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Learning with Multimedia: Effects of Different Modes of Instruction and Animation on Student Understanding

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ABSTRACT

In a series of experimental studies, this paper reports on the understanding achieved by learners when studying a complex domain in computer science, that is, the subject of memory management concepts in operating systems. Seven different multimedia instructions were used in this study to explain the subject of memory management concepts – (G1) Static and text (Control), (G2) 2-D Animation and Text, (G3) 2-D Animation and Voice, (G4) 2-D Animation and Voice and Text, (G5) 3-D Animation and text (G6) 3-D Animation and Voice, (G7) 3-D Animation and Voice and Text. The purpose of these experiments is to understand how students learn and which combination of instructions help student learn better. A total of a hundred and twenty students who had no prior knowledge on the subject were given a test on recall and transfer knowledge after viewing the treatments. An independent sample t-test, paired t-test and two-way ANOVA test was run to get the results. This paper reports the results of the experiment which may provide useful guidance for instructional designers specifically in the area of computer science.

Keywords: Visual informatics, animation, instructional design, multimedia learning, memory management concepts

ABSTRAK

Dalam satu siri eksperimentasi, pemahaman pelajar dalam pembelajaran sains komputer telah diuji. Tujuh prototaip yang mempunyai kandungan maklumat yang sama tetapi menggunakan elemen multimedia berbeza untuk pembelajaran 'konsep memori' telah di gunakan dalam kajian ini. Tujuh prototaip yang berbeza itu termasuklah: (G1) Gambar static dan teks, (G2) 2-D animasi dan teks, (G3) 2-D animasi dan suara, (G4) 2-D animasi, teks dan suara, (G5) 3-D animasi dan teks, (G6) 3-D animasi dan suara serta (G7) 3-D animasi, teks dan suara. Tujuan kajian ini dilakukan adalah untuk mengetahui kombinasi multimedia yang bagaimana lebih berkesan untuk pelajar. Untuk itu, sejumlah seratus dua puluh pelajar telah di bahagikan secara rawak kepada tujuh kumpulan untuk mempelajari subjek topic memori dan mereka di suruh ambil ujian dalam bentuk 'recall' and 'transfer'. Kertas kajian ini melaporkan keputusan eksperimentasi ini yang boleh dijadikan bahan rujukan penting bagi pereka bentuk system multimedia terutamanya dalam bidang sains komputer

Kata kunci: Informatik visual. animasi, reka bentuk sistem pembelajaran, pembelajaran multimedia, konsep memori

INTRODUCTION

Recent developments in multimedia techniques have increased the interest in the effect that different presentation modes have on learning. With a pool of elements to play with like text, pictures, audio, video and animation, which can be all brought into action, instructional designers are often tempted to 'overdo' with special effects and multiple elements when delivering multimedia instructions. As a result, the learner is bombarded with multimedia contents that are dramatic, colorful and action-packed. They have to 'form' or develop multimedia interfaces 'that best match all the resources of their target learners' (Baddeley 1986) and understand how such interfaces assist in 'forming' or developing understanding in the user. Therefore, it is important for the designers of multimedia interfaces to have a clear understanding of how information that is presented in different digital media is stored, manipulated and recalled by learners (Alty et al. 2006). Multimedia is the presentation of material using both words (printed or spoken text) and pictures (graphics, illustrations, graphics, photos, maps, animation, and video). (Mayer 2001). Multimedia will make the learning experience for students more exciting as it triggers the different senses of a human such as hearing and seeing with the various media available.

Operating Systems (OS) is an important course in many Computer Science, Information Science and Computer Engineering curricula. Some of its topics require a careful and detailed explanation from the lecturer as they often involve theoretical concepts and somewhat complex calculations, demanding a certain degree of abstraction from the students if they are to gain full understanding (Maia et. al. 2005). The traditional course model, in which the lecturer follows a text book, prepares and exhibits slides and presents some theoretical exercises, is not enough to assure a precise comprehension of what is being taught (Maia et. al. 2005). And without a practical vision the students tend to lose touch of the introduced concepts and therefore face difficulties when it comes to solving problems in tests and exams. Instructional design methods for teaching science and math receive considerable attention, but less emphasis is paid specifically to computer science education (Becker 2006). In an earlier study done by the author, an analysis on past exam results in the faculty of IT at University Technology Mara had shown that students performed the worst in the topic of memory management in the past years.

This study attempts to examine the effects of 2-Dimensional and 3-Dimensional animation with three different combinations of either text, voice or both text and voice, and the effects it has on student achievement in recall and transfer tests in understanding memory management concepts. This paper is organized in the following manner. First, a literature review discusses key findings of related research on cognitive theory of multimedia learning. This section would provide a brief description of Mayer's model on multimedia learning and recent literature on similar work conducted. This is followed by the use of animation in teaching and learning technical and conceptual subjects and finally the literature review will look at the usage of 3-Dimensional animation. The second part of the paper will look at the features and structure of the system development. This is followed by the methodology of conducting the experiments. The results are then presented and analyzed. Finally, conclusions are drawn and future work is discussed.

RELATED WORK

COGNITIVE THEORY OF MULTIMEDIA LEARNING

Mayer's cognitive theory of multimedia learning (Mayer 2001) is based on an integration of Sweller's cognitive load theory (Chandler and Sweller 1991; Sweller 1994), Pavio's dual-coding theory (Paivio 1991), and Baddeley's working memory model (Baddeley 1986). This theory claims that information should be presented in such a way that the learner's limited working memory resources are employed as efficiently as possible. This is especially the case with multimedia instruction, where learners have to integrate different information sources like text, pictures and spoken words, cognitive overload can be a serious threat to learning. The theory provides useful insights into why different combinations of media can have different effects on comprehension and learning. Mayer focuses on the auditory/verbal channel and visual pictorial channel, and he defines multimedia as the presentation of material using both words and pictures, thus the definition of multimedia is narrowed down to two forms-verbal and pictorial because the research base in cognitive psychology is most relevant to this definition (Mayer 2001). Figure1 is an illustrated explanation of Mayer's Cognitive Theory of Multimedia Learning.

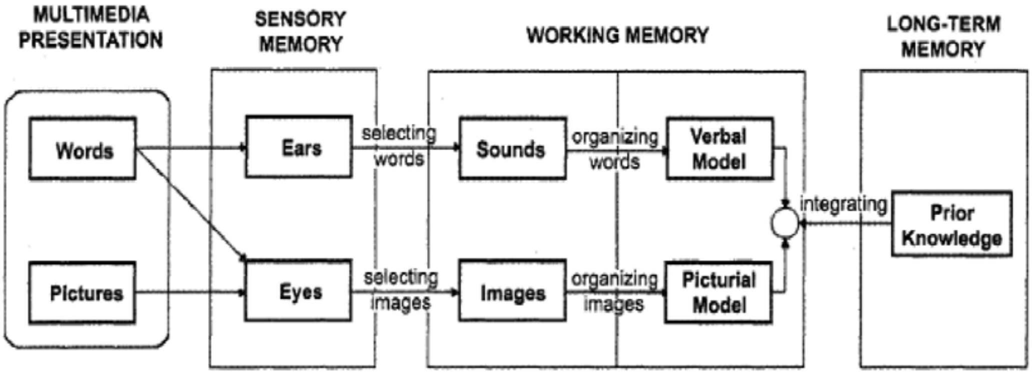

FIGURE 1. Mayer's Cognitive Theory of Multimedia Learning (Mayer 2001)

This model is based on three primary assumptions (Mayer 2001):

i. Visual and auditory experiences/information is processed through separate and distinct information processing 'channels'.
ii. Each information processing channel is limited in its ability to process experience/information.
iii. Processing experience/information in channels is an active process designed to construct coherent mental representations.

Mayer and his colleagues have conducted a decade's worth of research investigating the nature and effects of multimedia presentations on human learning. For example, the modality principle states that people learn better from graphics and narration than from graphics and on-screen text. And the redundancy principle states that learning is done better when information is presented with graphics and narration rather than from graphics, narration and on-screen text (Mayer and Moreno 2002; Mayer and Moreno 2003).

In recent years' researchers from all over the world had begun to test Mayer's theory of multimedia learning. Many domains and different approaches were used to test the theory. Alty et. al. (2006) replicated Mayer's research and the domain used was more complex domain-that of Statistics. The authors did not use animation, but a combination of text, sound, and diagram. The authors differed when using learning styles by Felder and Soloman. There were mixed results in the findings except for the modality principle, which was in line with Mayer's theory but the other principles tested were not.

In another study (Tabbers et. al. 2004), the researcher tested the generalisability of the modality and cueing effect in a classroom setting. Adding visual cues to the pictures resulted in higher retention scores, while replacing visual text with spoken text resulted in lower retention and transfer scores. Only a weak cueing effect and even a reverse modality effect have been found, indicating that both effects do not easily generalize to non-laboratory settings. A possible explanation for the reversed modality effect is that the multimedia instructions in this study were learner-paced, as opposed to the system-paced instructions used in earlier research (Tabbers et. al. 2004).

In a slightly different research (Craig et. al. 2002), animated pedagogical agents were used to study the effects of agent properties, picture features, and redundancy. Two experiments explored the integration of animated agents into multimedia environments in the context of Mayer's cognitive theory of multimedia learning. Experiment 1 was a 3 (agent properties: agent only, agent with gesture, no agent) x 3 (picture features: static pictures, sudden onset, animation) design. In experiment 2, they explored the effects of printed text, spoken narration, spoken narration with the printed text, in a multimedia environment which included an agent, to investigate effects of redundancy. The findings indicated that Agent properties produced no significant effects. Both sudden onset and animation conditions facilitated performance relative to the static-picture condition. The spoken-narration-only condition outperformed the other two, with no differences between printed text and printed text with spoken narration.

More recently (Schar and Kaiser 2006), three of Mayer's multimedia learning principles were tested out, i.e., the multimedia principle, the modality principle and the redundancy principle. They wanted to investigate if Mayer's principles apply in general for a differentiated span of learning outcomes. Forty two Swiss forth level primary school pupils (mean age was 10) were tested upon on 7 different presentation forms: (text, voice, picture, text + voice, text + picture, voice + picture, text + voice + picture). Their results did not generally contradict Mayer's principles, but rather showed that the extent to which certain media combinations support learning is a matter of how well the media (combinations) fit with the learning goals. In another related study, Dunsworth (2005) entailed 3 levels of presentation mode(on-screen text, narration, narration+agent). The findings support the modality effect but did not support reported embodied agent effect or image effect since the visual presence of the animated agent was detrimental to learning.

In this paper, the modality and redundancy principle are tested along with the use of 2D and 3D animations. An instruction using static pictures and text was used as the control group.

Use of Animation

One of the frequently used features in computer-based multimedia learning environments is animation. Any elements on a computer screen can be animated, but the most frequent use of animation concerns animated pictures. Animated pictures can be used to support 3-D perception by showing an object from varying perspectives. They can be used to direct the observer's attention to important (and unimportant) aspects of a display, convey procedural knowledge (e.g., in software training), demonstrate the dynamics of a subject matter, and allow exploratory learning through manipulating a displayed object. Furthermore, they can have a supplantative effect (Salomon 1994), when they help learners to perform a cognitive process process that they could not otherwise perform without this external support. Despite a widespread belief that animation is a powerful instructional device, however, it is still an open question under which conditions animated pictures really enhance comprehension and learning (Betrancourt and Tversky 2000).

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

In addition, several other experimental studies conducted after 2000 included at least one animation treatment. Some reported significant effects for the animation treatment under certain circumstances (Blankenship and Dansereau 2000; Catrambone and Seay 2002), while others reported insignificant effects for the animation treatment (Chanlin 2001; Koroghlanian and Klein 2004; Lowe 2004). Chanlin (2001b) even reported that for novice students, the use of static graphics was better than animation in procedural learning.

English and Rainwater (2006) studied the instructional effectiveness of using animations to teach 32 learning objectives in an undergraduate operating systems course. Statistical analysis using a paired t-test indicated inclusion of animations in an undergraduate operating systems course yielded significant overall student achievement gains as measured by pretest and posttest scores. Many instructors in computer science today are reluctant to design and include animation and visualizations as teaching tools due to time constraints and doubts about their benefits.

3-Dimensional Animation

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 dimensional animations, three dimensional 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 three dimensional animations encourage active learning better than static figures.

In the context of our research, we wondered if a 3-D animation is any better than 2-D animation. In a recent study conducted by Schanze (2003) which focused on students in the first two years of chemistry instruction (15 to 16- year old students in German grammar schools) investigated weather the use of 3-D simulations lead to a better understanding of chemical structures than conventional 2-D figures. Schanze's results indicate that chemistry beginners can profit from computer-based 3-D simulations which led to better understanding of chemical structures than 2-D figures (Schanze 2003).

In another study on comparing 2D and 3D display (Tavanti and Lind 2001), this time on learning the place of an object, the results showed that a realistic 3D display better supports a specific special memory task and an increase in performance compared to the 2D version. A more recent study on the comparison between 2-D and 3-D animation (Hao-Chuan et al. 2007), a medium effect size was observed in favor of the 3D group in terms of practical significance. It is rather inconclusive whether 3D animation and features bring students additional learning benefits (Hao-Chuan et. al. 2007).

Creating 3D animation is intended to provide cues that naturally cognition and action in contrast with its 2D counterpart. There is however, a general lack of comparable experimental results on the superiority of 3D in relation to 2D animation. This study investigates if the use of 3D animation is better than 2D or static pictures in student understanding in recall and transfer tests for a computer science subject.

Methodology

A total of one hundred and twenty students were randomly selected from the student list that registered at Faculty of Information Technology and Computer Sciences, UiTM Shah Alam. All of them were in their first semester and they had no prior knowledge in the subject of operating systems. If they have knowledge or had been studied of operating systems and memory management concepts, they are definitely eliminated from this study. To be certain, a prior knowledge survey and demographic survey questions were filled out by these participants and they had either none or very little knowledge in the area of operating systems and memory management concepts. All the participants were homogenous and had similar backgrounds in terms of age, race, religion and education. These students were divided randomly into seven groups of treatment.

The self-paced multimedia-based instruction explains on the memory management concepts which consist of background on memory management, swapping technique, contiguous allocation technique and paging technique. To guarantee the optimal design of the external graphical representations, Mayer's recommendations were taken into account (Mayer 2001). He states that the graphical representations should have a potentially meaningful structure (a cause-effect relationship, interdependencies or hierarchies) and depict the different states of the complex structure. Special care was taken when representing the animations in the body of knowledge (such as the use of boxes, trucks and racks, colors, et cetera).

The multimedia instruction designed was aimed to produce animations that would complement existing lecture and textbook materials (Stallings 2004), and improve student understanding, of a complex operating systems concept. Over a period of months, the instructions were designed after a number of consultations with subject matter experts on the storyboard, design implementation and development of the animation.

The entire system was developed using Macromedia Flash MX 2004™. In the design of 3-D animation, the use of 3DMax application was used. The syllabus was taken from textbook used this course in the faculty (Silberschatz et. al. 2006). In order for students to relate to the animation shown, a constructivist approach was used throughout the development. Constructivism is where each individual learner combines new information with existing knowledge and experiences (Jonassen 1999). At the beginning of the slides shown, students were shown a cinema sitting. They were told that each sitting in a cinema is mutually exclusive and no two persons will have to share a seat. The same concept is applied in memory management, where each data is given a specific address. The concept of cinema sitting is then repeated in a few slides for recall purposes and was shown in all the seven versions (G1- G7). The usage of a truck is used to carry data into a large rack as seen in Figure 3 This concept is used so that students can relate the usage of a truck in a store at a hypermarket to store supplies with the same idea related to contiguous memory allocation in a CPU. The usage of the truck is shown in the 3D animated version (G5, G6 and G7) only. The animations show, step by step, the build up of the representations incorporated in the printed materials. The students controlled the speed of the animations by clicking on the continue button on the screen.

All students were given 2 hours to view the multimedia learning system and then they need to answer the recall and transfer questions within that hour. Participants were given a headset to prevent any disturbance in the lab. The est was divided into two parts, which are, the recall test and transfer test. Recall test asked questions which required them to recall or remember some basic facts mentioned in the slides. A sample recall test asked in this study is:-

Example 1:

The solution to internal fragmentation is

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

The transfer test required them to solve some problems based on the knowledge learned in the multimedia system. The recall test had some fill in the blanks and multiple choice questions whereas, the transfer test had only multiple choice questions. The recall and transfer score were converted into percentage for each test, separately.

A sample transfer test question asked in this study is:-

Example 2:

Given a physical memory size is 64 bytes; page size is 8 bytes and the page table as below;

TABLE 1. Summary of Mean Score Test

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

Calculate the physical address for the logical address of:

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

The transfer test above required the students to really understand the calculation method and formula to solve the problem stated.

TABLE 2. The group and mode of instruction

GROUP	MODES OF INSTRUCTION
Group 1 (G1)	Static and text (control)
Group 2 (G2)	2-D Animation and text
Group 3 (G3)	2-D Animation and voice
Group 4 (G4)	2-D Animation and text and voice
Group 5 (G5)	3-D Animation and text
Group 6 (G6)	3-D Animation and voice
Group 7 (G7)	3-D Animation and text and voice

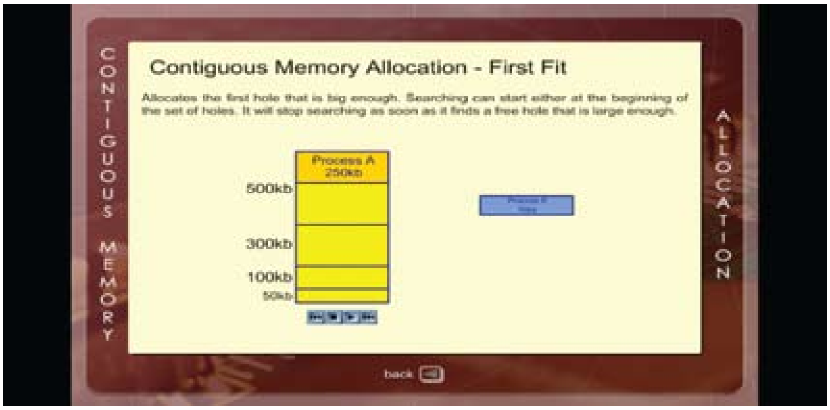

FIGURE 2. Screen snapshot showing 2-D animation, text and voice (G4)

FIGURE 3. Screen snapshot 3-D animation and voice (G6)

RESULTS

Seven different presentation modes were chosen for analysis. The presentation mode was the independent variable and the recall and transfer score were the dependent variables. An independent sample t-test used to evaluate the differences in means between two groups. Paired t-test used to determine whether the means tests of paired samples are equal.

At the beginning of the analysis, the mean score for each test was calculated to give a first overview to the participant's performance. Table 1 shows the summary of mean score for recall test and transfer test for each group. The higher the mean score test, it will give a better result on recall and transfer test. The participants gave a higher score on the recall questions by using 3D Animation & Text. But when they are answering transfer knowledge questions, 2D Animation & Text & Voice will give a better results compare with the other experimental groups. Unfortunately, the percentage of transfer score test is much lower compared to recall test since the percentage is below 50% for all treatment groups.

A paired t-test was used to compare the difference in means. Based on the paired t-test result on the Table 3, there is a significant difference for recall knowledge scores and transfer knowledge scores for the students since the p-value = 0.000. The students got a higher score on recall knowledge question (64.3%) compared to transfer knowledge question (34.6%).

TABLE 3. Paired sample t-test on Recall and Transfer Test

Test	Mean	Std. Deviation	N	t-value	p-value
Recall Knowledge Scores	64.3333	18.5497	120	13.420	0.000
Transfer Knowledge Scores	34.6429	18.0191	120		

Two-way ANOVA, also called two factors ANOVA, determines how a response is affected by two factors. In this objective we are interested to measure a response (recall score test / transfer score test) to three different narrations (text, voice, combination) in both 2D and 3D animation. In this analysis, we did not included group 1 since we were only interested in studying the effect of Dimension and Type/Narration. Based on Table 4, a two-way ANOVA result on the recall score test was conducted, we can conclude that Type/Narration is the only factor that may effected on the recall test since the p-value is less than α=0.05. ANOVA can tell us only "at least one pair of the treatment means is different" but which particular pairs are different is not specified. So, we proceed to conduct multiple comparisons test to find out which pairs are significantly different. From the multiple comparisons on Table 5, we can say that there is no difference when we using Text or Voice as a medium in student learning process, both will give the same result. But when comparing Text and combination of Text and Voice, there is a significant difference on the recall knowledge score test where Text will give a better result on student's recall test in the learning process. The mean difference between Text and Both is 17.6%. Same result where, there is a significant difference on the recall knowledge score test where Voice will give a better effect on student's recall test in learning process. The mean difference between Voice and Both is 14.47%. From the graph, we can see that Text will give a higher score on the recall test for the students. Or we can recommend using Text as a medium in learning process for recall test.

TABLE 4. Two-way ANOVA for Recall Test

Dependent Variable Recall Knowledge Score (%)

Source	Sum of Squares	df	Mean Square	F	Sig
dimension	463.241	1	463.241	1.567	.214
type	5872.092	2	2936.046	9.929	.000
dimansion* type	1059.861	2	529.930	1.792	.172
Error	28090.642	95	295.691		
Total	35744.554	100			

TABLE 5. Multiple Comparisons Test

Dependent Variable Recall Knowledge Score (%)
Turkey HSD

(I) type	(J) type	Mean Difference (I-J)	Std. Error	Sig	95% Confidence Interval	
					Lower Bound	Upper Bound
Text	Voice	3.1362	4.21332	.738	-6.8957	13.1681
	Text + Voice	17.6144*	4.11223	.000	7.8232	27.4056
Voice	Text	-3.1362	4.21332	.738	-13.1681	6.8957
	Text + Voice	14.4782*	4.27027	.003	4.3107	24.6457
Text + Voice	Text Voice	-17.6144*	4.11223	.000	-27.4056	-7.8232
		-14.4782*	4.27027	.003	-24.6457	-4.3107

Same approach was conducted for transfer knowledge score. Unfortunately, Dimension, Type/Narration and Interaction effect do not give impact on the transfer knowledge score test since all the p-value is greater than α=0.05 (See Table 6). Since no factor is significantly difference on the transfer knowledge score test, no need to proceed with multiple comparisons test and interaction plot.

To test if there is a significant difference in recall score test or transfer score test in the modality principle for the 2D and 3D animation, independent sample t-test is used. Table 7 shows the summary of independent sample t-test. Independent sample t-test used to evaluate the differences in means between two groups. Based on result, conclude that there is no significant difference on the student recall and transfer score in the modality principle both for 2D and 3D groups for students since all the p-value is greater than α=0.05.

Table 8 shows the summary of independent sample t-test for redundancy principle. For redundancy principle, there is a significant difference in recall test for both 2D and 3D groups since the p-value is less than α=0.05. But for transfer test, there is no significant difference in the redundancy principle for both 2D and 3D groups. For 2D group, 2D & Voice will give a better result on recall score compared with 2D & Text & Voice with the mean difference 13.889%. Same result found for 3D group where Voice give a better result compare with Text & Voice with the mean difference 15.192%.

With respect to computer based (multimedia) learning materials the condition where animations are enriched with audio should, according to the modality principle, lead to higher performance than the condition where the animation is enriched with screen text. The descriptive results in the transfer scores do not support this, though none of the differences found are significant.

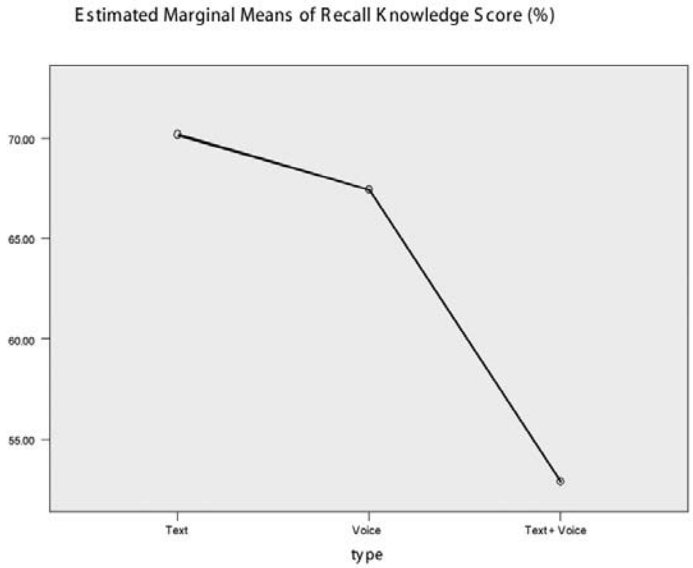

FIGURE 4. Main effect plot of Type/Narration on Recall Knowledge Score

TABLE 6. Two-way ANOVA for Transfer Test

Dependent Variable: Transfer Knowledge Score (%)

Source	Sum of Squares	df	Mean Square	F	Sig
dimension	350.526	1	350.526	1.023	.314
type	117.953	2	58.976	.172	.842
dimansion* type	707.223	2	353.612	1.032	.360
Error	32545.744	95	342.587		
Total	33711.861	100			

TABLE 7. Summary table of Independent sample t-test on Modality Principle

Comparing two-groups		Score Test	t-test	Mean Difference	Sig. (2-tailed)
No Prior Knowledge					
2D Animation & Text	2D Animation & Voice	Recall	- 0.617	- 3.693	0.542
2D Animation & Text	2D Animation & Voice	Transfer	- 0.497	- 2.848	0.622
3D Animation & Text	3D Animation & Voice	Recall	1.534	9.149	0.136
3D Animation & Text	3D Animation & Voice	Transfer	- 0.134	- 0.925	0.894

TABLE 8. Summary table of Independent sample t-test for Redundancy Principle

Comparing two-groups		Score Test	t-test	Mean Difference	Sig. (2-tailed)
No Prior Knowledge					
2D Animation & Voice	2D Animation & Text & Voicez	Recall	2.300	13.889	0.028
2D Animation & Voice	2D Animation & Text & Voice	Transfer	- 0.366	- 2.381	0.716
3D Animation & Voice	3D Animation & Text & Voice	Recall	2.405	15.192	0.023
3D Animation & Voice	3D Animation & Text & Voice	Transfer	1.140	7.692	0.264

DISCUSSION AND CONCLUSION

Results stated above indicate that the Cognitive Theory of Multimedia Design does not necessarily apply to different domains as well. The domain used in this study was that of a topic in operating systems which required students to understand some complex concepts and calculation. From this study, we can conclude that 2D or 3D animation does not give significant impact on the student's performance on computer science subject. Modality principle concept stated that student will learn better from graphics and narration than graphics and on-screen text also failed to support both for recall and transfer test, 2D and 3D animation. But, for redundancy principle, graphics and narration gives a better result for recall test result both for 2D and 3D animation. This finding is consistent with the redundancy and modality principle by Mayer (Mayer 2001)in the recall scores only. Nevertheless, the superiority of the modality principle is questioned when said that words are processed better auditory rather than visually (Penny 1989). In the findings above, the recall score was highest for the group that viewed the 3-D animated and text version(G5). However, the groups that viewed the G3 and G6 scored fairly well compared to the remaining four groups.

Another study was carried out recently by the author (Riaza and Halimah 2008) which reported similar results. The study which had a smaller group of students reported better performance in recall scores when animation and narration was used, which is consistent with the modality principle.

The redundancy theory for the recall test scores extends the demonstration of the redundancy effects in learning (Mayer and Moreno 2003). Groups from G4 and G7 had performed poorly in the recall questions. This is because learners perform better when presented with animation and narration instead of animation and narration combined printed text when the printed text matches the narration (Mayer 2001).

The lack of improvement for students in the transfer test who had learned with the assistance of animated diagrams compared to just static pictures in the experiment above supports the view that 'continuous animation offers no real advantage' to achieve more effective student understanding of complex computer concepts (Naps et. al. 2002). It is therefore considered possible that CD animations included with textbooks, or on-line links to multimedia resources, will not necessarily improve student understanding above that expected from a static diagram.

The results were in accordance with many previous literature and animation-related studies. Mayer (1997) justified the effect of using coordinated presentation of explanation in visual format (illustrations). Wilson (1998) found a general tendency of the mean score for the static treatment produce somewhat better results than any of the dynamic treatments. Owen (2002) found a trend that the students' performance decreased as animation strategies were added to the instructional screens.

It was expected that the 3-D animated version will provide a better understanding especially in the transfer test. The total score was in favor of the 3-D animated and text version (G6) but the score difference was not significant to the static version (G1). This study therefore shows that the usage of animation requires more development and quantitative evaluation to determine if an improvement in learning can be achieved over a static diagram. A possibility of the results outcome could also be because 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.

Motivation could have also played a role in the poor results especially in the transfer test. The students knew that the test results would not affect their GPA for that semester, so they did not have to try so hard to achieve good marks in the given test.

The quality of the animation could also be questioned on why the use of 2-D and 3-D animation did not have a significant impact on the test scores (particularly the transfer test). Much time and effort was invested in the design of the animation and the graphics used in the 2-D version can be considered to be typical for those found in the textbook (Silberschatz et al. 2006). However, the animation used for 3-D representation was entirely the idea of the author which had incorporated a constructivist approach and used items such as trucks, excavators, racks and boxes (to depict the idea of arranging boxes in a warehouse to the likes of the operating system arranging data to the respective addresses in memory).

Time on task is an important factor in a lot of researches and analyses. This research had, as said in the methodology section, a two hour limit; students could work as long as they wanted on their material and tests within that time. However, the exact time taken was not included in this research, but will be taken into account in future research.

Practically, results of the study has raised some questions to the practice of instructional designer, is it really worth it to design and develop instructions utilizing animated strategies versus 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, maybe it is better to utilize static graphics as much as possible and use animations only when the use of animation is justified (Reiber 1990).

Nevertheless, results of the present study suggest that developers of learning materials pay attention to 'abundant supply' as a central quality of the representations (Westelinck et al. 2005). The developers could design the learning materials in such a way that students could pick and choose whichever mode of instruction they want to view or they could ask students to develop representations themselves.

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