The Effect Of Oral Description In Complementing Animated Instruction In A Web-based Learning Environment On Undergraduate Students Achievement Of Different Educational Objectives

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Abstract

The purpose of this study was to test the principle of modality by using audio to deliver verbal information when that information is designed to support non-verbal information such as animations in a computer-based lesson. This was done by comparing the effect of two types of audio support mechanisms- a simple support mechanism consisting of declarative statements explaining the animated sequence and a complex support mechanism consisting of questions and answers explaining the animated sequence- on undergraduate student achievement of conceptual, rule and procedure knowledge. A control group consisting of the same computer-based lesson without any auditory support of the animation was also employed. Learning was measured through drawing, terminology, and comprehension tests. The results indicate student achievement was not enhanced by the addition of auditory support.

Introduction

With computers coming equipped with multi-media features such as the ability to play sound and animation, teachers and instructional designers are able to develop and deliver lessons in novel ways using both the visual and auditory channels of students. But, is student performance improved by the use of both channels as opposed to the traditional delivery method relying solely on the visual channel? And, at what learning level (the factual, conceptual, rule & procedure level) is there improvement in performance when both channels are used?

According to cognitive load theory (Kalyuga, Chandler and Sweller 1988, 1989; Sweller 1988; Baddeley 1986, 1992) methods of instruction reducing working memory load in order facilitate the encoding and storing of the information in long-term memory are effective. One such method is dual coding theory (Sadoski and Paivio 2001; Clark and Paivio 1991; Paivio 1971, 1986, 1990). Dual coding theory assumes we have two information processing systems: a verbal system, comprised of words, whose strength lies in its sequentially ordered hierarchy, each bit of information paves the way for the next, and a non-verbal system whose strength lies in its synchronous (holistic) hierarchy.

Using audio to deliver verbal information when that information is designed to support non-verbal information such as graphics, pictures, and animations can enhance the effect of using both the verbal and visual systems. This is known as the modality effect (Clark & Mayer 2003; Penney 1989; Paivio 1986). The modality effect (Clark & Mayer, 2003, pp. 93) states "people learn more deeply from multimedia lessons when words explaining concurrent animations or graphics are presented as speech rather than as onscreen text."

The studies reviewed indicate that the modality effect works well at improving student's verbal recall of factual information (Mayer 1991, Mayer 1992, Barron 1993, Mousavi 1995, Mann 1995, Mayer 1996, Mayer 1998, Moreno 1999, Mayer 2001, and Moreno 2002). There is also indication that the modality effect works at improving student's ability to solve problems (Mayer 1991, Mayer 1992, Barron 1993, Mayer 1994, Mousavi 1995, Mayer 1996, Mayer 1998, Moreno 1999, Chuang 1999, Mayer 2001, Moreno 2002). However, there is limited information regarding the effect of modality of student achievement of learning concepts, rules and procedures. The studies conducted by Mayer (1998) and Moreno (1999, 2002) found evidence to support the positive effect of modality on student's ability to learn conceptual information but these learning levels were not isolated and studied on their own. In these studies, student's ability to recall facts, identify concepts, and solve problems were tested together. This leaves open the question of how effective is the use of modality if the goal of the lesson is to facilitate achievement of conceptual and rule/procedure knowledge? This study seeks to begin filling in the gap in the literature by isolating these two intellectual skill learning-levels.

Literature Review

Studies Exploring The Effect Of Dual-Coding: Using The Visual And Verbal Channels

Mayer, in his study on how computer based animations can be used to promote scientific understanding (1991) and in his study aimed at identifying the role of student's spatial ability in learning from words and pictures (1994), found that undergraduate college students, given a lesson in an area of non-expertise, performed better on recall and problem solving tests when both the verbal and visual systems were utilized. Mayer also found that the effect of dual coding was enhanced when the verbal and visual information was presented concurrently, at the same time as the animation rather than before or after it (Mayer 1991, 1992, 1994). This finding was duplicated by Moreno (1999) who tested undergraduate college students with low prior knowledge of meteorology, ability to recall information about the process of lightning. Chuang (1999) found similar results working with seventh grade students in Taipei, Taiwan when studying the role of gender and field dependence/independence on the ability to solve math problems.

Placing supporting text near the animation it is meant to support in known as the contiguity principle (Clark and Mayer 2000) or the split-attention effect (Chandler and Sweller 19992; Sweller, Chandler, Tierney, and Cooper 1990; Tarmizi and Sweller 1988). The split-attention affect happens when students must divide their attention between multiple sources of information (Mousavi 1995). The split-attention effect can be reduced by placing printed words next to the animation they are supporting (Clark and Mayer 2000).

The positive effect of dual coding in reducing cognitive load also was evident in studies exploring the impact of reducing cognitive load in the lesson summary. In his study to see if reducing cognitive load in lesson summaries would help increase student's retention, Mayer (1996) found that undergraduate students performed better on tests of recall and problem solving when summaries included both illustrations and text.

The results indicate the effectiveness of verbal, in the form of text, support of animation in reducing cognitive load. Animation complemented with a textual explanation enabled students to take greater advantage of their capability to process information on two levels by stimulating the visual system and by reducing the load placed on the verbal processing system. This re-shuffling of information in working memory increased their ability to make meaning out of the information in preparation for storage in long-term memory. The placement of the supporting textual explanation next to the animation further reduced cognitive load and enhanced performance.

Studies Exploring The Effect Of Modality: Using The Spoken Word In Place Of The Written Word To Support The Visual Channel

While animation helped to reduce cognitive load it was not reduced as much as it could be because both text and animation have to pass through the same (the visual) sensory channel (Mousavi 1995; Chandler and Sweller 1992. This meant that students were forced to shift their attention between the text and the animation while going through the pattern recognition and selective perception processes. Miller (1956, pp. 85) referred to the limitation of the sensory register as our "channel capacity." Channel capacity is the maximum amount of information we can hold in our sensory memory at any given point in time.

When animation is supported by a spoken explanation, as opposed to a textual explanation, cognitive load is further reduced. This time the reduction comes through the way that information passes from the environment through sensory memory and into working memory (Chandler and Sweller 1992; Paivio 1986; Penney 1989).

Mann (1995), in as study testing student's ability to construct a solution to an educational problem, used temporal sound, spoken information that highlights or details static or moving visuals, in a computer-based lesson to more effectively use student's channel capacity in sensory memory by using sound with text to support concurrent animation. Mann found that students were able to recall a greater amount of critical detail when temporal sound was used.

While Mann used both written text and temporal sound simultaneously, Mayer (1998), in a study that tested student's ability to recall how lightening works, compared the effect of using either temporal sound or written text to support concurrent animation and found that students were able to recall more information and perform better on problem solving tests if they received the lesson using temporal sound.

Lai (2000), in her study testing the evarious types of visual illustrations on concept learning, also found that students receiving lessons using temporal sound to support static graphics performed better on matching tests than students receiving lessons that used text to perform the same function.

Similar to spatial contiguity, the placement of text near the animation it supports, the contiguity affect also applies when temporal sound is used to support animation. Temporal contiguity occurs when visual and spoken materials are presented simultaneously rather than successively (Moreno 1999). Moreno (1999), using a lesson on the process of lightning formation, found that learning was negatively impacted if the temporal sound was not placed concurrent with the animation it supported matching Mayer's (1994) findings with written text.

Using written text or temporal sound that closely matches the animation it supports without a lot of extraneous details is also an important factor for success. In a study on reducing the cognitive load in lesson summaries, Mayer (1996), using a lesson on the process of lightning formation, found that students receiving concise lesson summaries, that included both visual and verbal information, performed best on verbal recall and problem solving tests. Similarly, Moreno (2002) found that extraneous details hurt student perfomance when using the lesson on the process of lightning formation.

Issues Of Instructional Consistency

Instructional consistency (Canelos 1983; Gagne and Medsker 1996)) states that intellectual skills are hierarchical in nature and that lower order skills are prerequisite for learning higher order skills. Verbal skills comprise the base of the hierarchy and are the ability to recall factual information. Verbal skills are a prerequisite for learning discriminations. Discriminations, the ability to distinguish between things, come next and are a prerequisite for concept formation. Concepts are the ability to classify information based on its critical attributes and are a prerequisite for the learning of rules, which are the ability to specify the relationship between concepts. At the top of the hierarchy sits higher order rules, the ability to use multiple rules in order to perform a task or solve a problem (Gagne and Medsker 1996, pp. 32-33).

Therefore, if the objective is to generate solutions the instructional unit must contain the rules/procedures, concepts, and facts that represent the prerequisite knowledge needed to solve the problem. In the studies reviewed animation supported by narration increased students ability to recall factual information and to generate solutions to problems. The majority of studies reviewed explored student's ability to recall factual information and solve problems (Mayer 1991, 1992 1996; Mousavi 1995), to solve problems (Barron 1993; Mayer 19994, 2001), or to recall information (Mann 1995). These studies do not give us an indication of where or how animation supported by narration works in the instructional hierarchy. Is animation supported by concurrent narration effective at teaching concepts or rules/principles? Or is there something about the animation with narration that enables students to build connections among intellectual skills?

This study aims to build on the existing knowledge base and begin to fill in the gaps in the literature by testing the hypothesis that animation supported by concurrent temporal sound is better at teaching concepts and rules/principles than animation alone.

Purpose Of This Study

The purpose of this study was to test the principle of modality by using audio to deliver verbal information when that information is designed to support non-verbal information such as animations in a computer-based lesson. This was done by comparing the effect of two types of audio support mechanisms - a simple support mechanism consisting of declarative statements explaining the animated sequence and a complex support mechanism consisting of questions and answers explaining the animated sequence - on undergraduate student achievement of conceptual, rule and procedure knowledge. The questions the current study seeks to provide insight into include:

1. Do students receiving the treatment consisting of the simple audio support (declarative statements explaining the animation) perform better on tests of conceptual and rule & procedural knowledge than students receiving the treatment with animation alone?
2. Do students receiving the treatment consisting of complex audio support (questions followed up with declarative statements explaining the animation) perform better on tests of conceptual and rule & procedural knowledge than students receiving the simple audio treatment and the treatment consisting of animation alone?

Research Design And Methodology

A posttest only design method was used. The placement and use of animation and temporal sound was derived based on the results of two pilot studies. In the first study a computer-based lesson using Dwyer's (1977) lesson on the human heart, titled "The Heart And Its Functions", was used to determine where to place the animation. Since the goal of the primary study was to test student's ability to perform on tests of conceptual and rule/procedure knowledge, the lesson was designed using programmed instruction to ensure that adequate factual knowledge was achieved. An item analysis was completed to determine where to place the animation in the lesson for the subsequent study. A difficulty level of .60 was used as the cutoff meaning that any item with a difficulty level below sixty percent was targeted for animated support.

A series of four tests consisting of 20 questions each were used to assess student achievement. An identification test was used to assess factual knowledge. A drawing test and a terminology test were used to measure conceptual knowledge. A comprehension test was used to measure rule/procedure knowledge. The validity and reliability of the tests was reported by Dwyer and Moore (1978). Based on the outcomes of the pilot study, 18 animations were developed and placed in the lesson adjacent to the textual material they were designed to support.

A second pilot study was conducted in order to determine which of the animated sequences required the use of temporal support. Again, item difficulty was set at .60 with any items supported by animation scoring below sixty percent targeted for support using temporal sound. The same four tests were used to assess student achievement. Based on the results of this analysis two treatments, one using simple audio support and another using complex audio support, were developed to support the animations.

For the primary study, eighty-eight undergraduate students were recruited from a management class, an educational psychology class, and an information systems class. These students were randomly assigned to one of three experimental groups: A control group that received the lesson with animation but no audio (NA) support. A treatment group assigned a lesson that used simple audio (SA) explanations, in the form of declarative sentences, in support of the animation. And, a treatment group assigned a lesson that used complex audio (CA) explanations, in the form of Questions and answers, in support of the animation. Twenty-nine students received the treatment with no audio support. Thirty students received the treatment with simple audio support. Twenty-nine students received the treatment with the complex audio support. All students received extra credit towards their final grade in the class for participating in the study.

All three experimental groups (NA, SA, CA) received a treatment where the beginning of the lesson was comprised of programmed instruction to ensure the prerequisite factual knowledge was gained. However, due to the nature of the content it was impossible to deliver the lesson with each learning level isolated. Therefore, the programmed instruction section also contained conceptual information along with the factual information. The programmed instruction consisted of a web page containing one or two pieces of factual knowledge. This meant that these pages also contained animation or animation with temporal support if the item analysis indicated it was needed.

After a series of three to four pages like this, students were asked to answer a series of practice questions based on the material just presented. If the student's score was satisfactory they were able to move on to the next part of the lesson. If the score was unsatisfactory they student was brought back to the beginning of that series of content. There was no limit placed on the amount of time or the number of times the student could spend on one section. Once the student satisfactorily completed the programmed instruction segment they were given a pencil and paper drawing test in which they were asked to draw and label the main sections of the human heart. Once that was completed the students were asked to complete an online identification test. In this test a picture of a heart was presented with an arrow pointing to the section to be identified. Students were asked to select the name of the section from a list of four choices.

The second part of the lesson was primarily focused on rule/procedure information although there was also some conceptual information presented. Students went through a series of web pages describing the flow of blood as it passes through the heart. Some pages contained animated support of the content and some pages contained animation along with temporal support. The control group (NA) lesson contained only animation. Where the SA group received temporal support for animation it was in the form of simple declarative sentences. For example, if the animation were designed to show that the ventricles are the thickest walled chambers of the heart, the student, when he/she selected the play button would see the animation and simultaneously hear a statement that said, "The ventricles are the thickest walled chambers of the heart."

The CA group received the same treatment as the SA group except that the temporal support was delivered in a question and answer format. Continuing the example above regarding the ventricles, a student in the CA group would hear while the animation was playing, "What are the thickest walled chambers of the heart? The ventricles are the thickest walled chambers of the heart."

The same voice was used in both treatment groups and the speed at which the animation was played was adjusted to fit the length of the temporal support. In all three experimental groups, students were allowed to replay the animation, as many times as they felt was necessary to understand the material.

At the end of the lesson students in each group were asked to complete a terminology test where they were asked to complete a sentence by selecting the appropriate word or phrase from the choices provided, and a comprehension test where they were asked to answer a question by selecting the appropriate answer from a list of choices. The identification, terminology, and comprehension tests were built into the computer-based lesson and completed on-line.

Results And Implications

ANOVA was conducted to compare the differences between the three experimental groups on scores on the four criterion tests. Alpha was set at the .05 level. Comparisons were made at two levels: using all items and using only the items identified by the item analysis. Comparisons were made using all four tests.

Results Using All Items

The table below details the mean and standard deviation for each treatment group counting all items

		Mean	Std. Deviation
drawing test	control	15.97	3.257
	simple	16.00	3.280
	complex	17.31	2.714
	Total	16.42	3.125
identification test	control	17.62	2.470
	simple	17.40	2.094
	complex	17.88	2.215
	Total	17.62	2.247
terminology test	control	11.93	5.028
	simple	12.70	4.170
	complex	12.58	5.077
	Total	12.40	4.714
comprehension test	control	11.00	3.464
	simple	11.27	3.600
	complex	12.08	4.069
	Total	11.42	3.688
Test Total	control	56.52	11.903
	simple	57.37	10.545
	complex	59.73	9.298
	Total	57.80	10.637

The F statistic for the drawing test was 1.787; the F statistic for the identification test was .319; the F statistic for the terminology test was .218; the F statistic for the comprehension test was .621. The F statistic for the total of all tests was .659. These results indicate that there were no significant differences in the performance of students in each group. The reliability coefficient was .8612.

Results Using Only Items Identified Through Item Analysis

The table below details the mean and standard deviation for each treatment group for only the items identified as deficient through item analysis

		Mean	Std. Deviation
Drawing Test	control	3.28	1.601
	simple	2.97	1.450
	complex	3.93	1.163
	Total	3.39	1.458
Terminology Test	control	4.14	2.489
	simple	4.93	2.243
	complex	4.73	2.539
	Total	4.60	2.416
Comprehension	control	4.38	1.635

Test			
	simple	4.60	2.010
	complex	4.69	2.074
	Total	4.55	1.893
Item Total	control	11.79	4.378
	simple	12.50	4.392
	complex	13.27	3.853
	Total	12.49	4.222

The F statistic for the drawing test was 3.547; the F statistic for the identification test was .851; the F statistic for the comprehension test was .198. The F statistic for the item total on these tests was .835. These results indicate that there were no significant differences in the performance of students in each group. The reliability coefficient was .7778.

Implications Of The Results

The lack of significance in performance between the experimental groups indicates that using either animation or animation along with temporal support may be problematic when it comes to teaching concepts and rules/principles. These results are interesting in lieu of prior studies whose results indicated animation supported with temporal sound was effective at teaching facts and problem-solving skills. With factual knowledge being a prerequisite for learning concepts, rules/principles and rules/principle knowledge being a prerequisite for problem solving learning it was thought that animation supported by temporal sound would have been effective at teaching concepts and rules/principles. However, the results of this study do not support this hypothesis.

These results do, however, suggest possibilities for further research. Some possible avenues for exploration include: What is it, of there is anything, about the nature of concepts and rules/procedures that may not make them amenable to animation based learning? Does temporal sound increase cognitive load when the lesson is aimed at conceptual or rule/principle information? Does the kind of content being presented limit the effectiveness of modality? Are methods other than simple declarative sentences or questions followed by answers better suited for teaching concepts and rules/procedures?

Summary

Using temporal sound to support animation in computer-based lessons has been effective when the goal is to teach factual knowledge. There is also indication that it is effective for teaching problem-solving skills. This study, however, did not find evidence to support that using animation with temporal sound to teach concepts, rules/principles is effective. The results indicate that there is a problem of instructional consistency when applying the modality effect to the learning of intellectual skills.

References

Baddeley, J. R. (1986). *Working Memory*. Oxford, England: Oxford University Press.

Baddeley, J. R. (1992). Working Memory. *Science*(255), 556-559.

Barron, A. E. (1993). The Effectiveness of Digital Audio in Computer-Based Training. *Journal of Research on Computing in Education, 25*(3), 277-290.

Chandler, P., & Sweller, J. (1992). The split-attention effect as a factor in the design of instruction. *British Journal of Educational Psychology, 62*, 233-246.

Chuang, Y.-R. (1999). Teaching in a Multimedia Computer Environment: A Study of the Effects of Learning Style, Gender, and Math Achievement. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning, 1*(10).

Clark, J. M., & Paivio, A. (1991). Dual Coding Theory In Education. *Educational Psychology Review, 3*, 149-210.

Clark, R. C., & Mayer, R. E. (2003). *e-Learning and the Science of Instruction*. San Francisco, CA: John Wiley & Sons.

Driscoll, M. (2000). *Psychology of Learning for Instruction* (2nd ed.). Needham Heights, MA: Allyn and Bacon.

Gagne, R., & Medsker, K. (1996). *The Conditions of Learning: Training Applications*. Orlando, FL: Harcourt Brace.

Lai, S.-L. (2000). Influence of Audio-Visual Presentations on Learning Abstract Concepts. *International Journal of Instructional Media, 27*(2), 199-206.

Mann, B. L. (1995). Focusing Attention with Temporal Sound. *Journal of Research on Computing in Education, 27*(4), 402-425.

Mayer, R. E. (1992). The Instructive Animation: Helping Students Build Connections Between Words and Pictures in Multimedia Learning. *Journal of Educational Psychology, 84*(4), 444-452.

Mayer, R. E. (1993). Cognitive Constraints on Multimedia Learning. *Journal of Educational Psychology, 93*(1), 187-198.

Mayer, R. E. (1994). For Whom is a Picture Worth A Thousand Words?: Extensions of a Dual-Coding Theory of Multimedia Learning. *Journal of Educational Psychology, 86*(3), 389-401.

Mayer, R. E. (1996). When Less is More: Meaningful Learning From Visual and Verbal Summaries of Science Textbook Lessons. *Journal of Educational Psychology, 88*(1), 64-73.

Mayer, R. E. (1998). A Split-Attention Effect in Multimedia Learning: Evidence for Dual Processing Systems in Working Memory. *Journal of Educational Psychology, 90*(2), 312-320.

Mayer, R. E., & Anderson, R. (1991). Animations Need Narrations: An Experimental Test of a Dual-Coding Hypothesis. *Journal of Educational Psychology, 83*(4), 484-490.

Mayer, R. E., & Heiser, J. (2001). Cognitive Constraints On Multimedia Learning: When Presenting More Material Results In Less Understanding. *Journal of Educational Psychology, 93*(1), 187-198.

Mayer, R. E., & Moreno, R. (2002). Aids to Computer-based Multimedia Learning. *Learning and Instruction, 12*(1), 107-119.

Miller, G. (1956). The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information. *The Psychological Review, 63*, 81-97.

Moreno, J. (1999). Cognitive Principles of Multimedia Learning. *Journal of Educational Psychology, 91*(2), 358-368.

Moreno, J., & Mayer, R. E. (2002). Verbal Redundancy in MultiMedia Learning. *Journal of Educational Psychology, 94*(1), 156-163.

Mousavi, J. (1995). Reducing Cognitive Load by Mixing Auditory and Visual Presentation Modes. *Journal of Educational Psychology, 87*(2), 319-334.

Paivio, A. (1979). *Imagery and Verbal Processes*. Hillsdale, NJ: Lawrence Erlbaum Associates.

Paivio, A. (1986). *Mental Representation: A Dual Coding Approach*. Oxford, England: Oxford University Press.

Penney, C. G. (1989). Modality Effects and the Structure of Short-term Verbal Memory. *Memory and Cognition, 17*, 398-422.

Sadowski, M., & Paivio, A. (2001). *Imagery And Text: A Dual Coding Theory Of Reading And Writing*. Mahwah, NJ: Lawrence Erlbaum Associates.

Sweller, J. (1988). Cognitive Load During Problem Solving: Effects on Learning. *Cognitive Science, 12*, 257-285.

Sweller, J., Chandler, P., Tierney, P., & Cooper, M. (1990). Cognitive load and selective attention as factors in the structuring of technical material. *Journal of Experimental Psychology: General, 119*, 176-192.

Tarmizi, R., & Sweller, J. (1988). Guidance During Mathematical Problem Solving. *Journal of Educational Psychology, 80*, 424-436.