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**EFFICACY OF MULTIMEDIA INSTRUCTION  
AND AN INTRODUCTION TO DIGITAL  
MULTIMEDIA TECHNOLOGY**

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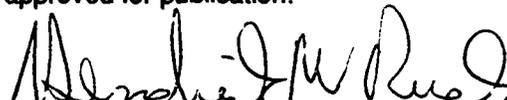
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## PREFACE

This paper explores the effectiveness of multimedia technology in instruction. A literature review was conducted to gauge support for the belief that multimedia presentations influence learning. Research in areas that support effective design of multimedia presentations is discussed.

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## SUMMARY

This paper investigates the effectiveness of multimedia technology in instruction. Multimedia refers to the combination of audio, video graphics and text for communication. There are many areas of research related to developing and implementing multimedia instruction. A literature review conducted to gauge support for the belief that multimedia presentations influence learning revealed mixed results. Multimedia instruction, in general, is an effective approach to educating students. Even linear multimedia instruction, which often failed to enhance learning, can reduce the cost of educating students without hindering learning. Research in areas that support effective design of multimedia presentations is discussed.

Digital multimedia is a recent innovation. The flexibility and interactivity inherent with digital information allows applications to be developed with less effort and equipment. The development of sophisticated data compression algorithms combined with the use of microprocessors has enabled microcomputers to support digital multimedia presentations.

Digital multimedia technology can be applied to several areas, including training, job aiding and telecommunications. Realistic simulations can improve training. Presentations that convey information about a procedure that is difficult to convey with text can enhance job aids. Lastly, DVI can improve telecommunication by reducing the cost and increasing the convenience of videoconferencing.

Digital multimedia can benefit the consumer and industry. Companies report significant savings in design of digital multimedia applications compared to analog. Also, an unprecedented degree of interactivity is possible. Future research should seek to identify the characteristics of the technology that account for the greatest variance in learning and propose models for the design of effective multimedia presentations.

## I. INTRODUCTION

The term *multimedia* has been used for several decades and has a variety of definitions associated with it. In the broadest sense, multimedia refers to the combination of audio, video, graphics and text for communication. Examples of multimedia presentations include:

- ◆ Pictures with corresponding text in books.
- ◆ Slide shows synchronized with tape presentations.
- ◆ Use of posters, radio and television to advertise a product.
- ◆ Use of a computer to simulate a driving environment for student training.

For this paper, the term *multimedia* will be restricted to refer to media that support motion video. A more general term often used in place of multimedia is *media*. *Media* does not necessarily imply the use of more than one symbolic code (audio, video, text or graphics) for communication.

There are several ways to classify multimedia presentations. One way is to classify presentations based on how they present data-- Linearly versus Nonlinearly. A linear multimedia presentation has a starting point and an ending point and presents information from start to finish along a single path. Examples include film, instructional television and videotape. A nonlinear multimedia presentation has a starting point and an ending point but does not present information from start to finish along a single path. Instead, one might proceed through several paths. For example, the individual can move from segment A to segments B, C or D then to E. Examples of nonlinear multimedia technology include presentations on compact disk, videodisc, and to a lesser degree, videotape. The interruption of the normal sequential flow of a presentation, characteristic of nonlinear multimedia presentations, is referred to as branching.

The second dimension refers to the representation of data being output by some device. The presentation is in an analog format if any device that could drive the presentation cannot recognize the data it is presenting. If the presentation is in a digital format, then there exists a device (a computer) that can recognize the data being presented. An example of a digital multimedia presentation would be a computer displaying data resident on a hard disk.

## II. ANALOG MULTIMEDIA PRESENTATIONS

The advantage of multimedia over more conventional educational approaches is that the multimedia approach uses more

than one sensory domain (sight and sound) for communicating information. This allows students to experience and process events to a greater extent than afforded by books or verbal explanations. In addition to seeing pictures and hearing sounds, students can witness interactions that could not otherwise be realistically replicated in a classroom. Multimedia technology also allows educational techniques such as lectures to be sent to other locations through satellite or repeated at different times and locations through videotape.

Educational institutions and the military have considered multimedia presentations helpful for two reasons:

1. They enhance learning.
2. They reduce costs, especially for remote locations.

Rose (1976) examined thirteen instructional technologies used by the Department of Defense. These included computer and audiovisual technology, instructional television, cable television, satellite communication and computer assisted instruction (CAI). He concluded that the proper combination of these technologies and the pooling of resources and delivery systems would improve the quality of personnel and reduce cost. More recently, Jenkins (1990) claimed that children learn by using their senses. This multisensory learning is more compatible with multimedia instruction.

### Linear

Before computers, multimedia based educational programs using motion video could only be delivered through film or broadcast through television. Instruction was presented in a linear fashion and could only be paused for a predefined duration or stopped (film). The introduction of videotape increased the flexibility of delivery systems, segments of the presentation could be rewound and replayed or skipped by fast forwarding. Although basic interactivity in the form of branching was limited and cumbersome, educators quickly adopted this approach.

Other research on the efficacy of linear multimedia instruction using motion video has yielded mixed results. In a review of research on instructional media, Jamison, Suppes and Wells (1974) maintained that instructional television did not differ significantly in effectiveness from conventional instructional paradigms. After examining research on the efficacy of media based classes, Clark (1983) concluded there were no differences in achievement attributable to media. He even recommended that "...researchers refrain from producing

additional studies exploring the relationship between media and learning unless a novel theory is suggested."

Other researchers have not gone so far as to discount absolutely the effectiveness of multimedia instruction. Rose (1976) expected videodisc technology to address the problems of earlier forms of multimedia presentations by permitting random access and switching to other modes of presentation (i.e. computers). Kulik, Kulik and Cohen (1980) analyzed research on various instructional technologies. Their analysis included audio and video based training. They concluded that these technologies produced positive results. However, the results were not "large" and would be barely perceptible in typical classes. Kozma (1991) described televised presentations as transient and identified two problems associated with transient presentations:

1. They are not sensitive to the cognitive constraints of the learner. Instead, they progress regardless of comprehension.
2. The viewer cannot review data already presented.

Kozma stated that transient information may be useful in building the dynamic properties of mental models. He also explained how computers, interactive video and hypermedia can be used to aid learning. Learning across these three media is influenced through interaction between the user and the system controlling the media.

Salomon (1976, 1979) claimed that changing the technology used to present instruction does not influence learning. Instead, he attributed differences in learning to the symbolic code of the message. Symbolic codes are sets of units (points, alphanumerics, frequencies, colors etc.) that are combined or used to represent information. Salomon and Clark (1977) distinguished between research *with* and research *on* media. Research *with* media involves comparisons based solely on the modes of presentation. Research *on* media involves creative uses of the media and their affects on learning. By focusing on psychological effects rather than appearance, researchers can address issues such as information processing.

### Nonlinear

Research suggests that for learning to be enhanced, a multimedia presentation must be designed to encourage students to process the data. One way to achieve this is to make the presentation interactive. Although VCRs can display data randomly without a computer, students must position the tape to certain positions. This competes for cognitive resources and may

restrict data processing. Alternatively, a computer could control an analog device (i.e. videodisc).

Nonlinear presentations have two advantages over linear presentations. First, nonlinear technology offers more opportunities for interactivity. The capabilities cited by Rose for videodiscs are available through a computer, not only for videodisc presentations but for videotape as well. Branching is supported through some form of menu-driven interface designed to reduce the look and feel of text-based, menu-driven interfaces. Mode switching is controlled automatically and is transparent to the user. The second advantage is that, for many projects requiring interactivity, a nonlinear presentation is easier to implement. This is largely a result of the first advantage. For linear multimedia technologies branching could only be simulated by using multiple devices (i.e. projectors) controlled by an individual monitoring the instruction. In addition, the instruction must be synchronized to insure that a response was quickly accompanied by an appropriate segment of instruction.

Later research on analog multimedia instruction has yielded positive results. Kulik, Bangert and Williams (1983) examined the influences of computer-based instruction (CBI) including simulations using audio, graphics and text. They found that compared to conventional instruction, CBI resulted in increased performance with less time needed for students to learn the material. Nugent (1987) examined several studies on the efficacy of videodisc based training. Nugent concluded that videodisc based instruction resulted in lower study times and equal or better performance.

### III. RESEARCH RELATED TO MULTIMEDIA

#### Dual Code Theory

Dual code theory (Paivio, 1971) rests on the premise that information can be stored in a semantic or imagery format (Paivio, 1971). The semantic format represents meaning (i.e. Chimpanzees are bipeds). The imagery format represents visual data. Best (1989) described the imagery format as the elements of a stimulus that are represented by the nervous system in a way that preserves many of the relationships seen among those elements in the natural world. These representations are not necessarily duplicates of visual stimuli. However, they have properties similar to visual stimuli (i.e. shape, size, detail etc). According to Paivio, memory will function better when both representations can be crossreferenced.

Research on dual code theory has yielded positive results. Shepard and Metzler (1971) studied the time it takes for a person

to identify an object as being the same or different from a reference object. They found it to be directly proportional to the angular disparity between the two objects. Such a relationship should not exist unless people are rotating an image of the objects mentally. Hence, this research supports the idea of an analog representation in memory. More recently Amlund, Gaffney and Kulhavy (1985) had students look at a map of the island of Ako and listen to a taped presentation about its people. They found that subjects recalled more information involving features from the map than information not involving features from the map. They concluded that had subjects used a unitary coding system, recall would have been the same for feature and nonfeature information. So, a dual coding system must have been in use.

Support for dual coding theory adds credibility to the idea that multimedia presentations can enhance learning. If memory does function better when imagery and verbal representations can be crossreferenced, then multimedia presentations provide a way to form those representations. More research is needed to determine how multimedia presentations support development of these representations.

### Multiple Resource Theory

Multiple resource theory offers an alternative explanation to central capacity theories for task interference (Navon and Gopher, 1979). According to Norman and Bobrow (1975), all mental processes demand a certain amount of cognitive resources. These processes compete with other mental processes for those resources. Every person has a limited supply of resources available to process stimuli and perform tasks. Performance degradations occur when tasks and stimuli compete for the same resources. Multiple resource theories differ from central capacity theories in that central capacity theories treat indifferently the resources available to a person for processing data.

Research on multiple resource theory has focused on determining the validity of the theory while expanding understanding of it. Wickens and Liu (1988) found that the degree of performance degradation at one task was reduced when another task performed simultaneously did not involve the same processing codes. Wickens (1980) initially proposed three dimensions -- early versus late processing stages, auditory versus visual processing modalities and verbal versus spatial processing codes. He claimed that interference will increase as more levels across these three dimensions are shared by two tasks. Hirst and Kalmar (1987) identified three models of multiple resources including the one proposed by Wickens. Their research suggests that an integration of existing models may be

needed to better explain experimental results.

Multiple resource theory offers a direct explanation of how multimedia presentations can produce greater knowledge gains than conventional presentations. Presenting information across a variety of media reduces competition for limited resources across a single dimension. Therefore, performance decrements resulting from cognitive overload would be reduced. This theory, however, has not been developed as fully as the other theories described in this section. Until more research has been conducted, applications of multimedia design based on multiple resource theory should be conservative.

### Transfer

Transfer was studied by Thorndike and Woodworth as early as 1901. It refers to the activation and application of knowledge to new situations (Gagné, 1985). Transfer is different from learning. Learning involves consistently activating and applying a specific knowledge set upon exposure to a particular stimulus based on experience. The stimulus or situation does not need to be new. While all learning involves transfer at some trivial level (Salomon and Perkins, 1989), transfer is distinguished from learning by the degree that a new situation is novel. An example of learning is when a student studying Spanish is given a list of English words and their Spanish equivalents to memorize. The next day the teacher asks him to write the Spanish equivalent for several English words from the list. If the student answers correctly, he has learned the words. An example of transfer is when a student, aware of several rules for arithmetic, is given a problem whose solution requires him to combine the rules. If the student correctly solves the problem, transfer has occurred.

There is abundant research on transfer. Today, research focuses on the dynamics of transfer rather than whether transfer occurs. Gagné and White (1978) reviewed research dealing with memory and learning. They assert that transfer of knowledge is eased by the degree of interrelationship between propositions, intellectual skills, images and episodes. Salomon and Perkins (1989) identify two types of transfer: High-road transfer and Low-road transfer. Low-road transfer is achieved by "automatic, stimulus-controlled and extensively practiced behaviors or cognitions." High-road transfer is achieved by "mindful deliberate processes that decontextualize the cognitive elements which are candidates for transfer."

There are many ways that multimedia instruction could enhance learning through transfer. One way is through the number of cues that multimedia provides. Multimedia presentations offer a continuous array of audio, video and textual information which can be combined to form rich knowledge structures. Any

combination of stimuli in the real world may activate associations involving these structures. Then, the person would use that knowledge to aid performance. Multimedia technology also allows students to practice various tasks through realistic simulations. This opportunity for practice should promote lowroad transfer.

### Attributions

There is abundant research on the influence of perceptions on task selection, effort invested and overall performance. Much of this research has involved perceived self-efficacy, outcome expectancies, perceived demand characteristics, and locus of causality. Perceived self-efficacy refers to an individual's confidence in the ability to perform tasks at a given level (Shell, Murphy and Bruning, 1989). Outcome expectancies are beliefs about contingent relations between successful task performance and perceived outcomes. Perceived demand characteristics are inferences that an individual makes about task requirements. Locus of causality refers to the beliefs about one's success or failure. The common idea behind these theories is that behavior is influenced not by the actual characteristics of the stimulus, but by the individual's perceptions about the stimulus.

Research on behaviors resulting from a student's perceptions of a medium is of particular interest to multimedia instructional designers. Salomon (1984) found that children attributed successful comprehension of televised presentations to external sources. In contrast, they attributed successful comprehension of text presentations to internal sources. He found correlations between perceived self-efficacy and amount of invested mental effort, and between attributed realism (an indicator of perceived demand characteristics) and invested mental effort. He maintained that children who scored high in perceived self-efficacy perceived the task of televised learning as "easy." So, they invested less mental effort in the learning task.

The notion that individual perceptions of a stimuli or event can influence mental processing has important implications for instructional design. Salomon's findings suggest that we should persuade students to perceive multimedia presentations in such a way that encourages them to increase the amount of mental effort invested to process the information. Multimedia instruction could even be used to influence the development of perceptions about the task being trained. Students could learn how to perform a task, perceive the task as interesting and enjoy successful task performance.

## Modeling

Bandura (1969) describes modeling as the ability of individuals to learn a behavior or attitude without direct reinforcement. An example would be if a child who has watched another child in a film receive praise for turning off the lights after leaving a room, begins to turn lights off after leaving a room. Modeling is closely related to social learning theory and vicarious conditioning. Effectiveness depends in part on the similarity between the model and the observer, and the nature of reinforcement given to the model for performing a behavior. Bandura argued that all learning involving direct reinforcement could also result from observation.

A classic study of modeling is an experiment performed by Bandura, Ross and Ross (1961). They found that children exposed to an adult displaying aggression toward a Bobo doll later also performed acts of aggression against the doll. Rather than random acts of aggression, the children used the same acts and vocalizations used by the model. Later they found that modeling via television was as effective as modeling via a live model (Bandura, Ross and Ross 1963). More recently, Schunk and Gunn (1985) have found that modeling which emphasizes the importance of task strategies increases a student's skill at performing a task. It also increases perceived self-efficacy. Perceived self-efficacy is greatest when the model also emphasizes achievement beliefs.

A multimedia presentation can provide an avenue through which modeling can be easily supported. In addition to showing people how to behave in certain situations, instructional designers can structure these presentations to increase students' perceived self-efficacy. Bandura and Gunn's research suggests that modeling might also influence aspects of one's self-concept other than perceived self-efficacy. More research is needed to determine how much modeling influences learning and motivation.

## IV. DIGITAL MULTIMEDIA

Some new multimedia products handle data in a digital format. They treat information differently from multimedia products that handle data in analog format. This results in greater interactivity, flexibility and ease of implementation. The technology is young, but is maturing rapidly and could significantly increase training effectiveness.

## Advantages Over Traditional and Analog Nonlinear Multimedia

One advantage that a digital format has over an analog format is a greater degree of interactivity. Branching locations must still be predefined. However, because the computer is aware of the audio and video being output, images may be easily manipulated. Applied Optical Media Corporation took advantage of this capability when designing their truck driving simulation package for DuPoint. Lane changes were simulated by warping the image in real time. Two videodisc players would be required for an analog multimedia presentation to support lane changes. Both players would have to be synchronized to maintain the appropriate perspective of the road without shifts (forward or backward) in ones relative position on the road when changing lanes.

Another advantage of digital format is flexibility. Data can be stored on a variety of storage media including hard drives, optical drives and tape drives. Hard drive storage is helpful for two reasons. First, it enables data to be transferred by networks and removable media to many users. Once users receive the data, they may work independently of other users accessing the data. This would be impossible with information stored in an analog format on a laserdisc. Second, hard drive storage allows segments of data to be changed instead of having to create a whole new presentation. In addition, entire segments of a presentation may be replaced as necessary. For data in an analog format such changes would require producing a new videodisc. Since data can be easily changed, time required to organize the data (i.e. scripting) is reduced. Data in digital format can also be duplicated an unlimited number of times without reduction in quality.

An important point to remember is that many of the advantages of digital video involve ease of implementation. This results largely from the increased control developers have over the data. Once stills are stored on the hard drive, they can be edited with a professional paint program like Lumena. Tools that enable users to edit individual frames of motion video are likely to be developed. Special effects including skewing and dissolves are already possible on a per frame basis. However, many applications involve only simple branching restricted to single user systems, and data that is unlikely to change. For these applications an analog format may provide an effective and less expensive presentation mode.

## Explanation of the Technology

The benefits inherent within digital multimedia are dependant on the combination of several technologies. For example, an important difference between analog and digital

formats is the ability to store digital data on disk drives. By itself, such a benefit is of little significance since video, and to a lesser extent, audio require extremely large amounts of memory. A frame of video displayed at a regular television resolution (512 X 480) using 16Bpp (Bits Per Pixel) requires 480Kb (Kilobytes). Full motion video is, at least, 24Fps (frames per second) requiring about 10.5Mb (Megabytes) of disk space. In the United States full motion video refers to 30Fps and would require 14.4Mb for one second of video. A single 600Mb hard drive could only store about 42 seconds of video. For full-motion video the data must be transferred from the drive to the screen at speeds of at least 14.4Mb per second. This is well beyond the rates supported by today's microcomputers. If we were willing to tolerate somewhat jerky movement, we could display data at 10Fps reducing the data transfer rate requirement to 4.8Mb per second. Today a PS/2 model 95 can transfer data at up to only 2Mb per second. Compact Disc Read Only Memories (CD-ROMS) only have a 150Kb data transfer rate.

To make digital multimedia presentations realistic, data must be compressed to a level supported by current transfer rates and storage capacities. Luther (1990) divides compression algorithms into two groups: lossless and lossy. Lossless compression reduces the quantity of data without altering the image displayed. An example would be dividing the picture into  $n$  blocks and checking each block to see if it contained one color. If it did, then the computer would refer to the block instead of each pixel in the block. Lossy compression reduces the quantity of data by altering the image. An example would be forcing the image to be represented in eight bits per pixel instead of 16. This would result in variations of a color (lime green, emerald green and olive green) being represented by one color (green).

Data transfer rates and storage capacities are immaterial if the data cannot be processed efficiently. Data needs to be read from the hard drive, pixels need to be manipulated then converted into an output suitable for monitors, and other information not dealing specifically with images must be handled. If the central processing unit (CPU) in a computer were expected to process this data, it would take several seconds for each image. As a result, motion would often be imperceptible. Luther (1990) maintains that 80286s don't have an instruction set specifically designed to support video. So, they fail to handle pixel manipulations efficiently. These intensive processing demands are met by using a video coprocessor. According to Harney, Keith, Lavelle, Ryan and Stark (1991) the 82750PB, a pixel processor developed by Intel Corporation, is five to ten times faster than a conventional microprocessor running at the same clock speed. It is even faster for operations that take advantage of special hardware assists. A video coprocessor also frees the CPU to perform other activities. This feature is helpful in simulations that provide feedback based on individual responses.

## Available Products

Two products now incorporate digital motion video: Digital Video Interactive (DVI) and Compact Disc Interactive (CD-I). Both products were developed about the same time and support audio, video, text and graphics. Differences between these products stem from the markets they were developed for. While DVI was developed for the business and professional users, CD-I was developed for the home consumer market.

There are several important differences between CD-I and DVI. First is cost. Hardware requirements for development are similar between the two systems. However, delivery costs differ. CD-I does not require a computer and can cost much less than DVI. Capability is another consideration. CD-I can only display motion video at speeds of up to 15 Fps. The format most suited for video, Run-Length, can only display up to seven or 128 colors depending on the mode. This gives images a cartoon appearance. Also, CD-I does not run under DOS or the Macintosh Operating System. Instead, it runs under OS/9 and requires an OptImage Emulator to work with Macintoshes and IBM PCs. On the other hand, DVI can display motion video at speeds of up to 30Fps with over 32000 colors. DVI runs under DOS and requires no additional equipment for PCs. Development on a Macintosh, however, requires equipment to transfer the data from the Macintosh to a PC and store the data in a format that DVI recognizes.

### DVI

RCA Laboratories' David Sarnoff Research Center began developing DVI in 1984. The goal was to develop an all-digital approach for supporting interactive video. In 1986, General Electric acquired RCA and demonstrated a DVI product the next year. One year after the demonstration General Electric sold the technology to Intel. Intel now owns and continues to develop the product.

Intel's DVI consists of a custom VLSI chip set, a specification for a runtime software interface, some audio and video data file formats and compression/decompression algorithms (Luther 1990). Although it cannot function independently of a microcomputer, it can run on two platforms: IBM PS/2 and PC/AT computers. A capture board converts audio and video signals from analog to digital formats. The converted data is then sent to a delivery board which compresses then stores the data. Only systems designing DVI applications need the capture board.

An appropriate system for developing DVI applications would consist of several components. First, the system would need some devices to read visual and audio data from the environment.

Motion video could be read from a video camera at more than satisfactory resolution for screen displays. Although stills could also be read by the camera, a color scanner provides greater detail. These images could be displayed on the screen without losing detail by showing part of the image at a time and allowing individuals to adjust the still to display the appropriate portion. One capture and delivery board are needed to digitize and compress data. Once processed, the data is stored. Storage would require a high capacity (600Mb) hard drive or rewriteable optical drive. A tape backup would help prevent unrecoverable data loss due to a power surge or operator error. The tape drive could produce a premaster of a presentation, reducing CD production costs. A CD-ROM drive is also needed if CD's are to be used. Video output would require a color monitor capable of supporting 512 X 480 resolution. A second monitor for developers to read messages and track the flow of execution along with the audio and video being displayed by the VGA monitor would be desirable. Audio can be manipulated with a mixer and should be output through speakers that can support the desired sound quality. The computer should have at least an 80386 CPU and an IBM AT, AT compatible, microchannel or microchannel compatible bus with at least four megabytes of memory. Lastly, developers would need some way to manipulate stored data. This can be done with an authoring package (i.e. Authology or MediaScript) or a programming language (i.e. C or C++) and a professional paint program (i.e. Lumena).

A delivery (end-user) system requires only a fraction of the equipment needed to run a DVI program. A delivery board decompresses data. Although memory requirements may vary, four megabytes is typical. Data should be displayed on a color monitor that supports 512 X 480 resolution or better. The computer must have at least an 80286 CPU and an AT compatible bus.

### CD-I

CD-I is still being developed by its originator, Phillips Corporation. Development began in 1983 with the goal of providing interactive audio and video without the look and feel of a computer. In 1986, Phillips and Sony Corporation jointly announced that specifications would be developed for CD-I players aimed at the consumer market. These specifications were submitted a year later. Now, CD-I units are available to meet the needs of the home consumer and industry.

CD-I consists of custom VLSI chips, system specifications, Motorola 68070 CPU, file formats and compression/decompression algorithms. Phillips markets CD-I as an independently functioning unit; it does not require a computer. A CD-I unit (base case decoder) can be connected to a television and stereo

system to allow the user to interact with data. The most sophisticated of the units is the CDI-602. The CDI-602 has a floppy drive and the capability to double the amount of memory from one to two megabytes. The CDI-602 also has several ports in addition to those for the stereo and television. Developers can connect devices like keyboards and joysticks to improve interactivity.

An appropriate system for developing CD-I applications requires components similar to those required for developing DVI applications. Memory, disk storage and input device requirements are the same. However, CD-I does not offer an image capturing capability. Images must be captured by a computer and transferred to the CD-I system. This means that developers must buy a separate computer (Macintosh or IBM) and capture board. The advantage is that developers have the option of performing the development work on the computer or on a CD-I authoring system. If development is to take place on the computer, developers may choose the computer with which they are most familiar. Unless there is a need for high quality stills, a television should be sufficient for display.

A delivery system requires a base case decoder and a television or stereo. If the application requires more than one megabyte of memory or an interface other than the mouse included with the decoder (i.e. keyboard), a CDI-600 series unit is required. Data should be displayed on a television that can support 360 X 240 resolution or better.

### Applications for the Technology

#### Training

Training is perhaps the most frequently cited domain that digital multimedia is expected to impact. Manufacturers of multimedia products and developers of multimedia applications believe that video enhances learning. They are quick to provide examples to show how video can be used in training. Ripley (1989) stated that students can use DVI to compare images (still or motion video), to see and hear explanations of procedures for completing tasks, and to explore environments that would be difficult to explore in real life (i.e. the brain).

Ripley identified simulations as an avenue where DVI has potential to enhance training. Experiments could be simulated allowing students to perform various experiments without actually performing the tasks. There are several benefits to simulated laboratory experiments. First, many laboratory experiments entail risk. Even high school chemistry experiments involve acids and dangerous chemicals. By performing experiments with these materials students gain knowledge about the task that could

not be easily obtained through explanation. With a simulated lab, students can gain experience at a task without incurring risk. Cost is also important. Some experiments can be expensive to conduct. However, with a simulated lab manipulations can be performed on a device or organism repeatedly without requiring replacement. Student architects, for example, could create realistic representations of buildings and examine alternative designs and structures. Projects could be completed and inspected in a fraction of the time otherwise required. Lastly, simulated laboratory projects could provide an intermediary step between classroom learning and real laboratory projects. Scuba-diving students could learn important information through interactive video even though some practice in a pool would still be necessary.

### Job Aiding

Another domain that digital multimedia could be expected to impact is job aiding (i.e. electronic performance support systems). Most job performance aids do not yet incorporate motion video or sound. They are usually produced in the form of manuals or tables. Computer based job performance aids consist only of text and graphics. A digital multimedia job performance aid would add motion video and sound.

There are two advantages to a digital multimedia job aiding approach. First, information that is difficult to convey through text and graphics can be more clearly presented through motion video and sound. For example, a text-based job performance aid may tell you to listen for a "rattle". However, a digital multimedia approach could give examples of what is and is not considered a "rattle," thus reducing ambiguity. Individuals could even change the characteristics of the "rattle." The computer could then indicate whether the new version of the "rattle" would likely be the targeted "rattle." Audio and video could also be used to convey a better understanding of the nature of the problem. Second, a digital multimedia job performance aid could be combined with related programs. Job performance aids of this nature could be added to diagnostic programs. This would enable computers to diagnose and explain how to repair a problem.

## Telecommunication

Digital multimedia can promote the development of telecommunication through videoconferencing. As of this publication, no videoconferencing products are available that are designed for use with DVI or CD-I. However, several companies including IBM and Picturatel are developing such products.

DVI videoconferencing has two advantages. First, it would reduce the cost of a videoconferencing system. With DVI, many of the components (compression/decompression algorithms, support for image formats etc.) are already available. Videoconferencing simply becomes an option with DVI. Eventually, Intel intends to downsize DVI so it can fit on the motherboard. Intel speculates that videoconferencing will then involve little more than software and an inexpensive camera. Second, a DVI videoconferencing package would increase the convenience of participating in a videoconference. Videoconferencing will take place at the desktop, with no need to go to a separate room, sit at a table and have someone point the camera at speakers.

## Resources Required

The hardware and software needed to develop applications in DVI and CD-I has been discussed in previous sections. However, hardware and software are only a small part of the total resources required for developing digital multimedia applications. Any multimedia training application of some significance will, in all likelihood, require the expertise of a group of people. Production (premastering, mastering and stamping) must also be considered.

Developers cannot expect wondrous instructional packages to be produced simply because they have bought the hardware and software needed to produce them. To develop a multimedia presentation, an understanding of audio, video, editing, instructional design, the task that students are expected to perform, graphic design, computers, authoring systems and programming languages is necessary. One person cannot be expected to have all this knowledge. So, application development is likely to involve a team of people. Isbouts (1991) maintained that for any multimedia project, there will be a need for production talent and the skills of an experienced software specialist. A development team will include an instructional designer, subject matter expert and systems specialist. Other people likely to be involved with the team include technical writers, teachers, graphics artists and video producers.

Other costs involve the development process. After the presentation has been stored, it should be formatively evaluated before a decision to distribute the instruction is made. The formative evaluation is a cyclic process involving testing, modification and retesting with a variety of students until results are satisfactory. This can get expensive if the instruction consistently fails to achieve the desired outcomes. Once the decision to distribute the instruction has been made, an appropriate medium must be selected for distribution. If compact disc is selected, a master must be created and discs must be pressed. Although prices will vary, the cost of creating a master is around \$1200.00. Depending on the format of the data and the medium the data is on, there may be an additional mastering charge of up to \$750.00. Once the master has been made, other disks may be pressed for \$1.65 each. Somewhere during the development and production process, a decision will have to be made about the quality of the video. Perhaps higher quality video is necessary than that provided by the development system. If so, video can be sent to a central facility to produce a higher quality compressed video. This support (Intel refers to it as PLV [Production Level Video]) is available now for DVI. Phillips is experimenting with compression on a POOMA computer and may offer similar support soon. The cost of creating PLV is about \$250.00 per minute of video.

### Future Trends

Digital multimedia is in its infancy but maturing rapidly. Hardware manufacturers continue to improve their products or replace them with better products. Other companies are developing applications and development tools. New standards are being promoted. These trends will hasten the adoption of digital multimedia products.

Improvements in storage medium and processors are the most germane to the proliferation of digital multimedia products. New releases of storage devices such as hard drives have consistently operated faster and stored more information while costing less. In 1984, \$1500.00 would buy little more than a ten megabyte hard drive with an average access time of 80Ms. Today forty megabyte hard drives with average access times around 28Ms cost \$250.00. Rewritable optical drives have been introduced. Memory chip prices have also declined in price while offering higher capacities and greater speeds. Improved processors offer greater capability and speed. With the introduction of the 80386, the problems of protected mode operations inherent in the 80286 disappeared. The 80386SX provides a version of the 80386 more comparable in cost to the 80286. Also of special interest is Intel's i486 chip which includes a coprocessor. The first

computer based on gallium arsenide, rather than silicon, has been released.

Based on past developments and finding no reason to suspect that manufacturers will quit improving their products, it is likely that future hardware will be faster, more compact, and less expensive. It will also offer greater storage capacity and capability. Luther (1990) predicts storage to "leap from megabytes to gigabytes per medium." Ultimately, Intel intends to integrate DVI with the CPU. Use of gallium arsenide could increase CPU and bus performance significantly. Such improvements will enable more data to be transferred and processed. Eventually, full screen full motion video without loss of resolution will be supported, with resolutions beyond 512 X 480. Sending video to central facilities will be unnecessary except perhaps for Advanced Television (ATV) quality full motion video.

As digital multimedia products are adopted more applications will be developed, further increasing the motivation to adopt these products. Tools for developing applications will also become more available. These tools will include sophisticated and user friendly authoring systems as well as motion video artistic editing tools. Such editing tools will take changes made to one frame and apply them to a series of frames, requiring changes to be made only once. Apple is designing an authoring system that will provide revolutionary capabilities for digital multimedia presentations. These tools will reduce the degree of technical expertise required to create applications. This in turn further increases the availability of products and reduces development costs.

Committees like the Joint Photographic Expert Group (JPEG) and Motion Picture Coding Expert Group (MPEG) are developing standards for digital video. Standards provide a common ground for products and reduce the risk that companies take when developing applications for particular domains. One reason that motion video artistic editing tools haven't been released, for example, is because no company wants to risk designing a tool that might be incompatible with digital motion video standards. Once MPEG issues the standards, such tools are likely to be released. Another standard that would influence digital multimedia is the ATV standard targeted for 1993. Proposals include:

- ◆ Enhanced NTSC (National Television Systems Committee) by the David Sarnoff Research Center, a 525 line noninterlaced format.
- ◆ DSC-HDTV (Digital Spectrum Compatible High Definition Television) by Zenith Electronics Corporation, a 787 line non-interlaced format.

- ◆ ADTV (Advanced Digital Television) by N.A. Phillips, a 1050 line interlaced format.

Digital television systems also set the foundation for many digital multimedia applications to be developed for the home consumer.

## V. CONCLUSIONS

Research dealing with linear multimedia instruction has produced mixed results. Several reviews of experiments dealing with the efficacy of media have found that most of these experiments report no significant difference between media based presentations and conventional presentations. Research on analog multimedia instruction has produced more positive results.

Overall, multimedia instruction is an effective approach to education. Even linear multimedia instruction, which often did not enhance learning, has been found to reduce costs without hindering learning. The failure of these experiments to show increased learning compared to traditional techniques could be the result of two errors. First, according to Salomon (1976), the multimedia presentations could be failing to offer anything new. One would not expect students to learn more from watching a lecture on television than from being at the actual lecture. Second, linear multimedia does not allow a student to refer to previous words, sentences, paragraphs and chapters at will as when reading a textual description. However, linear multimedia potentially provides a variety of stimuli to learn from. It also increases the cognitive resources one can allocate to the presentation. The relative benefits of the two techniques may have a canceling effect. Future research should seek to identify the characteristics of the technology that account for the greatest variance in learning and propose models for the design of effective multimedia presentations.

Digital multimedia technology allows applications to be developed with less effort and equipment, due to the flexibility and interactivity inherent with digital information. Most multimedia applications based on a digital format could also be developed and implemented with analog format. Ease of development is often the critical consideration.

Digital multimedia presentations are data intensive. In their raw form, information could neither be stored in sufficient quantities nor displayed at satisfactory rates to support digital multimedia applications. The development of sophisticated compression algorithms combined with the use of coprocessors has enabled microcomputers to support digital multimedia presentations.

The cost of developing products with digital multimedia does not stop with the purchase of the development and delivery products. Developing an application requires a team of professionals. The products must be formatively evaluated. Depending on the application, PLV quality and CD production may be necessary.

In the future, computers will be faster, offer more capability and have greater storage capacities. Digital multimedia products will be downsized, become more powerful and less expensive. Sending data to central facilities for high quality compression will be required only for very limited applications. More applications will be produced and tools will be developed to ease manipulation of video. Adoption of standards will allow design of products with less risk.

Digital multimedia benefits the consumer and industry. Companies have reported significant (up to 50%) savings designing digital multimedia applications compared to analog multimedia applications. Reduced development cost is a strong motivation for adopting a digital format. Savings can also be realized through distributed multimedia instruction over networks. Such instruction is not supported by analog multimedia except through television and has very limited application. Once videoconferencing is brought to the desktop an unprecedented degree of interactivity will be possible. Instructors will be able to interact with students as they are working, without entering into a classroom. The large amount of training that takes place in the military, combined with a declining military budget, should encourage consideration of the savings inherent in digital data when deciding which technologies to use to develop a multimedia application.

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