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CAN DIFFERENT TYPES OF ANIMATION ENHANCE RECALL AND TRANSFER OF KNOWLEDGE? A CASE STUDY ON A COMPUTER SCIENCE SUBJECT

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Abstract
Does animation play a role in learning? Compared to static visuals, multimedia animation is considered beneficial to learning, especially when the learning material demands visual movements. The emergence of three-dimensional animated visuals has expanded the presentation mode in multimedia learning. A case study on a computer science subject was used to test the effect of animation in learning. The field of computer science, especially in operating systems concepts, uses an array of abstract concepts such as virtual memory, paging, and fragmentations to describe and explain the underlying processes. Various studies, together with our own observations, strongly indicate that students often find these concepts difficult to learn because they cannot easily be demonstrated. This study investigates the effects of animation on student understanding when studying a complex domain in computer science, that is, the subject of memory management concepts in operating systems. A multimedia learning system was developed in three different versions: static graphics, 2-D animation, and 3-D animation. Fifty-five students participated in this study and were randomly assigned to one of the three groups. All participants had little prior knowledge in this subject. After viewing a lesson, they were asked to take a test that assessed their recall and transfer of knowledge. This test was used to determine if, in fact, improved learning occurred and the version of animation that produced the better outcome. An initial analysis of the results showed no statistical difference between the scores for the three versions, which suggests that animations, by themselves, do not necessarily improve student understanding.

Keywords: animation, 3-D animation, memory management, multimedia learning

INTRODUCTION

Learning with computer-generated visualizations has become a topic of major interest in recent years. According to Mayer (2001), multimedia learning refers to learning from words and pictures and a multimedia instructional message or multimedia instructional presentation (or multimedia instruction) refers to presentation involving words and pictures and is intended to foster learning.

Research has shown that computer-based instruction and multimedia presentations enhance learning and foster positive attitudes towards instruction (Kulik et al., 1985). In accordance with Schnotz and Lowe (2008), dynamic visualizations such as animations are depictions that change continuously over time and represent a continuous flow of motion, whereas static visualizations do not show any continuous movement but present only specific states taken from such a flow of motion. Over the years, studies have been inconsistent with regard to whether animation, compared to static pictures, actually aids learning. A recent meta-analysis (Hoffler & Leutner, 2007) revealed a medium-sized overall advantage of animation over static visualizations. In contrast, in a review by Tversky, Bauer-Morrison, and Betrancourt (2002), most of the studies failed to show any advantages of animation (dynamic) compared to static visualizations. To account for this inconsistency, a consideration of when and why dynamic and static visualizations might be best suited has been recommended (Betrancourt, 2005; Schnotz & Lowe, 2008).

The present study is aimed at expanding the findings on the benefits of animated instruction in a two-dimensional (2-D) or three-dimensional (3-D) form. A theoretical framework on multimedia learning (Mayer, 2001) was used as basis for this study. Figure 1 illustrates Mayer's cognitive theory of multimedia learning.

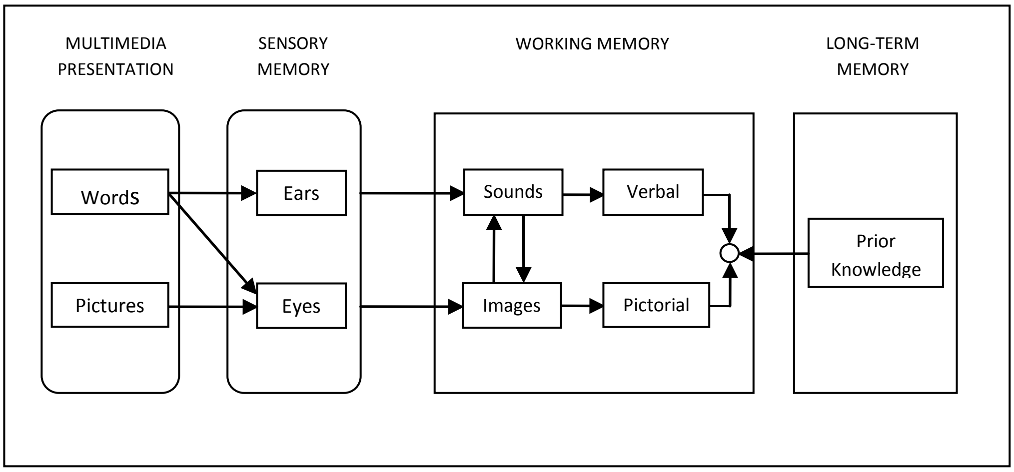

Figure 1 Visual representation of the Cognitive Theory of Multimedia Learning
Source: (Mayer 2001: 47)

This model is based on three primary assumptions. (i) Visual and auditory experiences and information are processed through separate and distinct information processing 'channels'. (ii) Each information-processing channel is limited in its ability to process experiences or information. (iii) Active processing of experiences or information in the channels is designed to construct coherent mental representations (Mayer, 2009). This theory also states that a learner has to select, organize, and integrate new information to understand the instructional material. Selecting and organizing verbal information leads to the construction of a verbal mental model, whereas the selection and organization of pictorial information results in a pictorial mental model. In order to achieve a deeper understanding of the content, learners need to integrate the information from these two mental models by building connections between them based on their structural correspondence (Mayer, 2001; Kuhl, 2011).

The subject taught in this multimedia presentation is memory management, a topic under operating systems (OS). OS is an important course in many computer science, information science, and computer engineering curricula. Some of its topics require careful and detailed explanations from the lecturer, as they often involve theoretical concepts and somewhat complex calculations that demand a certain degree of abstraction if students are to gain complete understanding (Park, & Gittleman, 1992; Maia et al., 2005).

Learning with Animation

Animated pictures are used in multimedia environments to represent the dynamic aspects of complex subject matter in an explicit way (Lowe, 2004). According to Schnotz and Rasch (2005), animations have two positive functions in learning. First, they enable learners to perform more cognitive processing (enabling function) by providing them with additional information that cannot be displayed by static pictures. Second, they help learners to build a dynamic mental representation by providing them external support for simulating the behaviour of the system depicted.

Although there is some evidence that animations have positive effects on the understanding of dynamic situations (e.g. Mayer & Anderson, 1992), research has failed to establish the systematic benefits of using animated graphics compared to static graphics (e.g. Betrancourt & Tversky, 2000; Chandler, 2009). In some cases, animations may even prejudice learning (Lowe, 2004). Lowe (2004) suggested two different types of problems to explain these negative results, that is, overwhelming and underwhelming. First, given the limited capacity of working memory, learners may not be able to meet the additional processing demands associated with animations. When learning from dynamic visualizations, they have to select relevant elements (for the purpose of the task) from a larger amount of information provided by multiple frames in a very limited time. They also have to hold in memory and integrate information distributed spatially across the display area or temporarily through the frames of the animation, which imposes a cognitive load that reduces the resources available for learning (Sangin et al., 2006; Sweller, 1994).

In Mayer's generative theory of multimedia learning (Mayer, 2001), one assumption is that humans are limited in the amount of information that can be processed in each channel (auditory/verbal or visual/pictorial) at one time. Complex illustrations enhance the cognitive load. In contrast to 2-D animations, 3-D images or simulations can relieve cognitive load. Spatial structures are better demonstrated and easier to conceive (Schanze, 2003). Another assumption of Mayer's theory interprets learning as an active process. Interactive 3-D animations encourage active learning more effectively than static figures.

In the context of this research, we wanted to determine if 3-D animation is more effective than 2-D animation. Cockburn and McKenzie (2001) compared the use of 3-D interfaces with their traditional 2-D counterpart. The study describes the comparative evaluation of two document management systems that differ only in the number of dimensions used for displaying and interacting with the data. The primary purpose of this experiment was to see if there were any differences between the 2-D and 3-D interfaces in the efficiency of storing and retrieving web page thumbnail images. In addition, they wanted to know how performance in these tasks might be affected by increasing densities of data ('clutter') within the displays. The 3-D system supports users in sorting, organizing, and retrieving 'thumbnail' representations of documents such as bookmarked webpages. Results showed that subjects were faster at storing and retrieving pages in the display when using a 2-D interface, but not significantly so. Retrieval times significantly increased as the number of thumbnails increased. Despite the lack of significant differences between the 2-D and 3-D interfaces, subjective assessments showed a significant preference for the 3-D interface.

Computer-based multimedia material offers different means of supporting 3-D information representations (Huk, 2006) Viewing dynamic and 3-D animations is assumed to be a possible way of changing and improving students' incomplete mental models (Wu & Shah, 2004). Nevertheless, various researchers (Gerjets & Scheiter, 2003; Paas et al., 2003) found that 3-D models may lead to cognitive overload problems in hypermedia learning environments in particular. The findings of Ferk et al. (2003), however, revealed that some representations of molecular 3-D structure are better understood and can be more readily used by students in solving tasks of different complexity. However, to date, empirical studies that focus on the impact of 3-D visualization on learning have been rare and inconsistent (Keller, Gerjets, Scheiter, & Garsoffky, 2004).

METHOD

A total of 56 students were randomly selected from first-year students from the Faculty of Computer and Mathematical Sciences at UiTM, Shah Alam. These students were then divided randomly into three groups [*n* = 19, 18, and 19]. However, one student was excluded from the study owing to being absent on the day of the experiment; therefore, the group was reduced to 55 students in three groups [*n* = 19, 17 and 19].

All students were in their first semester, and they had no prior knowledge of OS because computer science students take this subject during their third semester. It was assumed that the groups were homogenous in terms of age, education, and cultural background. To be certain, surveys were conducted to ascertain their prior knowledge and demographics. A similar methodology was used by Moreno (2003) to conduct research on cognitive load and student understanding. On the prior knowledge survey, the students were asked basic questions on OS and memory management. All students participating in this experiment reported either none or very little knowledge in the area of OS and memory management concepts.

In the experiment, Group 1 (G1) viewed the static graphic version accompanied by the text. Group 2 (G2) viewed the version with 2-D animation, and Group 3 (G3) viewed the 3-D animated version. The text content in all three versions was identical and in accordance with the syllabus for the subject taught (Silberschatz & Gagne, 2006).

All students were given two hours to view the multimedia learning system and answer the recall and transfer questions. This test procedure followed the conventional paradigm used to evaluate the mental model constructed during multimedia learning (Mayer & Anderson, 1992). All course materials and test questions were validated by experts from the Faculty of Computer and Mathematical Sciences, UiTM, Shah Alam. The test was divided into two parts: the recall test and transfer test. The recall test asked questions that required students to remember basic facts mentioned in the slides. The following is a sample recall question:

Example 1:

The solution to internal fragmentation is

A. *Contiguity*
B. *Compaction*
C. *Page replacement*
D. *Swapping*

The transfer test required students to solve problems based on the knowledge learned in the multimedia system. The recall test consisted of fill-in-the-blank and multiple-choice questions, whereas the transfer test had only multiple-choice questions. The transfer test required students to fully understand the calculation method and formula to solve the problem stated.

The following is a sample transfer test question.

Example 2:

Given a physical memory size of 64 bytes, page size of 8 bytes, and the page table as shown below,

Page Number	*Frame Number*
0	*1*
1	*4*
2	*3*
3	*7*

Calculate the physical address for the logical address of:
(2, 3)

A. 32
B. 27
C. 35
D. 22

A descriptive analysis was used to explain the number of students involved in this study. The first and third groups have 19 students each, and the second group has 17 students. The total number of students involved in this study was 55.

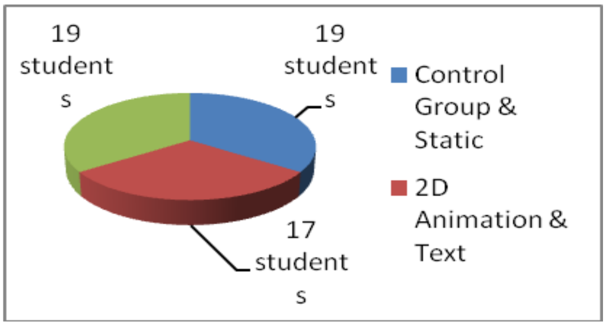

Figure 2 Pie chart showing the number of participants in each treatment group

The self-paced, multimedia-based instruction explained memory management concepts, which consisted of background on memory management, swapping technique, contiguous allocation technique, and paging technique. Students were then asked to view the multimedia instructions that were installed in each computer in the computer lab. The animation was self-paced and interactive. Students could view the animation with the play button and could rewind, pause, or stop according to their needs. After the treatment, each participant completed a test.

The version with 2-D animation and text (G2) had animation designed using Macromedia Flash, and the concepts of swapping, contiguous memory allocation, and paging techniques were explained in an animated 2-D form. For example, the use of geometric shapes and arrows showed movements of data from memory to backing store, as shown in Diagram 1. The version with 3-D animation and text (G3) had animation designed using 3D Max, and

the concepts of memory management were explained using 3-D, realistic animation. For example, the concept of contiguous memory allocation was explained using a forklift to carry large chunks of data and place them into empty memory spaces, as shown in Diagram 2.
The static graphic version (G1) had non-animated pictures that were similar to the 2-D version, and the text was the same for all the three groups.

Experimental Group	**Recall Knowledge Score Test**		**Transfer Knowledge Score Test**	
	Mean	Std. Deviation	Mean	Std. Deviation
Static & Text (G1)	67.9	16.5	30.8	15.9
2-D Animation & Text (G2)	63.5	16.2	34.4	14.3
3-D Animation & Text G(3)	69.6	16.7	35.3	20.9

Table 1 Results for the three groups

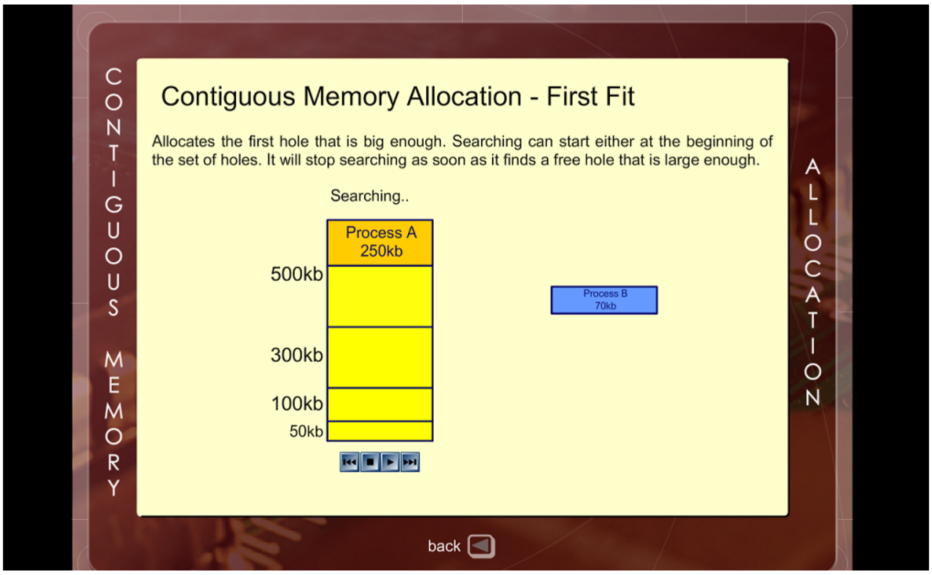

Diagram 1 Snapshots of Contiguous Memory Allocation in 2-D animation

Diagram 2 Snapshot of Contiguous Memory Allocation in 3-D animation

RESULTS

At the beginning of the analysis, the mean score for each test was calculated to give a first overview of participants' performance. Three presentation modes were chosen for analysis. Table 1 shows the summary of mean scores and standard deviations for the recall test and transfer test for each experimental group. Higher mean scores reflect better results on the recall and transfer tests. Students using 3-D animation and text performed better on the recall questions, as indicated by the mean recall test score of 69.64%. Those using 3-D animation and text also performed better on transfer knowledge questions compared to the other experimental groups, as indicated by the mean transfer test score of 35.34%. Students in all three groups performed poorly on the transfer test compared to the recall test, with the percentage in each group below 50%.

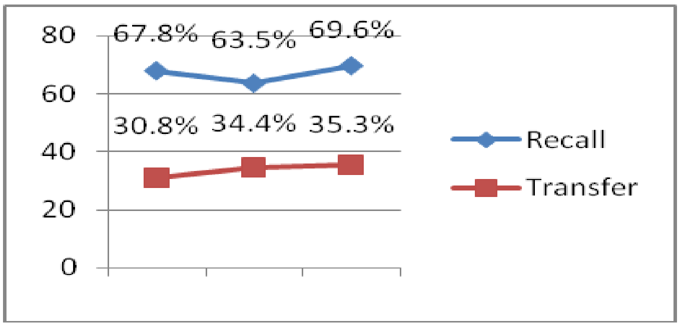

Figure 3 Line chart showing recall and transfer test results

The presentation mode was the independent variable and the recall and transfer scores were the dependent variables. Based on the ANOVA, we can conclude that the three experimental groups are significantly different in their performance on the recall test. A post-hoc analysis was conducted to determine which treatment pairs reflect significant differences in performance.

Table 2 ANOVA results

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig*
Between Groups	1678.176	2	839.088	3.091	0.045
Within Groups	14114.551	52	271.434		
Total	15792.727	54			

From the multiple comparisons test above, we can say that there was no difference in using static and text or 2-D animation and text since the p-value is equal to 0.709, which is greater than α = 0.05. Similarly, there was no significant difference when using static and text or 3-D animation and text as a medium in student learning. Both produced similar results because the p-value is equal to 0.225. However, there is a difference between 2-D animation and text and 3-D animation and text. Students in the 3-D animation and text group produced better recall test results compared to the 2-D animation and text group, with a mean difference of 13.31%.

Table 3 Multiple comparisons of the recall test

Multiple Comparisons

Dependent Variable: Recall Knowledge Score (%)
Tukey HSD

(I) Experimental Group	*(J) Experimental Group*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*	*95% Confidence Interval Lower Bound*	*95% Confidence Interval Upper Bound*
Control Group + Static	*Control Group + Static*					
	2D Animation + Text	*4.36533*	*5.50024*	*.709*	*-8.9045*	*17.6352*
	3D Animation + Text	*-8.94737*	*5.34528*	*.225*	*-21.8434*	*3.9486*
2D Animation + Text	*Control Group + Static*	*-4.36533*	*5.50024*	*.709*	*-17.6352*	*8.9045*
	2D Animation + Text					
	3D Animation + Text	*-13.31269**	*5.50024*	*.049*	*-26.5826*	*-.0428*
3D Animation + Text	*Control Group + Static*	*8.94737*	*5.34528*	*.225*	*-3.9486*	*21.8434*
	2D Animation + Text	*13.31269**	*5.50024*	*.049*	*.0428*	*26.5826*
	3D Animation + Text					

**. The mean difference is significant at the .05 level.*

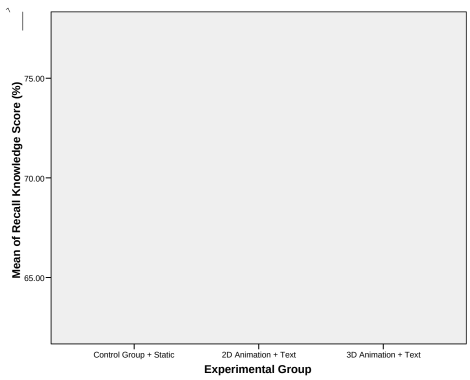

Figure 4 Main effect plot

From Figure 3, we can see that 3-D animation and text produced a higher score on the recall test, and we can recommend using 3-D animation and text as a learning process medium for a recall test.

For the transfer test, the ANOVA (Table 4) shows that there were no significant differences between the three experimental groups. Each of the experimental groups received similar results on the transfer test since the p-value is equal to 0.697, which is greater than $\alpha = 0.05$. Results shown in the ANOVA table are consistent with the multiple comparisons test in Table 5 with all p-values on the Tukey HSD greater than $\alpha = 0.05$ for the transfer test. Consequently, we can conclude that animation does not help students to improve their understanding in multimedia learning with respect to their performance on transfer or problem-solving tests. It appears at first glance, that more correct answers were achieved by group 3 (G3). Students' performance on the recall test was better than the transfer test.

Table 4 ANOVA for transfer test

	Sum of Squares	*df*	*Mean Square*	*F*	*Sig*
Between Groups	215.420	2	107.710	0.364	0.697
Within Groups	15383.838	52	295.843		
Total	15599.258	54			

Table 5 Multiple comparisons for transfer test

Multiple Comparisons

Dependent Variable: Transfer Knowledge Score (%)
Tukey HSD

(I) Experimental Group	*(J) Experimental Group*	*Mean Difference (I-J)*	*Std. Error*	*Sig.*	*95% Confidence Interval Lower Bound*	*Upper Bound*
Control Group + Static	*Control Group + Static*					
	2D Animation + Text	*-3.62671*	*5.74223*	*.803*	*-17.4804*	*10.2270*
	3D Animation + Text	*-4.51128*	*5.58045*	*.700*	*-17.9746*	*8.9521*
2D Animation + Text	*Control Group + Static*	*3.62671*	*5.74223*	*.803*	*-10.2270*	*17.4804*
	2D Animation + Text					
	3D Animation + Text	*-.88456*	*5.74223*	*.987*	*-14.7382*	*12.9691*
3D Animation + Text	*Control Group + Static*	*4.51128*	*5.58045*	*.700*	*-8.9521*	*17.9746*
	2D Animation + Text	*.88456*	*5.74223*	*.987*	*-12.9691*	*14.7382*
	3D Animation + Text					

DISCUSSION AND CONCLUSION

The fact that no difference was found for students who had learned with the assistance of animated diagrams supports the view that 'continuous animation offers no real advantage' for the effective understanding of complex computer concepts (Naps & Robling, 2002; Riaza & Halimah, 2011). It is therefore considered possible that animations in compact discs included with textbooks or on-line links to multimedia resources will not necessarily improve student understanding beyond that expected from a static diagram.

The results were in accordance with previous literature and animation-related studies. Mayer (1997) justified the effect of using coordinated presentation of explanatory material in visual format (illustrations). Wilson (1998) found a general tendency of mean scores for static treatment to reflect somewhat better results than any for the dynamic treatments. Owen (2002) found a trend for students' performance to decrease as animation strategies were added to instructional screens. Kuhl et al. (2011) observed no differences between dynamic and static conditions concerning any learning outcome measures.

We had expected that the 3-D animated version would provide better understanding, especially in recall and transfer. The total score supported the 3-D animated version (G3), but the score was not significantly higher than that for the static version (G1), with a difference of only 4.35%. Therefore, this study shows that the use of animation requires further development and quantitative evaluation to determine whether improvement in learning can be achieved with animated rather than static illustration. Kuhl et al. (2011) concluded that whether dynamic visualization leads to better learning outcomes than static visualizations may depend on the type of learning activities employed, such as retrieving static visualizations more frequently. However, in our research, the amount of time taken to view each version was not measured, and the frequency of each page view was not noted; therefore, these are some factors that need to be considered for future improvements.

One possible reason for our results could also be that the participants had no prior knowledge in this subject and therefore found it difficult to absorb some important concepts and ideas from the multimedia learning software. As a comparison to this study, further research should be carried out with students who have greater prior knowledge in this subject.

In practical terms, the results of this study raise a question for instructional designers. Is it actually worthwhile to design and develop instructions utilizing animated strategies compared to simply using static graphics if static graphics have been shown to be at least as effective as animation? It is known that static graphics are more cost effective and cost efficient than animations. In future design, it may be better to utilize static graphics as much as possible and animations only when their use is justified (Reiber, 1990).

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