Dual Coding as a Possible Explanation for the Effects of Multimedia on Learning

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Abstract

This paper examines the possibility of using Paivio's (1971, 1991; Clark & Paivio, 1991) dual coding theory as an explanation for the effects of multimedia on learning. The paper describes dual coding theory, then examines the suitability of dual coding theory as an explanation of the results of a large number of studies using multiple media. It appears that dual coding theory may be a reasonable explanation for many of these studies. People seem to learn better when related information is presented simultaneously via verbal and pictorial media than when the information is presented via verbal or pictorial media alone. (11 pages, 45 references)

Introduction

The term "multimedia" has been used for decades (Brown, Lewis, & Harclerod, 1973) and can be thought of as the use of several media for the purpose of communicating information to a person. Multimedia is being used increasingly for educational purposes, especially via computer. One reason for this increase is that a computer-based multimedia tutorial allows the instructional designer to use a variety of media to present the learning material. These media include text, graphics, pictures, animation, sound, and video.

Computer-based multimedia instruction has enormous potential for improving learning. Not only is it possible to use the most effective medium to communicate information, but, once created, multimedia instruction can be easily and cheaply copied. This allows the instructional developer to amortize the cost of development and to increase the available number of potential students. For example, Andersen Consulting expects a $10 million return on investment from a multimedia version of its Business Practices course and Pacific Bell believes its multimedia internal policies and procedures course will save about $6 million (Jerram, 1994). Steelcase used self-paced multimedia to reduce the cost of training a student from about $200 per year to $20 per year (Rifkin, 1991).

From a cognitive psychology perspective, "learning is the act of deliberate study of a specific body of material, so that the material can be retrieved at will and used with skill" (Norman, 1982, p. 3). So, learning can be thought of as the process of assimilating new information such as facts, procedures, or concepts. Learning may be measured through a wide variety of tests. For example, a free recall test measures how many items a person can remember from a list. A recognition test measures how many items a person recognizes from a prior learning session. A problem-solving test measures a person's ability to integrate prior knowledge in a new way. Since multimedia is employed for many different kinds of learning, this paper will describe studies that use a variety of tests to measure learning.

Utilizing computer-based multimedia such as computer-based tutorials to present educational information is generally thought to improve learning compared to less media-rich techniques such as traditional classroom lecture. However, to take advantage of multimedia to improve learning, we need to understand why multimedia may help people to learn.

This paper examines the possibility of using Paivio's (1971, 1991; Clark & Paivio, 1991) dual coding theory as an explanation for the effects of multimedia information on learning. The paper describes dual coding theory, then examines the suitability of dual coding theory as an explanation of the results of a large number of studies that presented information using multiple media.

Paivio's Dual Coding Theory

According to Paivio's dual coding theory (1971, 1991; Clark & Paivio, 1991), information is processed through one of two generally independent channels. One channel processes verbal information such as text or audio. The representations of information processed by this system are known as logogens (from Morton, 1969). The other channel processes nonverbal images such as illustrations and sounds in the environment. The representations of information processed by this system are known as imagens. Both kinds of representational units are concrete, modality-specific (visual versus auditory versus sensorimotor), analogs rather than abstract, amodal structures.

Logogen and imagen representational units are connected by three processes so that activation can spread between units. The interconnections have varying activation

strengths, so activation flows probabilistically from a stimulus through the links. In this way, a word can evoke a picture and a picture can evoke a word. Representational processing is the direct activation of logogens (verbal representations) by linguistic stimuli and the direct activation of imagens (imaginal representations) by nonverbal stimuli. For example, the word "dog" can trigger an association with the "dog" logogen. According to Paivio, all cognitive tasks involve representational processing. Referential processing is activation that goes across the two representational systems. For example, the word "dog" can activate an image of the person's pet dog Spot. Associative processing is activation within one representational system. For example, the logogen "dog" can trigger an association with the logogen "cat."

Information can be processed through both the verbal and nonverbal (e.g., pictorial) channels. This occurs, for example, when a person sees a picture of a dog and also processes the word "dog." Information processed through both channels has an additive effect on recall (Mayer & Anderson, 1991; Paivio & Csapo, 1973), possibly because the learner has more cognitive paths that can be followed to retrieve the information. Paivio (1967, 1991) calls this expectation the additivity hypothesis. For example, information that uses text and relevant illustrations (verbal and pictorial channel) will likely be learned better than information that uses text alone (verbal channel only), audio alone (verbal channel only), combined text and audio (verbal channel only), or illustrations alone (pictorial channel only).

This idea is supported by one of Paivio's studies (Paivio, 1975). In this study, Paivio successively presented concrete items that included repeated pictures, repeated words, and picture-word combinations. People recalled more items that were successively presented as picture-word combinations compared to repeated pictures or repeated words. Paivio believes that this effect resulted because people differentially encoded the successive picture-word combinations.

This study (Paivio, 1975) also found that people recalled more successively repeated pictures than successively repeated words. Paivio believes that this is because people recall pictures better than words. This result is known as the picture superiority effect (Nelson, Reed, & Walling, 1976; Paivio, Rogers, & Smythe, 1968) and may be because pictures access meaning more quickly and completely than words (Smith & Magee, 1980; Nelson, 1979).

Although it appears that dual coding theory may be generalized to explain many kinds of learning, one limitation of dual coding theory is that it is most often used to explain only the learning of simple, concrete nouns. For example, using paired associates, Paivio (1963, 1965) found that nouns were better remembered than adjectives, and that concrete nouns (e.g., "lamp") were better remembered than abstract nouns (e.g., "loyalty"). Apparently (Paivio & Foth, 1970; Rowe & Paivio, 1971), the concreteness of the paired associates allowed the learner to integrate the two items into a single image.

Also, dual coding theory is not accepted by all cognitive scientists. Dual coding theory emphasizes that there are two modes of representation in memory—verbal and pictorial. Information is stored in the representation mode that most closely matches its presentation. However, the concept of dual coding is challenged by other investigators (e.g., Anderson & Bower, 1973; Norman & Rumelhart, 1975; Pylyshn, 1973) who believe that information is stored in a single, abstract memory.

So, Paivio's dual coding theory supports the idea that people learn by connecting new knowledge to prior knowledge. People learn better when the learning materials involve related verbal and pictorial information compared to verbal material alone or pictorial

material alone. It also appears that information presented through the pictorial channel is more salient and better remembered than information presented through the verbal channel.

The next two sections try to use dual coding theory to explain the results of many studies that examined the effects of presenting multimedia information on learning.

Dual Coding Improves Multimedia Learning

The following studies support the idea that dual coding is a possible explanation for multimedia learning.

Text and Illustrations

In a review of the literature on text and illustrations, Levie and Lentz (1982) found that text that was accompanied by illustrations showing what was described in the text was learned better by children than text that was not accompanied by supportive illustrations. For example, Peeck (1974) asked fourth grade children to read a story with or without supportive illustrations, measured learning via multiple choice, verbal recognition tests, and found that retention was better with supportive, illustrated text. Levie and Lentz estimated that children reading illustrated text learned one-third more than children reading unillustrated text, especially when the illustrations supported information presented in the text.

Dual (verbal and pictorial) media also seem to improve the ability to learn assembly instructions. College students who used text with pictures made fewer construction errors on an assembly task than college students who used only text (Stone & Glock, 1981).

Dual coding may help people learn spatial information. For example, Garrison (1978) presented to children short stories with and without supportive illustrations. One day later, the children who saw pictures with the text recalled and recognized more spatial relationships between concepts in the stories than children who saw only text. A series of studies by Dwyer (1967, 1978) found that learning via illustrated text was better than text alone when students were tested on spatial information using a drawing test. So, people appeared to find it easier to learn spatial information when they saw pictures and text than when they saw only text.

Interestingly, Levie and Lentz (1982) also found that illustrations that did not show what was described in the text did not improve learning. For example, Sewell and Moore (1980) added to textual material small cartoons that did not support the textual information. Although the students enjoyed the cartoons, the cartoons did not affect learning. Evans and Denney (1978) found that the short phrases in picture-phrase combinations were recalled better as the pictures and phrases became more related. Using verbal captions, Bahrick and Gharrity (1976) showed that pictures helped people recall captions that were related to the pictures, but not captions that were unrelated. These results suggest that the mere presence of illustrations does not improve the learning of textual information. The illustrations must show information that is presented in the text. It appears that supportive illustrations allow learners to build referential connections between the verbal and pictorial information (Paivio, 1971, 1991; Clark & Paivio, 1991), and improve memory and learning.

The learning advantage found when supportive verbal and illustrated information are presented together appears to be due to the dual coded integration of the information rather than due to repetition of the information. For example, Levin, Bender, and Lesgold (1976) presented to children (1) one oral sentence at a time, (2) the same sentence twice in succession, or (3) the sentence with a related illustration. So, this study included conditions in which the information was repeated using the same medium or was presented via dual (verbal and pictorial) media. A cued-recall test using short questions about the

stories formed by the sentences found that learning was best with the sentence-illustration combination. So, learning was better in the dual (verbal and pictorial) media condition than in the repetition condition.

In a related study, Paivio and Csapo (1973) presented words and pictures in a random sequence that included presenting (1) a word twice, (2) a pictorial representation of the word twice, or (3) the word once and the picture once. So, this study included conditions in which the information was repeated using the same medium (verbal or pictorial) or was presented via dual (verbal and pictorial) media. A free recall test found that learning was best when the word and picture were each presented once. Learning was best in the condition that encouraged dual coding.

The results of the Levin, Bender, and Lesgold (1976) and Paivio and Csapo (1973) studies suggest that dual coding, rather than repetition, is responsible for the improvements in recall for verbal-illustration combinations.

Audio and Illustrations

Static pictures appear to help children learn auditory, oral prose. Levin and Lesgold (1978) reviewed a dozen studies that examined the effect of pictures on children's ability to learn auditory, oral, fictional, stories. The pictures reflected the contents of the stories. Learning was measured by short answers to factual questions. The reviewers found that related pictures improved learning of the oral prose. So, dual (verbal and pictorial) media improved learning compared to single (verbal) media.

Audio and Video

When children saw (video condition), heard (audio condition), or saw and heard (audiovisual condition) commercials imbedded in a short story, the children who saw or saw and heard the short story recognized more advertised products than the children who only heard the short story (Stoneman & Brody, 1983). For recognizing advertised products in a short story, the audiovisual media and the visual media were more effective than the auditory media alone. On an immediate test of factual recall, children who saw a movie with an audio narration did better than children who heard a similar narration via radio (Barrow & Westley, 1959). Children recalled more story details when the story was presented via television with a narrated soundtrack than radio (soundtrack alone) (Beagles-Roos & Gat, 1983). Another study (Meringoff, 1980) found that children remembered more story actions when they saw a televised film with story narration than when they were read a very similar illustrated story.

Since learning was better in the combined verbal-pictorial (audiovisual) conditions than in the verbal (audio) conditions, these results support Paivio's (1971, 1991; Clark & Paivio, 1991) dual coding theory. Also, since learning in the pictorial (video and audiovisual) conditions was superior to learning in the verbal (audio) conditions, these results are consistent with the picture superiority effect (Nelson, Reed, and Walling, 1976; Paivio, Rogers, & Smythe, 1968).

Media Synchronization

The order in which media are sequenced appears to affect multimedia learning. The results of these studies can be explained using dual coding theory. For example, Baggett and Ehrenfeucht (1983) arranged for college students to see and hear a narrated movie on carnivorous plants or to first see the movie without narration, then hear the narration. On 63 true-false, multiple choice, and short answer questions, the students who saw the movie and heard the narration simultaneously scored higher than the students who saw the movie without narration, then heard the narration.

Mayer and Anderson (1991, 1992) performed a series of studies in which mechanically naive college students watched an animation showing how a bicycle pump or automobile drum brakes worked and heard a verbal explanation. The verbal explanation was presented before the animation or during the animation. The students who heard the verbal explanation with the animation performed higher on a creative problem-solving test than the students who heard the verbal explanation before the animation.

So, synchronized presentation of verbal-pictorial information appears to be better than sequential presentations, possibly because the synchronized presentation helps learners use dual coding to increase interconnections to information already in memory and, for example, to develop device cognitive models (Baggett, 1984; Baggett & Ehrenfeucht, 1983).

Dual Coding Impairs Multimedia Learning

Although the studies described above support dual coding as an explanation for multimedia learning performance, there are some studies in which dual coding appears to impair multimedia learning. For example, in a study by Palmiter and Elkerton (1991), students who learned user interface procedures via text (verbal condition) outperformed students who learned via animation and auditory narration (pictorial and verbal condition). This unexpected result may have been obtained because the text only group had to perform active encoding, but the animation and auditory narration students passively watched the highly salient animation, ignored the auditory information, and may have learned the procedural steps less well.

In a classroom test, Samuels (1967) found that a related picture accompanying a simple short story interfered with poor first grade readers' ability to learn a sight vocabulary. In a laboratory study, Samuels (1967) presented words only or words with identifying pictures to kindergarten children who were learning to read words. When tested using only pictures, the children who saw words with pictures correctly named more words than the children who saw only words. However, when tested using only words, the children who saw words only performed better than the children who saw words with pictures. For this latter test, it appears that the pictures distracted the young children. Also, transfer appropriate processing (e.g., Morris, Bransford, & Franks, 1977) or an encoding specificity effect (Tulving & Thomson, 1973) appears to have occurred. Learning was best when the test stimuli matched the encoding stimuli.

Conclusions

It appears that Paivio's (1971, 1991; Clark & Paivio, 1991) dual coding theory is a reasonable explanation for the results of a large number of studies of multimedia learning. People appear to learn better when related information is presented simultaneously via verbal and pictorial media than when information is presented via verbal or pictorial media alone. This result may occur because referential connections (connections between verbal and pictorial concepts) provide the learner with more cognitive paths that can be followed to retrieve the learned information. This support for dual coding theory suggests that computer-based multimedia instructional system designers should consider supplementing on-screen textual information with closely related pictorial information.

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