DOCUMENT RESUME

ED 455 812 IR 020 768

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TITLE The Use of Audio and Animation in Computer Based Instruction.
PUB DATE 2000-10-00
NOTE 10p.; In: Annual Proceedings of Selected Research and Development Papers Presented at the National Convention of the Association for Educational Communications and Technology (23rd, Denver, CO, October 25-28, 2000). Volumes 1-2; see IR 020 712.
PUB TYPE Reports - Research (143) -- Speeches/Meeting Papers (150)
EDRS PRICE MF01/PC01 Plus Postage.
DESCRIPTORS *Animation; Audio Equipment; Biology; *Computer Assisted Instruction; High Schools; Illustrations; Instructional Effectiveness; *Instructional Materials; *Multimedia Instruction; *Multimedia Materials; Spatial Ability; Teaching Methods; *Visual Aids

ABSTRACT

This study investigated the effects of audio, animation, and spatial ability in a computer-based instructional program for biology. The program presented instructional material via test or audio with lean text and included eight instructional sequences presented either via static illustrations or animations. High school students enrolled in a biology course were blocked by spatial ability and randomly assigned to one of four treatments (Text-Static Illustration, Audio-Static Illustration, Test-Animation, Audio-Animation). The study examined the effects of instructional mode (Text versus Audio), illustration mode (Static Illustration versus Animation), and spatial ability (Low versus High) on practice and posttest achievement, attitude, and time. Results for practice achievement indicated that high spatial ability participants achieved more than low spatial ability participants. Similar results for posttest achievement and spatial ability were not found. Participants in the Static Illustration treatments achieved the same as participants in the Animation treatments on both the practice and posttest. Likewise, participants in the Text treatments achieved the same as participants in the Audio treatments on both the practice and posttest. Findings for time-in-program and time-in-instruction indicated that participants in the Animation treatments took significantly more time than participants in the Static Illustration treatments. No time differences of any type were found for participants in the Text versus Audio treatments. Implications for the design of multimedia instruction and topics for future research are included. (Contains 32 references.) (Author/AEF)

The Use of Audio and Animation in Computer Based Instruction

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Abstract

This study investigated the effects of audio, animation and spatial ability in a computer based instructional program for biology. The program presented instructional material via text or audio with lean text and included eight instructional sequences presented either via static illustrations or animations. High school students enrolled in a biology course were blocked by spatial ability and randomly assigned to one of four treatments (Text-Static Illustration, Audio-Static Illustration, Text-Animation, Audio-Animation). The study examined the effects of instructional mode (Text vs. Audio), illustration mode (Static Illustration vs. Animation) and spatial ability (Low vs. High) on practice and posttest achievement, attitude and time.
Results for practice achievement indicated that high spatial ability participants achieved more than low spatial ability participants. Similar results for posttest achievement and spatial ability were not found. Participants in the Static Illustration treatments achieved the same as participants in the Animation treatments on both the practice and posttest. Likewise, participants in the Text treatments achieved the same as participants in the Audio treatments on both the practice and posttest.
Findings for time-in-program and time-in-instruction indicated that participants in the Animation treatments took significantly more time than participants in the Static Illustration treatments. No time differences of any type were found for participants in the Text versus Audio treatments. Implications for the design of multimedia instruction and topics for future research are included.

Introduction

Multimedia computer-based instruction (CBI) is increasingly used as an adjunct to traditional instruction in schools and corporations. CBI has typically incorporated text and graphics, but technology now exists which allows the easy and inexpensive inclusion of audio and animation into CBI programs. However, little research exists to support the notion that adding audio or animation to CBI improves learning.

Research in audio-text instruction is contradictory with some studies indicating that text plus audio is more effective than either alone (Enerson & Tumey, 1984; Hartman, 1961; Lauret, 1998; Menne & Menne, 1972; Nasser & McEwen, 1976). Other studies indicate that text plus audio is not more effective than either alone (Barron & Atkins, 1994; Barron & Kysilka, 1993; Barton & Dwyer, 1987; Furnham, Gunter & Green, 1990; Nugent, 1982; Rehaag & Szabo, 1995; Van Mondfrans & Travers, 1964). These contradictory results can be explained by Paivio's dual coding theory which proposed that two separate systems are involved in cognition, one for verbal information and another for image formation (Paivio, 1986). In Paivio's view, spoken and written language are both verbal information and are encoded into verbal representations (Clark & Paivio, 1991). In terms of dual coding theory, redundant audio is single channel verbal information and would not be expected to increase learning.

Audio combined with animation is a relatively new research field that evolved from research into the effective integration of text with illustrations. Some audio-animation research has found the combination an effective technique (Lee, 1996; Mayer & Anderson, 1991; Mayer & Anderson, 1992; Mayer & Moreno, 1998; Mayer & Sims, 1994; Moreno & Mayer, 1999), while other such research has not found positive results (Childress, 1995; Lee, 1997; Palmiter & Elkerton, 1993; Wilson, 1998).

The role spatial ability plays in learners' interpretation and comprehension of animated and static graphics is unclear. Some researchers have found animation beneficial to low spatial ability learners

(Blake, 1977; Hays, 1996). Other studies have found animation more beneficial to high spatial ability learners (Hegarty & Sims, 1994; Hegarty & Steinhoff, 1997; Mayer & Sims, 1994).

The present study investigated the effects of audio, animation and spatial ability utilizing a multimedia CBI program concerning a scientific process. The major independent variables were instructional mode (text versus audio), illustration mode (static versus animated) and spatial ability (low versus high).

Instructional mode consisted of two versions, text and audio. In the text version, the instruction was presented as screen text, while in the audio version, the instruction was presented as spoken words with limited screen text. The spoken words of the audio version matched the text of the text version.

There were two versions of illustration mode, static and animated. The static version consisted of a graphic depicting the process with no visual movement to show the process in operation, while the *animated version showed the process with visual movement to demonstrate the process in operation.*

Spatial ability represented another variable in this study. All participants were classified as low or high spatial ability based on learners' scores on the Paper Folding Test (Ekstrom, French, & Harmon, 1976).

Research Questions

What is the effect of instructional mode, illustration mode and spatial ability on achievement, amount of invested mental effort and time?
Does instructional mode, illustration mode and spatial ability interact to influence achievement, amount of invested mental effort and time?

Method

Participants

One hundred and nine students from an urban high school biology course participated in this study. Participants were blocked by spatial ability and randomly assigned to one of four treatments (Text-Static Illustration, Audio-Static Illustration, Text-Animation, Audio-Animation).

Materials

A CBI program, *The Cell Cycle*, was the primary instructional material. This CBI covered mitosis and meiosis and took 40-70 minutes to complete. The CBI was based upon the objectives and content of the biology course and included information, examples, activities, practice with feedback and review. Figure 1 shows sample instructional screens for Text-Static Illustration and Audio-Static Illustration program versions.

Procedures

A spatial ability test was administered to the participants approximately one week prior to the study. Scores from all participants were ranked and median split to classify participants as high or low spatial ability. Participant assignment to each of the four treatments was counterbalanced by spatial ability. On the first day of the study, participants received instructions from the researcher and worked through the CBI program. On the second day of the study, participants completed the CBI program, an amount of invested mental effort survey and a posttest. All events occurred during normally scheduled class time.

Criterion Measures

There were three criterion measures employed in this study: an amount of invested mental effort survey, practice item results and posttest scores. En-route time data was also examined.

A 3-item Likert scaled (5 point scale from Strongly Agree to Strongly Disagree) amount of invested mental effort survey was administered prior to the posttest. This survey had a reliability of 0.57. The three items were similar to those developed by Salomon (1984) and concerned the amount of effort and concentration expended by the participants as well as how well they thought they understood the material.

Achievement was measured by a 27-item posttest. The posttest included 15 selected response and 12-constructed response items with each item worth one to three points for a total of 30 possible points. The reliability of the posttest was 0.82.

The practice items were similar in form and content to the posttest and included 17 selected response and 11-constructed response items with each item worth one to three points for a total of 30 possible points. The reliability of the practice items was 0.70.

Results

No differences in posttest achievement for instructional mode, illustration mode or spatial ability were found. The overall mean for the posttest was 17.34 (57.8%). Practice achievement differences by spatial ability were found (see Table 1). High spatial ability participants had greater achievement on practice items than low spatial ability participants. The overall mean practice score was 15.45 (51.5%).

There was a significant difference between High and Low spatial ability participants for amount of invested mental effort (see Table 2). Low spatial ability participants indicated a greater amount of invested mental effort than high spatial ability participants. The overall mean for invested mental effort was 4.04.

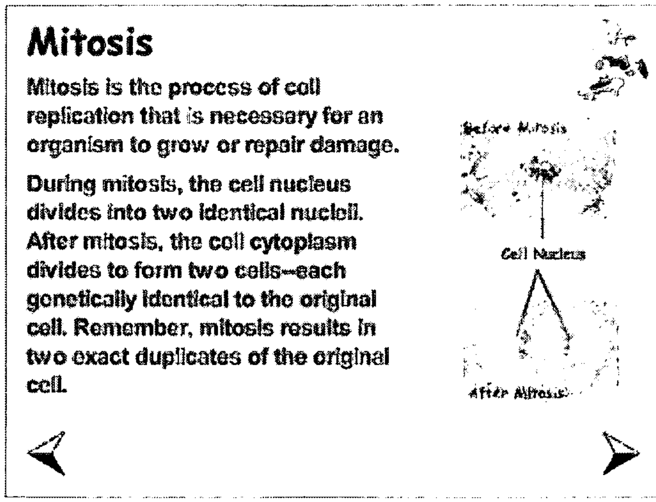
Three types of en route time data were collected. For the purposes of the study, total time-in-program was defined as the time elapsed between the participant entering and exiting the CBI program; time-in-practice was defined as the time the participants spent completing the practice items within the CBI program; and time-in-instruction was defined as the difference between total time-in-program and time-in-practice. Since the practice screens were identical in all four treatments, time-in-instruction represented the time participants spent within the treatments (Text versus Audio, Static illustration versus Animation). Time data revealed that participants spent significantly more time-in-program and time-in-instruction for illustration mode with animation taking longer than static illustration mode (see Tables 3 and 4).

Table 1. Practice Achievement Means and Standard Deviations.

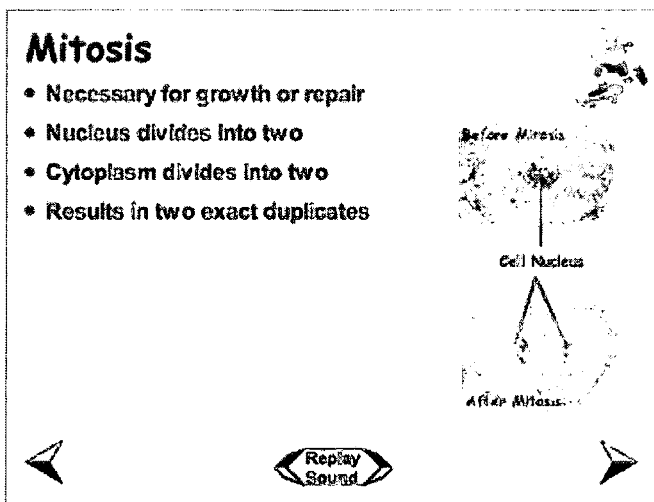
Instructional Mode		Illustration Mode		Spatial Ability	
Text		Static		Low	
M	***15.95***	*M*	15.59	*M*	14.41
SD	4.47	*SD*	4.68	*SD*	4.54
N	44	*N*	41	**N**	***41***
Audio		Animation		High	
M	14.90	*M*	15.33	*M*	16.44
SD	4.33	*SD*	4.19	*SD*	4.09
N	***40***	**N**	***43***	**N**	***43***

Table 2. Amount of Invested Mental Effort Means and Standard Deviations.

Instructional Mode		Illustration Mode		Spatial Ability	
Text		Static		Low	
M	***3.96***	*M*	3.98	*M*	4.21
SD	0.66	*SD*	0.71	*SD*	0.58
N	51	*N*	56	**N**	***50***
Audio		Animation		High	
M	4.11	*M*	4.11	*M*	3.87
SD	0.63	*SD*	0.56	*SD*	0.67
N	***52***	**N**	***47***	**N**	***53***



Text-Static Illustration Version Instructional Screen



Corresponding Audio-Static Illustration Version Instructional Screen
Figure 1. Sample Instructional Screens for Text-Static Illustration and Audio-Static Illustration program versions.

Table 3. Time-in-Program Means and Standard Deviations.

Instructional Mode			Illustration Mode			Spatial Ability		
Text			Static			Low		
M		***54.46***		*M*	50.40		*M*	53.32
	SD	10.42		*SD*	11.41		*SD*	13.05
	N	44	*N*		41	**N**		***37***
Audio			Animation			High		
	M	51.89		*M*	56.35		*M*	53.29
	SD	11.38		*SD*	9.48		*SD*	8.73
N		***36***	**N**		***39***	**N**		***43***

Note. Time-in-Program is reported in minutes.

Table 4. Time-in-Instruction Means and Standard Deviations.

Instructional Mode			Illustration Mode			Spatial Ability		
Text			Static			Low		
M		***42.51***		*M*	39.16		*M*	42.17
	SD	7.67		*SD*	8.89		*SD*	10.25
	N	44	*N*		41	**N**		***37***
Audio			Animation			High		
	M	40.63		*M*	44.30		*M*	41.23
	SD	9.32		*SD*	7.17		*SD*	6.62
N		***36***	**N**		***39***	**N**		***43***

Note. Time-in-Program is reported in minutes.

Discussion

Results for practice achievement indicated that high spatial ability participants achieved more than low spatial ability participants. These findings may best be understood in terms of dual coding theory which proposes two separate systems for cognition—verbal and visual (Paivio, 1986). Under dual coding, images such as static illustrations or animations are organized into visual representations while verbal information such as text or audio is organized into verbal representations. Referential connections are then built between the verbal and visual representations. It is thus likely that high spatial ability participants built visual representations more easily and completely than did low spatial ability participants. This allowed high spatial ability participants to invest more cognitive resources towards integrating verbal with visual information and resulted in higher practice achievement.

While results for practice achievement indicated a relationship with spatial ability, similar results for posttest achievement were not found. Both high and low spatial ability participants achieved more on the posttest than on the practice and high spatial ability participants achieved more than low spatial ability participants. However, the achievement difference between low and high spatial ability participants was not statistically significant.

One potential reason for this lack of differences in posttest achievement by spatial ability may be related to the design of the CBI program used in this study. It was designed to be instructionally effective and included instruction, interactive activities, practice with feedback and reviews. Previous studies that have investigated spatial ability and animation or animation with audio have found significant posttest achievement differences by spatial ability. However, these studies have not incorporated practice into their designs (Hays, 1996; Hegarty & Sims, 1994; Hegarty & Steinhoff, 1997; Mayer & Sims, 1994). Since the current study did include practice, it might be more appropriate to compare practice results of the current study to the posttest results of the previous studies. Viewed thusly, the difference in practice achievement found for the current study supports the findings for posttest achievement differences found by previous studies. It is also possible that the effect of practice, followed as it was in the CBI program by a review, helped low spatial ability learners compensate for their lower visualization capabilities, thus raising their scores close to those of high spatial ability learners.

Although the CBI program included elements of effective instruction, overall performance on both the practice and posttest was quite low (51.5% for the practice, 57.8% for the posttest). This was probably due to several factors. As with most science topics, the CBI program was heavily laden with the technical jargon necessary to understand the content. Considering the short time of the treatment, participants may have been unable to acquire the extensive vocabulary required by the material despite activities incorporated into the CBI to aid in learning and retaining this terminology. In addition, this course was the first high school science course for many of the participants and they may have had few existing science concepts with which they could relate new concepts. To be concise, the CBI covered a lot of material in a relatively short amount of time. It is possible, and indeed the overall achievement scores suggest, that more time and practice was necessary for participants to master the material.

Examination of the Amount of Invested Mental Effort (AIME) results indicated significant differences by spatial ability. Low spatial ability participants reported greater AIME than high spatial ability participants. This result can be explained by dual coding theory (Paivio, 1986). Low spatial ability participants probably spent more time and effort building visual representations than high spatial ability participants. The low spatial ability participants thus had fewer cognitive resources available for building the referential connections between the visual and verbal information in the CBI program (Mayer & Sims, 1994). Consequently, low spatial ability participants would naturally perceive they had expended a greater amount of mental effort than high spatial ability participants.

Findings for time-in-program and time-in-instruction indicated that participants in the Animation treatments took significantly more time (five to six minutes longer) than participants in the Static Illustration treatments. This difference was expected and supports Baek and Layne's (1988) finding that animations require more instructional time than static illustrations. In the current study, the eight Animated instructional sequences took 9 minutes and 20 seconds to play assuming no sequence was replayed by the participant. The corresponding eight Static Illustration instructional sequences should have required less time for the participants to complete as they need not have waited for an animation to finish before proceeding. In contrast, no difference in terms of time-in-practice was found. Participants in the Animation treatments spent the same amount of time-in-practice as participants in the Static Illustration treatments. Since the practice screens contained only static illustrations or no illustrations at all, this result was expected.

No time differences of any type were found for participants in the Text versus Audio treatments. Again, differences for time-in-practice were not anticipated since the practice screens were the same in the Text as in the Audio versions. However, the results for time-in-program and time-in-instruction are puzzling.

Participants spent the same amount of time in the Text as in the Audio treatments. Based on previous studies (Barron & Kysilka, 1993; Koroghlanian & Sullivan, 2000) and common sense, one would have expected the Audio version to take longer than the Text. Examination of data collected during CBI program development indicates that participants in the Text versions should have completed the CBI program 10 to 15 minutes sooner than those in the Audio versions. This time difference did not occur. Perhaps participants in the Text versions spent those 10 to 15 minutes rereading the text, examining the static illustration/animation or trying to integrate the text information with the static illustration/animation.

Implications for Instructional Design

The results of this study supports previous research that suggests moving some text from the screen to audio neither hinders nor improves learning. This finding has important implications for multimedia development. If screen "real estate" is needed for something other than instructional text, which is especially true for simulations and concepts difficult to explain with words alone, then text can be moved from the screen to audio with no loss in achievement. This is an important and useful instructional technique for instructional designers to consider, especially when designing materials with scientific or technical content.

The implications of this study are less straightforward in terms of animation. Animation did not improve learning for this content and age group. Animation did take more instructional time than static illustrations with no corresponding improvement in achievement or difference in attitude. Whether to include animation or not in multimedia programs or CBI is still a matter of instinct, not research, and the final decision may be dictated by pragmatic concerns such as budget or time.

While this study was conducted with computer based instructional materials; the results have wider implications for multimedia instruction in general. Web based instruction, for example, increasingly incorporates multimedia attributes such as audio and animation. The incorporation of these attributes should be based on instructional design principles and research to ensure effective and efficient instruction.

Suggestions for Future Research

Several avenues of future research are suggested by the findings of this study. One area that warrants further investigation is the physical combination of audio and animation. Some researchers might argue that the present study did not minimize the split attention effect and thereby did not optimize the instruction or research conditions. Future research could examine superimposing text on the illustrations and animations as well as utilizing audio only with illustrations or animations followed by text at the end of the sequence. These sequencing and layout situations would tend to minimize the split attention effect and might clarify research results and subsequent instructional design decision-making.

One puzzling and fascinating result of the present study concerns the activities and mental processes of the participants. Participants spent the same amount of time in the Text as in the Audio versions although participants in the Text version would have been expected to finish 10-15 minutes sooner than those in the Audio version. Interposing questions during the instruction or formally observing participants might provide information of use and interest to the researcher and instructional designer.

Further research into text density and structure would be valuable to instructional designers designing both traditional CBI and web-based instruction. Reducing instructional screen text while providing the majority of instruction via an audio track, is an extremely useful technique in situations of highly complex processes and simulations where there is a need to maximize screen space for non-text purposes. Research into the amount of text required when text is combined with audio and the manner in which that text should be structured and presented warrants further investigation.

Audio and animation are powerful tools for the instructional designer. Deciding when and how to use these tools is an important field of inquiry that deserves more attention and effort.

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