Malaysian Journal of Educational Technology
Volume 10, Number 2, December 2010

Effects of Segmented Animation among Students of Different Anxiety Levels: A Cognitive Load Perspective

Soon Fook Fong & Lee Pei Lin Lily
School of Educational Studies, Universiti Sains Malaysia, Penang, MALAYSIA

Abstract

This study aimed to investigate effects of segmented animation on the procedural knowledge of the meiotic cell division among students of different anxiety levels. The computer-assisted instructional multimedia was developed in three different modes: text plus static graphics (TGS), text plus animated graphics (TGA) and text plus segmented animated graphics (TGAB). These presentation modes acted as independent variables, while the dependent variable was the students' post-test score in the category of concept learning and problem-solving. The moderator variable was the trait anxiety levels of the students. The study sample comprised of 250 Form Four students from three secondary schools. Analyses of t-tests and ANCOVA were carried out to examine the effects of the independent variables on the dependent variable. Students in TGAB group performed significantly better, which suggested that viewing a segmented animation could reduce excessive cognitive load and so yield better learning. High anxiety students in the TGAB group performed significantly better than those in the TGA and TGS groups. Segmented animation seemingly decreases the anxiety of students to an optimum level, hence enhancing their information processing abilities resulting in better learning.

Fong, S.F. & Lily, L.P.L. (2010). Effects of Segmented Animation among Students of Different Anxiety Levels: A Cognitive Load Perspective. *Malaysian Journal of Educational Technology, 10*(2), pp. 91-100.

Learning from Visual Presentation

It is customary to use languages, represented by words either as printed text or narration, to communicate instructional information to students. In fact, words can only convey limited information, especially if the subject matter to be explained is abstract and dynamic. Most studies have confirmed the supportive function of static visual presentations (e.g., Levie & Lentz, 1982; Levin et al, 1987; Levin & Lesgold, 1978), as well as dynamic visual presentations on learning (e.g., Catrambone & Seay, 2002; Large et al, 1996; Park & Gittelman, 1992; Rieber, 1990; Thompson & Riding, 1990). These positive findings correspond to what Clark and Mayer (2008) called the "multimedia effect": the combination of words and illustrations results in better learning rather than words alone. The positive effect of visual presentation is generally explained by mental model theories (Bétrancourt et al, 2008). Visual presentation could offer an external representation and so facilitates the construction of corresponding mental model (Mayer, 1989). Mayer's (2001) cognitive theory of multimedia learning suggested that adding relevant visualizations to words enable learners to construct both pictorial and verbal mental representations, subsequently building meaningful connection between them and their existing knowledge. Moreover, visual presentations would free up some working memory resources for deeper cognitive processing (Bétrancourt, et al., 2008), thereby fostering meaningful learning. On the contrary, presenting words alone to describe a material content is sufficient only to promote shallow learning, as it does not establish links between the words and other knowledge (Clark & Mayer, 2008).

Static visual presentations have been widely used in educational settings. Based upon research evidences, static visual presentations could facilitate adults (Alesandrini, 1984) and children (Pressley, 1988) in learning. Levin and his associates (Levin et al, 1987; Levin & Lesgold, 1978) and Levie and Lentz (1982) found that static visual presentations help students better understand a newly-learnt material content from a given text. Mayer and Gallini (1990) revealed that using a static visual presentation to explain how scientific devices work can help students recall conceptual information and extend into problem-solving transfer. The positive effect of static visual presentations is most pronounced for abstract subject matter (Moore & Skinner, 1985). With the help of appropriate motion cues such as arrows and path lines, static visual presentations enable learners to imagine the underlying concepts described in the text (Scallert, 1980). Moreover, viewing a static visual presentation can help learners to infer the changes within a to-be-explained process and so construct a "mental animation" (Hegarty et al, 2003). However, understanding a static visual presentation may impose heavy cognitive load as learners have to make inferences from static displays while trying to construct a corresponding mental representation (Bétrancourt, et al., 2008).

Since the last two decades, spurred by rapid computer technology advances, the use of dynamic visual presentations, particularly animations, in education settings becomes commonplace. Numerous research studies reported that animations are beneficial to learning (e.g., Catrambone & Seay, 2002; Large et al, 1996; Park & Gittelman, 1992; Rieber, 1990; Thompson & Riding, 1990). However, many of these so-called successful applications of animation turned out to be a consequence of incomparable content in animations and static displays (Tversky et al, 2002). Since animations are likely to present more detailed information, any benefits of animation may be due to the additional information rather than the presentation mode – dynamic or static (Tversky et al, 2002). Graphic designers are inconclusive concerning the advantages of animation over static graphics in learning (Boucheix & Schneider, 2009; Hegarty et al, 2003; Lewalter, 2003; Mayer et al, 1989). These contradictory results imply that animations are not necessarily more effective, but sometimes even detrimental to learning.

Park and Hopkins (1993) highlighted the potential of animation "as a visual analogy or reasoning anchor for understanding abstract and symbolic concepts or processes". Given two perceptual attributes of animation – motion and trajectory (Klein, 1987), animation offers learners the most precise external representation (Rieber, 1990), helping them to elaborate "runnable mental model" (Mayer, 1989), resulting in better comprehension. Rieber (1990) suggested that animation could help learners to better retain, retrieve and apply the learning outcomes into problem-solving context. On the contrary, Hegarty (2004) argued that viewing an animation "does not necessarily lead to an accurate internal representation of the event". Some learners, particularly novices, may not be able to extract thematically important information from an animation, thereby constructing deficient mental representations (Lowe, 1999). Some may even perceive the animation features literally, such as interpreting colors and shapes as the actual reality of represented elements (Falvo, 2008), which in turn, results in misinterpretations. Nevertheless, animation still offers a more effective way of learning because it could reduce cognitive demands and so increases information-processing abilities (Rieber & Kini, 1991), rather than having to mentally infer from static display which imposes heavy cognitive load.

Based upon a meta-analysis conducted by Hoffler and Leutner (2007), the pooled effect size was found to be favoring animations over static displays. That is, learning from animation is more effective than learning from static displays. However, given the human cognitive system limitation, learners may not be able to process the visually changing information presented in an animation (Bétrancourt et al, 2008). This is particularly problematic if learners are inexperienced or with low prior knowledge (Mayer, 2005). Understanding an animation may be cognitively too demanding, as it could overload learners with vast content and rapid changes (Hoffler & Leutner, 2007). Mayer (2005) called this situation "essential overload": both auditory/verbal and visual/pictorial channel are overloaded by essential processing demands. More specifically, learners may not have sufficient cognitive capacities to make sense of the presented material, and so full comprehension may be unachievable (Mayer, 2001; Mayer & Moreno, 2003). Accordingly, several researchers suggested that animation presented in segments could facilitate better learning (Clark & Mayer, 2008; Fong, 2000; Mayer, 2005; Mayer & Chandler, 2001; Mayer & Moreno, 2003).

Segmenting Principle

Animation could promote better learning if it is aligned with human cognitive architecture (Bétrancourt et al, 2008). Breaking a continuous animation into segments, for example, which allows people to learn chunk by chunk, may be better fit their cognitive capabilities. The distinct function of segmenting techniques is supported by the cognitive theory of multimedia learning (Mayer, 2001). There are three assumptions serve as the foundation for this theory: dual channel assumption, limited capacity assumption and active processing assumption. Mayer assumes that human possess two separate cognitive channels: an auditory/verbal channel for processing auditory input and verbal representations; a visual/pictorial channel for processing visual input and pictorial representations (Mayer & Moreno, 2003). Each channel can only cognitively process a finite amount of information at any one time. To generate meaningful learning, a substantial amount of cognitive processes should take place in both channels and

the processes refer to selecting relevant words and images, mentally organizing words and images into logical mental constructs, and integrating new information with existing knowledge (Mayer, 2001).
Extensive examination of segmentation and its effects on learning was undertaken by Mayer and Chandler, (2001) and Mayer et al (2003). Drawing upon these studies, Mayer (2005) reported a large positive effect size, with a medium of 0.98. The results implied that learners who study segmented animation were better able to comprehend the material content and accordingly extend the learning outcomes into problem-solving application. Spanjers e al (2010) thought it possible that breaking a continuous animation into segments could help learners to fully elaborate the structures underlying the material content. Mayer (2005) took a step further and contended that the pause between each segment yields extra time for necessary cognitive processes that refer to Mayer's (2001) selecting-organizing-integrating processes. This eventually will help learners to construct meaningful mental model and promotes full understanding of the presented material. In short, segmented animation could prevent learners from overusing working memory resources, optimizing their information-processing capabilities, hence resulting in better learning (Moreno, 2007).

Anxiety and Academic Achievement

Within anxiety research, the commonly cited definition of anxiety comes from Spielberger (1966), who formulated a conceptual framework of trait-state anxiety. Trait anxiety (A-trait) is concerned with the relatively stable personality characteristic of an individual that pertaining to the tendency to be anxious. A-trait level does not vary within an individual, but across different individuals (Poborskii et al, 2009). State anxiety (A-state), on the other hand, is defined as "subjective, consciously perceived feelings of apprehension and tension, accompanied by or associated with action or arousal of the autonomic nervous system" (Spielberger, 1966). Thus, A-state is specifically related to the impact of situational variables. A-state level is usually low unless if the subject perceives a particular situation as potentially dangerous, harmful or threatening.

Numerous different examples of anxiety are well-documented in the literature, such as mathematics anxiety, science anxiety, test anxiety and social anxiety. As cited by Fong and Aldalalah (2010), despite provoking under different situations, these examples generally refer anxiety as an emotional state overwhelmed with tension, apprehension or fear (Warr & Downing, 2000). Such emotional state will eventually influence the appraisal of stimulus for learning behavior. High anxiety generates excessive stimulus, causing them to learn with great anxiety. These learners may find the subject matter is too demanding, even though the learning outcomes are achievable. By contrast, low anxiety provokes minimal stimulus, insufficient to stimulate motivation, and this accounts for boredom in learning. For this reason, low anxiety learners may not pay attention during the classroom instruction.

Literature to date exhibits significant evidence that anxiety has strong impact on learning outcomes and academic achievement, regardless of the subject areas. Some of the educators claimed that low anxiety level contributes to better learning, while high anxiety level impairs learning (e.g., Karimi & Venkatesan, 2009; Zakaria & Nordin, 2008). In fact, an inverted-U relationship exists between anxiety and academic achievement (Duffy, 1972). That is, beyond a certain degree of anxiety, either higher or lower, it may constrain performance. Duffy suggested a moderate anxiety may induce optimum performance. This is statistically supported by Fong (2000), Fong and Aldalalah (2010) and Toh (1998), who reported the outperformance of medium anxiety students. However, Zakaria and Nordin (2008) proved the contrary by showing that low anxiety students had significantly higher scores than medium and high anxiety students.
Ashcraft and Kirk (2001) took a step further and brought up a discourse on the detrimental effect of anxiety level on working memory capacity.

High anxiety individuals showed a significant decline in problem-solving performance, which suggests that they possess insufficient information-processing abilities (Ashcraft & Kirk, 2001). They may use up some of their working memory resources to cope with the intrusive thought that provoked by anxiety, leaving limited available resources for other tasks (Fong & Aldalalah, 2010). Given the limited human cognitive system, it is unlikely that high anxiety individuals can handle working memory load task while dealing with the anxiety-provoking stimuli. If this is the case, the working memory capacity required will eventually go beyond its limit and cognitive overload may occur (Jun-Xia, 2007). The present study confronts the disruptive effects of anxiety on working memory. The researchers attempt to examine whether segmented animation can help learners of different anxiety levels to off-load some working memory space that could in turn be used to facilitate information processing and hence better learning.

Research Questions

The present study sought to address the following questions:

- Will students using the TGAB mode achieve significantly higher post-test score than students using the TGA and TGS mode?
- Will HA students with using the TGAB mode achieve significantly higher post-test score than students HA student using the TGA mode?
- Will HA students with using the TGA mode achieve significantly higher post-test score than students HA student using the TGS mode?
- Are there interaction effects between treatment modes and anxiety on the post scores?

Methods and Procedures

Experimental Condition

The students were randomly assigned to one of the three treatment groups (TGS group, TGA group and TGAB group) with different modes of presentation. Students in these treatment groups were exposed to exactly the same educational material, but displayed in three different modes of graphic presentation as follows:

- **TGS group**: Static graphics and text (as written text on the screen) was presented simultaneously to explain the concept of meiosis.
- **TGA group**: The on-screen text is being displayed simultaneously with relevant animated graphics. The animated graphic demonstrated the whole process of meiosis continuously from phase to phase (Prophase I to Telophase II). This animation can be replayed by clicking on the 'Start' button.
- **TGAB group**: The relevant animated graphic in a segmented manner was presented in addition to the on-screen text simultaneously. The animation was separated into segments according to the eight phases of meiosis (Prophase I, Metaphase I, Anaphase I, Telophase I, Prophase II, Metaphase II, Anaphase II and Telophase II). Animation of each of these phases can be replayed by clicking on the 'Start' button.

Research Design

The present study employed a 3×2 quasi experimental design. The factors of the design were the three modes of presentation (TGS, TGA and TGAB) and three different levels of anxiety level, high anxiety (HA), medium anxiety (MA) and low anxiety (LA).

Research Variables

The present research contains three types of variables, namely independent, dependent and moderator variables. The independent variables were the multimedia courseware with meiosis process presented in three modes of presentation (TGS, TGA and TGAB). The dependent variable was the students' post-test score in the category of concept learning and problem-solving, while the trait anxiety level of students acted as the moderator variable.

Results

Pre-Quasi Experimental Study

A pretest was administered before the beginning of the study. A series of t-tests was used to determine if there were significant differences in students' pre-test mean scores between TGS, TGA and TGAB groups at a 0.05 significance level. The results showed pre-test mean scores were not significantly different between TGS and TGA group ($p = 0.708$); TGS and TGAB group ($p = 0.338$); TGA and TGAB group ($p = 0.532$). This implies that students across the three groups were equivalent in their prior knowledge of meiosis.

The Cattell Culture Fair Intelligence Test was distributed to the students after the pretest. A series of t-test was used to determine the effect of Cattell scores on students' achievement scores. The results revealed that students' achievement was significantly influenced by their Cattell scores, $p < 0.05$. To examine the correlation between intelligence level and achievement scores, the Pearson's correlation procedure was used. The Pearson's correlation coefficient with p = 0.000 showed that there was statistical correlation between students' Cattell scores and their achievement mean scores. From these findings, there was significant evidence that Cattell scores was a confounding variable that influences the dependent variable (post score) being measured. To reduce the error variance, the Cattell scores is used as the covariate in this study.

T-test of the Post Scores of Students with Different Anxiety Levels in Various Treatment Groups

A post-test was administered to students across three groups after the intervention using different presentation modes (TGS, TGA and TGAB). T-test analysis was used to determine if the mean scores of students with different anxiety level across three treatment groups are statistically different. The results were summarized in Table 1.

Table 1 T-test of post scores of students with different anxiety level

Variables	N	Mean	Standard Deviation	t-value	Df	Sig 2-tailed
High anxiety (HA) Low anxiety (LA)	83 79	11.55 12.22	4.01 3.84	-1.07	160	.286
High anxiety (HA) Medium anxiety (MA)	83 75	11.55 14.11	4.01 4.34	-3.84	156	.000*
Low anxiety (LA) Medium anxiety (MA)	79 75	12.22 14.11	3.84 4.34	-2.87	152	.005*

Significance * $p < 0.05$

Table 1 descriptively showed that the mean scores of students with different anxiety level across three treatment groups were differed in this order: MA ($\mu = 14.11$) > LA ($\mu = 12.22$) > HA ($\mu = 11.55$). The mean scores differences between MA and LA students was significantly different, t = -2.87 (df = 152), $p < 0.05$. The comparison of mean scores of MA and HA students indicated significant results, t = -3.84 (df = 156), $p < 0.05$. However, the difference in mean scores of HA and LA students was found to be statistically insignificant, p = 0.286 (> 0.05).

T-test of the Post Scores of High Anxiety Students in Three Treatment Groups

A comparison was made between post scores of HA students in TGS, TGA and TGAB group, using a series of t-tests. The results were summarized in the Table 2.

Table 2 T-test of post scores of HA students in three groups

Treatment Mode	N	Mean	Standard Deviation	t-value	Df	Sig 2-tailed
TGS Mode TGA Mode	25 29	10.48 10.62	3.10 4.49	-0.13	52	.896
TGS Mode TGAB Mode	25 29	10.48 13.41	3.10 3.63	-3.17	52	.003*
TGA Mode TGAB Mode	29 29	10.62 13.41	4.49 3.63	-2.60	56	.012*

Significance * $p < 0.05$

Table 2 descriptively presented the differences in mean scores between HA students across three treatment modes, in this order: TGAB ($\mu = 13.41$) > TGA ($\mu = 10.62$) > TGS ($\mu = 10.48$). According to the t-tests results, the mean scores of TGAB and TGA group was significantly different, t = -2.60 (df = 56), p <

0.05. The mean scores differences between TGS and TGAB group was also found to be statistically significant, t = -3.17 (df = 52), $p < 0.05$. On the other hand, the comparison of mean scores of TGA and TGS group provided insignificant results at a 0.05 significance level.

ANCOVA of Main Effect of Treatment Modes and Anxiety Level

The main effect of treatment modes and anxiety level on achievement scores was examined using ANCOVA procedure. To reduce the statistical error, the Cattell scores were used as the covariate. The result is tabulated in Table 3.

Table 3 Main effect of treatment modes and anxiety level

Sources	Sum of Squares	df	Mean Square	F	Sig F
Covariate	762.521	1	762.521	67.139	.000*
Cattell	762.521	1	762.521	67.139	.000*
Main Effect	823.513	4	205.878	18.127	.000*
Mode	553.995	2	276.998	24.389	.000*
Anxiety	255.553	2	127.777	11.251	.000*
2-way Interaction	52.840	4	13.210	1.163	.328
Mode	52.840	4	13.210	1.163	.328
Anxiety					
Explained	1566.342	9	174.038	15.324	.000
Reja	2555.386	225	11.357		
Total	4121.728	234	17.614		
250 case processed 15 (6.0 pct) case lost					

Significance * $p < 0.05$

The ANOVA results, as shown in Table 3, indicated that the main effects of treatment modes on mean scores was significant, $F(2, 225) = 24.389$, $p < 0.05$. This means that three different treatment modes had reliable effect on achievement scores, in this order: TGAB> TGA > TGS. Other than treatment modes, the main effects of anxiety level on mean scores was also significant, $F(2, 225) = 11.251$, $p < 0.05$. This implies that achievement scores were also influenced by anxiety level, in this order: MA > LA > HA.

ANCOVA of Interaction Effect between Treatment Modes and Anxiety Level

To examine if the effects of treatment mode on post scores depend on the anxiety level of students in TGS mode, TGA mode and TGAB mode, analysis of covariance (ANCOVA) was conducted. The Cattell scores were used as the covariate. The ANCOVA results as shown in Table 3, revealed that the interaction effect between treatment modes and anxiety level on the post mean score was not significant, $F(4, 225) = 1.163$, $p > 0.05$. This means that there were no statistical interaction effects between these two variables on the achievement scores across the TGS, TGA and TGAB groups.

Discussion

The result showed that students in TGAB group significantly outperformed students in TGA and TGS group in conceptual and problem-solving task. This implies that learners using the segmented animation are not merely able to better understand the material content, but also able to better extend their learning outcomes into problem-solving application. This result is concurred with the study by Mayer and Moreno (2003) and Moreno (2007). There are several explanations that can help to explain the positive effect of TGAB presentation mode. In TGAB mode, animation was segmented into smaller chunks of information, seemingly offering a visual presentation that better fit learners' cognitive capacities. More specifically, TGAB mode enables learners to process the information without overloading their cognitive system, as suggested in Clark and Mayer (2008), Mayer and Moreno (2003) and Moreno (2007). Learners in TGAB mode, thus, have more cognitive resources available for incoming information-processing. In short, reducing cognitive load using segmented animation may contribute to effective information processing, thus yielding better learning. Moreover, students in TGAB group could choose when to start the next phase, or in other words, they could control over the presentation pace. For this reason, they have sufficient time to engage in active learning. Mayer (2001) suggested that learning takes place through students' selection of words and images, organizing them into coherent mental model and finally integrating them with prior knowledge. This implies that segmented animation could facilitate learners to construct more relevant internal representation, resulting in better comprehension.

The data revealed that students in TGA group outperformed students in TGS group. However, the difference was found to be statistically insignificant, which suggests that a continuous animation is no more effective than static graphics. This result is parallel to the findings of Lewalter (2003) and Hegarty (2003). Unlike TGAB mode, TGA mode presented all the information continuously, and thus learning from TGA mode may impose heavy cognitive load. The poor performance of TGA group suggests that learners failed to construct meaningful mental model, or in other words, full comprehension was not achieved. This is because they may not be able to mentally hold and manipulate the visually-changing information presented in TGA mode. This is consistent with Mayer and Moreno (2003), who claimed that students viewing a continuous animation failed to engage in all of the needed processing, particularly the processes of organizing and integrating. On the other hand, TGS mode requires learners to mentally visualize the entire dynamic processes from the static displays. In other words, learning from static displays invests excessive mental efforts, leaving limited working memory resources available for other learning tasks.

The results reinforced the hypothesis that the achievement scores among students with different anxiety level were significantly different, regardless of the treatment modes. High anxiety students scored lower post-test scores in the achievement test, which suggests that HA students experienced cognitive overload while trying to deal with both anxiety reactions and information-processing. This result concurred with the prediction of academic achievement by anxiety level in the consensus of literature (e.g., Fong, 2000; Fong & Aldalalah, 2010; Toh, 1998). Nevertheless, high anxiety students in TGAB group had better performance than high anxiety students in both TGA and TGS groups, which implies that segmenting animation into smaller chunks of information could reduce cognitive demands. This result is consistent with Mallow (1981) and Bandura (1982) claims that high anxiety students perform better if the instructional material is presented in a series of well-structured segments. This result also provides strong evidence that segmented animation allows students to control over the pace of the presentation and so reduces their anxiety level, as suggested in Jonassen and Grabowski (1993). In short, segmented animation reduces anxiety of these students to an optimum level, maximizing their information-processing capabilities, thereby resulting in better learning.

Conclusion

This study found that learning from a segmented animation is significantly better than learning from a continuous animation, whereas continuous animation is not significantly more effective than static displays. Segmented animation seemingly reduces cognitive overload, leaving more working memory resources for deeper cognitive process, resulting in better learning. Moreover, the pause between each segment eventually enables learners to possess sufficient time for cognitive processes that are necessary to generate meaningful learning. As expected, high anxiety students are more likely to experience difficulties in learning. However, the implementation of segmented animation does aid high anxiety students in learning by reducing their anxiety level, minimizing cognitive demands, and hence improving information-processing abilities. Instructional designers should take into consideration the segmenting principle when using animation to present dynamic and abstract concepts.

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