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Breaking It Down: Knowledge Transfer in a Multimedia Learning Environment

Gina Mariano
Troy University

The purpose of this study was to determine the effects of segmentation on immediate and delayed recall and transfer in a multimedia learning environment. The independent variables of segmentation and non-segmentation, as well as immediate and delayed transfer assessments, were manipulated to assess the effects of segmentation on the participant's ability to recall and transfer information from the multimedia tutorial. Data was analyzed using a 2x2 factorial design. The results of this study found that segmentation of multimedia tutorials did not result in significant differences in recall or transfer. The results also revealed that the time period between when a tutorial was viewed and when the recall and transfer assessments were taken did significantly affect participants' abilities to recall and transfer information.

The use of multimedia environments as learning tools is on the rise, especially in educational settings. In the past, multimedia research had been primarily focused on the technologies used to deliver instruction. More recently, however, the focus has shifted to a more learner-centered approach that is grounded in theories of how people learn (Mayer & Moreno, 2002).

The purpose of this study was to examine the role of transfer in multimedia instructional environments in light of current multimedia and transfer theory, specifically, how past and current understandings of knowledge transfer impact current learning and instructional design of multimedia environments.

Cognitive Theory of Multimedia Learning

The cognitive theory of multimedia learning seeks to explain how humans learn in a multimedia environment. The theory focuses on how humans process information in working and long-term memory so that delivery of information in a multimedia environment can result in a meaningful learning experience (Mayer, 2001). Specifically, the theory focuses on how words and pictures are selected, organized and integrated to form meaningful learning. This theory is based on a combination of three different theories—(a) working memory model (Baddeley, 1986; Baddeley & Hitch, 1974), (b) dual-coding theory (Paivio, 1990; Sadoski & Paivio, 2001), and (c) cognitive load theory (Chandler & Sweller, 1991; Sweller, 1994)—and three related assumptions: (a) dual-channel processing, (b) limited capacity, and (c) active processing. The cognitive theory of multimedia learning theory has also resulted in several principles demonstrated to affect the cognitive processing of information: the modality principle, redundancy principle, contiguity principle, coherence principle, signaling principle, segmenting principle, personalization principle, voice principle and individual differences principle (Mayer, 2005).

Dual-channel processing assumption. The dual-channel processing assumption states that humans have two separate channels that process auditory and visual information. This dual-channel assumption aligns with and merges both Baddeley's (1986) working memory model and Paivio's (1990) dual-coding theory. Baddeley's (1986, 2007) working memory model describes how information is processed after it is perceived by sensory organs and proposes separate channels for processing visual and auditory information.

While Baddeley's (1986, 2007) working memory model focuses on dual channels of visual and auditory information, Paivio's (1971, 1990) dual-coding theory emphasizes dual channels for verbal and non-verbal information. These two processing channels, verbal and non-verbal, are functionally independent, yet interconnected. The verbal system processes verbal information, such as spoken or written words, regardless of the modality of origin. The nonverbal system processes nonverbal information, such as pictures, gestures and music, again, regardless of origin.

It is apparent that Baddeley's (1986, 2007) and Paivio's (1971, 1990) interpretation of "dual-channels" is different: visual/auditory versus verbal/non-verbal. Mayer (2005) sought a compromise between both Baddeley's (1986, 2007) and Paivio's (1971, 1990) understandings of the separate channels. Mayer (2005) offered this explanation:

> For purposes of the cognitive theory of multimedia learning, I have opted for a compromise in which I use the sensory modality approach to distinguish between visually presented material (e.g., pictures, animations, video, and on-screen text) and auditorily presented material (e.g., narration and background sounds) as well as a presentation-mode approach to distinguish between the construction of pictorially based and verbally based models in working memory. (p. 34).

Limited capacity assumption. The limited capacity assumption holds that individuals are limited in the amount of information, or load, that can be processed in either of the dual channels at one time.

The limited capacity assumption follows the view of the working memory capacity literature. Working memory capacity has been seen as a limit in the ability to store information in working memory (Miller, 1956). This view was expanded upon to include the idea that working memory has two functions that must be considered: a limited storage capacity and a limited processing capacity (Engle, Tuholski, Laughlin, & Conway, 1999).

Active processing assumption. The active processing assumption holds that individuals actively engage in cognitive processing to construct mental representations of their experiences. This occurs through attending to, organizing and integrating incoming information (Mayer, 1997, 2005). The active processing assumption views individuals as actively processing and interacting with incoming information.

These three assumptions—dual-channel processing, limited capacity processing, and active processing—form the foundation of the cognitive theory of multimedia learning (Baddeley, 1986, 2007; Engle, Tuholski, Laughlin, & Conway, 1999; Mayer, 1997, 2005; Miller, 1956). They affect each other and should be viewed as a collective unit of variables that affect learning in multimedia environments (Mayer, 1997, 2005). This foundation is important because it provides a starting point for decisions regarding how to design multimedia instruction.

The cognitive theory of multimedia learning incorporates several principles based on these three assumptions (Mayer, 1997, 2005). These principles focus on how to design instruction in multimedia environments that take into account what is known about the cognitive processes and limitations of working memory, in order to promote meaningful learning (Mayer, 1997, 2005).

Segmenting principle. The segmenting principle explains that individuals learn better when a multimedia message is presented in learner-paced segments instead of a continuous flow of information (Mayer & Chandler, 2001). Learner-paced segments refers to segments of multimedia instruction that stop and provide a "Continue" button that allows the student to decide when to resume the instruction. Studies have found that when individuals have control over the pace of presented information, connections between verbal and visual stimuli have an increased chance of being made (Aly, Elen, & Willems, 2005; Dalton, 1990). Although there are nine principles, the segmentation principle will be the focus of this research.

The cognitive theory of multimedia learning seeks to explain how individuals can learn in a multimedia environment. The three assumptions and nine principles of multimedia learning provide guidelines regarding the development and design of multimedia instruction. The theory seeks to develop approaches to instructional design, which take into account information processing, in order to better understand human learning. This effectiveness of multimedia instruction has been measured by recall and transfer tests (Mautone & Mayer, 2001; Moreno & Mayer, 1999). Transfer is an important concept in the areas of learning and education because the goal of learning is to apply information to different situations and problems (Anderson, Reder, & Simon, 1996).

Knowledge Transfer

Researchers in the area of learning have studied and supported the concept of transfer and its importance in academic settings for decades. Transfer can be described as the ability to apply or use knowledge from one problem, situation or context to another (Anderson, 2005). Edward Thorndike, a learning theorist in the early 1900s, developed the seminal "identical elements" theory of transfer (Thorndike, 1903; Thorndike & Woodworth, 1901). The identical elements theory of transfer states that the amount of transfer between familiar and unfamiliar situations is determined by the number of elements the situations have in common (Thorndike, 1903; Thorndike & Woodworth, 1901). Charles Osgood (1949) developed a theory of transfer based on behaviorist stimulus-response pairs. Osgood's (1949) theory states that when stimulus-response pairs are similar in two situations, positive transfer occurs; when stimuli are different but responses are the same in two situations, some degree of positive transfer will occur; and when stimuli are the same but responses are different in two situations, no transfer will occur. Singley and Anderson (1989) stated that transfer was the product of overlapping or shared elements or abstract knowledge structures between a learned task and a new task. Each of these three theories of transfer is based to some extent on Thorndike's original idea that transfer is based on some type of similarity between the original learning situation and the subsequent transfer situation (Thorndike, 1903; Thorndike & Woodworth, 1901). However, what constitutes "similarity" is still at issue. These theories, however, have helped bring the concept of transfer to light within both research and education. Within the field of education, a central goal is that information learned in the classroom will be applied to problems and situations outside of the classroom. Unfortunately, this goal is not always achieved and students are often unable to transfer information outside of the context in which it was originally learned (Detterman & Sternberg, 1993).

Types of Transfer

While the concept of transfer has evolved, researchers have constructed several types of transfer. These types of transfer can be divided along three dimensions: (a) positive, negative, and zero transfer; (b) near and far transfer; and (c) lateral and vertical transfer (Glick & Holyoak, 1987). Positive transfer occurs when knowledge learned in one situation benefits learning in a new situation. For example, when key words and phrases were signaled, using a slower, deeper tone in the narration of a multimedia tutorial, there was an increase in problem solving transfer (Mautone & Mayer, 2001). Negative transfer occurs when knowledge learned in one situation interferes or hinders learning in another situation. An example of this occurred when Mayer, Sobko and Mautone (2003) found that problem solving transfer decreased when native-English speaking individuals listened and viewed a multimedia tutorial with a foreign accent narration. And finally, zero transfer occurs when learning in one situation has no effect on learning in another situation.

Near transfer, or specific transfer, refers to the transfer that occurs between two situations or tasks that are similar in both their superficial and underlying characteristics and principles (Glick & Holyoak, 1987). Far transfer, or general transfer, refers to transfer between two situations or tasks that are dissimilar in both their superficial and underlying characteristics (Glick & Holyoak, 1987). In a different vein, lateral transfer is said to occur when the transfer of knowledge or skills occurs between two tasks or skills that are of similar complexity (Lee, Pass, & Homer, 2006). This was found when Lee et al. (2006) observed that individuals showed transfer between low complexity multimedia tutorials and low complexity problem solving transfer tasks requiring them to answer questions of similar concepts to the tutorial. And finally, vertical transfer refers to the transfer of knowledge or skills between a less complex task or skill, usually a pre-requisite skill, and a more complex task or skill (Gagné & Paradise, 1961). An example of this can be seen when a segmented and non-segmented multimedia tutorial found that individuals engaging in the segmented version of the tutorial prior to the non-segmented version were able to make connections between the segments at their own pace (Mayer & Chandler, 2001).

In light of this, it should be noted that positive/negative, near/far, and lateral/vertical transfers can occur simultaneously as they all incorporate the transfer of knowledge among similar pieces on knowledge. Thus, if a student learns the cause of lightning and then successfully transfers this to a problem addressing how to reduce the likelihood of lightning, positive-near-lateral transfer will have occurred.

Transfer Within the Cognitive Theory of Multimedia Learning

Knowledge transfer in multimedia learning literature is often represented by how basic cause and effect knowledge can be transferred to similar situations and problems (Hummel, Paas & Kroper, 2004; Mayer & Moreno, 1998). These cause and effect situations involve the use of animation and narration (i.e., concurrent visual animation and audio narration) in scenarios such as how a tire pump works, as compared with animation or narration alone (Mayer & Anderson, 1991). It has consistently been found that individuals construct a more integrated mental model when animation and narration are provided concurrently, rather than animation or narration only (Fletcher & Tobias, 2005).

Knowledge transfer in multimedia learning research tends to be measured through a series of problem-solving transfer questions (Mayer, 1999; Mayer & Chandler, 2001). These questions are designed to measure near, lateral, and positive transfer. The determining factor is whether or not learners are able to answer these questions. For example, Mayer, Moreno, Boire, and Vagge (1999) had students watch a multimedia tutorial addressing the cause of lightning, followed by a recall item (i.e., "Write down an explanation of how lightning works"; p. 639) and four transfer questions: (a) "What could you do to decrease the intensity of lightning?"; (b) "Suppose you see clouds in the sky but not lightning. Why not?"; (c) "What does air temperature have to do with lightening?"; and, (d) "What do electrical charges have to do with lightning?" (p. 639).

Multimedia learning research has focused not only on near, lateral, and positive transfer, but also on immediate transfer: transfer that is measured immediately after the learning episode. This type of measurement, however, does not provide evidence of sustained and durable transfer. Would the learning tasks typically provided in the current multimedia learning literature (e.g., how lightning forms, how a car brake works, how human respiration works) result in far transfer: transfer to a transfer task that is less similar to the learning task than the typical problem-solving transfer questions and/or a delayed transfer task? For example, the multimedia learning principle of segmentation has been studied and has been demonstrated to foster near and lateral transfer when assessed immediately. Would this principle also demonstrate deep, sustained, and durable learning as evidenced by delayed transfer?

Delayed Transfer

Current transfer tests within multimedia learning environments are typically given immediately after learning occurs. Historically, delay periods have not been a primary focus. Glick and Holyoak (1987) stated that “studies of delayed transfer have been infrequent in contemporary work” (p. 10). However, when delayed transfer is studied, differences vary between immediate and delayed transfer groups regardless of the length of the delay period. According to Salden, Paas, and van Merrienboer (2006), “Another, more indirect, way to create better understanding of the underlying cognitive processes would be to administer a delayed transfer test sometime after the training is given” (p. 360). Moreno and Valdez (2007) studied differences between participants who watched a video and students who read a narrative about the same topic. Participants were given a transfer test immediately after learning and 4 weeks later. Moreno and Valdez (2007) found that although the mean score differences in the delay test were lower, there was not a significant difference. Fong and Nisbett (1991) studied statistical reasoning through the use of the law of large numbers. Participants were given transfer tests immediately after learning or a two-week delay period. They found that, although transfer did decrease over the delay period compared to the immediate transfer tests results, delayed transfer was still significant. They attributed this to participants’ memory for a rule or law instead of memorizing the details of a problem. Phye (1989) studied immediate and delayed transfer using advice and feedback given during analogical reasoning problem solving. Phye (1989) found that the combination of advice and feedback had a positive effect on transfer; however, a comparison between the immediate and delayed groups was not discussed in depth and the length of the delay period was not reported. Schroth (2000) studied pretraining and its effect on immediate and delayed transfer, the delay period being 7 days. It was found that pretraining did facilitate transfer for both groups; however, no differences were reported for the delayed group. Delayed transfer has been used as a dependent variable, although differences between immediate and delayed groups, specific details regarding length of delay period, as well as differences among multiple delayed groups are often limited, or not compared. There is a paucity in the literature comparing results of immediate and delayed transfer groups, as well as studies using immediate and delayed transfer as independent variables. Therefore, differences between immediate and delayed transfer in multimedia environments has yet to be determined.

Research Questions

1. What are the effects of segmentation on recall and transfer in a multimedia instructional environment?
2. What are the effects of immediate and delayed assessment on recall and transfer in a multimedia instructional environment?
3. Are there interaction effects between (a) segmentation and non-segmentation, and (b) immediate and delayed assessment on recall and transfer in a multimedia instructional environment?

Method

Participants and Design

The participants in this study were 214 undergraduate students at a large research university in the Mid-Atlantic region of the US enrolled in a 1000-level non-major personal health course who were provided course credit for participating. Participants were randomly assigned to either a “Segmentation” or “No Segmentation” condition and an “Immediate Transfer” or “Delayed Transfer” condition (see Figure 1). The experimental design was a 2 (immediate transfer, delayed transfer) x 2 (no segmentation, segmentation) factorial design.

Figure 1
Experimental Design

		Transfer	
		Immediate	Delayed
Segmentation	No Segmentation		
	Segmentation		

Materials

The materials used in this study included a pre-experiment questionnaire, a recall test, a transfer test, and two versions of a multimedia tutorial addressing how a car's braking system works. The pre-experiment questionnaire assessed the participants' general mechanical experience. The recall test assessed the participant's knowledge of how brakes work. The transfer test assessed the participant's level of knowledge transfer of how brakes work to questions relating to this content. The multimedia tutorial explained how car brakes work. The content for each study session was exactly the same, but delivered via a segmented or non-segmented multimedia tutorial. The study and the test sessions were administered on Apple laptop computers using Adobe Flash with the aid of standard over-the-head audio headphones. The instruction was based upon a unit of instruction originally developed by Moreno and Mayer (2000) addressing the function of car brakes. The assessment questions for the recall test and transfer test were verbatim from the Moreno and Mayer (2000) study.

Pre-experiment questionnaire. Prior to beginning the actual experiment, participants were given a questionnaire to assess their knowledge of automobile mechanics and repair, as well as demographic information. The participants were given a six-item activity checklist and a five-item self-rating. The instructions for the six-item knowledge checklist explained that participants should "Place a check mark next to the things you have done" (Moreno & Mayer, 2000, p. 121). The six items were as follows:

- I have a driver's license
- I have put air into a tire on a car
- I have changed a tire on a car
- I have changed oil on a car
- I have changed spark plugs on a car
- I have replaced brake shoes on a car

In addition, a five-item self-rating scale required the participants to rate their knowledge of car mechanics and repair on a 5-point scale from 1 = *very little* to 5 = *very much*. The instructions for the self-rating were "Please put a check mark indicating your knowledge of car mechanics and repair" (Mayer & Moreno, 1998, p. 242). The pre-assessment questionnaire score was calculated by giving a point for each domain-related activity the participant checked from the checklist and adding that number to the number indicated by the participant in the self-rating scale. The maximum score a participant could receive on the pre-assessment questionnaire was 11. Only participants with low experience in car mechanics and repair indicated by a score of 5 or less were included in this study.

Recall assessment. The recall assessment consisted of one item: "Please write an explanation of how a car's breaking system works." Participants were given 10 minutes to complete this assessment. This was the same question used in the Moreno and Mayer (2000) study.

Transfer assessment. The transfer assessment consisted of the same four questions used in the Moreno and Mayer (2000) study and are as follows:

1. What could be done to make them more reliable, that is, to make sure they would not fail?
2. What could be done to make brakes more effective, that is, to reduce the distance needed to bring a car to a stop?
3. Suppose that you press on the brake pedal in your car but the brakes don't work? What could have gone wrong?
4. What happens when you pump the brakes (i.e., press the pedal and release the pedal repeatedly and rapidly)? (p. 122)

The transfer test was given to participants either immediately after viewing the tutorial or after a delay period of one week. Participants were given 20 minutes to complete all four transfer questions.

Multimedia tutorial. The computer based materials consisted of two versions of a multimedia tutorial on how car brakes function created using Adobe Flash animation. Both versions of the tutorial consist of a 60-second tutorial in which the animation demonstrates how car breaks function. The animation consisted of drawings of a foot pressing a brake pedal, a piston moving inside a master cylinder, brake fluid being pushed out of the master cylinder and expanding smaller pistons in the wheel cylinder, and the smaller pistons pushing the brake shoes against the brake drum. The segmented version was broken into three 20-second segments, whereas the non-segmented version ran continuously for 60 seconds (see Appendix). The segmented version had a "Continue" button on the screen, which the participant selected at the end of each segment of the tutorial in order to move on to the next segment.

Procedure

Undergraduates taking an introductory personal health course were solicited to take part in the study. Participants who were interested were required to go to a website and register for the study. The compensation for participating in the study was 15% of the participants' final course grade for the personal health course. Participants who chose not to participate in the study were given the option of a weight change project worth 15% of the their final course grade. As part of the registration for the study, participants provided demographic information, took a pre-experiment questionnaire, and scheduled a time to participate in the study. Prior to the registration process and the actual study, the protocol was approved by the university in accordance with the institution's Institutional Review Board (IRB) that governs all research conducted using human subjects.

As part of the online registration all participants were asked to read an electronic informed consent form, which provided general information about the study- purpose of the study, procedures, risks, contact information, confidentiality statement, and disclaimer that participation in the study is voluntary. The participants selected if they agreed or disagreed to take part in the study. Participants that agreed to take part in the study were automatically sent a copy of the Informed Consent form by e-mail and proceeded to the participant questionnaire section.

The first section, the participant questionnaire, consisted of general demographic information (i.e., e-mail, age, gender, academic classification, ethnicity, and major). After participants completed the demographic information, they were given basic instructions for the second section: the pre-experiment questionnaire. Participants were asked to place a check mark next to the items that applied to their knowledge of car mechanics (i.e., the six-item checklist) and place a check mark indicating their knowledge of car mechanics (i.e., five-item self-assessment). Once the online pre-experiment questionnaire was completed, the six-item knowledge checklist and five-item self-assessment scores were calculated and stored in a database along with the demographic information. The third section, the scheduling page, was designed for the participants to schedule a time to come into the computer lab to participate in the study. Once the participants submitted their schedule, the registration process was complete. The participants received an email confirmation that includes the date and time that they had selected and further details regarding the study.

Upon arrival at the computer lab, each participant was asked by the experimenter to sit at an available computer workstation. Participants were tested individually in groups of one to ten per session. Once all of the participants had arrived the session began. First, the experimenter presented oral instructions regarding the procedures for the study. The experimenter then explained that the study will take approximately 30 to 45 minutes to complete. After the oral presentation of instructions, the participants were provided with an opportunity to ask questions.

Second, the participants were asked to log in using the user information that they used during the registration process. Once the participants had logged in successfully, they were given on-screen instructions to wait for the experimenter before proceeding. After the experimenter confirmed that all participants have successfully logged in, the experimenter informed the participants that they should click the "Continue" button to begin the first part of the study.

Third, the participants were directed to the on-screen instructions for the unit on "how a car's braking system works" and were prompted to put on headphones. The participants then clicked "Continue" when they were ready to proceed. The participants in the non-segmented instructional group were presented with a 60-second tutorial with no opportunity to stop, pause, advance, or rewind. Participants in the segmented instructional group were presented with a 60-second tutorial broken into three 20-second segments. At the end of each segment, a "Continue" button appeared at the bottom of the screen. Once all participants completed the tutorial, they were instructed to click "Continue" to proceed to the assessment, starting with the recall question followed by the four transfer questions.

Following the tutorial, the recall question appeared ("Please write down an explanation of how a car's braking system works"). A text box appeared and the participants were asked to type their response. Participants were given 10 minutes to complete the recall test.

Once the experimenter acknowledged that all participants had completed the recall questions, they were verbally instructed to click the "Continue" button to proceed to the next section. This section consisted of the four transfer questions. Following each of the four questions, a text box appeared, and the participants were asked to type in the appropriate response. Once the participants completed the fourth question, they were instructed to click a "Continue" button to proceed. The transfer test that each participant completed depended on whether he or she was in the immediate transfer group or delayed transfer group. The immediate transfer group answered four transfer questions related to how brakes work immediately following the brakes tutorial. The delayed transfer group answered four questions related to the cause of lightening. In a second session one week later, the delayed transfer group took a transfer test consisting of the four transfer questions relating to how car brakes work, while the immediate transfer group answered the four questions related to the cause of lightening (see Table 1). The final screen of each session thanked participants for participating in the study. The experimenter also verbally thanked the participants for participating in the study and dismissed the participants.

Table 1
Assessment Schedule

	Week 1	Week 2
Immediate	Recall and Transfer Test—Brakes	Recall and Transfer Test—Lightning
Delayed	Recall and Transfer Test—Lightning	Recall and Transfer Test—Brakes

Scoring

Recall test. Two trained scorers were used to score the recall test. The recall test was scored by adding the number of idea units from the narration, out of a possible eight, although the wording did not have to be specific, just the main idea. One point was given for each of the following idea units:

> (a) driver steps on brake pedal, (b) piston moves forward inside master cylinder, (c) piston forces brake fluid out to the wheel cylinders, (d) fluid pressure increases in wheel cylinders, (e), small pistons move, (f) small pistons activate brake shoes, (g) brake shoes press against drum, and (h) drum and wheel stop or slow down. (Moreno & Mayer, 2000, p. 122)

Transfer test. Two trained scorers were also used for the transfer test. The transfer test was scored by adding the number of acceptable answers for the four questions. Acceptable answers were determined by those established by Moreno and Mayer (2000). Acceptable answers for the first transfer question—"What could be done to make them more reliable, that is, to make sure they would not fail?"—included adding a backup system or adding a cooling system; acceptable answers for the second transfer question—"What could be done to make brakes more effective, that is, reduce the distance needed to bring a car to a stop?"—included using more friction sensitive break shoes friction or reducing the distance between brake shoe and brake pad; acceptable answers to the third transfer question—"Suppose you press on the brake pedal in your car but the brakes do not work. What could have gone wrong?"—included that there may be a leak in the brake fluid line or a piston stuck in one position; and finally, acceptable answers to the fourth question—"What happens when you pump the breaks?" included reducing heat or preventing the pad from becoming worn in one spot. The two scorers determined whether the responses to the questions were within the acceptable answer range or were unacceptable. Inter-rater reliability was determined using a Pearson's *r* correlation.

Results

This experiment was designed to (a) validate the effects of segmentation on recall and transfer in a multimedia learning environment (Mayer & Moreno, 1998; Mayer et al., 1999; Moreno & Mayer, 2000), (b) evaluate the effects of segmentation on immediate and delayed recall and transfer, and (c) evaluate whether interactions effects occur between segmentation and transfer. These questions were analyzed using two 2 (non-segmentation, segmentation) x 2 (immediate recall and transfer, delayed recall and transfer) ANOVAs using the recall and transfer data. All pairwise comparisons used an alpha criterion of 0.05 and all effect size calculations involved Cohen's d (Cohen, 1998). Cohen's d effect sizes are interpreted as small, $d = 0.2$, medium, $d = 0.5$, and large, $d = 0.8$.

Analysis of the Segmentation Effect on Recall and Transfer

The first research question was the following: What are the effects of segmentation on recall and transfer in a multimedia environment? According to the segmentation principle of the cognitive theory of multimedia learning (Mayer, 2005), students who engage in segmented multimedia tutorials should achieve significantly higher on recall and transfer assessments than students who engage in non-segmented multimedia tutorials. Segmentation did not improve recall (see Table 2); therefore, no statistically significant main effect for the segmented group was found, $F(1, 210) = .96$, $p = .33$. Similarly, the segmented group showed no statistically significant main effect for transfer, $F(1, 210) = .16$, $p = .69$.

Analysis of Immediate and Delayed Assessment of Recall and Transfer

The second research question was the following: what are the effects of immediate and delayed assessment on recall and transfer in a multimedia environment? There was no statistically significant difference between segmented groups on immediate and delayed recall and transfer assessments. However, there were differences between the segmented and non-

Table 2

Means and Standard Deviations for Recall and Transfer Scores for Non-Segmented and Segmented Instruction

	Recall		Transfer	
	M	*SD*	*M*	*SD*
Non-Segmented	3.56	1.73	2.59	1.43
Segmented	3.29	1.62	2.48	1.28

Note. Max recall score = 8, max transfer score = 8.

Table 3

Means and Standard Deviations for Recall and Transfer Scores for Immediate and Delayed Assessment

	Recall		Transfer	
	M	*SD*	*M*	*SD*
Immediate	3.93	1.73	2.95	1.25
Delayed	2.89	1.46	2.10	1.34

Note. Max recall score = 8, max transfer score = 8.

Table 4

Means and Standard Deviations for the Interaction Between Segmentation and Immediate/Delayed Assessment

	Recall				Transfer			
	Non-Segmented		Segmented		Non-Segmented		Segmented	
	M	*SD*	*M*	*SD*	*M*	*SD*	*M*	*SD*
Immediate	4.17	1.72	3.61	1.72	3.06	1.27	2.80	1.24
Delayed	2.83	1.46	2.96	1.47	2.04	1.43	2.16	1.26

segmented groups on immediate and delayed recall and transfer assessments. There was a significant difference on recall between the immediate and delayed assessment groups (see Table 3), resulting in a significant main effect for the non-segmented group, $F(1, 210) = 20.53$, $p = .00$, $d = .64$. Similarly, there was a statistically significant main effect for immediate and delayed assessment on transfer for the non-segmented group, $F(1, 210) = 21.45$, $p = .00$, $d = .65$. These results demonstrated that statistically significant differences occurred between immediate and delayed recall and transfer groups.

Analysis of Interaction Effect

The third research question addressed whether non-segmentation and segmentation had differential effects on immediate and delayed transfer, that is, if there are any interaction effects between the groups (see Table 4). No interaction effect was found for recall, $F(1, 210) = 2.46$, $p = .12$. Similarly, no interaction effect was found for transfer, $F(1, 210) = 1.21$, $p = .27$.

Discussion

The goal of this research was to determine the effects of segmentation on immediate and delayed recall and transfer in a multimedia learning environment. The study utilized a multimedia tutorial to provide instruction on how car brakes work and was based on the segmentation principle of the cognitive theory of multimedia learning (Mayer, 2005).

The effects of segmentation were measured by immediate and delayed recall and transfer assessments. Participants were assessed on their ability to both remember and apply information from the tutorial to answer recall and transfer questions. Specifically, the independent variables of segmentation, non-segmentation, immediate transfer, and delayed transfer were manipulated to assess the effects of segmentation on the participants' ability to recall and transfer information regarding how brakes work during periods of immediate and delayed assessment.

In summary, the findings of the present study were consistent with previous segmentation research. Segmentation effects have been found to occur in multimedia learning environments, but not with consistency. This study found that segmentation had no effect on transfer and recall. This was consistent with previous findings, which suggest that variables such as length of segments (Hasler, Kersten, & Sweller, 2007) and type of tutorial, such as cause-and-effect (Mayer, 2005), may play a role in segmentation's effect on learning. Therefore, segmentation effects appear to be significant for longer length multimedia tutorials, but not significant for short duration (i.e., 60-second) multimedia tutorials. This study also found that recall and transfer decreased over a delay period. This was not surprising because memory is believed to decay over time. However, because delayed transfer was assessed only one time, after a week, it is not known how a longer delay period would compare to these findings.

Implications for Future Research or Theory

Previous research on the cognitive theory of multimedia learning environments and the results of the present study have raised many questions regarding segmentation and transfer in multimedia learning environments. Although this study did use segmentation within multimedia tutorials, the length of these tutorials may have played an important role in the results. Both the segmented and non-segmented tutorials were 60 seconds in length, and no segmentation effect was found. If the length of the tutorials were increased, then findings with regard to the segmentation effect may vary.

Although a delay period of one week was used in this study, more research involving longer delay periods will be important to help determine the effects of segmentation on delayed transfer. Studying how transfer is affected over varying delay periods can help increase our understanding of not only memory, but also how the transfer of knowledge changes over periods of time.

Limitations

The present study did face some limitations. First, the multimedia tutorial on how car brakes work is short in length and is a cause-and-effect lesson. A longer tutorial or a tutorial presenting information that is not primarily cause-and-effect may produce different results relating to the segmentation principle and recall and transfer assessments. Second, the delay period was one week. Studies using delay periods of varying length may see different results on recall and transfer assessments. Third, the transfer assessments consisted of four questions. Transfer assessments consisting of more questions may produce different results.

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GINA MARIANO is an Assistant Professor of Psychology at Troy University, where she teaches courses in educational psychology, basic statistics, and

research methods. Most recently, she served as chair for the Institutional Review Board (IRB) at Troy University. Dr. Mariano's current research interests include knowledge transfer in traditional and online environments, and faculty development in the area of online teaching improvement.