The Effects of Various Animation Strategies in Facilitating the Achievement of Students on Tests Measuring Different Educational Objectives

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Abstract

The purpose of this quantitative study was to investigate the instructional effects of various animation strategies. Three treatment groups involved include static graphic, animation used as an attention-gaining strategy, and animation used as an attention-gaining and elaboration strategy. Participants were 115 college student volunteers. Two-way multiple analysis of variance (MANOVA) was used to analyze the data. Important findings indicate equivalent, non significant difference in performance between high and low prior knowledge participants. This was so regardless of animation strategies. The effects of the animation strategies on the achievement of students with low prior knowledge are discussed in detail.

Introduction

The advancement of technologies make it possible to present computer-based multimedia instruction that includes motion, voice, data, text, graphics, and still images (Moore, Burton & Myers, 1996). One important combination of media is animation, that is, images in motion (Dwyer & Dwyer, 2003). Animation has been the focus of recent attention and interest and become more and more popular. Although animation seems to attract learners' attention and increase their motivation to learn, whether or not instructions using animation strategies can facilitate learning still remains a question. This study attempted to examine the effects of two specific animation strategies on student achievement.

Related Literature

Information Processing & Dual Coding

Many early information processing theories described a human brain as being similar to a computer, and human learning as being similar to how computer processes information. There are three main storage structures in the memory system: sensory register, which registers stimuli in the memory system; short-term memory (STM), which serves as temporary storage; and long-term memory (LTM) where information is permanently stored. Short-term memory can only hold five to nine chunks of information (Miller, 1956) before it is processed in LTM. Not all the information stored in the LTM can be retrieved. Retrieval is more likely when appropriate cues are provided in the encoding process (Driscoll, 1994).

Pavio's (1986) dual coding theory further stated that there are two separate information processing systems: a visual system which processes visual knowledge and a verbal system for processing verbal knowledge. Animation, because of its unique dynamic function, is more likely to be coded as both visual and verbal knowledge and stored into long-term memory. Therefore, animation strategies should facilitate encoding and retrieval process (Paivio, 1986; Rieber, 1994).

Dual coding theory also suggests there are three distinctive levels of processing that can occur between the verbal and visual system: representational, associative and referential (Rieber 1996). Representational processing connects the incoming stimuli from the environment to either the verbal or visual system. Associative processing constructs connections within either of the verbal or visual systems, and referential processing builds connections between the verbal and visual systems (Rieber). In this study, static graphics facilitate representational processing by providing the illustrations. Animation as an attention-gaining strategy facilitates associative processing by highlighting specific parts of the heart using animated arrows. Animation as an attention-gaining and elaboration strategy facilitates both the associative and referential processing by building the connections between the animation graphics and the correspondent texts.

Animation as an Aid to Information Processing

Animation, with its unique dynamic function, is expected to facilitate the learner encoding the information into long-term memory by providing a "deeper" and "harder" encoding process than static visuals (Lin, 2001). Reiber, Boyce, and Assad (1990) suggested 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 animations facilitate the reconstructing process during retrieval by encouraging organization.

One animation strategy used in this study was attention-gaining. Rieber (1990) pointed out attention-gaining is one of the three major functions of animation. Attention-gaining animations provide additional ways to insure selective perception where specific features of the presentation are emphasized, stored and processed in the STM (Gagné, 1985). Similarly, Hannafin and Peck (1988) suggested that animations can help emphasize important information by providing contrast to the static background. In addition, Levin, Anglin, and Carney (1987) argued attention-gaining graphics can help make relationships between ideas more apparent by facilitating organization.

Another strategy used in this study is animation for elaboration. According to E. Gagné (1985), "elaboration is the process of adding to the information being learned" (p. 83). Elaboration can have many forms: a logical inference, a continuation, an example, a detail, or anything else that serves to connect information. She further stated that elaboration facilitates retrieval because it provides alternative pathways and extra information to generate answers.

This study investigates the effects of animation as attention-gaining and elaboration strategies in facilitating students' achievement. Animated arrows which direct learners' attention to specific image parts were used as an attention-gaining strategy to help arouse student interest as well as help them attend to relevant cues or details provided by animation. Animated text prompts were used as an elaboration strategy to add extra new information to students' existing knowledge.

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

Gagné and Driscoll (1988) created a basic model of learning and memory underlying modern information processing theories. It was revised to show how animation works as an aid to dual-coding and information processing (see Figure 1). Humans process visual and verbal information from the environment simultaneously. Animation is processed as a part of the visual information. Animation as an attention-gaining strategy helps to gain attention and reduce the processing demands in STM, while animation as an elaboration strategy not only helps reduce the processing demands in STM, but also facilitates encoding and retrieval processes by connecting information and providing alternative retrieval pathways (E. Gagné, 1985).

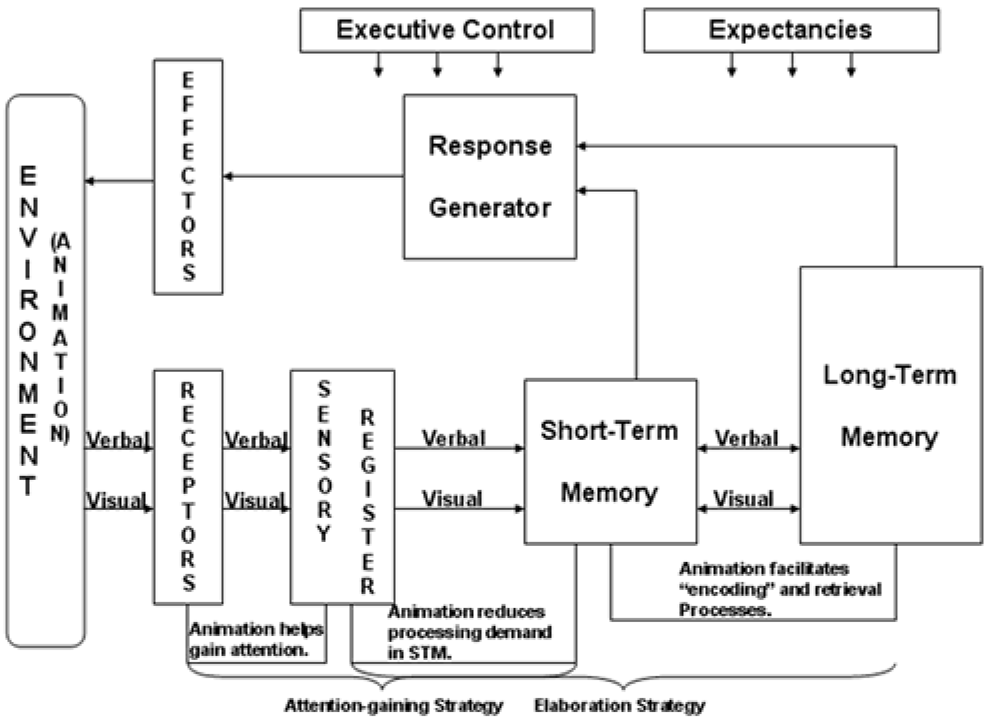

Figure 1. A model of Animation, Dual-Coding and Information Processing
Revised from "The Basic Model of Learning and Memory Underlying Modern Information Processing Theories," by R. M. Gagné and M. P. Driscoll, 1988, Essentials of learning for instruction, p. 13.

Animation Research

The previous research on animations in CBI has showed somewhat mixed results. Rieber (1990) reviewed 13 empirical studies investigating the effect of animation in CBI and found only 5 of them showed a significant effect for the animated treatments, while 8 showed insignificant differences. Park and Hopkins (1993) summarized 25 studies investigating the effects of dynamic versus static visual displays. Fourteen of the studies found significant effects for dynamic visual displays. Reiber (1990) suggested the reason for the mixed results could be rooted in the procedural flaws of the previous research, or maybe it was because animations were not used in locations where they were necessary.

More recent animation research has been conducted which use the same content as this study. Wilson (1998) tested four types of treatment groups: still graphics, progressive reveal, animation, and animation and progressive reveal. Haag (1995) conducted a study which included the following treatment groups: control group, visual summary with manipulation, learner-manipulation and computer manipulation group. Lin (2001) proposed using additional instructional strategies, and the treatment groups in his study were: static visual, animated only, animation with advance organizers and animation with adjunct questions and feedback. Owens (2002) used three treatment groups: animation, animation and attention-directing strategies, and animation and visual-elaborating strategies. The results of these studies showed insignificant differences in students' achievement among the treatment groups.

In sum, previous animation research shows mixed results while current animation research suggests insignificant differences for treatments incorporating animation strategies.

Prior Knowledge

Prior knowledge has been considered the most important single factor that influences learning (Ausubel, 1968). Jonassen and Grabowski (1993) defined prior knowledge and achievement as the knowledge, skills or abilities that the learners brings to the learning environment before the instruction. Dwyer (1994) further classified students' prior knowledge into high, medium and low level. 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 to their existing knowledge structure. Rieber (2000) also stated related prior knowledge provides the learners unique relevant elaboration that is unavailable to learners with limited prior knowledge. It is suggested that knowledge will be encoded more meaningfully and retrieved more easily by learners with high prior knowledge.

Mayer and Anderson (1992) found that learning significantly improved for students who possess low prior knowledge when verbal and visual information are presented simultaneously. They suggested that experienced students might be able to build referential connections between verbal and visual information and their existing knowledge on their own. The computer-based instruction utilized in this study presented verbal (the text) and visual (the graphic illustration or animation) information simultaneously. One of the purposes of this study is to investigate if varied animation strategies will improve the performance of the students identified as possessing low levels of prior knowledge.

Research Purpose and Questions

In this regard, the purpose of this research was to investigate the instructional effect of various animation strategies on facilitating achievement of college level students with high and low levels of prior knowledge. Three research questions were explored.

Do various animations used to gain attention or to gain attention and elaborate on the content improve students' performance on tests measuring different types of educational objectives?

Do various animations used to gain attention or to gain attention and elaborate on the content improve the performance of the students identified as possessing high and low levels of prior knowledge on tests measuring different educational objectives?

Is there an interaction between levels of prior knowledge and the selected animation strategies?

Methodology

Participants

One hundred and fifteen student volunteers participated in the study. Most were freshmen. Fifty eight were classified as high prior knowledge participants while 57 were classified as low prior knowledge participants. Four participants did not complete 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 (1997) about the human heart. The original script of the heart content contains 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 was determined by an item analysis which identified where students were having difficulties based on their performance on the criterion tests from a previous pilot study conducted in Summer, 2003.

Treatments

Static graphic (Control group, T1): This treatment contained one page of directions and twenty pages of instructional screens with instructional text on the left and the correspondent static graphic on the right. An example screen is shown in Figure 2.

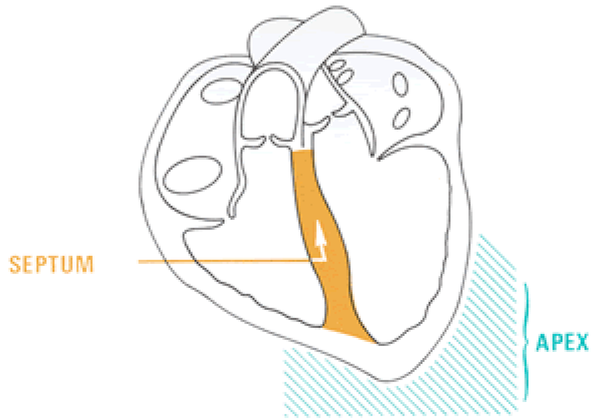

Figure 2. Example screen of static graphic treatment

Animation as attention-gaining strategy (T2): This treatment is the same as T1 except that thirteen instructional screens contained embedded attention-gaining animations. The other seven screens contained only static graphics since previous item analysis did not indicate students have difficulties with those items.

Thirteen screens contained animation with the static graphic on the right of the screen and a "Click to See the Animation" button below. Animated arrows were used as an attention-gaining strategy to direct students' attention to specific parts of the heart. In order to lower the cognitive load of the students, animations were grouped into chunks. When one animation was finished, a "Continue" button appeared. The students then clicked on the "Continue" button to see the next animation. After all the animations were shown, the static graphic was restored and a set of three buttons appeared: "BACK", "NEXT", and "Replay the Animation." See example screen in Figure 3.

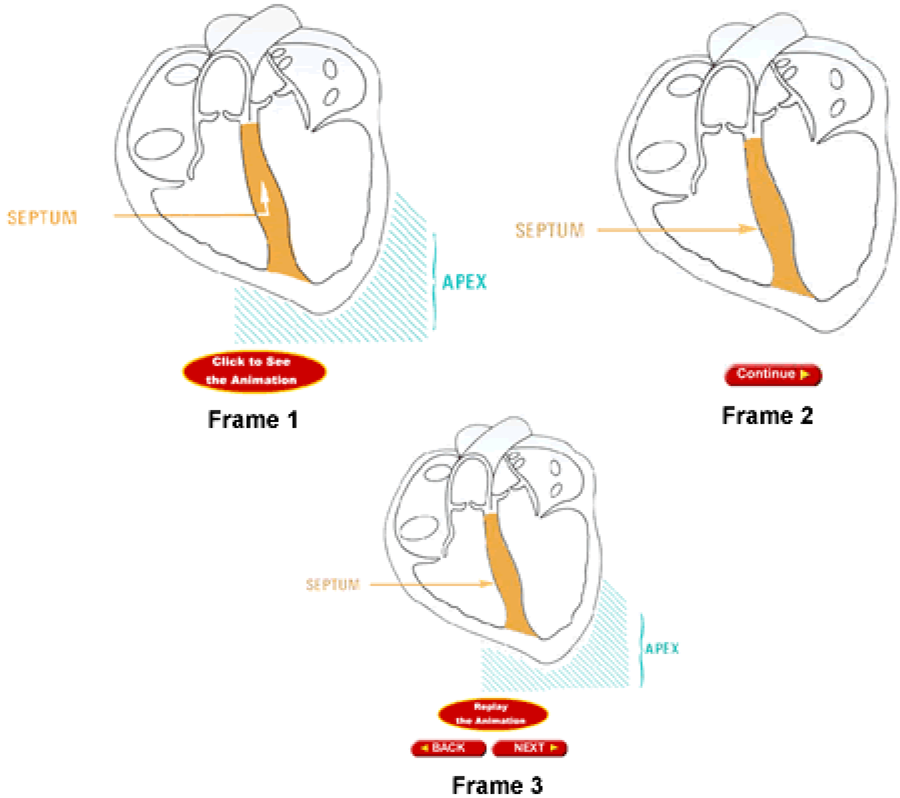

Figure 3. Example screen of animation as attention-gaining strategy treatment

Animation as attention-gaining and elaboration strategy (T3): this treatment is also the same as T1 except that thirteen instructional screens contained embedded attention-gaining and elaboration animations. A pop-up animation that highlighted the most important information in this instructional screen was used in combination with the animated arrows. See example screen in Figure 4.

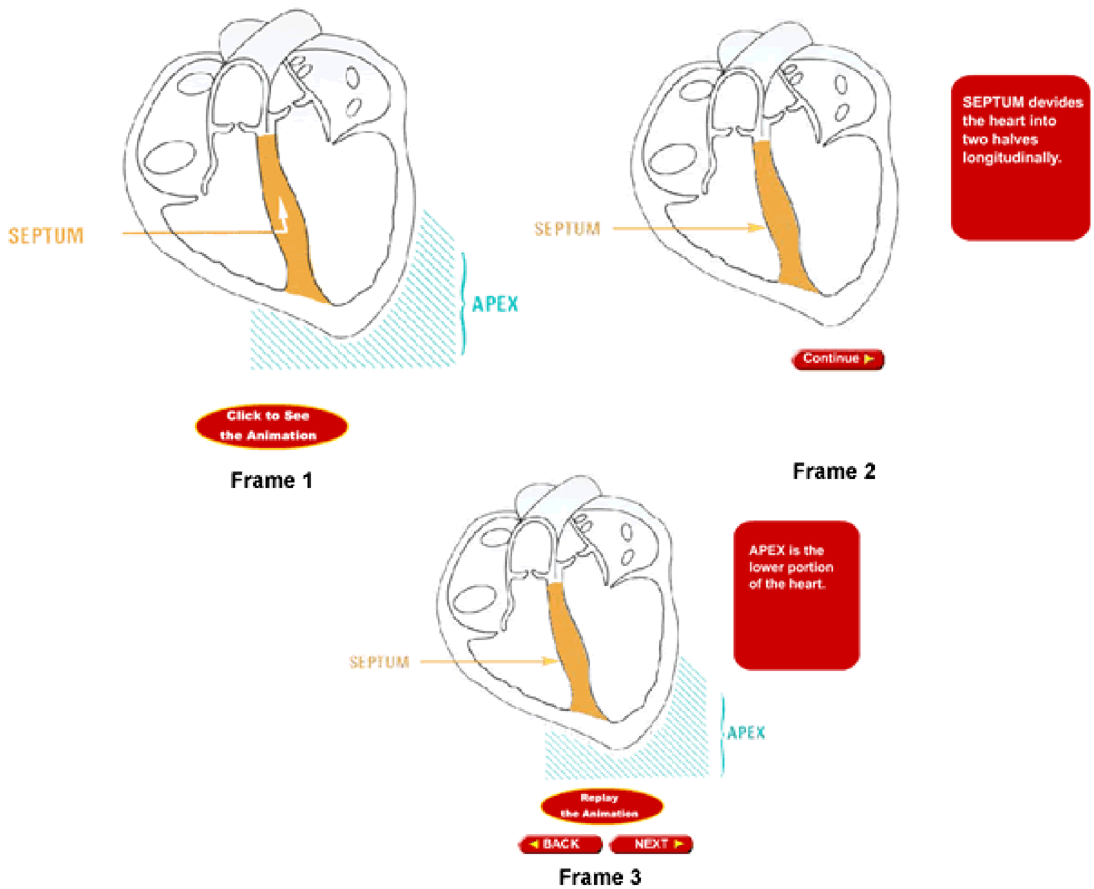

Figure 4. Example screen of animation as attention-gaining and elaboration strategies treatment

Procedures

The two-stage study included an online pretest to classify the participants into high and low prior knowledge and a following lab session. The mean of the human physiology pretest scores (57.55) of the original 115 participants was used as a cut point to distinguish between high or low prior knowledge individuals, who were then systematically assigned to one of the three treatment groups.

There were 111 participants who went to the lab session. The participants were instructed to go to a specified URL for the treatment. Afterwards, the participants took four criterion tests: the drawing test, identification test, terminology test and comprehension test.

Criterion Measures

The criteria measures included a 20-item paper-based drawing test, and three separate 20-item multiple-choice web-based criterion tests: identification test, terminology test and comprehension test.

In all the four criterion tests, the test reliabilities were all above 0.8 (Drawing = .89; Identification = .86; Terminology = .82; Comprehension = .82), which is the satisfactory reliability suggested by Anastasi and Urbina (1997).

Data Analysis

SPSS was used to analyze the data. The study used a 2 X 3 factorial design with two levels of prior knowledge and three animation strategies. A two-way MANOVA was used to test for the main effects and the interaction between the prior knowledge level and the three treatments.

Results

Analysis of the Physiology Pretest

The scores of the human physiology pretest were converted into percentages. They ranged from 33 to 78 with a mean of 57.55. A one-way ANOVA was conducted to determine if there was a difference among the three treatment groups in the means of their prior knowledge. The p-value from the ANOVA (p>.05) indicated that the three groups were not significantly different in terms of their prior knowledge.

Descriptive Statistics

Table 1 below shows the means and standard deviation for the four criterion tests and their combined total by treatments and levels of prior knowledge. They showed that the mean scores for the high and low prior knowledge participants in each treatment group were similar.

Table 1 *Means and Standard Deviation for Four Tests by Treatment and Levels of Prior Knowledge*

Prior Knowledge Level	N	Drawing		Identification		Terminology		Comprehension		Total	
		Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.	Mean	S.D.
Static Graphic Group (T1)											
Low	19	14.63	4.90	15.16	3.95	11.68	4.61	10.84	3.89	52.31	17.35
High	19	13.47	5.56	16.16	3.25	13.00	4.06	12.05	4.65	54.68	17.52
	38	14.05	5.23	15.66	3.60	12.34	4.34	11.45	4.27	53.50	17.44
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	21.90
High	19	12.95	4.37	13.89	5.05	11.63	4.65	10.68	4.35	49.15	18.42
	35	12.32	5.28	14.67	5.08	10.57	4.91	9.97	4.90	47.52	20.16
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	52.52	18.59
High	19	14.74	4.86	14.32	4.22	11.74	4.40	11.79	4.72	52.59	18.20
	38	14.50	4.91	14.08	4.42	12.14	4.55	11.84	4.53	52.56	18.40

Note: Drawing, Identification, Terminology and Comprehension scores could range from a low of 0 to a high of 20.

The results of an ANOVA for the sum means showed that the differences in variance were not significant among T1, T2 and T3, F(2,108)=.957, p=.387.

Table 2 below shows the means and standard deviation for the four criterion tests scores for the 23 questions identified in the pilot study that the students have difficulties with. Maximum possible score is equal to the number of items on each test.

Table 2 *Means and Standard Deviation for the Four Criterion Tests Scores (23 items) by Treatment*

Four Criterion Tests	Number of Items	Static Graphic		Animation as attention-gaining		Animation as attention-gaining and elaboration	
		Mean	S.D.	Mean	S.D.	Mean	S.D.
Drawing	4	2.66	1.38	2.31	1.37	2.68	1.45
Identification	3	1.92	1.15	1.83	1.04	1.66	1.12
Terminology	9	4.89	2.48	3.83	2.54	4.45	2.24
Comprehension	7	2.76	2.03	2.89	1.80	3.24	1.70
Sum	23	12.23		10.86		12.03	

Analysis of Null Hypothesis

A two-way MANOVA was run to test the research question. Two prerequisites, equality of variances and the correlations between the dependent variables, were checked before the MANOVA was used. In all cases, except the identification tests, the Pearson correlation coefficient is .6 or higher at the 0.01 level. A two-way ANOVA was conducted for the identification test to check if there were any differences.

Table 3 below showed the overall MANOVA Results using Pallai's Trace F.

Table 3 *Summary of Two-Way MANOVA Results of Four Achievement Measures (80-items) by Treatment Group and Prior Knowledge Levels (Low, or High)*

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

The results of Pillai's Trace in a two-way MANOVA analysis showed that:

There were no significant differences among the three animation strategies on any of the criterion tests, F(8,206)=.990, p=.445. Therefore, the null hypothesis 1 was retained

There were no significant differences between students with high and low prior knowledge on any of the criterion tests, F(4,102)=.452, p=.771. Therefore, as predicted, the null hypothesis 2 was retained.

There was no significant interaction between the two levels of prior knowledge and three types of treatments, F(8,206)=1.053, p=.398. Therefore, the null hypothesis 3 was retained.

Further analysis (See Table 4) was conducted for the 23 questions identified in the pilot study that the students were having difficulties with.

Table 4 *Summary of Two-Way MANOVA Results of Four Achievement Measures (23-items) by Treatment Group and Prior Knowledge Levels (Low, or High)*

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

Again, based on the above results, all the hypotheses were retained.

Conclusions and Discussion

Given that prior knowledge has been considered the most important single factor that influences learning (Ausubel 1968), the findings that low prior knowledge students perform equally well as those high prior knowledge students become important. Given that creating animation is also time-consuming and costly, these findings add to the growing literature supporting the power of static graphics.

Static Graphic vs. Animation Strategies

This study attempted to examine different animation strategies from the previous research. Insignificant differences were found between the groups using animation strategies and the control group using static graphics. The results showed that the static graphics group performed equally as well as the animation strategies group. This overall finding continues the debate about the value of animation versus just providing visualization. Visualization, included in all treatments seemed to be a powerful factor in learning this material. The results were in accordance with many previous literature and animation-related studies. Mayer (1997) justified the effect of using coordinated presentation of explanation in visual format (illustrations). Wilson (1998) found a general tendency of the mean score for the static treatment produce somewhat better results than any of the dynamic treatments. Owens (2002) found a trend that the students' performance decreased as animation strategies were added to the instructional screens.

Theoretically, the results of the study strengthened the results and conclusions of some of the previous animation-related studies. Practically, the results also raised a very important question to the practice of instructional designer, it is it really worth it to design and develop instructions utilizing animation strategies versus simply using static graphics if static graphics have been shown to be at least as effective as animation? As we all know, static graphics are more cost-effective and cost-efficient than animations. In future design, maybe it is better to utilize static graphics as much as possible and use animations only when the use of animation is justified (Rieber, 1990).

High vs. Low Prior Knowledge

The result of the interaction between level of prior knowledge and strategy use also provides an important contribution to the debate about the effectiveness of animation. What this study showed was that students 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 high prior knowledge students performing better than low prior knowledge students regardless of treatment. We believe this can be explained by dual coding theory. Students with low prior knowledge are helped more when verbal and visual information are presented simultaneously since it helps them build referential connections (Mayer & Anderson, 1992). In this study, by rearranging the layout of the instructional text and static visuals, the static graphics or the animations were put side by side instead of static graphics on the top and instructional text at the bottom. Based on the previous literature, the researchers believed that this layout would encourage the learners to read the instructional text as well as build connections with the static graphic or animations. There was a significant difference between the high and low prior knowledge participants in the pretest, but the differences were obviously reduced to insignificant differences in the four achievement tests after they went through the treatments.

Prior Knowledge and Treatments

The results also showed that there was an insignificant interaction between levels of prior knowledge and the instructional treatments, different from the predictions of the researchers. It was expected that the animation as an attention-gaining and elaboration strategy group would perform better than animation only as an attention-gaining strategy, which would be better than the static graphic group (control group). It was also predicted that the high prior knowledge participants would perform better than lower prior knowledge participants in each treatment.

One possible explanation is that the animations as an attention-gaining strategy were attracting the students' attention to the animation itself instead of to the instructional content. The repeated single movement of the animated arrows may have bored the students. Or the students just simply were not motivated enough to participate the study since their performance would not affect their course grade.

In addition to the above reasons, another important reason may be that for college students, static graphics are effective enough to facilitate referential connection between the verbal and visual information, making animation unnecessary.

To sum, the findings indicated that static graphics were as effective as animation. These results imply that it will be more beneficial to use correspondent static graphics more in our instructions.

Limitations

The results of the study are limited to the population of undergraduate students with similar characteristics (e.g. prior knowledge, field-dependence/field-independence, etc). Further, the study used systematic randomization to assign students to different treatment groups according to their pretest scores instead of strictly stratified randomization. Therefore, these generalizations should be interpreted cautiously.

Further Research Suggestions

Future studies may rerun this research with more generalized population and use strictly stratified randomization. Secondly, the effects of other animation strategies, such as animations as practice and feedback strategies, need to be explored. Lastly, future studies may assess the effectiveness of animation strategies on facilitating high order thinking, such as problem-solving.

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