AN EXAMINATION OF COGNITIVE LOAD THEORY IN MULTIMEDIA LEARNING

A Thesis

by

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Submitted to the College of Graduate Studies of
Tarleton State University
in partial fulfillment of the requirements for the degree of

MASTER OF SCIENCE

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May 2021

Major Subject: Applied Psychology

ACKNOWLEDGEMENTS

First, I would like to thank God for giving me the strength to complete my degree. Without him, nothing is possible. Next, I want to acknowledge my thesis advisor and mentor, Dr. Jennifer Dias. Thank you for your patience and wisdom throughout the years. I could not have imagined having a better mentor. Words cannot begin to describe how thankful I am for your constant support and the time and effort you put into helping me with this project. Additionally, I would also like to give a special thank you to my committee members for always supporting my projects. I appreciate you both very much. I would also like to thank my family, especially Mona Gonzalez and Lena Linan, for their love and support. Finally, I must thank Kayli Colpitts, Clarissa Montoya, Hannah Mesfin, Kim Power, and Macie Hudson for providing me with unconditional support and inspiring me throughout my college career. This goal would not have been possible without each of you. Thank you.

ABSTRACT

Linan, Sarah., An Examination of Cognitive Load Theory in Multimedia Learning, MASTER OF SCIENCE (Applied Psychology), May, 2021, 22 pp., 1 table, bibliography, 12 titles.

Cognitive Load Theory (CLT) is the mental capacity an individual can achieve in working memory while learning or completing a task. If an individual's cognitive load reaches capacity, it adversely impacts their ability to process and retain information fully. Current research has illustrated the relationship between cognitive overload and poor learning outcomes. For example, if an individual engages in overly complicated instruction, they are less likely to retain the information due to focusing on the instruction's complexity instead of learning new information. Complex instruction leads to insufficient learning as one's cognitive capacity becomes overloaded. The purpose of this study was to examine mental effort used in a simple versus complex multimedia lesson. After watching the multimedia lesson over APA format, participants completed a post-test. Following the post-test, participants rated how much mental effort was utilized using the Leppink Subjective Rating Scale, which measured the three types of CLT intrinsic, extraneous, and germane. A 2 x 3 factorial design determined a relationship between complex instruction and cognitive overload.
Keywords: Cognitive load, multimedia, Leppink Subjective Rating Scale

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CHAPTER 1

INTRODUCTION

Cognitive load theory (CLT) is defined as the mental capacity an individual can obtain during working memory while learning a task; in other words, mental capacity is limited (Greene et al., 2017). Examining cognitive load can lead to a better understanding of human behavior by demonstrating how individuals retain information. Cognitive load occurs when visual and auditory information is displayed. Cognitive load can be measured using several methods, such as physiological responses and performance measures (Greene et al., 2017; Palinko et al., 2010). Once maximum mental effort occurs, it can negatively impact one's ability to process and retain information, creating cognitive overload.

Intrinsic Load

CLT consists of three types of load: intrinsic, extraneous, and germane. Intrinsic load is the amount of mental effort needed to learn a new concept (Park et al., 2015). Intrinsic load requires an individual to review and analyze information. Task difficulty is determined by the total amount of interacting elements (Park et al., 2015). The more difficult a task is to complete, the larger the number of interacting elements. Low and high interactivity can also affect intrinsic load (Paas et al., 2003). An example of low interactivity is learning grammar or learning simple vocabulary. Low interactivity causes intrinsic load to decrease, while high interactivity causes it to increase. An example of high element interactivity is a challenging math problem. A complex sentence can influence intrinsic load more because it relies on the amount of mental effort needed to process the information (Zu et al., 2018).

Extraneous Load

Extraneous load occurs when the material being presented is distracting (Park et al., 2015). Distractions lead to a decrease in the retention of information. Individuals are not likely to retain information if the material presented is in an unorganized manner or after unnecessary information is distributed. For example, if visual or audio presentations are too loud or too distracting, extraneous load increases, negatively affecting an individual's learning (Park et al., 2015). Examples of unnecessary information include flashy or distracting colors or movements in a PowerPoint. Instructors unintentionally add distracting materials to catch students' attention. Students then become distracted by frequent movements or flashy colors and do not retain vital information. Other examples of extraneous load include speaking in a monotone voice or using complicated vocabulary (Park et al., 2015). Extraneous load correlates with spatial and temporal organizations within the brain. Extraneous load occurs after the brain evaluates the format and organization of information (Park et al., 2015).

Germane Load

Germane load is responsible for processing information and influences the individual's motivation and concentration levels (Park et al., 2015). Germane load helps create schemas that help move new information into long-term memory by finding connections between new and old information (Park et al., 2015). Germane load can increase when activities positively impact the learner, such as becoming engaged in activities or listening closely. The more motivated the student, the more likely they are to learn new concepts (Park et al., 2015). If the student is not motivated to learn new material, they may not grasp the information provided and fully process it into long-term memory (Park et al., 2015). Examples of how germane load is measured include worksheets, quizzes, and activities that require an individual to reflect on prior information.

Origin of Cognitive Load Theory

Cognitive load theory originated from Sweller (1988), which measured problem-solving skills. Participants were given a number and asked to change the number to a target number using a rule. For example, specific problems involved a two-step solution to get the target number. The solution involved an alternation of multiplying by three and subtracting 29 for a certain amount of times to get the correct solution. Although many participants were successful, not all participants could determine how the rule was manipulated (Sweller, 2016). The results indicated that participants could solve the problem without learning the manipulation in the rule. Sweller (2016) hypothesized that the same processes might occur in a learning experiment. The results determined that the participant's working memory became overloaded by trying to determine the solution, and more participants could have been successful if the instructions were different. Sweller (2016) also hypothesized students might learn more effectively if teachers demonstrated solving the problems instead of solving them by trial and error.

Sweller (2016) concluded that individuals can solve a problem but may not learn from completing the task if the information is too complicated. If working memory becomes overloaded while completing a task or learning new information, this can prevent information from being stored in long-term memory. Understanding cognitive load types are essential when measuring cognitive overload because each contributes to an individual's learning process.

Understanding the dynamics of cognitive load can improve educators' instructional design and lead to new learning outcomes. For example, if an individual is presented with simple and transparent material, they can retain knowledge and be more likely to complete tasks efficiently (Paas et al., 2003). If information is accurately presented, individuals can process the information more effectively without becoming overwhelmed or distracted (Paas et al., 2003).

Purpose of the Study

Unnecessary information causes an individual's cognitive load to increase, resulting in the individual not learning the material, leading to poor cognitive performance (Paas et al., 2003). Cognitive load theory states that an individual's working memory and overall mental efforts are limited when learning or completing a task (Greene et al., 2017). The purpose of the current study was to examine the likelihood of participants reporting higher mental effort levels after completing a complex versus simple multimedia lesson. Hypothesis 1 was that participants would be more likely to report lower mental effort in the simple multimedia condition due to the lesson requiring less cognitive activity than the complex condition. The second hypothesis was that participants in the complex condition would be more likely to rate items 1-3 on the Leppink survey (5+ or higher). The ratings were measured on an 11-point rating scale: 0 = not at all the case, 10 = completely the case (Leppink, 2013) (Appendix B, p. 19). The third hypothesis was that participants in the complex condition would be more likely to answer the post-test questions incorrectly than participants in the simple condition due to cognitive overload.

CHAPTER II

METHODS

Participants

A total of 214 participants participated in the research study; 98 individuals did not complete all the questions from either the post-test or the Leppink Subjective Rating Scale and were excluded. The experiment was completed by 121 participants. Participants included 31 male and 90 female participants from Tarleton State University. Overall, 63 individuals participated in the simple condition, and 58 participated in the complex condition. Participants were recruited by a social media post or by being enrolled in a psychology course at Tarleton State University. Participants completed the study as a course requirement or extra credit. All participants were over the age of 18 and provided an informed consent document before beginning the study. Participants were randomly assigned to one of two conditions. Each condition had a separate Qualtrics link, both links were uploaded into the SONA research system, and participants could only participate in one condition.

Materials

The study consisted of two separate multimedia lessons over APA 7th edition format. The multimedia lesson was self-developed using Microsoft PowerPoint. Each multimedia lesson was approximately 10 minutes long and consisted of animation, narration, and text. One lesson was simplified to use plain language, which is defined as easy to read (Federal Plain Language Guidelines, 2020). Simplifying a task (e.g., the multimedia lesson) can help with learning and retention. Information presented without exceeding the individual's cognitive load will result in learning the information more effectively instead of becoming overwhelmed or distracted.

Each multimedia lesson manipulated the three types of cognitive load. The information provided in the simple multimedia lesson was easy to read, short, and straightforward, versus the complex multimedia lesson, which had an extensive vocabulary, and provided longer sentences and paragraph format. It was hypothesized that participants would experience cognitive overload when the multimedia lesson was complex. If participants complete a more complex task, they are more likely to use higher mental effort to process the information (Zu et al., 2018).

Participants completed a demographic survey (gender, age, and race). The Leppink Subjective Rating Scale was utilized to measure the three cognitive load types (Leppink, 2013). Items 1, 2, and 3 evaluated the multimedia lesson's complexity and helped determine intrinsic load. Items 4, 5, and 6 asked participants to rate instruction and explanations on a 0 - 10 scale (0 = not at all the case, 10 = completely the case). The ratings help determine the extraneous load. Lastly, items 7, 8, 9, and 10 determined germane load and asked participants to rate how instruction contributed to learning (Leppink, 2013) (Appendix B, p. 19).

Procedure

The experiment was administered online via Qualtrics. After providing informed consent, participants watched the APA format multimedia lesson, followed by a ten-question post-test, the Leppink Subjective Rating Scale, and a demographic survey. The experiment consisted of a 2 (multimedia lesson: complex, simple) x 3 (intrinsic, extraneous, germane load) design. The experiment was similar to Zu et al. (2018) in that the three types of cognitive load were manipulated using a multimedia lesson.

After the multimedia lesson, participants were asked to complete the post-test regarding what they learned in the multimedia lesson (Appendix A, p.17). The post-test helped measure germane load. It was hypothesized that participants completing the complex multimedia lesson would be more likely to answer the questions incorrectly due to cognitive overload.

Statistical Analysis

Responses were collected in Qualtrics and then transferred to an excel document where responses were cleaned and scored. All data were analyzed with JASP software (JASP Team, 2020). A Cronbach's alpha was used to determine the post-tests reliability. A mixed ANOVA was conducted to determine the scores between the simple versus complex conditions while examining the three loads' effects. The independent variable had two levels, complex versus simple, and the dependent variable, the Leppink Subjective Rating Scale, had three levels: intrinsic, extraneous, and germane loads (Leppink, 2013) (Appendix B, p. 19).

CHAPTER III

RESULTS

The study's goal was to demonstrate the effects of cognitive overload by manipulating the three types of loads through a simple or complex multimedia lesson using the Leppink Subjective Rating Scale (Leppink, 2013) (Appendix B p. 19). (Table 1) displays demographic data of participants by condition.

Table 1. Participant Demographic by Condition

	Total (*n* = 121)		Simple Condition (*n* = 63, 52.06%)			Complex Condition (*n* = 58, 47.93)		
Variable	n	%	n	% Group	% Total	n	% Group	% Total
Age (years)								
18-24	67	55.37%	39	61.90%	32.23%	28	48.28%	23.14%
25-34	24	19.83%	11	17.46%	9.09%	13	22.41%	10.74%
35-44	14	11.57%	4	6.35%	3.31%	10	17.24%	8.26%
45-54	10	8.26%	6	9.52%	4.96%	4	6.90%	3.31%
55-64	4	3.31%	2	3.17%	1.65%	2	3.45%	1.65%
65+	2	1.65%	1	1.59%	0.83%	1	1.72%	0.83%
Gender								
Male	31	25.62%	19	30.16%	15.70%	12	20.69%	0.17%
Female	90	74.38%	44	69.84%	36.36%	46	79.31%	0.66%
Ethnicity								
Caucasian	61	50.41%	28	44.44%	23.14%	33	56.90%	27.27%
African American	12	9.92%	6	9.52%	4.96%	6	10.34%	4.96%
Hispanic	27	22.31%	16	25.40%	13.22%	11	18.97%	9.09%
Native American	3	2.48%	1	1.59%	0.83%	2	3.45%	1.65%
Other	18	14.88%	12	19.05%	9.92%	6	10.34%	4.96%

The mixed ANOVA compared the mean differences between the simple versus complex groups' ratings and for the three load types. Mauchly's test indicated that the assumption of sphericity had been violated, χ 2 (2) = 79.40, $p < .001$ therefore, degrees of freedom were corrected using Greenhouse-Geisser estimates of sphericity (ε=0.67). The within-subjects effects determined that the three load types had a significant effect. F (1.342,159.75) = 24.777, $p < 0.001$, η_p^2=0.172. This suggests the Leppink Subjective Rating Scale effectively measured the three types of load, as shown in (Table 2).

The germane load type was (M = 44.695; SD = 0.805) 95% CI [43.11, 46.279]. The extraneous load type (M = 9.963; SD = 0.805) 95% CI [8.379, 11.546]. Lastly, the intrinsic load type (M= 7.326; SD = 0.805) 95% CI [5.742, 8.910]. The small standard deviation score meant there was little variance between the germane load type scores.

The simple condition had (M = 21.682, SD = 0.800) 95% CI [20.098, 23.266]. The complex condition had (M = 19.640, SD = 0.800) 95% CI [18.056, 21.225]. The between subjects' effects compared the simple versus complex conditions revealed significant differences, F (1,119) = 19.197, p = 0.032. Participants in the simple condition had a significantly higher score than participants in the complex condition.

The simple extraneous load type had (M = 8.847, SD = 1.127) 95% CI [6.630, 11.064]. The simple germane load type (M = 43.450, SD = 1.127) 95% CI [41.233, 45.667]. The simple intrinsic load type (M = 6.624, SD = 1.127) 95% CI [4.408, 8.841]. The complex extraneous load type (M = 11.079, SD = 1.151) 95% CI [8.815- 13.342] The complex germane load type (M = 45.941, SD = 1.151) 95% CI [43.677, 48.204] The complex intrinsic load type (M = 8.027, SD = 1.151) 95% CI [5.763, 10.290]. The results indicated no significant combinatorial effect between load type and condition, F (1.342, 159.754) = 2.281, p = 0.124. There was not a significant difference between the complex and simple group when comparing scores from the three load types.

Table. 2 Repeated Measures ANOVA

Within Subjects Effects

Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Load Type	54.119	1.342	40.313	24.777	<.001
Load Type * Group	4.983	1.342	3.712	2.281	0.124
Residuals	259.928	159.754	1.627		

Between Subjects Effects

Cases	**Sum of Squares**	**df**	**Mean Square**	**F**	**p**
Group	19.197	1	19.197	4.681	0.032
Residuals	487.998	119	4.101		

The post-test was self-developed; therefore, to ensure reliability, a Cronbach's alpha was performed. The results demonstrated that the post-test was reliable with a score of 0.707, meaning approximately 70 percent of the scores' variance was reliable variance. The post-test was an accurate way to determine germane load.

CHAPTER IV

DISCUSSION

The purpose of the current study was to demonstrate the effects of cognitive overload by manipulating the three types of loads through a simple or complex multimedia lesson to determine how individuals can learn new information more effectively. Cognitive overload occurs when too much information is presented or if the information is too complex. Hypothesis 1 was that participants would be more likely to report lower mental effort in the simple multimedia condition due to the lesson requiring less cognitive activity than the complex condition. The between subjects' effects compared the mental effort ratings by the simple versus complex condition and found a significant difference between the simple and complex groups. Participants in the simple condition had a significantly higher score than participants in the complex condition. The hypothesis was not supported because it was predicted that the complex group would have a higher mean score. Hypothesis 2 was that participants in the complex condition would be more likely to rate items 1-3 on the Leppink survey (5+ or higher) (Appendix B, p. 19). The results found the complex group had a mean score of 8.027 for intrinsic load, and the simple group had a mean score of 6.624 for the intrinsic load. Items 1-3 on the Leppink survey determined intrinsic load, meaning that Hypothesis 2 was supported. Hypothesis 3 was that participants in the complex condition would be more likely to have an increased number of incorrect answers on the post-test than the simple condition participants. The study results found no significant effect by groups on the post-tests incorrect answers, meaning the complex group was not more likely to experience cognitive overload.

The results demonstrated that the load types had a significant effect. Because load types had a significant effect, the Leppink Subjective Rating Scale effectively measured the three types of load, as shown in Table 1. The Leppink Subjective Rating Scale was an effective way to determine mental effort. Items 1, 2, and 3 accurately measured participants' intrinsic load by having participants rate the multimedia lesson's complexity. Items 4, 5, and 6 accurately measured participants' extraneous load by asking participants to rate instruction and explanations given during the multimedia lesson. Items 7, 8, 9, and 10 accurately measured germane load by asking participants how instruction contributed to learning (Appendix B, p. 19).

The study's limitations include that females were more likely to participate in the experiment. The study was shared on social media and SONA research systems; however, 90 females participated in the experiment, whereas only 31 males participated. Group differences for load type were not significant. This could be the multimedia lessons did not have enough differences. The simple multimedia lesson could have been straightforward, using fewer colors and even shorter sentences, while the complex lesson could have been more challenging. Both lessons were approximately 10 minutes long and had animation and narration in future studies. Perhaps the complex lesson could be longer than the simple lesson. Another implication for a future study would only have one lesson with narration. Another limitation is that the complex multimedia lesson could have been more challenging by adding additional information and more irrelevant material. Another critical limitation to mention was that the multimedia lessons were self-developed. The multimedia lessons were over APA format because, in Deleeuw and Mayer's (2008) study, it was stated that there is a need for replication studies using different instructional materials. Several studies have used multimedia lessons over motor electrics, math problems, and ATP synthesis (Zu et al., 2018; Sweller, 2016; Park et al., 2015). However, no studies were conducted on APA format. This could be because many individual's especially science majors, know about APA format. For example, if an individual has prior knowledge, the intrinsic load is decreased (Park et al., 2015). Perhaps the multimedia lesson could be more complex and use a topic that is not commonly known in the future. Another suggestion for a future study is to examine the participant's prior knowledge about the multimedia lesson topic.

The current study contributes to the growing body of interest in cognitive science and multimedia learning. Previous research has indicated learners in multimedia learning environments are more likely to experience cognitive overload when information presented is overly complicated. While the current study was not able to support that hypothesis, it was able to provide suggestions for multimedia leaning in future studies. The study provided support that cognitive load theory can be measured using the three types of load: intrinsic, extraneous, and germane.

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APPENDIX A

APA Post-Test Questions

1. Which of the following is the correct parenthetical citation with two authors?
   a. Smith, Johnson, 2020
   b. (2020, Smith & Johnson)
   c. (Smith & Johnson, 2020)
   d. (James Smith & Sawyer Johnson, 2020)

2. What are the components to when completing a general reference in APA format?
   a. Placement, italicization, punctuation, capitalization
   b. Author, Date of publication, Title, Retrieval information
   c. Author, Title of the container, Other contributors, Publisher information
   d. Author, Date of publication, Version, Publisher information

3. Which of the following is the correct order to complete an APA reference?
   a. Author, Year, Name of article, Name of journal, Volume & page numbers, Doi
   b. Year, Author, Name of journal, Name of article, Volume & page numbers, Doi
   c. Author, Name of article, Name of journal, Doi, Volume & page numbers
   d. Year, Name of journal, Volume & page numbers, Name of article, Doi

4. Doi stands for ____?
   a. Data of identifier
   b. Digital online identifier
   c. Digital object identifier
   d. Data object identifier

5. The header for a student paper includes only the page number?
   a. True
   b. False

6. Which of the following is the correct first parenthetical citation with three or more authors?
   a. Martin, Bradley, and Johnson (2020)
   b. Martin et al. (2020)
   c. (Martin et al., 2020)
   d. (Martin et al. 2020)

7. How many different levels of heading in APA?
   a. 3
   b. 4
   c. 5
   d. 6

8. What are the main sections of an APA paper?
   a. Title page, Introduction, Discussion, Results,
   b. Methods, Results, Discussion
   c. Title page, Abstract, Introduction, Methods, Results, Discussion, Conclusion
   d. Title page, Introduction, Methods, Discussion, Results, Conclusion
9. What is the correct third level of heading?
   a. Centered, Bold, Title case, text will start on new paragraph
   b. Aligned left, Bold italic, Title case, text will begin as new paragraph
   c. Indented, Bold italic, Title case ending with a period, text will begin on the same line
   d. Aligned, Bold, Title case, text will begin on same line
10. What should the title page include?
    a. Running head, Page number, Author name, University name, Course name, Date
    b. Title, Author name, University name, Course number, Professor name, Date
    c. Page number, Author name, University name, Course name, Professor name, Due date
    d. Page number, Title, Author name, University name, Course name, Professor name, Due date

APPENDIX B
Leppink Survey and Scale

Dear Participant,
This inventory measures your cognitive load during the Multimedia lesson. All of the following 10 questions refer to the lesson that has just taken place. Please read each of the questions carefully and please check (√) your response on the column based on the following rating scale:

Not all the case | Completely the case

0 1 2 3 4 5 6 7 8 9 10

NO.	ITEMS	RATING SCALE										
		0	1	2	3	4	5	6	7	8	9	10
1.	The topics covered in the multimedia lesson were very complex.											
2.	The lesson covered terminologies that I perceived as very complex.											
3.	The lesson covered concepts and definitions that I perceived as very complex.											
4.	The instructions and explanations during the lesson were very unclear.											
5.	The instructions and explanations during the lesson were full of unclear language.											
6.	The instructions and explanations during the lesson were, in terms of learning, very ineffective.											
7.	The lesson really enhanced my understanding of the topics covered.											
8.	The lesson really enhanced my understanding of the terminologies covered.											
9.	The lesson really enhanced my knowledge of concepts and definitions.											
10.	The lesson really enhanced my knowledge and understanding of the subject.											