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

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## 29.1 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 will use them as the perspective for the review. Specifically, we will 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, however, resisted the temptation to include and thus report on cueing strategies and other remotely related theories. Related research literature in areas of multi-image 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, for example, 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, Myers & Burton, 1994). In part because we don't 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, etc., are covered elsewhere in this handbook, we will 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.

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## 29.2 INFORMATION -PROCESSING APPROACH TO HUMAN COGNITION

### 29.2.1 Historical Perspectives

Notions such as seeing with our "mind's eye" or "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 (nor as noncontroversial) as our conversational descriptions would imply.

Images are mentioned in Greek scrolls that date as early as 500 BC. 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 Descartes (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 sake, and to make discussions about modality easier, we have selected the model that began the current rise of cognitive psychology: information processing.

### 29.2.2 Cognitive Overview

The information-processing approach to human cognition (see 1.4.4, 5.2.4, 28.1.2.1, 30.2) 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. While 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 information until the stimulus 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; and Kerr, 1973). This limited pool is assumed to affect 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: long-term memory.

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, b). Basic research studies not only tend to confirm this treatment but also suggest that while 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 it 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 filler 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) can penetrate this proposed bottleneck. Current models (e.g., Shiffrin & Geisler, 1973) view attention as attenuation 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. While all information is registered by the sensory registers, 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. In fact, 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).

Long-term memory 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). These schema or "set of past experiences" are the cognitive structures that, when related to new information, cause 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 is 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).

### 29.2.3 Dual Coding

Imagery theorists obviously make a distinction between the codes used for images versus verbal information. Paivio (1971, 1986) developed the dual-code model (see 16.2.1), 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 to 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, while 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: While 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 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 analog ability to judge space from images, in at least some cases (Kosslyn, 1975), and finally for studies that indicate strong visual-memory abilities. Paivio's theory is also able to effectively 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.

#### 29.2.4 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 location 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 compared 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 as a bird, facilitated 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 from "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, like memory for text, we forget details (Miller & Burton, 1994).

Finally, where there are gaps, we unconsciously fill them. As you will see in later 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).

### 29.3 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 could 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 essen-

tial or basis 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* that 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 any 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 information-processing of human beings 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 Shannon and Weaver (1949), Spaulding (1956), and Cherry (1953) 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-channels 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 appears to be major concerns, however, involved in determining the amount of information a human being 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, the STM. The system from this point on operates as a single-channel system, Travers (1968) 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). Human beings 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 and complex data involves the discarding of redundant information. This process is referred to as "information compression" (Travers, 1968, p. 11).

It is also related to the information-processing system's strength: gist. Travers's 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 understanding of many multiple-channel presentations are examples of this model in action. Travers's (1964a, 1964b, 1966) studies support this contention that human beings 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 for an audiovisual presentation over presentations via audio and visual modalities alone. Cherry (1953) concluded that the utilization of information by the brain can be represented by a 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 (channel) 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." 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: (1) Human information-processing functions as a multiple-channel system until the capacity of the system is overloaded; (2) when input becomes greater than the system's capacity, the system reverts to a sin-

gle-channel system; and (3) an increase in the amount of information presented does not necessarily increase the rate of information transmission. Hsia (1971) asserts that, since 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 part of redundancy and noise are eliminated. Hsia (1971) and Carpenter (1953) feel that the processing capability of an individual is limited by the physiological aspects of the individual. A person can receive far more stimuli than he or she 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 which 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 (1966) explains that Travers's 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 learner 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 much of the data collected were from studies where unrelated and/or contradictory stimuli was presented to the learners simultaneously. It would seem reasonable under 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.

#### 29.4 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"
- 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 a visual presentation? For the purposes of this review, cue summation will include both the addition of cues 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's making the correct discrimination over time and increasing 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 by 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 does 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 an 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 age subjects 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/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 corresponding visual sequence, but speech given slightly after a visual sequence resulted in recall just as good as a simultaneous presentation. Nugent (1982) studied content redundancy of content across three channels and found that when the content was the same, subjects learned equally as 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 (see 11.2.3). Findahl (1971), Reese (1983), and Drew and Grimes (1987) reported the superiority of redundant audio and video presentations in the recall and 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 was better for memory than when channels were "mismatched." They concluded that a high degree of redundancy helps learning in the audio channel and hinders the visual channel. With nonredundant material, the students relied primarily on the video for meaning however. Calvert, Hudson, 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 visual component competes with 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 that can be understood independently of the visual mode (being present). In studies exploring irrelevant visual distractions (Festinger & Maccoby, 1964; Osthouse & Brock, 1970; Bither, 1972), it was 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 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 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 subjects 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) that focused on the comparisons of audio and print channels, and the Hoban and Van Ormer studies (1950a) that concentrated on pictorial comparisons, concluded similar findings. However, Hartman (1961a) distinguished four relationships between multiple-channel messages and those on 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 is 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.

Smith and Smith (1966) critiqued earlier multiple-channel research (sometimes called *audiovisual research*). The Smiths stated:

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 nonverbal 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 either through 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, were 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 sometimes use multiple channels without understanding the possibilities of interference between them, and information may be presented via two channels and testing mode presented with 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. 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, not 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, equivocation (loss of information) is caused by overloading the capacity limit. Hsia suggests that decreasing input information in accordance with the information-processing capacity will eliminate or reduce equivocation. Error, he submits, will be eliminated by adjusting redundancy to an optimum level so that maximum transfer may take place.

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" (Conway, 1968, 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 upon which they are made. Second, Conway goes to some length in 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 from Van Mondfrans and Travers (1964), and from Severin (1967a, c). Severin's (1967a) position states there is no advantage in using "redundant" information over two modalities versus either one used alone. An example would be 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 present-word/test-word plus picture or those of 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's (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.

More kinder to cue summation theory and Severin's (1967a, 1967b) views is Hsia (1968, 1971). He submits that "... 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" (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 (1968)

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 presentations for specific-learner types. Severin (1967a) makes the following predictions based on research when comparing single-channel communication and multiple-channel communication. Multiple-channel presentations that 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 & Lenz, 1982). From a review of over 155 experiments, Levie and Lenz (1982) suggest that: using attention-getting pictorials increase the possibility that material will be looked at; using text-redundant illustrations will facilitate learning 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 from 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.

Rigney and Lutz (1976) found that the use 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 that students may acquire concepts from verbal instructional materials. Their research also supports Levie and Lenz's (1982) findings that supplied illustrations are better than user-generated imaginal pictures.

Mayer (1989) 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 to assimilate the information into useful mental models.

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 would be the major component of a braking system and the changes each component undergoes in relationship 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. While inconclusive, the results supported the theory that coordinated presentation of narrative and visuals (animations) (see 16.2.1) results in better performance on tests of creative problem solving than the word-before-pictures group. 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, they found presenting unconnected words and pictures is not as useful as coordinated verbal narration simultaneous 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 degree of learning effect. Presenting materials on a computer, however, did increase attention and learning. Further, they found 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 which favor either channel. Katz and Deutsch (1963) and Travers (1964), for examples, reported results that supported the visual channel over the auditory channel. However, Carterette and Jones (1967), Hartman (1961a, b), 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 that verbal information recalled was incidental to the central plot of a televised program. Mudd and McCormick (1960) reported that, provided the information is related, auditory cues of various dimensions appreciably decrease the time involved in a visual-search task. Warsaw (1978) reported on a series of experiments in which

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. Warsaw continued and stated that multiple-channel presentations do attract more attention than either channel alone, but perceptual interferences across multiple channels 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 that in televised presentations, children's recall of "central" content was comparable to audio only, visual only, or simultaneous across both modes. Grimes (1991) continues: 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 in a nonredundant presentation in one study in which the group attended to the video and in another study in which 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.

## 29.5 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 (see 16.4.2.4) 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, and illustrations of relationships, or in 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 allows, as Perrin states:

... 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 may 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 (see 4.2.4). 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 are 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 the 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 that posits 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 ensure 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 is important in the design of multiple-image presentations produced for cognitive learning situations.

### 29.5.1 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 (see 16.11.1, 36.3.10) 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. Two factors affecting usefulness of large screens were identified by Schlanger (1966): 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 (1968), 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

(1966) stated that large screens can produce information rich in detail for the visual channel and simulate real environments, but Blackwell (1968) warned that any channel of communication loaded with information details may be distracting if the details are irrelevant to the learning situation. Travers (1966), while 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 (1968) 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's 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 that simultaneous images produce an increase in information density during presentations.

### 29.5.2 Information Density

A greater 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 to 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 presented simultaneously, or in the information density of the presentation.

Information density can be further increased 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 makes the information for the user easier to assimilate (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 significantly increased 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 (Smith, 1966) but that there is an optimum level. Eysenck (1963) found that for complex tasks, optimum performance is achieved when drive is relatively low; only for simple tasks is the optimum achieved with 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 a person sometimes performing very poorly in highly arousing situations, yet tending to remember most vividly those incidents in his life 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. Low arousal was accompanied by the normal forgetting curve. High-arousal responses 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 proved 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 may 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 (1975) 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 great 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 multi-image format to teach synthesis skills in history to 11th-grade students. He found no significant differences in males between the single-image and 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 females in the average- and high-achiever groups who 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 and audiences viewing single-image presentations, and to ascertain if the persons' relationship to the screen had any effect on shifts in evaluative meaning. In his conclusions, Bollman (1970) 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 significantly 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 significant 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. These are that few teachers were familiar with the characteristics and capabilities of large multi-image presentations, and they lack 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 theory, most researchers predict that learning will increase (however it is measured) when "the viewer makes his own montage of different image elements, increasing the probability of learning comparative information" (Perrin, 1969,

p. 369). Jonassen (1979) indicates that the mere presentation of simultaneous images does not necessarily lead to simultaneous mental processing. The view still must provide a cognitive strategy for processing and make sense of the presentation order. Just as linear-sequenced material must be processed based on content and syntactic associations, multi-image presentations must also. Jonassen (1979) found that the literature on multi-image (simultaneous) presentations has yielded contradictory results. He feels that incomplete questions in the research hypothesis were asked instead of just questions about linearity vs. simultaneity. Researchers should consider "how simultaneous images can best be structured to facilitate specific types of learning behavior" (p. 292). Jonassen (1979) 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 on 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 significant interactions 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), which found that both haptics and visuals benefited from multi-image presentations.

Burke and Leps (1989), gleaned information from the limited (and possibly flawed) research on multi-image presentations (see 16.4.2.4), feel that multi-image 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) have 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-image and multiple-image presentations that 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.

## 29.6 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 subject

(Moore, 1982). Subliminal perception, like multi-image presentations, is also 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 provides 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, Cutler & McNeil, 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, since 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 is of different brightness than the surrounding visual field. In other words, the closer to being consciously visible the material is, 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. One of the earliest of these experiments was reported by Hollingworth (1919). Others included 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 included those of Klein, Spence, Holt, and Gourevtich (1958), and Smith, Spence, and Klein (1959), all 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. This method was used by DeFleur and Petranoff

(1959) 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 on the procedures used in DeFleur and Petranoff's (1959) study. The low-intensity, constant-image technique that was 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 quickly flashed rather than constantly exposed, then the visual threshold of viewers would remain higher and the images would more likely remain subliminal (Moore, 1982).

Similar experiments have been reported by several other researchers. In these experiments, the subliminal shapes or words were nonmoving images on a neutral background, as compared to the moving foreground images used by DeFleur and Petranoff (1959). Schiff (1961) and King, Landis, and Zubin (1944) reported positive results, while Champion and Turner (1959) and Calvin and Dollenmayer (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 simultaneously presented 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 reconstruct mentally 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 answer did better than the group shown the incorrect answers, as hypothesized. Gerard's results partially confirmed Kolars' 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; Kolars,

1957) indicates that subliminal perception can occur among certain people in laboratory settings. Research dealing with educational uses has been conducted by Murch (1965) and Sharp (1959) who demonstrated that the test-taking behavior of students can be subliminally influenced. DeChenne (1975), Skinner (1969), and Taris (1970) studied either teaching subject matter or teaching a skill entirely by subliminal means (DeChenne, 1975, Moore, 1982).

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 conducive 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) asks 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. By not doing so, detecting the effect of the treatment would have been more difficult if aptitude-treatment interaction effects were occurring, as the slight increase in treatment effectiveness in these two studies may have indicated. 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 disembed the message from the surrounding television picture. Therefore, it was thought that the cognitive style of field dependence may have some relationship to the potential usefulness of subliminal perception. Since people have different ways of perceiving their environment, 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 disembedding 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, since 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 expect. These students were eliminated from subsequent analysis, since their recall may have reflected prior knowledge or 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 appears 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 preceding sections, e.g., multiple-channel, multi-image, and subliminal perception, have import to the design of multimedia presentations. Basic decisions have to be made to determine how the presentation is to be developed, the number of cues to be available, and the number of channels to be used.

## 29.7 MULTIMEDIA RESEARCH

Technology does not stand still. While the debate as to the efficacy of technology's impact on learning continues, microcomputers become more powerful and flexible. As opposed to the first microcomputers, today's classroom machines can easily have thousands of times the amount of internal memory available before. Audio and visual capabilities will soon exceed those of today's television, and auxiliary storage will soon be practically unlimited (Moore, Myers & Burton, 1994). Because of these (and related technological advances in software), everyday users, and most particularly educators, have access to systems called *multimedia* and *hypermedia* (see 24.6.3). 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 (see 21.1, 24.6.1) 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 audiotape). 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: Does multimedia include, for example, 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 these "interactive multimedia" should include motion, voice plus data, text, graphic, and still images. This definition permits multimedia to "absorb" the historically older and somewhat broader notion of hypermedia, which will be 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, are 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 also demand it (Gleason, 1991). By doing so, these technologies have closed the gap between some of the earlier theories of learner control and learning styles. Interactive multimedia allows the user to see, hear, and do. 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, Myers & Burton, 1994).

### 29.7.1 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, 1990; see 26.4.2.2). 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 in which it will be needed.

An excellent example of situated cognition is the use of the "anchored instruction" work (see 23.4.1.) done by the Cognition and Technology Group at Vanderbilt (1990).



They believe that young students learn better in meaningful, socially organized contexts. Their research indicates that problem-oriented approaches are more effective than fact-oriented approaches in overcoming inert knowledge (knowledge people know but often fail to use during 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 above comments are speculative and are not confirmed by direct research.)

### 29.7.2 Hypermedia

This technology parallels mental models by forming associations or links between various ideas, then constructing meaning among these relationships (Kozma, 1991). Research suggests that a number of concepts can be explored by using hypermedia's cognitive flexibility (see 12.2.3.5.4, 21.1). For example, users might be interested in pursuing information about land navigation. Searching on 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. While 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) suggests that "various aspects of the learning process are influenced by the 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 that 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.

### 29.7.3 Using 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 (see 24.6.3) and 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/media against another (or a control for that matter) are primarily evaluations. Evaluation seeks to find programs that "work" more cheaply, efficiently, quickly, effectively, etc. 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 terms *evaluation* and *research* are often used interchangeably in the fields of education and media (Moore, Myers & Burton, 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). 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, industry, and education. Educational use of multimedia programs is still limited and in most cases still experimental. Two multimedia formats (videodisc and videotape) are 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 (1987) reports evidence for both the effectiveness and efficiency of the interactive media on 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 while 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 (which are obviously not independent) their findings were:

1. Multimedia is at least as effective as conventional forms and has substantial cost benefits and efficiency.
2. Frequently, multimedia instruction is more effective than conventional instruction.
3. Multimedia is more efficient in terms of learning time than is 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.

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 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. (1993) stated that they were unable to predict which situations are appropriate for group-based multimedia, and that it would be erroneous to state that group-based multimedia is always superior to traditional instruction or individualized multimedia.

Though 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, Smith (1987) summarized the findings: "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).

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. After reflection on an extensive review of the literature, there appears to be little useful research on multimedia (Moore, Myers & Burton, 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 meta-analysis of some 60 studies of McNeil and Nelson (1991),

the work at the Children's Television Workshop (Strommen & Reville, 1990), and the reviews of Ragan et al. (1993). 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, Myers & Burton, 1994).

## 29.8 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 important variables are teacher-student interactions, methods, learner traits, and motivation. Based on our review of the literature, finding a multiple-channel research article that addressed more than one of these variables was an exception. At the beginning of this chapter, we highlighted the information-processing model, its impact on research, and the implications research results have on instructional design.

To briefly recap, 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 in order to facilitate cognitive processes particularly in the development of multimedia presentations.

Our review has focused on the effectiveness that multiple-channel communications, cue summation, and related areas such as multi-image and subliminal perception research may play 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 that are the antecedents of the concept of multimedia—e.g., multiple-channel, cue summation, multi-image, and subliminal perception—what did we find? We feel that instructional designers, looking for simple rationale methods or guidelines for effective multimedia (multiple-channel) presentations will be disappointed in the relevant research. While 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 mul-

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 capacity across the two 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 have 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 summed across channels, but when neither channel is superior or 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 theory about processing capacity in human beings. It is suggested that designers sometime do not understand the possibility that in multiple-channel communication irrelevant cues in either channel can cause interference. Research on multi-image presentations suggest 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 with studies on subliminal perception. Inconclusive results leaves 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? For one thing, educators appear unable to determine a universal definition for the concept of multimedia. Secondly, there is little research concerning the design and value of multimedia systems. Certainly, the use of the research and theoretical antecedents of multimedia reviewed in this paper (e.g., multiple-channel communication and cue summation theory) have not for the most part made it into the research literature on multimedia. Most of the literature appears to deal with their adoption and implementation or the visions of 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., "add up" over time. Research comparing media against media (see 4.3.4.2), 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 any dictionary. It will say *vehicle*, as in television or radio, or words to that effect. The concept, though blindly simple, is still misunderstood. Evaluating media against media in terms of learning outcomes (as in film versus television,) has not helped us. Testing media attributes (e.g., text and audio) against another doesn't help us either (see 4.4.4.6). What the argument doesn't have is a theory that explains what happens from a human learning/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, that learning may be unaffected by a particular media and that 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. If research in multimedia does not move quickly from evaluation to theory-based research, we will not only repeat the mistakes of the past, we also, as a discipline, will be made redundant by those working in human computer interface (HCI) and industrial systems engineering (ISE), who are grounding their work in theory.

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