A Framework for Learning from Media: The Effects of Materials, Tasks, and Tests on Performance

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October 24, 1997

(Technical Report GIT-GVU-97-21)

Keywords: Multimedia, learning

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Abstract

Existing theories (e.g., Baggett, 1984, 1989; Baggett & Ehrenfeucht, 1982, 1983; Clark & Paivio, 1991; Mayer, 1993; Paivio, 1971, 1991; Clark & Paivio, 1991) do not adequately predict the effects of multimedia on learning. We need to develop a more complete theoretical framework for understanding the effects of multimedia on learning. Four elements appear to be critical to this framework (e.g., Bransford, 1978; Jenkins, 1978; Najjar, 1995). These elements are the learners, the learning materials, the tasks performed by the learners, and the tests of learning. All four elements affect whether multimedia information is learned. The critical, common factor appears to be transfer-appropriate processing. Information that is processed the same way at learning and at test (e.g., verbally, pictorially) may be learned better than information that is not learned this way (e.g., Morris, Bransford, & Franks, 1977; Stein, 1978). This paper describes the literature that is the basis for these ideas.

Introduction

The effects of multimedia on learning are surprisingly inconsistent. Sometimes multimedia helps people to learn (e.g., Baek & Layne, 1988; Goldstein, Chance, Hoisington, & Buescher, 1982; Levie & Lentz, 1982; Severin, 1967), sometimes it does not help (e.g., Bahrick & Gharrity, 1976; Evans & Denny, 1978; Levie & Lentz, 1982; Peeck, 1985 as cited in Winn, 1993; Sewell & Moore, 1980). What appears to be missing is a general understanding or framework about the factors that affect whether multimedia helps people to learn.

The purpose of this paper is to build a theoretical framework that describes when and why multimedia information improves learning. The framework will be built on four basic factors that need to be considered when evaluating learning (Bransford, 1978; Jenkins, 1978; Najjar, 1995). The four factors are: (1) the learners, (2) the materials used to present information, (3) the tasks performed by the learners, and (4) the test of learning.

Within this framework, transfer-appropriate processing (e.g., Morris, Bransford, & Franks, 1977; Stein, 1978) appears to be one of the principal ways to improve learning from multimedia information. The way the learner processes the information when learning should match the way the learner processes the information for the test of learning. This effect is most evident when we compare the learning of verbal versus pictorial information.

The following sections will examine each of the four factors in the proposed framework.

Learners

Characteristics of the learners appear to affect learning from multimedia.

Prior Knowledge

Multimedia information appears to be more effective for learners with low prior knowledge or aptitude in the domain being learned. Regarding naive learners, Mayer and Gallini (1990) found that illustrations helped college students with low prior knowledge of automobile drum brakes, pumps, or generators to recall textual explanatory information and to solve creative problems. Adding the illustrations to the text did not generally affect the learning performance of students who had high prior knowledge of these devices. Other studies found similar effects for teaching natural science to fifth-graders (Kraft, 1961), geology and meteorology to college students (Dean & Enemoh, 1983; Kunz, Drewniak, & Schott, 1989), and basic training information to army recruits (Kanner & Rosenstein, 1960; Kanner, Runyon, & Desiderato, 1954).

Aptitude

Multimedia also appears to be more helpful for learners with low aptitude than learners with high aptitude. For example, in one study (Blake, 1977), college students with low or high aptitude in spatial and mental abilities learned the pattern of movement of five chess pieces via moving pictures (film), static pictures with animated arrows, or static pictures alone. The students with low aptitude performed better in the conditions with motion than the condition with static pictures alone. However, the students with high aptitude performed similarly on all three kinds of pictures. Wardle (1977, as cited in Levie & Lentz, 1982) gave 800-word textual passages on various science topics to seventh-grade students. Some of the passages included supportive illustrations. Poor readers performed better on a comprehension test when the passages included illustrations. For good readers, the illustrations had no effect.

Although only a handful of studies examined this principle, the results of these studies suggest that multimedia is most effective for people with low prior knowledge or aptitude in the domain being learned. This may be because experts have prior knowledge that can be used to understand and integrate the new information, but novices lack this advantage. Also, novices may not know which information is important and on which information they should focus their attention. Learners with high aptitude appear to be able to learn from relatively non-elaborative media such as text, but low-aptitude learners benefit most from the elaborative and explanatory advantages offered by multimedia. Also, high-aptitude learners may be good learners, regardless of the media used to present the information (e.g., Kanner & Rosenstein, 1960; Kanner et al., 1954; Kraft, 1961).

Materials

Characteristics of the learning materials appear to affect learning from multimedia.

Spatial Information

Illustrations are superior to text when learning spatial information. For example, Bartram (1980) arranged for college students to learn how to get from a starting point to a destination using a minimum number of buses. The researcher presented the bus route information via maps or lists and asked the students to provide as quickly as possible the correct list of bus numbers in the correct order. Bartram measured the time it took to correctly complete each bus route task. The study found that the students learned the bus route information more quickly when they used a map than when they used lists. Bartram believed that the students performed a spatial task, and the maps were superior to lists because the map presentation of information is consistent with people's preferred internal representation of spatial information.

In an exploratory study, Bell and Johnson (1992) allowed four people to select pictures or text for communicating instructions for loading a battery into a camera. Qualitative results showed a strong preference for pictures rather than text. The researchers believed that the information to be communicated was spatial, and that the results supported the hypothesis that spatial information should be presented pictorially.

A study by Garrison (1978) supported the idea that spatial relations are recalled and recognized better by children when the spatial relations are presented via story text and illustrations rather than story text alone. Also, a series of studies by Dwyer (1967, 1978) found that illustrated text was better than text alone when students were tested on spatial information using a drawing test.

Pictures appear to be an effective way to learn spatial information. This may be because spatial information tends to be encoded spatially (e.g., Kosslyn, 1973, 1975, 1976; Kosslyn, Ball, & Reiser, 1978) rather than verbally or by what it means (i.e., semantically).

Verbal Information

Verbal presentations (e.g., text, audio narration) can be better than pictorial presentations when learning verbal information. One study (Palmiter & Elkerton, 1991) found that text was better than animation for presenting procedural information. Seven days after seeing the information, participants who saw only text were faster and as accurate at performing the procedure as the participants who saw animated demonstrations. The participants who saw the procedures via text may have learned them better than the participants who saw pictorial demonstrations because procedures are mostly verbal information. It is also possible that the textual procedures were learned better than the animated demonstrations due to differences in processing effort (e.g., Jacoby, Craik, & Begg, 1979; Salomon, 1984; Walker, Jones, & Mar, 1983). The text learners may have expended more effort to read and understand the information, resulting in improved long-term encoding of the information. But the people who watched the animated demonstrations may have passively observed the demonstrations without processing the information as well.

The superiority of providing verbal presentations (versus pictorial presentations) to help people learn verbal information is not consistent. Sometimes simple pictorial information is verbally recalled better than simple verbal information. For example, Paivio (1967, 1975, 1991; Paivio & Csapo, 1973) successively presented simple concrete items that included repeated pictures and repeated words. The pictures were easy to verbally label (e.g., "chair"). People verbally 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 semantic meaning more quickly and completely than words (Smith & Magee, 1980; Nelson, 1979).

Providing pictures with verbal information also improves verbal learning performance. Pictures improved the recall of textual (Paivio & Csapo, 1973) or auditory (Severin, 1967) words, the recall and comprehension of textual passages (Levie & Lentz, 1982; Nugent, 1982), the recall of auditory passages (Barrow & Westley, 1959; Beagles-Roos & Gat, 1983; Levin & Lesgold, 1978; Meringoff, 1980; Nugent, 1982), the recall of a story's structure (Baggett, 1979), the comprehension of auditory passages (Bransford & Johnson, 1972), and problem-solving performance (Mayer & Anderson, 1991).

However, adding unrelated illustrations did not improve, and sometimes actually decreased, learning. Unrelated illustrations did not improve comprehension and recall of textual material (Levie & Lentz, 1982; Sewell & Moore, 1980) or recall of illustration captions (Bahrick & Gharrity, 1976; Evans & Denny, 1978). One investigator (Peeck, 1974) found that adding supportive illustrations to text helped fourth-grade children retain verbal information. But unrelated illustrations (Peeck, 1985 as cited in Winn, 1993) made it harder for learners to comprehend the text. Dual (verbal and pictorial) coding of related information may improve learning performance because it provides more cognitive pathways for the learner to follow when retrieving the information.

So, verbal presentations can result in better performance on verbal measures of learning than pictorial presentations. However, this is sometimes not the case. For simple stimuli, such as names and pictures of simple objects, pictorial presentations may be more effective than verbal presentations. For more complex verbal stimuli, providing related pictures with the verbal information usually results in better performance than providing the verbal information alone.

Tasks

Characteristics of the tasks performed during learning appear to affect learning from multimedia.

Information Processing

Learning appears to improve when the learning task encourages the learner to actively process the information (e.g., Bobrow & Bower, 1969; Bower & Winzenz, 1970; Jacoby, 1978; Slamecka & Graf, 1978). For example, one study (Dean & Kulhavy, 1981) asked students to learn the features of a fictitious country. One group of students studied a map on which the features were labeled. Another group copied the features and labels onto a blank map. The students who were forced to actively process the spatial information by copying the map performed better on a free recall test of the map information.

Rieber (1989, 1990) created computer-based instruction on Newton's laws of motion that presented information via textual and graphic chunks. Fourth- and fifth-grade students learned the information in one of three conditions: (1) text alone, (2) text and static graphics, or (3) text and dynamic graphics. After each of the four instruction segments, some students interacted with a simulation showing the effects of forces on the motion of a "starship" in a gravity-free environment. Another group of students did not interact with the simulation. The students who performed tasks that encouraged them to process the information (e.g., interact with the simulation) performed better on 26 multiple-choice questions than the students who did not perform the extra processing task. For the students who did not interact with the simulation, there were no differences in learning performance. So, tasks that encouraged the learners to process the information resulted in improved learning performance.

Reading text may also cause the learner to more actively process the information than simply hearing verbal narration (e.g., Aldrich & Parkin, 1988; Baggett & Ehrenfeucht, 1983; Palmiter & Elkerton, 1991; Pezdek et al., 1984) or watching a silent movie (Salomon, 1984). Similarly, materials that force the learner to figure out confusing information may cause the learner to more actively process the information and to improve learning performance (e.g., Auble & Franks, 1978; Bock, 1978; Hunt & Elliot, 1980; Kolers, 1979; Walker et al., 1983; Sherman, 1976).

Simple repetition of the information does not necessarily improve learning. For example, before changing the frequency of its radio broadcast, the BBC advertised the new frequency via radio, television, newspaper, and direct mailings. Listeners received around 1,000 exposures to the information about the new frequency. However, only 17% of the listeners learned the new frequency (Bekerian & Baddeley, 1980). To encourage listeners to actively process information, a different study (Thomson & Barnett, 1981) arranged for participants to hear 16 fake radio commercials. In one condition, the listeners heard the product name at the beginning (e.g., “Buy Brighto!”) and end of the commercial (e.g., “Buy Brighto!”). In another condition, listeners heard the product name at the beginning of the commercial (e.g., “Buy Brighto!”), but the product name was left hanging, unpronounced, at the end of the commercial (e.g., “Buy !”). The final condition was the same as the previous condition, except listeners wrote down the name of the product that was left unpronounced at the end of the commercial. Fifteen minutes later, an unexpected test showed that recall accuracy improved across the groups from 16% to 29% to 46%. Extra processing appeared to improve learning.

<u>Type of Task</u>

Also, the type of active processing is important. For example, Craik and Tulving (1975) found that processing the structural characteristics of each word in a list (e.g., “Is the word in capital letters?”) was not as effective as processing the meaning of the word (e.g., “Would the word fit the sentence: ‘He met a _____ in the street’?”). Other researchers (e.g., Craik & Watkins, 1973; Hyde & Jenkins, 1969; Parkin, 1984; Rundus, 1977) obtained similar results.

It is possible that tasks that encourage the learner to actively process the information may focus the learner's attention on the information and cause the learner to process the information more elaboratively. This appears to be especially true when the processing focuses on the meaning of the information rather than its appearance. Information that is processed in this way is easier to connect with long-term memories, may improve retrieval, and may therefore result in improved learning (e.g., Anderson & Reder, 1979; Burns, 1992; Hirshman & Bjork, 1988; Reder, 1979).

Tests

Characteristics of the test of learning appear to affect learning from multimedia.

Transfer-Appropriate Tests

Scores on learning tests are higher when the kind of information that the learner needs to retrieve to complete the test matches the kind of information that the learner studied (e.g., Dwyer, 1967, 1978; Morris, et al., 1977; Samuels, 1967; Stein, 1978; Watkins, 1974). For example, on a verbal learning test, children in a verbal condition performed better than children in a verbal-pictorial condition (Beagles-Roos & Gat, 1983). On a pictorial test, children in a verbal-pictorial condition performed better than children in a verbal condition. Another study (Garrison, 1978) found that children who read a story with related illustrations recalled and recognized more spatial relations between concepts in the story than children who read the story without illustrations.

Dwyer (1967, 1978) used text or text with various illustrations to teach heart anatomy to college students. He measured learning using a drawing test, an identification test, a terminology test, and a comprehension test. The drawing tests showed better learning performance for the text with illustrations conditions. However, the comprehension tests showed no difference in learning performance for text or text with illustrations. An explanation for these results is that the drawing test measured spatial information that was best communicated with text and illustrations, but the comprehension test measured heart actions that were best communicated verbally via text alone rather than through static illustrations. Poon, Szabo, and Ally (1997) obtained similar results. After reviewing Dwyer's work, Levie and Lentz (1982, p. 213) concluded that, "on the whole, the degree to which an educational objective is aided by pictures depends on the emphasis given to knowledge about spatial information in the test of learning."

So, learning performance appears to improve when the way the learner stores the information (e.g., verbally, pictorially) is similar to the way the information is tested. To improve student learning performance, the test should require the learner to retrieve the same kind of information that was stored. This effect is called transfer-appropriate processing (e.g., Morris et al., 1977; Tulving & Thomson, 1973).

Theoretical Contribution

This proposed theoretical framework makes several contributions to advancing the study of the effects of multimedia on learning. The theoretical framework appears to be superior to other theories of multimedia and learning. For example, Mayer’s (1993) theory of explanative illustrations includes, to some extent, factors for the learners, materials, and the tests. But the theory does not emphasize the importance of the tasks performed by the learners while learning. Paivio’s (1971, 1991; Clark & Paivio, 1991) dual coding theory emphasizes the materials and has explored the effects of learner tasks (e.g., Paivio & Foth, 1970; Paivio & Csapo, 1973). However, dual coding theory does not include as factors the learners or the tests of learning. Finally, Baggett’s (1984, 1989; Baggett & Ehrenfeucht, 1982, 1983) bushiness hypothesis includes as factors the materials, but does not address the effects of the learners, tasks, or tests.

All four factors are important in any learning situation, but no studies manipulate or consider all four factors. So, current multimedia studies do not address alternative explanations for their results and fail to advance the field. The proposed framework may help satisfy these needs.

The proposed theoretical framework includes more factors than existing theoretical explanations and should allow us to make more and better predictions. For example, the theories of Paivio and Baggett do not include the type of test as an influence on learning performance. As a result, the powerful effects of transfer-appropriate processing (e.g., Morris et al., 1977; Tulving & Thomson, 1973) cannot be used to predict performance. The Paivio and Baggett theories do not explain why children in a verbal condition outperformed on a verbal learning test children in a verbal-pictorial condition or why children in a verbal-pictorial condition outperformed on a pictorial learning test children in a verbal condition (Beagles-Roos & Gat, 1983).

The theoretical framework will help us to answer several questions. When presenting information to learners, does the media matter? Can we improve learning by asking learners to perform specific tasks while they learn? When measuring learning performance, does the kind of test we use make a difference? The answers to these questions should improve our understanding of how people learn from multimedia and allow us to build more effective educational multimedia applications.

Conclusion

The studies reviewed in this chapter provide support for the proposed theoretical framework. It appears that learners, materials, tasks, and tests affect learning. Learners who are already familiar with the domain being learned or have high aptitude in the domain appear to be able to process the new information more appropriately for a test than naive learners or learners with low aptitude in the domain. Materials and tasks that encourage processing that is consistent with the processing required to perform the test of learning (e.g., pictorial, verbal) appear to improve learning performance better than materials and tasks that do not encourage transfer-appropriate processing.

In particular, the literature review supports the idea that educational multimedia may be most effective when:

- Learners are naive about the domain being learned. These learners may be able to improve their understanding by connecting the rich multimedia information to prior knowledge (e.g., Dean & Enemoh, 1983; Kanner & Rosenstein, 1960; Kanner, Runyon, & Desiderato, 1954; Kraft, 1961; Kunz, Drewniak, & Schott, 1989; Mayer & Gallini, 1990).
- Learners have low aptitude in the domain being learned. These learners appear to benefit most from the elaborative and explanatory advantages provided by multimedia (e.g., Blake, 1977; Wardle, 1977, as cited in Levie & Lentz, 1982).
- If the information is spatial, pictures are used to present the information. Pictures appear to encourage the learners to process the spatial information the way that seems to be most effective--spatially (e.g., Bartram, 1980; Bell & Johnson, 1992; Dwyer, 1967, 1978; Garrison, 1978; Kosslyn, 1973, 1975, 1976; Kosslyn, Ball, & Reiser, 1978).
- If the information is verbal, text with pictures or audio narration with pictures is used to present the information. Text or audio narration may encourage learners to process verbal information verbally (e.g., Palmiter & Elkerton, 1991). The picture superiority effect may also boost verbal learning (e.g., Nelson, Reed, & Walling, 1976; Paivio, Rogers, & Smythe, 1968).
- Learners process the information in a way that is consistent with the way it is accessed during the test of learning (e.g., perform verbal tasks to prepare for a verbal test). Appropriate processing may encourage learners to store the information

in a way that is easier to retrieve for the test of learning (e.g., Craik & Tulving, 1975; Craik & Watkins, 1973; Dean & Kulhavy, 1981; Hyde & Jenkins, 1969; Parkin, 1984; Rieber, 1989, 1990; Rundus, 1977).

- The test of learning matches the way learners encoded the information (e.g., information stored pictorially is tested with a pictorial test). This consistency may increase the likelihood that learners will be able to retrieve the information and produce high scores on the test of learning (e.g., Beagles-Roos & Gat, 1983; Dwyer, 1967, 1978; Garrison, 1978; Morris, et al., 1977; Poon, Szabo, & Ally, 1997; Samuels, 1967; Stein, 1978; Watkins, 1974).

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Biography

Larry Najjar attended the College of the Holy Cross in Worcester, Massachusetts. He graduated with a BS in psychology in 1980. In 1983, he was awarded an MS in engineering psychology from the Georgia Institute of Technology in Atlanta, Georgia.

After graduating, Larry worked for Systems Research Laboratories in Hanover, Maryland. He designed the software and hardware user-interface for an advanced word processing and audio transcription work station. In 1984, he joined the IBM Corporation in Rockville, Maryland. Larry helped design the user-interface for the next-generation US air traffic control system, including the digital flight strips, keyboard, work station, and user warnings. In 1989, he transferred to Atlanta, Georgia, where he designed and tested user-interfaces for a wide variety of commercial applications.

Larry left IBM in 1993 to pursue his PhD in engineering psychology at the Georgia Institute of Technology. He is a graduate research assistant at the Georgia Tech Research Institute. He helps design and build a wearable computer that provides mobile performance support for poultry plant workers, develops educational multimedia applications, and designs and maintains numerous World Wide Web pages. For his dissertation, Larry is examining the effects of multimedia on learning.

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