacy. *Educational Communication and Technology Journal, 26,* 25–36.

Levie, W. H. (1987). Research on pictures: A guide to the literature. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration: Volume 1 Basic research* (pp. 1–50). New York: Springer-Verlag.

Levie, W. H., & Dickie, K. E. (1973). The analysis and application of media. In R. M. W. Travers (Ed.), *Second handbook of research on teaching* (pp. 858–882). Chicago: Rand McNally.

Levie, W. H., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Communication and Technology Journal, 30*(4), 195–232.

Levin, J. R. (1981). On the functions of pictures in prose. In F. J. Pirozzolo & M. C. Wittrock (Eds.), *Neuropsychological and cognitive processes in reading* (pp. 203–228). New York: Academic Press.

Levin, J. R., & Lesgold, A. M. (1978). On pictures in prose. *Educational Communication and Technology Journal, 26,* 233–243.

Levin, J. R., Anglin, G. J., & Carney, R. N. (1987). On empirically validating functions of pictures in prose. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration* (pp. 51–80). New York: Springer-Verlag.

Lowe, D. G. (1987). Three-dimensional object recognition from single two-dimensional images. *Artificial Intelligence, 31,* 355–395.

Lumsdaine, A. A., Sultzer, R. L., & Kopstein, F. F. (1961). The effect of animation cues and repetition of examples on learning from an instructional film. In A. A. Lumsdaine (Ed.), *Student Response in Programmed Instruction* (pp. 241–269). Washington, DC: National Research Council.

Marr, D. (1982). *Vision: A computational investigation into the human representation and processing of visual information*. San Francisco: W. H. Freeman.

May, M. A., & Lumsdaine, A. A. (1958). *Learning from films*. New Haven, CT: Yale University Press.

Miller, G. A. (1956). The magical number seven plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63,* 81–97.

Mitchell, W. J. T. (Ed.). (1980). *The languages of images*. Chicago: University of Chicago Press.

Morris, C. W. (1946). *Signs, language and behavior*. Englewood Cliffs, NJ: Prentice Hall.

Natsoulas, T. (1983). What are the objects of perceptual consciousness? *American Journal of Psychology, 96*(4), 435–467.

Neisser, U. (1976). *Cognition and reality*. San Francisco: W. H. Freeman.

Nelson, D. L. (1979). Remembering pictures and words: Appearance, significance, and name. In L. S. Cermak & F. I. M. Craik (Ed.), *Levels of processing in human memory* (pp. 45–76). Hillsdale, NJ: Erlbaum.

Nelson, D. L., Reed, V. S., & Walling, J. R. (1976). The pictorial superiority effect. *Journal of Experimental Psychology: Human Learning and Memory, 2,* 523–528.

Nodine, C. F., & Fisher, D. F. (Eds.). (1979). *Perception and pictorial representation*. New York: Praeger.

Olson, D. R. (Ed.). (1974). *Media and symbols: The forms of expression, communication, and education. The 73 yearbook of the National Society for the Study of Education*. Chicago: University of Chicago Press.

Paivio, A. (1971). *Imagery and verbal processes*. New York: Holt, Rinehart & Winston.

Paivio, A. (1978). A dual coding approach to perception and cognition. In J. &. H. L. Pick, Jr. & E. Saltzman (Eds.), *Modes of perceiving and processing information* (pp. 39–51). Hillsdale, NJ: Erlbaum.

Paivio, A. (1990). *Mental representations: A dual coding approach* (2nd ed.). New York: Oxford University Press.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45,* 255–287.

Park, O., & Hopkins, R. (1993). Instructional conditions for using animated visual displays: A review. *Instructional Science, 22,* 1–24.

Penrice, L. (1980). The background to perspective. *Information Design Journal, 1,* 190–203.

Perkins, D. N., & Leondar, B. (Eds.). (1977). *The arts and cognition*. Baltimore, MD: Johns Hopkins University Press.

Peterson, M. A., & Hochberg, J. (1983). Opposed-set measurement procedure: A quantitative analysis of the role of local cues and intention in form perception. *Journal of Experimental Psychology: Human Perception and Performance, 9,* 183–193.

Pierce, C. S. (1960). *The icon, index, andd symbol (1902): Collected papers*. Cambridge, MA: Harvard University Press.

Pirenne, M. H. (1970). *Optics, painting, and photography*. Cambridge: Cambridge University Press.

Pylyshyn, Z. W. (1981). The imagery debate: Analogue media versus tacit knowledge. *Psychological Review, 88,* 16–45.

Readence, J. E., & Moore, D. W. (1981). A meta-analytic review of the effect of adjunct pictures on reading comprehension. *Psychology in the Schools, 18,* 218–224.

Reed, E., & Jones, R. (Eds.). (1982). *Reasons for realism: Selected essays of James J. Gibson*. Hillsdale, NJ: Erlbaum.

Rieber, L. P. (1989, February). *A review of animation research in computer-based instruction*. Proceedings of selected research papers presented at the annual meeting of the Association for Educational Communications and Technology, Dallas, TX. (ERIC Document Reproduction Service No. 308–832)

Rieber, L. P. (1990). Animation in computer-based instruction. *Educational Technology Research and Development, 38*(1), 77–86.

Rieber, L. P. (1994). *Computers, graphics, and learning*. Madison, WI: WCB Brown & Benchmark.

Rogers, S., & Costall, A. (1983). On the horizon: Picture perception and Gibson's concept of information. *Leonardo, 16,* 180–182.

Rosenfeld, A. (1986). *Human and machine vision II*. New York: Academic Press.

Roupas, T. G. (1977). Information and pictorial representation. In D. Perkins & B. Leondar (Eds.), *The arts and cognition* (pp. 48–79). Baltimore: Johns Hopkins Press.

Salomon, G. (1979a). *Interaction of media, cognition, and learning: An exploration of how symbolic forms cultivate mental skills and affect knowledge acquisition*. San Francisco: Jossey–Bass.

Salomon, G. (1979b). Media and symbol systems as related to cognition and learning. *Journal of Educational Psychology, 71,* 131–148.

Samuels, S. J. (1967). Attentional process in reading: The effect of pictures on the acquisition of reading responses. *Journal of Educational Psychology, 58*(6), 337–342.

Samuels, S. J. (1970). Effects of pictures on learning to read, comprehension and attitudes. *Review of Educational Research, 40,* 397–407.

Schallert, D. L. (1980). The role of illustrations in reading comprehension. In B. Spiro & W. F. Brewer (Eds.), *Theoretical Issues in Reading Comprehension* (pp. 503–523). Hillsdale, NJ: Lawrence Erlbaum.

Scruton, R. (1974). *Art and imagination*. New York: Harper & Row.

Sebeok, T. A. (1976). *Contributions to the doctrine of signs: Studies in semiotics, Vol. 5*. Bloomington: Indiana University Press.

Shepard, R. N. (1978). The mental image. *American Psychologist, 33,* 125–137.

Sless, D. (1986). Reading semiotics. *Information Design Journal, 4,* 179–189.

Slythe, R. M. (1970). *The art of illustration 1750–1900*. London: The Library Association.

Smith, M. C., & Magee, L. E. (1980). Tracing the time course of picture-word processing. *Journal of Experimental Psychology: General, 109,* 373–392.

Spaulding, S. (1955). Research on pictorial illustration. *AV Communication Review, 3,* 35–45.

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12,* 257–285.

Sweller, J., Van Merrienboer, J. J. G., & Pass, F. G. W. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251–296.

Twyman, M. (1985). Using pictorial language: A discussion of the dimensions of the problem. In T. M. D. & R. Waller (Eds.), *Designing usable texts* (pp. 245–312). New York: Academic Press.

Veltrusky, J. (1976). Some aspects of the pictorial sign. In L. Matejka & I. R. Titunik (Eds.), *Semiotics of art* (pp. 245–264). Cambridge, MA: MIT Press.

Vitz, P. C., & Glimcher, A. B. (1984). *Modern art and modern science*. New York: Praeger.

Weber, J. J. (1926). Three important studies on the use of educational films. In A. P. Hollis (Ed.), *Motion pictures for instruction* (pp. 162–196). New York: Century.

Wilcox, S., & Edwards, D. A. (1982). Some Gibsonian perspectives on the ways that psychologists use physics. *Acta Psychologica, 52,* 147–163.

Winn, B. (1987). Charts, graphs, and diagrams in educational materials. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration* (pp. 152–193). New York: Springer-Verlag.