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**The Use of Animation in
Computer Assisted Instruction**

by

Alice Yee Kit Wong

A thesis submitted to
the Faculty of Graduate Studies and Research
in partial fulfillment of
the requirement for the degree of
Doctor of Philosophy

Department of Psychology
Carleton University
Ottawa, Ontario.

January, 1994.

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Abstract

This thesis examined learning effects of, and preferences for, animations in computer assisted tutorials. A set of guidelines for developing animated learning materials was developed. In Experiment 1, three tutorials covering the same learning materials were developed: a guideline consistent animation tutorial plus static graphics, a guideline inconsistent animation tutorial plus static graphics, and a static graphics only tutorial. These tutorials taught analysis of covariance concepts which involve spatial data adjustments. Subjects in the guideline consistent condition took the same amount of time and learned the same amount of materials as students who learned from static graphics alone. Students in the guideline inconsistent condition, who used animations that did not follow the guidelines, took longer and learned less than subjects in the other two conditions. Subjects gave high, equivalent ratings on quality, satisfaction and enjoyment for all three tutorials.

The second experiment used a within-subjects approach to examine user preferences for guideline consistent and guideline inconsistent animations, and for static graphics. Eighteen short tutorials were prepared. For each tutorial, there was a guideline consistent and a guideline inconsistent version. Seven tutorials also had a static graphic version. Subjects viewed all versions for each tutorial. Subjects were then asked to rank order, and comment on, the different versions. Subjects generally preferred guideline consistent versions over guideline inconsistent versions. It was also found that subjects preferred having access to both animated and static graphics. These two types of graphics appear to serve different functions in information presentation. Based on experience from Experiment 2, the guidelines were revised.

All experiments taken together suggest that, for concepts which involve simple spatial movements, well-designed animations provide no advantage over static graphics that convey equivalent amounts of information. However, animations that are of poor quality can hinder learning. It is recommended that developers follow the guidelines proposed in this paper when developing animated learning materials.

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CHAPTER 1

Introduction

One of the major goals of computer assisted instruction is to explore the unique capabilities a computer can offer which traditional learning media cannot offer (Rieber & Hannafin, 1988). The use of animation is one such capability. This thesis examines the effective use of animation in computer assisted instruction. Despite the popularity of the use of animation for entertainment purposes, little research has studied how animation can be used effectively for teaching purposes (Hativa & Reingold, 1987; Rieber, Boyce & Assad, 1990; Siliauskas, 1986).

Animation involves a series of rapidly displayed images that change in attributes such as orientation, location, sizes, or shape to generate an illusion of movement. When compared to static graphics, the illusion is created by drawing, erasing and rapidly changing the position of objects (Rieber & Kini, 1991). When compared to static graphics, illusion of movement of objects on the computer screen can be used to illustrate concepts, procedures, or ideas which involve motions or changes. Results of research on the effectiveness of animated graphics versus static graphics are mixed (Rieber, 1990). Before reviewing the literature on animation, characteristics of static and animated graphics are described.

The Characteristics of Static Graphics and Animated Graphics

Animated visuals are useful to represent changes in shapes or motions of objects across time. If no changes are involved, static visuals are sufficient. A number of static diagrams can also be used to represent a series of discrete motions and changes in graphical objects.

Static graphics to depict motions are commonly found in textbooks. Motions or movements are illustrated using two methods. In one method, motions of objects are represented by arrows or dotted lines. These symbols represent the animated path and the direction of movement. A learner generates and interprets a mental image of motions based on the text description, and arrow and symbols used in the diagram.

In the second method, motions or changes are illustrated using a sequence of representative, discrete diagrams or visual snapshots (Rieber & Kini, 1991; Thompson & Riding, 1990). A learner visualizes the motion sequence by comparing and integrating information across diagrams (Rieber & Kini, 1991; Salomon, 1979; Thompson & Riding, 1990). In this way, learners actively engage in creating a mental image of the motion depicted in the static diagrams. There is always the possibility that the mental image will be incorrect.

In an animated visual, the motion of an object is shown directly. Thus, concrete and accurate movement of the object is directly presented (Rieber & Kini, 1991). A learner experiences object movement by viewing rather than by imagining or interpreting movement representations. In contrast to viewing static visuals that are continuously presented, the previous state of an animated visual disappears as the next state is presented (Thompson & Riding, 1990).

There are a number of possible advantages of animation over static graphics. According to Rieber and Kini (1991), with an animated sequence of events, a viewer does not need to create a mental image of the action to understand the event. This should free short-term memory, and facilitate accurate encoding of the information into long-term memory. For this reason, Baecker, Small and Mander (1991) postulated that animated visuals

provide a better medium than static diagrams to communicate complex information which changes over time. In addition, Thompson and Riding (1990) believe that more information regarding a motion can be presented using an animation than using static graphics. Moreover, animation should help a learner understand dynamic processes that are difficult or impossible to visualize without aids.

Despite the apparent usefulness of animation, there are mixed results on the effectiveness of animated visuals on learning. The mixed results obtained can be attributed to a number of factors. The varying results can be due to confounding factors such as poor implementation of the animated visuals, the level of difficulty of the learning materials, the nature of the animation, and the quality of the animated visuals. A review of animation learning studies is presented in the next section.

Review of the Literature

Animation Research with Children

Rieber conducted four studies to examine the effectiveness of animation in teaching Newton's laws of motion to fourth-to sixth-grade students. The laws of motion were selected because of their conceptual difficulty and the need to conceptualize motion and trajectory. In the studies, simple animations were used to demonstrate the laws. For example, in the animation condition, students were shown a foot kicking a ball to the right. Then another foot kicked the ball to the left, causing the ball to halt. The studies compared performance of those who learned the information by either static graphics, animated graphics, or no graphics.

The studies obtained conflicting results. For example, Rieber and Hannafin (1988) found no learning performance differences among the groups using animation as a pre-instruction to a text-based lesson. When using animation as part of the lesson content, the animation group took less time to complete the quiz, but there was no increase in learning performance (Rieber, 1989).

Rieber (1990) improved the animations by adding explanations to provide better cueing of what the animation was demonstrating. In addition, the level of difficulty of the lesson content was reduced. Some positive learning effects were obtained for the animation group. However, the effect of animation was found to be dependent on the kinds of practice the students received. When given multiple choice practice questions, subjects in the animation group outperformed subjects in the static graphics and the no graphics groups. When students were given a game to practice (by applying forces to alter the path of a spaceship), the positive effect of learning from an animation during the tutorial was removed.

Finally, Rieber (1991) examined the amount of information acquired in both intentional and incidental learning. It was found that subjects in the animation group learned more intentionally- and incidentally- presented information. However, this group also acquired incorrect incidental information at the same time. Rieber (1991) suggests that designers should make use of students' ability to acquire incidental information while being careful not to accidentally convey misconceptions in the animation. In summary, the Rieber studies provide mixed evidence of the value of animation in learning.

Some positive learning effects were obtained by other researchers who studied the use of animation with children. Hativa and Reingold (1987)

taught geometric concepts to ninth grade children using animations with color and sounds. Students exposed to the animations scored higher than students who were exposed to the black and white static graphics with no sound. This effect was obtained in an immediate and a delayed test.

However, the effect of using animation alone cannot be isolated from the inclusion of color and sound.

Baek and Layne (1988) found significant improvements in learning how to calculate average speed using animation. The statement of the problem was illustrated either with static graphics, animated graphics or no graphics. For example, Figure 1 shows the graphics used to illustrate the information needed to calculate average speed for the static graphics condition. In the animated condition, the dashed line was animated to reflect the relative speed and traveling time. For example, if the speed was high, the dashed line moved faster. If the speed was slow, the dashed line moved slower. The results showed that the animation group performed better on the quiz, but took longer to complete the tutorial.

I-----I-----I	
I<- 180 miles	->I<- 69 miles ->I distance
I<- 6 hours	->I<- 3 hours ->I traveling time
I<- 30 mph	->I<- 23 mph ->I speed

Figure 1. An example of static graphics used in Baek and Layne's (1988) study.

Thompson and Riding (1990) examined the effect of showing different quality animations to students. Mathematical problems involving shears and rotations of geometrical figures were taught to 11 to 14 year-old students. Students learned the concepts by either viewing a smooth animation, a discrete animation, or static graphics. It was found that students learning

from a smooth animation outperformed students in the discrete animation group, while the discrete and static graphics group did not differ from each other.

In summary, research conducted with children found mixed effects of using animation. The next section examines animation research with adults.

Animation Research Using Adults

Rieber et al. (1990) attempted to replicate the findings obtained with children, but using adults. Newton's laws of motion were taught using a computer tutorial. The lesson introduced concepts such as weight, inertia, velocity and acceleration. The experimental design consisted of three levels of visual elaboration: static graphics, animated graphics, and no graphics. Three levels of practice were used: behavioral practice, cognitive practice, and no practice. At the end of each of four lessons, students in the behavioral practice condition answered multiple choice questions relevant to the tutorial. In the cognitive practice condition, students played with a computer simulation which controlled a starship. The no practice group did not practice. After this phase, subjects moved to the next lesson. A total of 141 undergraduate students participated in the experiment.

There was no main effect of the visual elaboration conditions on amount recalled, but there was a main effect on response latency. The time required to answer each question once prompted was on average two seconds faster for subjects in the animated group than for subjects in the static group. No significant interactions were obtained.

A. L. Caraballo (1985) also failed to obtain an effect on learning of using animation. In the experiment, 109 graduate students were taught

mathematical concepts using a computer tutorial. The tutorial emphasized rearranging parts of geometrical regions to calculate surface areas. Subjects were randomly assigned to a text-only condition, text plus static graphics condition, or a text plus still and animated graphics condition. A pretest, an immediate test, and a three-week delayed test were given.

There were no significant differences between the three conditions on test performance. All subjects were able to understand the lesson content as indicated by much higher immediate test scores when compared to pre-test scores. Delayed test scores for the three groups were also comparable.

A similar study was conducted by J. N. Caraballo (1985). A tutorial on the functions of the human heart consisted of 20 pages of information covering the parts of the heart, the circulation of blood, and the blood pressure cycle. Animations were used to show the movement of the valves in the two chambers, and how blood flows through the heart. Four treatment conditions were used: (1) control condition - no instruction, (2) text only, (3) text plus still graphics, and (4) text plus still and animated graphics. Performance measures were (1) terminology test, (2) identification test, (3) drawing test, and (4) comprehension test. Performance data were collected immediately after the presentation of the tutorial, and four weeks later.

When subjects were tested immediately, the three experimental treatment conditions generally resulted in comparable performance with two exceptions. The text-only group did not perform as well as the other groups on the identification test. The text plus still and animated graphics group did not perform as well as the other groups on the comprehension test. No difference in performance among the three experimental conditions was reported in the delayed testing. The author concluded that text plus static graphics was the most effective means of illustrating the functions of the

human heart as compared to text alone, or to text plus still and animated graphics.

The detrimental effect found in the comprehension test for the animated groups was probably a result of the poor quality animations. Figure 2 shows a screen shot of one of the animations used in the study. As can be seen, the animation was implemented using a text-based terminal. The graphics used in the animation were crude and difficult to recognize. It seems that poorly developed animations can actually hinder, rather than enrich learning.

Figure 2. A screen shot of the animation used in J. N. Caraballo's (1985) study.

Moore, Nawrocki, and Simutis (1979) used simple graphics, sophisticated graphics, and sophisticated graphics with animations to teach functions of the human ear. The three groups did not differ in learning performance and time to complete the tutorial. In King's (1975) study, trigonometry concepts were taught to three groups of subjects. Animation was used to show the changes in sine ratio with varying sizes and angles of a triangle. There were no learning time or performance benefits for the animation group when compared to the static graphics group.

Stasko, Badre, and Lewis (1993) used algorithm animations to teach how various search algorithms work. In the study, 20 computer science graduate students were taught a structure for organizing data. These subjects were randomly assigned to one of two conditions. The non-animated group was given 45 minutes to learn by reading a textual description of the data structure. The animated group was given 30 minutes to read the same text description. They were then given 15 minutes to watch an animation showing how the algorithm works. Subjects were tested immediately after the learning session.

There were no learning differences between the two groups on factual and analytical questions. Mean performance scores were approximately 50 percent. According to the authors, possible explanations for the failure to obtain any performance differences might be due to the absence of an explanation during the animation. In addition, the authors speculated that algorithm animation might not benefit novice students who did not understand the association of the animation with the underlying algorithm. They proposed that it should be possible to actively construct an animation for the algorithms rather than passively viewing an already constructed animation.

Reed (1985) conducted a series of studies to teach college students algebra using animation. The algebra problems involved calculating average speed, rate of filling tanks, and mixing of solutions with different concentrations. Viewing animated simulations of the problems did not improve learning when compared to a group without animations. The authors suggested that the failure to acquire the concepts through the animations was a result of the students' inability to correctly perceive and interpret relevant information. Simply viewing an event is not enough to understand the concept.

Therefore, in another experiment, after students viewed demonstrations of how fast water filled tanks using pipes of various sizes, students were asked to estimate how much time it would take if two pipes were used to fill the tank. By addressing these questions after a series of animations, students were encouraged to think through the process and to pay more attention to the demonstration. In addition, students received feedback about how much they over- or under-estimated the answers. The group of students who were asked questions after the animation performed better than students who were not asked questions. The results seem to suggest that animations alone do not improve learning. It is important to actively engage learners to think through the problem and to provide them with feedback throughout the learning process. This result is in line with basic learning theories which show the usefulness of feedback and active user engagement in the learning process (e.g., Venezky & Osin, 1990).

Blake (1977) reported that the effectiveness of an animation was a function of spatial aptitude of the learner. According to the author, learners with high spatial ability should be able to perceive the spatial relationships. Therefore, viewing the animation would not aid learning. However, those who were low on spatial ability would benefit from the animation. Eighty four undergraduate students who were naive about chess were taught movement patterns of chess pieces. All subjects took a spatial aptitude test before the experiment. They were then randomly assigned to one of three conditions. In the still condition, a series of still pictures of chess patterns were shown. Subjects were taught the moves of five chess pieces, and were shown examples of how to solve problems by moving various pieces to new locations. In the animated arrow condition, the pictures were the same with the exception of an additional animated arrow which traced the path through

which the chess piece would move. In the full motion condition, the chess pieces actually moved over the described path. The study showed that presentation modes had no effect on students who had high spatial ability. However, subjects who were low in spatial ability performed better with the two animated conditions when compared to the still condition. No performance difference was found between the animated arrow condition and the full-motion animation condition.

Palmiter and Elkerton (1991) examined the use of animation for explaining procedural tasks. The study compared learning procedural tasks (1) by watching animated demonstrations, (2) by following written text descriptions, and (3) by a combination of the demonstrations and a spoken version of the text descriptions. The learning tasks involved using the authoring tools available in HyperCard to create programs. Forty-eight paid volunteers participated in the experiment. These subjects had some experience using the Macintosh computer but no experience using the HyperCard program. Subjects were randomly assigned to three experimental conditions. In the demonstration-only condition, subjects were shown animations of the procedure for achieving certain tasks on the computer screen. Thus, all the mouse movements undertaken to accomplish a task were shown. In the text-only condition, subjects were given a written description of all the steps needed to accomplish a task. In the demonstration plus voice condition, subjects were given the animation accompanied by a voice narration of the procedure used in the text-only condition.

Subjects were taught a number of authoring tasks. A test was given immediately after training. The test covered some tasks that were presented in training, and some tasks that were similar to those presented in training. The same test was given to subjects seven days after training.

The researchers excluded the immediate testing data from analysis because different stopping criteria were used for the immediate and delayed testing. In the immediate testing, subjects could only perform the tasks once. In both the training session and the delayed testing, subjects performed tasks until they got them correct. Thus, only data collected during the training session and during the delay testing were used.

The results were that, during training, both demonstration groups took significantly less time and made less errors than the text-only group in completing the tasks. However, the text-only group was faster and more accurate than the demonstration groups in the delayed testing. It is possible that subjects in both demonstration groups were only mimicking actions shown in the animated demonstrations without understanding what they were doing. Thus, these subjects appeared to use the demonstration as the primary learning method while ignoring the text information.

Summary of Research on Animation in Learning

Research on animation and learning is sparse and few studies obtained positive effects. Some of the research that exists is of questionable quality, with conflicting results. Of the 16 studies reviewed, approximately half used children as subjects (Baek & Layne, 1988; Hativa & Reingold, 1987; Rieber & Hannafin, 1988; Rieber, 1989, 1990, 1991; Thompson & Riding, 1990). The remaining studies used adults as subjects (Blake, 1977; A. L. Caraballo, 1985; J. N. Caraballo, 1985; King, 1975; Moore et al., 1979; Palmiter & Elkerton, 1991; Rieber et al., 1990; Stasko et al., 1993).

Studies of animation on children showed no strong data to support the effectiveness of using animation. Only a few positive effects were reported. Six of the nine animation studies conducted using adults did not find

significant learning effects (A. L. Caraballo, 1985; King, 1975; Moore et al., 1979; Reed, 1985; Rieber et al, 1990; Stasko et al., 1993). The three studies that found an effect suggest that the usefulness of animation is limited. For example, Blake (1977) found that animations helped subjects with low spatial ability, but had no effect on students with high spatial ability. Palmiter and Elkerton (1991) found that animation actually impeded deep processing of the information in a procedural task. Finally, J. N. Caraballo (1985) found that the use of animated graphics interfered with students' comprehension.

The quality of the animations used in most of these studies was poor. Most animations were created using simple figures, lines and movements. With technology which can now support high quality animation, the effect of learning from animated visuals should be reexamined. The present thesis used sophisticated animations to teach a complex and difficult statistical concept. It was expected that learning would be enhanced with high quality animations.

Purpose of the Thesis

This thesis reports a preliminary study and two experiments. The preliminary study examined the quality of animations used in a tutorial, the sensitivity of the quiz, and the clarity of the lesson content.

The first experiment addressed two questions.

1. Does the use of high quality and appropriate animations which follow a set of animation guidelines enhance learning relative to static graphics?
2. Does the use of animations which do not follow the animation guidelines hinder learning?

The second experiment also addressed two questions:

1. Do students prefer tutorials with animations over tutorials with static graphics?
2. Is the use of guidelines for animations reflected in student's reactions to the tutorials?

Using Animation to Teach Statistical Concepts

Tutorials on analysis of covariance (ANCOVA) were developed to study the effect of using animations on learning. Analysis of covariance is a statistical technique which tests for significance of differences between groups on a dependent variable while adjusting for the effect of a covariate. A covariate is a nuisance variable which is correlated with the dependent variable but not correlated with the independent variable. By adjusting for the effect of the covariate, the amount of error variance in the dependent variable is reduced. The result of this adjustment is a statistical test where the effect of the covariate is statistically removed, or held constant.

The ANCOVA topic was chosen because it involves concepts that can be represented in terms of spatial movements of data points and regression lines during the adjustment process. The animations provide concrete representations of adjustments which are normally difficult to visualize. Furthermore, statistics is often considered a dry topic. Many students find statistical concepts difficult to grasp. It will be worthwhile to find out if using animations can make the learning of statistics enjoyable.

CHAPTER 2

Preliminary Study

Two tutorials on ANCOVA were developed. One used text and static graphics, the other used text and static graphics plus animated graphics. The main purpose of the preliminary study was to gain insight into the various aspects of developing animated tutorials. In addition, the study was conducted to examine the clarity of the lesson content; the quality of the animation, written material, and the static graphics; and the sensitivity of the performance test.

Method

Experimental Design

A one way between-groups design was used in the preliminary study. The between group independent variable was presentation mode with two levels. In the static-graphic condition, subjects were given a tutorial which used text and static graphics to illustrate ANCOVA concepts. In the animation condition, subjects were given the tutorial which used the same text and static graphics, as well as an animation of the static graphics. Figure 3 shows a sample screen from the ANCOVA tutorial. In the static-graphics condition, two graphs were presented on one screen. One graph showed the regression line between the dependent variable and the independent variable before adjusting for the covariate. The second graph showed the regression line after adjusting for the covariate. Arrows were used to indicate how the regression line rotates during the adjustment. In the animated condition, subjects were given the same information. In addition, they clicked on the

"animation" button to see movement of the regression line to adjust for the covariate. The same information was given in both conditions.

Figure 3: A sample screen from the animated tutorial used in the preliminary study.

Subjects

Twenty six volunteer subjects participated in the experiment. These subjects were enrolled in a graduate psychology statistics course. Because ANCOVA would be covered later in the course, students were willing to volunteer to learn the lesson material. All subjects knew how to operate a computer mouse.

Materials

Apparatus. The animated tutorial, the static tutorial, and the subjective questionnaire were all created using the multimedia package MacroMind Director 3.1 (MacroMind, 1992). The tutorials were implemented on a Macintosh IIsi computer. The information was presented on a 13-inch color monitor.

Tutorial. The tutorial provided an overview of ANCOVA. In the tutorial, teaching method was the independent variable, reading performance was the dependent measure, and IQ was the covariate. The tutorial consisted of 35 screens of information. On each screen, there was an area to display the textual information, and an area to display static and animated graphics. An animation was included only if it helped to explain the text material. In the animated tutorial, 15 animations consisting of 10 distinct types of animations were included in the 35 screens. In one animation, voice narration was included.

The animated tutorial was designed so that subjects had to view each animation at least once before they could move on to the next screen. This was done to ensure that subjects would view every animation. There was no limit to the number of times each animation could be viewed.

The static version of the tutorial contained the same information given in the animated tutorial. In cases where motions were involved, pointers or arrows were used to indicate direction of the movements. Subjects had to interpret the text, and imagine the movement of objects that would occur by comparing the graphics before and after the movement.

The content of the tutorials was evaluated and validated by two statistics professors to ensure that the materials were clear and accurate. The animations included in the tutorial went through several revisions to ensure good quality. Color coding was used in both the animated and the static tutorials to differentiate data points representing two different groups.

Subjective Ratings. This questionnaire measured user's perceptions about the computer tutorials. All questions were in the form of a 7-point rating scale. The questionnaire contained questions regarding satisfaction with the tutorial, difficulty level of the lesson content, perceived amount of

knowledge acquired from the tutorials, the level of enjoyment of learning from the tutorials, usefulness of the animated and the non-animated graphic visuals, and the quality of the tutorial. The questionnaire was implemented on the computer where subjects were shown each animation or graphic clip before they gave a rating on the usefulness of the animation. A copy of this questionnaire is provided in Appendix A.

Quiz. This quiz included 13 multiple-choice questions with four choices each. Of the 13 questions, answers to nine questions were discussed in the tutorial. The remaining four questions were transfer questions where answers were not directly obtainable from the tutorial. To answer these questions, a good understanding of the lesson material was required. The quiz was given on paper. A copy of the quiz is provided in Appendix B.

Procedure

Twenty-six subjects were randomly assigned to groups with 13 in each of the two experimental conditions. Subjects were told that the purpose of the experiment was to examine ways to present learning materials on a computer. They were also told that they would go through the tutorial, rate the tutorial, and then take a short quiz. Subjects were advised that the results would be anonymous, and scores on the quiz would not have any effect on course grades.

The experimental room included two Macintosh IIsx computers. A partition was used to separate two subjects. Headphones were provided to subjects in the animated-tutorial group to listen to the animation with the voice narration so that the static group subjects would not be disturbed.

When subjects arrived, they were given the informed consent form to sign. After that, they were given instructions about the experiment. All

subjects were provided with a blank piece of paper, and were told to write down any comments or suggestions they might have regarding the tutorial. Subjects were told to take their time going through the tutorial, and told that they probably would not need more than 35 minutes to complete the tutorial. At any time subjects felt they had learned the material, they could exit the tutorial. At that time, the computer automatically displayed the subjective questionnaire. After the instructions, subjects moved to the experimental room. Subjects completed the tutorial, followed by the subjective questionnaire. After completing the questionnaire, subjects moved to another room to write the quiz. There was no time limit for writing the quiz.

At the end of the experiment, subjects were thanked for their participation. They were asked not to discuss the experiment with their classmates before the experiment was over. Debriefing was provided to the whole class after the experiment was completed.

Dependent Measures

Amount of time needed to complete the tutorial was automatically recorded by the computer. The amount of time needed to complete the quiz was recorded by the experimenter. Performance measures included the overall score on the quiz, with separate quiz scores on factual and transfer questions. Other dependent measures included six subjective ratings.

Results

Independent group t-tests with $\alpha = .05$ were used to analyze the data. There were no significant differences between the static and the animated group in time to complete the tutorial ($\underline{M}_{\text{static}} = 23.75$ mins., $\underline{M}_{\text{animate}} = 22.76$ mins.), time to complete the quiz ($\underline{M}_{\text{static}} = 11.69$ mins., $\underline{M}_{\text{animate}} = 13.23$

mins.), performance on the whole quiz ($\bar{M}_{\text{static}} = 70.46$ percent, $\bar{M}_{\text{animate}} = 66.31$ percent), performance on the factual questions ($\bar{M}_{\text{static}} = 78.67$ percent, $\bar{M}_{\text{animate}} = 70.11$ percent), and performance on the transfer questions ($\bar{M}_{\text{static}} = 52$ percent, $\bar{M}_{\text{animate}} = 57.75$ percent). The means, standard deviations, and t values are provided in Table 1.

The analysis also showed no differences in subjective ratings. These ratings included satisfaction with the tutorial, the ease of understanding the materials, the amount of perceived learning involved, the amount of enjoyment involved in learning from the tutorial, and if similar tutorials would be used. The ratings results are summarized in Table 2. Ratings from the two groups were very high. On a 7-point rating scale, both the animated and the static group were highly satisfied with the tutorial (mean for all subjects = 6.0). Both groups thought that the materials were rather easy to understand (mean for all subjects = 5.43); that they had learned the material quite well (mean for all subjects = 5.31); and that they enjoyed using the tutorial (mean for all subjects = 6.12). When asked if they would like to use similar tutorials on other topics, both groups gave very high ratings (mean for all subjects = 6.73).

Mean ratings on the usefulness of animations by the animation group ranged from 5.46 to 6.62 with 1 being "not at all useful" and 7 being "very useful." This indicated that subjects in the animated-tutorial group judged all the animations to be useful in helping them understand the text material. To verify that the tutorials were well implemented and of good quality, subjects were asked to rate different aspects of the tutorial. A summary of the quality ratings is presented in Table 3. Subjects were satisfied with the quality of the animated visuals, the quality of the static illustrations, the quality of the written description, quality of the voice narration, the ease of moving

Table 1

Means, Standard Deviations, and t values on the Objective Measures for the Preliminary Study

	Static (n=13)	Animate (n=13)	t(24)	
Time-tutorial (mins.)				
<u>M</u>	23.75	22.76	0.42	n.s.
<u>SD</u>	7.76	3.44		
Time-quiz (mins.)				
<u>M</u>	11.69	13.23	1.01	n.s.
<u>SD</u>	3.57	4.17		
Total Quiz scores				
<u>M</u> (in percent)	70.46	66.31	0.85	n.s.
<u>M</u> (out of 13 questions)	9.16	8.62		
<u>SD</u>	1.77	1.45		
Factual Scores				
<u>M</u> (in percent)	78.67	70.11	1.66	n.s.
<u>M</u> (out of 9 questions)	7.08	6.31		
<u>SD</u>	1.26	1.11		
Transfer Scores				
<u>M</u> (in percent)	52.00	57.75	0.65	n.s.
<u>M</u> (out of 4 questions)	2.08	2.31		
<u>SD</u>	0.95	0.85		

Note: n.s. means that the t-value was not significant at alpha = .05.

Table 2

Means, Standard Deviations, and t values on the Subjective Ratings for the Preliminary Study

	Static (n=13)	Animate (n=13)	t(24)	
Satisfaction with the tutorial				
<u>M</u>	6.0	6.0	0.00	n.s.
<u>SD</u>	0.58	0.82		
Ease of understanding the material				
<u>M</u>	5.23	5.54	0.68	n.s.
<u>SD</u>	1.09	1.20		
Perceived amount of learning the lesson material				
<u>M</u>	5.54	5.08	1.43	n.s.
<u>SD</u>	0.66	0.95		
The amount of enjoyment involved in using the tutorial				
<u>M</u>	6.31	5.92	1.08	n.s.
<u>SD</u>	0.85	0.95		
Wanting to use a similar tutorial on a different topic				
<u>M</u>	6.77	6.69	0.43	n.s.
<u>SD</u>	0.44	0.48		

Note: n.s. means that the t-value was not significant at alpha = .05.

Table 3

Mean Ratings on the Quality of the Different Aspects of the ANCOVA Tutorial

(1=Not all satisfied, 7=Highly satisfied)	Static Graphics (n=13)	Animated Graphics (n=13)
Animations	–	6.46
Static illustration	6.38	5.23
Written description	5.62	5.54
Voice narration	–	5.54
Ease of moving through the tutorial	5.85	5.77

(1 = fast/long, 4 = Just Right, 7 = slow/short)	Static Graphics (n=13)	Animated Graphics (n=13)
Speed of moving between screens	4.23	4.15
Speed of the animation	–	4.15
Length of the tutorial	4.38	4.31

through the tutorial, the speed of moving between screens, the speed of the animation and the length of the tutorial.

In written comments, subjects were positive about using the tutorial. Twelve of the 26 subjects (half from each condition) made unsolicited positive remarks about the tutorial. In addition, half of the subjects from the animated group wanted to incorporate more voice narration in the tutorial. Three of the 26 subjects expressed the opinion that the tutorial was rather basic.

Discussion of the Preliminary Study

Although it was expected that the animated group would benefit from having the animation and would perform better than the static group, there was no significant difference in the amount of learning. While the animated group learned the material by watching the animation, the static group spent an equal amount of time learning the material by studying the static graphics. This suggests that the static group had the capability to form accurate mental images without the help of animation.

There was a discrepancy between the perceived usefulness of the animations and actual usefulness of the animations. Subjects in the animated group thought that all the animations were useful in helping them understand the lesson material (mean ratings ranged from 5.46 to 6.62 on a 7-point scale). However, in terms of quiz scores, subjects from the animated group did not learn more than the static group. One possible explanation may be related to the amount of mental effort involved in the learning process. The animated group was not required to put in as much effort as the static group in trying to understand the lesson materials since the

information was explained through the animation. Therefore, these subjects rated the animations as useful.

The failure to find any differences between groups in subjective ratings could be due to well-designed instruction in both versions. Because the tutorial was carefully planned, designed, and with information well-explained in both versions, ratings given in both groups were very high. All mean ratings were above five.

The absence of significant differences might be due to several other factors. First, the tutorial might have been too basic for graduate students. The first half of the tutorial provided the context for ANCOVA. It was a review of basic materials that many subjects already knew. The new concepts of ANCOVA were introduced in the second half of the tutorial. Some researchers (Rieber, 1990; Rieber et al., 1990) believe that animation is only useful for teaching difficult materials. It might be useful to include more animations for the new materials in the tutorials, and put less emphasis on review materials. Furthermore, the subjects were all graduate students. These students were relatively skilled learners, who were probably motivated to do well. Such students may learn just as well with or without the help of animation. Therefore, it will be worthwhile to find out if animation will have any effect on less motivated and less knowledgeable students. Finally, the quiz that was given might not be sensitive enough to show a difference in performance. As there were only 13 questions on the quiz, there was approximately one question asked on each type of animation. As the ratings on the usefulness of the animations showed that some animations were more useful than others, more questions should address animations judging most useful. Of the 13 questions, two tested the concept of how data are adjusted when there is a mean difference on the covariate for the two groups.

There was a floor effect on one of the two questions. Only one of the 26 subjects answered the question correctly. This concept involved complex spatial movements which were not well explained in the animation. Therefore, a better animated tutorial and a more sensitive quiz should be developed.

CHAPTER 3

Guidelines for the Use of Animation in Tutorials

Based on the experience of developing tutorials for the preliminary experiment, the author formulated a set of guidelines for creating animated tutorials. Additional support for the guidelines comes from evaluating animated visuals for other tutorials, and suggestions in the literature on animated tutorials. The guidelines are not comprehensive. Rather they address common problems encountered by the author while developing tutorials and common problems found in commercially available tutorials.

The guidelines are described in three categories. These guidelines were used to develop materials for Experiment 1 and 2.

I. When to use animated visuals

1. Use animation with a purpose

Animation should only be used when the animation serves a purpose. (Hativa, 1988; Merrill, 1988; Rieber & Kini, 1991). For example, animation can be used when it helps to explain the text material, guide learner's attention, or make the learning materials more concrete or easier to understand. Animation should not be used when it is irrelevant to the learning materials.

2. Animation can evoke enjoyment

In many cases, a static diagram can convey just as much information as an animation. However, as long as the animation illustrates relevant information, it can also generate enjoyment. When an animation is entertaining, learners are likely to prefer the animation over seeing a static graphic (Venezky & Osin, 1991).

II. What should be animated

1. Avoid overuse of blinking

Avoid constant blinking in the background. Attention getting stimuli, such as blinking or repetitive movement can be very distracting (Haber & Hershenson, 1980). Attention directed at non-informative actions is attention distracted from relevant material. Thus, constant blinking is counterproductive.

2. Avoid overuse of transition effects

Transition effects are screen changes used to convey the shifting from one context to another. Although many different kinds of transition effects are provided with multimedia packages, they should be used sparingly. The transition effects used should be simple, clear and smooth. Fancy visual effects which involve blending two screens together can be confusing and distracting (Merwin, Dyne, Humphrey, Griffes, & Larish, 1990). When the transition draws attention from the task at hand, learning can suffer.

3. Animate essential objects only

Animate only essential objects, not background objects. The amount of information animated at one time should be the minimum required. With unnecessary movement, it will be difficult for the learner to keep track of all the motions and to sort out important from unimportant motions. This will help the learner focus on the more important issues, and avoid distraction from less important information.

III. How to present animated visuals

1. Do not present competing kinds of information simultaneously

Because humans have a limited channel capacity, only small amounts of information can be processed at any one time (Haber & Hersenson, 1980). Therefore, it is important to avoid presenting competing kinds of information simultaneously (Bangert-Drowns & Kozman, 1989). For example, when text and animation are presented simultaneously, they both demand attention. Students will not know where to look and will miss one or the other kind of information. Rieber (1990) suggests that instruction with text and animation should be presented in alternate chunks, so that only one kind of information is presented at a time.

2. Guide learners through one concept at a time in an animation.

Unless voice narration is used, avoid presenting too many concepts or points in a single animation. Students will be overwhelmed with information. Therefore, it is important to introduce one concept at a time and emphasize that concept in the animation. When the second concept is introduced, the same animation can be used again with emphasis on that concept.

3. Information should be made available outside the animation.

Avoid providing information that is available only in animated form and cannot be obtained in static form. Regardless of the length of the animation, it can still be tedious having to watch the entire animated sequence to obtain parts of the information. In addition, as noted by Stasko, Badre, and Lewis (1993), subjects reported that they found it difficult to remember the information after seeing an animation. Therefore, provide the necessary information in static form, and allow users to obtain an additional animation.

4. Embed short pauses to provide reflection time

Short pauses (one or two seconds) should be used at logical places in the animation sequence. Pauses can be used to indicate that a set of actions is complete. In addition, pauses should be used before any major changes in movements and directions. Learners need time to catch up with the animation. Without pauses, the animation sequences will be more difficult to follow. Philips (1986) also noted the importance of providing reflection time for viewers. During the animation, viewers do not have the time to structure the information. Therefore, it is important to provide time for viewers to interpret and to reflect upon the information.

5. Provide cues to guide what to look at in an animation

Prompts or cues that indicate where learners should look and what they are seeing should be provided either before or during the animation. This information is important to direct learner's attention to the relevant parts of the animation (Reed, 1985; Rieber, 1990).

6. Changes in an animation should be made distinct

In some demonstrations, motion in the animation can be subtle. Subtle changes can be obvious to the expert but may not be obvious to novices (Baek & Layne, 1988). In this case, educators can either use cueing to point out specifically what the learner should look at, or they can select an example that emphasizes the concept. Changes in the animation should be made distinct. For example, if an educator is trying to demonstrate that heavy molecules move slower than light molecules, the educator should create an animation using distinct differences in speed of movement with very heavy molecules and very light molecules. This will make the differences obvious.

7. Use smooth animation

Avoid using discrete animation. The animation should be smooth, not "jumpy." As reported by Thompson & Riding (1990), viewing highly discrete animations may interfere with attention, and understanding of the animated materials.

8. Use a consistent location to show text prompts

If text prompts are used in an animation, the text should be placed in the same position on the screen at all times. Pointers should be used to point at different objects described in the text. Although placing text right beside the object being described works well with static graphics, different placement of text in an animation can be confusing. During the animation, the text will appear to jump from place to place. There is no way for the user to predict where the text appear next. Time searching for text is time stolen from processing the information being conveyed.

9. Present repetitive information at an adaptable presentation rate

Tutorials should present repetitive information in an intelligent way. For example, one animation in the ANCOVA tutorial shows the relation between two variables. This is done by moving 30 data points, one at a time, from a chart on the left to a chart on the right. The animation is implemented so that the first few data points move slowly so learners can follow. Once the concept is conveyed, the rest of the data points are moved over rapidly. A constant rate that is too fast will be difficult to follow. A constant rate that is too slow will be annoying.

10. Allow user control over the animation

One of the essential characteristics of a computer tutorial is that it is self-paced. However, with many of the animations commercially available, users are provided the capability to pause, stop, or repeat the animation.

The speed of the animation is determined by the speed of the computer used. If the animation is too fast, learners will have a difficult time trying to follow what is going on. If the speed is too slow, the animation may lose continuity. Because people have different learning speeds (Ackerman, 1989; Venezky & Osin, 1990), users should have the capability to pause and restart the animation. These controls must be easy and natural to use.

11. Do not use realistic, detailed objects

Use simplified rather than realistic detail, color, and movements of objects in an animation. Some researchers have noted that using animations that are too realistic may hinder learning because viewers have difficulty differentiating what they should or should not attend to. The incorporation of unnecessary details can increase the amount of information processing required (Allen, 1975; Blake, 1977; Rudnick, Porter, & Suydam, 1973).

12. Clear text area before showing new text

When text is placed in a designated text area, it may be difficult to detect when a change in text occurs. This is especially the case when the wording and the length of a new sentence is similar to the sentence presented previously. Therefore, the previous text should be removed, and the text area should be blank for a short period before new text is presented. The blank period can serve as a cue that new text is being shown.

13. Voice narration is better than textual description

It is difficult to look at descriptive text and the animation at the same time. The use of voice to cue what the learner should look for as events occur during the animation can alleviate this problem. Baggett & Ehrenfeucht (1983) found that auditory and visual information do not compete and, therefore, can be presented at the same time. Learners can

concentrate on watching the animation while the process is being explained (Baggett, 1984; Mayer & Anderson, 1991).

14. Representative static diagrams plus a demonstration animation is better than having an animation with explanatory text.

The most important frames taken out of the sequence of frames can be presented as static diagrams. Text explaining each diagram can be presented with the diagrams. Thus, learners can compare and contrast the differences across the diagrams. By providing an animation without text descriptions in addition to the static diagrams, the static diagrams are integrated for students. Also, animated sequences that do not have text explanations are smoother and easier to follow. Learners can move back and forth between the animation and the static sequence with explanations.

CHAPTER 4

Experiment 1

The preliminary study did not find any learning effect when animations were given in addition to static graphics. Experiment 1 was conducted to re-examine the effect of using animations by making several changes to the preliminary study materials. Weak parts of the tutorial were improved. The ANCOVA tutorial was modified to include basic information about simple regression and correlation. An extra example which illustrated the different spatial adjustments of the data was added to the tutorial. Hence, more emphasis was put on the spatial part of the tutorial.

Because it was speculated that the quiz used in the preliminary study was not sensitive to performance differences, the quiz was revised. The level of difficulty of the quiz was adjusted to fit a broader population. Because the tutorial contains both text and graphical information, both verbal and visual questions were included in the quiz. The visual questions involved selecting the correct graphs from a set of graphs, or drawing mean lines for adjustment of different sets of data.

Two thirds of the subjects used in Experiment 1 were undergraduate psychology students. Graduate students who had not studied ANCOVA, or had studied ANCOVA at least two years earlier were also used. These students should be less knowledgeable and less motivated than students who participated in the preliminary study.

In addition to comparing static versus animated modes of presentation, Experiment 1 added a third condition to compare animations that follow the proposed guidelines with those that do not. With new technology, many developers are incorporating animations into their tutorials without the

benefit of guidelines. The majority of the animated learning visuals seen by the author are of questionable quality. These animations are often unrelated to the teaching materials, not well-explained, and are often distracting to learners. Therefore, it is important to compare animations that follow the proposed guidelines with those that do not. If the use of poorly developed animations actually hinders learning speed and performance, then it will be important to inform educational software developers and evaluators about the risk.

It was hypothesized that the guideline consistent animation condition would yield better performance than the static graphics condition, while the static graphics condition would yield better performance than the guideline inconsistent animation condition.

Method

Experimental Design

Experiment 1 used one independent variable, presentation mode, with three levels: (1) static graphics only, (2) guideline consistent animation plus static graphics, and (3) guideline inconsistent animation plus static graphics. Presentation mode was a between subject variable. The same dependent measures used in the preliminary study were used in Experiment 1.

Subjects

A total of 45 subjects participated in the experiment. Thirty were undergraduates who were taking the introductory psychology statistics course (49.300) at the time, or had taken the course before. These subjects had completed material on analysis of variance but had not been introduced to analysis of covariance. The other 15 subjects were graduate students in

psychology. Some of the graduate students had not taken ANCOVA at the graduate level, and some had taken ANCOVA at least two years previously. Ten undergraduates and five graduates were randomly assigned to each experimental condition with 15 subjects in each condition. All subjects were paid \$15 for their participation.

Materials

Apparatus. Two Apple Macintosh computers (IIsx, IIfx) were used to run two subjects simultaneously. The three tutorials were presented on the different machines an equal number of times so that any differences in time to complete the tutorials could not be due to the different machines.

Tutorials. Three different ANCOVA tutorials which provide equivalent amounts of information were used. In the static graphic tutorial, ANCOVA concepts were taught using text and static graphics. When there were movements and motions involved, arrows were used to indicate the direction of the movement. This tutorial consisted of 47 screens of information.

All information available in the static graphics tutorial was available in the animated tutorials. In addition, the subjects viewed animations when appropriate. For example, learners clicked an animation button to see an animation of the rotation of the regression line.

The guideline consistent animation tutorial, which followed the design guidelines outlined above, consisted of 47 screens of information. There were 10 different kinds of animations. Because some animations were repeated using different sets of data, there were 21 animations embedded throughout the tutorial. Descriptions of the 10 kinds of animations used in this tutorial are presented in Appendix C.

The guideline-inconsistent animation tutorial provided the same textual and static graphic information provided in the other tutorials. However, this tutorial was developed to reflect typical problems found in freely distributed and commercially available tutorials. Table 4 summarizes the guidelines that were violated, and provides the number of occurrences of the violations. One of the violated guidelines required presenting many concepts in one animation. Information from several screens was combined. Therefore, this tutorial had only 44 screens. An additional animation was added to this tutorial to reflect a typical problem found in tutorials. This animation consisted of a constant blinking of arrows or text in the background to highlight important points. In the static version and the guideline consistent animation versions, bold arrows and text that did not blink were used for highlighting.

Subjective Ratings. Subjects were asked to rate, on a 7-point rating scale, satisfaction with the tutorial, ease of understanding the lesson content, perceived amount of knowledge acquired from the tutorial, the level of enjoyment of learning from the tutorial, the quality of the animation, the quality of the illustration, the quality of the written description, and the willingness to use similar tutorials on other topics. This questionnaire which was provided on paper, contained questions similar to those used in the preliminary study. A copy of the questionnaire is provided in Appendix D.

After completing the questionnaire, subjects were shown the different kinds of animations. For each animation, they rated how useful the animation was in helping them understand information that was also presented in text and static graphics. Subjects were prompted to comment on the animations and to give reasons for their ratings.

Table 4

The Number of Violations of the Guidelines in the Guideline Inconsistent Animation Tutorial

Guideline Violations	Number of Occurrence
I.2. Avoid overuse of blinking	21
II.1. Avoid overuse of transition effects	10
II.2. Animate essential objects only	2
III.1. Do not present competing kinds of information simultaneously	3
III.2. Do not present too many concepts in one animation	2
III.4. Embed short pauses to provide reflection time	6
III.5. Provide cues to guide what to look for in an animation	2
III.7. Use smooth animation	1
III.9. Present repetitive information at an adaptable presentation rate	4
III.10. Allow user control over the animation	7

Quiz. The quiz contained 27 questions. There were 14 factual questions and 13 transfer questions. Six of the questions were text based. The rest of the questions involved diagrams. Eighteen of the 27 questions used a multiple choice format. The remaining questions involved drawing lines or dots to show what the dataset would look like after adjustment. The quiz is provided in Appendix E.

Procedure

The procedure was the same as that used in the preliminary study. Two subjects were scheduled to arrive half an hour apart. When subjects arrived, they read and signed an informed consent form. Subjects were instructed to take their time going through the tutorial, and told they probably would not need more than 45 minutes to complete the tutorial. After finishing the tutorial, subjects completed the questionnaire. Once the questionnaire was completed, the experimenter showed the subjects one animation at a time. Subjects commented and rated the usefulness of each animation. Upon finishing the ratings, subjects completed the quiz. There was no time limit for writing the quiz.

Results

Two multivariate analyses of variance (MANOVAs) were used to analyze differences among the three experimental conditions. Alpha was set at .05.

Performance Measures

The first MANOVA examined differences on objective performance measures. This MANOVA used two between-subjects variables: (1) education level with two levels -- graduate and undergraduate students, and

(2) presentation mode with three levels -- guideline consistent animation, guideline inconsistent version, and static graphics. Dependent measures included: (1) time to complete the tutorial, (2) time to complete the quiz, (3) performance on the factual questions, and (4) performance on the transfer questions. Means and standard deviations are presented in Table 5.

There was no interaction between education level and presentation mode. The main effect for education level was not significant. The overall MANOVA result for presentation mode was significant, $F(8,72) = 2.40$, $p = .024$. Significant univariate differences were obtained on the time to complete the tutorial, $F(2,39) = 6.84$, $p < .003$, and also on the performance on the factual questions, $F(2,39) = 3.92$, $p = .028$.

Time to complete tutorial. Because the univariate ANOVA was significant for the time to complete the tutorial, multiple comparison procedures were employed. The Newman-Keuls procedure was chosen because of its moderate control over Type I errors.

The guideline inconsistent animation group took longer ($M = 33.11$ minutes) to complete the tutorial than the static ($M = 25.92$ minutes) and the animated ($M = 27.52$ minutes) groups, while the latter two did not differ.

To further examine how the groups differed on time to complete the tutorial, an ANOVA was performed on the amount of time spent on screens with animations and on screens without animations. The means and standard deviations showing the time differences are provided in Table 6. Results of the Newman Keuls tests are provided in Table 7. The guideline consistent animation group spent less time viewing screens without animations ($M = 10.59$ minutes) than the other two groups, while the guideline inconsistent ($M = 13.38$ minutes) and the static ($M = 13.15$ minutes) groups did not differ. For screens that contained an animation, the static

Table 5
Means and Standard Deviations for the Objective Performance Measures in Experiment 1.

	Static Graphics (n=15)	Guideline Consistent Animation (n=15)	Guideline Inconsistent Animation (n=15)
Time to complete tutorial			
<u>M</u> (mins.)	25.92	27.52	33.11
<u>SD</u>	7.19	4.72	4.05
Time to complete Quiz			
<u>M</u> (mins.)	19.40	19.20	20.07
<u>SD</u>	8.50	6.27	7.92
Factual questions			
<u>M</u> (in percent)	79.50	78.07	65.71
<u>M</u> (out of 14 questions)	11.13	10.93	9.20
<u>SD</u>	2.38	1.87	2.27
Transfer questions			
<u>M</u> (in percent)	64.62	62.54	54.85
<u>M</u> (13 questions)	8.40	8.13	7.13
<u>SD</u>	3.34	2.82	2.69

Table 6

Means and Standard Deviations for the Amount of Time Spent on the Non-
animated and the Animated Screens

	Static Graphics (n=15)	Guideline Consistent Animation (n=15)	Guideline Inconsistent Animation (n=15)
Time spent on non-animated screens			
<u>M</u> (mins.)	13.15	10.59	13.38
<u>SD</u>	3.75	2.11	2.09
Time spent on animated screens			
<u>M</u> (mins.)	12.78	16.93	19.73
<u>SD</u>	3.78	3.10	2.56

Table 7

Multiple Comparison Results for the Amount of Time Spent on the Non-animated and the Animated Screens

	Guideline Consistent Animation	Guideline Inconsistent Animation
Time spent on non-animated screens		
Consistent	--	
Inconsistent	.03 *	--
Static	.02 *	.82
Time spent on animated screens		
Consistent	--	
Inconsistent	.02 *	--
Static	<.01 *	<.01 *

* $p < .05$

group spent less time on the corresponding static screens ($\underline{M}$ = 12.78 minutes) than the guideline consistent animation group ($\underline{M}$ = 16.93 minutes) which spent less time than the guideline inconsistent animation group ($\underline{M}$ = 19.73 minutes).

Performance on factual questions. Because the univariate ANOVA showed that there were performance differences on 14 factual questions, Newman-Keuls comparisons were made. The results indicated that both the guideline consistent animation group ($\underline{M}$ = 10.93, $p < .04$) and the static group ($\underline{M}$ = 11.13, $p < .05$) did better than the guideline inconsistent animation group ($\underline{M}$ = 9.20). The guideline consistent animation group and the static group did not differ.

Subjective Ratings

A second MANOVA was conducted to test for differences in subjective ratings. The means and standard deviations of the subjective ratings are presented in Table 8. The overall MANOVA was not significant. Ratings were generally very high. They ranged between 5.47 and 6.67 on a 7-point rating scale.

Subjects in the two animated conditions also rated the quality of the animations. Subjective ratings showed that subjects in the guideline inconsistent animation condition were generally insensitive to the lack of quality of the animations. Both the guideline consistent ($\underline{M}$ = 6.4) and the guideline inconsistent ($\underline{M}$ = 6.07) animation groups rated the quality of the animated materials very high. The mean ratings of quality were not significantly different.

Table 8

Means and Standard Deviations for Subjective Ratings in Experiment 1.

	Static Graphics (n=15)	Guideline Consistent Animation (n=15)	Guideline Inconsistent Animation (n=15)
Satisfaction with the tutorial			
<u>M</u>	6.07	6.20	6.07
<u>SD</u>	0.70	0.56	0.96
Ease of understanding the material			
<u>M</u>	6.00	6.27	5.80
<u>SD</u>	0.93	0.88	0.86
Perceived amount of learning the lesson material			
<u>M</u>	5.60	5.73	5.47
<u>SD</u>	1.06	0.96	0.99
The amount of enjoyment involved in using the tutorial			
<u>M</u>	6.33	5.73	5.87
<u>SD</u>	0.82	1.53	1.19
Willingness to use a similar tutorial on a different topic			
<u>M</u>	6.40	6.67	6.60
<u>SD</u>	1.12	0.62	0.63

Different Uses of Animation

For the animated groups, ratings on how essential it was to have each animation suggested that some animations were more essential than others. A summary of the usefulness ratings can be found in Table 9. The comments suggest that there were a variety of reasons why an animation was considered useful. In general, there was consensus on using animations to demonstrate complex concepts. For example, the animation which demonstrated the sliding of the datasets to adjust for differences on the covariate was rated very high ($\bar{M} = 6.34$). Comments about these animations indicated that the animation was essential in helping the subjects understand the concept. Some of these comments were:

"This is the most useful of all animations."

"This animation is very helpful... will not be able to conceptualize the process without seeing it."

"The animation is good. It shows the sliding of the scores. The direction of sliding the scores is important."

"The point is nicely illustrated."

Animations which were used to explain less difficult concepts had a wider range of responses and a wider range of reasons why the animations were useful. The use of guided blinking was the least useful ($\bar{M} = 2.94$) because the majority of the subjects commented that all the important information was circled in the diagram. Therefore, an animation was not necessary.

Using animation to help explain complex concepts was just one advantage of using animation. Other reasons were identified from subjects' comments regarding the usefulness of the animations. Four categories were identified: motivation, confirmation and reinforcement, forced attention, and less mental effort required. Motivation was enhanced because animations were found to be useful for keeping the learner's interest, and were fun to watch.

Table 9.

Mean Ratings on How Essential It Was to Have each Animation for the Guideline Consistent and the Guideline Inconsistent Animation Group.

1 = Don't need the animation 7 = The animation is absolutely essential to have	Guideline Consistent Animation	Guideline Inconsistent Animation	Both Groups
8. Sliding of the datasets	6.40	6.27	6.34
5. Rotation of the regression line	5.33	6.07	5.70
1. Move data points from a single frequency distribution to separate group frequency distributions	5.60	5.60	5.60
3. Plotting the relation between two variables	5.47	5.27	5.37
4. Separate regression lines generated from the overall regression line	4.93	5.53	5.23
7. Relative positions of scores	5.33	4.33	4.83
6. Regression line equaled mean line	4.87	4.53	4.70
9. Guided text prompts	4.67	4.40	4.54
2. Overlapping scores	3.93	5.00	4.47
10. Guided blinking	2.60	3.27	2.94

The animations were used as another method to confirm subjects' interpretations of the text and the static graphics. For some subjects, animations were useful because they were forced to process and to pay attention to the information by watching the animation. Finally, some comments suggest that the amount of mental effort required was less with animations. Although subjects thought that they could work through the text and be able to understand the information, seeing an animation helped them learn faster and made things easier to understand. Sample comments for each category are provided below.

I. Motivation

"The animation is cute."

"Fun to watch."

"It lightens things up."

"Animation is good to keep you interested."

II. Confirmation and Reinforcement

"Static information is good, but the animation drives the point home."

"Reinforces the information."

"Helps information sink in more."

III. Forced Attention

"Shows you what is important, otherwise it is easy to skip over information."

"Forces you to pay attention to the information especially when you are at the end of the tutorial."

"Replaces someone walking you through the information."

IV. Less mental effort required

"You can struggle with the text, but having the animation makes it simple to understand."

"It takes time to read the text. If people are lazy, then animation really helps."

"Makes it faster to learn to have things pointed out for you."

Discussion

Experiment 1 replicated results of the preliminary study. The guideline consistent animation group did not perform better than the static group on factual and transfer questions. There were no differences between the two groups on amount of time required to complete the tutorial and time to complete the quiz. These results were replicated using less motivated and less knowledgeable subjects, and with more emphasis placed on the visual and spatial aspects on both the quiz and the tutorial. Similar results were found in other studies (A. L. Caraballo, 1985; King, 1975; Moore et al., 1979; Rieber et al, 1990; Stasko et al., 1993).

It appears that, for two-dimensional spatial movements that are not very complex, providing good animations does not make learning faster and does not improve quiz scores when compared to static graphics. This result is true as long as an equivalent amount of static graphic information is provided.

Providing guideline inconsistent animations was worse than providing static graphics alone. The guideline inconsistent group did not perform as well as the other two groups on factual questions, and took approximately six minutes longer to complete the tutorials.

Possible Reasons for the Absence of an Effect of Animations on Learning

One possible reason why the animations did not enhance learning may be the carefully designed text and static graphics. Because the static graphics conveyed the same amount of information as the animations, no extra learning occurred. Secondly, it is possible that adult learners are capable of forming mental representations of motions and movements as long as (a) the motion is not too complicated (Rollins, 1989; Shepard, 1991), and (b) all the information needed to form the image is provided (A. L. Caraballo, 1985).

A more speculative argument is that the absence of an enriched learning effect in using animation could have been due to the different depth of processing required in learning from static graphics and animated graphics. As the learning literature shows (e.g., Chambers & Sprecher, 1983; Wedman & Regan, 1986), depth of information processing is a critical factors in learning. Creating images of the information is a deeper level of processing of the information than remembering textual descriptions (e.g., Ellis & Hunt, 1989). In viewing static graphics, students form their own images to visualize motions and movement, hence, deeper processing of the information is needed to understand the information. In viewing an animation, learners passively view the information as it is shown. A deep level of processing is not required to understand the information. Because less mental effort is required to understand the information from the animation, the information is not processed as much. When learning from static visuals, students who invest the effort to understand the information from the text and static graphics, can learn the information just as well as seeing an animation. Thus, the equivalent learning results might be obtained because of differences in how static and animated graphics information is processed. This possibility requires the assumption that ease of understanding in animation is matched by depth of processing of static graphics since no learning differences were obtained.

A fourth explanation relates to the fact that there were differences in the amount of time spent on screens with and without animations. The guideline-consistent animation group spent less time on non-animated screens and spent relatively more time on the animated screens when compared to the static graphics group. Thus, it is possible that the advantage

of good animations were offset by failing to attend to materials on non-animated screens.

The fact that less time was spent on explanations and more on animations has some important implications. It is possible that inclusion of animations provided a false perception that important information is animated so less effort could be placed on the textual information. Also, students might be more motivated to learn information accompanied by an animation and relatively less motivated to learn non-animated information. If the inclusion of animations distracts from time on static descriptions for whatever reasons, then the full benefit of animations will not be achieved.

Absence of Differences in Subjective Ratings

The absence of significant differences on the subjective ratings may be an artifact of using a between-subjects design. Subjects in all three conditions were pleased with the tutorial because of the quality of instruction. Since subjects were tested on only one condition, subjects in the guideline inconsistent animation group and the static graphic group were not aware of how well-designed animation could improve performance. Only by experiencing various versions of graphics material can subjects make direct comparisons. Experiment 2 was designed to provide direct comparisons of various versions of graphic materials.

CHAPTER 5

Experiment 2

Experiment 1 was primarily concerned with the effect of animation on learning performance. Experiment 2 was primarily concerned with subjective evaluations and user preferences for animated and static materials. This experiment used a within-subjects approach. All subjects experienced and compared a variety of animated and static visuals that followed or did not follow the proposed animation guidelines. Learning was not measured.

Rather than using a single tutorial, as in the previous experiment, Experiment 2 presented subjects with 18 unrelated, animated tutorial clips. These tutorial clips varied in content areas, in the nature of the animations, and in the guidelines to be evaluated. Each tutorial consisted of an animated version that was consistent with at least one of the guidelines, and an animated version that was inconsistent with that guideline. The two animated versions conveyed the same information. For seven tutorials, a static graphic version was also provided.

Method

Subjects

Forty eight volunteer introductory psychology students served as subjects. No specific knowledge or computer skills were required. Subjects were given course credit for participation.

Experimental Design

Experiment 2 used a within-subjects approach. Pilot studies indicated that a session took approximately two and one-half hours to complete the 18

tutorial clips. To avoid fatigue, two groups of 24 subjects were used. Subjects in the two groups viewed nine different tutorials. The two sets of tutorials were approximately equivalent in terms of presentation length and types of tutorials. For example, the first set included clips on thunderstorm development and the structure of the human eye. The other set included clips on the development of lightning and the structure of the human ear. Each set contained three of the longest tutorials. A summary of the tutorials used in the two groups is provided in Table 10.

Materials

Tutorials. A total of 18 tutorial clips illustrating a variety of concepts, were used to test the 18 animation design guidelines. An additional tutorial was used for practice for all subjects. Specific details about the tutorials and their associated versions are summarized in Appendix F. Some clips were animated segments taken from already available tutorials, while other clips were developed specifically for this experiment. For each tutorial, two or three versions were developed. The different versions used different methods of presenting the same information. For each tutorial, there was a version consistent with a guideline, and a version inconsistent with that guideline. For example, to test guideline III.5 - Provide cues to guide what to look for in an animation, the guideline consistent version provided cues to tell learners what they should look for in the animation. The guideline inconsistent version did not provide any cues.

Five tutorials included a third animation version to examine an alternate method of presenting the information. For example, to test guideline III.10 - Allow user control over the animation, the guideline consistent version provided full control over the animation. The guideline inconsistent

Table 10.

Order of Presentation of the Tutorials used for Group 1 and Group 2 in Experiment 2.

Tutorials used for Group 1 subjects

- III.7. Use smooth animation
(The mechanics of a bicycle tire pump)
- II.2. Avoid overuse of transition effects
(The structure of the human eye)
- III.3. Information should be available outside the animation
(The trajectory path of a ball)
- III.10. Allow user control over the animation
(The development of lightning)
- I.2. Animation can evoke enjoyment
(The meaning of the Chinese character - Exit)
- III.2. Guide learners through one concept at a time in an animation
(Three characteristics of a dataset)
- III.12. Clear text area before showing new text
(The forces acting on an airplane in flight)
- III.9. Present repetitive information at an adaptable presentation rate
(Plotting the relationship between two variables)
- III.1. Do not present competing kinds of information simultaneously
(The mechanics of a bicycle tire pump)

Tutorials used for Group 2 subjects

- III.6. Changes in an animation should be distinct
(Aerodynamics of airplane wings)
- III.14. Representative static diagrams plus a demonstration animation is better than having an animation with explanatory text
(The mechanics of a bicycle tire pump)
- I.1. Use animation with a purpose
(Spinning of graphs)
- III.4. Embed short pauses to provide reflection time
(Double-sided photocopying)
- II.3. Animate essential objects only
(Rotation of the regression line)
- III.13. Voice narration is better than textual narration
(The development of thunderstorms)
- III.5. Provide cues to guide what to look for in an animation
(The behavior of gas molecules.)
- III.8. Use a consistent location to show text prompts
(The mechanics of a bicycle tire pump)
- II.1. Avoid overuse of blinking
(The structure of the human ear)

version provided no control. The alternate version provided only minimal stepping forward and stepping backward capabilities.

Seven tutorials included a static version. These tutorials are: II.1 - Use of blinking to illustrate the structure of the human ear, III.3 - Trajectory paths of a ball, III.4 - Making double-sided copies, III.6 - Air movement above and below an airplane wing, III.12 - The forces acting on an airplane in flight, III.14 - Mechanics of a tire pump. One tutorial, I.2 - The meaning of the Chinese character Exit, had an inconsistent version which was static, and a guideline consistent version which was animated.

One guideline was not tested. This guideline (III.11 -- Do not use realistic detailed objects) states that simplified objects, rather than realistic and detailed objects, should be used in an animation. Irrelevant details can increase the amount of information processing required. By presenting simple figures, learners will not have problems differentiating what is important. This guideline was not tested because of the difficulty of implementing an animation that used realistic, detailed objects. In addition, this guideline has already been validated in three studies (Allen, 1975; Blake, 1977; Rudnick, Porter, & Suydam, 1973).

Recording Sheet. A recording sheet was used by the experimenter to record general comments, preference rankings on the various versions in a tutorial, reasons for the rankings, and the versions subjects found unacceptable. The recording sheet is provided in Appendix G.

Subjective Questionnaire. This questionnaire was used for the seven tutorials which had a static version. It was designed to compare animated and static graphics on 10 dimensions. A 7-point rating scale was used for each dimension. The dimensions rated were: enjoyment, effectiveness of illustrating information, attention guidance, informative, keeping learner's

interest, distracting, amount of effort required to understand the information, amount of time needed to present the information, ease of following, and annoyance. For each of these dimensions, subjects gave two ratings, one for the animated version they preferred, and the other for the static version. Subjects were also asked to indicate on a 7-point scale how essential it was to have the animated graphics if the non-animated graphics were also available. Subjects were asked which format they preferred for the tutorial: (a) non-animated static graphics, (b) animated graphics, or (c) both animated and static graphics. A copy of the questionnaire is provided in Appendix H.

Order of Presentation of Tutorials and Versions within Tutorials

There were two orders of presenting each set of nine tutorials. The first order of the nine tutorials was chosen so that the longer and the shorter tutorials were scattered throughout the session. The second order of presenting the nine tutorials was the reverse of the first order. The same ordering strategy was used for the second set of tutorials. Table 10 presents the order of presentation for each set of tutorials.

In terms of the order of presenting the different versions within each tutorial, all but two tutorials were counterbalanced. For each tutorial, there were either two or three versions available. The order of presentation for the different versions was completely counterbalanced with two orders for presenting tutorials with two versions, and six orders for presenting tutorials with three versions.

Two tutorials used a constant order of presenting the versions. Tutorial III.5 - Provide cues to guide what to look at, always presented the no cue version first so that subjects could watch the animation without knowing what to look for. If the cueing version had been presented first, then subjects

would know what to look for. Similarly, for tutorial III.10 - Provide user control, subjects were always given the no-control version first. The other two versions of the latter tutorial were counterbalanced.

Procedure

Subjects were tested individually. They were told that the purpose of the experiment was to examine various methods of presenting information on a computer. They were informed that they would be shown nine short tutorial clips, and for each clip, different methods of presenting the material. They were asked to evaluate the different methods of presentation and to indicate what they liked or did not like about each method. Subjects were encouraged to comment, or to make suggestions at any time during the experiment. They were told that their comments would be useful for future development of computer assisted instructions. The instructions are provided in Appendix I.

After the instructions, subjects were shown a sample tutorial with three versions. Subjects viewed the versions as many times as they desired. After seeing the different versions, subjects were asked to rank order the versions, and to explain why they ranked the versions as they did. They were then asked if they found any of the versions unacceptable. Unacceptable was defined as, "if you had to use this method of presentation to learn information on a regular basis, say once a week for the rest of the term, would you use this method?" Subjects were then given the subjective questionnaire. Each question was carefully explained by the experimenter.

Upon completion of the questionnaire for the practice tutorial, subjects were given further instructions. They were told that for some tutorials, differences between versions might seem subtle. If they could not see the difference, that would only mean that the versions were equally good or

equally bad. The subjects were also told not to be too concerned about the content of the learning material, but to pay attention to the different methods of presentation. However, they were warned that, for a few tutorials, they would be asked to learn the information as if they were learning it for a course. This was done to ensure that subjects would actually attend to the information rather than watching the animation without trying to understand what it tried to illustrate.

After the instructions, subjects reviewed the tutorials. They assigned ranks to the different versions according to their preferences. For tutorials with a static version, the subjective questionnaire was given. Experimental sessions lasted approximately one to one and a half hour.

Results and Discussion

Analysis considerations

An alpha level of .01 was used to decrease chances of making Type I errors because of the large number of analyses conducted for this experiment. An alpha level smaller than .01 was not used because this would increase the chances of making Type II errors, especially for analyses with a small number of degrees of freedom.

Results collected from the two groups were analyzed separately because the groups received different sets of tutorials. The interest of this experiment is to compare differences between versions within tutorials, and not to compare differences between the groups.

Results in this section address the comparison of the set of animated visuals that followed the guidelines with the set of animated visuals that did not follow the proposed guidelines, and the static graphics versions. The sets

of consistent and inconsistent versions were compared by obtaining a summary mean for a subject based on all tutorials experienced. Results for individual tutorials are presented later.

Overall Tutorial Analysis

Consistent versus Inconsistent Mean Rankings. Subjects ranked the versions in each tutorial from the most preferred to the least preferred. Two within-subjects ANOVAs, one for each group, were conducted on the mean rankings for the consistent and inconsistent versions collapsed over nine tutorials.¹ Thus, for each subject there were two mean ranks: one for the nine guideline consistent versions, and one for the nine guideline inconsistent versions.² This procedure was used for both groups, with separate analyses on the two groups.

For group 1, tutorial versions which followed a number of guidelines were ranked better ($\bar{M} = 1.28$) than versions inconsistent with the guidelines ($\bar{M} = 1.72$), $F(1,23) = 92.21$, $p < .001$. Similarly for group 2, the consistent versions ($\bar{M} = 1.31$) were ranked better than the inconsistent version ($\bar{M} = 1.69$), $F(1,23) = 44.19$, $p < .001$.

To elaborate on this point, an additional analysis examined the rankings for all tutorials separately. Figure 4 and 5 show that the mean ranking for consistent versions was higher than the mean ranking for inconsistent

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¹ A joint analysis using group as a random effect cannot be performed because of singular matrices. With all subjects using ranks of 1 and 2, mean ranking equals 1.5 for both groups.

² Some tutorials had three versions. Because only the consistent and the inconsistent versions were involved in this analysis, rankings for the consistent and inconsistent versions were recoded. The more preferred of the two versions was given a ranking of one, and the other version was ranked two.

Tutorials used for Group 1

Figure 4. Mean rankings for the consistent and the inconsistent versions for group 1.

Tutorials used for Group 2

Figure 5. Mean rankings for the consistent and the inconsistent versions for group 2.

versions for 16 out of the 18 tutorials for the two groups. The probability of obtaining 16 of 18 guideline consistent versions ranked better than the guideline inconsistent versions is less than .001 by a Sign Test.

The overall analyses show that application of the guidelines, across a number of tutorials, resulted in animated tutorials that were preferred over tutorials that did not follow the guidelines.

Comparing Use of Animation with Use of Static Graphics. The previous analysis compared animations that used guidelines with animations that did not use the guidelines. This analysis compared animation with and without guidelines to static graphics.

Two additional ANOVAs compared mean rankings for static, guideline consistent, and guideline inconsistent tutorials. For group 1, mean rankings were calculated for the static, consistent, and inconsistent versions based on two tutorials that included three versions. Similarly, for group 2, mean rankings were calculated based on four tutorials that included all three versions.

The ANOVAs had one within-subjects variable, presentation mode, with three levels (static, consistent, and inconsistent). The dependent variable was mean ranking for two and four tutorials for group 1, and group 2, respectively. There were significant differences among the three versions for both group 1 ($F(2,46) = 8.74, p < .001$) and group 2 ($F(2,46) = 20.8, p < .001$). Table 11 summarizes the multiple comparison results. For group 1, the Newman-Keuls tests showed that consistent versions ($\underline{M} = 1.70$) were ranked better than the inconsistent versions ($\underline{M} = 2.39, p < .001$). Also for group 2, the Newman-Keuls tests showed that the consistent versions ($\underline{M} = 1.54$) were ranked better than the inconsistent versions ($\underline{M} = 2.05, p < .001$).

Table 11

Multiple Comparison Results on Mean Ranking for the Guideline Consistent, Guideline Inconsistent, and Static Graphics for Group 1 and Group 2.

		Guideline Consistent Animation	Guideline Inconsistent Animation
Group 1			
Consistent	(<u>M</u> = 1.70)	--	
Inconsistent	(<u>M</u> = 2.39)	<.001	--
Static	(<u>M</u> = 1.92)	n.s.	.008
Group 2			
Consistent	(<u>M</u> = 1.54)	--	
Inconsistent	(<u>M</u> = 2.05)	<.001	--
Static	(<u>M</u> = 2.41)	<.001	n.s.

Note. Alpha = .01

For group 1, mean ranking for the static versions ($\underline{M} = 1.92$) was comparable to the consistent versions ($\underline{M} = 1.70$), but ranked significantly better than inconsistent versions ($\underline{M} = 2.39$, $p = .008$). For group 2, mean rankings for the static versions ($\underline{M} = 2.41$) were comparable to the inconsistent versions ($\underline{M} = 2.05$), but was ranked significantly worse than the consistent versions ($\underline{M} = 1.54$, $p < .001$). Thus, the static versions were rated as better than (group 1), or equal (group 2) to the inconsistent versions.

Figure 6 shows the mean rankings for tutorials with a static graphics, guideline consistent and guideline inconsistent version. As indicated, the consistent versions were the highest rated version (lower rankings) for five of the six tutorials.

Data collected on the preferred tutorial format suggested that subjects wanted access to both static and animated graphics. Figure 7 presents the preferred format ratings in bar graph format. The figure shows that subjects wanted both kinds of presentation mode in five of seven tutorials

Versions Judged as Unacceptable. After seeing the different versions, subjects were asked if they found any of the versions unacceptable. With 24 subjects rating 18 tutorials, there were 432 ratings for each version. Nevertheless, most versions were acceptable. The consistent versions were considered unacceptable 17 times out of 432 (4 percent), while the inconsistent versions were considered unacceptable 117 times (27 percent). The number of unacceptable ratings for each tutorial are listed in Table 12.

In general, the overall analyses indicate that animations which follow a variety of guidelines result in higher ranking, and are considered unacceptable less often than animations which do not follow the guidelines. The overall results also indicate that a variety of animations which do not follow the guidelines are ranked as no better than, and may be ranked worse

Tutorials used for Group 1 and 2

Group 1

III.3. Information should be available outside of an animation (The trajectory path of a ball)

III.12. Clear text area before showing new text (The four forces of an airplane)

Group 2

II.1. Avoid overuse of blinking (The structure of the human ear)

III.4. Embed short pauses to provide reflection time (Double-sided photocopying)

III.6. Changes in an animation should be distinct (Aerodynamics of airplane wings)

III.14. Representative static frames plus a demonstration animation is better than having an animation with explanatory text (The mechanics of a bicycle tire pump)

Figure 6. Mean rankings for the static, consistent, and inconsistent versions for six tutorials.

Figure 7. Preferred format ratings for the seven tutorials with a static version.

Table 12

The Number of Subjects who Indicated that a Version was Unacceptable.

Animation Design Guidelines		Consistent	Inconsistent
I.1.	Use animation with a purpose	0	4 (17%)
I.2.	Animation can evoke enjoyment	0	0
II.1.	Avoid overuse of blinking	1 (4%)	12 (50%)
II.2.	Avoid overuse of transition effects	1 (4%)	9 (38%)
II.3.	Animate essential objects only	0	2 (8%)
III.1.	Do not present competing kinds of information simultaneously	1 (4%)	10 (42%)
III.2.	Guide learners through one concept at a time in an animation	1 (4%)	3 (13%)
III.3.	Information should be available outside of an animation	0	8 (33%)
III.4.	Embed short pauses to provide reflection time	5 (21%)	8 (33%)
III.5.	Provide cues to guide what to look for in an animation	0	15 (63%)
III.6.	Changes in an animation should be distinct	1 (4%)	3 (13%)
III.7.	Use smooth animation	0	4 (17%)
III.8.	Use a consistent location to show text prompts	1 (4%)	5 (21%)
III.9.	Present repetitive information at an adaptable presentation rate	1 (4%)	2 (8%)
III.10.	Allow user control over the animation	1 (4%)	19 (79%)
III.12.	Clear text area before showing new text	2 (8%)	5 (21%)
III.13.	Voice narration is better than textual narration	2 (8%)	5 (21%)
III.14.	Representative static diagrams plus a demonstration animation is better than having an animation with explanatory text	0	3 (13%)
Total		17 (4%)	117 (27%)

than, static graphics.

Analyses of Individual Tutorials

The results presented so far examined how the guidelines, as a set, were evaluated across tutorials. This section presents results for individual guidelines. It should be pointed out that each guideline is tested with one instance of the guideline consistent and guideline inconsistent implementations. Therefore, whether a guideline will be significant depends, among other things, on the degree or severity of violating the guideline in the tutorial used.

The results for individual tutorials are interpreted based on ranking data, acceptance ratings, comments and questionnaire ratings. For each tutorial, ranking results are presented first, followed by acceptance ratings, then a summary of comments.

Ranking results. Although the overall analyses showed that versions consistent with the proposed guidelines were generally ranked higher than the inconsistent versions, the rankings for each tutorial were designed to evaluate specific guidelines. Therefore, specific ANOVAs examined mean rankings for each tutorial. Hence, 18 repeated-measures ANOVAs were performed. The within subject variable was presentation mode. The number of levels of presentation mode, either two or three, was determined by the number of versions within a tutorial. The dependent variable was mean ranking. For tutorials with three versions, if the overall result was significant, multiple comparisons using Newman-Keuls' procedure were performed. Alpha was set at .01 for all analyses. The mean rankings for individual tutorials are presented in Figure 4 and 5.

Acceptance ratings. The number of subjects who indicated that a version was unacceptable are provided. These are summarized in Table 12.

Comments. A summary of comments that supported or did not support the guideline is provided for each tutorial. The number of subjects who made each comment is included.

Analyses for Tutorials with a Static Graphics Version.

For the seven tutorials with a static graphics version, three more types of information were collected: subjective ratings on 10 different dimensions of the questionnaire, rating of whether the animation was essential or not, and what was the preferred tutorial format.

Questionnaire ratings. Subjects provided ratings on a seven-point scale for the most liked animated version and the static version on 10 dimensions. These results were analyzed using a within-subject MANOVA. In the MANOVA, the within-subject variable had two levels: static graphics versus animated graphics. If the overall MANOVA was significant, 10 individual univariate ANOVAs were performed. If the overall MANOVA was not significant, ANOVAs were not performed.

Essential ratings. An additional question asked how essential it would be to have an animation if static graphics were available. A score of one meant the animation was not essential, while a score of 7 meant the animation was essential. Table 13 presents the mean essential ratings for the seven tutorials with a static version.

Preferred format. Subjects indicated preferred format for the tutorial. The three choices were: (a) non-animated static graphics is good enough, (b)

Table 13

Mean Essential Ratings of the Animations for Tutorials with a Static Version.

Tutorials with a static version		Mean
III.14	The mechanics of a bicycle tire pump.	6.13
III.6	Air movements above and below an airplane wing	5.92
II.1	Use of blinking to illustrate the structure of an human ear	4.96
III.3	Animation of a ball along a trajectory path	4.91
III.4	Making double-sided copies	4.88
I.2	The meaning of the Chinese character - Exit	4.17
III.12	The four forces of an airplane	3.42

animated graphics is good enough, or (c) have both animated and static graphics. Figure 7 presents the preferred format ratings in bar graph format.

Results for the 18 tutorials are summarized next. A detailed description of each guideline can be found in the "Animation Design Guidelines" section. A detailed description of the different versions of each tutorial is provided in Appendix F.

Individual Tutorial Analyses Results and Discussions

This section presents the results of the 18 guidelines in four categories. The first category presents the seven guidelines with a significant difference in mean rankings found between the consistent and inconsistent version. The second category presents five guidelines where the mean rankings were not significant. However, there were supportive evidence obtained from subjects' comments, acceptance ratings and the direction of the mean differences. The third category presents three guidelines that were revised based on the results obtained. The final category presents three guidelines that should be re-tested because of use of poor examples in the tutorials. A summary of the mean rankings and probabilities for all the guidelines listed according to the categories is presented in Table 14.

Guidelines supported by significant differences in mean rankings.

(III.5.) Provide cues to guide what to look for in an animation.

This tutorial showed the different behavior of two types of gas molecules. It consisted of two versions. The consistent version provided cues telling learners what they should look for in the animation. The inconsistent version did not provide any cues.

Table 14.

Mean Rankings and p-value for the Guideline Consistent versions and Guideline Inconsistent versions for 18 Animation Guidelines.

	Con- sistent	Incon- sistent	p
Supported by mean rankings and comments			
III.5. Provide cues to guide what to look for in an animation	1.00	2.00	<.001
III.7. Use smooth animation	1.29	2.71	<.001
III.10. Allow user control over the animation	1.50	2.92	<.001
III.13. Voice narration is better than textual narration	2.00	2.67	<.004
II.2. Avoid overuse of transition effects	1.71	2.52	<.007
II.1. Avoid overuse of blinking	1.46	2.46	<.001
III.3. Information should be made available outside of an animation	1.21	2.52	<.001
Supported by the directions of mean rankings and comments			
III.1. Do not present competing kinds of information simultaneously	2.08	2.54	n.s.
III.2. Guide learners through one concept at a time in an animation	1.29	1.71	n.s.
III.6. Changes in an animation should be distinct	1.46	1.75	n.s.
III.14. Representative static diagrams plus a demonstration animation is better than having an animation with explanatory text	1.42	1.90	n.s.
III.4. Embed short pauses to provide reflection time	1.83	2.10	n.s.
Guideline revised			
I.2. Animation can evoke enjoyment	1.40	1.60	n.s.
III.12. Clear text area before showing new text	2.19	2.25	n.s.
III.8. Use a consistent location to show text prompts	1.44	1.56	n.s.
Should be re-tested			
I.1. Use animation with a purpose	1.31	1.69	n.s.
II.3. Animate essential objects only	1.56	1.44	n.s.
III.9. Present repetitive information at an adaptable presentation rate	1.52	1.48	n.s.

Ranking results. An analysis on mean rankings was not needed because all 24 subjects preferred the consistent version over the inconsistent version.

Acceptance ratings. The numbers of subjects out of 24, who found the versions unacceptable were: Consistent - 0; Inconsistent - 15.

Comments. Comments made by the subjects are presented in Table 15. The numbers indicate the number of subjects who made each comment.

Table 15
Comments for Tutorial III.5.

Support Guideline	Do Not Support Guideline
<u>Consistent Version</u>	None.
" liked the cueing version more because it gave more explanation"	18
" know what to look for in an animation"	8
<u>Inconsistent Version</u>	
" did not know what was happening"	15
" cannot see any differences between the movement of the two types of molecules"	4
" ineffective in presenting information"	6

Discussion. The guideline which states that cues should be provided to learners to tell them what they should look for in an animation was validated. The results revealed that subtle differences are difficult to detect without knowing the focus of attention.

(III.7.) Use smooth animation.

This tutorial showed animations of an air pump using three levels of smoothness. The consistent version showed very smooth motions, the inconsistent version showed very jagged motions. The alternate version

showed motions that were intermediate in smoothness. The jagged animation was designed to be adequate to portray the motions using the minimum number of frames.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 26.48, p < .001$. The Newman-Keuls test showed that the consistent version ($M = 1.29$) was ranked higher than the alternate version ($M = 2.00, p < .001$), which was ranked higher than the inconsistent version ($M = 2.71, p < .001$).

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 0; Inconsistent - 4; Alternate - 2.

Comments. Comments made by the subjects are presented in Table 16. The numbers indicate the number of subjects who made each comment.

Table 16
Comments for Tutorial III.7.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		" the animation moves in intervals. With the pauses, you can see what is going on" 2	
" gradual"	6		
" smoother"	6		
" more natural and real"	4		
" easier to follow"	3		
" more detailed"	3		
" more pleasing "	2		
<u>Inconsistent Version</u>			
" too quick"	5		
" choppy and jagged"	8		
" missing information"	2		
" oversimplified"	2		

Discussion. Within the range tested, the smoother the animation, the more it was preferred. Subjects' acceptance of the quality of all three animations was quite high. However, of the 24 subjects, only four indicated

that the jagged version was unacceptable. The rest of the subjects thought that they could still learn from the jagged animations. Thus, although learners prefer smoother animation, they were tolerant of low-quality animation materials.

(III.10.) Allow user control over the animation

This tutorial illustrated the development of lightning. Three versions were provided. The consistent version provided easy and full control over the animation (i.e., speed control, playing, stopping and stepping forward and backward). The inconsistent version provided no control. The alternate version provided only stepping forward and stepping backward capabilities.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 39.49$, $p < .001$. The Newman-Keuls test showed that both the consistent version ($\underline{M} = 1.50$) and the alternate version ($\underline{M} = 1.58$) were ranked higher than the inconsistent version ($\underline{M} = 2.92$, $p < .001$). The consistent and the alternate versions did not differ.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 19; Alternate - 1.

Comments. Comments made by the subjects are presented in Table 17.

Table 17
Comments for Tutorial III.10.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		None	
" have many control options"	14		
<u>Inconsistent Version</u>			
" too fast"	21		
" don't have control over the animation"	6		
" did not learn anything from it"	5		
Comments Favor Consistent		Comments Favor Alternate	
" it's tedious to have to click the button every time to move to the next section in the other version"	4	" features other than stepping forward and backwards are not needed"	4
" have many control options"	14	" controls are simple enough"	12
		" controls are too much work in the other version"	4

Discussion. The guideline of providing user control over the animation was validated. Subjects liked to be able to set their own pace of learning by either stepping forward one screen at a time, or selecting their own speed of watching the animation.

The alternate version was included to show another method of controlling the animation. Preferences for the consistent version and the alternate version were split. Half of the subjects preferred the consistent version more than the alternate version, while the other half preferred the alternate version more. It is recommended that easy-to-use, full control options be provided for long animations.

(III.13.) Voice narration is better than text narration.

This tutorial showed the development of thunderstorms using three versions. The consistent version used a voice narration, the inconsistent version showed a text explanation and the animation in separate chunks, and the alternate version provided the information in text form with a simultaneous voice narration.

Ranking results. There was a significant difference between the three versions in rankings, $F(2,46) = 18.40$, $p < .001$. The Newman-Keuls test showed that the consistent version ($M = 2.0$) was ranked higher than the inconsistent version ($M = 2.67$, $p < .004$). The alternate version ($M = 1.33$) was ranked higher than both the consistent ($p < .004$) and the inconsistent version ($p < .001$).

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 2; Inconsistent - 5; Alternate - 1.

Comments. Comments made by the subjects are presented in Table 18.

Table 18
Comments for Tutorial III.13.

Support Guideline		Do Not Support Guideline	
" it's difficult to read and watch the animation. With voice narration, can better concentrate on the graphics"	9	" would like to read rather than to listen"	7
" the voice narration version is more interesting"	5		
" the voice catches your attention"	2		

Comments Favor Consistent		Comments Favor Alternate	
" text is not needed when there is a voice narration"	3	" it is difficult to learn from just having the voice"	3
" text is distracting because it catches your eye"	5	" want access to written information"	6
		" voice plus text version gives the best of both worlds"	9
		" want to have the text there because if you missed something, you can always look at it"	8

Discussion. The guideline which suggests that voice narration is a better method to describe the animation than using textual information was validated. Generally speaking, subjects found it difficult to read the text and watch the animation even though the information was presented in separate chunks. Being able to listen to the explanation allowed viewers to concentrate on the animation, helped to maintain their interest and captured their attention. However, seven subjects indicated that they preferred to read the text and not listen to the voice.

An alternate version was well liked by the subjects because they wanted access to the text in case they missed anything in the voice description. However, providing the text at the same time as the voice narration and the animation was found to be distracting for some subjects. The results suggest that the optimum approach may be voice navigation with the capability to turn text on or off during the animation.

(II.2.) Avoid overuse of transition effects

This tutorial described the structure of the human eye in three layers. Three versions were developed. The consistent version did not use any

transition effect when going from one layer to another. The inconsistent version used three different kinds of fancy transition effects to introduce layers. The alternate version used a simple visual dissolve effect to introduce the layers.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 6.32, p < .004$. The Newman-Keuls test showed that the consistent version ($M = 1.71$) was ranked higher than the inconsistent version ($M = 2.52, p < .007$). The alternate version ($M = 1.77$) was ranked better than the inconsistent version ($p < .005$) but comparable to the consistent version.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 9; Alternate - 4.

Comments. Comments made by the subjects are presented in Table 19.

Table 19
Comments for Tutorial II.2.

Support Guideline		Do Not Support Guideline	
" the fancy transitions were not needed"	11	" the no transition version was not exciting and was not attention catching"	7
" the fancy transitions were distracting"	11		
" took up more learning time"	3		
Comments Favor Consistent		Comments Favor Alternate	
" the transition effects are not necessary, its distracting, and it takes up too much time"	6	" simple transition helps to differentiate layers"	6
		" neat and fun"	3

Discussion. Although fancy transition effects are available in most multimedia development packages, these effects should be used sparingly. Subjects found the fancy transitions unnecessary and distracting.

The author recommends that transition effects should only be used when there is a major change in topic or context. For minor changes in context, such as the different layers within the eye structure, even simple transitions should not be used. As the ranking data revealed, there was no difference in preferences of no transition versus simple transitions. In addition, the use of simple transitions were found to be distracting for some subjects.

(II.1.) Avoid overuse of blinking

The tutorial showed the structure of the human ear. It consisted of three versions. The static version darkened the part being described. The consistent version used temporary blinking to indicate the part being described. Learners could activate the blinking on demand. In the inconsistent version, the part blinked constantly.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 7.88, p < .001$. The Newman-Keuls test showed that the consistent version ($\underline{M} = 1.46$) was ranked higher than the inconsistent version ($\underline{M} = 2.46, p < .001$). The static version ($\underline{M} = 2.08$), however, was not ranked differently from either the consistent version or the inconsistent version.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Static - 1; Consistent - 1; Inconsistent - 12.

Comments. Comments made by the subjects are presented in Table 20.

Table 20
Comments for Tutorial II.1.

Support Guideline		Do Not Support Guideline	
<u>Consistent version</u>		<u>Inconsistent version</u>	
" The flashing was helpful to distinguish the exact size and shape of the part."	6	" When the part blinked constantly, you will know which part the text is talking about all the time."	5
" Like having control over the flashing."	15		
<u>Inconsistent version</u>			
" The constant flashing was distracting."	12		
" Difficult to study for a long time."	7		
" Eyes get tired, take longer to read and comprehend the information, cannot concentrate on the text. "	7		
" Difficult to see the part if it keeps blinking constantly."	2		

Comments Favor Static		Comments Favor Animation	
" The static version was good enough."	7	" The static version does not get your attention."	5
" It's less distracting without the flashing."	2	" For the static version, graying out the rest of the parts is not a good way of highlighting the part you are interested in."	8

Questionnaire ratings. The overall MANOVA was significant for the questionnaire ratings, $F(10,14) = 6.36$, $p < .001$. Mean ratings and significant ANOVA results are presented in Table 21.

Table 21
Significant Questionnaire Items for Tutorial II.1.

Questionnaire Items	Mean Animate	Mean Static	p
keeping the learner's interest	6.12	4.63	< .002
ease of following	6.50	5.46	< .007

Essential ratings. Ratings on how essential it was to have an animation showed that 20 percent of the subjects rated a 2 or below meaning that they did not think the blinking was necessary. On the other hand, 55 percent rated a 6 or above meaning that these subjects found it essential to have. Mean essential rating was 4.96.

Preferred format. Ratings on the preferred format were split. Thirty three percent of the subjects thought that having just the static graphics without the blinking was good enough. Twenty five percent wanted to have just the constant blinking. Forty two percent wanted to have both the static graphics and also the capability to blink the part being described.

Discussion. The use of a constant blinking was generally not liked by subjects. Subjects found the blinking distracting, taking attention away from the text, and making it difficult to see the part when the part was blinking constantly. The use of blinking as a part indicator was liked by the subjects if they had control over the blinking.

The method used to highlight a specific part of the ear in the static version was not adequate. Subjects commented that graying out the rest of the ear while darkening the part being illustrated was not a good method. The graying out of the diagram made the structure difficult to see. It is therefore recommended that for static versions, using a distinct color to highlight relevant parts of a diagram will be a better approach than graying out irrelevant parts of a diagram. Ratings on the questionnaire also reflected this concern. The static version was rated as more difficult to follow than the animated version. The animated version was found to be better in maintaining the learner's interest. In summary, it seems that the use of blinking is appropriate if users have control over the blinking.

(III.3.) Information should be made available at all times.

This tutorial used three versions to show the trajectory path of a moving ball escaping from a round tube. The static version showed the path of the ball using line drawings with arrows indicating direction. The consistent version showed the path, and an animation of the movement. The inconsistent version showed only the animation without showing the path.

Ranking results. There was a significant difference, $F(2,46) = 22.17, p < .001$. The Newman-Keuls test showed that the consistent version ($M = 1.21$) was ranked higher than the inconsistent version ($M = 2.52, p < .001$). The consistent version was also ranked higher than the static version ($M = 2.27, p < .001$), and the static version was ranked the same as the inconsistent version.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Static - 2; Consistent - 0; Inconsistent - 8.

Comments. Comments made by the subjects are presented in Table 22.

2

PM-1 3 1/2" x 4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

PRECISION^{SM} RESOLUTION TARGETS

Table 22
Comments for Tutorial III.3.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>			
" showing the path helps to know where the ball is going. Therefore it is easier to follow"	4	" having both the path and the animation does not add much"	2
" the path helps you to visualize the movement"	4	" do not need to see the lines, because the lines distract you"	1
" this version gives more information"	3	" seeing the animation is more important than seeing the path"	1
" seeing the path up front makes it easier to compare across the diagrams"	2		
<u>Inconsistent Version</u>			
" difficult to follow the ball without knowing the path"	8		
" some paths looked very similar"	4		
" it's difficult to remember the ball movement"	3		
" want to see the path in static form so I will know where the ball will go"	4		
Comments Favor Static		Comments Favor Animation	
" it's straight forward, you don't really need the animation"	6	" it's fun and interesting to watch"	5
		" the animation gives more information"	4

Questionnaire ratings. The overall MANOVA was significant for the questionnaire ratings, $F(10,14) = 16.31, p < .001$. Mean ratings and significant ANOVA results are presented in Table 23.

Table 23
Significant Questionnaire Items for Tutorial III.3.

Questionnaire Items	Mean Animate	Mean Static	p
enjoyment	6.49	4.71	< .001
effective in illustrating information	6.67	5.04	< .001
guides attention	6.63	4.92	< .001
informative	6.58	5.50	< .007
keeping the learner's interest	6.50	4.50	< .001
effort required to understand info	6.75	5.54	< .002
ease of following the information	6.88	5.79	< .003

Essential ratings. Sixteen percent of the subjects gave a two or below on a 7-point scale indicating that the animation was not essential to have, while fifty percent of the subjects rated a six or higher indicating that the animation was essential to have. Overall mean rating was 4.92.

Preferred format. Ratings on the preferred format generally favor having both static and animated graphics. Sixty six percent of the subjects wanted both formats.

Discussion. The guideline of providing information at all times is validated. Subjects found it difficult to remember or to differentiate the trajectory paths of the ball when the paths were not shown. The static information served as a reference to make comparisons across diagrams. The static information also served as a cue to the learners, telling them what to expect in the animation.

Subjects liked having both the animation and the static path. The animated version had both motivational and informational value.

Guidelines supported by the direction in mean rankings and by comments.

There were no significant differences among the consistent and inconsistent versions for the following five tutorials. However, in all cases,

the mean ranking for the consistent version was higher than the mean ranking for the inconsistent version. In addition, comments strongly support the guideline. In some cases, other measures also provide support for the guidelines.

(III.1.) Do not present competing kinds of information simultaneously

This tutorial showed the mechanics of an air pump using three versions. The consistent version showed text explanations and animations in alternate chunks while the inconsistent version showed the text and the animation simultaneously. The alternate consistent version showed the animation with a simultaneous voice narration.

Ranking results. There was a significant difference between the three versions, $F(2,46) = 12.97, p < .001$. The Newman-Keuls test showed that the consistent version ($\bar{M} = 2.08$) was comparable to the inconsistent version ($\bar{M} = 2.54$). The alternate version ($\bar{M} = 1.38$) however, was ranked better than both the consistent version ($p < .004$) and the inconsistent version ($p < .001$).

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 10; Alternate - 0.

Comments. Comments made by the subjects are presented in Table 24.

Table 24
Comments for Tutorial III.1.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		" like to see the animation at the same time with the text because you can go back and forth between the two sources of information"	
" this is good because you can first read the text description and then watch the animation"	8		2
<u>Inconsistent Version</u>			
" too much to look at"	7		
" too fast"	9		
" distracting"	2		
" cannot learn from this method"	5		
Comments Favor Consistent		Comments Favor Alternate	
" want to learn from reading text rather than learning from just the voice"	6	" liked the use of voice because can concentrate on watching the animation"	9
		" the voice keeps your interest"	3
		" the information is easier to understand"	4
		" more relaxed and more enjoyable to learn from a voice narration"	2

Discussion. Comments made by subjects generally supported the guideline. The inconsistent version presented too much to look at, making learning difficult. Of the 24 subjects, 10 found the inconsistent version unacceptable, and would not want to learn using this method of presentation. Therefore, considering all data, there is support that presenting competing kinds of information simultaneously is not advisable.

The animation with a voice narration was well liked by the subjects. This version was ranked significantly higher than both the consistent and

the inconsistent versions. Subjects liked the voice narration because it was easier to listen than to read the explanation. In this way, they could concentrate on watching the animation. In some respects, the alternate version was a better implementation of the guideline than the consistent version.

(III.2.) Guide learners through one concept at a time in an animation.

This tutorial showed three characteristics of a set of data. Two versions were implemented. The consistent version illustrated the three characteristics in three different animations. The inconsistent version illustrated the three characteristics in a single animation.

Ranking results. There was no significant difference between the consistent ($M = 1.29$) and the inconsistent ($M = 1.71$) versions.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 3.

Comments. Comments made by the subjects are presented in Table 25.

Table 25

Comments for Tutorial III.2.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		" prefer to see everything at once, in this way, you can understand all the information as a whole"	4
" show the changes step by step"	9	" the other version is too time consuming"	4
" it is easier to follow"	4		
" it is more informative and clear"	4		
<u>Inconsistent Version</u>			
" the other version has too much information to read and to comprehend at one time"	12		

Discussion. Although 17 out of 24 subjects preferred the consistent version over the inconsistent version, the difference in mean rankings did not reach statistical significance. Comments made by the users generally supported the guideline. Subjects preferred a step by step approach to learning from an animation and found this method more informative and easier to follow. Despite these positive comments, four subjects preferred seeing all descriptions at once. It seems that the best way to present complex information is to first introduce each element separately. After each component is animated separately, the relationship among components can be illustrated by showing all the information in one animation.

(III.6.) Changes in an animation should be made distinct.

This tutorial showed the difference in speed of air movement above and below an airplane wing. The static version used the number of dots to illustrate speed with more dots above the wing. The consistent version animated the air movement using considerable contrast in speed (with the dots above the wing moving much faster than dots below the wing). The inconsistent version used less contrast in speed.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 26.57, p < .001$. The Newman-Keuls test showed that the consistent version ($\underline{M} = 1.46$) was comparable to the inconsistent version ($\underline{M} = 1.75$). The static version ($\underline{M} = 2.79$) was ranked worse than both the consistent version and the inconsistent version ($p < .001$).

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Static - 11; Consistent - 1; Inconsistent - 3.

Comments. Comments made by the subjects are presented in Table 26.

Table 26
Comments for Tutorial III.6.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		<u>Consistent Version</u>	
" showed bigger contrasts between the speed of the air above and below the wing"	5	" the air is moving too fast"	2
<u>Inconsistent Version</u>		<u>Inconsistent Version</u>	
" showed the speed effectively"	2	" the air is animated slower and therefore it's easier to follow"	4
" able to get the idea faster"	5		
<u>Inconsistent Version</u>			
" less effective because the difference between the speed was not as noticeable"	6		

Comments Favor Static		Comments Favor Animation	
" do not need the animation to understand the information"	3	" the static version did not show the speed or the movement"	7
		" the static version was less interesting"	9
		" the static version was not attention catching"	3
		" having many dots are distracting"	2

Questionnaire ratings. The overall MANOVA was significant for the questionnaire ratings, $F(10,14) = 11.39, p < .001$. Mean ratings and significant ANOVA results are presented in Table 27.

Table 27
Significant Questionnaire Items for Tutorial III.6.

Questionnaire Items	Mean Animate	Mean Static	p
enjoyment	6.17	3.46	< .001
effective in illustrating information	6.58	3.96	< .001
guides attention	6.63	3.58	< .001
informative	6.46	4.96	< .001
keeping the learner's interest	6.42	3.33	< .001
distracting	6.04	4.71	< .001
effort required to understand info.	6.25	4.17	< .001
ease of following the information	6.50	4.42	< .001
annoying	6.33	4.75	< .001

Essential ratings. Eighty percent of the subjects rated a six or higher indicating that the animation was essential to have. Mean essential rating was 5.92.

Preferred format. Almost all subjects (96 percent) preferred having the animation. Of these seventy five percent of the subjects wanted to have both static and animated graphics.

Discussion. Verbal comments made by the subjects generally supported this guideline. Subjects thought that the consistent version that showed better speed contrast was easier to understand. The static version was not liked by the subjects.

(III.14.) Representative static frames plus a demonstration animation is better than having an animation with explanatory text.

This tutorial showed the mechanics of an air pump using three versions. The static version used static diagrams plus text explanation to describe the pumping movements. The consistent version gave the same information as the static version, plus an animation of the pumping action with no

explanation. The inconsistent versions showed the pump using two kinds of animation: (1) an animation which showed just the pumping movement, (2) an animation which showed the pumping movement with text explanations presented in alternate chunks.

Ranking results. The ranking results showed a significant difference between the three versions, $F(2,46) = 16.40$, $p < .001$. The Newman-Keuls test showed that the consistent version ($M = 1.42$) was ranked comparable to the inconsistent version ($M = 1.90$). The static version ($M = 2.69$) was ranked significantly worse than both the consistent version ($p < .001$) and the inconsistent version ($p < .001$).

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Static - 3; Consistent - 0; Inconsistent - 3.

Comments. Comments made by the subjects are presented in Table 28.

Table 28
Comments for Tutorial III.14.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>			
" the diagrams gave you step-by-step illustration and you first read and then watched an animation"	11	" all the diagrams looked cluttered, looks like more work"	5
" can compare valves simultaneously"	4	" just having the animation with the explanation is clear what's going on"	3
" can go back to the diagrams if you forget anything"	4	" learn better from this method"	2
" the animation pastes the pictures together for you"	4		
<u>Inconsistent Version</u>			
" the animation is difficult to follow"	4		
" takes too long to present"	2		
" easy to forget about previous parts"	3		
" it's difficult to learn from this method"	3		

Comments Favor Static		Comments Favor Animation	
" can compare the valves simultaneously"	4	" with just the diagrams, you have to focus harder to learn"	4
" can learn from just the diagram and imagine how the valves move"	2	" the static diagrams are more boring"	2
		" want to have animation"	4

Questionnaire ratings. The overall MANOVA was significant for the questionnaire ratings, $F(10,14) = 15.26$, $p < .001$. Mean ratings and significant ANOVA results are presented in Table 29.

Table 29
Significant Questionnaire Items for Tutorial III.14.

Questionnaire Items	Mean Animate	Mean Static	p
enjoyment	6.58	3.79	< .001
effective in illustrating information	6.70	4.54	< .001
guides attention	6.46	4.46	< .001
informative	6.41	5.79	< .004
keeping the learner's interest	6.50	3.96	< .001
distracting	6.42	5.25	< .008
effort required to understand info.	6.00	4.17	< .001
ease of following the information	6.54	4.54	< .001

Essential ratings. Over 80 percent of the subjects found the animation essential (ratings 6 or higher). Mean ranking = 6.13.

Preferred format. Eighty eight percent favor having both the static graphic and the animation. Eight percent wanted to have just the animation and not the static, and 4 percent of the subjects thought that having just the static diagrams was good enough.

Discussion. The differences in means were in the predicted direction. Comments from users suggest that the static diagrams are useful because they can be studied at the users pace and because they provide an overview of what to look for in the animation. Subjects liked a demonstrative animation because the animation integrated the static diagrams. Subjects strongly preferred having both static and animated graphics.

(III.4.) Embed short pauses to provide reflection time.

This tutorial showed the process of making double-sided copies. The static version showed 15 representative screen shots of 393 frames plus textual explanations to illustrate the process. The other versions used animation to

show the process. The consistent version embedded one second pauses at key places in the animation. The inconsistent version did not use pauses.

Ranking results. There was no significant difference between the three versions, $F(2,46) = 0.54$, $p = .59$. Means rankings for the consistent, static, and the inconsistent versions were 1.83, 2.06, 2.10 respectively.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Static - 6; Consistent - 5; Inconsistent - 8.

Comments. Comments made by the subjects are presented in Table 30.

Table 30
Comments for Tutorial III.4.

Support Guideline		Do Not Support Guideline	
<u>Consistent Version</u>		" the consistent version was still too fast"	7
" this version slows things down for you so that you can understand the information"	6	" the inconsistent version was better because it is faster and more fluent, and therefore it would not take too much time"	3
" it clearly illustrated the idea"	4	" can not tell the difference between the two animated versions"	7
<u>Inconsistent Version</u>			
" it's too fast"	11		
" it's confusing"	2		
" did not have enough time to retain or to register the information in your mind"	3		

Comments Favor Static		Comments Favor Animation	
" static version was better because it was self-paced"	12	" the static version was confusing"	8
" it's easier to understand"	3	" the information presented was disjointed and not well illustrated"	3
" the animation is not necessary"	2	" it was time consuming to move through a number of screens"	4
		" the animation clearly illustrated the idea of how to do the photocopying"	5

Questionnaire ratings The overall MANOVA was not significant for the questionnaire ratings.

Essential ratings. Ratings on how essential it was to have an animation were split. Thirty three percent of the subjects gave a two or below indicating that the animation was not essential to have. Sixty seven percent of the subjects rated a six or higher indicating that the animation was essential to have. Overall mean rating was 4.88.

Preferred format. Ratings on the preferred format were also split. Thirty percent of the subjects thought that having just the static graphics was good enough, 20 percent wanted to have just the animation, and 46 percent wanted both the static graphics and the animation.

Discussion. There was no consensus on the preferred version. Seven subjects could not tell the difference between the version with and without pauses. Despite the inclusion of the short pauses, seven subjects felt that the animation was still too fast. These comments indicate support for the guideline even though the implementation of the guideline in this tutorial was inadequate. Subjects wanted both static and animated graphics.

Guidelines Revised

Based on the results obtained, the following guidelines were revised.

(I.2.) Animation can evoke enjoyment.

This tutorial provided a visual mnemonic for the Chinese character "exit." The consistent version used an animated approach to provide the mnemonic. The inconsistent version presented the mnemonic using three static diagrams.

Ranking results. There was no significant difference between mean ranking for the consistent ($\bar{M} = 1.4$) and inconsistent ($\bar{M} = 1.6$) versions.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 0; Inconsistent - 1.

Comments. Comments made by the subjects are presented in Table 31.

Table 31

Comments for Tutorial I.2.

Support Guideline		Do Not Support Guideline	
" The animation is fun, interesting, appealing, and it captures attention."	10	" For the static version, the information is always available for you. You can take your time to read the information, make comparisons, and associate the character with the word."	12
" The screen is not cluttered and the animation connects the man to the character."	4		

Questionnaire ratings. The overall MANOVA was significant on the questionnaire ratings, $F(10,14) = 4.26$, $p < .007$. Mean ratings and significant ANOVA results, which support the guideline, are presented in Table 32.

Table 32
Significant Questionnaire Items for Tutorial I.2.

Questionnaire Items	Mean Animate	Mean Static	p
enjoyment	6.71	5.13	< .001
keeping the learner's interest	6.38	5.25	< .001

Essential ratings. Ratings on how essential it was to have an animation were split. Forty percent of the subjects gave a two or below on a 7-point scale indicating that the animation was not essential to have. Forty five percent of the subjects rated a six or higher indicating that the animation was essential to have. Overall mean rating was 4.17.

Preferred format. Ratings on the preferred format were also split. One third of the subjects thought that having just the static graphics was good enough. One third wanted to have the animated graphics only, while one third wanted both formats.

Discussion. Although it was expected that providing an animation could provide a more enjoyable environment, there were no strong preferences in mean rankings. Subjects laughed at the static version as well as the animated version when they saw the mnemonic. The results suggest that animations with only affective values but no additional information value are not essential to have.

(III.12.) Clear text area before showing new text

This tutorial showed four kinds of forces that act on an airplane as it flies. The static version showed all the forces and descriptions on a simple static screen. The other versions animated the forces, one at a time. In the consistent version, the text area was cleared before new text was shown. In

the inconsistent version, the new text replaced the old text without clearing the text area.

Ranking results. No significant differences between the three versions were found. Mean rankings for the static, consistent and inconsistent versions were 1.56, 2.19, and 2.25, respectively.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were. Static - 0; Consistent - 2; Inconsistent - 5.

Comments. Comments made by the subjects are presented in Table 33.

Table 33

Comments for Tutorial III.12.

Support Guideline	Do Not Support Guideline
<u>Consistent Version</u>	None
" The text disappeared and then came back. This gives you a break. It's showing you that something is new and you should look at it. It's more a prompt for the eyes. In the other version, this is not as obvious."	1
" this is not as fast as the other version"	2

Comments Favor Static		Comments Favor Animation	
" static version was good because all the information was there at once"	10	" animation is cute and attractive"	5
" allows you to make comparisons"	4	" want to first see the animation of each force, then at the end of the animation, show a static screen with all the forces"	6
" no time constraint to study the information"	5		
" the animation is not needed"	2		
" difficult to remember if you cannot see all the forces"	6		
" words are going too fast"	6		

Questionnaire ratings. The overall MANOVA was not significant.

Essential ratings. Fifty percent of the subjects gave a rating of one or two indicating that the animation was not essential. Twenty five percent of the subjects rated a six or seven indicating that the animation was essential.

Overall mean rating was 3.42.

Preferred format. Forty two percent of the subjects thought that having just the static graphic was enough. Another 42 percent wanted to have the animation and the static graphics. Only 16 percent wanted to have only the animated graphics.

Discussion. The guideline of blanking the previous text before showing new text was not validated. The differences were very subtle. Only one subject correctly pointed out the difference between the two animated versions. These results suggest a revision to the guideline. Clear the text area only when the previous text and the current text are similar in length and wording. For example, "If object 1 moves forward, then object 2 moves backward," is replaced by "If object 2 moves forward, then object 1 moves backward," learners are unlikely to tell that there is a text change.

Therefore, a blank period can serve as a cue that new text is shown. If the

previous text and the new text are not similar, then blanking the text is not necessary.

This tutorial provided evidence on an issue that was not anticipated. The static version provided accessibility of the forces because all the forces were shown on one screen. By seeing everything at the same time, subjects could make comparisons to see how the forces differ. Those subjects who wanted an animation wanted access to the static graphics as well.

(III.8.) Use a consistent location to show text prompts.

This tutorial showed the mechanics of a bicycle tire pump. The consistent version showed textual explanations accompanying the animation placed at a single location on the screen. The inconsistent version showed the textual explanation at different locations. The explanations which appeared adjacent to the part of the pump being explained seemed to "jump" from position to position.

Ranking results. No significant difference between the two versions was found. Mean rankings for the consistent and inconsistent versions are 1.44 and 1.56, respectively.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 5.

Comments. Comments made by the subjects are presented in Table 34.

Table 34
Comments for Tutorial III.8.

Support Guideline		Do Not Support Guideline	
" keeping the text in the same position is more uniform and helps to keep your concentration"	2	" showing the text at different position is good because you do not have to always stare at the same position"	3
" moving the text around is distracting"	2	" the movement attracts your attention"	1
" it is difficult to anticipate where the text will show up"	3	" the location tells you which part of the diagram the text is talking about"	1
" will lose time tracking the text"	1	" could not tell the differences between the two versions"	11

Discussion. The guideline of keeping the text at a designated text area was not validated. Eleven of 24 subjects could not find a difference between the consistent and the inconsistent versions and, therefore, ranked them equally. The results appear to suggest that as long as sufficient time is provided for learners to read the text explanation, it is not important whether the text is consistently presented at the same location. In addition, the change in location can be used a cue to tell learners that new text is being presented. A constant placement of the text would probably be important when a minimum amount of time is provided to read the text. In this case, the learner might lose time tracking the text at unpredictable locations.

Guidelines To Be Re-tested

Tutorials were inadequate to evaluate three guidelines. These guidelines should be re-tested with more appropriate tutorials.

(I.1.) Use animation with a purpose

This tutorial has two versions. The consistent version used a simple method to place graphs axes on the left and the right of the screen. The

inconsistent version used a fancy method in which the two graphs spun onto the screen.

Ranking results. Mean rankings for the consistent version ($M = 1.31$) and the inconsistent version ($M = 1.69$) were not significantly different $F(1,23) = 3.96, p = .059$. Thus, this guideline was not validated.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 0; Inconsistent - 4.

Comments. Comments made by the subjects are presented in Table 35.

Table 35

Comments for Tutorial I.1.

Support Guideline		Do Not Support Guideline	
" The spinning animation is not needed."	11	" The spinning animation gets my attention."	5
"It is better for a tutorial to get right to the point. Would not waste time to see an animation that is not useful."	9	" The spinning animation was cute and fun to watch."	5
" The spinning animation is difficult to follow and it's distracting."	4		

Discussion. Although a number of subjects noted that the animation was not necessary, other subjects indicated that the spinning animation was entertaining. It is not known if attention directed at the irrelevant animation would be distracted from the learning task. It is expected that once the novelty effect is gone, subjects would not like animations that do not provide information. This guideline should be re-tested by exposing the subjects to similar examples for a longer period of time.

(II.3.) Animate essential objects only

This tutorial showed a regression line before and after it was rotated. In the consistent version, after the rotation, the regression line moved from the left graph to the same axes on the right graph. In addition to the regression line, in the inconsistent version, the horizontal and vertical axis labels for the graph moved with the regression line. The inconsistent version was based on the assumption that moving the axes, which were the same in both graphs, were not essential to understanding.

Ranking results. There was not a significant difference between the two versions. Mean rankings were 1.56 and 1.44 for the consistent version and the inconsistent version respectively.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 0; Inconsistent - 2.

Comments. Comments made by the subjects are presented in Table 36.

Table 36

Comments for Tutorial II.3.

Support Guideline		Do Not Support Guideline	
" it is better to transfer just the important information because that's the part you should attend to"	4	" moving just the data and not the whole graph is confusing because it is taking the graph apart and then putting in back together"	4
" it's confusing, there are too many movements to keep track of"	4	" moving the whole frame from the left to the right tells you that the graphs are the same"	7

Discussion. This guideline was not validated because moving the graph axes was actually perceived to have value. Moving the frame as well as the data reinforced the perception that the two graphs were the same. The failure to validate this guideline was probably an effect of choosing an

inappropriate example. The guideline should be re-examined using graphics that animate materials that are truly unnecessary.

(III.9.) Present repetitive information at an adaptable presentation rate.

This tutorial showed how data points for two variables in a table on the left were plotted in a scatter plot on the right. The points moved from the table to the graph. Scores for 14 individuals were plotted. The consistent version plotted the first four scores slowly, and then plotted the rest rapidly. The inconsistent version plotted all 14 scores at constant moderate speed. According to the guideline, the constant, slow rate of plotting, should be unnecessary for a large number of points.

Ranking results. No difference between the two versions was found. Mean rankings were 1.52 and 1.48 for the consistent and inconsistent versions respectively.

Acceptance ratings. The numbers of subjects who found the versions unacceptable were: Consistent - 1; Inconsistent - 2.

Comments. Comments made by the subjects are presented in Table 37.

Table 37
Comments for Tutorial III.9.

Support Guideline		Do Not Support Guideline	
" you get the idea after a few moves"	6	" the points are moving too fast at the end"	7
" would not have to go through with the whole thing"	5	" the other version is slower and easier to follow"	8
" plotting every point is tedious, boring and annoying"	4	" have more time to process the information when the animation is slow"	3
" it takes too long and it's a waste of time"	3		

Discussion. The guideline of using an adaptable presentation rate to present repetitive information was not validated. It is possible that subjects were not familiar with graphing tabular data on a chart. Therefore, graphing every point had helped them understand the graphing process. In addition, because subjects viewed the animation only one time and there were only a few points, the repetition was not annoying. It is recommended that this guideline be re-tested by exposing the subjects to more examples with a larger number of data points.

Experiment 2 Discussion

When the guidelines were examined as a set, there was strong support for the guideline consistent animations versus the guideline inconsistent animations. Preference ranking results, sign test of the direction of rankings, acceptance ratings, and comments all supported the general use of the guidelines. In addition, Experiment 1 showed that using animations that did not follow the guidelines actually degraded performance. Therefore, this thesis shows that the guidelines can be very helpful when designing animated materials.

For individual guidelines, whether or not significant differences were obtained depends to some extent on the appropriateness of the specific example chosen, and the differences in versions chosen. However, every effort was made to develop realistic implementations and tentative conclusions about the individual guidelines have been reached. Seven of 18 guidelines resulted in a significant difference in mean rankings, five more were supported by non-significant mean rankings in the desired direction

combined with strong support from subjects' comments, three guidelines were revised based on the results obtained, and three guidelines should be re-tested with better tutorial material. The revised guidelines, based on the empirical evidence, are presented in the next section.

CHAPTER 6

Revised Animation Design Guidelines

Testing of individual guidelines provided added insights and refined understanding of the guidelines. Based on findings obtained from the study, a revised set of guidelines was developed. The revised set of guidelines is organized under four major themes.

Avoid cognitive overload.

Do not present too many concepts in one animation.

If an animation involves several concepts, do not try to describe all the concepts in a single animation. Divide the concepts into meaningful units, and illustrate each unit with an animation. Then provide an integrated summary of all the concepts at the end. In this way, learners will not be overloaded with information, yet they will be able to obtain a comprehensive view of the information.

Do not present text description and an animation at the same time.

Text materials explaining the animation should be presented before a diagram is animated. After the learner has read the text, the text description should remain on the screen during the animation. If text is presented during an animation, halt the animation to provide time to read the text. Provide controls to resume the animation.

Provide voice narration.

If possible, use a voice narration to call attention to important information during the animation. Learners can view the animation while being guided by the narration. The narration must be carefully coordinated to describe

events as they occur. Information provided in a voice narration should be accessible in written form when the animation is not being used.

Facilitate Information Extraction

Do not animate materials that are unrelated to the lesson content.

Because movements in animations can catch learners attention, animation that is irrelevant to the learning material should not be presented. Irrelevant information will require processing and attention that would otherwise be devoted to the learning task.

Keep the number of animated objects to a minimum.

When animation is used to illustrate relevant materials, only essential objects should be animated. For example, in animating the combustion/exhaustion cycle of a car engine when the car is in motion, only the movement of a single piston should be animated. Movement of the car is neither necessary nor desirable.

Provide cues to guide what to look for in the animation.

For animations which involve subtle spatial or speed changes, cues must be provided to show learners what they should look for. Cues such as text prompts or voice narration, and non-textual cues such as brief blinking or highlighting can be used. Without cues, students will look at the animation, but will not know what the animation is demonstrating. The use of cues and pacing of cues must be closely coordinated in the animation to insure that the cues are presented at the best time and that they do not interfere or disrupt the animation.

Do not use realistic, detailed objects.

Use simplified representations that emphasize important issues, rather than realistic detail, color, and movements of objects in an animation.

Animations that are realistic may require extra information processing because viewers have to differentiate what they should or should not attend to.

Provide Visual Aids that Do Not Distract

Avoid overuse of blinking.

User-initiated blinking can be useful to identify the structure or parts being illustrated. However, constant flashing or blinking that cannot be controlled by users should be avoided.

Avoid overuse of transition effects.

Simple visual transition effects can be used to indicate major changes in topic, such as changing from an animation of the human eye to the human ear. Fancy and complicated transition effects should be avoided. Visual transition effects should not be used during minor changes in topic, such as describing different layers of the human eye. In general, do not use a transition at a time when the student is concentrating on materials in the animation.

Make changes in an animation distinct.

When creating an animation, choose an example that can indicate the most distinct changes and movements. For instance, to demonstrate the relationship between force and weight, choose an example that maximizes the difference in weight between objects. This will make the changes much easier to detect. However, it is important to make sure that the animation is accurate. If the changes are still not distinctive enough, cueing can be used.

Use smooth animation.

Avoid jumpy and discrete animations. Up to a point, the smoother the animation the better. Ensure all important components of the animation are illustrated.

Place text at the same location throughout an animation.

Generally, if text descriptions are presented to guide what to look at in an animation, place all text at the same location on the screen. A constant placement of the text is especially important if the pace can not be controlled by students. In this case, learners may lose time finding the text if it appears at unpredictable locations. Placing the text at a constant location is not essential if learners have control over the animation.

Blank text area before showing new text.

When wordings used in the previous, and the new text are highly similar, and the text appears at a constant location, clear the text area for a brief period before showing the new text. Clearing the text area serves as a cue that there is a change in text. Clearing the text is not essential if the difference between the previous and the new text is distinct.

Present information in both animated and static graphic format.

Animated and static graphics provide different perspectives on the same material. In all but simple animations, it is recommended that static graphics that use conventional non-animated techniques to show components and sequences of events should also be provided.

Provide Variable Presentation Rate

Allow users to control the animation.

No single animation rate can accommodate different learning speeds. A pace that is too slow reduces continuity in the animation. A speed that is too

fast makes the animation difficult to follow. Learners should have control over the pace of viewing an animation. For long animations, easy-to-use, full control capabilities should be provided. These include stepping forward and backward one meaningful unit of information at a time, speed control, and pausing/restarting. For shorter animations, providing the capability to stop and restart the animation at any time will be sufficient.

Present repetitive information at an adaptable presentation speed.

For showing large amounts of repetitive information, a rate that is too fast is difficult to follow and a rate that is too slow can be annoying. If control of rate cannot be provided, an adaptable presentation rate should be used. Presentation of repetitive information should first occur at a slow rate to provide students time to assimilate the information. Once the concept is conveyed, the presentation of repetitive information can be faster. For small amounts of repetitive information, a constant, intermediate or slow rate for presenting a small amount of repetitive information may be used. A fast rate should not be used.

This set of guidelines is not exhaustive. These guidelines primarily address common problems found in freeware and commercially available software. An important characteristic of these guidelines is that they can all be implemented quite easily. Knowing what common problems are, and knowing how to avoid them should enable developers to produce better animated learning materials.

CHAPTER 7

General Discussion

Animation and Learning

Experiment 1 and the preliminary study used animations that followed the proposed set of guidelines. When equivalent information was conveyed in static graphics and well-designed animated graphics, the addition of animations to the static graphics did not enhance learning, and did not reduce learning time. Failure to find a positive learning effect when using animated learning visuals was also reported by A. L. Caraballo (1985), King (1975), Moore et al. (1979), Rieber et al. (1990), and Stasko et al. (1993).

Although good animations did not help learning, poor animations actually hindered learning. Experiment 1 subjects who received static graphics plus animated visuals that violated the guidelines took longer to complete the tutorial and performed less well than subjects who received static graphics alone. The guideline inconsistent animations used in this study were developed to be typical of the kinds of animations that are prevalent in the educational software market. Educators must realize the possible detrimental effects of poorly developed animations. Because it is just as difficult, and expensive to develop poor animations as it is to develop good animations, the proposed animation design guidelines can be useful to avoid common animation problems.

The finding that subjects were tolerant of poor animated materials has important implications. In Experiment 1, subjects who received the guideline inconsistent tutorial still rated the quality of the animation highly. In Experiment 2, animations that violated guidelines were usually found to be

acceptable. Students who were tolerant of poor quality animations were probably not aware of potential detrimental effects on learning. Educators responsible for evaluating computer animated learning materials for possible adoption must assess the quality of the animations. The animation design guidelines may be useful for evaluating animated computer instructional materials. Developers can use the proposed guidelines to develop and help evaluate the quality of their products.

The Roles of Animated and Static Graphics

Throughout all three experiments, animated and static graphics were found to play different roles in the process of learning. This section examines the different functions of static and animated graphics.

Information and Motivation

Animations can provide information which is difficult to provide in static graphics in a direct and accurate manner, and can increase the motivation of students. As shown in Experiment 2, animations that were informative were often found to be more enjoyable and interesting when compared to static graphics. Animations which were enjoyable, but did not provide relevant information were considered less beneficial. In general, static graphics may not convey the same information, and do not provide motivation as well as animations.

Information Synthesis and Analysis

Static and animated graphics differ in terms of the type of information they best convey. In general, the primary advantage of animations is in information synthesis, whereas, the primary advantage of static graphics is in information analysis. Animations easily convey a sequence of movements of objects over time. Animations synthesize the information by showing how

concepts and objects interact in an integrated fashion. Static graphics help learners discriminate among objects and concepts by illustrating what and where the objects are, and by breaking the animation into distinctive frames to show similarities and differences among the frames. Thus, in static graphics, the analysis process involves fragmenting information.

To give an example, static graphics are best at identifying the different components of a tire pump. In addition, static graphics illustrate the distinct states of valve movements in isolation. Learners will not achieve maximum benefit from the animation without this analytic process. Animation, on the other hand, nicely illustrates the sequences and movements involving the components in a tire pump and how they are coordinated. The animation effectively provides a synthesis of how the components interact over time and space. Since much learning involves both synthesis and analysis, animations and static graphics are complementary.

Other Functions of Static and Animated Graphics

If a series of static graphics are presented over a number of screens, they are a poor substitute for an animation. If the essential static graphics can be presented on a single screen, they provide a number of important advantages over an animation. Firstly, important components are all visible at once, while this is usually not true of animations. The learner can determine what to look at and when, rather than waiting for the animation to get to the part desired. Secondly, the static graphics can serve as cues to inform students what to look for before the animation is viewed. Thirdly, once the components are learned and the sequence understood, the static graphics serve as a convenient summary of the animation. In an animation, a summary of the key elements of an animation is not generally available. The entire animation must be viewed.

Thus, static graphics serve a preparatory and analytic function before an animation, and a review function after the animation.

Animation and Enhanced Learning

This thesis found no advantages of good quality animations over static graphics in learning. Yet, animations clearly provide information that is difficult to convey in static form. This section speculates about the conditions under which animation might enhance learning.

Firstly, animations should only enhance learning of complex movements or motions that evolve over time. None of the animations used in this thesis, and none of the animations in other studies reviewed earlier, would be considered complex. It seems likely that complex motions which are difficult to convey in text and static graphics should be easier to convey in animation. These processes will likely involve coordinating intricate spatial movements, spinning, rotation, changes in speed and orientation of a number of objects happening over time. The complexity insures that the material is difficult to visualize, and exceeds short-term memory capacities. With an animation, the complex information is directly shown. This eases the process of visualization and reduces the cognitive burden on learners. Animation of complex information should be a parsimonious and effective method to convey complex motions. Information that might take pages of text and static graphics to describe could be shown in a few seconds. Hence, using an animation to communicate complex motions should shorten learning time.

Secondly, the animation, not necessarily the concept that is being taught, must be complex. For example, concepts involved in analysis of covariance are complex. ANCOVA was chosen for studying animation because of the

difficulty students have learning the concepts. However, the animations used to illustrate the concepts are relatively simple. Therefore, it was possible to develop static graphic versions that were found to be as effective as the animated versions.

Thirdly, regardless of whether the information is complex or not, animations should be effective in conveying concepts that cannot be illustrated with text or static graphics. For example, a series of static graphics can show the basic strokes for writing Chinese characters. However, text and static graphics cannot easily show the pressure, the speed and the flow of the strokes, the brush stroke movements, and other features that might be characterized as penmanship style.

Simple animations do not enhance learning when compared to well-developed static graphics. All the research on the effect of animations on learning has used relatively simple animations. Until studies use more complex animations, we must reserve judgment on the usefulness of animations in learning.

Suggestions for Future Research

The thesis has advanced understanding of the use of animations in computer assisted instruction. However, it leaves many questions unanswered, and raises a number of questions that should be examined. The following issues should be addressed.

1. The present study did not find a positive learning effect using animations that involved relatively simple two-dimensional spatial movements. Future research should determine if learning can be enhanced with

animations that illustrate highly complex motions and changes of multiple features in two and three dimensional space.

2. There is a need to understand the cognitive activities involved when learning from animated, as opposed to static graphics. Of particular concern, it would be helpful to understand the relatively active process of creating mental images using static graphics versus the relatively passive process of learning by viewing an animation.
3. The present experiment and most other studies (A. L Caraballo, 1985; J. N. Caraballo, 1985; King, 1975; Moore et al., 1979; Stasko et al., 1993) examined the effect of learning using animated materials as a supplement to static graphics. Future studies should examine the effect on learning from animated graphics with and without access to static graphics. It would be helpful to better understand how the different functions of animated and static graphics affect learning. With a better understanding of the functions of static and animated graphics, we might understand how to effectively combine the different capabilities to improve learning.
4. This study found that students who were given animations tended to spend relatively less time on non-animated screens as compared to those who used static graphics. It is not possible to determine if learning would have improved if students had spent the same amount of time on non-animated materials as subjects in the static graphics condition. This result suggests a number of questions. Why did subjects spend less time on non-animated materials? Did the animations inaccurately convey the impression that the non-animated materials were less important, or that

the animated materials were adequate without reading the text materials? Was less time devoted to non-animated materials because the animations were more enjoyable? Would subjects in an animated condition learn more if they spent more time on the non-animated materials? Can non-animated and animated materials be better integrated to insure that adequate time is devoted to the non-animated materials?

5. Finally, the preliminary study and experiment 1 examined the effect of using animations on a one time tutorial of limited duration with an immediate test of recall. Future research should examine tutorials of longer duration with tests of retention over longer periods.

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Appendix A

Subjective questionnaire used
in the animated condition
of the preliminary study

1. How satisfied were you with this overview of ANCOVA?

Not at all							Highly
Satisfied							Satisfied
1	2	3	4	5	6		7

2. How difficult or easy was it to understand the information presented?

Very							Very
difficult							Easy
1	2	3	4	5	6		7

3. How well do you think you learned the material?

Not							Very
very well							Well
1	2	3	4	5	6		7

In this section, you will view and evaluate a number of animated graphics presented in the tutorial. On a scale of 1 to 7, please rate how **useful** you think each animated graphic was in helping you understand the material.

You may begin by pressing the RETURN key.

- 4a. having a voice narration to explain the material

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4b. movement of data from the overall frequency distribution to the group frequency distribution

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4c. successive display of scores for group 1 and group 2 to show the difference in mean scores

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4d. movement of scores to show the amount of overlap between the two groups

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4e. movement of scores from the frequency distribution graph to the graph showing the relation between reading performance and IQ

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4f. indication of how regression line for each group is obtained from the overall regression line

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4g. rotation of the regression line to indicate how reading scores are adjusted

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4h. successive display of the regression line before and after it is adjusted to show that mean reading score does not change when groups have the same mean on the covariate

Not at all							Very
Useful							Useful
1	2	3	4	5	6		7

- 4i. movement of indicator lines to show that the relative positions of scores remains the same after adjustment

Not at all Useful							Very Useful
1	2	3	4	5	6		7

- 4j. successive display of the change in variability in scores after the adjustment

Not at all Useful							Very Useful
1	2	3	4	5	6		7

- 4k. movement of scores to show how ANCOVA adjusts for differences in mean IQ (covariate) of the two groups

Not at all Useful							Very Useful
1	2	3	4	5	6		7

5. How enjoyable was it to use the tutorial?

Not at all Enjoyable							Highly Enjoyable
1	2	3	4	5	6		7

- 6a. How satisfied were you with:
quality of the animation

Not at all Satisfied							Highly Satisfied
1	2	3	4	5	6		7

- 6b. How satisfied were you with:
quality of the non-animated illustration

Not at all Satisfied							Highly Satisfied
1	2	3	4	5	6		7

- 6c. How satisfied were you with:
quality of the written description

Not at all Satisfied							Highly Satisfied
1	2	3	4	5	6		7

- 6d. How satisfied were you with:
quality of the voice narration

Not at all Satisfied							Highly Satisfied
1	2	3	4	5	6		7

- 6e. What do you think about the:
speed of moving from one screen to another screen

Much too fast				Just right			Much too slow
1	2	3	4	5	6		7

- 6f. What do you think about the:
speed of the animation

Much too fast				Just right			Much too slow
1	2	3	4	5	6		7

- 6g. What do you think about the:
length of the tutorial

Much too long				Just right			Much too short
1	2	3	4	5	6		7

- 6h. How satisfied were you with:
ease of moving through the tutorial

Not at all Satisfied							Highly Satisfied
1	2	3	4	5	6		7

7. Would you use similar tutorials on other topics in 49.540 and 49.541?

Definitely Not				Neutral			Definitely
1	2	3	4	5	6		7

Appendix B

Quiz used in
the preliminary study

Quiz

1. When the frequency distributions for the DV for two groups are highly overlapped
  - a. You are very likely to have a significant difference in ANOVA.
  - b. A significant ANCOVA is impossible.
  - >c. Mean differences are small relative to the variability in the DV.
  - d. There is less variability in the covariate
2. A good covariate is one which
  - >a. Has high correlation with the DV
  - b. Has a predicted value equal to the mean for the DV
  - c. Has a high correlation with the IV
  - d. Can be rotated.
3. Which correlation between a covariate and a DV would most reduce the overlap in adjusted scores given that the means on the covariate between the groups are equal?
  - a. .46
  - b. .00
  - >c. -.73
  - d. I have insufficient information to decide.
4. Which correlation between a covariate and a DV would not reduce the variability within groups?
  - a. .46
  - >b. .00
  - c. -.73
  - d. I have insufficient information to decide.
5. ANCOVA starts by
  - a. Fitting a regression line between the covariate and the DV for each group separately.
  - >b. Fitting a regression line between the covariate and the DV based on all the data.
  - c. Fitting a regression line between IV and DV
  - d. Adjusting the DV for the IV.
6. The adjusted DV will always have
  - a. The same slope as the DV when predicted from the covariate.
  - b. The same overlap between groups as the DV.
  - >c. A slope of 0, when predicted from the covariate.
  - d. None of the above.

7. The difference between the adjusted scores and the mean of the adjusted scores
  - >a. Is the same as the difference between the original score and the regression line.
  - b. Is the same as the difference between the original score and the mean.
  - c. Is the same as the covariate.
  - d. Cannot be determined without more information.
8. The amount of rotation of the regression line due to adjustment will be greatest when
  - a. There is small variability in the covariate.
  - b. The difference in group means is large.
  - c. The covariate and the DV have a slope of zero.
  - >d. There is a large slope for the original DV.
9. Adjustment of the means of the dependent variable due to the covariate will occur whenever
  - >a. There is a difference in the covariate means for the groups.
  - b. There is a difference in the DV means for the group.
  - c. There is a non zero slope for predicting the DV from the covariate.
  - d. There is large overlap in the groups.
10. A reduction in overlap between groups results from
  - a. Differences in the group covariate means
  - >b. A relation between the covariate and the DV.
  - c. A relation between covariate and the IV.
  - d. None of the above.
11. Assume there is a strong inverse relation between the covariate and the DV (i.e., negative correlation), but no difference in covariance means for the groups. Which of the following would be true of ANCOVA.
  - a. It shouldn't be done.
  - b. The adjusted scores will have a negative slope.
  - c. The overlap between groups will be greater in the adjusted scores than in the original scores.
  - >d. None of the above.

12. Assume there are three groups instead of two groups in the experiment. There are no group differences in the covariate means. The DV and covariate have a high correlation. Which of the following would be true of the ANCOVA.
- It shouldn't be done.
  - There will be less overlap between the groups in the adjusted scores.
  - There will be a large adjustment in the group means due to the covariate.
  - None of the above.
13. Below are four different sets of regression lines for the original DV scores for two groups. Examine each of the following and indicate which one will result in having a greater difference between the adjusted means for the two groups after the adjustment.

Appendix C

Descriptions of the 10 kinds of animations used in
the ANCOVA tutorial in Experiment 1.

1. Move data points from a single frequency distribution to separate group frequency distributions

On the left, the screen showed an overall frequency distribution of red and blue points for group 1 and 2 respectively. The animation showed all the data points for group 1 moving to a frequency graph on the right. A horizontal line indicating mean reading performance scores for group 1 was drawn. The same animation was repeated for group 2 data points. The animation then alternated the scores for group 1, and then the scores for group 2. This indicated that group 1 had a higher mean reading performance score when compared to group 2. Scores for both groups were then shown simultaneously emphasizing the amount of overlap between the two sets of scores.

2. Overlapping scores

The area of overlap on reading performance scores for the two groups was indicated in a shaded area. The animation moved one set of scores to the right, away from the other set of scores to clearly show the extent of each set of scores. The set of scores was then moved back, falling on top of the other set.

3. Plotting the relation between two variables

This animation showed how each data point from a frequency distribution graph on the left moved systematically to a scatterplot that included the correlated IQ on the right. As points were systematically plotted on the right graph, the relation between reading performance and IQ was demonstrated. Data points filled the scatterplot from the lower left (low reading performance, low IQ) to the upper right (high reading performance, high IQ).

4. Separate regression lines generated from the overall regression line

This animation showed how a single regression line was generated for individual groups. A line parallel to the overall regression line was generated. It then moved up to the mean of group 1. The regression line of group 2 moved down to the mean of group 2.

5. Rotation of the regression line

This animation showed the process of removing the effect of the covariate by rotating a regression line through the group mean to become a flat line. The data points were shown to maintain their same relative position as they rotated with the line.

6. Regression line equaled mean line

This animation toggled between the images of the regression line before and after adjustment. This illustrated that the group mean did not change with adjustment. The screens toggled between the two lines three times.

7. Relative positions of scores

Two graphs were shown on the screen. The left graph showed the positions of the scores before the adjustment. The right graph showed the positions of scores after the adjustment. Lines indicating the positions of the scores in relation to the regression line were drawn for two scores. The animation first blinked on the line of a score on the left graph, then blinked on the line for the same score on the right graph. The two lines were placed beside each other indicating that the position of the score relative to the regression line remained the same after the adjustment process. The same animation was repeated for a second score.

8. Sliding of the datasets

This animation showed how data moved along the regression line to adjust for the difference in mean scores on the covariate for the two groups.

9. Guided text prompts

This animation showed four short text prompts, appearing one at a time, beside appropriate areas of the graphs to indicate the differences between the previous example and the new example.

10. Guided blinking

This animation used blinking of important figures in a table to point out that the error term decreased after the adjustment, while the F-value increased. The blinking was presented with a short text explanation.

Appendix D

Questionnaire used
in Experiment 1

Subjective Questionnaire

1. How satisfied were you with this overview of ANCOVA?

Not at all Satisfied						Highly Satisfied
1	2	3	4	5	6	7

2. How difficult or easy was it to understand the information presented?

Very difficult						Very Easy
1	2	3	4	5	6	7

3. How well do you think you learned the material?

Not very well						Very Well
1	2	3	4	5	6	7

5. How enjoyable was it to use the tutorial?

Not at all Enjoyable						Highly Enjoyable
1	2	3	4	5	6	7

- 6a. How satisfied were you with the quality of the animation?

Not at all Satisfied						Highly Satisfied
1	2	3	4	5	6	7

- 6b. How satisfied were you with the quality of the non-animated illustration?

Not at all Satisfied						Highly Satisfied
1	2	3	4	5	6	7

- 6c. How satisfied were you with the quality of the written description?

Not at all Satisfied						Highly Satisfied
1	2	3	4	5	6	7

7. Would you use similar tutorials on other topics?

Definitely Not			Neutral			Definitely
1	2	3	4	5	6	7

Appendix E

Quiz used
in Experiment 1

1. Match the following items used in the tutorial.

— reading performance scores	a. independent variable
— teaching method	b. covariate
— IQ	c. dependent variable

2. What is the IQ score of the subject who is circled on the top graph?

3. Circle the points on the lower diagram which correspond to the points circled on the upper diagram?

4. Here are four sets of scores on a dependent variable before adjusting for the effect of IQ. These groups have equal means on the covariate. Would the ANCOVA adjustment process be made based on the regression lines shown?

Yes**No** **Yes****No** **Yes****No** **Yes****No**

5. The point circled on the left is the data for Mary Smith before adjusting for the covariate. On the right, carefully draw the data point for Mary Smith after adjusting for IQ.

6. A good covariate is one which
- has a mean equal 0.
  - has little variability.
  - has high correlation with the independent variable.
  - has high correlation with the dependent variable.
7. Other things being equal, which of the following relations between the dependent variable and the covariate will yield the most reduction in variability of scores?
- -
  -
  -
8. Which of the covariates listed in the question above will yield the least or no adjustment?
- -
  -
  -

9. ANCOVA starts by
- fitting a regression line between the covariate and the dependent variable for each group separately.
  - fitting a regression line between the covariate and the dependent variable based on all the data.
  - fitting a regression line between independent variable and dependent variable.
  - adjusting the effect of the independent variable.
10. The diagram below shows what a set of scores for one group looks like before the covariate adjustment is made. Select the diagram which shows what the scores will look like after the adjustment process.

11. For groups with or without differences on the mean covariate, the adjusted dependent variable will **always** have
- a regression line equal to the original mean line.
  - a regression line with a slope = 0
  - more variability in scores when compared to the original dependent variable.
  - both b and c.

12. For each of the following cases, indicate whether an adjustment of the means on the covariate is needed?

- will require adjustment of covariate means
 — will not require adjustment of covariate means

- will require adjustment of covariate means
 — will not require adjustment of covariate means

- will require adjustment of covariate means
 — will not require adjustment of covariate means

- will require adjustment of covariate means
 — will not require adjustment of covariate means

13. How does the result of an ANCOVA differ from the result of an ordinary ANOVA when the two groups are **equal** on the covariate mean?

- F-value increases, error decreases.
- F-value decreases, error decreases.
- F-value increases, error increases.
- F-value decreases, error increases.
- F-value increases or decreases, error decreases.
- F-value increases or decreases, error increases or decreases.
- F-value increases or decreases, error increases.

14. How does the result of an ANCOVA differ from the result of an ordinary ANOVA when the two groups are **not equal** on the covariate mean?

- F-value increases, error decreases.
- F-value decreases, error decreases.
- F-value increases, error increases.
- F-value decreases, error increases.
- F-value increases or decreases, error decreases.
- F-value increases or decreases, error increases or decreases.
- F-value increases or decreases, error increases.

15. For a through g, the diagram on the left shows the means for the **dependent variable before** the ANCOVA adjustment for two groups. On the right, draw in the corresponding **mean lines** on the dependent variable **after** adjustment for the covariate.

Means on dependent variable (D.V.)
before adjustment.

Draw in mean lines on the
D.V. after adjustment

15. Continue.....

Means on dependent variable (D.V.)
before adjustment.

Draw in mean lines on the
D.V. after adjustment

15. Continue.....

Means on dependent variable (D.V.)
before adjustment.

Draw in mean lines on the
D.V. after adjustment

Appendix F
Descriptions of tutorials
used in Experiment 2

Sample tutorial.

Topic

Writing Chinese characters.

Description

This clip was used to familiarize subjects with the ranking procedure and how to give ratings on the questionnaire. This clip explained how to write a Chinese character called "field."

Version 1: Static graphics only

This version showed the order of writing the six different strokes of the word field using six static graphics. The direction of writing a stroke was indicated using an arrow. (See Figure F-1.)

Figure F-1. Static graphics version

Version 2: Static graphics plus animation

This version used both static diagrams and an animation to show the order of writing the Chinese character. When a subject clicked on the "Show Animation" button, an animation showing the order and direction of writing the word was shown on the left side of the screen. Six static diagrams

representing the stroke order were shown on the right side of the screen. (See Figure F-2.)

Figure F-2. Static plus animated graphics version

Version 3: Animation only

This version showed the animation of how to write the Chinese character when subjects clicked on the "Show Animation" button. The static diagrams were not provided. (See Figure F-3.)

Figure F-3. Animation only version

Guideline : (I.1.) Use animation with a purpose.

Topic

Spinning axes.

Description

This tutorial clip consisted of two graphs. The animation showed data from the left graph moving to the right graph. The end result is shown in Figure F-4. diagram below. The main difference between versions 1 and 2 was the way the graphs were introduced.

Figure F-4. Final screen of the animation.

Consistent: Regular animation

In this version, axes of the left graph were shown. Then the axis labels were shown one at a time. The same technique was used for the graph on the right. The rest of the animation showed the data points on the left graph moving over and being plotted on the right graph. (See Figure F-5.)

Figure F-5. Guideline consistent version

Inconsistent: Useless animation

In this version, the axes of the left graph came spinning out from the center left of the screen. The axes got larger as they were spinning. After the graph was placed on the screen, the labels for the X and the Y axes spun into place in a similar manner. The same introduction was used for the graph on the right. The rest of the animation was identical to the consistent version. The spinning served no purpose. (See Figure F-6.)

Figure F-6. Guideline inconsistent version

Guideline : (I.2.) Animation can be affective.**Topic**

The meaning of the Chinese character - Exit.

Description

This tutorial provided a visual mnemonic for a Chinese character that means exit. The meaning of the word was introduced with a man jumping out a window to escape a fire. The shape of the man when exiting the building resembled the Chinese character for exit.

Consistent: Animated version

This version showed a man exiting the building using an animation. The initial screen consisted of the Chinese character accompanied by the word "exit." (See Figure F-7.) The viewer clicked on a "Show Animation" button to see an animation of the man jumping out of the window to exit the building. (See Figure F-8.) At the end of the animation, the shape of the man dissolved into the Chinese character for exit. There was no text for this version.

Figure F-7. Initial screen for tutorial I.2.

Figure F-8. Guideline consistent version

Inconsistent: Static version

This version used three static diagrams to show the man exiting from the building. The three diagrams fit on one screen. At the bottom of the screen, the Chinese character appeared accompanied by the word "exit." A statement describing the resemblance of the man's shape and the Chinese character was included. (See Figure F-9.)

Figure F-9. Guideline inconsistent version

Guideline (II.1.) Avoid overuse of blinking.

Topic

The structure of the human ear.

Description

This clip used blinking to identify five parts of the human ear. This tutorial contained five screens of information. Each screen highlighted and described one part of the human ear. Subjects used the left and right arrows to navigate between screens.

Static: Static version

The part of the ear that was described on a screen was shown in black while the rest of the ear was grayed out. (See Figure F-10.)

Figure F-10. Static graphics version

Consistent: Blink on demand

When a subject went to a new screen, the part of the ear being described blinked twice, and then stopped. The part of the ear was labeled on the screen. Subjects clicked on a "Show" button if they wanted to blink the part of the ear being described on the screen. (See Figure F-11.)

Figure F-11. Guideline consistent version

Inconsistent: Constant blinking

The part of the ear being described blinked constantly on the diagram. The part was not labelled. There was no animation button in this version. (See Figure F-12.)

Figure F-12. Guideline inconsistent version

Guideline : (II.2.) Avoid overuse of transition effects

Topic

The structure of the human eye.

Description

This tutorial showed the main structures of the human eye. The eye was divided into three layers: The sclera, choroid, and the retina. Functions of the individual layers and the parts that make up each layer were introduced. A sample screen for this tutorial is shown in Figure F-13.

Figure F-13. Sample screen in tutorial II.2.

Consistent: No transition effect

This version differentiated the different layers by first showing the title of a layer in bold text on the upper left hand corner of the screen. The different parts of the eye within that layer were introduced while the title remained on the corner of the screen.

Inconsistent: Fancy transition effects

This version used different transition effects to differentiate the three layers of the eye. The name of the new layer was introduced by fading out the screen to a complete black while presenting the name of the new layer in large white text in the center of the screen. Bit dissolve, checkerboard, and randomized column effects were used to introduce the three different layers.

Alternate: Simple transition effects

This version was basically the same as the inconsistent version with the exception, that the visual effect for different layers was less fancy. The same fast, visual dissolve effect was used for all three levels.

Guideline : (II.3.) Animate essential objects only

Topic

Rotation of the regression line.

Description

This clip was taken from the ANCOVA tutorial. The screen showed two graphs. One graph showed what the regression line looked like before rotation. Arrows were used to indicate the direction of rotation. The other graph showed what the regression line looked like after rotation. (See Figure F-14.) The animation showed how the regression line rotates to adjust for the effect of the covariate on the left graph.

Figure F-14. Screen snapshot from tutorial II.3

Consistent: Animate necessary objects only

For this version, after the rotation was made, the regression line was animated to move over to the right. At the end of the animation, the before-rotation and after-rotation graphs were presented. Figure F-15 shows an intermediate step with the axes in place and the data part way over.

Figure F-15. Guideline consistent version

Inconsistent: Animate unnecessary objects as well

This version was the same as the consistent version with one exception. Rather than having just the regression line move over to the graph on the right, the X and Y axes for the graph moved over with the regression line. Figure F-16 shows the axes and data part way over.

Figure F-16. Guideline inconsistent version

Guideline : (III.1.) Do not present competing kinds of information simultaneously

Topic

The mechanics of a bicycle tire pump.

Description

This tutorial illustrated and explained the mechanics of a bicycle tire pump. The clip showed the animation of the bicycle tire pump together with explanations describing the process. Throughout the animation, there were labels and pointers to the parts being described.

Consistent: Information shown in separate chunks

This version first showed a series of textual explanations of the pumping process. A static diagram of the pump and the parts being described were provided with each explanation. After the viewer had a chance to read an explanation, the air pump diagram beside the explanation animated to show what was being described. After an animation, the next explanation was

shown. The process was repeated until the whole pumping action was described. (See Figure F-17.)

Figure F-17. Guideline consistent version

Inconsistent: Too much information presented at one time

This version showed a textual explanation of the pumping process. At the same time, there was an animation of the pumping action being described.

Alternate: Animation shown with a voice narration

An alternate version with voice narration was included. This version showed the animation of the air pump with a voice narration explaining the process. The voice narrations, which were identical to the textual explanations, were given as the animation occurred. Appropriate parts of the pump were labelled during the animation. (See Figure F-18.)

Figure F-18. Alternate version

Guideline : (III.2.) Guide learners through one concept at a time in an animation.

Topic

Three characteristics of a dataset.

Description

The tutorial clip explained three changes in the characteristics of a dataset after a data adjustment was made.

Consistent: Concepts presented separately

This version presented the three changes in characteristics of the data, one at a time, after the adjustment. For each change, a description of the change was first presented. Once viewers finished reading the description, they clicked the mouse, and an animation of the data adjustment process was shown. Blinking arrows during the animation pointed to the change being described. (See Figure F-19.)

Figure F-19. Guideline consistent version

Inconsistent: Concepts presented simultaneously

This version presented all three changes in characteristics of the data on one screen using one animation. Text descriptions regarding the changes were provided all at once. Blinking arrows were used to point to the three different changes occurring during the animation. (See Figure F-20.)

Figure F-20. Guideline inconsistent version

Guideline : (III.3.) Information should be available outside the animation.

Topic

The trajectory path of a ball.

Description

This clip illustrated the trajectory paths of a ball leaving a round tube with an opening in it. Three different methods of the ball leaving the tube were shown. The three paths were presented as multiple choice items.

Static: Static version

The static version indicated the three different trajectory paths using lines and arrows in three static diagrams. (See Figure F-21.)

Figure F-21. Static graphics version

Consistent: Information available at all times

This version was a combination of the static version and the inconsistent version. The different trajectory paths were constantly indicated, while viewers had an option to see an animation of the ball moving along the path by clicking on the "Animate" buttons. (See Figure F-22.)

Figure F-22. Guideline consistent version

Inconsistent: Information available only through the animation

This version provided an "Animate" button for each choice. Viewers clicked on these buttons to see the various trajectory paths. The paths were illustrated in an animated form. No lines and arrows outlining the paths were presented. Thus, the three diagrams looked identical to one another in a static format. As the viewer animated the diagram one at a time, the associated trajectory path was shown. (See Figure F-23.)

Figure F-23 Guideline inconsistent version

Guideline : (III.4.) Embed short pauses to provide reflection time.**Topic**

Double-sided photocopying.

Description

This tutorial clip showed how to make double-sided photocopying using a simple photocopying machine. The animation demonstrated how to insert the first side of the original document into the copy machine, how to flip the copies over and put the copies back into the paper tray, and how to copy the second side of the original document onto the other side of the copies.

Static: Static version

This version took 15 representative static screens to describe the photocopying process. Addition descriptions were included to explain the diagrams and to describe the copying process. A sample screen for this version is provided in Figure F-24.

Figure F-24. Static graphics version

Consistent: Use of pauses at various logical sections of the animation

This version used an animation to illustrate the photocopying process. Throughout the animation, one second pauses were embedded within the animation. These pauses were added in logical breaks of the animation process. For example, these pauses were added after the first side of the original document was copied, after the copies were flipped, after opening the paper tray, after putting the copies in the paper tray, and after closing the paper tray, etc. A sample screen for this version is provided in Figure F-25.

Figure F-25. Guideline consistent version

Inconsistent: Do not have extra pauses embedded in the animation

This version is similar to version 2 with the exception that there were no additional pauses.

Guideline : (III.5.) Provide cues to guide what to look for in an animation.

Topic

The behavior of gas molecules.

Description

This tutorial clip showed the behavior of two types of gas molecules: oxygen and hydrogen. The molecules were confined to move within a rectangular area. As the molecules bounced against each other, the heavier oxygen molecules moved relatively slower than the lighter weight hydrogen molecules. The different behavior of the molecules tended to be obvious for experts and not for novices. Therefore, without knowing what to look for, the differences between the molecules were difficult to detect.

Consistent: Provided cues to guide what to look at

This version included an introduction that stated that the animation showed behavior of two types of gas molecules. In addition, it specifically prompted the subjects to look for the heavier molecules moving at a slow pace while the lighter-weight molecules moved at a faster pace. The viewers were then asked to click on the "Show Animation" button to see an animation of the molecules. (See Figure F-26.)

Figure F-26. Guideline consistent version

Inconsistent: No cues to guide what to look at

This version included only a statement that the animation showed different behavior of two types of gas molecules. Thus, there was no specific cues provided in this version. Viewers were then asked to click on the "Show Animation" button to see an animation of the molecules. (See Figure F-27.)

Figure F-27. Guideline inconsistent version

Guideline : (III.6.) Changes in an animation should be made distinct.

Topic

Aerodynamics of airplane wings.

Description

This clip showed how the shape of an airplane wing is designed so that air passing above the wing moves faster than air passing below the wing. It is this difference in speed of air movements which creates an uplifting force, causing the plane to lift.

Static: Static

The static version used tiny dots to represent air. The diagram showed more dots on top of the airplane wing while less dots were shown below the airplane wing. Text indicated that air above the wing moved faster than air below the wing. (See Figure F-28.)

Figure F-28. Static graphics version

Consistent: Distinct animation

This version showed an animation with the faster movement of air above the wing made distinct. The difference in movement of the air above and below the wing was obvious. (See Figure F-29.)

Figure F-29. Guideline consistent version

Inconsistent: Less distinct animation

This version was similar to version 2 with the exception that the difference in speed of the air above and below the wing was made less distinct. That is, the ratio of the speeds was not as high. The differences in speed were not as obvious as in the consistent version.

Guideline : (III.7.) Use smooth animation.

Topic

The mechanics of a bicycle tire pump.

Description

The clip showed an animation of the mechanics of a bicycle tire pump. The opening and closing of the inlet and the outlet valve, and the movement of the air were shown. Different numbers of frames were used to represent the pumping motion. Presentation time was the same for all three versions. A sample screen for this tutorial is shown in Figure F-30.

Figure F-30. Sample screen for tutorial III.7.

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PM-1 3 1/2"x4" PHOTOGRAPHIC MICROCOPY TARGET
NBS 1010a ANSI/ISO #2 EQUIVALENT

Consistent: Smooth animation

This version used 20 different frames to represent the pumping motion. Thus, the animation was very smooth when compared to the other two versions.

Inconsistent: Jagged animation

This version used 5 frames to represent the pumping motion. Although the motion was jagged, the motion can be adequately represented.

Alternate: Semi-jagged animation

This version used 7 frames to represent the pumping motion. The quality of this animation was intermediate between the smooth and the jagged versions.

Guideline : (III.8.) Use a consistent location to show text prompts.

Topic

The mechanics of a bicycle tire pump.

Description

The tutorial clip explained how a bicycle tire pump works by showing an animation of the tire pump plus showing text descriptions of the process.

Consistent: Text shown at the same position at all times

This version showed the texts describing the animation at a single location on the screen. (See Figure F-31.)

Figure F-31. Guideline consistent version

Inconsistent: Text shown at different positions on the screen

This version showed the texts describing the animation at different locations. The texts were shown at the location closest to the part of the pump being described. (See Figure F-32.)

Figure F-32. Guideline inconsistent version

Guideline : (III.9.) Present repetitive information intelligently

Topic

Plotting the relationship between two variables.

Description

This tutorial clip showed the process of plotting the relation between two variables, reading performance scores and IQ scores, onto a graph. The reading performance scores and IQ scores for 14 individuals were plotted on a graph, and the end result showed a positive relation between the two variables. The final screen of the animation is shown in Figure F-33.

Figure F-33. The final screen of the animation.

Consistent: Intelligent version

This version used an intelligent method of plotting the data on the graph. Scores for the first four individuals were animated very slowly from the numeric data onto the graph so that the subjects would understand where the data came from. After slowly plotting scores for the four individuals, the remaining scores were plotted rapidly since the process was repetitive. (See Figure F-34.)

Figure F-34. Guideline consistent version

Inconsistent: Unintelligent version

The version was similar to the intelligent version with the exception that all data points were plotted individually at a constant rate.

Guideline : (III.10.) Allow user control over the animation

Topic

The development of lightning.

Description

This tutorial clip explained how positive and negative charges are formed and eventually lead to lightning. In this tutorial clip, information was presented in separate chunks. That is, text first, then animation, then text, then animation.

Consistent: Full control

This version provided a variety of controls over the animation for viewers. The subjects could step back to the previous screen and step forward to the next screen. They could play and pause the animation at any time. The subjects could also change the playing speed to fast, medium or slow so that

they would not be forced to repeatedly click on a button to move to new screens. Figure F-35 shows the controls for this version.

Figure F-35. Guideline consistent version

Inconsistent: No control over the animation

A majority of the animations the author has seen were presented at a rather fast speed. This version was fast, and the viewer had no control over the animation. (See Figure F-36.)

Figure F-36. Guideline inconsistent version

Alternate: Stepping forward and stepping backward only

This version provided minimum control of the presentation of the animation. The animation showed the first chunk of information. Once viewers were ready to see the next chunk, they clicked on a "Step forward" button. The rest of the animation followed the same format. At anytime the viewer wanted to go back to the previously presented animation, they clicked on the "Step Back" button. This button would take the viewers back one chunk of information at a time. Figure F-37 shows the controls for this version.

Figure F-37. Alternate version

Guideline : (III.12.) Blank text area before showing new text

Topic

The four forces acting on an airplane.

Description

This clip described the four different forces that act on an airplane as an airplane flies. These four forces were drag, thrust, lift and weight.

Static: Static

This version showed the four forces and the description of all the four forces on one screen. Comparisons of all the forces were made possible. (See Figure F-38.)

Figure F-38. Static graphics version

Consistent: Blank text version

This version animated an airplane flying into the center of the screen. Each of the four forces was drawn, one at a time, and the description of each force was shown accordingly. Before showing a new description, the text of the previous force was blanked out. (See Figure F-39.)

Figure F-39. Guideline consistent version

Inconsistent: Do not blank text version

This version was the same as version 2 with the exception that the old text was replaced without blanking the previous text.

Guideline : (III.13.) Voice narration is better than text narration.

Topic

The development of thunderstorms.

Description

This tutorial clip explained the development of thunderstorms. The process of cold air lifting up warm humid air, formation of a cumulonimbus cloud, development of rain or hail were described.

Consistent: Voice narration only

This version explained the development of thunderstorms by providing synchronized voice narrations while the animation was being presented. (See Figure F-40.)

Figure F-40. Guideline consistent version

Inconsistent: Text explanation only

This version explained the development of thunderstorms by presenting written explanations, and then showing an animation. Texts and animation were shown in separate chunks of information so that subjects could first read the text, and then watch an animation. (See Figure F-41.)

Figure F-41. Guideline inconsistent version

Alternate: Voice narration plus text explanation

This version explained the development of thunderstorms by providing voice narrations together with written descriptions while the animation was presented.

Guideline : (III.14.) Representative static frames plus a demonstrative animation is better than having an animation with explanatory text.

Topic

The mechanics of a bicycle tire pump.

Description

This tutorial clip explained the mechanics of a bicycle tire pump. The animation showed the movements of the valves inside the pump, how air was drawn into the pump, and how air was pumped out through the hose.

Static: Static diagrams only

This version showed the pumping motion in six representative static diagrams. Three diagrams were presented on one screen illustrating the pumping movement when the handle was pulled up. Another three diagrams illustrated what happened when the handle was pushed down. Subjects used a left and a right arrow button to navigate between the two screens. (See Figure F-42.)

Figure F-42. Static graphics version

Consistent: Static diagrams plus an animated demonstration

This version was almost identical to version 1 with the exception that an extra "Show Animation" button was provided on each screen. An animation of repetitive pumping motion was shown when subjects clicked on the

button. No text explanation was provided for the animation. The animation was a pure demonstration of the continuous movement of the pump without interference of presenting the text. (See Figure F-43.)

Figure F-43. Guideline consistent version

Inconsistent: An animated demonstration plus an animated explanation

This version was rather different from the other two versions. In this version, a parts identification of the tire pump was presented (i.e., each part of the pump was labeled.) Two other buttons were provided. The "Explanation" button showed an animation of the pumping movement together with a text describing the process. The text and the animation were presented in separate chunks so that the text and the animation would not be presented at the same time. When a subject clicked on the "Demonstration" button, then a demonstrative animation was shown. The demonstrative animation did not have any textual explanation. (See Figure F-44.)

Figure F-44. Guideline inconsistent version

Appendix G

Sample recording sheet used
in Experiment 2

Tutorial 1

1. What differences between the versions did you notice?

2. Rank order the different versions from the one you like best, to the one you like least. If you can't tell the difference, let me know.

Rank 1: _____

Rank 2: _____

Rank 3: _____

3. Are any of the presentation methods used in the different versions unacceptable?

_____

Appendix H

Subjective Questionnaire used
in Experiment 2

						Animated Graphics	Non-animated Static Graphics
Not Enjoyable					Enjoyable		
1	2	3	4	5	6	7	-----
Not effective in illustrating information					Effective in illustrating information		
	2	3	4	5	6	7	-----
Does not guide your attention					Guides your attention		
1	2	3	4	5	6	7	-----
Not informative					Informative		
1	2	3	4	5	6	7	-----
Does not keep your interest					Keeps your interest		
1	2	3	4	5	6	7	-----
Distracting					Not Distracting		
1	2	3	4	5	6	7	-----
A lot of effort is required to understand the information					No effort is required to understand the information		
1	2	3	4	5	6	7	-----
Takes too long to present					Does not take too long to present		
1	2	3	4	5	6	7	-----
Difficult to follow					Easy to to follow		
1	2	3	4	5	6	7	-----
Annoying					Not Annoying		
1	2	3	4	5	6	7	-----

If you are given the non-animated static graphics, how essential is it to have the animated graphics as well?

Not essential
to have

1

2

3

4

5

6

Essential
to have

7

If you could choose the format of this tutorial, which format would you choose:

- (1) having non-animated static graphics is good enough
- (2) having animated graphics is good enough
- (3) have both of the above

Appendix I

Instruction used in
Experiment 2

Instruction

The purpose of this experiment is to examine how to effectively present computer-based learning materials to students. I will show you 9 short tutorials covering a variety of topics. I want you to comment on what you like and don't like about the way information is presented to you.

Now let's go through a sample tutorial to give you an idea of what you will be doing. This tutorial explains how to write chinese characters. You can see that there are 3 different versions for this tutorial. The versions differ in terms of the methods used to present the information to you.

I will show you one version at a time, and you will see how these versions differ. After you have seen all the versions, you will rank order them and to tell me which version you like best and which version you like least. You can see the different versions as many times you want before indicating your preference.

As you go through the tutorial, make any comments or suggestions you have regarding the way information is presented. If you find that the tutorial is going too fast or too slow, or if there are features you want in the tutorial, or you find anything confusing, or you have any recommendations for how things can be done better, let me know. This information will be used to develop future tutorials.

Do you have any questions? Let's see the first version of this tutorial.

After going through sample tutorial:

Now, I will show you a number of tutorials which follow the same format. For some tutorials, the differences between the versions may be very subtle, so, see if you can tell the difference. If you cannot tell the versions apart, let me know. This will only mean that the different versions are equally good or bad. For most of the tutorials, I want you pay more attention to the way information is presented to you, and I don't want you to be too concerned about learning the materials. However, there are a few tutorials to which I want you to learn and read the materials as if you were learning the information for a course. Doing this will provide us with more useful feedback which is representative of an actual learning environment. I will let you know when I need you to learn the information. Also, when you are rating the different versions, I would like you to think in terms of using this method of presentation on a regular basis, say once a week, for the rest of the term.

Do you have any questions? Let's begin.

END

0 8-1 1-9 4

FIN