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MULTIPLE-CHANNEL COMMUNICATION: THE THEORETICAL AND RESEARCH FOUNDATIONS OF MULTIMEDIA

David M. (Mike) Moore, John K. Burton, and Robert J. Myers
Virginia Polytechnic Institute and State University

36.1 INTRODUCTION

The ability of technology to make information available quickly and provide an individualized learning opportunity has long been discussed and dreamed of. These desires go back to Pressey's teaching machines of the 1920s and Bush's theoretical *Memex* information retrieval system of the 1940s. Since the beginning of the microcomputer computer revolution in the late 1970s, however, the dream has become a reality. Proponents have extolled the virtues of instruction supported, assisted, or conducted by the computer (e.g., Papert, 1977; Suppes, 1980). Others have exercised less enthusiasm about the effects of any media per se. Clark (1983), for example, said that mediated environments are merely sufficient, not necessary for the learning process. Teachers, as practitioners, will ultimately decide whether incorporation of new technologies into the classroom is worth the time and effort (Moore, Myers, & Burton, 1994).

This chapter focuses on the theories and effects related to multiple-channel communication, which undergirds notions of multimedia instruction. Because cognitive notions of learning currently have widespread acceptance, we use it as the perspective for the review. Specifically, we use the information processing view of the cognitive system because it, like current views of multimedia itself, relies so heavily on the computer. The information processing approach focuses on how the human memory system acquires, encodes retrieves, and uses information. This approach applies information theory and computer analogies to human learning. Within the information processing model, topics and research reviewed include multiple-channel communication—including modalities of instruction, cue summation and stimulus generalization, channel interference, and capacity. We resisted, however, the temptation to include, and thus report on, cueing strategies and other remotely related theories. Related research literature in the areas of multiimage and subliminal perception are also investigated and summarized.

The term *multimedia* has been used for a long time by educators as well as those in the technology industry, yet there is little consensus as to what, exactly, the concept includes (Strommen & Ravelle, 1990). Until recently, the term has meant the use of several media devices in a coordinated fashion (e.g., synchronized slides with audiotape). Advances in technology, however, have combined these media so that information previously delivered by several devices is now integrated into one device (Kozma, 1987, 1991). Obviously the computer plays a central organizing role in this environment, and just as obviously the computer allows interactivity and, constrained only by the size of the lesson, unlimited branching. Because of this history, many authors (see, e.g., Matchett & Elliot, 1991) argue that multimedia should encompass interactive systems. This allows the notion of multimedia not only to accommodate interactive video, for example, but also to absorb the historically older concept of hypermedia (Moore et al., 1994). In part because we do not agree (we tend to see multimedia as a special case of hypermedia with one, linear path specified) and in part because of the more practical reason that such things as interactive video are covered elsewhere in this handbook, we limit our definition, and hence our coverage, to systems that include two or more of the following: motion, voice, data, text, graphics, and still images.

Multimedia research is evaluated with the intent of answering the question: Does multimedia really work? Speculation on multimedia message design based on past and current research concludes this chapter.

36.2 INFORMATION PROCESSING APPROACH TO HUMAN COGNITION

36.2.1 Historical Perspectives

Notions such as seeing with our *mind's eye* and *listening to our inner voices* portray an ancient metaphor of a mind with sense organs much like the body. The mind feels pain (e.g., "It hurts me when I think about. . . "), has a sense of taste (e.g., "I want this so bad I can taste it") and smell (e.g., "The more I think about this the more it smells"), etc. Moreover, our language reflects specific, organ-based memories as in "I'll never forget the look on his face or the sound of his voice" or "I can still feel (or smell) it after all these years." Yet the nature of sensory image processing, storage, interpretation, and generation is not nearly as clear (or as noncontroversial) as our conversational descriptions would imply.

Images are mentioned in Greek scrolls that date back as early as 500 B.C. A few hundred years later, a building collapsed during an earthquake; Simonodes, a survivor, related his use of mental images to recreate the seating arrangement at the feast he had been attending in the building. The power of the mind to *see* is exemplified, for example, by authors such as St. Augustine (who refers to inner sight or insight) and De Cartes (who believed that during dream states the mind could both see and hear during its *travels*).

To understand the current views of these historical concepts, however, it is necessary to take a position on how the human memory system works. For simplicity, and to make discussions about modalities, channels, etc., easier, we have selected the model that began the current rise of cognitive psychology: information processing.

36.2.2 Cognitive Overview

The information processing approach to human cognition relies on the computer as a metaphor. Gardner (1985) states that cognitive science was *officially* recognized at the Symposium on Information Theory held at MIT in 1956. Although Broadbent (1958) published the first model, it was Neisser, in his 1967 book, *Cognitive Psychology,* who synthesized earlier attempts to apply information theory and computer analogies to human learning (see, e.g., Bartlett, 1958; Broadbent, 1958; Miller, 1953; Posner, 1964).

The information processing approach focuses on how the human memory system acquires, transforms, compacts, elaborates, encodes, retrieves, and uses information. The memory system is divided into three main storage structures: sensory registers, short-term memory (STM), and long-term memory (LTM). Each structure is synonymous with a type of processing.

The first stage of processing is registering stimuli in the memory system. The sensory registers (one for each sense) briefly hold raw information until the stimulus pattern is recognized or lost. Pattern recognition is the matching of stimulus information with previously acquired knowledge. Klatzky (1980) referred to this complex recognition process as assigning meaning to a stimulus. Unlike the sensory registers, STM does not hold information in its raw sensory form, (e.g., visual—*icon,* auditory—*echo*) but in its recognized form. For example, the letter *A* is recognized as a letter rather than as just a group of lines. STM can maintain information longer than the sensory registers through a holding process known as maintenance rehearsal, which recycles material over and over as the system works on it. Without rehearsal, the information would decay and be lost from STM.

Another characteristic of STM is its limited capacity for information. Miller (1956) determined that STM has room for about seven items (chunks) of information. Moreover, STM has a *limited pool of effort* or cognition capacity (see, e.g., Britton, Meyer, Simpson, Holdredge, & Curry, 1979; Kahneman, 1973; Kerr, 1973). This limited pool is assumed to effect everything from decision making to the sizes of visual images that can be processed (e.g., Kosslyn, 1975). Klatzky (1980) defined STM as a *work space* in which information may be rehearsed, elaborated, used for decision making, lost, or stored in the third memory structure: LTM.

LTM is a complex and permanent storehouse for individuals' knowledge about the world and their experiences in it. LTM processes information to the two other memory structures and in turn receives information from the sensory registers and STM. First, the stimulus is recognized in the sensory registers through comparison with information in LTM. Second, information manipulated in STM can be permanently stored in LTM.

Perception is an interpretive process involving a great deal of unconscious inference (Helmholtz, 1866, as cited in Malone, 1990). An important characteristic of STM, for our purposes, is that, despite the fact that it *can* apparently manipulate visual information (e.g., Cooper & Shepard, 1973), phonemic coding is the preferred modality (Baddeley, 1966; Conrad, 1964; Sperling, 1960). Related to this phenomena is that STM apparently treats printed text and spoken words the same: acoustically (e.g., Pellegrino, Siegel, & Dhawan, 1974, 1976a, 1976b). Basic research studies not only tend to confirm this treatment, but suggest that whereas people can remember information as being presented by picture or spoken word, printed text is identified as printed (versus spoken) at about a chance level (Burton, 1982; Burton & Bruning, 1982).

To understand how an individual is able to interpret information, the researcher must first focus on decisions made at each memory storage structure. Within the information processing model, attention and pattern recognition determine the environmental factors that are processed. A large amount of information impinges on the sensory registers but is quickly lost if not attended to. Attention, therefore, plays an important role in selecting sensory information.

Early information processing models viewed attention as a filter or bottleneck (e.g., Broadbent, 1958). For example, an individual could follow an auditory message across many *ears* (headphones) but could attend to only one message; the rest were filtered out. Work by Cherry (1953, 1957), Moray (1959), and Treisman (1960) indicated, however, that information in an unattended channel (same modality) *could* penetrate this proposed bottleneck. Current models (e.g., Shiffrin & Geisler, 1973) view attention as attenuation (much like a volume control on a TV or radio) with unlimited capacity for recognition of stimuli coming from different channels at the same time. Recognizing a stimulus in one channel does not disturb the process of recognizing a second stimulus in another channel (Bourne, Dominowski, Loftus, & Healy, 1986). Attention is conceived of as being a very limited mental resource (Anderson, 1985). It is difficult to perform two demanding tasks at the same time. Although the sensory registers register all information, only information attended to and processed to a more permanent form is retained. Bruner, Goodnow, and Auston (1967) stated that a person tends to focus attention on cues that have seemed useful in the past. Pattern recognition enables the individual to organize perceptual features (cues) so that relevant knowledge from LTM is activated. In other words, recognition *is* attention (Norman, 1969). Pattern recognition integrates information from a complex interaction that uses both bottom-up and top-down processing (Anderson, 1985). Bottom-up processing is the use of sensory information in pattern recognition. Top-down processing is the use of pattern context and general knowledge. Attention is assumed to use both processes, that is, it is interactive (Neisser, 1967). Once relevant information is activated from LTM, the individual focuses attention on the relevant stimulus and brings it into the working memory (STM).

LTM contains large quantities of information that have to be organized efficiently so they can be effectively encoded, stored, and retrieved. These three processes are interdependent. For example, the method of presentation determines how information is stored and retrieved (Klatzky, 1980). Encoding is related to the amount of elaboration and rehearsal conducted in STM. Elaboration uses information received from LTM after the stimulus is recognized. As new information is compared to the old and manipulated information, it is either added or subsumed into the existing schema, then encoded in LTM (Anderson, Greeno, Kline, & Neves, 1981). This schema or *set of past experiences* is the cognitive structure that, when related to new information, causes meaning (Mayer, 1983, p. 68). As information is restructured and added, new structures are formed that result in new conceptualizations (Magliaro, 1988). These knowledge structures combine information in an organized manner. Evidence for memory storage indicates that representations can be both meaning-based and perception-based. Retrieval of information is also an active process. Information is accessed by a search of the memory structures. The speed and accuracy of retrieval are directly dependent on how the information was encoded and the attention being given to the stimulus. To be recalled from LTM, information must be activated. The level of activation seems to depend on the associative strength of the path. The strength of the activation increases with practice and with the associative properties (Anderson, 1985).

36.2.3 Dual Coding

Imagery theorists obviously make a distinction between the codes used for images and those used for verbal information. Paivio (1971, 1986) developed the dual-code model, which stated that the two types of information (verbal and imaginal) are encoded by separate subsystems, one specialized for sensory images and the other specialized for verbal language. The two systems are assumed to be structurally and functionally distinct. Paivio (1986) defined structure as the difference in the nature of representational units and the way in which these units are organized into higher-order systems. Structure, therefore, refers to LTM operations that correlate with perceptually identifiable verbal or visual objects and activities.

It is important to note that Paivio defines his two systems very broadly. An image can be a picture or a sound or even perhaps a taste, whereas the verbal store, on the other hand, is construed broadly to mean a language store (Burton & Bruning, 1982). In Paivio's (1971) words, image refers

> . . . to concrete imagery, that is, *nonverbal* memory representations of concrete objects and events, or nonverbal modes of thought (e.g.., imagination) in which such representations are actively generated and manipulated by the individual. This will usually be taken to mean *visual* imagery, although it is clear that other modalities (e.g., auditory) could be involved and when they are, this must be specified. Imagery, so defined, will be distinguished from verbal symbolic processes, which will be assumed to involve implicit activity in an auditory-motor speech system. (p. 12)

Functionally, Paivio's two hypothesized subsystems are independent, meaning that either can operate without the other or both can work parallel to each other. Even though independent of one another, these two subsystems are interconnected so that a concept represented as an image can also be converted to a verbal label in the other system, or vice versa (Klatzky, 1980). Paivio is very explicit, however, about the power of images: Whereas words that can be imaged *may* be, images (and presumably all concrete sensory input) that can be translated *will* be, automatically. Paivio argues that this is why pictures are often remembered better than verbal information (Pressley & Miller, 1987).

Dual-code theorists accept that mental images are not exact copies of pictures but, instead, contain information that was encoded from a sensory event after perceptual analysis and pattern recognition (Klatzky, 1980). It is thought that the images are organized into subunits at the time of perception (Anderson, 1978). Paivio (1986) further explained that mental representations have their developmental beginnings in perceptual, motor, and affective experience and are able to retain these characteristics when being encoded so that the structures and the processes are modality specific. For example, a concrete object such as the ocean would be recognized by more than one modality—by its appearance, sound, smell, and taste. Therefore, a continuity between perception and memory as well as between behavioral skills and cognitive skills is implied (Paivio).

There are, however, the same limits on imaginal processing that we see throughout the information processing model. The concept of limited space was demonstrated by Kosslyn (1975), who asked students to visualize two named objects and then to answer questions about one of the objects. Students were slower to find parts that were next to an elephant than to find those next to a fly. STM for visuals appeared to have a processing limitation. Large objects like elephants (or even *very large* flies) *fill up* the system and slow it down. Retrieval of visually coded material also differs from other forms of internal representation. As previously stated, information is available simultaneously rather than by a sequential search and can be located by template or by an unlimited-capacity parallel search (Anderson, 1978).

Dual-coding theory can account for our personal impression of having images. The theory is often supported by research studies that conclude that individuals have a continuous and analogue ability to judge space from images, in at least some cases (Kosslyn, 1975), and, finally, by studies that indicate strong visual memory abilities. Paivio's theory is also able effectively to support the recurrent finding that memory for pictures is better than memory for words (Shepard, 1967), otherwise known as the *pictorial superiority effect* (Levie, 1987). Imagery theories have been used by researchers to construct and test hypotheses on learning from graphics (Winn, 1987) and seem a fruitful heuristic source for multimodality research in the future.

36.2.4 Detail and Experience

In terms of simple recognition, text modality detail does not seem to be important. Nelson, Metzler, and Reed (1974), for example, varied visual representations of the same scene from nondetailed drawings to photographs and compared recognition for the visuals versus text descriptions. As we would expect, pictures were superior in recognition tests, but there were no differences among the detail levels used. For recall, however, detail is important in at least two ways. Mandler and Parker (1976) showed that the locations of detail elements are best recalled if they are organized in a meaningful way. Thus, for example, graphic elements of classroom items that are placed in their *usual* locations are superior to the same elements when they are not organized in a meaningful manner. Obviously, *meaningful* reflects prior knowledge, including culture. In a related way, specific expertise impacts memory for visuals. Egan and Schwartz (1979) demonstrated that skilled electronics technicians showed superior recall for circuit diagrams relative to novices *as long as* the diagrams made sense, that is, were organized in a meaningful manner.

Images can also be used to organize incoming information. The classic demonstration of this use of visuals to make sense of subsequent textual information is Bransford and Johnson's (1972) *Balloons* passage. In their study, people found text without the visuals (or the visual following the text) to be difficult to comprehend and remember relative to the same text following an organizing visual. A related effect, *priming* (see, e.g., Neely, 1977; Posner & Snyder, 1975), has been demonstrated with text. Basically, a categorical prime, such a bird, facilitates access to a specific bird, such as a robin. Conversely, an incorrect categorical prime inhibits access. A representative of the category in whatever modality should produce a similar effect (Miller & Burton, 1994).

Theory, basic research, and applied research predict and support the efficacy of images (and instructions to image) in learning and memory. Yet images are prone to the same processes (and problems) that affect all aspects of the human system: distortions of *reality*. We assume that human sensation is about the same for all of us. When confronted with a visual stimulus, we assume that our rods, cones, optic nerves, and so forth, react about the same. Perceptually, however, we do not *see* the same things. We extract (and create) meaning from visual stimuli just as we do from text. Therefore, our prior experience, inferences, expectations, beliefs, physical state, and other factors determine what we see as surely as the stimulus before us. A similar process operates when we recall an image from memory: We reconstruct from our constructed images. Naturally, as in memory for text, we forget details (Miller & Burton, 1994).

Finally, where there are gaps, we unconsciously fill them. As you will see in other chapters, images are effective for connecting items to be remembered and, if the level of detail is correct, for learning new facts and relationships. However, these tasks are rather low level and rote. In general, unless images are entrained to the point of pattern recognition, we can assume that the human memory system deals with images as it deals with text: generally or prototypically. The system is great at *gist* or meaning and poor at specifics. Thus, images may work *better* than text in many applications, but they probably do not work differently (Miller & Burton, 1994).

36.3 MULTIPLE-CHANNEL COMMUNICATION

Of major interest to communication theorists and instructional designers is whether humans can accommodate simultaneous audio and visual stimuli and, if so, the amount and types of information that can be so processed. Multiple-channel communication involves simultaneous presentations of stimuli ". . . through different sensory channels (i.e., sight, sound, touch, etc.) which will provide additional stimuli reinforcement" (Dwyer, 1978, p. 22).

Broadbent (1958) and later Feigenbaum and Simon (1963) espoused the single-channel theory, in which, if information arrives simultaneously in separate channels, information jamming will occur. Broadbent (1958, 1965) suggests that one reason for reduced learning in multiple-channel presentations is a result of the filtering process (bottleneck) occurring in an individual's information processing system, which reduces superfluous elements and permits only essential or basic information to be received; the nervous system acts as a single channel. Similarly, research conducted by Hernandez-Peon (1961) has led to a hypothesis known as the *Hernandez-Peon* effect, which contends that when information is being processed via one sense, this act may cause an impediment to the processing of a stimuli through other senses. Likewise, Jacobson (1950, 1951) contended that the brain is able to process only small proportions of the large amounts of stimuli received. Thus, regardless of the amount of information presented in which sensory modality, learners are able to accept only limited amounts in the information processing center (Attneave, 1954; Brown, 1959; Dwyer, 1972; Livingstone, 1962). Broadbent (1958) asserts that the human information processing can receive information from only one source at a time—the additional information is temporarily stored (in the sensory register). However, Hartman (1961b) also points out that Broadbent's thesis regarding the filtering of information in the central nervous system is based on data obtained from presenting unrelated information to learners through two or more modalities simultaneously. If, after this momentary storage, the information is not used, it is not retained. Thus, people viewing multiple-channel presentations are presented with the problem of switching from one channel to another (Broadbent, 1956, 1965). Other researchers including Cherry (1953), Shannon and Weaver (1949), and Spaulding (1956) support this theory. Corballis and Reaburn (1970), Clark (1969), Herman (1965), and Welford (1968) have documented the reduction (impairment) of the processing of information in multiple-channel communication situations. Travers (1968) concurs in his review of multiple-channel communication. He suggests that there is no convincing evidence that *multiple-channel communications* were any more effective in producing learning than single-channel inputs. There appear to be major concerns, however, involved in determining the amount of information a human can process at any one time. Travers (1968) indicates unequivocally that the human processing system is one of limited capacity (see also Miller, 1956). To recognize information simultaneously, the various receptors (eyes, ears) would have to analyze a great variety of different cues. At this initial stage, the system *does* function as a multiple-channel system. But once recognition has occurred (and hence attention; see also Norman, 1969), the remainder of operations on the incoming information is undertaken by a system with a limited capacity, STM. The system from this point on operates as a single-channel system. Travers states, ". . . Unless the rate at which the incoming information being received is less than the capacity of the system for handling information. Only under the latter condition can two separate and distinct sequences of messages be received at the same time" (p. 10). Humans are able to deal with the vast complexities of various types of data from the environment. These data are then simplified to be handled by the perceptual system. Much of the simplification of this huge amount of complex data involves the discarding of redundant information. This process is referred to as *information compression* (Travers, 1968, p. 11).

Given the complexity of multimedia and its close relationship to cognitive and information processing theories, it is helpful to review a perspective known as cognitive load theory to understand the possible implications of multichannel processing on cognitive structures (K. Smith, 2001). Mayer's (2001) discussion of limited capacity assumptions suggests that humans are limited in the amount of information that can be processed in each channel at one time. Mayer distinguishes between two types of cognitive load. Intrinsic cognitive load "depends on the inherent difficulty of the material—how many elements there are and how they interact with each other" (p. 50). Extraneous cognitive load, on the other hand, depends on the way the instructional message is designed, organized, and presented (p. 50). Mayer also cites metacognitive strategies as techniques for allocating, monitoring coordinating, and adjusting limited cognitive resources (K. Smith).

Sweller and Chandler (1994) provide empirical evidence related to the analysis of both intrinsic and extraneous cognitive load and conclude that such analysis can lead to instructional design that will generate gains in learning efficiency. Sweller and Chandler base their conclusions on the following assumptions.

- Schema acquisition and automation are major learning mechanisms.
- Limited working memory makes it difficult to assimilate multiple elements of information simultaneously.
- Multiple elements must be assimilated when the elements interact.
- Heavy cognitive load is caused by material with a high level of interactivity.
- High levels of interactivity may be caused by the nature of the material being learned and by the method of presentation.
- If intrinsic element interactivity and consequent cognitive load are low, extraneous load may not be important (K. Smith, 2001).

Sweller and Chandler (1994) also suggest that schema acquisition and automatic processing become important mechanisms that could be fostered to prevent issues with cognitive load. They define schemata as "cognitive constructs that organize information according to the manner in which it will be dealt" (p. 186). Automation, on the other hand, occurs with time and practice and allows cognitive process to occur with out conscious control. Sweller and Chandler additionally caution against such design issues as split-attention and redundancy effects. The split-attention effect occurs when instructional material requires students to split their attention among multiple sources of information and then integrate that information (K. Smith, 2001). The redundancy effect is a phenomenon that deals with segments of information that can be understood in isolation. Chandler and Sweller (1991) found that by adding redundant elements such as text, students may associate those elements with a diagram, which may increase the element interactivity and lead to cognitive overload.

Cognitive load is also related to the information processing system's strength: gist. Travers' perceptual model thus includes a high-capacity information system up to the point of recognition and a very limited system beyond. Lack of retention and lack of understanding of many multiple-channel presentations are examples of this model in action. Travers' (1964a, 1964b, 1966) studies support this contention that humans cannot receive more information if exposed to two or more sources simultaneously than if exposed to just one source or if the information is transmitted by two different modalities. Van Mondfrans (1963), in a study using nonsense syllables and words, showed no advantage of an audiovisual presentation over presentations via audio and visual modalities alone. Cherry (1953) concluded that the utilization of information by the brain could be represented by single-channel input. Travers (1968) continues and states that since the perceptual channel is very limited, we must assume that the receiver (learner) cannot process multiple-channel inputs as efficiently as "designers of audiovisual materials have commonly assumed" (p. 10).

Other researchers have supported the efficacy of single-channel presentations. These include Fleming (1970), who reviewed research studies dealing with single- and multiple-channel presentations and noted the possibility that many instructional programs are already "perceptually overloaded." He suggests that additional "jamming" of the perceivers' senses through multiple media (channels) may have negative results. Fleming suggests that the only possible instructional situation where "stepped up sensory environments" are useful is when the desire is to "overwhelm, impress or to exhilarate" (pp. 69–100). Hartman (1961a) concludes that multiple-channel presentations do not produce increases in learning (however defined) over single-channel communication unless the situation in which the learning takes place also contains the necessary additional cues. Hartman (1961b) has also expressed concern about the act of increasing the number of cues and/or the number of channels used with the expectation that more learning will occur. He states,

> A common practice among multiple-channel communicators has been to fill the channels, especially the pictorial, with as much information as possible. The obvious expectation is for additional communication to result from the additional information. However, the probability of interference resulting from the additional cues is very high. The hoped-for enhanced communication resulting from a summation of cues occurs only under special conditions. Most of the added cues in the mass media possess a large number of extraneous cognitive associations. The possibility that these associations will interfere with one another is probably greater than that they will facilitate learning. (p. 255)

Hsia (1971) drew several conclusions from an extensive review of literature comparing multiple and single-channel presentations. These include the following: (a) Human information processing functions as a multiple-channel system until the capacity of the system is overloaded; (b) when the input becomes greater than the system's capacity, the system reverts to a single-channel system; and (c) an increase in the amount of information presented does not necessarily increase the rate of information transmission. Hsia (1971) asserts that, because all incoming information needs to be coded prior to being processed by the human processing system, it would seem reasonable that all extraneous, irrelevant, and superfluous information be eliminated or reduced at that time. Hsia (1971) contends that by reducing this *extra* information, the learner is spared from having to discriminate the relevant from the irrelevant. In addition to filtering information, a large portion of redundancy and noise is eliminated. Hsia (1971) and Carpenter (1953) feel that the physiological aspects of the individual limit the processing capability of an individual. A person can receive far more stimuli than they can effectively process. Clark (1969), Corballis and Reaburn (1970), Herman (1965), and Welford (1968) indicate that there are a substantial number of research results that support the position that single-channel communication can be as effective as multiple-channel orientations. Dwyer (1978) cites approximately 50 studies in which the contention that additional cues—"provided by the use of two or more information channels simultaneously—or excessive realistic cues within a single-channel may be distracting or even evoke responses in opposition to the desired types of learning" (pp. 29–30).

There is also much criticism of the research that supports the single-channel view. For example, Norberg (1966) takes Travers to task for basing his assumption concerning single-channel communication on experiments using verbal material in both auditory and visual channels (i.e., no pictures presented). Norberg explains that Travers' studies

> . . . deal exclusively with verbal symbols, whereas most two-channel presentations actually used in instructional situations typically combine nonverbal signs in the visual channel with verbal auditory stimuli. . . . But it is still necessary to distinguish carefully between the actual experimental findings and theoretical statements regarding nonverbal "realistic" stimuli which have not entered into the experimental work cited. . . . it is one thing to say that the "density" of information in stimulus materials presented to the leaner may become a factor impeding efficient transmission; i.e., some presentations may be too realistic. (p. 307)

Other criticisms of single-channel research are that many of the data collected were from studies where unrelated and/or contradictory stimuli were presented to the learners simultaneously. It would seem reasonable in these circumstances that a person would attend to one stimulus (message) and not the other. The following section looks at multiple-channel communication and the influences of the cue summation theories.

36.4 CUE SUMMATION AND MULTIPLE-CHANNEL COMMUNICATION

It is relatively easy to find current literature extolling the virtues of multimedia or hypermedia environments. Among the commonly mentioned advantages are

- the ability to place learners in a context-rich environment;
- an increase in learning due to the combination of text, graphics, full-motion video, and signs;
- the ability to navigate complex nonlinear *hyperspace*; and
- an increase in motivation due to intrinsic aspects of the media.

Desktop hardware and software have become more powerful, flexible, and sophisticated in the types of presentations that they can author and deliver. Moreover, such systems are within the budgets of many, if not most, K–12 classrooms. There has been a proliferation of authoring packages and CD-ROM-based programs that can deliver high-fidelity sound, realistic color images in stills, graphics, and full-motion video. The central issue in this chapter, however, is whether multiple-channel presentations provided by multimedia environments contribute to an increase in the amount of learning.

The terms *multiple-channel communication* and *cue summation* are routinely used interchangeably in the literature. Is there a difference? The cue summation principle of learning theory predicts that learning is increased as the number of available cues or stimuli is increased (Severin, 1967a). Does this mean the addition of cues within a single-channel (such as adding color to a picture)? or Does it mean adding cues across channels (such as adding audio to visual a presentation)? For the purposes of this review cue summation includes the addition of cues both within and across channels. Therefore the multiple-channel communication research in this review may be subsumed under the cue summation theories. Supporting this approach is Miller's (1957) view concerning cue summation, which is frequently cited:

> When cues from different modalities (or different cues within the same modality) are used simultaneously, they may either facilitate or interfere with each other. When cues elicit the same responses simultaneously, or different responses in the proper succession, they should summate to yield increased effectiveness. When the cues elicit incompatible responses, they should produce conflict and interference. (p. 78)

Hoban (1949), in a summary of the instructional value of increasing the number of cues and/or realistic detail (which some call *single-channel realism theory*) in a visual presentation, concluded that the power of a medium of communication is determined by "the richness of the symbols employed" (p. 9) within that medium. These cues lead to greater understanding of the message by the audience.

Miller (1957) cites his views on the need to increase the number of cues in a presentation. He states that if one stimulus complex is to be identified versus another, the individual may use any number (even one) of available cues to make this discrimination. Increasing the number of available cues will increase the likelihood of an individual making the correct discrimination over time and the likelihood of a number of individuals making the correct discrimination simultaneously.

Dwyer (1978) suggests that the above views can be classified under the theoretical orientation collectively referred to as *realism theories*. The assumption is that "learning will be more complete as the number of cues in the learning situation increases. They suggest that an increase in realism in the existing cues in a learning situation increases the probability learning will be facilitated" (p. 6). (It should be noted that making a learning situation more complex does not necessarily make it more realistic).

Allen and Cooney (1963) suggest that age and maturity have effects on recall of information from multiple- or single-channel presentations. The mode of presentation has less effect on learning than maturity. Hsia (1969) studied the relationships between modalities and learner intelligence; he concluded that less intelligent learners would be assisted positively if input, noise, and redundancy were controlled. Audiovisual (multiple-channel) presentations rather than single-channel presentations were suggested to optimize the information processing rate of less intelligent subjects. Further, Hsia recommended keeping cross-channel redundancy high in audiovisual (multiple-channel) presentations. Hsia (1968) similarly states that

> . . . in dual or multi-channel information processing, dimensionality of information generally increases, and one channel provides cues and clues for the other, provided that the amount of information to be presented has not reached the capacity limit, thereby eliminating probable interference or information jamming. Increase in dimensionality usually results in the increase of information processing. (p. 326)

Severin (1967b) suggests that "multiple-channel communications appear to be superior to single-channel communications when relevant cues are summated across channels, neither is superior when redundant between channels, and are inferior when irrelevant cues are combined (presumably because irrelevant cues cause interference between them)" (p. 397). Severin's theory of cue summation differs slightly from others in that he stresses the addition of *relevant* cues. This is somewhat of a caveat to the general theory of cue summation, which states that any increase in cues will summate in more learning. Severin (1967c) also places emphasis on the use of pictorial presentations as the vehicle to add cues.

Van Mondfrans and Travers (1964) found that redundant information presented over two-sense modalities (auditory plus visual) resulted in no better learning than from either sense modality used alone. Severin (1967a) points out that the work of Van Mondfrans and Travers did not deal with nonredundant information presented over two channels. Their work looked at verbal material in both channels—omitting the use of pictorial information.

Baggett and Ehrenfeucht (1983) reported that when college students are watching a film presentation, and related information is presented simultaneously across two mediums—visual and auditory—there is no competition for resources. When encoding visual and auditory information sequentially the extraction of information is not increased. They concluded that synchronous visual and auditory input is an efficient way to present information. Baggett (1984) reported superiority of a simultaneous presentation of narrative and visuals over a presentation of the narration prior to the corresponding visual sequence, but speech given slightly after a visual sequence resulted in recall just as good as that of a simultaneous presentation. Nugent (1982) studied redundancy of content across three channels and found that when the content was the same, subjects learned equally well from all modes and, by combining modes, generally maximized learning.

It is not surprising that much of the multiple-channel (audiovisual) research has been conducted in the television venue, particularly with studies dealing with questions of redundancy. Findahl (1971), Reese (1983), and Drew and Grimes (1987) reported the superiority of redundant audio and video presentations in recall, retention of verbal information, and understanding of content. Likewise, Pezdek and Stevens (1984) found that with kindergarten students audio and video channels with *matched* information were better for memory than *mismatched* channels. They concluded that a high degree of redundancy helps learning in the audio channel and hinders it in the visual channel. With nonredundant material the students relied primarily on the video for meaning, however. Calvert, Huston, Watkins, and Wright (1982) reported that children learned more when verbal content was supported by understandable video than when abstract audio was accompanied by recognizable video.

Rolandelli (1989) reports that, in television presentations, the visual mode is more important than the auditory mode when the visual component competes with an incongruent audio tract, but when visual superiority is confounded with complexity and comprehensibility, comprehensibility appears to be a more critical factor in viewer behavior. Audio can enhance comprehensibility by signaling what is worthy of attention and conveys information, which can be understood independently of the visual mode (being present). Studies exploring irrelevant visual distractions (Bither, 1972; Festinger & Maccoby, 1964; Ostehouse & Brock, 1970) found that irrelevant visual distractions have an adverse effect on audio recall.

Lumsdaine and Gladstone (1958), Kale, Grosslight, and McIntyre (1955), and Kopstein and Roshal (1954) found the use of pictorial information or picture–word combinations to be more effective than words alone. Setting out to develop a hypothesis for these findings, Severin (1967a) suggested that the principles of cue summation and stimulus generalization accounted for the improvement in learning. Stimulus generalization implies that learning improves as testing situations become more similar to the presentation situation.

Additional studies have shown the superiority of the multiple-channel presentations of information. Severin (1967b, 1967c) reported that participants receiving information with audio and related pictures received the highest scores of four treatments (sound only, picture only, sound and pictures, sound and unrelated pictures). He also reported finding that individual intelligence scores were less important in predicting learning than types of treatments. Hartman (1961a), in summarizing his study on multiple-channel effectiveness, indicated that "redundant information simultaneously presented by the audio and print channels is more effective in producing learning than the same information in either channel alone" (p. 42). Likewise, reviews of literature by Day and Beach (1950), which focused on the comparisons of audio and print channels, and the Hoban and Van Ormer studies (1950a), which concentrated on pictorial comparisons, made similar conclusions. However, Hartman (1961a) distinguished four relationships between multiple-channel messages in those studies: redundant, related, unrelated, and contradictory. If multiple-channel messages are unrelated or contradictory, they compete with each other, and information interference is the result. That is why multiple-channel presentations were less effective in some studies. But if audio and visual messages were identical or closely related, they complement the other to form one thought and improve learning (Hanson, 1989; Ketcham & Heath, 1962). In educational practices, we seldom deliver unrelated or contradictory messages through multiple-channels. Therefore, an improvement of learning is expected by adopting the multiple-channel approach (Yang, 1993).

The implications of this work for development of multimedia products are considerable. It suggests that the addition of *bells and whistles* may contribute unrelated cues. As Severin (1967b) says, "If interference is accidentally introduced between channels, then much effort, time, and money is wasted, for one channel could then communicate more effectively" (p. 399). This work could provide advice for those engaged in the development of multimedia products for *at-risk* audiences. For these groups, less emphasis on print material combined with the summation of cues using relevant material in the other channels may be more appropriate.

K. U. Smith and Smith (1966) critiqued earlier multiple-channel research (sometimes called *audiovisual research*). The Smiths state,

> Implicit in many of the older research designs which tried to make direct comparisons between different techniques was the assumptions that different types of instruction promoted the same type of learning—presumably the learning of verbal knowledge. These experimental comparisons usually were based on verbal criterion tests, for it was not realized that specialized audiovisual procedures might teach specialized non-verbal knowledge. (p. 142)

Dwyer (1978) identified 19 factors that complicate interpretation and cause contradictory results of the single- and multiple-channel communication research studies. Some criticisms include weakness in experimental design, studies lacking hypotheses, research conducted in nonrealistic situations, and lack of relationship content used in one channel versus another.

Hartman (1961b), commenting on a review of 30 studies of channel comparisons, suggested that for presenting related information through either one or two channels, there is a strong indication of an advantage of combining channels. Severin (1967a) points out, however, that most of these studies were completed prior to 1940 and many contained poor research designs, lacked controls, and had test-channel bias. Interference between channels due to unrelated or opposing information was not recognized in many of the studies. Severin (1967a) continues that a common practice among many communication researchers was to fill all channels in a multiple-channel situation with as much information (cues) as possible, with the expectation that this additional information would increase communication. The probability is quite high, however, that the additional information will only "evoke irreverent cues" (p. 234). Also see a strikingly similar statement by Hartman (1961b, p. 255).

Severin (1967a) attempts to explain the contradictory research findings of those who have studied multiple-channel and single-channel communication. Severin asks why some studies show an increase in learning in cross (multiple)-channel redundancy and others do not. Severin (1967a) suggests that educators sometime use multiple channels without understanding the possibilities of interference between them, and information may be presented via two channels and testing mode presented via only one channel. If, as Broadbent (1957) suggests, the central nervous system is a single system, separate presentations across two channels may not exceed its capacity but, together, could overload and jam it. Gulo and Baron (1965) and Williams and Ogilvie, (1957) suggest that presentations do not always use the second channel to convey information and, thus, add nothing, even redundancy, and might cause interference.

Hsia (1968) also questions the inconsistent findings. He feels that a major cause is the failure to take into account the capacity limit theorem and redundancy. First, redundancy causes information processing to fluctuate. Second, overloading the capacity limit causes equivocation (loss of information). Hsia suggests that decreasing input information in accordance with the information processing capacity will eliminate or reduce equivocation. Adjusting redundancy to an optimum level so that maximum transfer may take place, he submits, will eliminate error.

Conway (1968), however, suggests that "the distinction between redundant and related information must now be regarded as an artifact of faulty conceptualization" (p. 409). He opines that equivalence in referential function is the criterion for redundancy. That is, "two items are redundant in that as sign vehicles they are interpreted to make reference in an equivalent fashion" (p. 409). Two important issues are implied in this discussion. First, Conway questions Severin's hypotheses concerning cue summation and stimulus generalization and the criteria on which they are based. Second, Conway goes to some length discussing whether relationships involving two signs or two modalities are redundant or related. If, as Conway proposes, most of the above relationships are redundant, as opposed to related, then there is no advantage in combining signs or sensory modalities. In refuting the hypothesis that presentations combining two sensory modalities are more efficient than either one of the modalities used alone, Conway cites findings of Van Mondfrans and Travers (1964) and Severin (1967a, 1967c). Severin's (1967a) position states that there is no advantage in using *redundant* information over two modalities versus either one used alone. An example is a presentation of the spoken word *moose* and the written word *moose.* Severin (1967a) hypothesizes that *related or relevant* presentations using two signs offer the greatest gain in communications. An example of the latter would be a picture of a *moose* and the written word *moose* or a picture of a *moose* along with the spoken word *moose.*

Conway (1968), in an attempt to analyze the cue summation and stimulus generalization theories, tested word plus picture presentations against other conditions. He found that the present-picture/test-picture condition to be superior to those of presentword/testword plus picture or present word/test word. He failed to find significance in the present-word/test-picture and present-picture/test-word conditions. Conway suggests that the dual-coding theory (Paivio, 1971) may account for the failure to support the stimulus generalization theory. For example, ". . . Simple pictorial (line drawing) sign vehicles, although presented as single units, are, it is suggested, most likely to be coded and stored in two internal forms and therefore more likely than either word or word plus picture presentations to be readily assessed by the sign-vehicle presentations used to test memory" (p. 412). Using somewhat analogous reasoning to explain Van Mondfrans and Travers' (1964) failure to support an advantage to combined spoken and printed-word presentations, Conway suggests that these messages are functionally equivalent and are already stored in word form. Therefore, using either spoken- or printed-word presentations would be equal in learning to a combined presentation. It would follow that recall would also be equal under either stimulus because the material is stored as a verbal string under both modes of presentation.

Much kinder to cue summation theory and Severin's (1967a, 1967b) views is Hsia (1968, 1971). He submits, ". . . Tangible evidence suggests the possibility that when the amount of information to be processed is optimal, the audiovisual channels may be a more effective means of communication than either single channel" (1968, p. 246). Hsia (1971) makes a very thorough literature review of the discrete ranges of audio, visual, and audiovisual information processing rates and capacities. One of his conclusions is that combined audiovisual presentations produce more dimensionality than audio or visual alone. This dimensionality, he says, brings about an increase in information transfer within the information processing capacity.

Hsia (1968) cautions, however, that multimodal information processing seems to reach the overloading point faster than using single channels alone, especially when the between-channel redundancy is low. In essence, Hsia is proposing that designers remain cognizant of the principle that audiovisual communications will provide dimensionality and address individual learner differences when used within the capacity of the nervous system. He also addresses individual learner traits. For example, he cites research that supports use of the audio channel for young children, poor readers, and those of limited ability. In dealing with literate subjects, however, he provides evidence for using visual presentations. We could easily deduce that this information supports a need for multiple-channel presentations, especially when resources do not permit developing for specific learner types. Severin (1967a) makes the following predictions based on research comparing single-channel communication and multiple-channel communication. Multiple-channel presentations, which combine words and relevant visuals across channels, will be the most effective and superior to single-channels alone. This is due to cue summation across the channels. Multiple-channel communication with unrelated cues across both channels will cause interference and thus single channel presentations will be superior. Single-channel communication will be as effective as multiple-channel presentations when words (aurally and visually) are combined across channels.

Whether one subscribes to Severin's (1967) theory of using related multiple-channel communications or the more generally held notion of using redundant information (Hsia, 1968), there is a considerable body of research supporting combined presentations (Levie & Lentz, 1982). From a review of over 155 experiments, Levie and Lentz suggest that using attention-getting pictorials increases the possibility that material will be looked at, using text-redundant illustrations will facilitate learning of the textual material, illustrations will help learners understand and remember readings, learners often need prompting to pay attention to critical information found in illustrations, learners' enjoyment and affective reactions may be evoked by illustrations, poor readers may benefit from illustrations, and learner-generated imaginal pictures are generally less useful than supplied illustrations.

Supporting both cue summation and stimulus generalization were two studies by Beck (1987). His findings indicated that labeled pictures used during instruction provided more effective encoding cues than arrowed or noncued pictures. During evaluation, the repetition of identical cues appeared to assist learners in retrieving critical information. Mayer (1989) also found evidence that the use of labeled illustrations helped students with limited prior knowledge of mechanical systems recall more explanative information and perform better on problem-solving transfer. He suggested that a meaningful learning model using illustrations helps focus attention on explanative textual information and assimilate the information into useful mental models. Similarly, Rigney and Lutz (1976) found that the addition of images significantly improved learning of complex concepts. Students also found the graphics versions to be more enjoyable. The enjoyment, it appears, increases involvement so those students may acquire concepts from verbal instructional materials. Their research also supports Levie and Lentz's (1982) findings that supplied illustrations are better than user-generated imaginal pictures.

Mayer and Gallini (1990) tested two major features of illustrations that would assist learners in building mental models: system topology and component behavior. The former portrays each major system component; the latter portrays state changes in major components and the relationships of the components as the system functions. An example is the major components of a braking system and the changes each component undergoes in relation to the others as the system is employed. Findings supported their hypothesis that these illustrations would assist explanative recall and improve creative problem solving for low prior knowledge learners.

Mayer and Anderson (1991) extended previous research (Mayer, 1989; Mayer & Gallini, 1990) by using voice narration and animation. Although inconclusive, the results supported the theory that coordinated presentation of narrative and visuals (animation) results in better performance on tests of creative problem solving than presentation of the word before pictures. This research on integrated dual coding was adapted from Paivio's (1971) dual-code hypothesis. This extended theory posits that learners can build both visual and verbal representations as well as connections between them. Significant for designers was the finding that animation without narration had about the same effect as no instruction. Further, presenting unconnected words and pictures is not as useful as presenting coordinated verbal narration simultaneously with animation.

Reynolds and Baker (1987) were interested in the notion of selective attention and its influence on using text and graphical representations. They found that texts with graphs and texts without graphs did not differ in amounts of learning. Presenting materials on a computer, however, did increase attention and learning. Further, that interactive, graphical representation increased attention. The amount learned, although not significant, did show an increase. Their research suggested that when attention was increased, so was the amount of learning.

As noted earlier, questions over the superiority of individual channels have intrigued researchers for years. Conflicting results can be found that favor either channel. Katz and Deutsch (1963) and Travers (1964), for example, reported results that supported the visual channel over the auditory channel. However, Carterette and Jones (1967), Hartman (1961a, 1961b), Henneman (1952), and Mowbray (1952) determined that auditory presentations were superior for young children and had more resistance to interference. Other researchers (Beagles-Roos & Gat, 1983; Meringoff, 1980) found that recall by children is comparable for visual and auditory modalities. However, Hayes, Kelly, and Mandel (1986) disagree and feel verbal information recalled was incidental to the central plot of a televised program. Mudd and McCormick (1960) reported that provided that the information is related, auditory cues of various dimensions appreciably decrease the time involved in a visual search task. Warshaw (1978) reported on a series of experiments where subjects were shown commercials with various juxtapositioning of different levels of audio and video information. He reported that when auditory information was presented without background video (a blank screen), more content was recalled than when audio appeared simultaneously with relevant video, regardless of the level of information content in the second channel. Warshaw continued and stated that multiple-channel presentations do attract more attention than either channel alone, but perceptual interference across multiplechannels will hamper assimilation of the content.

Other studies (supporting the single-channel, nervous system theory; Broadbent, 1958) found no difference between modalities (Baker & Alluisi 1962; Hill & Hecher, 1966). Lorch, Bellock, and Augsback (1987) also noted, in televised presentations, that children's recall of "central" content was comparable to audio only, visual only, or simultaneous across both modes. Grimes (1991) continued, that in studies conducted with television where two channels—audio and visual—are highly redundant, people view the two channels as components of a single message. In a medium-redundancy situation, attention was shifted away from the visual channel and more attention was applied to the auditory channel. He reported contradictory results for a nonredundant presentation; in one study the group attended to the video, and in another study they did not. However, in the two experiments with nonredundant presentations, viewers' memory dropped for auditory messages and suggested low visual attention but high visual memory.

Another area very closely akin to the theoretical base of multiple-channel research is multiple external representations (MERs). Students are given more than one representation (usually visual and words) for the same concept or idea. Moving from one representation of a concept to another is neither automatic nor intuitive. Students do have the opportunity to *see* a concept from a different visual perspective or a different organizational pattern. Ainsworth (1999) suggests a speculative taxonomy for the study and design of multiple external representations.

Ainsworth (1999) asserts that the concept of multimedia and multirepresentational learning environments are essentially the same. The reasons for using MERs are to increase learner's interest and to promote effective learning. The use of such multirepresentational learning environments appear to becoming more widespread but research ". . . has produced mixed results and implies a degree of caution in their use" (p. 132). Research finds that learners have difficulty in translating information from one representation to another and making links across multiple representations is not automatic (Schoenfeld, Smith, & Arcavi, 1993; Yerushalmy, 1991). Ainsworth (1999) argues that MERs must be used for specific purposes, and the failure to take this into account explains some of the conflicting research studies. The specific functions for MERs need to be categorized. Ainsworth (1999) proposes a taxonomy consisting of three separate functions: (a) to support complementary processes and information, (b) to constrain interpretations, and (c) to provide for deeper understandings. Identifying these functions that MERs play should allow the opportunity for learning goals to be supported. Function a means providing alternative representations, which present a different view and different strategies for solving or presenting a problem. This function is supportive and explains the same solutions in a different ways. Constraining interpretations (function b) can be seen as "the more that the format and operators of two representations differ, the harder it will be for the learner the appreciate the relations between them" (p. 147). Function c is when the purpose is to develop a deeper understanding of the situation. These can be done through abstracting, generalizing, or teaching the relationship between the two representations (see also Trepanier-Street, 2000). Ainsworth (1999) suggests that if MERs are designed to support concepts or information, then the relationships should be evident; if they are designed to constrain interpretations, then the relationships should be automatic; if they are to develop deeper understanding, then the relationships should be scaffolded or addative.

36.5 MULTI-IMAGE PRESENTATIONS

The concept of multi-image is closely akin to properties of cue summation research, which suggests increased learning from more cues within a single channel or using more cues across (multiple) channels. Multi-image research was very popular in the 1960s and 1970s. The multi-image format in these earlier studies generally referred to the use of more than one image, with or without audio synchronization, on single- or multiple-projection screens. Millard (1964) stated that simultaneous images can be used advantageously in instructional situations that require comparisons, the development of interrelated concepts, illustrations, of relationships, or the presentation of dimensional and spatial characteristics of objects. Perrin's (1969) theory of using multi-images is based on the simultaneous presentation of images in which images interact; this may be of significance in making comparisons and establishing relationships. Film, slides, television, etc. (not current interactive multimedia formats), presented content and images in a sequential, linear format; the meaning was based on the context (content that preceded) of the image. However, multi-image, as Perrin states, allows ". . . the viewer to process larger amounts of information in a very short time. Thus information density is effectively increased, and certain kinds of information are more efficiently learned" (p. 369). However, questions raised earlier by Hartman (1961), Hsia (1971), and others concerning the efficacy of simultaneously presenting information across (and within) channels also apply to the concept of multi-image presentations.

Burke and Leps (1989) indicated that there might have been a *failure* by multiple image enthusiasts to prove its effectiveness. Multi-image, like other specific technologies, has always had to use traditional media comparison studies, with their inherent problems. Fradkin (1974, 1976) noted that although there was wide use of multi-image in education, there was little empirical evidence in support of increased learning. Moreover, Burke and Leps (1989) note that little research on multi-image presentations has investigated the validity of aspects of Perrin's theory and that many studies of multiple-image presentations have been limited to self-serving individuals involved in the hardware and production processes.

All of these instructional situations require association, which, according to Gagné (1965), is one of the basic mechanisms of learning. According to Perrin (1969), the number of instances available to the viewer to make associations by visual comparison is greater with simultaneously presented images than with sequentially presented images. Low (1968) pointed out that in single-image presentations one image follows another, thus determining the interrelationships between images. In multiple-image presentations, several images appear simultaneously and "interact upon each other *at the same time,* and this is of significant value in making comparisons and relationships" (Perrin, 1969, p. 90).

Perrin (1969) stressed that images are especially rich in information and in the range of associations they stimulate. Without careful control by the communicator, there is the possibility that some associations can conflict with the intended message, causing interference. Relevance, realism, and simplicity have been found to be important in learning from book illustrations (Spaulding, 1956) and in learning from films (May & Lumsdaine, 1958). These factors are equally important in presentations utilizing multiple-imagery (Perrin, 1969). A viewer's ability to determine relationships between images has an effect on memory and recall (Berger, 1973; Low, 1968). Low stated that no single image can establish certain memory combinations, but a group of images perceived simultaneously often recalls long forgotten memories. Berger (1973) found that multi-image techniques are effective in expediting the recall of events and thought-feeling associations in analytic psychology. The recall of memories and of events attributed to simultaneous images may be a function of viewers' freedom to select their own sequence (Bruner, 1967; Gagné & Briggs, 1974). Therefore, as Perrin (1969) pointed out, presenting images simultaneously and allowing viewers to select their own sequential order may have an effect on the learning taking place. Roshka (1960), Malandin (cited in Perrin, 1969), and Allen and Cooney (1963) found simultaneous presentation of images effective in instruction with younger children. Roshka (1960) found that simultaneous images had less effect with older children, and Allen and Cooney (1963) stated that simultaneous images had a significant effect on learning of sixth graders but not eighth graders. Malandin (cited in Perrin, 1969) found that primary classes had difficulty with recall from sequential images but that grouping the images permitted an increase in the number of recollections and organization of the recollections. These studies support Perrin's (1969) view that image simultaneity is a significant factor in some learning situations. Beck (1983), in a study, that supported Perrin's views, found that subjects exposed to simultaneous picture formats achieved significantly higher scores than subjects exposed to successive (linear) formats. Goldstein (1975) stated that the simultaneous presentation of multiple images is in many respects "like the environment, it contains meaningful material, it surrounds us, and it is constantly changing" (p. 63).

A caution that emerges from the literature concerning the simultaneity of multiple images is that the theory of cue summation may not be valid in some contexts. (Recall that cue summation, as noted earlier, is the general theory positing that the more cues that are given through various communications channels, the more learning occurs [Whitley, 1977].) Perrin (1969) notes that the use of simultaneous multiple images places a burden on the visual channel and that, in the multiplication of visual stimuli, irrelevant as well as relevant detail is increased. Therefore, care must be taken to assure that the visual stimuli are clear and simple and that detail included is relevant.

Otherwise the result is not cue summation, but confusion. A study by Fradkin and Meyrowitz (1975) supports this hypothesis that cue summation and the avoidance of conflicting cues are important in the design of multiple-image presentations produced for cognitive learning situations.

36.5.1 Screen Size

The use of a large screen coupled with the simultaneous projection of two or more images has been cited as one of the major, inherent advantages of multiple-imagery. A large screen provides better approximations of *real* environments by supplying the physical and psychological factors necessary for realism and involvement (Perrin, 1969).

Blackwell (1968) indicated that tasks requiring high visual acuity, such as detecting differences in texture or patterns, might benefit from the use of large screen presentations. Schlanger (1966) identified two factors affecting usefulness of large screens: visual impact and visual task. Visual impact is the amount and forcefulness of information available to the sense of sight. The visual impact is proportional to the amount of the viewer's field of view that the screen occupies. According to Blackwell, visual impact on the viewer is greater in large screen presentations because more of the viewer's field of vision is occupied by the projected image—therefore limiting the chance of distraction from the surrounding environment. Schlanger stated that large screens can produce information rich in detail for the visual channel and simulate real environments, but Blackwell warned that any channel of communication loaded with information details might be distracting if the details are irrelevant to the learning situation. Travers (1966), in attempting to deal with excess details, hypothesized that line drawings would be advantageous because they eliminated superfluous detail. His experiments with oversimplified drawings, however, indicate poor transfer of learning to real situations. Blackwell stated that the advantage of a large screen to reduce the visual task factor is conditional. Presented images, for example, must contain enough irrelevant detail to convey the proper message (which may not have been the situation in Travers' experiments) but not so much detail as to distract learners. Barr (1963) stated that a large screen opens up the frame and gives a greater sense of continuous space. The more open the frame, the greater the impression of depth; the image is more vivid. This suggests simultaneous images produce an increase in information density during presentations.

36.5.2 Information Density

A higher density of information is possible with multiple than with linear imagery. There are several dimensions to information density in multiple-image presentations (Whitley, 1977). Perrin (1969) believes that it is important to distinguish between the method of presentation and the mechanism of perception. He states that the theory of multiple images suggests that for making contrasts and comparisons, and for learning relationships, "simultaneous images reduce the task of memory (a dimension of visual task) and enable the viewer to make immediate comparisons" (p. 376).

Langer (1957) utilizes the terms *linear* and *nonlinear* to distinguish between verbal and iconic signs. She stresses the sequential ordering, the *strung-out* arrangement of linear (verbal) signs in time and contrasts this with the *all-at-once* (parallel) character inherent in pictorial signs (p. 83). Her position is that even single pictures shown in sequential order are essentially nonlinear (Whitley, 1977).

Nonlinearity and simultaneity go hand in hand. The use of visual images, inherently nonlinear, allows the presentation of a great deal of information simultaneously rather than sequentially, as with words arranged in sentences and thus bound to grammatical ordering and syntax. Perrin (1969) expands this line of analysis and hypothesizes that when visual images are combined in multi-image presentations, the result is an increase in the amount of information that is presented simultaneously or in the information density of the presentation.

Information density can be increased further if the information is organized properly (Whitley, 1977). McFee (1969) believes that visual organization is more important than the actual amount of information present. Much of our responding occurs so quickly that we are unaware of our own processing. Selecting and organizing visuals in advance make the information easier to assimilate for the user (p. 85).

Investigative confirmation of the importance of organization is illustrated by the introduction of a carefully organized and automated televised instructional system called TeleMation at the University of Wisconsin. Hubbard found (1961) that information density could be increased significantly through proper organization without loss of material or loss of learning by students. A similar finding resulted when the Army Ordinance Guided Missile School conducted a series of evaluative studies in 1958 (U.S. Army, 1959). Instruction time was reduced 19.5% to 41% for a similar level of achievement, and an increase in learning was reported for the experimental groups 9 weeks later. Allen and Cooney (1963), however, suggested that time saved in instruction was as much a function of care in preparation as it was a function of the multi-imaged delivery of the subject matter.

Commercial producers claim that information density created through multiple-imagery results in motivation and arousal. A serious question is whether or not this arousal is beneficial (Whitley, 1977). Research on motivation indicates that an increase in motivation improves performance (R. L. Smith, 1966) but that there is an optimum level. Eysenck (1963) found that for complex tasks, optimum performance is achieved when the drive is relatively low; only for simple tasks is the optimum achieved with a relatively high drive. Kleinsmith and Kaplan (1963, 1964) and Kleinsmith, Kaplan, and Tarte (1963) found that there is some confusion between learning and performance, with individuals sometimes performing very poorly in highly arousing situations, yet tending to remember most vividly those incidents in their lives that were most traumatic or arousing. These researchers measured skin conductivity, and their findings indicated that high-arousal associates showed stronger permanent memory and weaker immediate memory than low-arousal associates did. Low arousal was accompanied by the normal forgetting curve. High-arousal subjects showed poor immediate recall. This may explain some inconsistencies in research with regard to long-term retention. For example, VanderMeer (1951) found that color films did not increase immediate learning but produced greater long-term retention. The findings of Kleinsmith suggest that the cause may have been the arousal produced by the color films.

Fleisher (1969) stated that the mind and eye have proven to be capable of tremendous speed and versatility in accepting multiple impressions and that during a multi-image presentation the viewer's eyes explore the entire screen and keep the viewer very conscious of what is happening. In contrast, Goldstein (1975) indicated that multi-image presentation might cause information overload by presenting more information than the viewer can process and thus create arousal through frustration. This arousal may cause multi-image presentations to be highly motivating but not very informative (Kreszock, 1981). Goldstein stated that when presenting specific concepts or highly technical information, multi-image presentations should be used with restraint. Perrin (1969) concluded that it is clear that high densities of information can be *perceived* during a multi-image presentation, but he went on to question whether great amounts of information were *learned* from these perceptions.

Several studies have compared different aspects of single-image and multi-image presentations. Lombard (1969) used both a single-image and a multi-image format to teach synthesis skills in history to eleventh-grade students. He found no significant differences in males between the single-image and the multi-image presentations at any achievement level, and the only female group to demonstrate any significant difference were the low achievers. These low-achieving females who received the multi-image presentations surpassed both the males and the females in the average and high-achieving groups that received the single-image format. Some of the procedures used in Lombard's study, however, make his findings dubious.

Conducting a study to explore the affective impact of multi-image presentations, Bollman (1970) experimented to see if there was any difference in the amount of shift in evaluative meaning of audiences viewing multi-image presentations versus audiences viewing single-image presentations and to ascertain if the person's relationship to the screen had any effect on shifts in evaluative meaning. In his conclusions, Bollman stated that this experiment did not produce significant statistical evidence or conclusive answers.

Atherton (1971) conducted a study to determine if a multi-image slide presentation would result in greater affective and cognitive learning than similar content presented by a 16-mm film. No significant differences were found between groups in the amount of attitudinal change elicited as a result of the presentation or between treatment of groups relative to the cognitive learning resulting from viewing the presentations. These analyses indicated that one treatment was not more effective (or even affective) than the other in producing positive increases in affective or cognitive learning (Atherton, 1971). Didcoct (1958) conducted a study of the cognitive and affective responses of college students to single-image and multi-image presentations. He found no difference in attitude or cognitive retention between a group viewing a single-image presentation and a group viewing a multi-image presentation.

Westwater (1972), in conducting a descriptive study to gather information about the field use of a multi-image presentation, found that about 80% of the teachers who participated in the study would like to use such presentations to a greater degree. Westwater, however, pointed out two major limitations to the development of multi-image presentations: Few teachers were familiar with the characteristics and capabilities of large multi-image presentations, and there was a lack of knowledge concerning their utility.

Jonassen (1979) states that it is generally believed that research on multi-image presentation revolves around linear vs. simultaneous presentation factors. Using Perrin's (1969) theory, most researchers predict that learning will increase (however that is measured) when "the viewer makes his own montage of different image elements, increasing the probability of learning comparative information" (p. 369). Jonassen indicates that the mere presentation of simultaneous images do not necessarily lead to simultaneous mental processing. The viewer still must provide a cognitive strategy for processing and making sense of the presentation order. Just as linear sequenced material must be processed based on content and syntactic associations, so must multi-image presentations. Jonassen finds that the literature on multi-image (simultaneous) presentations has yielded contradictory results. He feels that incomplete questions were asked in the research hypothesis instead of just asking about linearity vs. simultaneity. Researchers should consider "how simultaneous images can best be structured to facilitate specific types of learning behavior" (p. 292). Jonassen continues by indicating that proponents have assumed that multi-image presentations are a unique form of communication. Multi-imagery is *not a medium;* it is a presentation mode that can manipulate visual perception. Therefore, study of multi-image presentations should be based on established principles of concept learning. To date, little research in this area has been conducted with concept teaching in mind. An exception would be the study conducted by Whitley and Moore (1979), which found a significant interaction between a student perceptual type (visual vs. haptics) and presentation mode (linear vs. simultaneous). Haptics scored higher with multi-image presentations. Another exception was completed by Ausburn (1975), who found that both haptics and visuals benefited from multi-image presentations.

Burke and Leps (1989), gleaning information from the limited (and possibility flawed) research on multi-image presentations, feel that multi-imagery as a concept offers little to learners to improve cognitive potential or *affective impact*. This is due to conceptually weak studies. The limited number of reviews concerning multiple-image research (Allen & Cooney, 1964; Burke, 1987; Burke & Leps, 1989) has revealed few usable results. There is, of course, the seemingly ever-present problem of research design and implications. These basic problems included retention studies comparing single-images and multiple-image presentations, which were flawed by the presence of unnecessary recall data in both sound tracks. In addition, " the comparisons were usually of single and multiple-screen versions of the same material, thereby canceling out Perrin's theoretical call for multi-image to enhance a basic message" (Burke & Leps, 1989, p. 185). Burke and Leps, however, feel that multi-image presentations were given little opportunity to prove themselves due to cost and technical execution of the presentations.

36.6 SUBLIMINAL PERCEPTION AND INSTRUCTION

Subliminal perception refers to visual and auditory information presented at a speed and or intensity that is below the conscious threshold of perception through one or more channels and thus not readily apparent to the person (Moore, 1982). Subliminal perception, like multi-image presentations, is closely related to the theoretical bases of cue summation and multiple-channel research. All are interested in providing the learner with the maximum amount of usable cues, with the idea that these cues will support and reinforce each other. This is similar to multiple-channel theory, which suggests that additional simultaneous cues within and across sensory channels provide greater reinforcement in organizing and structuring information.

Experiments using subliminal exposure to visual and audio stimuli have been reported in psychological journals since 1863 (*Application of Subliminal Perception in Advertising,* 1958). Reviews of experimentation in subliminal perception have contributed summaries of various points of view. Three excellent sources on the subject were published by Miller (1942), Adams (1957), and McConnell, Cutler, and McNeil (1958). All three sources indicate that research results have differed widely (DeChenne, 1975).

In reviewing three summaries of research on subliminal perception (Bevan, 1964; Dixon, 1971; McConnell et al., 1958), several generalizations become apparent. Susceptibility to subliminal stimulation varies among people and is dependent on factors such as anxiety, attentiveness, and need state. Sensitivity to subliminal effects tends to be cumulative, as repeated viewing of subliminal materials tend to make a person more aware of the technique. Differences in awareness thresholds also determine whether subliminal messages are perceived. Perception thresholds can be lowered if the duration of the subliminal exposure increases or if the message is of a different brightness than the surrounding visual field. In other words, the closer the material is to being consciously visible, the more likely it is to be perceived (Moore, 1982).

Early experiments were designed to provide evidence that the psychological phenomenon of subliminal perception was a reality. Hollingworth (1919) reported one of the earliest of these experiments. Others include experiments by Maker (1937), Coyne, King, Zubin, and Landis (1943), McGinnus (1949), Lazarus and McClearey (1951), and Wilcot (1953). All except Wilcot reported results that there had been definite unconscious recognition or influence by stimuli below the conscious threshold. These studies gained attention for the concept of subliminal perception but brought about additional research that was often inconclusive and contradictory (Moore, 1982). More recent experiments have focused on determining relationships between subliminal perception and behavior. Studies of this type include those by Klein, Spence, Holt, and Gourevtich (1958) and G. J. W. Smith, Spence, and Klein (1959), both of which reported tendencies of a positive nature concerning the effectiveness of subliminal perception.

Several studies have been conducted to determine whether subliminal shapes or words could be detected when superimposed on a still or moving picture. One method of operationalizing subliminal stimulation is to superimpose a message at a very low relative brightness for a long period of time. DeFleur and Petranoff (1959) used this method in one of the first studies of subliminal perception using television as a carrier medium. The subliminal material in this experiment was superimposed as an extremely faint image relative to the main program. Analysis of the results indicated that significantly more correct guesses had occurred than would have been expected by chance. It was not reported if the participants were asked whether they had consciously seen any of the shapes during the film. Nevertheless, the results seemed to indicate that TV images of extremely low brightness influenced their responses.

Moore (1982) commented that the low-intensity, constant-image technique that used by DeFleur and Petranoff could result in the subliminal image being consciously visible. Because the visual field of the motion picture was dynamic (the images moved and changed), the faint subliminal words or shapes that were on the screen may have become partially unmasked at times as the foreground images changed. For example, if the constantly superimposed, subliminal images were white and the foreground images (the motion picture) in the same area of the screen were momentarily dark, then the resulting contrast differences may have been sufficient to unmask and reveal the subliminal word or shape or an identifiable segment of it. If the superimposed words or shapes were flashed quickly rather than exposed constantly, then the visual threshold of viewers would remain higher and the images would more likely remain subliminal (Moore).

Several other researchers have reported similar experiments. In these experiments, the subliminal shapes or words were non-moving images on a neutral background, compared to the moving foreground images used by DeFleur and Petranoff (1959). Schiff (1961) and King, Landis, and Zubin (1944) reported positive results, whereas Calvin and Dollenmayer (1959) and Champion and Turner (1959) concluded that there was no definitive evidence that behavior was altered by subliminal presentations. The relationship between subliminal stimulation and cognitive functions has been studied in a number of experiments. Kolars (1957) (two studies) and Gerard (1960) used a problem-solving task in which rows of geometric figures were presented simultaneously by a tachistoscope. Kolars concluded that the presentations of subliminal stimuli did influence the frequency of correct answers in both studies. Gerard tested participants' ability to mentally reconstruct a composite, geometric figure into alternative assemblies. One group saw the correct solution, another group saw an incorrect solution, and the control group saw no subliminal solution.

The results indicated that the control group did better than either of the subliminal treatment groups. However, the group shown the correct answers did better than the group shown the incorrect answers, as hypothesized. Gerard's results partially confirmed Kolers' findings, however, that subliminal presentations could affect performance on problem solving tests (DeChenne, 1975; Moore, 1982; Moore & Moore, 1984).

The research described above (Calvin & Dollenmayer, 1959; DeFleur & Petranoff, 1959; Gerald, 1960; Kolers, 1957) indicates that subliminal perception can occur among certain people in laboratory settings. In contrast to Murch (1965) and Sharp (1959), who demonstrated that choice behavior could be altered in a test-taking situation, the experiments of DeChenne (1975), Skinner (1969), and Taris (1970) failed to demonstrate that direct teaching by subliminal perception can occur. Although various laboratory experiments have produced evidence that subliminal perception can occur, field experiments conducted to test direct teaching by subliminal perception have not yielded collaborative results.

Moore (1982) contends that when teaching by a subliminal means under conditions when the subject matter to be taught is transmitted with films that are unrelated and/or irrelevant to the subject matter, the possibility for content interference is great and the lack of conductive and focused learning setting would seem to hinder learning further. "Expecting subliminally produced learning to occur now seems less realistic than expecting a classroom teacher to teach while students are watching an Abbott and Costello comedy" (pp. 19–20).

A number of studies investigated the possibilities that motivation might be influenced by subliminal perception. Among these were studies by Byrne (1959) and Goldstein and Davis (1961), whose results indicated no influence on the subjects. Goldstein and Barthal (1968) and Zuckerman (1960) conducted studies to determine whether subliminal stimulation could influence elaborative thinking. In both studies positive and negative words were subliminally flashed with pictures from the Thematic-Apperception Test. Both studies reported contradictory results when participants were asked to create and elaborate on stories and the amount written as directed in the subliminal constructions. Shevrin and Luborsky (1958) and Johnson and Erikson (1961) reported similar results to support their theory that there was a tendency for tachiscopically presented material to appear in daydreams and dreams.

In addition to content reinforcement, Moore (1982) asked what effect individual cognitive style differences may have on learning from subliminal media treatments. Most early subliminal perception research limited consideration of individual participant differences to sex, race, and IQ. Other (undetected) differences in sample populations might explain why many replication attempts have failed to confirm original findings and why many findings are contradictory. In a review of subliminal research, McConnell et al. (1958) stated that individual differences "must be taken into account by anyone who wishes to deal with individuals. It is quite likely that many differences in the perception of subliminal stimuli do exist between individuals of differing classes, ages, and sexes" (p. 236). Allison (1963), Murch (1965), and Sackeim, Packer, and Gur (1977) have shown that individual differences such as thought strategies, cognitive set, and hemisphericity were related to susceptibility to subliminal stimulation. DeChenne (1975) and Skinner (1969) did not collect data on individual differences in learning styles or abilities within their samples. This would have made detecting the effect of the treatment more difficult if aptitude–treatment interaction effects were occurring, as the slight increase in treatment effectiveness in these two studies may indicate. The term *individual differences* is also associated with the concept of cognitive styles.

Past studies questioned whether subliminal perception could be a useful tool for producers of educational television and explored the feasibility of teaching one topic while students were watching a program unrelated in content (DeChenne, 1975; Skinner, 1969; Taris, 1970). The results indicated that subliminal messages were generally not powerful enough to cause learning when students were concentrating on an unrelated topic. In other words, it is unrealistic for educational producers to expect that students could be taught two topics simultaneously, one through normal channels and the other through subliminal perception (Moore, 1982; Moore & Moore, 1984). However, there was some evidence (DeChenne, 1975) that some students seeing subliminal cues performed better on a criterion task. This suggested that individual differences such as intelligence or perceptual abilities may be related to the ability to profit from subliminal messages implanted in a television program. This is generally consistent with Calvin and Dollenmayer (1959), Gerard (1960), Murch (1965), and Sharp (1959).

The properties of visual subliminal messages include being faintly and quickly embedded within a surrounding visual field. A student's ability to profit from subliminal messages could be related to the ability to dissembe the message from the surrounding television picture. Therefore, it was thought that the cognitive style of field dependence might have some relationship to the potential usefulness of subliminal perception. People have different ways of perceiving their environment, and these differences may have been associated with the differences in subliminal learning seen in various studies (Calvin & Dollenmayer, 1959; DeChenne, 1975; Gerard, 1960; Kolers, 1957). Based on the literature, it also could be expected that field-independent individuals, because they have highly developed skills at dissembedding one object or image from a surrounding array of objects or images, should likewise be able to distinguish the embedded subliminal messages in a television picture (Greco & McClung, 1979; Hessler, 1972). The real benefit in learning, however, could occur for those students who are field dependent, as they typically benefit from more salient content organization cues (Witkin, Moore, Goodenough, & Cox, 1977). Thus, the use of subliminal reinforcement cues (captions) could be of most value to field-dependent students, because the captions would supplant students' reduced ability to distinguish between relevant and nonrelevant cues and would make the relevant cues more salient.

In Moore's (1982) experiment, these differences in cognitive style were studied as a possible intervening factor for consideration in the production and utilization of subliminal materials. In the analysis of data, it was found that students having prior experience with the subject matter, such as in a previous course, averaged highest on the recall test, as one would execute. These students were eliminated from subsequent analysis, as their prior knowledge may have reflected outside influence.

The available experiments and observations on subliminal perception seem to indicate that in certain instances human subjects are capable of responding to audio and visual stimuli that are so weak in duration, intensity, or clarity that they are not consciously aware of them. Researchers have varying opinions as to the effectiveness of subliminal stimulation and there is no conclusive evidence as to its ineffectiveness or effectiveness. However, the body of evidence does indicate that, effective or not, there is perception below the threshold of awareness (DeChenne, 1975). There appear to be major concerns, however, involved in determining the amount of information a human can process at any one time. To recognize information simultaneously, the various receptors (eyes, ears) would have to analyze a great variety of different cues. All the findings noted in the previous sections, e.g., multiple-channel, communication, multi-imagery, and subliminal perception, have import to the design of multimedia presentations. Basic decisions have to be made to determine concerning how the presentation is to be developed, the number of cues to be available, and the number of channels to be used.

36.7 MULTIMEDIA RESEARCH

Technology does not stand still. As the debate as to the efficacy of technology's impact on learning continues, microcomputers become more powerful and flexible. Compared to the first microcomputers, today's classroom machines can have easily thousands of times the amount of internal memory. Audio and visual capabilities will soon exceed those of today's television, and auxiliary storage will soon be practically unlimited (Moore et al., 1994). Because of these (and related technological advances in software), everyday users, and most particularly educators, have access to systems called multimedia and hypermedia. Yet the development of the interactive technologies that we now call multimedia has not been without controversy or unfulfilled promises (Gleason, 1991).

Although the concept of multimedia has been present for a long time, educators and the technology industry cannot decide exactly what the concept of multimedia includes (Strommen & Revelle, 1990). Until recently, the term has meant the use of several media devices, sometimes in a coordinated fashion (e.g., synchronized slides with audio tape) Advances in technology, however, have combined these media so that information previously delivered by several devices is now integrated into one device (Kozma, 1991, p. 199). The computer now plays a central organizing role in this environment. Questions remain. For example, does multimedia include, interactive video, CDI, and DVI as well as traditional slide shows supplemented by sound and many other media formats?

The most commonly accepted definition of multimedia appears to support the concept of computer-driven interactivity with the learner's ability to determine and control the sequence and content selection. Matchett and Elliott (1991) argue that interactive multimedia should include motion, voice plus data, text, and graphic and still images. This definition permits multimedia to *absorb* the historically older and somewhat broader notion of hypermedia—which is discussed in more detail later. As such, interactive video is a ***high-bandwidth*** source in the sense that a great deal of information, in many modes, or channels, is available at once (i.e., parallel fashion). DeBloois (1982) indicates that "it is important to realize that interactive video (multimedia) is not merely a merging of video and computer mediums; it is an entirely new media with characteristics quite unlike each of the composites" (p. 33). The attraction of interactive multimedia is that it includes two of the more powerful educational technologies: the computer and video. Unlike some of the earlier linear technologies that allowed the user to remain passive, the new interactive programs not only allow viewers to become involved but demand it (Gleason, 1991). By doing so, these technologies have closed the gap between learner control and learning styles in some of the earlier theories. Interactive multimedia allows the user to see, hear, and do.

Others attempt more elaborate definitions of multimedia, especially as it pertains to its role in learning (K. Smith, 2001). Mayer (2001) defines three ways in which multimedia can be viewed: based on the delivery media, the presentation modes, and the sensory modalities involved in the process of receiving instructional messages. The delivery media view focuses on the physical system used to deliver the information. The combinations of two or more delivery devices comprise a multimedia system. Mayer (2001) rejects this view because the focus is on technology rather than on the learner. The presentation mode view focuses the combination of technologies, e.g., sound and image. This view became more learner centered based on a cognitive theory that assumes that learners have separate information processing channels (Paivio, 1971). The third view, the sensory modality view, focuses on the sensory receptor that the learner uses to perceive the material. Examples of this type of view include the use of animation, which can be perceived visually along with narration. This view became more learner centered because it takes into account the learner's information processing activity (Mayer, 2001). Through this mix of presentation techniques, interactive multimedia can appeal to learners who prefer to receive information by reading, those who learn best through hearing and those who prefer hands-on environments (Moore et al., 1994).

36.7.1 Multimedia

Research concerning the learning impact of this medium is still sketchy. Its potential is important because it can combine all the symbol systems discussed above. An important distinction in this medium, however, is that the computer controls the use of the various system states. Distinct potential advantages accrue when using this media-rich environment. The learner can develop pattern recognition skills from the video and access information (in all modes) in a random manner. The latter capability takes the learner out of the traditional sequential environment and into one in which he or she can explore the domain from multiple perspectives (Cognition and Technology Group at Vanderbilt, 1990). Using interactive videodisc, the learner can be placed into contexts that simulate the *real world*. This type of learning has been referred to as *situated cognition* (Brown, Collins, & Duguid, 1989) because the information learned is tied to retrieval cues in the environments it will be needed.

An excellent example of situated cognition is the *anchored instruction work* done by the Cognition and Technology Group at Vanderbilt (1990). They believed that young students learn better in meaningful, socially organized contexts. Their research indicated that problem-oriented approaches are more effective than fact-oriented approaches in overcoming inert knowledge (knowledge people know but often fail to use in problem-solving situations). The methodology is designed to help students develop rich mental models as the basis for future learning, create environments that permit sustained exploration by students and teachers, help students explore the domain from multiple perspectives, and develop integrated knowledge structures that help students transfer knowledge to more complex tasks. (It should be noted that the preceding comments are speculative and are not confirmed by direct research.).

36.7.2 Hypermedia

This technology parallels mental models by permitting associations or links among various ideas to be formed, then constructing meaning among these relationships (Kozma, 1991). Research suggests that a number of concepts can be explored by using hypermedia's cognitive flexibility. For example, users might be interested in pursuing information about land navigation. Searching in this area might turn up information about magnetic principles, topography, uses of the compass, terrain orientation, the coordinate system, and celestial navigation. The learner could follow one or all of these links—all of which would provide further links. There might also be an opportunity to watch a video of participants engaged in the sport of orienteering or simulations using triangulation to determine location. Although research on hypermedia is in its infancy, the learner will have access to a multitude of information. This information will allow the formation (and tracking) of mental models or schemata on unlimited types of domains.

Kozma (1991) suggested that " various aspects of the learning process are influenced by cognitively relevant characteristics of media: their technologies, symbol systems, and processing capabilities" (p. 205). He also submits that learning is influenced by taking "... advantage of the medium's cognitively relevant capabilities to complement the learner's cognitive abilities and prior knowledge and cognitive skills" (p. 205). The discussion has considered basic cognitive learning theory and the dual-code theory, which links learning to the symbol systems inherent in multimedia. Also important is the strategy used by the instructional designer or teacher to take advantage of cognitive psychology in employing media. The discussion now turns to two approaches in which multimedia applications demonstrate the use of cognitive theory.

Liao (1999) conducted a metanalysis on 46 studies conducted from 1996 to 1998, which compared the effects of hypermedia versus nonhypermedia instruction. These studies came from computer searches of ERIC, Comprehensive Dissertation Abstracts, and bibliographies from review and computer searches. Liao noted that his findings acknowledge the concerns noted by Clark (1983) about the problems of comparison studies and suggested that Clark "might overlook the fact that certain media attributes make certain methods possible, particularly when new technology such as hypermedia, is used as the delivery system" (p. 256).

Liao (1999) reported that in the 46 studies included in his metanalysis, 61% (28) favored hypermedia instruction (including interactive videos, computer simulations, and interactive multimedia) compared to nonhypermedia instruction (e.g., traditional instruction, computer-assisted instruction or videotapes). Thirty-seven percent of these comparison studies favored the nonhypermedia instruction groups and 2% found no differences in the two. Likewise, regarding the effect size of 143 comparisons within the 46 studies reviewed, 60% (86) were positive and favored the hypermedia instruction group, whereas 37% (53) were negative and favored the nonhypermedia instruction groups. Liao suggested that these results clearly indicated the positive effects of hypermedia instruction over nonhypermedia instruction and "should not be confused with the uncontrolled effects of instructional method noted by Clark" (p. 270). (Note: The authors of this chapter are still quite concerned about the reliability and validity of these *comparison studies,* Liao's earlier comments not withstanding. Moreover, Liao's type of interpretation is a good example of what Orey, Garrison, and Burton [1989] have described as accepting the null hypothesis but not embracing it as true. This situation creates some interesting assumptions between so-called *hard* and so-called *soft* sciences. For example, Meehl [1967] articulated that a major concern about social science research was the tendency to 'treat disconfirming instances with equal methodological respect as if one could, so to speak, 'count noses,' so that if a theory has somewhat more confirming instances it is in pretty good shape evidentially" [p.112].)

Tergan (1997) reviewed several empirical studies, conducted a theoretical analysis, and suggested that the literature made the following assumptions concerning hypertext and/or hypermedia research.

1. Structural and functional features of hypertext/hypermedia mimic the structure and function of the human mind (p. 258).
2. Hypermedia/hypertext match instructional principles for self-regulation and constructivist learning (p. 262).
3. Hypermedia/hypertext match cognitive principles of multiple modes for the mental representation of knowledge (p. 271).

Tergan's (1997) review indicated that research on multimedia has been based on technology rather than on new instructional concepts that use technology but are not driven by it. He continued that most multimedia research is not theoretically sound. Many cognitive theories do not cope with complex self-regulated hypermedia-based learning, because these theories have been misinterpreted, e.g., "like the constructivist principle which has conceptually been put on the same level with exploratory cognitive processing itself-regulated interactive learning" (p. 276). Knowledge acquisition and transfer to complex hypermedia environments have been overgeneralized. For instance, Tergan suggested that in the apparent match of the technical features of multimedia, neither theory nor empirical evidence matches the functions of the human mind (p. 262). His second review dealt with the assumption that hypermedia technical functions match the instructional function of self-regulation and constructivist learning. He concluded that hypermedia did not "induce incidentally efficient autonomous constructive cognitive processes," (p. 269). When positive results are reported, it is based on the learners themselves, independent of the hypermedia itself (see Dee-Lukas & Larkin, 1992; Jonassen & Wang, 1992; Jonassen, 1993). Only under conditions of "self-regulating competencies, well defined roles, and explicit scaffolding" are learners' cognitive processing functions supported by hypermedia structures (p. 269). (See also Rouet, 1992; Jonassen, 1993; and Jacobson, Maouri, Mishra, & Kolar, 1995.) Tergan's summary of the third assumption (that hypermedia functions match the multiple modes of mental representation of knowledge) concluded that these "theories based upon assumptions concerning possible additive and integrative effects of multimedia are underdetermined, because of possible interactions of psychologically relevant media with learner prerequisites, cognitive requirements of the task to be accomplished, and (the) constraints of instructional design are not taken into account" (p. 275). Also see Clark (1983).

36.7.3 Using the Evidence to Evaluate Multimedia Programs

Does multimedia really work? To answer this question, it is necessary to note some of the earlier-mentioned learning theories but also to note earlier media-related research. It may also be useful to differentiate between evaluation studies and research. Evaluation is practical and is concerned with how to improve a product or whether to buy/use a product. Studies that compare one program or media against another (or a control for that matter) are primarily evaluations. Evaluation seeks to find programs that *work* more cheaply, efficiently, quickly, and effectively. Research, on the other hand, tends to be more concerned with testing theoretical concepts and constructs or attempting to isolate variables to observe their contributions to a process or outcome. Having said this, we should point out that the two terms evaluation and research are often used interchangeably in the fields of education and media (Moore et al., 1994).

Multimedia is a combination of many technologies, most notably the computer, which allows for true interaction. Strommen and Revelle (1990) stress the importance of existing research literature on computer usage for understanding the pragmatic requirements of developing interactive tasks in the multimedia programs that were developed at the Children's Television Workshop. This literature helped "take children's special needs into account and . . . [delineate] what the content of our interactive tasks should be and how those tasks should be structured" (pp. 77–78).

E. E. Smith (1987) indicated that there are three major sectors in our society that use, and conduct research on the effects of interactive multimedia: the military, the industry, and education. Educational use of multimedia programs is still limited and, in most cases, still experimental. Two multimedia formats (videodisc and videotape) predominate in education. As you would expect, multimedia researchers are still debating their relative values and virtues (Smith, 1987). However, the marketplace may decide the winner and DVI technologies such as CD-ROM and Quicktime may well settle the debate in a practical sense. Despite the short duration of multimedia's availability, Smith reports evidence for both the effectiveness and the efficiency of the interactive media in learning. Other researchers argue that there is little to support the contentions of the effectiveness of interactive media. They contend that little progress has been made since Clark (1983) argued that media in general have little substantial impact on learning (Hannafin, 1985; Slee, 1989). Hannafin (1985) asserts that although the interactive technology, as noted earlier, offers interesting potential, interactive video differs little from the allied technology from either *learning or cognitive perspectives*.

Ragan, Boyce, Redwine, Savenye, and McMichael (1993) summarized the findings of seven major reviews of research on multimedia. The 139 reviews were from a variety of settings, but the majority concerned adults. Among their (obviously not independent) findings were the following:

(1) multimedia is at least as effective as conventional forms and has substantial cost and efficiency, benefits
(2) frequently, multimedia instruction is more effective than conventional instruction, and
(3) multimedia is more efficient in terms of learning time than conventional instruction (30% savings).

Ragan et al. (1993) stated that they were unable to determine why multimedia was appreciably more effective than conventional instruction and cautioned that it would be inappropriate to say that multimedia is always the most effective delivery system. They suggested that certain instructional design features appear to enhance the quality of multimedia instruction. Among them are higher levels of interactivity, program or advised learner control, integration of multimedia with other delivery forms, and structured rather than totally exploratory learning.

P. L. Smith, Hsu, Azzarello, and McMichael (1993) reviewed 28 group-based multimedia studies. They indicate that group-based multimedia can be as effective as individualized multimedia, and it can be as effective as, or more so than, traditional forms of instruction. They also found that learners prefer group-based multimedia to individualized multimedia and traditional instruction. Again, Smith et al. stated that they were unable to predict what situations are appropriate for group-based multimedia and that it would be erroneous to that state group-based multimedia is always superior to traditional instruction or individualized multimedia.

Through hypermedia is relatively new, there are hundreds of reports and studies about its implementation. However, most of them deal with the excitement of adopting this new technology or envision its potentials in education (Yang, 1993). Only a few of these reports are experimental studies. In these limited studies, some positive results of using hypermedia have been reported. Abrams and Streit (1986) as well as Jones and Smith (1989) reported significant gains in learning achievement. Janda (1992) found a positive attitude toward the use of hypermedia systems. Higgins and Boone (1992) reported a decreased demand on teaching time. Hardiman and Williams (1990) noted that the completion rate of courses was increased with the use of hypermedia. Liu (1992) found that hypermedia was very effective in the teaching of English as a second language. In a review, E. E. Smith (1987) summarized the findings thus: "The effective evidence seems to indicate that the medium is both effective and efficient. . . " (p. 2). Thompson, Simonson, and Hargrave (1992) also suggested that hypermedia was promising in a learning context (Yang, 1993).

One of the more unique and interesting inquiries into the effects of multimedia was conducted by Gerlic and Jausovec (1999), who investigated the cognitive processes involved in multimedia (sound and video), text, and image-oriented presentations using electroencephalographic (EEG) measures. The results indicate that the multimedia (sound and video) and image presentations induced visualization strategies, whereas the text presentations generated mental processes related to verbal processing. This study has shown promise in employing methods developed in brain research and relating them to cognitive psychology.

From a review of research literature dealing with simulations, Reigeluth and Schwartz (1989) suggest 3-D simulation and video and graphics representation forms for physical movement procedures. Rieber (1990) cautions that special effects including animation and 3-D graphic displays should be used only if the learning tasks require them. Likewise Harrington and Oliver (1999) conducted a qualitative study describing students' use of higher-order thinking in an interactive multimedia program based on a situated learning framework. They concluded that this environment could provide the setting that would support and maintain high levels of higher-order thinking.

Park (1998) investigated the instructional effects of three types of visual presentations including animation and static graphics without motion cues. Parks concluded that the dynamic aspects of static graphics with motion cues were as effective as those of the animation presentation. The results suggest that if static graphics contain "appropriate cues," they can facilitate understanding of the dynamic functions and formation of appropriate mental models (p. 38). Others like Bagui (1998) reviewed the research literature and touted the "success of multimedia" (p. 15) for increasing learning. He suggests that this success is due to dual coding (Paivio, 1986) and cites Shih and Alessi (1996) and Najjar (1996) in his contention that verbal and visual codes interact with each other and blend and support each other without a "clear division." Bagui restates oft-stated advantages of multimedia including that multimedia allows students to control pace and direction and develop more of a constructivist approach to learning (as cited in Jurden, 1995), allows interactivity (Najjar, 1996), and is flexible.

What does the research say about multimedia and its interactive technologies? Unfortunately, not much. The terms *multimedia* and *interactivity* are defined universally by neither the developers nor the researchers. Many of the current guidelines for the development of multimedia programs can be traced to just a few sources. One source is the behaviorist learning theory tradition of Thorndike and Skinner; the second is existing research investigating computer-assisted instruction. The most prevalent sources however, are assumption, intuition, and (apparently) common sense. Another source for much of the *supposed* support for the use of multimedia instruction lies in the many *comparison studies,* which essentially compare multimedia instruction with traditional or conventional classroom instruction. These studies are legion (e.g., Fletcher, 1990; Erwin & Rieppi, 1999; Mayer, 1997; Stoloff, 1995). Whereas these studies generally show support for multimedia use or *no significant difference* in presentations, one thing in common is the fundamental methodological flaws (Clark, 1983; Lookatch, 1995; Lockee, Moore, & Burton, 2001). Najjan (1996) contends that much of the support for multimedia appears to be from personal opinion or thoughts other than research studies. After reflection on an extensive review of the literature, there appears to be little useful research on multimedia (Moore et al., 1994). Quite frankly, with few exceptions there is *NOT* a body of research on the design, use, and value of multimedia systems. The few exceptions include the metanalysis of some 60 studies by McNeil and Nelson (1991), the work at the Children's Television Workshop (Strommen & Revelle, 1990), and the reviews by Ragan et al. (1993) and Mayer (1997, 2001).

Mayer (1997) and Reiber (1990) contend that the technological advancements in the area of multimedia environments have outstripped the research on how people learn from pictures and words. Mayer (1977, 2001) has conducted extensive research on learning from multimedia based on a generative theory of learning (based on earlier work by Wittrock, 1989; Paivio 1986, and Mayer, 1992). Mayer's (1997) hypothesis says that meaningful learning occurs when learners

1. select relevant information from what is presented,
2. organize information into a mental representation,
3. integrate the new information, and
4. separate the information into two information processing systems (visual and verbal) as suggested by Paivio (1986).

"(T)he learner is viewed as a knowledge constructor who actively selects and connects pieces of visual and verbal knowledge" (p. 4).

Reiterating Clark's view (1994) that studying the effectiveness of a particular media is no longer productive but focusing on how "instructional treatments affect the cognitive processing within the learner" (p. 7), Mayer and his associates have conducted an extensive program of research to test his generative theory of multimedia learning in which learners select, organize, and integrate visual and verbal information. Mayer and associates, in eight studies, compared problem-solving transfer performance of students who viewed coordinated multiple representations (words and pictures) with that of students receiving only verbal expansions. Overall, Mayer found that students who received the coordinated word and image presentations produced 75% more creative solutions than did students receiving only information in a verbal form (Mayer, 1997). Mayer then compared students receiving visual and verbal information in a linear fashion. Although acknowledging some methodological concerns Mayer reported that the coordinated presentations created more creative solutions than the linear presentations (p. 12). Looking then at the interactions between high- and low-prior knowledge learners and coordinated multimedia presentations, the results indicated that multimedia presentations were effective for students with low prior knowledge and relatively ineffective for students with high prior knowledge (Mayer & Gallini, 1990; Mayer, Steinhoff, Bower, & Mars, 1995). An additional study by Mayer and Sims (1994) reviewed the interaction between high- and low-spatial ability students and coordinated multiple presentations and linear presentations. They found strong effects for high-spatial ability students on coordinated presentations, but not for low-spatial ability students. Mayer (1997) concluded that the theoretical aspects of the generative theory are supported by his research in that coordinated presentations of words and images guide and select relevant information, help serve as organizers to build cause-and-effect relationships, and make connections between actions in the visual and verbal representations (pp. 27–28).

The lack of research concentrating on the interactive features that maximize learning effectiveness has been noted by both practitioners and researchers alike. Specific programs of research have been suggested to fill these gaps, e.g., Hannafin (1985) and Kozma (1991). Until these calls are taken seriously multimedia development will have a less than adequate research base (Moore et al., 1994).

36.8 DISCUSSION AND SUMMARY

"Design decisions are not made based solely on a given foundation, but upon presumed processing requirements, the strategies and methods deemed reasonable in supporting those processes, and the manner in which technology options support or hinder combinations of learning strategies and cognitive processes" (Park & Hannafin, 1993, p. 67). Among the important variables are teacher–student interactions, methods, learner traits, and motivation. Based on our review of the literature, a multiple-channel research article that addressed more than one of these variables is an exception. At the beginning of this chapter, we highlighted the information processing model, its impact on research, and the implications research results have for instructional design.

To recap, briefly the information processing model hypothesizes several information storage areas governed by processes that convert stimuli to information. The goal for instructional designers is to take advantage of suggestions from multiple-channel research to facilitate cognitive processes, particularly in the development of multimedia presentations.

Our review has focused on the effectiveness of multiple-channel communications, cue summation, and related areas such as multi-image and subliminal perception research in learning situations. Unfortunately, most literature addressing these issues is conflicting and/or dated. Not once did we encounter research that thoroughly investigated these theories in the context of hypermedia or multimedia. In addition, much of the research reported is based on the well-documented limitations of media comparison studies. We also feel that the literature dealing with multiple-channel communications and cue summation should provide a portion of the foundation from which to design learning environments in the multimedia arena. Based on the review of pertinent research on the antecedents of the concept of multimedia, e.g., multiple-channel, presentations, cue summation, multi-imagery, and subliminal perception, what did we find? We feel that instructional designers, looking for simple rationale, methods, or guidelines for effective multimedia (multiple-channel) presentation will be disappointed in the relevant research. Although much of the evidence from the research studies appears to support multiple-channel design, the overall evidence on the effectiveness of single-channel versus multiple-channel presentations is confusing at best. The human information processing system appears to function as a multiple-channel system until the system capacity overloads. When the system capacity is reached, the processing system seems to revert to a single-channel system. In other words, a fixed cognitive capacity limits the absolute amount of information that the individual can *handle*. Adding information channels does not enlarge the system; rather it distributes the system capacity across the additional input channels. Conflicting research results are also present concerning the use of redundant information presented across two or more channels. People apparently view highly redundant information presented over two or more channels as components of a single message. Research on the cue summation and stimulus generalization theories has produced opposing results (no surprise). However, there appears to be some evidence to suggest that multiple-channel presentations are superior to single-channel presentations when cues are summated across channels but neither channel is superior when content is redundant or irrelevant across channels. Redundancy may cause information processing to fluctuate and become less efficient. There also may be failure to take into account the human processing capacity theory. It is suggested that designers sometimes do not understand the possibility that, in multiple-channel communication, irrelevant cues in either channel can cause interference. Research on multi-image presentations suggests that the mere presentation of simultaneous images does not necessarily lead to simultaneous mental processing. Like the other research in this area, multi-image research has revealed few usable results. The familiar problem of how much information an individual processes at any one time is also raised by multi-image presentations and studies on subliminal perception. Inconclusive results leave us with no definite evidence as to subliminal perception's effectiveness or ineffectiveness. However, there appears to be evidence that there is human perception below the threshold of awareness. Where does this leave us in relationship to multimedia? First, educators appear to be unable to determine a universal definition for the concept of multimedia. Second, there is little research concerning the design and value of multimedia systems. Certainly, use of the research and theoretical antecedents of multimedia reviewed in this paper (e.g., multiple-channel communication and cue summation theory) has not, for the most part, made it into the research literature on multimedia. Most of the literature appears to deal with their adoption, their implementation, or visions for their potential use. Some of the evaluative studies available, however, tend to support the use of such presentations.

There is a rather obvious lesson to be learned in reviewing the literature in this area and, we suspect, many of the areas that this handbook is meant to deal with: theory-based research such as that grounded in dual-coding theory, cue summation theory, etc., adds up over time: research comparing media against media, which we have characterized as evaluations, does not. As Clark (1983) readily acknowledges, such studies were criticized long before he put forth his delivery truck metaphor. This metaphor does not seem counterintuitive or, for that matter, controversial. We invite you to look up the term *media* in a dictionary. It will say *vehicle, as in television or radio,* or words to that effect. The concept, though blindingly simple, is still misunderstood. Evaluating media against media in terms of learning outcomes (as in film versus television, etc.) has not helped us. Even testing media attributes per se (e.g., text and audio) against each other has not helped us much. Neither approach is grounded in a theory that explains what happens from a human learning or memory point of view. Clark and others suggest that there are *deeper processes* at work in learning and that the various media attributes employed are surrogates for those processes that can be cued or accessed in many ways. Simply put, learning may be unaffected by a particular media and learning of any type can be achieved through a variety of paths (media) if the methods of providing information are well designed, have a theoretical base, and are well executed (Hergert, 1994). If work in multimedia does not move quickly from evaluation to theory-based research, not only will we repeat the mistakes of the past, but we, as a discipline, will be made redundant by the workers in human–computer interface and industrial systems engineering, who *are* grounding their work in theory.

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