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Web-Based Animation or Static Graphics: Is the Extra Cost of Animation Worth It?

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This quantitative study compared the instructional effects of two web-based animation strategies against static graphics by high and low prior knowledge participants. One strategy used animation to gain attention; the second to gain attention and provide elaboration. Participants were 111 college student volunteers. Two-way multiple analysis of variance (MANOVA) was used to analyze the data. Important findings included equivalent, nonsignificant differences in performance between high and low prior knowledge participants. No main effects were found among the three treatment groups. The effects of the web-based animation strategies on the achievement of participants with low prior knowledge are discussed in detail.

Technological advances make it possible to present computer- and web-based multimedia instruction that includes motion, voice, data, text, graphics, and still images (Moore, Burton, & Myers, 2003). One important advancement is animation, in which images are exhibited in motion (Dwyer & Dwyer, 2003). Animation has been the focus of recent attention and interest and has become more popular in computer and web-based instruction (CBI/WBI). Although animation appears to attract learners' attention and increase their motivation to learn, it is still unclear whether animation strategies can facilitate learning. Reiber (1990) suggested that animation can have one of three functions in instruction: (a) attention-gaining, (b) presentation, and (c) practice. However, he pointed out that not enough research had been conducted to ascertain its instructional effectiveness. This lack of empirical research was especially true for animated attention-gaining and practice strategies.

This study sought to add to this literature by investigating the instructional effects of two specific web-based animation strategies in facilitating participants' academic achievement: animated attention-gaining and animated elaboration strategies and compare them against static graphics. Animated arrows that directed learners' attention to specific image parts were used as an attention-gaining strategy to arouse participants' interest and aid them in attending to relevant cues and details. Animated text prompts were used as an elaboration strategy to provide additional information and emphasize the most important information in a corresponding instructional text passage.

RELATED LITERATURE

Information Processing

Many early information-processing theories (Atkinson & Shiffrin, 1968; Klatzky, 1980) described the human brain as similar to a computer, while human learning has been likened to a computer's information processing function. The memory system has three main storage structures: (a) sensory register, which gathers stimuli in the memory system; (b) short-term memory (STM), which serves as temporary storage; and (c) long-term memory (LTM), which permanently stores information. In the sensory register, only a portion of the information is attended to and transferred into STM. Information is selected through a process known as selective perception (Gagné & Driscoll, 1988). Short-term memory can only hold five to nine chunks of information (Miller, 1956). Information in STM may be encoded and stored into LTM. However, not all information stored in LTM may be retrieved. Retrieval is more likely when appropriate cues are provided in the encoding process (Driscoll, 2005).

Animation as an Aid in Information Processing

Reiber, Boyce, and Assad (1990) maintained that "...although animation did not affect learning, it helped decrease the time necessary to retrieve information from long-term memory and then subsequently reconstruct it in short-term memory" (p. 50). Reiber (1990) further explained that animation facilitates the reconstruction process during retrieval by encouraging organization.

One animation strategy used in this study was animated arrows used to gain attention. As noted earlier, Rieber (1990) pointed out that attention-gaining is one of the three major functions of animation. Attention-gaining animations provide additional ways to ensure selective perceptions of specific presentation features as they are stored and processed in the STM (R. M. Gagné, 1985). Similarly, Hannafin and Peck (1988) suggested that animations can help emphasize important information by providing contrasts with a static background. In addition, Levin, Anglin, and Carney (1987) argued that attention-gaining graphics can make relationships between ideas more apparent by facilitating organization.

Another strategy used in this study was elaboration using animated text prompts. Rieber (1990) suggested that animation can be used with accompanying text to elaborate a lesson fact, concept, rule, or procedure. According to E. D. Gagné (1985), "...elaboration is the process of adding to the information being learned" (p. 83). Elaboration may take many forms: a logical inference, a continuation, an example, a detail, or anything that serves to connect information. She further stated that elaboration facilitates retrieval by providing alternative pathways and extra information to generate answers (E. D. Gagné, 1985).

Animation as an Aid in Dual Coding

Paivio's (1986) dual coding theory further explained two separate information-processing subsystems in human cognition: a visual system that processes visual knowledge and a verbal system for processing verbal knowledge. The two subsystems are structurally and functionally independent yet interconnected in the encoding, storage, organization, and retrieval of information. According to dual coding theory, learning is enhanced when information is coded both visually and verbally (i.e., dually coded). The chances of retrieval are doubled when information is dually coded because learners have two ways to retrieve the information. This prediction has been used to explain the superiority of pictures to words in recall (Kobayashi, 1986; Paivio, 1991; Paivio & Caspo, 1973; Rieber, 1996). Animation, due to its unique dynamic qualities, is more likely to be dually coded "deeper" and "harder" into the long-term memory than are static graphics (Lin, 2001, p. 20). Therefore, animation should do a better job of facilitating the encoding and retrieval processes than static graphics.

In dual coding theory there are three distinct levels of processing within and between the verbal and visual systems: (a) representational, (b) associative, and (c) referential (Paivio, 1986). Representational processing connects incoming environmental stimuli to either the verbal or visual system. Associative processing constructs connections within either the verbal or visual systems, and referential processing builds connections between these two systems (Paivio, 1986; Rieber, 1996). In this study, the animated attention-gaining strategy facilitated associative processing by highlighting specific parts of the heart using animated arrows. Animated elaboration strategies enabled referential processing by emphasizing the most important information in a corresponding text using animated text prompts.

A Model of Animation, Dual-Coding, and Information Processing

Gagné and Driscoll (1988) created a basic model of learning and memory based on modern information-processing theories. This model was revised to show how animation should work as an aid to both dual-coding and information processing (see Figure 1). Humans process visual and verbal information from the environment simultaneously. Animation is more likely to be coded as both visual and verbal knowledge because of its dynamic qualities (Lin, 2001). Animation as an attention-gaining strategy helps in capturing attention and ensuring selective perception, while animation as an elaboration strategy not only helps to ensure selective perception but also facilitates encoding and retrieval processes by connecting information and providing alternative retrieval pathways (E. D. Gagné, 1985).

Animation Research

Previous research on animations in CBI has led to somewhat mixed results. Rieber (1990) reviewed 13 empirical studies of animation's effects on CBI and found only 5 revealed significant effects for the animated treatments, while 8 found insignificant differences. He pointed out that the reason for the mixed results could be "...rooted in general procedural flaws such as poor conceptualization of the research problem or inappropriate implementation of methods" (p. 84). Park and Hopkins (1993) summarized 25 studies of the effects of dynamic versus static visual displays. Fourteen studies revealed significant effects for dynamic visual displays. They suggested that the reasons for the inconsistent results "...seem to be related to the different theoretical rationales and methodological approaches used in various studies..." (p. 427).

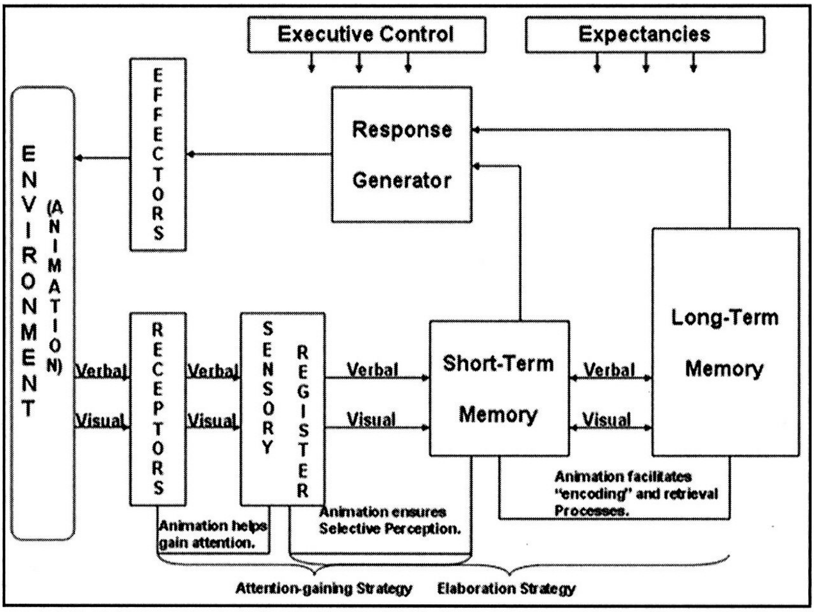

Figure 1. A model of animation, dual-coding and information processing.

Note. From Gagne, R. M. & Driscoll, M. P. Essentials of Learning for Instruction, 2/e Published by Allyn and Bacon, Boston, MA. Copyright © 1988 by Pearson Education. Adapted by permission of the publisher.

More recently, Anglin, Vaez, and Cunningham (2003) summarized the results from 42 studies accomplished between 1949 and 2000 that included at least one animation treatment, and identified significant animation effects in 21 of 45 comparisons. These studies used various animated visual content and covered a wide variety of general content areas. Participants in these studies ranged in age from children to adults. A wide variety of tests were used to evaluate different learning outcomes. Although the "box score" results indicated that the use of animated graphics does not facilitate learning, they concurred with Rieber (1990) and Park and Hopkins (1993) and suggested that methodological issues need to be considered. Many studies neither provided a rationale for using animation nor indicated that animation was relevant or congruent with the text information presented.

In addition, several other experimental studies conducted after 2000 included at least one animation treatment. Some reported significant effects for the animation treatment under certain circumstances (Blankenship & Dansereau, 2000; Catrambone & Seay, 2002), while others reported insignificant effects for the animation treatment (Chanlin, 2001a, 2001b; Koroghlanian & Klein, 2000; Lowe, 2003). Chanlin (2001b) even reported that for novice students, the use of static graphics was better than animation in procedural learning.

In this study, special attention was given to recent animation studies that used instructional content that was identical to that used here. Wilson (1998) tested four types of treatment groups: (a) still graphics, (b) progressive reveal[1], (c) animation, and (d) animation and progressive reveal. Haag's (1995) study included four groups: (a) static graphics, (b) visual summary with manipulation, (c) learner-manipulation, and (d) computer manipulation group. Lin (2001) used additional instructional strategies in combination with animation to study static visuals, animation only, animation with advance organizers, and animation with adjunct questions and feedback. Owens (2002) used three treatment groups: (a) animation, (b) animation and attention-directing strategies, and (c) animation and visual-elaborating strategies. The results from these studies revealed insignificant differences in students' achievement among treatment groups.

In sum, there have been mixed results from previous animation research, while animation research using instructional content identical to that used here suggests insignificant differences for treatments incorporating animation strategies. As previously noted, the reason for the mixed results could be rooted in methodological issues. However, if those research studies that reported insignificant effects for animation treatments followed correct procedures and utilized sound methodologies, then animation may not be significantly effective under certain circumstances. Animation may be equally effective as static graphics under certain conditions.

Prior Knowledge

Prior knowledge has been considered the most important single factor influencing learning (Ausubel, 1968). Jonassen and Grabowski (1993) defined prior knowledge and achievement as the knowledge, skills, or abilities brought by learners to the learning environment before instruction. According to Dwyer (1994), because prior knowledge of lower-level objectives predicts performance in higher-order objectives, it should be included in any study of higher-order learning. Hannafin (1997) suggested that compared to individuals who have lower prior knowledge, individuals who have higher prior knowledge can quickly determine their own learning needs, generate their own learning strategies, and assimilate new information into their existing knowledge structure. Rieber (2000) also stated that related prior knowledge provides the learners with a unique relevant elaboration of the content that is not available to learners with low prior knowledge. Therefore, it is suggested that high prior knowledge learners will encode information more meaningfully and retrieve it more easily than will low prior knowledge learners.

Mayer and Anderson (1992) found that students who possessed low prior knowledge attained a higher degree of learning when verbal and visual information were presented simultaneously. They suggested that students with high prior knowledge might be able to build referential connections between verbal and visual information and their existing knowledge on their own. In the web-based instruction used in this study, verbal (textual) and visual (the graphic illustration or animation) information was presented simultaneously to support referential connections of low prior knowledge participants. Therefore, one purpose of this study was to investigate whether these two animation strategies would result in equal or higher performance of low prior knowledge students as compared with high prior knowledge students, such as those found in Mayer and Anderson's (1992) study.

RESEARCH PURPOSE AND QUESTIONS

The purpose of this research was to investigate the instructional effects of two web-based animation strategies compared with static graphics on achievement of college-level students with high and low levels of prior knowledge. Three research questions explored this comparison: (a) Do animations used only to gain attention or to gain attention and elaborate on the content improve participants' performance on tests measuring four types of educational objectives? (b) Do animations used only to gain attention or to gain attention and elaborate on the content improve performance of the participants identified as possessing high and low levels of prior knowledge on tests measuring four types of educational objectives? (c) Is there an interaction between treatment group and prior knowledge level?

METHOD

Participants

One hundred and fifteen (115) college student volunteers participated in this study. Most were freshmen. Fifty eight (58) were classified as high prior knowledge participants while 57 were classified as low. One hundred and eleven (111) participants completed the study.

Instructional Materials

The self-paced web-based instruction used in this study was adapted from paper-based text materials developed by Dwyer and Lamberski (1977) about the human heart. The original script for the heart content contained approximately 1,800 words divided into three sections: the parts of the heart, circulation of blood, and cycle of blood pressure. Integration and positioning of the animation strategies were determined by an item analysis that identified where students were having difficulties based on their performance on the criterion tests from a previous pilot study conducted in summer 2003. The item analysis identified 23 test items in which student achievement was less than 53%. The content referred to in the 23 test items was located on 13 web-based instructional screens.

Treatments

Static graphic (Control group, T1). This treatment contained 1 page of directions and 20 pages of web-based instructional screens with instructional text on the left and the corresponding static graphic on the right. Two navigation buttons were located at the bottom of each screen: "Back" and "Next." Participants clicked through each screen at their own pace. A sample screen shot of the static graphic treatment is shown in Figure 2.

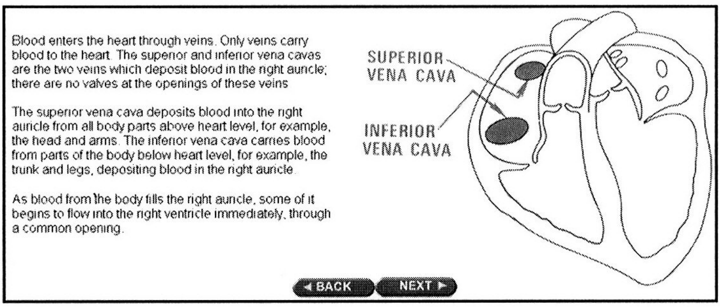

Figure 2. A sample screen shot of the static graphic treatment.

Animation as attention-gaining strategy (T2). This treatment was the same as the control group (T1) except that 13 of the 20 web-based instructional screens contained embedded attention-gaining animations. The other seven screens contained only static graphics since the item analysis did not indicate student difficulties with those items.

These 13 screens contained animations with the static graphic on the right side of the screen and a "Click to See the Animation" button below. Animated arrows were used to direct participants' attention to specific parts of the heart. To lower students' cognitive load, animations were chunked. When one animation finished, a "Continue" button appeared. The participants then clicked on the "Continue" button to see the next animation. After all of the animations were shown, the static graphic was restored and a set of three buttons appeared: "BACK," "NEXT," and "Replay the Animation." See sample screen shots in Figure 3.

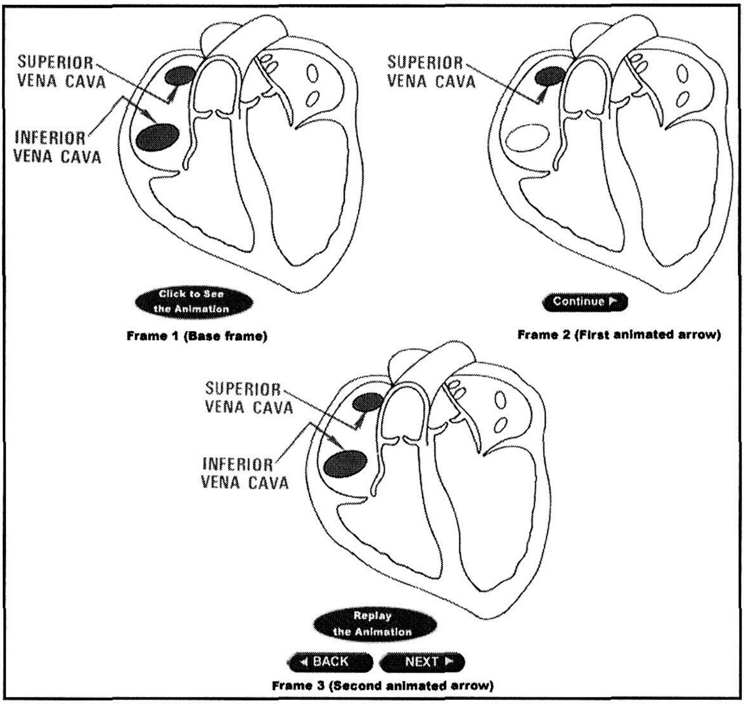

Figure 3. Progression of screen shots of the animation as attention-gaining strategy treatment (corresponding instructional text is presented simultaneously to the left of the graphic in this treatment).

Animation as attention-gaining and elaboration strategy (T3). This treatment was the same as treatment 2 (T2) except that the 13 web-based instructional screens contained embedded elaboration animations in addition to attention-gaining animations. An animated text pop-up window highlighting the most important information in the corresponding instructional text was used in combination with animated arrows. See sample screen shots in Figure 4.

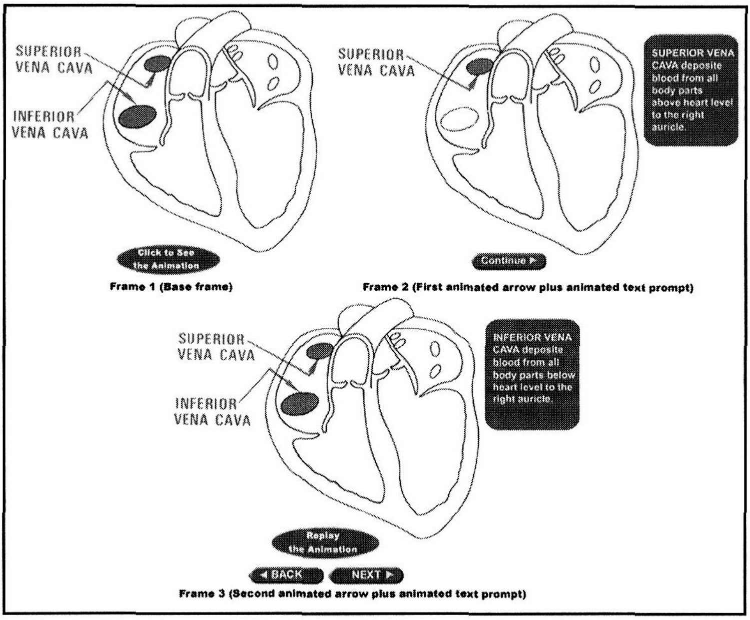

Figure 4. Progression of screen shots of the animation as attention-gaining and elaboration strategies treatment (corresponding instructional text presented simultaneously on the left of the graphic in this treatment).

Procedures

The two-stage study included an online pretest to classify the participants into high and low prior knowledge, followed by the treatments in a computer lab. The pretest developed by Dwyer (1978) consisted of 36 multiple-choice questions on human physiology. The mean for the pretest, 57.5%, from the original 115 participants was used as a cut-off point to distinguish between high and low prior knowledge participants, who were then systematically assigned to one of the three treatment groups.

The participants were instructed to go to a specific web site for the web-based treatments. Afterwards, the participants took four criterion tests: (a) drawing test, (b) identification test, (c) terminology test, and (d) comprehension test. They were given the paper-based drawing test first. After they finished the drawing test, they were instructed to go to a web site to take the three other tests online. After they finished all four tests, they were instructed to log off the computer and leave the lab quietly.

Criterion Measures

The four criterion tests were developed by Dwyer (1978) to measure different learning objectives. Each consists of 20 multiple-choice questions. The drawing test measures the ability to create and/or replicate items in their appropriate context. Participants were asked to draw a simple line diagram of a heart and place the corresponding number for each of 20 identified parts at its respective position on the heart. The identification test measures the ability to discriminate structures of different parts of the heart and to associate specific parts of the heart with their names. Participants identified the parts of the heart by noting the corresponding numbered arrow on a drawing of an outline of a heart. The terminology test measures knowledge of specific facts, terminologies, and definitions. Participants answered multiple-choice questions by selecting the answer that best describes different parts of the heart. A sample test item follows:

____ is (are) the thickest walled chamber (s) of the heart.

a. Auricles b. Myocardium c. Ventricles d. Pericardium e. Endocardium

The comprehension test measures understanding of complex procedures and/or processes. Given the location of certain parts of the heart at a specific time of its functioning, participants located the position of other specified parts of the heart at the same time. An example of a test item follows:

When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?

a. Closed b. Beginning to open c. Open d. Beginning to close

None were timed. Each item was worth 1 point. A satisfactory internal consistency of Cronbach's alpha reliability was found for the four criterion tests (Drawing = .89; Identification = .86; Terminology = .82; Comprehension = .82) (Anastasia & Urbina, 1997).

Design and Data Analysis

The study used a 2 x 3 factorial design with two levels of prior knowledge (high versus low) and three treatment groups (static graphic, animation as attention-gaining strategy, and animation as attention-gaining and elaboration strategy). The data were analyzed using SPSS. A two-way multiple analysis of variance (MANOVA) was conducted to test for the main effects and the interaction between the prior knowledge level and the three treatments. A significance level of .05 was set for all statistical tests.

RESULTS

Physiology Pretest

The scores for the human physiology pretest were converted into percentages that ranged from 33% to 78% with a mean of 57.5%. A one-way analysis of variance (ANOVA) indicated that the three groups were not significantly different in terms of their prior knowledge, $F(2, 108) = .90, p = .914$.

Posttest Achievement

Table 1 shows the means and standard deviations for the four criterion tests and the combined total by treatment group and prior knowledge level. The means and standard deviations for high and low prior knowledge participants in each treatment group were similar.

Table 1

Means and Standard Deviations for the Four Criterion Tests (80 Items) and Their Combined Total by Treatment Group and Prior Knowledge Level

Prior Knowledge Level	*n*	Drawing *M*	Drawing *SD*	Identification *M*	Identification *SD*	Terminology *M*	Terminology *SD*	Comprehension *M*	Comprehension *SD*	Total Sum *M*	Total Sum *SD*
Static Graphic Group (T1)											
Low	19	14.63	4.90	15.16	3.95	11.68	4.61	10.84	3.89	52.32	10.27
High	19	13.47	5.56	16.16	3.25	13.00	4.06	12.05	4.65	54.68	12.13
Total	38	14.05	5.20	15.66	3.60	12.34	4.33	11.45	4.27	53.50	11.15
Animation as Attention-Gaining Strategy (T2)											
Low	16	11.69	6.19	15.44	5.10	9.50	5.16	9.25	5.45	45.88	17.80
High	19	12.95	4.37	13.89	5.05	11.63	4.65	10.68	4.35	49.16	12.55
Total	35	12.37	5.24	14.60	5.06	10.66	4.94	10.03	4.86	47.66	15.03
Animation as Attention-Gaining and Elaboration Strategy (T3)											
Low	19	14.26	4.95	13.84	4.61	12.53	4.70	11.89	4.33	52.53	13.93
High	19	14.74	4.86	14.32	4.22	11.74	4.40	11.79	4.72	52.58	13.40
Total	38	14.50	4.85	14.08	4.36	12.13	4.50	11.84	4.47	52.55	13.48

Note. Each of the criterion tests contains 20 items. Each item was worth 1 point. Thus the scores for each criterion test could range from a low of 0 to a high of 20.

As stated previously, 23 test items were identified through a previous item analysis in which student achievement was less than 53%. The content referred to in the 23 items was located in 13 instructional screens that were improved with animation strategies. One competing hypothesis suggests that the treatment effects would appear only on the test items where the instructions were improved using the animation strategies. To test this hypothesis, further analysis was done with this subset of test items. Table 2 shows the means and standard deviations for the four criterion tests scores and their combined total by treatment group and prior knowledge level for the 23 test items specifically taught using animation strategies. Again, the mean scores and standard deviations for the high and low prior knowledge participants in each treatment group were similar.

Table 2

Means and Standard Deviations for the Four Criterion Tests (23 Items) and Their Combined Total by Treatment Group and Prior Knowledge Level

Prior Knowledge Level	*n*	Drawing (4 items)		Identification (3 items)		Terminology (9 items)		Comprehension (7 items)		Total (23 items)	
		M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*	Sum *M*	Sum *SD*
Static Graphic Group (T1)											
Low	19	2.63	1.34	1.89	1.15	4.47	2.63	2.68	1.70	11.68	4.70
High	19	2.68	1.46	1.95	1.18	5.32	2.31	2.84	2.36	12.79	4.78
Total	38	2.66	1.38	1.92	1.15	4.89	2.48	2.76	2.03	12.24	4.71
Animation as Attention-Gaining Strategy (T2)											
Low	16	2.25	1.65	2.00	1.10	3.50	2.61	2.75	2.08	10.50	5.62
High	19	2.37	1.12	1.68	1.00	4.11	2.51	3.00	1.56	11.16	3.98
Total	35	2.31	1.37	1.83	1.04	3.83	2.54	2.89	1.80	10.86	4.74
Animation as Attention-Gaining and Elaboration Strategy (T3)											
Low	19	2.68	1.38	1.58	1.22	4.79	2.25	3.00	1.63	12.05	3.88
High	19	2.68	1.57	1.74	1.05	4.11	2.23	3.47	1.78	12.00	4.66
Total	38	2.68	1.45	1.66	1.12	4.45	2.24	3.24	1.70	12.03	4.23

Note. Each item was worth 1 point. Thus the score ranges for the four criterion tests were: Drawing: 0 – 4; Identification: 0 – 3; Terminology: 0 – 9; Comprehension: 0 – 7.

Analysis of Null Hypothesis

A two-way MANOVA was run to provide answers to the three research questions. Two prerequisites, equality of variances and correlations between dependent variables, were checked before the MANOVA was run. In all cases except the identification tests, the Pearson correlation coefficient was .60 or higher at the 0.01 level. A two-way ANOVA indicated no significant differences among the three treatment groups ($F(2, 105) = 1.254, p = .289$) and between the high and low prior knowledge students ($F(1, 105) = .001, p = .978$) on the identification test. Table 3 shows the overall MANOVA results using Pallai's Trace F.

Table 3
Summary of Two-Way MANOVA Results of the Four Criterion Tests (80 Items) by Treatment Group and Prior Knowledge Level

Source	Pillai's Value	*F*	*df1*	*df2*	*P*
Treatment	.074	.990	8	206	.445
Prior Knowledge	.017	.452	4	102	.771
Interaction	.079	1.053	8	206	.398

Note. Each of the criterion tests contains 20 items.

There were no significant differences among the three treatment groups on any of the criterion tests, $F(8, 206) = .990$, $p = .445$. Also, there were no significant differences between participants with high and low prior knowledge on any of the criterion tests, $F(4, 102) = .452$, $p = .771$. Finally, there was no significant interaction between treatment group and prior knowledge level, $F(8, 206) = 1.053$, $p = .398$.

To test the strength of these findings, four two-way ANOVAs for each of the criterion tests were conducted. Again, no significant differences were found.

The results from analyzing the subset of test items generated from content specifically addressed by the animations also revealed no significant differences among the three treatment groups and between the high and low prior knowledge levels, and no significant interaction between treatment group and prior knowledge level (see Table 4).

Table 4
Summary of Two-Way MANOVA Results of the Four Criterion Tests (80 Items) by Treatment Group and Prior Knowledge Level

Source	Pillai's Value	*F*	*df1*	*df2*	*P*
Treatment	.071	.945	8	206	.480
Prior Knowledge	.007	.184	4	102	.946
Interaction	.045	.591	8	206	.785

Note. The drawing test contains 4 items, the identification test contains 3 items, the terminology test contains 9 items, and the comprehension test contains 7 items.

DISCUSSIONS AND CONCLUSIONS

Given that prior knowledge has been considered the most important single factor influencing learning (Ausubel, 1968), the finding that low prior knowledge students performed ***equally*** as well as those with high prior knowledge is important. Also, given that the creation of web-based animation is also time-consuming and costly, the finding that participants in the static graphics groups performed ***equally*** as well as those in the animation strategies group adds to the growing literature that supports the power of static graphics and questions the instructional value of animation.

Static Graphic versus Animation Strategies

This study sought to examine two types of web-based animation strategies described in previous research. Insignificant differences were found between the animation strategies groups and the static graphics control group. The results showed that participants in the static graphics group performed ***equally*** well to those in the animation strategies groups. This overall finding continues the debate about the value of animation versus static visualization. Web-based static visualization was included in all treatments and visual and verbal information was presented simultaneously. These strategies seemed to be powerful enough to aid learning of this material. The results accorded with those reported in previous literature and animation-related studies. For example, Mayer (1997) found that using the coordinated presentation of explanations in a visual format (illustrations) was effective. Wilson (1998) ascertained that, among study participants, the mean score for static graphic treatment was somewhat better than that for any dynamic treatment. Owens (2002) revealed a nonsignificant trend in decreased student performance once animation strategies were added to instructional screens.

Theoretically, our study results strengthen the results and conclusions of some previous animation-related studies. On a practical level, the results also raise a very important question about the practices of instructional designers, that is, is it really worthwhile to design and develop instructions using web-based animation strategies versus simply using static graphics if the latter have been shown to be at least as effective as animation? After all, static graphics are more cost-effective and cost-efficient than animation. In future instructional design projects, it may be better to use web-based static graphics as much as possible and use animation only when it is integral to the learning objective (Rieber, 1990).

High versus Low Prior Knowledge

The results also showed that participants with lower prior knowledge performed ***equally*** well to those with high prior knowledge in all three treatments. This result was contrary to much previous research that showed that high prior knowledge students performed better than low prior knowledge students regardless of treatment. The researchers believe this can be explained using dual coding theory. Students with low prior knowledge receive greater assistance when verbal and visual information is presented simultaneously (Mayer & Anderson, 1992). In this study, the instructional text and the static visuals or animations were put side by side. Based on the previous literature, the researchers believe that this layout would encourage the learners to read the instructional text as well as build referential connections between the instructional text and the static graphic or animation. This was especially helpful to participants with lower prior knowledge. There was a significant difference between the high and low prior knowledge participants in the pretest, but the differences became insignificant in the four achievement tests after they went through the treatments.

RESEARCH SUGGESTIONS

First, this study should be rerun with a more generalized population. Second, although the researchers believe the results of this research may be generalized to other domain knowledge, further studies need to be done to test this belief. Third, this study tested the effects of animation as attention-gaining and elaboration strategies. The elaboration strategy used in this study was only one type of presentation strategy referred to by Rieber (1990). Fourth, two functions of animations suggested by Rieber (1990), attention-gaining and presentation, were tested in this study. However, the effects of the other function of animation, animations as a practice strategy, still need to be explored. Finally, future studies may assess the effectiveness of animation strategies in facilitating higher-order thinking, such as problem-solving.

References

Anastasia, A., & Urbina, S. (1997). *Psychological testing* (7th ed.). Upper Saddle River, NJ: Prentice Hall.

Anglin, G. J., Vaez, H., & Cunningham, K. L. (2003). Visual representation and learning: The role of static and animated graphics. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 865-916). Mahwah, NJ: Lawrence Erlbaum.

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory* (Vol. 2, pp. 89-195). New York: Academic Press.

Ausubel, D. P. (1968). *Educational psychology: A cognitive view.* New York: Holt, Rinehart & Winston.

Blankenship, J., & Dansereau, D. F. (2000). The effect of animated node-link displays on information recall. *Journal of Experimental Education, 68*(4), 293-308.

Catrambone, R., & Seay, A. F. (2002). Using animation to help students learn computer algorithms. *Human Factors, 44*(3), 495-511.

Chanlin, L.-J. (2001a). The effects of gender and presentation format in computer-based learning. *Educational Media International, 38*(1), 61-65.

Chanlin, L.-J. (2001b). Formats and prior knowledge on learning in a computer-based lesson. *Journal of Computer Assisted Learning, 17*(4), 409-419.

Driscoll, M. P. (2005). *Psychology of learning for instruction* (3rd ed.). Boston, MA: Allyn & Bacon.

Dwyer, F. M. (1978). *Strategies for improving visual learning.* State College, PA: Learning Services.

Dwyer, F. M. (1994). One dimension of visual research: A paradigm and its implementation. In D. M. Moore & F. M. Dwyer (Eds.), *Visual literacy: A spectrum of visual learning* (pp. 383-401). Englewood Cliffs, NJ: Educational Technology Publications.

Dwyer, F. M., & Dwyer, C. (2003, October). *Effect of animation in facilitating knowledge acquisition.* Paper presented at the meeting of the Pennsylvania Educational Research Association, Hershey, PA.

Dwyer, F. M., & Lamberski, R. (1977). *The human heart: Parts of the heart, circulation of blood and cycle of blood pressure.* State College, PA: Learning Services.

Gagné, E. D. (1985). *The cognitive psychology of school learning.* Boston: Little, Brown, and Company.

Gagné, R. M. (1985). *The conditions of learning* (4th ed.). New York: Holt, Rinehart, & Winston.

Gagné, R. M., & Driscoll, M. P. (1988). *Essentials of learning for instruction* (2nd ed.). Englewood Cliffs, NJ: Prentice-Hall.

Haag, B. B. (1995). *The effects of visual manipulation strategies within computer-based instruction on various types of learning objectives.* Unpublished doctoral dissertation, The Pennsylvania State University.

Hannafin, M. J. (1997, October). *Better learning with multimedia? Concepts and results from psychology and education.* Paper presented at the Multimedia und internet- neue perspektiven fŸr die bildung, Gesellschaft fŸr Padagogik und Information (GPI), Munich, Germany.

Hannafin, M. J., & Peck, K. (1988). *The design, development, and evaluation of instructional software.* New York: Macmillan.

Jonassen, D. H., & Grabowski, B. L. (1993). *Handbook of individual differences, learning and instruction.* Hillsdale, NJ: Lawrence Erlbaum.

Klatzky, R. L. (1980). *Human memory* (2nd ed.). New York: Freeman.

Kobayashi, S. (1986). Theoretical issues concerning superiority of pictures over words and sentences in memory. *Perceptual and Motor Skills, 63*, 783-792.

Koroghlanian, C., & Klein, J. D. (2000, October). *The use of audio and animation in computer based instruction.* Paper presented at the National Convention of the Association for Educational Communications and Technology, Denver, CO.

Levin, J., Anglin, G., & Carney, R. (1987). On empirically validating functions of pictures in prose. In D. Willows & H. Houghton (Eds.), *The psychology of illustration, Vol. 1: Instructional issues* (pp. 51-85). New York: Springer-Verlag.

Lin, C.-L. (2001). *The effect of varied enhancements to animated instruction on tests measuring different educational objectives.* Unpublished doctoral dissertation, The Pennsylvania State University.

Lowe, R. K. (2003). Animation and learning: Selective processing of information in dynamic graphics. *Learning and Instruction, 13*(2), 157-176.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1-19.

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology, 84*(4), 444-452.

Miller, G. A. (1956). The magical number seven, plus or minus two: Some limits on our capacity for processing information. *Psychological Review, 63*(2), 81-97.

Moore, D. M., Burton, J. K., & Myers, R. J. (2003). Multiple-channel communication: The theoretical and research foundations of multimedia. In D. H. Jonassen (Ed.), *Handbook of research on educational communications and technology* (2nd ed., pp. 979-1005). Mahwah, NJ: Lawrence Erlbaum.

Owens, R. (2002). *An investigation to explore the effects of cueing strategies that complement animated visual imagery in facilitating student achievement of different educational objectives.* Unpublished doctoral dissertation, The Pennsylvania State University.

Paivio, A. (1986). *Mental representations: A dual coding approach.* New York: Oxford University Press.

Paivio, A. (1991). *Images in mind: The evolution of a theory.* New York: Harvester Wheatsheaf.

Paivio, A., & Caspo, K. (1973). Picture superiority in free recall: Imagery of dual coding. *Cognitive Psychology, 5*, 176-206.

Park, O.-C., & Hopkins, R. (1993). Instructional conditions for using dynamic visual displays: A review. *Instructional Science, 21*(6), 427-449.

Rieber, L. P. (1990). Animation in a computer-based instruction. *Educational Technology Research and Development, 39*(1), 77-86.

Rieber, L. P. (1996). Animation as feedback in a computer-based simulation: Representation matters. *Educational Technology Research and Development, 44*(1), 5-22.

Rieber, L. P. (2000). *Computers, graphics, and learning.* Retrieved March 8, 2006, from http://www.nowhereroad.com/cgl/toc2535.html

Rieber, L. P., Boyce, M., & Assad, C. (1990). The effects of computer animation on adult learning and retrieval tasks. *Journal of Computer-Based Instruction, 17*(2), 46-52.

Wilson, F. S. (1998). *The effect of time and level of visual enhancement in facilitating student achievement of different educational objectives.* Unpublished doctoral dissertation, The Pennsylvania State University.

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Notes

[1] Progressive reveal is "a dynamic visual enhancement that entails a sudden color change, or a sudden addition of graphic elements" (Wilson, 1998, p. 33).