ABSTRACT

R0BERTS, WILLIAM EDWARD. The Use of Cues in Multimedia Instructions in Technology as a way to Reduce Cognitive Load. (Under the direction of Dr. Eric N. Wiebe.)

This study was designed to address cognitive overload issues through the use of visual cueing as a means to enhance learning.

While there has been significant research such as use of color for cueing to address many of the cited problems, there are missing elements in this research that could go a long way toward designing more effective solutions and teaching methods for Technology Education students. One aspect that is missing is a better understanding of how color cueing and narration interact with various aspects of information overload, split attention effect, and overall instructional difficulty.

When teaching technical topics to a technical or non-technical audience using multimedia instructions or tutorials, there is a problem of information overload when using these methods of delivery. Without the proper testing and methods for designing these types of presentation, the students or the audience the instructor plans to present this information to may likely experience cognitive overload, reducing the effectiveness of the instructions and tutorials. Cognitive overload is the result of excessive demands made on the cognitive processes, in memory particular.

The research was also designed to move beyond theory and to research hands-on instructional activities with typical students to prove that certain multimedia interventions reduce cognitive load and make learning more efficient when presenting technical information.

The principal research uses two rating scale assessment techniques: the SSI and NASA-Task Load Index (TLX), to assess levels of cognitive load. Previous research demonstrated that the SSI and TLX had different sensitivities to cognitive load.

The research adds to the existing research base, address some of these missing elements, and gain a better understanding of how to address the problems that have been presented above specific to Technology Education students, but equally relevant to other subject matter.

Visual cueing shows promise as a means to reduce cognitive overload and enhance learning.

The Use of Cues in Multimedia Instructions in Technology as a way to Reduce Cognitive Load

by
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DEDICATION

This dissertation is dedicated to my parents Dorothy L. Crowell, and the late William R. Roberts, to my sister Michelle Roberts McCulloch, to my son Robert Clayton Roberts, and a very special thanks to my long time best friend and business/technology advisor who became my wife as of January 2009; Julie Levitt Roberts and her son Colin and daughter Tiara.   My new bride, Julie provided me with her steadfast confidence and encouragement during my years away in college as well as recording the test modules, and providing writing and research advice. I additionally would like to thank my Chair, Dr. Eric Wiebe, and fellow members of my doctoral committee, Dr. William DeLuca, Dr. William J. Haynie III, and Dr. Brad Mehlenbacher as well as the departmental professors, and student colleagues for their support they have provided in this accomplishment in my professional development. And finally, I would like to offer much overdue appreciation to all my former colleagues and professors who encouraged and supported my pursuit of my doctoral studies from Appalachian State University, especially Dr. Marie Hoepfl, Mr. Eric Reichard, Dr. Kevin Howell, Dr. John Thomas, and Mr. David Pittman of Mayland Community College.

BIOGRAPHY

William Edward Roberts was born in Asheville, North Carolina on May 27, 1955. Edward attended Asheville city schools until he moved to Spruce Pine, North Carolina in 1969. Edward graduated from Harris High School in 1974. In 1976 Edward enrolled at Gupton-Jones College of Mortuary Science in Atlanta, Georgia and graduated in 1977. Edward then worked at Webb Funeral Home as a licensed embalmer and funeral director until 1992, before beginning his Associates degree at Mayland Community College in Spruce Pine, North Carolina, graduating in 1994.

After graduation, Edward worked at Hampshire Hosiery until 2001, and in August 2001 Edward enrolled at Appalachian State University in Boone, North Carolina, where he graduated with a Bachelor of Science degree in Industrial Technology/Electronics with a minor in physics in 2003. He received his MA in Technology Education from Appalachian State University in Boone, North Carolina in 2004 with a concentration in Jr. College and technical college teaching, and a minor in physics. Edward earned his doctorate of education degree at North Carolina State University Technology Education program with a minor in training and development from NC State University in Raleigh, North Carolina in 2008. While at NC State University, Edward worked as a graduate assistant in the graphics communication program teaching the Fundamentals of Graphic Communications. His special interests including but not limited to finding new cueing methods to reduce cognitive overload as students are exposed to more complex learning in a multimedia setting; use of wiki technology in a technology education setting and in improving methods of teaching technical material in a college setting.

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Chapter 1: Introduction

Multimedia in the Classroom

Numerous technologies provide multimedia integration and education in the classroom (Mayer & Moreno, 2003). This includes a tremendous influx of technologies such as personal computers, PDAs, cell phones, integrated and interactive Power Point presentation slides, integrated audio, iPod casting, instant Messaging, along with integrated multimedia applications and features inherent to these products. Almost 100% of the K-12 and college level classes use some form of multimedia instruction (Marrison & Frick, 1993; Johnson, Johnson, & Stanne, 1985). However, Mayer (2002) states that students seem to lack the ability to navigate multimedia lessons and directions such as those provided in the MTE (Modular Technology Education) program. This is important since a majority of the modular multimedia learning experience presentations are presented in a self-instructional format which was first coined by J.D. Russell. (Russell, 1974, p. 3).

Multimedia Overload Problems

The use of multiple types of delivery methods brings problems of multimedia modality overload (Atkinson & Mayer, 2004). For example, Atkinson and Mayer (2004) note overcomplicated Power Point slides can mean diminished productivity of the student in a learning situation. Doolittle (2002) expounds on Mayer’s (2001) assumptions that each information-processing channel is limited based on experience and information. Multiple media elements and modalities can be brought together in many ways within learning modules. The key is to find which modalities reduce overload and improve the effectiveness of the learning experience.

Problem of Information

This general problem of too much information (both text and graphics) creates real problems with information overload. This problem is enhanced when the information is spread out over multiple slides and pages of information compounding opportunity for overload.

Various techniques that designers commonly use to address information overload include narration, highlighting, and cueing. Narration is often utilized to reinforce the material; while highlighting or cueing (visually or auditory) key pieces of information can help guide the learner's eyes to the relevant information and key points. Modality integration used in Technology Education instructional materials is generally useful for graphics and narration, but can lead to problems and information overload when graphics, narration and text are combined (Mayer, 2001). Adding multimedia without consideration has often meant that the information is not presented properly, or in a way that inundates the student (Doolittle, 2002).

Researchers have been using new technologies and techniques to study these issues and develop better solutions to address these problems. To date, much of the work has been theory-driven research (Mayer & Moreno, 2000).

Theories under Study

Cognitive load theory has been defined by Dr. Cooper as the "total amount of mental activity imposed on working-memory at an instance in time" (Cooper, 1998). Cognitive load theory predicts two key effects: split-attention effect, and modality effect. Split-attention effect describes how attending to two distinct sources of information may impose a high cognitive load (Meij, 2000). The effect occurs when learners must split their attention between and mentally integrate multiple sources of information. Vekiri (2002) separately in a review of graphical displays explained the role of graphical displays in learning and synthesized relevant findings into principles for effective graphical design. Modality effect describes the advantages of using different modalities when two or more sources of information are presented simultaneously (Sweller, Merrienboer & Paas, 1998). An example of modality effect is when words are presented as narration through the auditory modality and pictures are presented in the visual modality.

Two important classes of cues include audible and visual cues. Auditory cues can be verbal, as a person speaking or reading text, or simply a sound or tone. Visual cues use design techniques such as color, arrows, and highlighting to draw attention to certain information.

How Cueing Interacts with Cognitive Load Theory

Cueing interacts with cognitive load by reducing extraneous load. The use of cueing to minimize the split-attention effect can be achieved by guiding the learner between the two information sources (Merrienboer & Sweller, 2005). Chandler and Sweller (1991) have said that effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning rather than toward preliminaries to learning. Similarly, Perlman and Swan (1995) showed that color-coding improved search time compared to no coding situations.

Tabbers, Martens and Merrienboer (2004) state that according to cognitive load theory and Mayer's theory of multimedia learning (Mayer, 2001), replacing visual text with spoken text (the modality effect), and adding visual cues relating elements of a picture to the text (the cueing effect) increase the effectiveness of multimedia instructions in terms of better learning results or less mental effort spent. From an earlier paper, Tabbers (1999) attests that visual cueing restored learning results that could have been expected from audio-visual instructions because of modality effect.

Aspects of Missing Research

While there has been significant research such as use of color for cueing to address many of the cited problems, some missing elements in this research could go a long way toward designing more effective solutions and teaching methods for Technology Education students. One aspect that is missing is a better understanding of how color cueing and narration interact with various aspects of information overload, split attention effect, and overall instructional difficulty. The proposed research is intended to add to the existing research base, address some of these missing elements, and gain a better understanding of how to address the problems that have been presented above specific to Technology Education students, but equally relevant to other subject matter.

Research Questions being addressed

Therefore, the following research questions were addressed in this study:

1. How does the use of color cueing interact with the split attention effect?
2. How does the use of color cueing interact with the modality effect?
3. How does the use of color cueing interact with instructional difficulty?

Assumptions/Hypotheses

1. Cognitive load theory predicts that the split attention effect condition will have heightened cognitive load relative to the modality effect condition.
2. Cognitive load theory also predicts that the lowering of cognitive load will only improve learning when load is initially high (i.e., at or near maximum capacity).
3. Design heuristics concerning the use of color as a cueing device leads us to believe that this technique should lower extraneous load due to the improved design's ability to guide the learner to key pieces of information.

Therefore, the following hypotheses were predicted:

1a. The student's total cognitive load should be lower in the modality effect conditions relative to the split attention effect condition.

1b. The student's total cognitive load should be lower in the cued conditions relative to the non-cued conditions.

2a. The modality effect condition test scores will only be higher than the split attention effect condition for the more difficult instructional modules.

2b. The cued condition test scores will only be higher than the non-cued condition for the more difficult instructional modules.

3. The lowering of cognitive load due to cueing should be greater for the split attention effect condition than the modality effect condition.

Technology educators have been limited in available research that specifically provides guidance to improve their use and effectiveness of multimedia in the Technology

Education classroom specifically. Some of the research seems to point to the possibility that cueing does reduce cognitive overload. Some of the research seems more ambiguous or theory based. This study offers insight into the design of Technology Education materials to better address cognitive overload. Lowering cognitive load is an important means of improving the students' learning experience.

This research into the effect of different combinations of cueing can be interpreted in ways that will improve the Technology Education student's experience. The questions asked in this study offer a more complete understanding of whether or not we can lower cognitive load through specific cued conditions to help guide Technology Education learners to which information has been pre-determined to be important. The findings can be used to better design materials, to lower total cognitive load, and to improve student test scores all of which meet the needs of our students.

Significance of the Study

The significance of this study is to better understand the use of different cueing and other techniques and to see if cueing can help guide Technology Education students to the most important information. This will also help address multimedia and its use specifically with Technology Education students. It is also designed to move beyond theory and to research hands-on instructional activities with typical students to prove that certain multimedia interventions reduce cognitive load and make learning more efficient when presenting technical information.

Limitations of the Study

This study was limited because it was conducted using a small number of undergraduate engineering majors, mainly sophomores from one university, North Carolina State University. There may be limitations as to how well this population generalized to all technology and technical education majors in other departments, other colleges or in other regions in the country. The study also only looked at a small number of lessons on the fundamentals of electronics. There may be limitations as to how well this subject matter generalized to other technical instructional areas.

Summary

When dealing with multimedia instructions or tutorials, there is a problem of information overload when using these methods of delivery. Without the proper testing and methods for designing these types of presentation, the students or the audience presented this information may likely experience cognitive overload, reducing the effectiveness of the instructions and tutorials. Cognitive overload is the result of excessive demands made on the cognitive processes, especially memory. Visual cueing shows promise as a means to reduce cognitive overload and enhance learning.

Definition of Key Terms

1. Cognitive Load Theory

   Optimum learning occurs in humans when the load on working memory is kept to a minimum to best facilitate the changes in long-term memory.

2. Modality Effect

   Replacing visual text with audio will decrease working memory load and improve learning.

3. Split Attention Effect

   Using information sources that are distributed over time and space (i.e., cannot be captured in a single view) causes higher cognitive load on working memory, and therefore impedes the learning process and leading to degraded learning performance.

4. Cueing Foundations

   Replacing visual text with spoken text and the addition of visual cues relating pictures and text increase the effectiveness of multimedia instructions in terms of better learning results or less mental effort spent.

Chapter 2: Literature Review

Introduction

In this chapter, we will cover two primary areas of research, cognitive load theory, and research related to the managing of attention with cues. There really is no cueing theory per se but a group of literature that draws on a number of theories and empirical findings that are classified as cueing foundations.

Summary of Cueing and Cueing Foundations

Cognitive load theory is defined as the total amount of activity that is imposed on working-memory at a given instance in time (Cooper, 1998). Basic memory contains two types of memory: short-term, and long-term. Short-term memory, or working-memory, is limited to the amount of information that can be held there, and this information decays over a short time span. Long-term memory is the permanent memory storage where we organize our general world knowledge for later recall and use. Working-memory consists of two complementary systems: verbal and non-verbal. The dual coding theory assumes that these two types of working memory are part of a two cognitive subsystem, one specialized for the representation and processing of nonverbal objects/events (i.e., imagery), and the other specialized for dealing with language (Paivio, 1991). The organization and functionality of memory as defined by cognitive load and dual coding theory lead to the hypotheses of two key influences multimedia instructions can have on learning: the split-attention and modality effects. The literature reviewed here will review basic cognitive theory, working-memory, cognitive load theory in general, and the split-attention and modality effects in particular.

The last research area we will look at is cueing foundations. Cueing foundations can be thought of as visual and auditory aids that guide students through multitudes of information (Mayer & Moreno, 2003). By guiding the learner, it reduces search time and reduces the load on working memory (Xing, 2006). The literature reviewed will define the different types of cues, and how cognitive load theory predicts how these cues interact with split-attention and modality effects.

Basic Memory

Working memory (Short-term memory) was defined by Baddeley (1992) initially in the 1980s as the ability to hold multiple facts or thoughts in memory temporarily while simultaneously solving a problem or performing a task. This system provides a place for the organization and temporary storage of information that is needed to complete the complex task of learning and reasoning. Working memory can be divided into three different sub components: the central executive, visual-spatial sketchpad, and the phonological loop (Baddeley, 1992). The central executive, an attentional-controlling system, is important in skills such as chess playing and is particularly susceptible to the effects of Alzheimer's disease. The visual-spatial sketchpad deals primarily with visual images and the control of these images. The last sub component is the phonological loop that deals with auditory, primarily speech-based, information. The two biggest influences on working memory are verbal and non-verbal inputs (Paivio, 1991; Sadoski & Paivio, 2004). Even though working memory is temporary, it is also limited to the amount of information that it is able to hold at a given period. Miller (1956) stated that working memory is only capable of holding about seven elements, or chunks, of information at a time. Besides being very limited in its capacity to handle multitudes of information at any given time, this information decays very rapidly over a short period. Since this information is limited by capacity and decays over time, you only have temporary recall of this information while it is being processed (Cowan, 2000). While working memory focuses on a limited number of elements, long-term memory provides humans with the ability to vastly expand this processing ability (Paas, Renkl & Sweller, 2003; Paas, Tuovinen, Tabbers, & Gerven, 2003). Long-term memory is the permanent memory storage where we organize our general world knowledge for later recall and use.

Visual and verbal information are each processed differently, along distinct channels with the human mind creating separate representations for information processed in each channel that Paivio (1991) states. Supporting evidence comes from research that shows that memory for some verbal information is enhanced if a relevant visual is also presented or if the learner can imagine a visual image to go with the verbal information. Likewise, verbal information can often be enhanced when paired with a visual image, real or imagined. Research findings (e.g., Tindall-Ford, Chandler & Sweller, 1997) tell us that the use of the dual-mode instruction using multiple sources of information creates a positive effect on learning. There also needs to be a balance to give equal weight to verbal and non-verbal processing (Sadoski & Paivio, 2004). When equal weight is not given through the use of dual coding, we end up with a cognitive overload, where either one or both of the channels are overloaded, and short term memory is over capacity.

Basics of Cognitive Load Theory

The basics of cognitive load theory (CLT) originated during the 1980s and underwent substantial development and expansion in the 1990s by researchers from around the globe (Paas, Tuovinen, Tabbers, & Gerven, 2003; Sweller, Merrienboer, & Paas, 1998).

In the articles by Paas, Tuovinen et al. (2003), and Sweller et al. (1998), they state that cognitive load theory is a major theory for providing a framework for investigations into cognitive processes and instructional design. Cognitive load theory deals with the design aspects of different instructional methods that work efficiently with students' limited cognitive processing capacity by helping to apply acquired knowledge and skills in new situations. Cognitive load theory is based on the fact that the cognitive architecture only consists of a limited working memory with a separate processing space for visual and auditory information inputs that interact with an unlimited long-term memory (Paas, Tuovinen et al. 2003; Sweller et al. 1998). Exceeding the limited working memory processing capacity in working memory causes cognitive overload. The most vital process used for learning, and problem solving of any kind, is the ability to transfer acquired knowledge and skills to long-term memory through schema construction and automation.

According to the literature on cognitive load theory, multiple elements of information can be chunked as single elements in cognitive schemas, which can be automated to a large extent. Then, they can bypass working memory during mental processing thereby circumventing the limitations of working memory. However, before information can be stored in schematic form in long-term memory, it must be extracted and manipulated in working memory. Schema acquisition and limited processing capacity contribute to cognitive overload (Paas, Tuovinen et al. 2003; Sweller et al. 1998).

Three types of cognitive load are differentiated including intrinsic cognitive load, extraneous cognitive load, and germane cognitive load.

Intrinsic cognitive load is an interaction of individual differences with the nature of the instructional materials. The primary individual differences of interest are the students' past knowledge or experiences. As a rule, if a student is facing a complex and novel instructional content, intrinsic cognitive load will rise. Similarly, if a student encounters a situation or problem that they have experienced before or are familiar with, they will yield smaller levels of intrinsic load, which shows that they have to put forth less effort (Paas, Tuovinen et al. 2003; Sweller et al. 1998). The volume of essential information to be learned in part defines intrinsic cognitive load. However, almost as important to intrinsic cognitive load is how those elements of information interact with each other. Interactivity rises when the information to be learned is dependent on other pieces of information and must be processed simultaneously to attain a good understanding of the information presented. An example of this would be the understanding of sentences in a paragraph (Sweller et al. 1998).

Germane Cognitive Load can be necessary in novel learning environments. The load is created in a construction of schemas and mental models. Schemas are stored in long-term memory. One of their obvious functions is to provide a mechanism for knowledge organization and storage. Schemas classify information in long-term memory so that experience used to help understand novel situations helps to reduce working memory load (Sweller et al. 1998). Such schemas and mental models facilitate learning by automating the input of new information to be learned. The effective automation of schemas is also a learned process, thus additionally contributing to germane load (Paas, Tuovinen et al. 2003; Sweller et al. 1998).

The manner in which information is presented to learners and the learning activities required of learners can also impose a cognitive load. When that load is unnecessary and interferes with schema acquisition and automation, it is referred to as an extraneous or ineffective cognitive load (Sweller et al. 1998). Extraneous load, or ineffective load, is that cognitive load which is not necessary for learning. Consider another common instructional design. Frequently, instruction includes multiple sources of information such as a combination of mutually referring diagrams and texts. In order to understand the diagram or the text, it may be necessary to mentally integrate them. Such mental integration likely imposes a heavy, intrinsic load. The extraneous load comes from less than optimal formatting or layout of that information. The load is extraneous because it is caused entirely by the format of the instruction rather than by the intrinsic characteristics of the material (Sweller et al. 1998). In circumstances of poor design, increased amounts of extraneous load can lead to poor performance and lowered amounts of knowledge acquisition. When intrinsic and germane load are both low, the effects of high extraneous load may not be apparent because the overall load still does not reach an individual’s maximum capacity. Only under generally high load conditions will the effects of extraneous load be apparent (Sweller et al. 1998).

Two influences on cognitive load are split-attention effect and the modality effect. Yeung, Jin, and Sweller (1997), state that this process of attending to two distinct sources of information may impose a high cognitive load, referred to as the split-attention effect. The effect occurs when learners must split their attention between and mentally integrate multiple sources of information. In a split-attention situation, where the student is using a textbook with graphics and text, the student's visual attentional resources are used to hold words and graphics in working memory so there is no extra space for the student to be able to build a connection between the graphic and text (Mayer & Moreno, 1998; Yeung et al. 1997). The split-attention effect is derived in part from the worked-example effect (Sweller et al. 1998). The design of good worked examples is also difficult. For instance, worked examples that require learners to integrate different sources of information (e.g., text and diagrams) are often not effective because they yield a high extraneous cognitive load. The same may be true for worked examples that convey redundant information or a low-variability sequence of worked examples that do not allow for an effective construction of schemas (Sweller et al. 1998). In split-attention situations, an overload in a visual working memory reduces the learner's ability to build coherent mental models that can be used to answer questions (Mayer & Moreno, 1998). Sweller et al. (1998) state that high intrinsic load and high extraneous load from split-attention leads to cognitive overload.

A spatial split-attention may occur when learners have to observe a complex animation and simultaneously read the explanatory text that is provided. Besides this spatial split-attention effect in animated models, a temporal split-attention effect may occur. The transient nature of an animated model implies that information is dispersed over time. This means that once a part of the animation is missed or only partly processed, the remaining parts might become incomprehensible. This is especially relevant for novice learners, who lack the prior knowledge to attend to relevant aspects of the animated model, and might easily get lost in the continuous stream of information. From a cognitive load perspective, this means that novices will often use cognitive resources inadequately, for instance, by attending to the most salient features of an animation that are not the most thematically relevant (Wouters, Paas & Van Merrienboer, 2005).

The research literature states that multimedia instructions consisting of verbal and pictorial information, for example a picture of a machine and a text about its functioning, place a high demand on working memory resources because the learner has to switch between text and picture in order to integrate them mentally. An interesting finding in the literature research is that this memory load can be reduced by presenting the verbal information auditorily (e.g., narration) instead of visually. They call this phenomenon the modality effect or modality principle. The results of both experiments in this study show that replacing onscreen texts with audio will only increase the effectiveness of multimedia instructions, but only if the student has no control over the pacing of the instruction and the pace is set by the time of the narration (Tabbers, Martens, & Merrienboer, 2001).

A number of principles for the creation of lesson materials have been developed based on controlled experiments that measure learning from the study of instructional materials (books or multimedia) teaching scientific processes. The modality principle asks the question, ‘‘is learning better when instructional visuals are described with printed text or with audio narration?’’ A number of experiments in which multimedia lessons teaching scientific processes, such as how lightening forms or how a brake works, used animation explained either by text or by the same words delivered in audio narration. The materials using audio to describe the words resulted in an 80% median gain in learning (Clark & Harrelson, 2002).

The researchers concluded that learning is deeper when the limited capacity of working memory is maximized by coordinated inputs into the visual and auditory subsystems rather than just the visual subsystem, as is the case when text is used to describe visuals. From their research, they have developed examples in athletic training education to help illustrate when these methods are appropriate, and state that instructional methods can be incorporated into lesson design and improve learning by managing cognitive load in working memory, stimulating encoding into long-term memory, and supporting transfer of learning (Clark & Harrelson, 2002).

Tindall-Ford, Chandler, and Sweller (1997) state that instructional materials that use dual-mode presentation techniques (e.g., auditory text and visual diagrams) can result in superior learning to equivalent, single-modality formats (e.g., visual text and visual diagrams). This modality effect may be attributed to an effective expansion of working memory. Using a variety of instructional materials, the authors found in three experiments that participants studying materials incorporating audio text and visual diagrams or tables performed better than those studying a conventional, visual-only format (Tindall-Ford, Chandler, & Sweller, 1997).

In a study done by Moreno and Mayer (1999), students learned better in multimedia environments when words and pictures were presented in separate modalities than in the same modality. When pictures and words are both presented visually, learners are able to integrate fewer pieces of relevant information because visual working memory is overloaded. When words and pictures are presented in separate modalities, visual working memory can be used to hold representations of pictures and auditory working memory can be used to hold representations of words. In their research, the first two studies revealed a split -attention effect in which students learned better when the instructional material did not require them to split their attention between multiple visual sources of information. The third study revealed a modality effect in which students learned better when verbal input was presented auditorily as speech rather than visually as text (Moreno & Mayer, 1999).

When students have to split their attention between multiple sources of information, Mousavi, Low, and Sweller (1995) suggests this can result in a heavy cognitive load. Their research with presentation-modality effects suggest working memory has partially independent processors for handling visual and auditory material. Effective working memory, therefore, may be increased by presenting material in a mixed rather than a unitary mode (Mousavi, Low, & Sweller, 1995).

The articles of Gellevij, Meij, Jong, and Pieters (2002), Clark and Paivio (1991) support the notion that working memory consists of two distinct systems: a verbal and a non-verbal. The verbal system consists of visual, auditory, articulatory, and other modality-specific verbal codes. The verbal system stores linguistic information or verbal descriptions for such words as book, text, school, teacher, learn, strategy, mathematics. The non-verbal system consists of the modality-specific images for shapes, environmental sounds, actions, skeletal or visceral sensations related to emotion, and other nonlinguistic objects. After training, the authors tested students' learning on trained and untrained tasks. The results for cognitive load, training time, and learning effects initially supported dual coding theory. The results show that even in this complex situation, multimodal instruction led to a better performance than unimodal instruction (Gellevij, Meij, Jong, & Pieters, 2002).

Low and Sweller's (2005) research brings us better understanding that under certain conditions, by presenting some information in visual mode and other information in auditory mode, we can expand effective working memory capacity and so reduce the effects of an excessive cognitive load. Low and Sweller (2005) state this is just one technique that can effectively expand working memory capacity. This effect is called the modality effect or the modality principle. It is an instructional principle that can substantially increase learning. Presenting some information in visual mode and other information in auditory mode can expand effective working memory capacity and so reduce the effects of an excessive cognitive load (Low & Sweller, 2005).

Reinforcing the information in this study by Low and Sweller (2005) that presenting some information in visual mode and other information in auditory mode can expand effective working memory capacity, and so reduce the effects of an excessive cognitive load, we can look at the research of Mousavi, Low, and Sweller (1995) that tested for the modality effect using geometry instruction. The geometry diagram obviously must be presented in visual form, but the textual information could be presented in either written (or hence visual) versus auditory form. A visually presented diagram and auditorily presented text may increase effective working memory over conditions where visual working memory alone must be used to process all of the information. As a consequence, learning may be enhanced.

In a series of experiments, Mousavi et al. (1995) obtained results suggesting that when students must split their attention between multiple sources of information that require mental integration, cognitive resources available for learning can be increased by presenting some of the verbal material in auditory rather than written form (Mousavi et al. 1995).

Mousavi et al (1995) stated that audio/visual instructions were consistently superior to visual/visual instructions, demonstrating the modality effect. Tindall-Ford, Chandler, and Sweller (1997) replicated this finding in another series of experiments using electrical engineering instructional materials. The modality effect was obtained only when using high element interactivity materials. The researchers obtained strong evidence that the cognitive load was higher under visual/visual than under audio/visual conditions but only when the material was high in element interactivity (Sweller, Merrienboer, & Paas, 1998).

Summary

Cognitive load theory is based on the idea that the amount of activity that is imposed on working-memory at any given time during the manipulation of information will affect how we learn. This theory is based on what we know about the basic memory components of short-term and long-term memory. Short-term memory or working-memory is limited to the amount of information that can be held there, and this information decays over a short time span. Long-term memory is the permanent memory storage where we organize our general world knowledge for later recall and use. Working memory consists of two complimentary systems: verbal and non-verbal. We know from the research that when pictures and words are both presented visually and separated spatially or temporally, learners end up being able to integrate fewer pieces of relevant information because visual working memory is overloaded. To avoid this type of situation, we can present the information simultaneously so the diagram or graphic is presented visually and the text presented auditorily to increase working memory efficiency. The organization and functionality of memory as supposed by cognitive load theory and dual coding theory leads to the hypotheses of two key influences multimedia instructions can have on learning: the split-attention and modality effects.

Principles of Cueing Theory

Introduction

Guiding attention through the use of cues--whether it be using arrows, colors, or highlighting--reduces the time it takes for a student to find the key information in instructional materials. Cues can either be of the visual or auditory type. When you reduce the search for information, you reduce the time and amount of information that had to be held in working memory, thus reducing extraneous load. Since working memory decays over time, reducing search latency means that information that needs to be connected is more likely to still be in working memory. Cueing can also be used as a way to structure information by guiding students to the most pertinent information. Since working memory is finite in size, cueing helps assure that working memory does not overflow with irrelevant information and allows the most relevant information to reside in working memory at the same time.

Goals of Cueing

The goal of cueing is to reduce the workload by guiding attention by using either visual or auditory cues. Xing (2006) states that flight controllers need to instantly detect critical information in Air Traffic Control displays without serially searching complex scenes. The target that represents critical information should immediately become obvious and capture attention. An example provided by Xing notes that a typical radar display such as the Display System Replacement (used by controllers in En Route Traffic Control Centers) includes a central area for current flight situations and one or several menu bars along the sides of the display. Controllers spend a great deal of time scanning the flight situation area. However, an alert message that appears in the left-top corner of the display may require immediate detection. Because a controller does not often look at the corners, that message may go unnoticed unless the message “pops out” and captures the controller’s attention (Xing, 2006). Another goal of cueing is to reduce search time and increase retention. Tabbers, Martens, & Merrienboer (2004) indicate cognitive load theory would predict that presenting text accompanying a picture as spoken text will decrease the extraneous load and increase the effectiveness of instruction (the modality effect). In addition, including visual cues to a picture that relates the relevant elements of the picture to the text will reduce visual search and also increase the effectiveness of the instructions (the cueing effect). This, in turn, reduces the latency in finding key information, allowing this information to stay in working memory longer and making it easier to integrate all of the information (Tabbers, Martens, & Merrienboer, 2004). Using cues helps the student select and organize relevant information by pointing to pertinent information. This in turn minimizes extraneous information that working memory has to process (Mayer & Moreno, 2003).

Types of Cueing

Two primary types of modalities used for cueing are visual and auditory. Visual cues use design techniques such as color, arrows, and highlighting to draw attention to certain information. Auditory cues can be verbal, as a person speaking or reading text, or simply a sound or tone. Landin (1994) states that verbal cues are concise phrases, often just one or two words that are used as an alternate method of communicating task information and that research in motor learning and sports pedagogy has examined the effects of verbal cues in directing attention to critical task stimuli and information, recalling series of motor activities, and initiating movement sequences. In two experiments conducted by Loman and Mayer (1989), high school students read and listened to either a signaled or non-signaled expository passage. The signals consisted of preview sentences, underlined headings, and logical connective phrases. The results indicated a pattern in which the signaled groups performed better on recall of conceptual information and on generating high quality problem solutions, whereas the non-signaled groups excelled on recall of information from the beginning and end of the passage and on generating low quality problem solutions. These results suggest that signaling was effective in modifying students' reading strategies (Loman, & Mayer, 1983).

Different techniques can be used to add either auditory or visual cueing to different types of instruction or tutorials. Tabbers, Martens, & Merrienboer, (2004) state that adding visual cues to illustrations results in higher retention scores of the students in that study. If we look at the context of visual cueing, we know that visual context effects have been studied in numerous eye movement studies, object and scene recognition studies, and attention tasks (Chun, 2000). Contextual cueing is important because it may give insights on how we integrate and use information from many sources. Contextual cueing is driven by incidentally learned associations between spatial configurations (context) and target locations (Chun & Jiang, 1998; Chun, 2000).

One type of visual cueing is the use of icons. In research by Niemela (2000), the role of icons and their grouping in a computer interface was investigated. The results showed that both the presence of icons and the spatial grouping of icons speeded the search for a target file. The researchers concluded that icon or picture superiority over text has been well reported in research on recall and recognition and also in studies of information search and recognition based on their own results. A short review of previous comparisons of icon versus text concluded that the advantages of icons are not a result of the icons themselves but of their effective implementation (Niemela & Saarinen, 2000). Niemela and Saarinen (2000) expresses that icons may have other inherent properties that lead to improved user performance in an interface.

This brings us to the use of color as a visual cue. Hughes & Creed (1994) infer that color is recognized faster than the icon shape in a visual search. Colors and simple shapes "pop-out" in search and can be used as a way to separate features as text segregation or figure ground groupings (Treisman & Gelade, 1980; Treisman & Paterson, 1984). Busse, Katzner, and Treue (2006) states that the use of color cues are more attentional orienting to the cued item than exogenous cues (or outside the cued item), symbolic (or iconic) cues, and arrows.

The temporal dimension is the use of a visual variable such as a cue in addition to the visual variable of the main phenomenon in a certain time span. By adding visual cues to the pictures, the result is higher retention of the information presented (Tabbers, Martens, & Merrienboer, 2004). Posner and Cohen (1984) tell us that visual cueing can be used to orient the attention of the user to a specific point or information. From the research of Perlman & Swann (1995) we can use color and texture coding to speedup visual searches of information in different learning situations. Temporal reasoning is essential when time plays a crucial role in many aspects of everyday problem solving (Decortis, 1988).

Visual and Color Cueing

When we talk about color, we need to look at the color dimensions. The basic dimensions of color are hue, value, and chromaticity/saturation. Hue is the dimension of color that specifies a color's position in the visible spectrum. Humans are able to interpret different combinations of red, green and blue and "see" the range of colors shown in the hue diagram. Tints and shades are variations of these pure hues; tinting occurs when white is added to a color. The value or brightness of a color is based on the amount of light being given off by the color. The easiest way to remember this dimension of color is to visualize the "grayscale" which runs from black to white and contains all of the possible grays. The brighter the color is, the higher its value. Saturation, also known as "intensity," describes the strength of a color with respect to its value or lightness. What that means is a color's saturation is the degree to which it is different than gray at a given lightness. For instance, colors near middle gray are relatively unsaturated compared to brighter, more vibrant colors (Bertin, 1983). In the article by Christ (1975) he states that color aids both the identification and the searching of important pieces of information when used as a label or cue. Deubel (2003) states color should enhance communication. Pastels and soft grays provide a nonintrusive background that leads to less fatigue than highly saturated colors. Deubel suggested using a maximum of three to six colors per screen. Use bright colors for the important information and dark text color on neutral backgrounds. Avoid hot colors and color schemes such as blue/orange, red/green, and violet/yellow. Use commonly accepted colors for certain actions, as red for stop or yellow for caution. However, research has not supported the role of color as a primary instructional variable. Color is most effective for organizing information and for providing contrast between screen objects (Deubel, 2003). Research has clearly indicated that visual materials facilitate instruction, but research has not fully delineated how the design factors of visual complexity, and color, specifically, interact with cognitive processes to produce this advantage (Berry, 1991). Dwyer and Lamberski (1982-83) states that while color has been used as an attention gaining and an attention sustaining device in instructional situations. However, even though the use of color in the production of instructional materials is wide-spread, its relative effectiveness as an aid in improving student achievement still remains inconclusive and at best contradictory. In the research by Baker and Dwyer (2000) states that color is an important instructional variable for facilitating achievement of specific types of objectives. Baker and Dwyer (2000) also state that learning will be more complete as the number of cues in the learning environment increases. They suggest that an increase in realism in the existing cues increases the probability that learning will be facilitated. Since pictorial and textual materials often contain large numbers of stimuli, the learner may need assistance in locating the most relevant information, Research based on pictorial (i.e., arrows and labels) and textual (i.e., underlining and color coding) cues has produced inconsistent findings, especially in the case of younger learners, As a result, few guidelines exist for selecting or recommending one cueing strategy over another (Beck, 1984). Through the use of detailed color photographs and accompanying passages. Beck (1985) tested 136 fourth-grade students and found that the combined visual cues produced significant gains, for both reading groups, on the cued information without having a detrimental effect on the non-cued information. The average reading group significantly outscored the low reading group on both the cued and non-cued information. The results support a visual cueing technique by which instructional designers can highlight critical information without sacrificing the noncritical information.

Two recent studies (Beck, 1987, 1990) demonstrated that the cued pictorial measure groups significantly outscored the no pictorial measure groups. The cues that were added to the pictorial measures in each study (i.e., arrows and labels in the first study and pointer-shaped labels in the second study) were designed to match the encoding cues in the instructional materials. The findings from both studies indicate that the use of identical cues at the instructional and evaluation stages enabled the learners to retrieve a greater amount of critical information. Several related factors may help to account for these results. First, by adding label cues to highlight pictorial information, this may have enabled the learners to conduct memory traces based on dual retrieval (i.e., visual and verbal) systems. Second, the presence of pictorially cued information may have added clarity and concreteness to the test items. Finally, the mere repetition of label cues in the instructional and evaluation materials may have helped to reinforce critical information (Beck, 1991). Janelle, Champenoy, Coombes, and Mousseau (2003) state that the results of their research indicated that those who used video modeling with visual and verbal cues collectively displayed less error and more appropriate form across acquisition and retention trial blocks, compared with other groups. And that their findings suggest that verbal information in addition to visual cues enhances perceptual representation and retention of model activities to improve task reproduction capabilities.

Auditory Cueing

The last type of cueing technique used in instructions is auditory cueing. Mayer and Moreno (2003) state in their research that students who received the signaled version of the narrated animation performed better on a subsequent test of problem-solving transfer than did students who received the un-signaled version. Mayer et al. (2003) acknowledge that language or narration provides better transfer of information; also, narration is more descriptive in describing how certain elevations on a map are displayed to the student as an example (Mayer & Anderson, 1991). Sound, on the other hand, gets your attention but provides no positive influence on the information being relayed to the student (Dwyer, 1978). By using narration, you get the students attention and provide information at the same time. In the research by Jeung and Chandler (1997) they state that in accordance with current views of the structure of working memory, it was suggested that mixed sensory mode presentations (e.g. visual diagrams and auditory text) would result in effectively more working memory capacity being available for learning when compared with equivalent visual only formats consisting of both visual diagrams and visual text. Furthermore, it was argued that the additional memory capacity provided in mixed mode presentations would only be of use if cognitive resources were not unnecessarily devoted to extensive search to relate audio and visual information. It was suggested that in areas of high search, a visual indicator such as electronic flashing may be necessary to reduce search and exhibit modality effects. It was also suggested that when visual search is trivial, then a mixed mode presentation would not require any visual prompts. Overall, the data supported this chain of hypotheses (Jeung, & Chandler, 1997).

Advantages of Cueing

Two key advantages to cueing including first; it draws the attention of the individual, so a cue helps to reduce the search time when looking for information. Second, cueing can also be used in the identification of certain types of information and to segment this information into different elements. Xing (2006) explains that air traffic controllers need to instantly detect critical information in ATC displays without serially searching complex scenes, so the target that represents critical information should immediately become obvious to capture attention. The use of pop-outs or cues is especially useful when targets need to be detected in large displays because targets located in the peripheral visual field can be quickly brought to the forefront for detailed inspection (Xing, 2006).

Another effective way to reduce cognitive workload is to organize information in complex visual scenes into categories and denote the categories with visual attributes that can be easily identified. Xing states that color is often used denotatively to identify an object. The task of using color for identification is essentially the task of color naming in which observers can associate targets with specific color names (Xing, 2006). Another advantage to cueing is segmentation of elements. Segmentation is based on uniformity and consistency of elements. An area composed of uniform elements can be easily segmented from its surroundings. Since the human visual system processes color separately from achromatic visual features, color is one of the ways to segment a display into separate regions (Xing, 2006). Johnson and Haggard (2003) state that attending to a cued location in space leads to faster reaction times when a stimulus is presented there, the reasons for this attentional effect, and its specific focus in the information-processing chain. Kauchak, Eggen, and Kirk (1978) state that the transmission of information in science texts is often accomplished through the use of graphs. Graphs are typically viewed as helpful adjuncts to information transmitted in prose form. However, research on the effectiveness of graphs in printed material has shown that graphs often add little to the understanding of textual materials, and may under certain conditions have a deleterious effect on learning from a text. Research in the area of mathemagenic behaviors had demonstrated the effectiveness of certain types of questions and cues interspersed in textual materials. The function of cues in written text has been hypothesized to be one of inducing search or attending behaviors in the reader. Such cues help to focus the learner's attention on important aspects of the text, while at the same time maintaining attending behaviors. Lorch (1989) states that in his study that the most consistent finding is that typographical cuing improves memory for the signaled content. Second, the memory benefits of typographical cues appear to be selective. Although memory for signaled content is improved, memory for un-signaled content is either unaffected or inhibited by the presence of typographical cues in a text. Mautone and Mayer (2001) states that According to the knowledge construction hypothesis, signaling can serve as a cognitive guide that helps learners make sense of the presented material. The present series of experiments focused on whether the principles and techniques underlying signaling in text can be applied to other media, including spoken text and narrated animation. Mautone and Mayer (2001) defined text signals as aspects of a passage that do not convey content information but rather "serve as guides to the reader by giving emphasis to certain aspects of the semantic content or pointing out aspects of the structure of content so that the reader can see the relationships stated in the passage more clearly." Thus, text signals appear to work, in part, by guiding the learner in selecting, organizing, and integrating explanatory information (Mautone, & Mayer, 2001). In one of the studies reviewed by Schwier and Misanchuk (1995) one hundred and nine ninth grade students learned geometric concepts when a computer was used in combination with the use of one of three conditions: monochrome, functional color (used as a Cue), and non-functional color (used indiscriminately). Immediate and delayed post test showed significantly better learning under the functional color (used as a cue), with low ability learners benefiting the most. High aptitude students showed the most positive attitude toward the treatment (Schwier, & Misanchuk, 1995). In the research by Tabbers, Martens, and Merrienboer (2000) they state that from their test results it seems that preventing visual search by adding visual cues to the diagrams has been effective. Students that have received the cues are scoring higher on the reproduction test than students that haven't. However, this advantage disappears in the transfer test, except for a small effect in the audio conditions. The second strategy that they applied, replacing text with audio, has not produced the increase in effectiveness as was expected. The test results do show a modality effect, only it is exactly opposite to what Cognitive Load Theory would have predicted. The students in the visual condition have scored better on the reproduction test than the students in the audio conditions. However, the higher reproduction scores are coupled with a higher mental effort spent on the test, which could partly explain the difference (Tabbers, Martens, & Merrienboer, 2000). Based on the study by Koning, Tabbers, Rickers, and Paas (2007) provide a new way of reducing the visual complexity of animations in order to promote learning in the form of cueing. Cueing can play a crucial role in the comprehension of an animation by a more efficient use of working memory resources. Moreover, cueing may have the additional advantage of organizing information presented in the animation. In conclusion, incorporating a visual cue in the design of an animation seems an interesting tool for instructional designers to enhance learning from an animation (Koning, Tabbers, Rickers, & Paas, 2007). In the research by Lorch, and Lorch (1996) the results of the comparisons between the half-signal condition and the other two signaling conditions are easily summarized. Signaled content was recalled well than un-signaled content in the half-signal condition. Signaled content in the half-signal condition was recalled at the same level as the corresponding content in the full-signals condition. However, un-signaled content in the half-signal condition was recalled more poorly than the corresponding content in the no-signals condition. Thus, the presence of signals interfered with memory for un-signaled content in the half-signal condition (Lorch, & Lorch, 1996). In the research by Lorch, Lorch, and Inman (1993) signaling produced better memory for the topics and their organization. In one experiment, subjects recalled the content of the text they read, and recalls were scored for the number of accurately recalled ideas. Signals produced recalls that were better organized by text topics. Signals also influenced the distribution of recall of ideas: Subjects remembered more topics but recalled less about each accessed topic if the text they read contained signals than if it did not. The results are interpreted as supporting a model in which signals influence readers' representations of a text's topic structure, which, in turn, is used to guide the recall of text content (Lorch, Lorch, & Inman, 1993). In the research paper by Ayers, and Paas (2007A) cueing was used as a strategy to direct the learner's attention to a key aspect of the instructional animation. It was found that learners who received the cue performed better on both comprehension and transfer questions than those who observed the animation without he cue. This finding supports the hypothesis that cueing by highlighting a key aspect and darkening the other aspects, reduces the effects of extraneous cognitive load induced through unnecessary searches. In addition, earners performed better on both the actual content that was cued, and also non-cued content. The authors argued that this result was most likely caused by the cued material freeing up cognitive resources, which could be spent on germane load on the non-cued material. They also suggest that the cued material may have underpinned the understanding of the non-cued material in a functional relationship (Ayers, & Paas, 2007A).

Disadvantages of Cueing

Even though cueing offers many advantages, some disadvantages to cueing include distraction, uncertainty, loss of integration, coding interference, and lastly- readability. Distraction and inattentional blindness occurs when you focus a person's attention to one piece of information to the detriment of their attention to other information. Since the human ability to attend to stimuli is limited, attending to a salient target in a complex scene acts as a distraction from other materials in the scene. Therefore, the perception of other stimuli is reduced. Hence, what facilitates attention is also the source of distraction (Xing, 2006; DiVita, Obermayer, Nugent, & Linville, 2004).

Another distraction is uncertainty in identification of color use in visual displays, and Xing (2006) concluded that the advantage of color could be significant only when color was highly correlated with the information it denoted; if color was only partially correlated with the content of information, then a user could not use color as the unique selection criterion for decision-making, and color had no advantage over achromatic attributes (Xing, 2006; Jeffrey & Beck, 1972).

Loss of integration is another distraction in cueing. When using colors to categorize information, the brain tends to process different colors separately and is less likely to associate the pieces of information displayed in different colors. This can pose a risk to tasks in which different types of information have to be considered together simultaneously (Xing, 2006).

Color-coding interference is also a disadvantage to cueing from a cognitive point of view. When people use color displays they build a mental model of the display in which colors are associated with certain categories of information. When several sets of color-coding are used in a display, users' cognitive workload is significantly increased due to switches between the coding schemes. Moreover, multiple color schemes often lead to the following situations: one color has multiple meanings in a display, and several colors are assigned the same meaning (Xing, 2006; Yuditsky, Sollenberger, Rocco, Friedman-Berg, & Manning, 2002).

Lastly, text readability is a disadvantage in cueing. An example from Xing's article on air traffic controllers states that a great deal of text reading is involved in an ATC job because text comprises a relatively large part of the materials presented on displays. Readability is primarily determined by the luminance contrast between text and its background colors. Luminance contrast can be calculated as the luminance difference between the text and background divided by the sum of the luminance (Xing, 2006; Legge, Rubin, & Luebker, 1987).

In a study by Blohm (1986) subjects in the study represented mature readers, evidently possessing their own successful internalized strategy for immediately distinguishing the structural importance among ideas. For these readers, color cueing as an extension of signaling structural importance was unnecessary or helping them determine more important ideas from less important ones. It cannot be concluded, however, that developing readers would not benefit from this form of cueing. Younger and/or disabled readers, who are not aware of the relationships which exist among ideas in text, might well benefit from color cueing. Blohm stated that further research with younger populations seems in order before the conclusion can be made that color cueing is generally ineffective. Asking younger readers to respond to different types of decision statements might also reveal that its effectiveness is a function of reading maturity. Assimilation of encoding might, in fact, is a necessary prerequisite to distinctiveness of encoding for improving learning and remembering among readers (Blohm, 1986).

In the research by Haynie (1978) states that cues work under many normal conditions but breaks down when cues are such that they cause interference. Haynie states that there is a limit to the channel capacity of the human receivers, and therefore the experimenter must be careful when flooding sensory inputs that the inputs are only flooded by meaningful information. Only then will the researcher be able to make useful inferences about the capacity of the channel or the optimal number of cues to provide (Haynie, 1978). In the research by Lorch (1989) he also found some several failures to find benefits of typographical cues suggest possible boundary conditions on the effects of the signaling device. First, some studies failed to specifically test whether memory for signaled content was affected by typographical cues. Thus selective effect of cuing may have been obscured by the global performance measures employed in those experiments. Second, most studies have at least produced trends in the direction of better memory for cued information, with two exceptions. Two studies have examined complex typographical cuing schemes in which four or five categories of text content have been signaled by different combinations of cues (color variation, typeface variation, and underlining). Although the trends were not always reliable, the studies found poorer memory for both signaled and un-signaled content if typographical cues were present in the text. Thus, typographical cuing may be beneficial only if the nature of the cuing is simple enough for the reader to readily grasp the relationship between the cues and the text content. In the study by Moreno (2007) there was no parallel finding for the signaling (cueing) method. A potential explanation for the lack of a signaling (cueing) effect is that the benefits of the signaling (cueing) method may have been offset by a visual split-attention effect. A split-attention effect occurs when learning is impaired from forcing a learner to mentally integrate separate sources of information. The signaling (cueing) method used in the present study forced students to split their visual attention between the video/animation and the side figure highlighting the essential skills that were being illustrated. Had the signaling (cueing) consisted of a message integrated in the video/animation itself, the results may have shown a positive signaling (cueing) effect (Moreno, 2007).

Cueing and Interaction with Cognitive Load Theory

Cueing interacts with instructional materials design by reducing extraneous load. Cueing can reduce extraneous cognitive load by minimizing search time between multiple pieces of information. Effective instructional material facilitates learning by directing cognitive resources toward activities that are relevant to learning, rather than just toward preliminaries to learning (Chandler & Sweller, 1991). One example of ineffective instruction occurs if learners unnecessarily are required to mentally integrate disparate sources of mutually referring information, such as separate text and diagrams. Such split-source information may generate a heavy cognitive load because material must be mentally integrated before learning can commence (Chandler & Sweller, 1991). In research of search times, errors, and subjective rankings of the coding methods that were recorded, the results showed that color coding improved search time compared to no coding situations (Perlman & Swan, 1995).

Cueing and Modality Effect

According to cognitive load theorist Tabbers, Martens, and Merrienboer (2004) and Mayer's theory of multimedia learning (Mayer, 2001), replacing visual text with spoken text (the modality effect) and adding visual cues relating elements of a picture to the text (the cueing effect) both increase the effectiveness of multimedia instructions in terms of better learning results or less mental effort spent (Tabbers, Martens, & Merrienboer, 2004). Visual cueing restored learning results that could have been expected from audio-visual (Tabbers, 1991). From an earlier paper, instructions were misunderstood as a result of modality effect (Tabbers, 1999). In the study done by Mousavi, Low, and Sweller (1995) students learn better when auditory narration was presented simultaneously with corresponding diagrams. The diagram was a geometry worked problem, the statement was a problem statement and a proof statement in auditory. Problem statement given O is the center of the circle; AB=CB all the letters are in the diagram. They were using narration to cue certain aspects of the problem (Mousavi, Low & Sweller, 1995). Merrienboer and Sweller (2005) explain that by replacing multiple sources of information (frequently pictures and accompanying text) with a single, integrated source of information we can reduce extraneous cognitive load because there is no need to mentally integrate the information sources (Merrienboer & Sweller, 2005). Two cases are described in Kalyuga (2000) where combining audio explanations with visual instructions has had negative rather than positive or neutral effects. The results were explained as a consequence of working memory overload. In the research by Kalyuga, Chandler, and Sweller (1999) they studied two experiments ran and the investigated alternatives to split-attention instructional designs. It was assumed that because a learner has a limited working memory capacity, any increase in cognitive resources required to process split-attention materials decreases resources available for learning. Using computer-based instructional material consisting of diagrams and text, Experiment 1 attempted to ameliorate split-attention effects by increasing effective working memory size by presenting the text in auditory form. Auditory presentation of text proved superior to visual-only presentation but not when the text was presented in both auditory and visual forms. In that case, the visual form was redundant and imposed a cognitive load that interfered with learning. Experiment 2 ameliorated split-attention effects by using color coding (cues) to reduce cognitive load inducing search for diagrammatic referents in the text. Mental load rating scales provided evidence in both experiments that alternatives to split-attention instructional designs were effective due to reductions in cognitive load (Kalyuga, Chandler, & Sweller, 1999).

Summary

In this chapter, we have covered two primary areas of research, cognitive load theory and research related to the managing of attention with cues. From the literature, we draw on a number of theories and empirical findings that we can classify as a foundation of cueing.

We know that cognitive load theory is the amount of activity that is imposed on working-memory at any given time during the manipulation of information, and that the basic memory components consist of short-term and long-term memory. Short-term memory or working-memory is limited to the amount of information that can be held there, and this information decays over a short time span. Long-term memory is the permanent memory storage where we organize our general world knowledge for later recall and use. We understand that working memory consists of two complimentary systems: verbal and non-verbal. Through the dual coding theory, these two parts of working memory are part of a dual cognitive subsystem, one dealing with just images, and the other specializing in dealing with just language (Paivio, 1991). Through the literature review, we have understood how the organization and functionality of memory is dependent on cognitive load theory, and dual coding theory. Through the research, we also learned that the two key influences on learning with multimedia instructions are the split-attention and modality effects.

Finally, we understand through the research and literature that cueing can be thought of as visual and auditory aids that guide students through multitudes of information (Mayer & Moreno, 2003). By guiding the learner, it reduces search time, and reduces the load on working memory (Xing, 2006). The literature we have reviewed has defined the different types of cues we can use and how cognitive load theory predicts that these cues will interact with split-attention and modality effects. The research tells us that both positive and negative advantages exist in the use of cueing in multimedia instructions. The positive advantages of cueing with its effect of reducing extraneous load on working memory outweighs the negative effects of using cueing in multimedia instructions.

Chapter 3: Research Methodology

Research Questions

The following research questions were addressed in this study:

1. How does the use of color cueing interact with the split attention effect?
2. How does the use of color cueing interact with the modality effect?
3. How does the use of color cueing interact with instructional difficulty?

Assumptions/Hypotheses

5. Cognitive load theory predicts that the split attention effect condition will have heightened cognitive load relative to the modality effect condition.
6. Cognitive load theory also predicts that the lowering of cognitive load will only improve learning when load is initially high (i.e., at or near maximum capacity).
7. Design heuristics concerning the use of color as a cueing device leads us to believe that this technique should lower extraneous load due to the improved design's ability to guide the learner to key pieces of information.

Therefore, it was predicted:

1a. The student's total cognitive load should be lower in the modality effect conditions relative to the split attention effect condition.

1b. The student's total cognitive load should be lower in the cued conditions relative to the non-cued conditions.

2a. The modality effect condition test scores will only be higher than the split attention effect condition for the more difficult instructional modules.

2b. The cued condition test scores will only be higher than the non-cued condition for the more difficult instructional modules.

3. The lowering of cognitive load due to cueing should be greater for the split attention effect condition than the modality effect condition.

Participants Involved in the Study

One hundred forty-two students enrolled in six sections of the GC-120 Foundations of Graphics laptop sections with approximately twenty-four plus students per class participated in this study. All students were entered in a raffle for a gift card from a department store worth one hundred dollars. Students withdrawing prior to completing the study were given participation credit and their data was not used for the final analyses.

The participants were known only by selected numbers generated at the time of the study. A list of the participants' names and the identifying numbers generated for them were held in confidence by the investigator and no one else for the purpose of the gift card drawing at the end of the study. A North Carolina State University Professor, Dr. Eric Wiebe drew the name of the student after the study was completed. No students were pre-screened prior to being exposed to the experimental conditions for previous experience in electronic courses. The reason for this was a hand count of six sections of GC-120 classes in the fall 2006 semester showed that less than two percent of those students had ever taken an electronics class. One fourth of the students who participated in the study (24) were randomly assigned to each of the experimental conditions (A, B, C, and D).

Materials

The learning modules (LM) for this study were presented to each student on a CD. The number generated for each student determined the assigned condition the student received. The assigned conditions that were given to the participants of this study were broken down into four sections depicted in the Table 3.1 below.

Table 3.1. *Assigned Conditions*

	Split Attention	Modality
Non-Cueing	A (Figure 3.1)	B (Figure 3.3)
Cueing	C (Figure 3.2)	D (Figure 3.4)

As you can see from Table 3.1., the first condition "A" was a split-attention effect that was not cued; "B" is a modality effect that was not cued; condition "C", which uses auditory narrations, is a split-attention effect that was cued; and the last condition is "D" which was a modality effect that was cued.

Each of these conditions contained five learning modules that lasted approximately ten minutes each. The CD program ran from the students own laptop disk drive; the students completed the lesson and recorded their answers on a paper test. Participants in modality conditions where auditory cueing and narration were used (condition "B" and condition "D") used stereo headphones during the study.

A sample of what the typical slides looked like is seen in Figures 3.1 through 3.4.

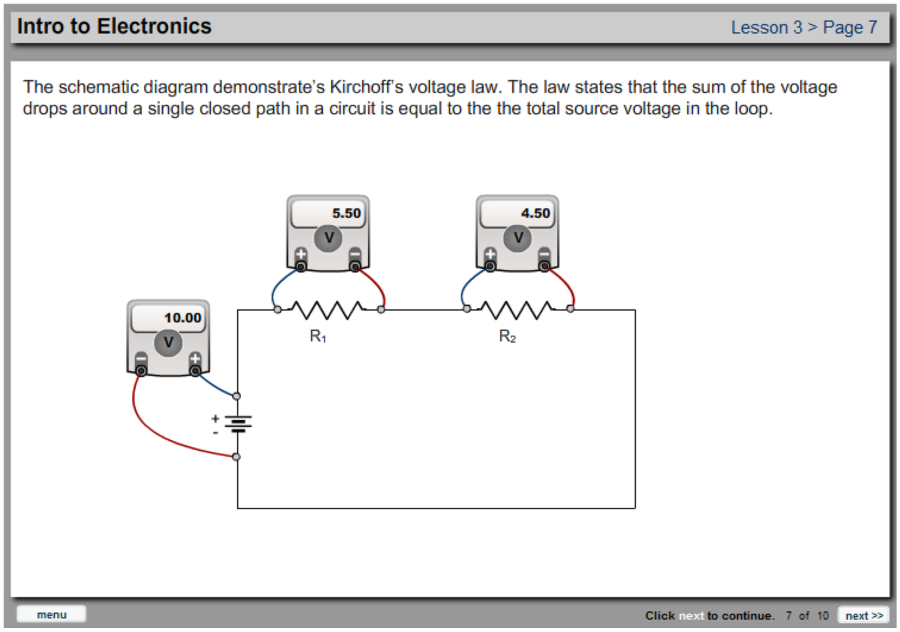

Figure 3.1: Example of a non-cued split attention effect condition.

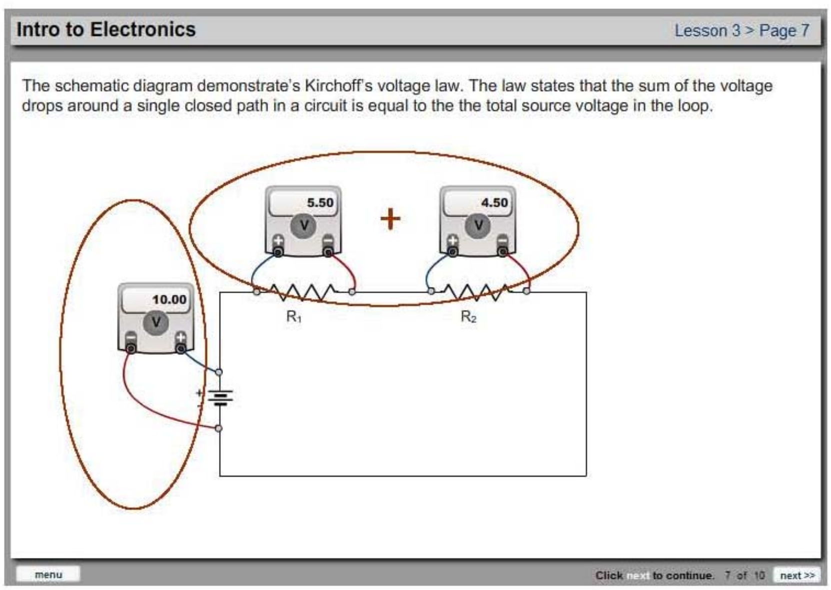

Figure 3.2: Example of a cued split attention effect condition.

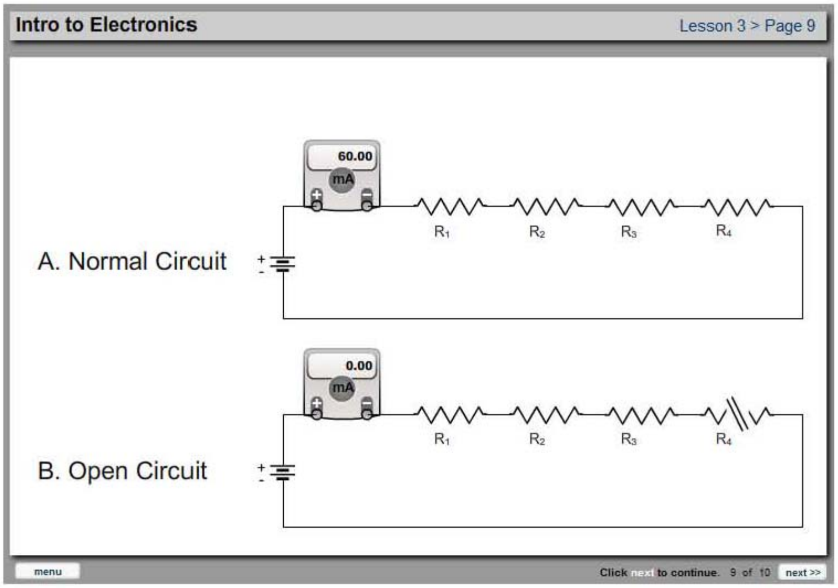

Figure 3.3: Example of a non-cued modality effect condition.

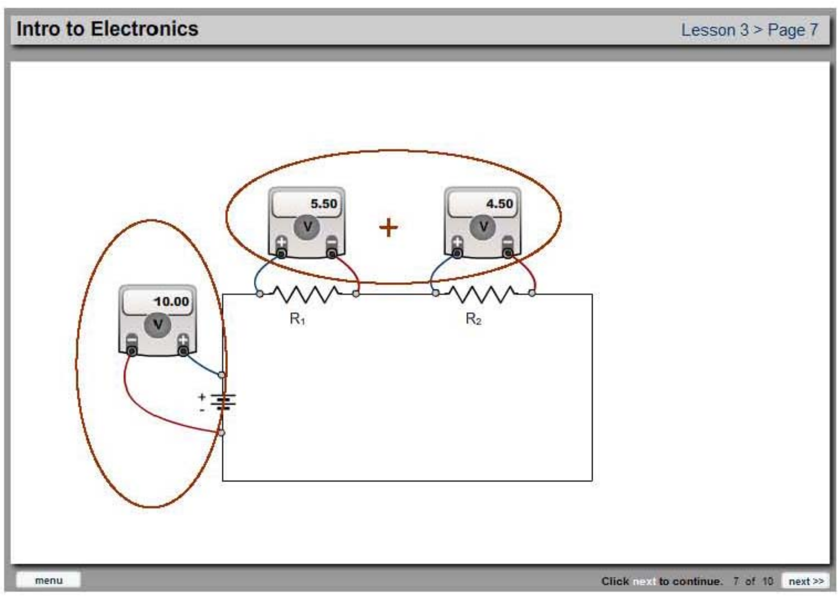

Figure 3.4: Example of a cued modality effect condition.

Figure 3.3 and 3.4 depict the modality effect although narration cannot be shown within this document.

SSI and NASA-TLX Instruments Methodology

The current research used two rating scale assessment techniques: the SSI and NASA-Task Load Index (TLX), to assess levels of cognitive load. This research approach of using both SSI and NASA-TLX was used based on the research by Windell, 2006) which demonstrated that the SSI and TLX had different sensitivities to cognitive load. The reason for this is that the SSI rating scale is based on prior research that the assumption is a safe and reliable one in learning tasks. People can reliably provide accurate mental burden ratings (Gopher & Braune, 1984) presenting the individual with one or more dimensions, anchored at either end with an extreme descriptor of that dimension; and that these scales are sensitive to small changes in overall load (Gimino, 2002; Paas, van Merrienboer, & Adam, 1994). See Paas, et al. (2003) for a comprehensive list of studies.

Differences between the two assessment techniques are not trivial (1 question SSI versus 6 question NASA-TLX along with pair-wise comparisons), but should be noted that all participants in the current study completed five distinct learning modules as well as the multidimensional NASA-TLX, including the associated paired comparison, and the Short Subjective Instrument (SSI).

NASA-TLX Methodology

NASA-TLX overall was seen as the most effective measures of perceived workload and cognitive workload. Based on a multi-year research program to validate the NASA-TLX, the team used the subjective evaluation of 10 workload-related factors obtained from 16 different experimental tasks. The experimental tasks included such aspects as simple cognitive and manual tasks as controls and complex laboratory and supervisory tasks and aircraft simulation. Based on this extensive research, the NASA-TLX multi-dimensional rating scale came into use based on the concept that the magnitude and sources of six common workload factors are combined to come up with a reliable estimate of the perceived workload (Hart & Staveland, 1988). The goal was to be able to validate the methodology behind the NASA-TLX and to understand the relevancy of using a framework to relate imposed task and incidental subjective workload experiences and formal workload evaluation as a measure that could be used across a variety of activities to measure both human performance and workload. The study was based on an understanding of how subjects perceive workload across a wide variety of simple cognitive and manual tasks. The results were able to provide sufficient data to formulate the reliability and validity data for using NASA-TLX using a multi-dimension rating scale and to derive the reliability and validity data for NASA-TLX.

The a priori weighting evaluation in Table 3.2 below was based on a loading of each factor and the correlations between ratings and overall workload (OW) and the correlations ratings of the scale and OW ratings resulted in the following findings:

Table 3.2 Correlational *Data for the NASA TLX*

	Weight	Loading	Correlation with OW
Time Pressure	4.75	.09	.60
Task Difficulty	4.50	.55	.83
Mental Effort	4.36	.21	.73
Overall Performance	3.95	-.02	.50
Stress Level	4.56	.10	.62
Frustration	4.51	.01	.40
Fatigue	3.56	.01	.30
Activity Type	3.60	.01	.30
Physical Effort	2.21	.07	.52

From Hart & Staveland (1988)

Within the same overall study, the findings provided a reliability index of overall workload (test-retest correlation = .83) based on a scale from (0-100) (Hart & Staveland, 1988). A variety of other statistical analysis methods were used to demonstrate the effectiveness, including analyses of variance and correlations among measures of workload and performance, multiple correlations among individual rating scales and coefficients of variation (SD/Mean) for overall weighted workload and sensitivity tests were conducted to compare the percentage of variance (SD/Mean) accounted for by overall workload.

In other research, reliability and test validity data verified that NASA-TLX was considered to be one of the most effective measures of perceived workload currently (Nyugren, 1991). Since NASA-TLX is considered a subjective scale, there is always some question as to whether self- reporting accurately reflects respondent’s true perceptual experience.

When compared to other subjective assessment techniques (e.g. SWAT, Cooper-Harper scale), studies showed that the NASA TLX is favored by most participants, when compared to other subjective workload assessment techniques such as SWAT and Cooper-Harper scale) and was highly correlated with other measures of workload (Battiste & Bortoussi, 1988; Hill, et al., 1992; Byers, et al., 1988). NSA-TLX reliability for repeated measures of different types of workload has shown correlations of 0.77 (Battiste & Bortoussi 1998). Separately, the reliability and validity of subjective workload assessment technique and NASA-TLX using two mental workload assessments, (e.g. SWAT and NASA TLX) using randomized cluster sampling was conducted. Reliability retest coefficients for SWAT was more than 0.80 and as for NASA-TLX; the split-half reliability and alpha coefficient was more than 0.80 with both scales having good inner consistency. (Zhonghua,et al, 2005)

The NASA Task Load index (NASA-TLX) is used to assess levels of cognitive load. Since its creation in the 1980's, this assessment technique has incorporated six different dimensions of workload measurement: mental demands, physical demands, time demands, frustration, effort, and own performance. Experimenters are given the ability to weight each dimension in order to get an overall workload measurement that is task specific. The NASA-TLX mental demands subscale is well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000). The NASA-TLX uses a robust measurement technique and has been shown to be more sensitive than the short subjective instrument (SSI) test for variations in load across multiple combinations of extraneous load and intrinsic load (Windell, 2006). The NASA Task Load index (NASA-TLX) test instrument that was used can be found in Appendix B. Additionally, simple spreadsheets were used to record the results from the NASA-TLX, and the researcher, was then able to calculate the NASA-TLX weighted work load index. While the NASA-Task Load Index (NASA-TLX) instead incorporates six different dimensions of work load measurement and experimenters are given the ability to weight each dimension so that the overall workload measurement is task specific. The weights are determined from a set of relevance ratings provided by the participants. (Windell, 2006). The NASA-TLX mental demands subscale is well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000). The NASA-TLX is a subjective multi-dimensional workload technique. An overall workload rating is determined from a weighted combination of scores on the six dimensions. The weights are determined from a set of relevance ratings provided by the participants. Use of the TLX requires two steps. First, participants rate each task performed on each of the six subscales: Mental demand, Physical demand, Temporal demand, Performance, Effort, Frustration level to derive an overall workload score based on a weighted average of the ratings. They are measured in scales of 0 to 100. Secondly, participants must perform 15 pair-wise comparisons of six workload scales. The number of times each scale is rated as contributing more to the workload of a task is used as the weight for that scale. The ratings and weights are then combined to calculate a weighted average for an overall workload score. Mean weighted workload of six subscales was used as an overall workload rating. Three of the subscales relate to the demands imposed on the subject (mental, physical and temporal demand) while the other subscales focus on the interaction of the subject with the task (performance, effort and frustration level) (Sohn & Jo, 2003).

Short Subjective Instrument (SSI) Methodology

Short Subjective Instrument Methodology was first introduced by Paas and published in an article in 1992 which appeared in the publication Journal of Educational Psychology. SSI remains the most widespread measure of working memory load within cognitive load theory research. In Paas' initial introduction of SSI methodology, he notes that the scale was based on a measure of perceived task difficulty modified but originally devised by Bratfisch, Borg, and Dornic's scale (Paas, 1992) for measuring perceived task difficulty. In the Paas' (1992) study, what was considered the golden standard, a Spearman rank order correlation of 0.9, was obtained between objective and subjective task difficulty. In the same study, the reliability of the scale was estimated with Cronbach's coefficient alpha. For the condition-independent instructional problems, a coefficient of reliability of .90 was obtained.

In Paas, et al. (1994), they note that the SSI scale's reliability and sensitivity and moreover its ease its ease of use have made this scale and variants of it, the most widespread measure of working memory load within Cognitive Load Theory research. Rating Scales, although introspective, rely on the idea that people are able to give accurate ratings on mental burden. Prior research has shown that this assumption is a safe and reliable one in learning tasks (Gopher & Braune, 1984) and that subject can introspect on their cognitive processes with no difficulty in assigning numerical values to the imposed mental load or the invested mental effort. Semantic differential scales present the individual with one or more dimensions, anchored at either end with an extreme descriptor of that dimension with a range of options falling in between, usually using a seven or nine point scale. Scales using semantic differential technique are relatively sensitive to small changes in overall load (Gimino, 2002;

Paas, van Merrienboer, & Adam, 1994) and results can often be similar to objective techniques (Moray, 1982). Such semantic differential scales have been used in numerous studies to assess cognitive load in past research. See Paas, et al. (2003) for a comprehensive list of studies.

Most semantic differential questions asked how difficult the task was, and respondents were to rate the task as 1, extremely easy, through 7, extremely difficult. This scale is referred to as the Short Subjective Instrument or SSI for this study. The Short Subjective Instrument (SSI) test instrument that was used for this study can be found in Appendix A. This scale (Paas et al, 1994) and its reliability and sensitivity and ease of use measures only overall load and does not attempt to give a measurement that allows designers to parse out the cause of cognitive load, i.e. what combination of extraneous, intrinsic, and germane load created the overall load. Semantic differential scales have been used in numerous studies to assess cognitive load in past research. Semantic differential scales present the individual with one or more dimensions, anchored at either end with an extreme descriptor of that dimension with a range of options falling in between.

Newer studies typically refer to the reliability and sensitivity data from the initial studies such as Paas, 1992) but use different scales with fewer categories and different labeling related to task difficulty. These revised studies make enough differences that there remain concerns that changes in the studies are not sensitive enough to measure the performance effort properly and may neglect performance efforts such as requiring different amounts of effort to produce that performance’s standard. (Paas, et al, 2003). This means that often the reliability and sensitivity data for these adapted scales were not reported and that the reliability and sensitivity of these adapted scales need to be reestablished. Another factor that may have been neglected in the measurement of cognitive time and calculation of mental efficiency is time on task and Paas continues to maintain that further study is needed when these deviations are used in a study. (Paas, et al, 2003).

Procedures of the Study

Prior to entering the experiment, participants were randomly assigned to one of the four experimental conditions outlined above. Upon entering the lab, students were greeted and asked to fill out an informed consent form. The informed consent form that was used in this study can be found in Appendix C. The experimenter then asked the students to fill a demographic information sheet and explained to the students that the higher scoring participants were entered into a raffle for a gift card from a department store worth one hundred dollars. The experimenter then will tell the students that those withdrawing prior to completing the study were given participation credit and their data will not be used for the final analysis. The experimenter will inform the students that if they need to take a break that they can, if needed, during the study. Following this procedure, the participants were handed a CD containing all the different learning conditions for the study.

Students started the CD on their computer and started Learning Module 1. After each learning module, the participant answered a set of test questions pertaining to the content of that module, and then filled out both the Short Subjective Instrument and the NASA-TLX 6-sub-scale instruments. When the students were finished, they were instructed to continue with Learning Module 2. After completion of the last dependent measure for Learning Module 5 (SSI and NASA-TLX), students completed the NASA-TLX pair wise comparison, which immediately followed the last Learning Module 5 questions, the SSI, and the NASA-TLX.

After the completion of the experiment, the experimenter debriefed the participant, answered any questions pertaining to the research, and offered to point students to results following the completion of the research. Students then returned to their seats until the class time is over. Those that choose not to participate in the study were assigned a different task in the classroom.

Data Analysis

This study was a 2 x 2 x 5 mixed method model design with two Cueing Conditions (cued, non-cued) between subjects, two Design Conditions (split attention effect, modality effect) between subjects, and five levels of module difficulty within subjects as shown in Figure 3.1 to Figure 3.4 above. (These figures depict Learning Modules 1-5). As you can see from Figure 3.1 through Figure 3.4, the first condition “A” was a split-attention effect that is not cued; “B” was a modality effect that is not cued and uses auditory narrations; condition “C”, which was a split-attention effect that is cued; and the last condition was “D” which is a modality effect that is cued and uses auditory narrations.

Multiple dependent variables were analyzed: SSI score, NASA-TLX weighted workload score, and the Module Test taken after each learning module.

A two-way mixed-model factorial analysis of variance (ANOVA) was conducted for each dependent variable—SSI, NASA-TLX weighted workload scale, and the knowledge test for each module— across the independent variable factors of Cueing Condition(between-subjects independent variable), Design Condition (between-subjects independent variable) and Learning Module (within-subjects independent variable). Results from each dependent variable were plotted and compared to other dependent measures.

Here are the hypotheses reiterated:

1a. The student's total cognitive load should be lower in the modality effect conditions relative to the split attention effect condition.

1b. The student's total cognitive load should be lower in the cued conditions relative to the non-cued conditions.

2a. The modality effect condition test scores will only be higher than the split attention effect condition for the more difficult instructional modules.

2b. The cued condition test scores will only be higher than the non-cued condition for the more difficult instructional modules.

3. The lowering of cognitive load due to cueing should be greater for the split attention effect condition than the modality effect condition.

For the analysis of hypotheses 1a, we ran a two-way mixed-model factorial analysis of variance (ANOVA) with the independent variables being Design (split attention, modality), Cueing (cued and non-cued), and Module (1-5), and the dependant variable being SSI/NASA-TLX. The assumption for the hypothesis is that Design was significant with no significant interactions. In the analysis of hypotheses 1b, using the same ANOVA, the assumption is that Cueing was significant with no significant interactions.

For the analysis of the hypotheses 2a, we will run a two-way mixed-model factorial analysis of variance (ANOVA) with the independent variable being Design (split attention, modality), Cueing (cued and non-cued), and Module (1-5), and the dependant variable being the pre-test/post-test Module Test difference score. The assumption for the hypothesis is that Design was significant with no significant interactions. A post hoc Bonofferi test was conducted with the assumption that the only significant differences are between Modules 4 and 5 and the earlier modules. In the analysis of hypotheses 2b, using the same ANOVA and post-hoc testing, the assumption is that Cueing was significant with no significant interactions.

For the analysis of hypotheses 3, the ANOVA from hypothesis 1 was used to test for an interaction between Design and Cueing.

Prior to hypothesis testing, descriptive statistics was used to ensure against missing or mis-entered data points (i.e., outliers). All data categories were tested for missing data points or outliers. If outliers are found, appropriate steps for data correction was made prior to hypothesis testing.

A two-way mixed-model factorial analysis of variance (ANOVA) was run for each dependent variable—SSI, NASA-TLX weighted workload scale, and the knowledge test for each module— across the independent variable factors of Cueing Condition(between-subjects independent variable), Design Condition (between-subjects independent variable) and Learning Module (within-subjects independent variable). Results from each dependent variable was plotted and compared to other dependent measures.

Results from the mixed-model ANOVAs were used to test the hypotheses. If significant interaction is found between Cueing Condition, Design Condition or Learning Module and a significant main effect for Learning Module is found, post hoc contrast tests was conducted to test for significance between individual levels of the significant variable without collapsing the other independent variable(s). If no significant interaction is found but a significant main effect is found, then the testing was done with the independent variable collapsed across levels. If significant main effects for Cueing or Design Condition are found, a similar analysis strategy was taken.

Chapter 4: Presentation and Discussion of Data

Preliminary Analyses

Preliminary analyses examined the variability of scores on the dependent variables, and the prevalence of missing data. The present sample would not provide an adequate test of the hypotheses if scores on the dependent variables fall within a restricted range because the assessments are too easy or too difficult for the sample as a whole. As shown in Table 4.2, the standard deviation of the scores on the dependent variables suggest that performance on these tasks varied as one might expect among subjects in the present sample. None of the measures had more than five missing data points in all data categories, they were also tested for outliers, and no extreme values were found.

Table 4.1: Demographics

Gender	**Male**	**Female**									
	116	22									
Age	**Under 18**	**18-19**	**20-21**	**22-23**	**24-25**	**26-27**	**28-29**	**30-31**	**32-33**	**34-35**	**36-38**
	0	64	44	20	2	0	1	2	1	2	1
Major	**Computer Science**	**Wood Products**	**Textile Engr.**	**Aerospace**	**TED**	**Graphics Comm.**	**Elec. Engr.**	**Civil Engr.**	**ACR**	**Mech. Engr.**	**Ind. Engr.**
	1	2	7	15	10	8	2	24	1	40	1
	IND. Design	**Economics**	**Environmental Engr.**	**Nutrition**	**Physics**	**Undecided**	**Chemical Engr.**	**Construction Engr.**	**Mathematics**	**Landscape Architecture**	**Computer Engineering**
	1	1	4	1	1	1	4	3	2	1	1
	Engineering	**Biological Engr.**	**Computer Science**	**Bio Medical**	**Business Management**						
	3	1	1	1	1						
Have you previously taken any high school or college courses in basic electronics?							**Yes**	**No**			
							77	61			
If yes, please list course(s):			**Physics**	**Robotics**	**TED-359**	**ECE-200**	**Computer Classes**	**ECE-206**	**Basic Electronics**	**Digital Electronics**	**ECE-331**
			55	1	8	3	4	1	4	1	2
Do you feel you have a better understanding of basic electronics after completing today's study?						**Yes**	**No**				
						92	45				
Prior to today's session, what was your interest level in basic electronics?						**None**	**Slight**	**Moderate**	**Heavy**		
						20	68	49	2		
After today's session, what is your interest level in basic electronics?						**None**	**Slight**	**Moderate**	**Heavy**		
						17	65	54	2		

Table 4.2: Statistics for SSI, NASA-TLX and TEST for All Learning Modules

	SSI		NASA-TLX		TEST	
Module	Mean	SD	Mean	SD	Mean	SD
Module 1	2.61	1.04	33.02	16.14	.84	.12
Module 2	3.88	1.16	47.48	19.69	.74	.17
Module 3	3.86	1.01	46.51	19.41	.74	.15
Module 4	4.49	1.23	54.19	19.98	.54	.18
Module 5	4.86	1.38	57.76	21.34	.61	.22

Main Analyses

The main analyses of the present study utilized a 2 x 2 x 5 mixed method Analysis of Variance (ANOVA) model to test the hypotheses proposed earlier using PROC MIXED on SAS v9.1. This ANOVA model contained two between-subjects factors: Cueing Conditions (cued versus non-cued), and Design Conditions (split attention effect versus modality effect). The specific levels of Cueing and Design were shown earlier in Figures 3.1, 3.2, 3.3, and 3.4 above. The within-subject factor, Learning Module (LM), contained five levels of module difficulty. Levels of the between-subjects factors are crossed with one another in the following manner (Table 3.1): Condition, A is a split-attention effect that is cued, Condition B is a split-attention effect that is not cued, Condition C, which uses auditory narrations, is a modality effect that is cued, and Condition D is a modality effect that is not cued.

If a significant interaction was found between Cueing Condition, Design Condition or Learning Module (LM), post hoc contrast tests were conducted to test for the significance between individual levels of the significant variable without collapsing the other independent variable(s). If no significant interaction was found but a significant main effect was found, then the testing was done with the independent variable collapsed across levels. If significant main effects for Cueing or Design Condition were found, a similar analysis strategy was taken. The two-way mixed-model factorial analysis of variance (ANOVA) and follow-up tests were run for each dependent variable—SSI, NASA-TLX weighted workload scale, and the Knowledge Test, using Type III fixed effects. The results for each dependent variable are presented below:

Analysis of the SSI

The results of the ANOVA for the SSI are presented in Table 4.2. The main effect of Learning Module was statistically significant (F = 120.46; df = 4, 289; p < .001). The main effects of Design (F = .14; df = 1, 140; p= .24) and Cue (F = .96; df = 1,140; p= *.96.)* failed to attain statistical significance. The two-way interaction between Cue and Learning Module was not statistically significant (F = 2.2; df = 4, 289; p=.07. The two-way interactions of Cue by Design (F = .59; df = 1, 140; p=.44), and Design by Learning Module (F = 2.6; df = 1, 289; p =.034) attained statistical significance. The three-way interaction of Cue by Design by Learning Module (F = 1.78; df = 4,289; p=.13) also failed to attain statistical significance.

Table 4.3: SAS PROC MIXED ANOVA Results for Fixed Effects Short Subjective Instrument (SSI)

Source	Num DF	Den DF	F	p
Cue	1	140	.964	.964
Design	1	140	.142	.236
LM	4	289	120.46	< .001*
Cue × Design	1	140	.59	.444
Cue × LM	4	289	2.22	.067
Design × LM	4	289	2.65	.034*
Cue × Design × LM	4	289	1.78	.133

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

Because of the nature of the learning task and the fact that the five learning modules were presented in the same order (1, 2, 3, 4, 5) to all participants, a set of orthogonal contrasts was used to compare successive pairs of learning modules to determine where significant differences occurred. Results are shown in Table 4.3, along with means and standard deviations for SSI scores for each module (Table 4.4). Mean SSI score increased significantly from Module 1 to Module 2, as well as from Module 3 to 4 and Module 4 to 5. There was no difference in mean scores between Modules 2 and 3. Overall, participants' perceived load increased as they moved from Module 1 (beginning of the study) to Module 5 (end of the study).

Table 4.4: Orthogonal Contrasts for Significant Main Effect of Learning Module on SSI

Contrast	Num DF	Den DF	F	p
Mod 1 vs. Mod 2	1	467	246.43	< .001*
Mod 2 vs. Mod 3	1	467	.08	.775
Mod 3 vs. Mod 4	1	468	58.13	< .001*
Mod 4 vs. Mod 5	1	468	24.26	< .001*

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

Table 4.5: Mean SSI Scores by Learning Module

Learning Module	N	Mean	SD
Module 1	142	2.61	1.04
Module 2	142	3.88	1.16
Module 3	142	3.86	1.01
Module 4	141	4.49	1.23
Module 5	140	4.86	1.38

To explore the interaction effect, the same orthogonal contrast procedure was performed for the five modules within each of the two levels of Design, yielding similar patterns of results as noted in the main effect of module, except that Modules 4 and 5 were not found to be significantly different for the split attention group (Figure 4.1). Further, Tukey pairwise comparisons were performed between the two levels of design within each module. Only Module 5 showed a significant difference between designs, F (1,298) = 7.17, p = 0.008. The modality group had a significantly higher mean SSI score (M = 5.15, SD = 1.35) than the split attention group (M = 4.60, SD = 1.35).

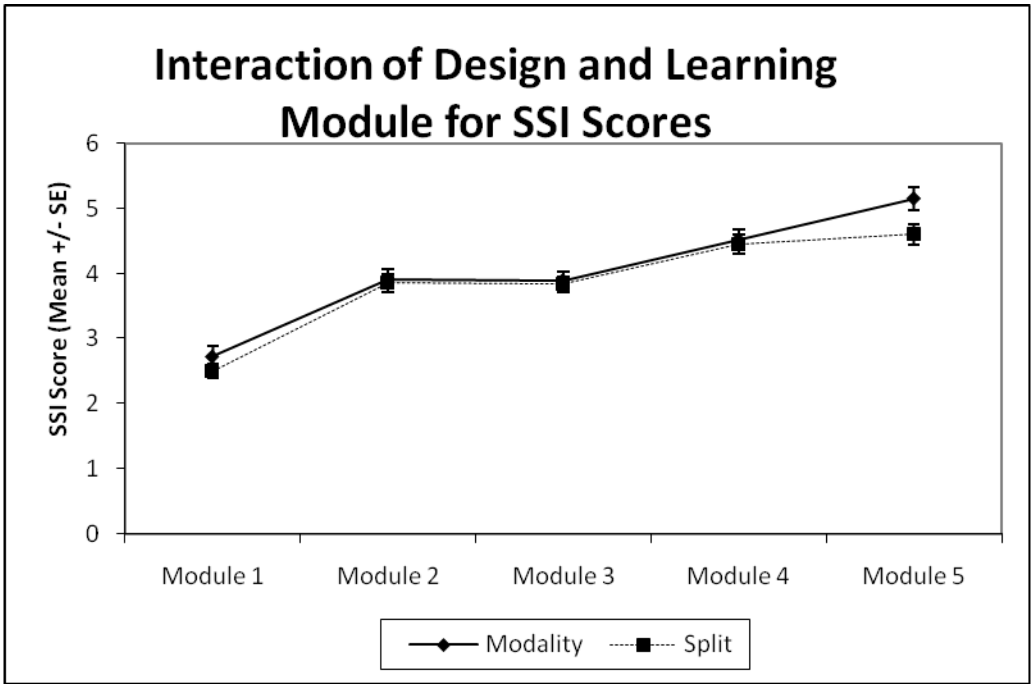

Figure 4.1: Comparing SSI Mean to Learning module under each design condition

Analysis of the NASA-TLX

A mixed-model ANOVA was carried out using PROC MIXED on SAS v9.1 and run for each NASA-TLX subscale dependent variable, Frustration, Effort, Performance, and Mental Demands, across independent variables of Cue (cued, non-cued) and Design (split attention, modality). The within subject independent variable was LM. The dependent variable was NASA-TLX score.

The results of the ANOVA for the NASA-TLX are presented in Table 4.5. Significant main effects were found for Design (*F* = 5.14; *df* = 1,140; *p* = .025) and Learning Module (*F* = 72.70; *df* = 4, 273; *p* < .001). The main effect for Cue was not significant (*F* = .21; *df* = 1, 140; *p*=.545). None of the two-way or the three way interactions between Design, Cue, or Learning Module were statistically significant.

Table 4.6: SAS PROC MIXED ANOVA Results for TLX

Source	Num DF	Den DF	F	p
Cue	1	140	.21	.644
Design	1	140	5.14	.025*
LM	4	273	72.70	< .001*
Cue × Design	1	140	.05	.826
Cue × LM	4	273	1.10	.355
Design × LM	4	273	.08	.990
Cue × Design × LM	4	273	.31	.873

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

In order to interpret the significant main effects for Learning Module, post-hoc orthogonal contrasts between each level of Learning Module were conducted, with Bonferonni adjustments for multiple comparisons. As shown in Table 4.6, successive Learning Modules had higher TLX scores. As with SSI scores, a set of orthogonal contrasts was used to compare successive pairs of learning modules to determine where significant differences occurred. Mean TLX score increased significantly from Module 1 to Module 2, as well as from Module 3 to 4 and Module 4 to 5 (Figure 4.2). There was no difference in scores between Modules 2 and 3. Overall, perceived mental load increased as participants moved from Module 1 (the beginning of the study) to Module 5 (the end of the study). The separation of the lines shows the main effect of Design while the fact that they are nearly parallel shows that there is no significant interaction between Design and Learning Module.

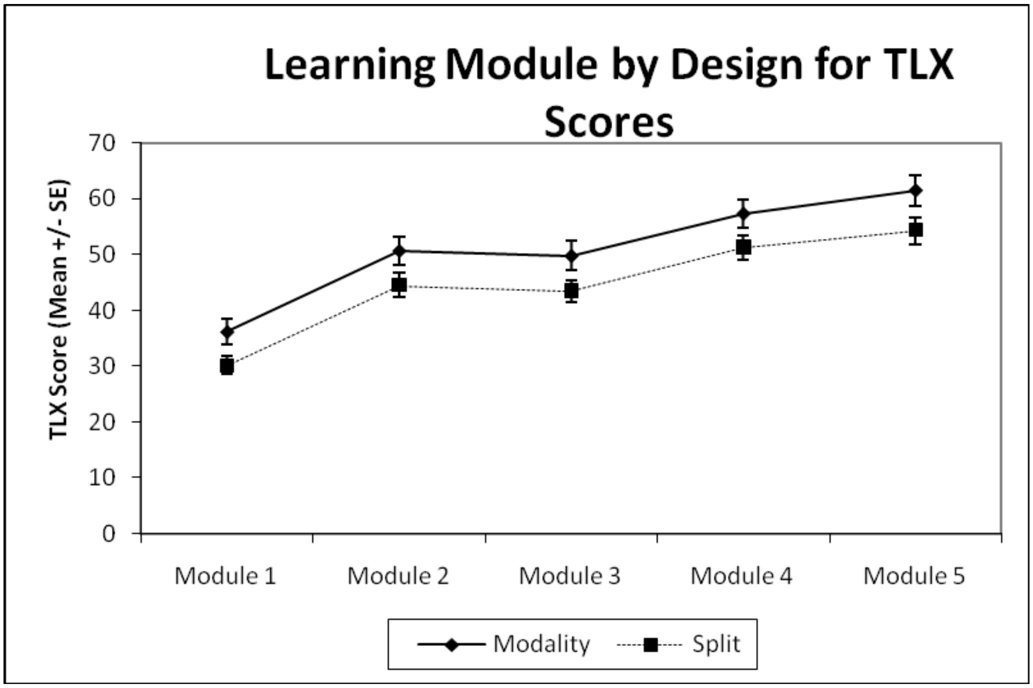

Figure 4.2: Comparing NASA-TLX Mean to Learning module under each design condition

Table 4.7: Orthogonal Contrasts for Significant Main Effect of Learning Module on TLX

Contrast	Num DF	Den DF	F	p
Mod 1 vs. Mod 2	1	447	163.56	< .001*
Mod 2 vs. Mod 3	1	445	.74	.390
Mod 3 vs. Mod 4	1	445	46.19	< .001*
Mod 4 vs. Mod 5	1	445	10.13	.002*

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

Table 4.8: Mean TLX Scores by Learning Module

Learning Module	N	Mean	SD
Module 1	137	33.02	16.14
Module 2	137	47.48	19.69
Module 3	137	46.51	19.41
Module 4	137	54.19	19.98
Module 5	137	57.76	21.34

Analysis of the Knowledge Test

A mixed-model ANOVA was carried out using PROC MIXED on SAS v9.1. Between subjects independent variables were Cue (cued, non-cued) and Design (split attention, modality). The within subject independent variable was LM (or learning module, with five levels). The dependent variable was Test score. The results of the ANOVA for the NASA-TLX are presented in Table 4.8 which shows the main effect for Learning Module was statistically significant (F = 89.03; df = 4, 286; p < .001). The main effects for Design (F = 1.11; df = 1, 137; p=.29) and Cue (F = .37; df = 1, 137; p=.55) failed to attain statistical significance. None of the two-way or the three way interactions between Design, Cue, or Learning Module was statistically significant.

Table 4.9: SAS PROC MIXED Results for Test

Source	Num DF	Den DF	F	p
Cue	1	137	.37	.545
Design	1	137	1.11	.294
LM	4	286	89.03	< .001*
Cue × Design	1	137	1.71	.194
Cue × LM	4	286	.83	.506
Design × LM	4	286	1.88	.114
Cue × Design × LM	4	286	.75	.561

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

In order to interpret the significant main effects for Learning Module, post-hoc contrasts between each level of Learning Module were conducted, with Bonferonni adjustments for multiple comparisons. As shown in Table 4.9, orthogonal contrasts were used for follow-up, as with the previous two dependent variables. Mean test score significantly decreased from Module 1 to Module 2 (F= 36.42; df=1,429; p=<.001), remained the essentially the same from Module 2 to Module 3, significantly decreased from Module 3 to Module 4 (F= 153.80; df=1,431; p=<.001), and then significantly increased from Module 4 to Module 5 (F= 16.93; df=1,430; p=<.001) (Figure 4.3). While not formally tested, the standard errors of the means suggest that Module 5's mean is still significantly less than Module 3's mean. While there is no significant main effect for Design or interaction between Design and Learning Module, the graph in Figure 4.3 shows the Split-Attention Test scores being lower than the Modality Effect Test scores for Modules 4 and 5.

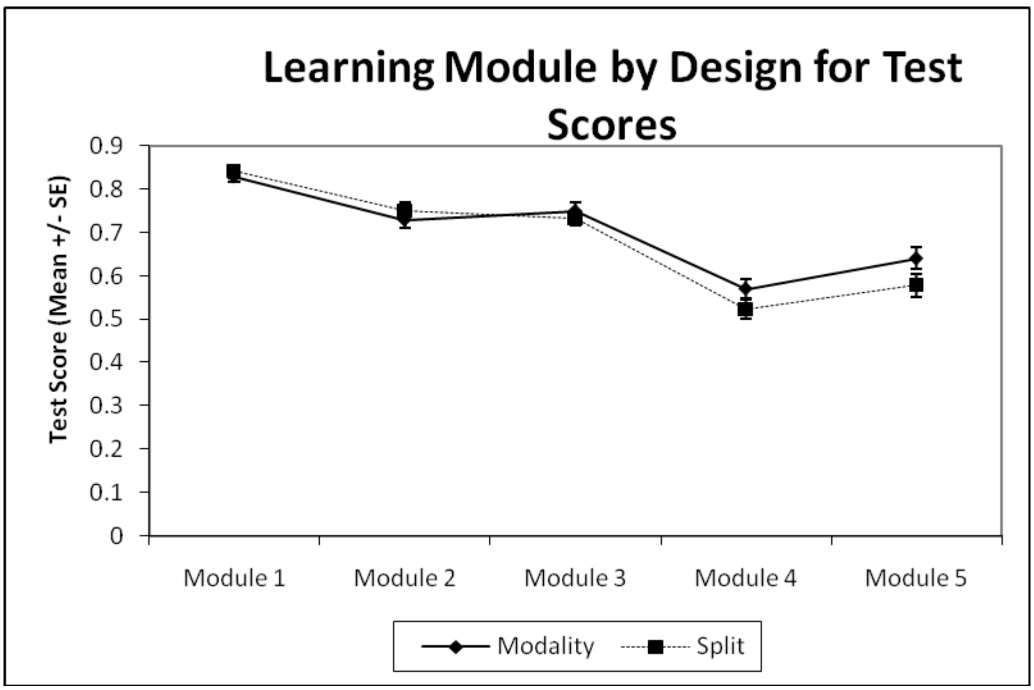

Figure 4.3: Comparing Test Mean to Learning module under each design condition

Table 4.10: Orthogonal Contrasts for Significant Main Effect of Learning Module on Test

Contrast	Num DF	Den DF	F	p
Mod 1 vs. Mod 2	1	429	36.42	< .001*
Mod 2 vs. Mod 3	1	429	.02	.892
Mod 3 vs. Mod 4	1	431	153.80	< .001*
Mod 4 vs. Mod 5	1	430	16.93	< .001*

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

Table 4.11: Mean Test Scores by Module

Learning Module	N	Mean	SD
Module 1	142	.84	.12
Module 2	142	.74	.17
Module 3	142	.74	.15
Module 4	141	.54	.18
Module 5	140	.61	.22

Support for Hypotheses

Hypothesis 1a stated that the student's total cognitive load should be lower in the modality effect conditions relative to the split attention effect condition. Specifically, this hypothesis predicted a significant main effect for Design with no interaction. Contrary to this hypothesis, in the present study, there was no main effect of Design (Modality vs Split Attention) on SSI, but there was a main effect of Design on TLX. The modality group had a higher mean TLX; the reverse of the hypothesis. Hypothesis 1a is not supported.

Hypothesis 1b stated that the student's total cognitive load should be lower in the cued conditions relative to the non-cued conditions. This hypothesis would receive support if Cueing had a significant main effect with no interaction. Contrary to this hypothesis, there was no main effect of Cue on either SSI or NASA-TLX, so the hypothesis is not supported.

Hypothesis 2a stated that, in the modality effect condition, scores on the SSI and NASA-TLX will only be higher than the split attention effect condition for the more difficult instructional modules. If Hypothesis 2a is true, then there should be a significant two-way interaction between Design and Learning Module. Partially supporting this hypothesis, there is a significant interaction between Design and LM for SSI. However, only for Module 5 was there a difference between Design groups —the Modality group was higher, which partially contradicts the hypothesis.

Hypothesis 2b stated that, in the cued condition, scores would be higher than the non-cued condition only for the more difficult instructional modules. If Hypothesis 2b is true, then there should be a significant two-way interaction between Cueing and Learning Module. This interaction effect was not significant for the SSI or the NASA-TLX. The interaction of Cue and Learning Module for the SSI is approaching significance but was not statistically significant (p-value = 0.067). There were no follow-ups done, so the nature of the slight interaction is unknown.

Hypothesis 3 proposed that the lowering of cognitive load due to cueing should be greater for the split attention effect condition than the modality effect condition. This hypothesis implies a significant two-way interaction between Design and Cueing. However, contrary to this hypothesis, the interaction of Design by Cueing was not significant for the SSI or the NASA-TLX. Thus, Hypothesis does not receive support from the findings of the present study.

Chapter 5: Conclusions and Recommendations

Statement of the Problem

When dealing with multimedia instructions or tutorials, there is a problem of information overload when using these methods of delivery (Sadoski & Paivio, 2004). Without the proper testing and methods for designing these types of presentation, the students or the audience may likely experience cognitive overload, reducing the effectiveness of the instructions and tutorials. Cognitive overload is the result of excessive demands made on the cognitive processes, especially memory. Visual cueing shows promise as a means to reduce cognitive overload and enhance learning as cited by Tabbers, Martens, & Merrienboer, (2004).

Technology educators have been limited in available research that specifically provides guidance to improve their use and effectiveness of multimedia in the Technology Education classroom specifically. Some of the research seems to point to the possibility that cueing does reduce cognitive overload. Some of the research seems more ambiguous or theory based. This study offers insight into the design of Technology Education materials to better address cognitive overload. Lowering cognitive load is an important means of improving student learning experiences.

This research into the effect of different combinations of cueing can be interpreted in ways that will improve the Technology Education student's experience. The questions asked in this study offer a more complete understanding of whether or not we can lower cognitive load through specific cued conditions to help guide Technology Education learners to which information has been pre-determined by instructional specialists to be important. The findings can be used to better design materials, to lower total cognitive load, and to improve student test scores all of which meet the needs of our students.

Significance of the Study

The significance of this study is to better understand the use of different cueing and other techniques and to see if cueing can help guide Technology Education students to the most important information. This will also help address multimedia and its use specifically with Technology Education students. It is also designed to move beyond theory and to research hands-on instructional activities with typical students to prove that certain multimedia interventions reduce cognitive load and make learning more efficient when presenting technical information.

Conclusions

This study successfully builds on past research by both re-affirming some of the central tenets of cognitive load theory (Tabbers, Martens, & Merrienboer, 2000) while highlighting some of the areas in need of further research. In this study, the assumption was that the student's total cognitive load should be lower in the modality effect (Mayer, 2001), conditions relative to the split attention effect condition.

Both the SSI and NASA-TLX instruments were used to test cognitive load and because of the limitations cited by Windell (2006) related to solely using the SSI test instrument.

Contrary to our hypothesis, there was no main effect of Design (Modality vs. Split Attention) on SSI, but there was a main effect of Design on NASA-TLX (Gopher & Braune, 1984, Windell, 2006). The modality group had a *higher* mean NASA-TLX – the reverse of the proposal hypothesis (Xie & Salvendy, 2000) which was not expected and there was not enough previous testing of this type in past documented research. While these subscales are well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000), neither scale was sensitive enough because the learning modules did not include enough complexity because either the test instruments were limited to 5 or the complexity load was not added significantly by the time we got to learning modules 4 and 5. The reason for this is that the students that were used in this study were engineering students from the GC-120 (graphic communication) classes. The initial assumptions were this material had sufficient complexity that it would demonstrate our hypothesis. However, as the study showed, highly educated students were more familiar with the split-attention effect from the use of textbooks in their classes from high school through college. The addition of two more complex learning modules than those used in the study would have increased cognitive load up to the maximum NASA-TLX and SSI. Within this study, by learning module 5, cognitive load had only reached 50% of the scale for SSI and NASA-TLX.

The assumption was made that the student's total cognitive load should be lower in the cued conditions relative to the non-cued conditions. (Gimino, 2002; Paas, van Merrienboer, & Adam, 1994) From the data analysis, there was no main effect of Cue on either SSI or NASA-TLX, so the hypothesis is not supported. The reason for this is that by the time the students get to Learning Module 5, their cognitive load on the SSI mean and the NASA-TLX mean were only at half the scale of these tests, which demonstrates that the study should have added two more learning modules of extreme difficultly to increase the cognitive load to the maximum scale of the test. This might have more clearly demonstrated the effects of cueing in reducing cognitive load.

The next assumption was that the modality effect condition test scores will only be higher than the split attention effect condition for the more difficult instructional modules. From the data analysis of the Test scores, there is a significant interaction between Design and Learning Module for SSI. Only for Module 5 was there a difference between Design groups – the Modality group was higher, which partially contradicts the proposal hypothesis. The reason for this is that students are used to the split-attention effect that occurs from the habit of using textbooks in their classes from high school through college, and partly because the cognitive load for Learning Module 5 for the SSI mean is only 4.86, and for the NASA-TLX mean are only 57.76. Windell (2006) demonstrated that the SSI and NASA-TLX had different sensitivities to cognitive load. Results from his study demonstrated that the NASA-TLX differs in measurements of the demands faced by learners in a multimedia environment versus the single-questions short subjective instrument.

The findings of this study demonstrates that better results would have been seen if we were able to correct deficiencies in the test instruments resulting in significantly increasing cognitive load to the extreme. The initial assumption was we did not need additional learning modules but the study results demonstrate that we did not increase cognitive load enough to fully see the benefits. When cognitive load is at its maximum is when we will see more of a response to cognitive load in the modality effect.

The next assumption we made was that in the cued condition, scores will be higher than the non-cued condition only for the more difficult instructional modules. Contrary to this hypothesis, the interaction of Cue and LM is approaching significance but was not statistically significant (*p*-value = 0.067).

This interaction was not statistically significant for the SSI or the NASA-TLX means for the current study. In this study, the SSI mean was higher in the cued condition only in Learning Module 5; and only in the modality effect suggesting that we cannot argue that the impact of cueing on cognitive load are greater with more difficult materials. Lastly we made the assumption that the lowering of cognitive load due to cueing should be greater for the split attention effect condition than the modality effect condition. From the data analysis, there is no interaction between Design and Cueing. From this present study, this was not significant to the SSI mean or the NASA-TLX mean, and only was it significantly higher in Learning Module 5, and only in the modality effect; suggesting that the effects of cueing on cognitive load may be greater with more difficult materials. While these subscales are well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000), neither scale was sensitive enough because not enough complexity was built into the 5 test instruments.

In the interaction of cueing and the split attention effect from the data analysis, a significantly higher score in the SSI mean occurred in the cued condition than in the non-cued condition. However, contrary to this hypothesis, the interaction of Design by Cueing was not significant for the SSI and the NASA-TLX. Thus, this hypothesis does not receive support from the findings of the present study.

In the data analysis for Test mean score in Learning Module-5 is significantly higher in the Split-attention effect than in the non-cued condition, and runs almost parallel to the cued condition in Learning Modules 1-4. The test scores for the modality condition are opposite with the cueing condition being higher than the non-cued condition. The NASA-TLX mean are also significantly higher in the cued condition than in the non-cued condition and progressively increases in Learning Modules 4-5 as cognitive load is increased in the manipulation of the Learning Module materials. The interaction of cueing and the modality effect from the data analysis shows a significantly higher SSI mean in the cued condition; only in Learning Module 5. Test scores, however, did not move in relation to load scores as they did with manipulations in the intrinsic load. Instead, test score movement, though not significant, seemed to decrease as cognitive load increased for the more difficult modules. The NASA-TLX mean in the Modality effect is significantly higher in the cued condition than in the non-cued condition, but only in Learning Module 5, and runs parallel with each other in Learning Module 1-4. While these subscales are well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000), neither scale was sensitive enough because we were not able to test with enough complexity because we limited the test instruments to 5 tests.

Limitations

Several limitations must be recognized to appropriately frame the results presented here. In using a subject pool from a limited group within a single university, the researcher's demographics were skewed to a particular age group and a particular assumption of prior knowledge in the subject matter. Subjects used for future research should more adequately reflect the focus population and should be tested for prior knowledge of the subject matter reflected in the designed materials.

As well the researcher, having limited resources used self-designed questions and test materials which were not pre-tested and that, therefore, may have lacked validity. This limitation often occurs because technology education teachers frequently author their own tests, lack sufficient training in test development, fail to properly analyze tests, and do not establish reliability or validity (Haynie, 1992). One specific example was the test items were all multiple choice items which often brings serious flaws when teachers develop their own test (Haynie, 1990). Another limitation was that there may have not been enough of a difference between the cued and non-cued designs for the cognitive load instruments to pick up the difference. There was only very limited pilot testing because of the time and availability of test subjects. Future research should carefully include proper pilot testing of the instructional materials being used to ensure that differences in cognitive load (if any) can be detected.

A related limitation, as mentioned in the conclusions, is that neither scale employed was sensitive enough because the learning modules did not include enough complexity (i.e., element interactivity), primarily in Modules 4 and 5. Better piloting might have resulted in this problem being identified and addressed but was not possible given the researcher's limited time and resources. This limitation could have been addressed by adding additional learning modules but, in this case, adding to the test time which was not feasible because the research could only be done within a specific scheduled class with a scheduled instructor. Another option would have been to make each successive module increasingly more difficult. Both of these modifications would be based on pilot results using the cognitive load and test measures.

While the SSI and NASA-TLX subscales are well recognized as a standard for measuring mental workload (Xie & Salvendy, 2000), neither scale was sensitive enough because the researcher was not able to test with enough significant complexity to fully be able to accurately test what happens when severe cognitive load complexity is reached. This limitation became critical in not being able to prove the study hypotheses.

Finally, another limitation was that the testing was based on a researcher-designed content knowledge test that may have lacked corresponding validity or reliability data (Haynie, 1992). The researcher's self-designed tests had not been fully tested, validated, or vetted as a reliable test instrument. This means that a test that is not reliable cannot be valid. In order to make a valid consensus of our findings, the test questions needed further testing and review using outside resources or with test subjects prior to going forward with the testing. Pre-testing and analysis would have identified a potential flaw in the research questions which could then have been changed to add additional complexity or difficulty to reach the desired result of increased cognitive load.

Recommendations for Further Research

No previous studies were found that tested for the use of cueing in the modality effect and the split attention effect. Studies were found that discussed cueing in general such as for computer programs but nothing that tied to its use in delivering multimedia materials or tutorials. It is clear that NASA-TLX reveals different sensitivities to cognitive load (Windell, 2006) than the SSI and the NASA-TLX. Also the NASA-TLX was shown to have much more sensitivity across changes in cognitive load subclasses (Windell, 2006) but unfortunately severe cognitive load was not elicited during this set of testing modules. This is the basis for future research in this area.

The result of this study helps reinforce findings of previous research and the guidance it provides in the design of multimedia materials and tutorials. It points to the importance of attention to design and use of different media elements as the difficulty and the complexity of the material increases. This study also supports the contention that the embedded assessments of cognitive load may be useful in the management of the way that we deliver this type of instructional material. This study does not provide a clear cut guide as to how cueing should be used in tutorials or different types of instructional materials from a statistical standpoint, because we were not able to reach a maximum mental work load (Xie & Salvendy, 2000). Neither scale was sensitive enough because we were not able to test with enough complexity to reach severe cognitive load

However the literature does provide a clear cut guide for the use of cueing in multimedia materials and tutorials. This study does hint at the impact it has on both cognitive load and learning along with its interaction with different design conditions presented in this study. Based on the research findings, the following recommendations for further research can be made.

1. That this present research be duplicated with the design conditions but with the addition of more complex test modules plus the addition of two more difficult modules; with greater complexity; and use NASA-TLX as it is more sensitive to cognitive load. This could be done in a future study to clarify the impact of cueing and its interaction with graphics, text, and narration.

2. To research this study to find out why that there was no significant interaction between the Design condition and the SSI mean and the Design condition in the NASA-TLX mean in this present study.
3. To identify a more valid approach to writing the test questions and testing the validity of the results.
4. To research this study to find out why the Test mean did not move in relation to load scores as they did with manipulations in the intrinsic load. Instead, test score began to get lower as the cognitive load increased but not specifically enough because we were not able to produce a high enough cognitive load.
5. To research this study to find out why cognitive load in the split attention effect was not greater than in the modality effect when using cues, unlike what was supported in the literature review.
6. To find out whether using students with different backgrounds or less exposure to electronics or complex materials in textbooks during their high school and early college years would bring similar results.
7. Further research is needed to investigate use of other types of cueing instead of solely using highlighting; such as arrows, different colors, and sound or combination of visual and audible cueing.

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Appendices

Appendix A: Short Subjective Instrument (SSI)

This Instrument was given to all participants following the completion of each Learning Module test.

Short Subjective Instrument
Roberts Dissertation 2007
Circle the number that best describes your experience today
How difficult was it for you to understand this learning module and correctly answer the questions that followed?
Extremely Easy Extremely Difficult
1------------2------------3------------4------------5------------6------------7

Appendix B: NASA Task Load index (TLX)

This Instrument was given to all participants following the completion of each Learning Module NASA-TLX pair wise comparisons were given following the completion of each Learning Module.

NAME	TASK	DATE

TASK LOADING INDEX

Mental Demand — How mentally demanding was the task?

Very Low ... Very High

Physical Demand — How physically demanding was the task?

Very Low ... Very High

Temporal Demand — How hurried or rushed was the pace of the task?

Very Low ... Very High

Performance — How successful were you in accomplishing what you were asked to do?

Perfect ... Failure

Effort — How hard did you have to work to accomplish your level of performance?

Very Low ... Very High

Frustration — How insecure, discouraged, irritated and annoyed were you?

Very Low ... Very High

AFOTEC FORM JUL 94 SAH-10

NASA- Task Load indeX
Paired Comparison
Instructions- Select the member of each pair that provided the most significant source of work to you in today's tasks (circle your answer)

Physical Demand	or	Mental Demand
Temporal Demand	or	Mental Demand
Performance	or	Mental Demand
Frustration	or	Mental Demand
Effort	or	Mental Demand
Temporal Demand	or	Physical Demand
Performance	or	Physical Demand
Frustration	or	Physical Demand
Effort	or	Physical Demand
Temporal Demand	or	Performance
Temporal Demand	or	Frustration
Temporal Demand	or	Effort
Performance	or	Frustration
Performance	or	Effort
Effort	or	Frustration

Appendix C: Informed Consent Form, Regulatory Compliance Exemption, IRB Application

North Carolina State University

INFORMED CONSENT FORM for RESEARCH

Principal Investigator- Edward Roberts   Faculty Sponsor- Dr. Eric Wiebe

We are asking you to participate in a research study. The purpose of this study is gain a better understanding of the best way to present information to learners in a multimedia learning environment

INFORMATION

If you agree to participate in this study, you will go through 5 learning modules. Following this you will answer a few questions to display what you learned. You will also be asked to give the researchers some demographic information about yourself.

RISKS

There are no foreseeable risks or discomforts associated with this study.

BENEFITS

This study aims to give you (the participant) a better understanding of basic electronics, ohm's law, series, and parallel circuits. In addition, your participation in this study will allow the researchers to gain a better understanding on the design and implementation of multimedia education materials.

CONFIDENTIALITY

The information in the study records will be kept strictly confidential. Data will be stored securely in electronic format and physical forms will be destroyed following data analysis. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION (if applicable)

For participating in this study the higher scoring participants will be entered into a raffle for a gift card from Best Buy worth one hundred dollars. If you withdraw from the study prior to its completion, you will still receive participation credit.

CONTACT

If you have questions at any time about the study or the procedures, you may contact the researcher, Edward Roberts, at 919.571.3208. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. David Kaber, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Mail Stop 7514, NCSU Campus (919/ 515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION

Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

CONSENT

"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

Subject's signature____ Date _________________

Investigator's signature___________________________________ Date _________________

NC STATE

Date: **March 15, 2007**

Project Title: **The Use of Cueing in Multimedia Instructions in Technology Education as a Way to Reduce Cognitive Load, and Improve the Transfer of Knowledge**

IRB#: **96-07-3**

Dear Mr. Roberts:

The research proposal named above has received administrative review and has been approved as exempt from the policy as outlined in the Code of Federal Regulations (Exemption: 46.101.b.1). Provided that the only participation of the subjects is as described in the proposal narrative, this project is exempt from further review.

Sincerely,

Debra Paxton NCSU IRB

North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research

Submission for New Studies

Title of Project: The use of cueing in multimedia instructions in Technology Education as away to reduce cognitive load, and improve the transfer of knowledge.

Principal Investigator Department MSTE
William Edward Roberts

Source of Funding (**required** information): No funding required

(if externally funded include sponsor name and university account number)
Campus Address (Box Number) 7801
Email: eroberts9@nc.rr.com Phone: 919-571-3208 Fax:

RANK: ☐ Faculty
☒ Student: ☐Undergraduate; ☐ Masters; or ☐ PhD ☒ Ed.D.
☐ Other (specify): ______

As the principal investigator, my signature testifies that I have read and understood the University Policy and Procedures for the Use of Human Subjects in Research. I assure the Committee that all procedures performed under this project will be conducted exactly as outlined in the Proposal Narrative and that any modification to this protocol will be submitted to the Committee in the form of an amendment for its approval prior to implementation.

Principal Investigator:

Wm. Edward Roberts William Edward Roberts 3/5/07
(typed/printed name) (signature) (date)

As the faculty sponsor, my signature testifies that I have reviewed this application thoroughly and will oversee the research in its entirety. I hereby acknowledge my role as the ***principal investigator of record****.*

Faculty Sponsor:

Dr. Eric Wiebe Eric N. Wiebe 3/5/07
(typed/printed name) (signature) (date)

PLEASE COMPLETE IN DUPLICATE AND DELIVER, ALONG WITH A PROPOSAL NARRATIVE, TO:

Institutional Review Board, Box 7514, or email as an attachment to debra_paxton@ncsu.edu

****

For SPARCS office use only

Reviewer Decision (Expedited or Exempt Review)

☐ Exempt ☐ Approved ☐ Approved pending modifications ☐ Table

Expedited Review Category: ☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5 ☐ 6 ☐ 7 ☐ 8a ☐ 8b ☐ 8c ☐ 9

____

Reviewer Name Signature Date

North Carolina State University
Institutional Review Board for the Use of Human Subjects in Research
GUIDELINES FOR A PROPOSAL NARRATIVE

In your narrative, address each of the topics outlined below. Every application for IRB review must contain a proposal narrative, and failure to follow these directions will result in delays in reviewing/processing the protocol.

A. INTRODUCTION

1. Briefly describe in lay language the purpose of the proposed research and why it is important.

   The current research is concerned with studying the design of multimedia instructional materials and how material design factors affects two measures of mental effort. This study aims to look at the interaction between the use of visual cues to key pieces of information and the use of narration. In doing so, the researchers hope to better understand how to design multimedia instructional materials in ways that optimize learning.

   The study will have different groups of undergraduate students use multimedia instructional materials to learn about electronic circuits over five modules. Four different groups of students will receive one of the following multimedia design conditions: sequential presentation of text and then graphics with no visual cues and no narration; sequential presentation of text and graphics with visual cues in the graphics and no narration; graphics with narration and no visual cues; or graphics with narration and visual cues. Both mental effort and learning will be measured with self-report instruments.

2. If student research, indicate whether for a course, thesis, dissertation, or independent research.

   This research is for my doctoral dissertation research.

B. SUBJECT POPULATION

1. How many subjects will be involved in the research?

   Four sections of students with approximately twenty-four plus students per class for a total of up to ninety-six students, enrolled in the GC-120 Foundations of Graphics will participate in this study.

2. Describe how subjects will be recruited. Please provide the IRB with any recruitment materials that will be used.

   We are recruiting students from the GC120 classes.

3. List specific eligibility requirements for subjects (or describe screening procedures), including those criteria that would exclude otherwise acceptable subjects.

   There is no specific eligibility requirements for subjects.

4. Explain any sampling procedure that might exclude specific populations.
5. Disclose any relationship between researcher and subjects - such as, teacher/student; employer/employee.

   There is no relationship between the researcher and the subjects. The GC120 sections are taught by instructors other than the researchers.

6. Check any vulnerable populations included in study:

minors (under age 18) - if so, have you included a line on the consent form for the parent/guardian signature

fetuses

pregnant women

persons with mental, psychiatric or emotional disabilities

persons with physical disabilities

economically or educationally disadvantaged

prisoners

elderly

students from a class taught by principal investigator

other vulnerable population.

If any of the above are used, state the necessity for doing so. Please indicate the approximate age range of the minors to be involved.

C. PROCEDURES TO BE FOLLOWED

1. In lay language, describe completely all procedures to be followed during the course of the experimentation. Provide sufficient detail so that the Committee is able to assess potential risks to human subjects.

Prior to the start of the study, the instructor for each of the four sections will announce to the subjects that the study will take place during their next class period. The consent form will be handed out and explained and students allowed to decide whether they want to participate.

During the class period when the study will take place, students who have agreed to participate will receive a CD containing one of four randomly assigned experimental conditions outlined section A. Those students not participating in the study will be allowed to do alternate work during the experiment.

Students participating in the study will start their CD where they will have an opportunity to review the consent form and that the top 10% scoring participants will be entered into a drawing for a $100 gift card from Amazon. After this, they will start the first learning module. At the completion of each learning module, students will answer a short test about the information contained in the lesson. Immediately following, participants will fill out both the (SSI) Short Subjective Instrument and the NASA-TLX. When the students are finished, they are instructed to continue on to the next learning module. After completion of Learning Module 5, students will complete the NASA-TLX pair wise comparison and a short demographic questionnaire.

After the completion of the experiment, the experimenter will debrief the participant, answered any questions pertaining to the research, and offer to point students to results following the completion of the research. Students then return back to their regular class `

3. How much time will be required of each subject?

The experiment lasted approximately 1 hour.

D. POTENTIAL RISKS

1. State the potential risks (physical, psychological, financial, social, legal or other) connected with the proposed procedures and explain the steps taken to minimize these risks.
   There are no potential risks connected to this study.
2. Will there be a request for information which subjects might consider to be personal or sensitive (e.g. private behavior, economic status, sexual issues, religious beliefs, or other matters that if made public might impair their self-esteem or reputation or could reasonably place the subjects at risk of criminal or civil liability)?
   No.
   a. If yes, please describe and explain the steps taken to minimize these risks.
3. Could any of the study procedures produce stress or anxiety, or be considered offensive, threatening, or degrading? If yes, please describe why they are important and what arrangements have been made for handling an emotional reaction from the subject.
   No.
4. How will data be recorded and stored?
   a. How will identifiers be used in study notes and other materials?
      There will be no identifiers that can link results to individual students in this study and the entire process will be confidential. Instructors will keep a separate list of students who would like to receive results of the study. The researchers will keep the research data on a password protected computer.
   b. How will reports will be written, in aggregate terms, or will individual responses be described?
      There will be no individual responses described or written.
5. If audio or videotaping is done how will the tapes be stored and how/when will the tapes be destroyed at the conclusion of the study.
   No audio or video will be done.
6. Is there any deception of the human subjects involved in this study? If yes, please describe why it is necessary and describe the debriefing procedures that have been arranged.
   There will be no deception of any humans involved in this study.

E. POTENTIAL BENEFITS

This does not include any form of compensation for participation.

1. What, if any, direct benefit is to be gained by the subject? If no direct benefit is expected, but indirect benefit may be expected (knowledge may be gained that could help others), please explain.
   There are two main benefits expected from this research. This study aims to give the participant a better understanding of basic electronics, the types circuits that are involved, and their workings in electronics. In addition, student participation in this study will allow the researchers to gain a better understanding about the design and implementation of multimedia education materials. The Graphic Communication and Technology Education programs are investigating increased use of multimedia instruction and this study will help inform decisions on who these materials should be designed.

F. COMPENSATION

1. Explain compensation provisions if the subject withdraws prior to completion of the study.
   The top 10% scoring participants will be entered in a raffle for a gift card from Amazon worth one hundred dollars. Students withdrawing prior to completing the study will not have their data used for the final analyses. The purpose of this award is to encourage best effort on the part of the study participant. Students who do not complete the study will not be eligible for this award.
2. If class credit will be given, list the amount and alternative ways to earn the same amount of credit.

G COLLABORATORS

1. If you anticipate that additional investigators (other than those named on **Cover Page**) may be involved in this research, list them here indicating their institution, department and phone number.
   None other than those named on the cover page.

3. Will anyone besides the PI or the research team have access to the data (including completed surveys) from the moment they are collected until they are destroyed
   No one else will access to the data other then the PI or the research team.

H. ADDITIONAL INFORMATION

1. If a questionnaire, survey or interview instrument is to be used, attach a copy to this proposal.
2. Attach a copy of the informed consent form to this proposal.
3. Please provide any additional materials that may aid the IRB in making its decision.

Appendix D: IRB Consent

North Carolina State University
INFORMED CONSENT FORM for RESEARCH

Principal Investigator- Edward Roberts Faculty Sponsor- Dr. Eric Wiebe

We are asking you to participate in a research study. The purpose of this study is gain a better understanding of the best way to present information to learners in a multimedia learning environment

INFORMATION
If you agree to participate in this study, you will go through 5 learning modules on principles of electronics. Following each module you will answer a few questions to measure how much mental effort you expended and what knowledge you have gained from each module. Further more you will also be asked to give the researchers some demographic information about yourself participation in this study is not a mandatory part of your class, and that an alternate educational activity will be offered instead to those who do not participate in the research.

RISKS
There are no foreseeable risks or discomforts associated with this study.

BENEFITS
This study aims to give you (the participant) a better understanding of basic electronics, ohm's law, series, and parallel circuits. In addition, your participation in this study will allow the researchers to gain a better understanding on the design and implementation of multimedia education materials.

CONFIDENTIALITY
The information in the study records will be kept strictly confidential. Data will be stored securely in electronic format and physical forms will be destroyed following data analysis. No reference will be made in oral or written reports which could link you to the study.

COMPENSATION (if applicable)
For participating in this study the top 10% scoring participants will be entered into a raffle for a gift card from Amazon worth one hundred dollars. Participants in this study will not be eligible for the raffle if they withdraw from the study.

CONTACT
If you have questions at any time about the study or the procedures, you may contact the researchers, Edward Roberts, at 919.571.3208 or Eric Wiebe at 919.515.1753. If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. David Kaber, Chair of the NCSU IRB for the Use of Human Subjects in Research Committee, Mail Stop 7514, NCSU Campus (919/ 515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148)

PARTICIPATION
Your participation in this study is voluntary; you may decline to participate without penalty. If you decide to participate, you may withdraw from the study at any time without penalty and without loss of benefits to which you are otherwise entitled. If you withdraw from the study before data collection is completed your data will be returned to you or destroyed at your request.

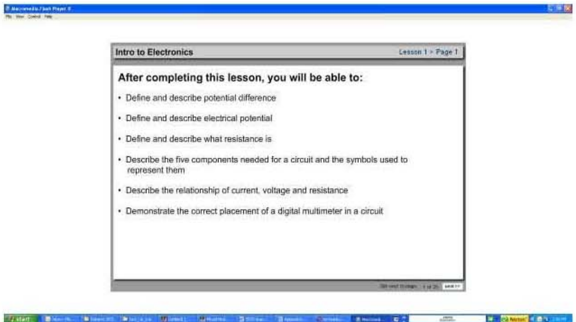
CONSENT
"I have read and understand the above information. I have received a copy of this form. I agree to participate in this study with the understanding that I may withdraw at any time."

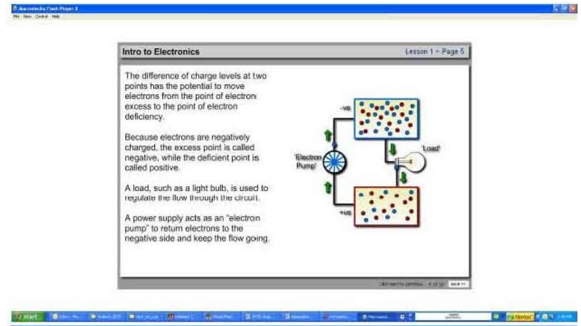
Subject's signature____ **Date** _________________

Investigator's signature____________________________________ **Date** _________________

Appendix E: Screen captures of Design condition A (Non-Cued Split Attention Effect) Learning Modules 1-5

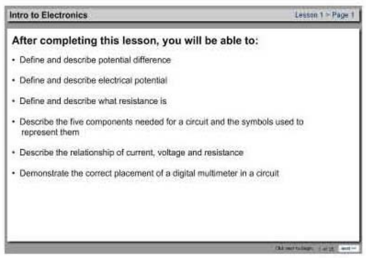
Learning Module-1

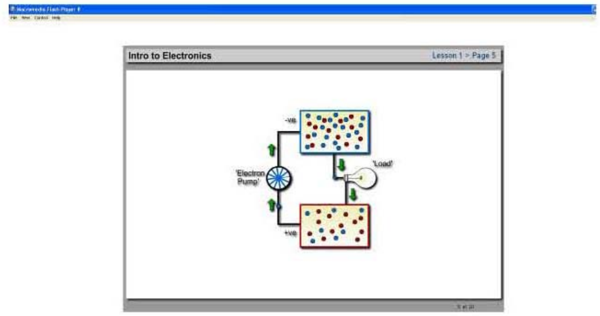




Appendix F: Screen captures of Design condition B (Non-Cued, Modality Effect) Learning Modules 1-5

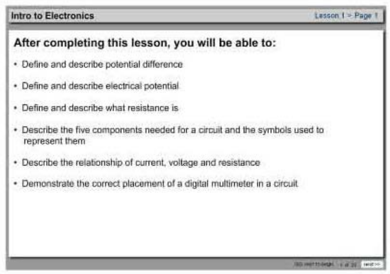
Learning Module-1

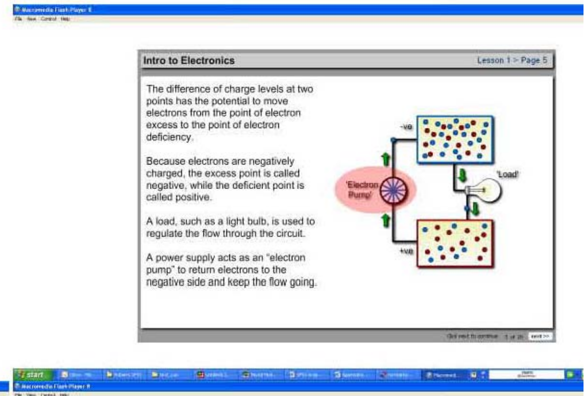


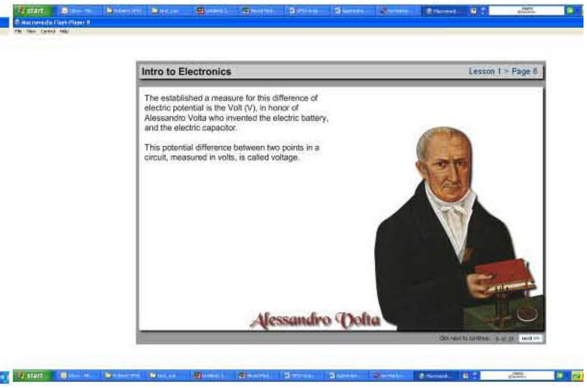


Appendix G: Screen captures of Design condition C (Cued, Split Attention Effect) Learning Modules 1-5

Learning Module-1







Appendix H: Screen captures of Design condition D (Cued, Modality Effect) Learning Modules 1-5

Learning Module-1