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Evaluating User Modality Preference Effect On Cognitive Load In A Multimedia

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ABSTRACT

Scott, Justin. M.S., Purdue University, May, 2010. Evaluating User Modality Preference Effect on Cognitive Load in a Multimedia. Major Professor: La Verne Abe Harris.

Meaningful learning is defined as a deep understanding of the material, which includes attending to important aspects of the presented material, mentally organizing it into a coherent cognitive structure, and integrating it with relevant existing knowledge (Mayer & Moreno, 2003). Mayer and Moreno (2003) defines multimedia learning as learning from words and pictures, and multimedia instruction as presenting words and pictures that are intended to foster learning. The emergence of numerous learning style models over the past 25 years has brought increasing attention to the idea that students learn in diverse ways and that one approach to teaching does not work for every student or even most students (Hawk & Shah, 2007). Various studies attempting to understand the relationship between personality and academic achievement have concluded that this relationship is moderated by both learning and teaching style (Furnham, 1992). The goal of this study is to analyze several methods of using words and pictures to effectively present information for meaningful learning.

CHAPTER 1. INTRODUCTION

This chapter provides a brief introduction into the background and overview of this thesis. This chapter introduces the reader to the problem statement, scope, significance of the problem, research question, assumptions, limitations and delimitations of the research.

1.1. Background

The active processing assumption states that meaningful learning requires a substantial amount of cognitive processing to take place in the verbal and visual information processing channels (Mayer, 2003).This assumption is central to Wittrock's (1989) generative-learning theory and Mayer's (1999, 2002) selecting-organizing-integrating theory of active learning.

Limitations in working memory, as identified by Miller (1956), Baddeley (1992), Sweller (1994), and Sweller, van Merrienboer and Paas, (1995), show that only a few elements of information can be processed in working memory at a time, and that too many elements may overburden working memory, decreasing the effectiveness of processing – a situation called *cognitive overload* (Mayer & Moreno, 2003). In contrast to working memory, an unlimited number of elements can be held in long-term memory in the form of hierarchically organized schemas, which permit us to treat multiple sub-elements of information as a single element categorized according to the manner in which it will be used (Kalyuga, Chandler & Sweller, 1999). Schemas not only allow us to store learned information in long-term memory but, because multiple elements of information are treated as a single element in working memory, schemas also reduce the burden on working memory (Kalyuga, Chandler & Sweller, 1999).

As a consequence of this architecture, any increase in information processing not directly related to the acquisition of new schemas inevitably consumes part of the available work memory capacity, decreasing resources available for learning (Kalyuga, Chandler & Sweller, 1999). Sweller (1994), Sweller, van Merienboer and Paas (1995), and Mayer and Moreno (2003) incorporating schema acquisition and cognitive load theory developed a number of instructional procedures designed to optimize limited working memory. The theory assumes that information presented to learners and the activities required of them should be structured to eliminate any avoidable load on working memory and to maximize the acquisition of new schemas (Kalyuga, Chandler & Sweller, 1999).

1.2. Problem Statement

The cognitive load of a multimedia can be minimized by having the display of information match the preferred way in which a user likes to receive and process information.

1.3. Significance

Multimedia learning is a learning situation in which words and pictures are presented. A potential problem is that the processing demands evoked by the learning task may exceed the processing capacity of the cognitive system. This ever-present potential for cognitive overload is a central challenge for instructors (including instructional designers) and learners (including multimedia learners) because meaningful learning often requires substantial cognitive processing using a cognitive system that has limits on cognitive processing (Mayer & Moreno, 2003).

1.4. Solution

This study proposes to duplicate an interactive science multimedia on lightning formation for the instructional tool, and analyze: (1) the subjective ratings of mental load reported, (2) the test performance scores from the matching questionnaire, and (3) the Visual. Aural, Read/Write, and Kinesthetic scores obtained from the VARK Learning Styles Inventory.

By matching the display of information to the modality preferences of the user the processing demands of the learning task will be minimized allowing for more germane processing of the subject matter.

1.5. Research Question

When a user's modality preference coincides with a multimedia's display of information will perceived mental load decrease, while gain scores increase?

1.6. Assumptions

The assumptions for this study will include:

1. The test instruments will be the same for each subject.
2. The participants will remain anonymous during the study.
3. The participants are proficient in computer usage.
4. The participants are fluent in English.

1.7. Limitations

The following limitations to the investigation are noted:

1. The instructional tool will be developed using Adobe Flash. Flash is a vector or object-based editing software program utilizing geometric shapes and mathematical statements to create design elements.
2. The study will take place during the time listed in the methodology.
3. The subjects will have minimal knowledge of the content of the instructional tool.
4. The subjects will be Purdue University undergraduate students in Computer Graphics Technology.
5. The study will take place in a laboratory setting.

6. Only one subject area, lightning formation, will be used to measure achievement in this study. Generalizations to other subject areas may be limited, even in similar conditions.

1.8. Delimitations

The following delimitations to the investigation are noted:

1. Transfer of information will not be assessed.
2. Although this study is not limited to CGT students, CGT students will be the only ones tested during this study.

1.9. Terminology

Cognitive Overload: When the processing demands evoked by the learning task exceed the processing capacity of the cognitive system (Mayer & Moreno, 2003)

Multimedia Learning: Learning from words and pictures (Mayer & Moreno, 2003)

Multimedia Instruction: Presenting words and pictures that are intended to foster learning (Mayer & Moreno, 2003)

1.10. Summary

This chapter discusses a brief introduction of the background for this study. The scope, significance, and research questions, assumptions, limitations, and delimitations of the project addressed in this thesis to prepare the reader for Chapter 2, which is the literature review.

CHAPTER 2. LITERATURE REVIEW

The following literature review discusses the following topics:(1) Multimedia Learning, (2) Cognitive Processing, (3) Cognitive Overload, (4) Learning Styles, and (5) the VARK Survey

2.1. The Approach To This Review

The magnitude of literature related to multimedia learning and learning styles is both far-reaching and all encumbering. Exploration started with current theories and practices and slowly traced back through the branches of the tree towards the roots from which they were based. To concisely provide a breadth of coverage while not delving unnecessarily deep into a particular topic principle areas that provided for an entire grasp of the research were highlighted.

2.2. Multimedia Learning Movement

Since 1995, rapid advances in computer and other digital technology, as well as the Internet, have led to a rapidly increasing interest in, and use of, these media for instructional purposes, particularly in training in business and industry. In academia during the first half of the decade, many instructional improvement centers were created with the intent of helping faculty use media and instructional design procedures to improve the quality of their instruction (Gaff, 1975; Gustafson & Bratton, 1984), and In business and industry, many organizations, seeing the value of using instructional design to improve the quality of training, began adopting the approach (Mager, 1997; Miles, 1983). However, there are no proven standard for the development and implication of multimedia learning applications. Without these standards, many different learning tools were implemented ineffectively into the educational community. By researching more established theories on instructional design, it will allow for the development of general design standards for multimedia learning applications.

Research by Mousavi, Low & Sweller (1995) identified working memory limitations as a major factor that needs to be considered when instruction is designed. They used cognitive load theory to suggest that many commonly used instructional procedures are inadequate because they require learners to engage in unnecessary cognitive activities that impose a heavy working memory load. However, recent research by Tabbers, Martens & van Merrienboer (2004) on the influence of presentation format on the effectiveness of multimedia instruction has yielded results indicating that some effects in cognitive load theory do not easily generalize to non-laboratory settings. Further research should be conducted to better identify cognitive load theory's generalizability to non-laboratory settings.

Research done by Branson, Rayner, Cox, Furman, King, & Hannum (1975), Gaff (1975), and Gustafson & Bratton (1984) noted an increasing interest in the use and creation of instructional design in business, academia, and the military. It was also notated by Miles (1983), Chadwick, (1986), Morgan (1989), and Mager (1997) that internationally, during this time, many nations supported the design of new instructional programs, created organizations to support the use of instructional design, and provided support to individuals desiring training in the field of instructional design.

Lewis, Snow, Farris, Levin, and Greene (1999) was concerned with distance learning in the mid to late 1990's and found that between the 1994-95 and 1997-98 academic years, enrollments in distance learning courses in higher education institutions in the United States nearly doubled. Also during this time, Anderson and Ronnkvist (1999) found a significant increase in the amount of technology available in schools in the United States. With 1995 having an average of one computer for every nine students and by 1998 there being one computer for every six students. Moreover, their research also found the percentage of schools that had Internet access increased from 50% in 1995 to 90% in 1998.

Research by Sweller (1999) and Feinberg and Murphy (2000) focused on the demand for web-based instruction and use of distance education via the Internet in higher education. They analyses concluded that distance education via the Internet has been seen as a low-cost method of providing instruction to students who, because of a variety of
factors (e.g., job and family responsibilities, geography), might not otherwise have been able to receive it, and that web-based instruction is in high demand, from both corporations using it for employee training and educational institutions interested in meeting student needs.

According to Mayer (2001), the use of multimedia computers in education has led to the development of all sorts of instructional material in which verbal and non-verbal presentation modes are combined. Unfortunately, educational research has not yet identified how to design effective multimedia instructions. Currently, to meet the demand for web-based instruction, often course lectures or seminars are video-taped and "dumped" into a shell for an instructional web site. Although the original course presentation may have worked successfully for an on-site audience, the presentation and materials may not be the most effective learning materials for web-based instruction (Feinberg & Murphy, 2000). However, two recent lines of research that have yielded some promising results are the work on cognitive load theory by Sweller (1999) and the experiments on multimedia learning carried out by Mayer (2001). Both researchers base their instructional design principles on human cognitive architecture and the way in which the multimedia material is processed.

According to Mayer & Moreno (2003), a central challenge facing designers of multimedia instruction is the potential for cognitive overload—in which the learner's intended cognitive processing exceeds the learner's available cognitive capacity. Chandler and Sweller (1991) addressed this challenge by utilizing cognitive load theory and by focusing on the graphical user interface and multimedia formats of web-based instruction. They surmised that three learning techniques (split-attention effect, the redundancy effect and the modality effect) have direct application in the generation of web-based instruction using multimedia technology.

Mayer and Moreno (2003), and Clark and Mayer (2003) combined previous research done on cognitive load theory to present a general framework for all instructional designs created using multimedia

2.3. Cognitive Modal Model of Learning

Sensory memory deals with incoming stimuli from our senses, including sights, sounds, smells, tastes, and touches. Working memory (previously named short-term memory) is a three-part system (Baddeley, 1992) that includes a central executive system acting as the attention-controlling system, and two slave systems: the visuospatial sketch pad that manipulates visual images, and the phonological loop that stores and rehearses speech-based information (see Figure 2.1). In working memory learning takes place, but working memory has limitations.

Figure 2.1. Baddeley and Hitch Working Memory Model (Baddeley, 1992)

Long-term memory refers to the immense body of knowledge and kills that we hold in a more-or-less permanently accessible form. Everything that we “know” is held in our long-term memory. Long-term memory can contain vast numbers of schemas – cognitive constructs that incorporate multiple elements of information into a single element with a specific function (Paas, Renkl, & Sweller, 2003).

Schemas can be brought from long-term to working memory. Whereas working memory might, for example, only deal with one element, that element may consist of a larger number of lower level, interacting elements. Those iterating elements may far exceed working memory capacity if each element had to be processed. Their incorporation in a schema means that only one element must be processed. A schema is available for this written word along with lower level schemas for the individual letters and further schemas for the squiggles that make up the letters. This complex set of interacting elements can be manipulated in working memory because of schemas held in long-term memory (Paas, Renkl, & Sweller, 2003). The automation of these schemas so that they can be processed unconsciously further reduces the load on working memory. It is by this process that human cognitive architecture handles complex material that appears to exceed the capacity of working memory (Paas, Renkl, & Sweller, 2003).

2.4. Cognitive Load Theory

In the late 1970s and early 1980s, experiments using puzzle problems began to yield disquieting results. Subjects seemed able repeatedly to solve puzzle problems involving transformations and yet remained oblivious to the fact that the problem solutions used all could be described by a very simple rule (Mawer & Sweler, 1982; Sweller, 1983; Sweller & Levine, 1982; Sweller, Mawer, & Howe, 1982). It was concluded that, contrary to common assumptions, there was an incompatibility between learning and problem solving under some circumstances. This result was explained by assuming that, when solving a novel problem by means-ends analysis, attention is directed to the complex mechanics of the means-ends process that is necessary to attain the problem goal, rather than at the relations between previous moves necessary to learn the rule (Sweller & Chandler, 1991). In other words, cognitive resources were directed appropriately from the point of view of solving the problem efficiently, but inappropriately if learning the structure of the problem was a primary aim.

First we begin with three assumptions about how the human mind works based on research in cognitive science. First, the human information-processing system consists of two separate channels. An auditory channel for processing auditory input and verbal representations, and a visual/pictorial channel for processing visual input and pictorial representations (Paivio, 1986)(Baddeley, 1998). This dual-channel assumption is a central feature of dual-coding theory and theory of working memory (Mayer, 2001).

Second, each channel in the human information-processing system has limited capacity with only a limited amount of cognitive processing can take place in the verbal channel at any one time, and only a limited amount of cognitive processing can take place in the visual channel at any one time. This is the central assumption of Chandler and Sweller's (1991;Sweller, 1999) cognitive load theory and Baddeley's (1998) working memory theory.

Third, meaningful learning requires a substantial amount of cognitive processing to take place in both the verbal and visual channels. This is the central assumption of Wittrock's (1989)generative-learning theory and Mayer's (1999, 2002) selecting–organizing integrating theory of active learning.

According to Paas, Renkl, and Sweller (2003) although the information that learners must process varies on many dimensions, the extent to which relevant elements interact is a critical feature. Information varies on a continuum from low to high in element interactivity. Each element of low-element interactivity material an be understood and learned individually without consideration of any other elements. In contrast, the elements of high-element interactivity material can be learned individually, but they cannot be understood until all the elements and their interactions are processed simultaneously. As a consequence, high-element interactivity material is difficult to understand. Element interactivity is the driver of the first category of cognitive load – intrinsic cognitive load (Paas, Renkl, & Sweller, 2003). Different materials differ in their levels of element interactivity and thus intrinsic cognitive load, and they cannot be altered by instructional manipulations; only a simpler learning task that omits some interacting elements can be chosen to reduce the load. The omission of essential, interacting elements will compromise sophisticated understanding may be unavoidable with very complex, high-element interactivity tasks.

As well as element interactivity, 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 so interferes with schema acquisition and automation, it's referred to as an extraneous or ineffective cognitive load (Paas, Renkl, & Sweller, 2003). Many conventional instructional procedures impose extraneous cognitive load because most instructional procedures were developed without any consideration or knowledge of structure of information or cognitive architecture.

Extraneous cognitive load is primarily important when intrinsic cognitive load is high because the two forms of cognitive load are additive. If intrinsic cognitive load is low, levels of extraneous cognitive load may be less important because total cognitive load may not exceed working memory capacity. As a consequence, instructional designs intended to reduce cognitive load are primarily effective when element interactivity is high. When element interactivity is low, designs intended to reduce the load on working memory have little or no effect (Paas, Renkl, & Sweller, 2003).

The last form of cognitive load is germane or effective cognitive load. Like extraneous cognitive load and unlike intrinsic cognitive load, the instructional designer influences germane cognitive load. Instead of working memory resources being used to engage in search, for example, as occurs when dealing with extraneous cognitive load, germane cognitive load results in those resources being devoted to schema acquisition and automation (Paas, Renkl, & Sweller, 2003).

Intrinsic, extraneous, and germane cognitive loads are additive in that, together, the total load cannot exceed the working memory resources available if learning is to occur. The relations between the three forms of cognitive load are asymmetric. Intrinsic cognitive load provides a base load that irreducible other than by constructing additional schemas and automating previously acquired schemas. Any available working memory capacity remaining after resources have been allocated to deal with intrinsic cognitive load can be allocated to deal with extraneous and germane load (Paas, Renkl, & Sweller, 2003).

2.5. Multimedia Learning

Animations are increasingly used in technology-based learning resources because of their assumed superiority over static graphics. However, empirical research has failed to provide evidence for such superiority (Lowe, 2004). In fact, research results support the static media hypothesis, in which static illustrations with printed text reduce extraneous processing and promote deeper processing as compared with narrated animations.

The static media hypothesis can be interpreted with the framework of cognitive load theory (Paas, Renkl, & Sweller, 2003; Sweller, 1999, 2005) and the cognitive theory of multimedia learning (Mayer, 2001, 2005), which hold that the attention of learners is limited. Attention can be used for extraneous processing - cognitive processing that does not foster the instructional objective; intrinsic processing - cognitive processing that involves attending to the key material and relations; and germane processing - cognitive processing that involves deeper processing of key material by mental organization of it into a coherent cognitive representation and integration of it with other representations and prior knowledge (Mayer, Hegarty, Mayer, & Campbell, 2005).

Table 2.1
Cognitive Process (Mayer, Hegarty, Mayer, & Campbell, 2005)

Static illustrations and text help learners:

- Manage intrinsic processing because learners can control the pace and order of presentation (i.e., learner control effect).
- Reduce extraneous processing because learners see only frames that distinguish each major step (i.e., signaling effect).

Table 2.1 (continued)
Cognitive Process (Mayer, Hegarty, Mayer, & Campbell, 2005)

- Engage in germane processing because learners are encouraged to explain the changes from one frame to the next (active processing effect).

Animation and narration help learners:

- Reduce extraneous processing because animation requires less effort to create mental pictorial representation (i.e., effort effect), narration requires less effort to create mental verbal representation (i.e., effort effect), and computer control requires less effort to make choices during learning (i.e., effort effect).
- Engage in germane processing because narrated animation creates interest that motivates learners to exert more effort (i.e., interest effect).

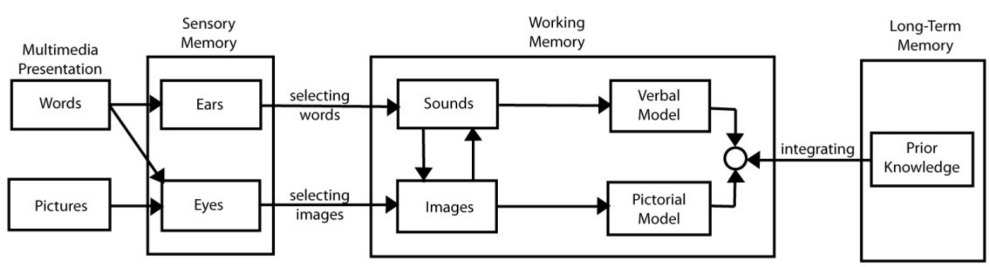


Figure 2.2. Cognitive Theory of Multimedia Learning (Mayer & Moreno, 2003)

Mayer and Moreno (2003), distinguishes three kinds of cognitive demands: (1) essential processing, (2) incidental processing, and (3) representational holding. *Essential processing* refers to cognitive processes that are required for making sense of the presented material, such as the five core processes in the cognitive theory of multimedia learning – selecting words, selecting images, organizing words, organizing images, and integrating (Mayer & Moreno, 2003).

In multimedia learning a potential problem is that the processing demands evoked by the learning task may exceed the processing capacity of the cognitive system - cognitive overload (Mayer, & Moreno, 2003). Currently we theorize three kinds of cognitive demands: essential processing (germane processing), incidental processing, and representational holding. Essential processing refers to cognitive processes that are required for making sense of the presented material, such as the five core processes in the cognitive theory of multimedia learning - selection words, selecting images, organizing words, organizing images, and integrating (Mayer, & Moreno, 2003),

2.5.1. Incidental Processing

Incidental processing refers to cognitive processes that are not required for making sense of the presented material, but are primed by the design of the learning task. For example, adding background music to a narrated animation may increase the amount of incidental processing to the extent that the learner devotes some cognitive capacity to processing the music (Mayer & Moreno, 2003).

2.5.2. Representational Holding

Representational holding refers to cognitive processes aimed at holding a mental representation in working memory over a period of time (Mayer & Moreno, 2003). For example, suppose that an illustration is presented on one page and a description of it is presented on another page, but only one page can be viewed at a time. In this case, the learner must hold a representation for the illustration in working memory while reading the description or must hold a representation of the verbal information in working memory while viewing the illustration.

2.6. Split Attention

According to research by Kalyuga, Chandler and Sweller (1999), many conventional instructional materials require learners to unnecessarily split their attention between diagrams and text. To understand a conventional separate text and diagram format, the learner must hold small segments of text in working memory while searching for the matching diagrammatic entity, with this ongoing process continuing until all the information is rendered intelligible (Kalyuga, Chandler & Sweller, 1999). Research by, Tarmizi and Sweller (1988), Mayer (1989), Mayer and Gallini (1990), Chandler and Sweller (1991, 1996), and Kalyuga, Chandler and Sweller (1999) indicated that instructions involving diagrams and text that need to be mentally integrated to be understood should be restructured into physically integrated formats with a small number of units as possible. The physical integration of related elements of diagrams and text reduces working memory load.

Kalyuga, Chandler and Sweller (1999) emphases that focus should be placed on the fact that the integration of diagrams and text is required if the sources of information are unintelligible in isolation for the learner. If individual sources of information are self-contained with, for example, the text merely redescribing information contained in a self-contained diagram, integration of the redundant information with essential information imposes a cognitive load that interferes with the learning process (Kalyuga, Chandler & Sweller, 1999). A number of previous studies done by Chandler and Sweller (1991), Bobis, Sweller and Cooper (1993), Sweller and Chandler (1994), and Kalyuga, Chandler and Sweller (1998, 1999) using diagrams-and-text instructional presentations found that, for this redundancy effect, the elimination, rather than integration, of redundant sources of information was beneficial for learning.

These techniques are based on the assumption that working memory consists of multiple, partly independent processors, with separate processors for auditory and visual information (Schneider and Detweiler, 1987, Penney, 1989, and Baddeley, 1992). Baddeley (1992) proposed a model including three stores: (1) a phonological loop, (2) a visuo-spatial sketch pad, and (3) a central executive. The phonological loop processes auditory information (verbal material in an auditory form), while the visuo-spatial sketch pad deals with visual information such as diagrams and pictures (Kalyuga, Chandler & Sweller, 1999). Pavio’s (1990) dual coding theory also suggests that information can be encoded, stored and retrieved from two distinct systems, one for verbal information, the other for visual images. Since these two systems are interconnected and may both contribute to memory performance, if information is coded in both the verbal and imaginal coding systems, memory for the information may be enhanced (Kalyuga, Chandler & Sweller, 1999).

According to Kalyuga, Chandler and Sweller (1999) and Mayer and Moreno (2003), learning might be inhibited when learners must split their attention between and mentally integrate text and graphics because the integration process might overburden limited working memory capacity. However, when textual information is presented in auditory form, mental integration with a diagram may not overload working memory because working memory may be enhanced by the use of both visual and auditory channels. Such a dual mode of presentation might be used to circumvent cognitive load problems caused by split-attention – a phenomenon known as *instructional modality effect* (Kalyuga, Chandler & Sweller, 1999).

Kalyuga, Chandler and Sweller (1999) points out that dual-mode presentations do not reduce extraneous cognitive load, but rather increase effective working memory capacity. The amount of information that can be processed using both auditory and visual channels might exceed the processing capacity of a single channel. Thus, limited working memory may be effectively expanded by using more than one sensory modality, and instructional formats in which separate sources of information (otherwise requiring integration) are presented in alternate, auditory or visual, forms might be more efficient than equivalent single-modality formats (Kalyuga, Chandler & Sweller, 1999).

In a series of experiments using geometry instructional material, Mousavi, Low, and Sweller (1995) found that a visually presented geometry diagram, combined with aurally presented statements, enhanced learning compared to conventional, visual-only presentation. In a split-attention situation, increasing effective working memory by using more than one modality produced a positive effect on learning, similar to the effect of physically integrating separate sources of information (Kalyuga, Chandler & Sweller, 1999). Tindall-Ford, Chandler and Sweller (1997) also investigated this effect using elementary electrical engineering instructions and showed that an audio text/visual diagram format was superior to purely visually based instructions. Measures of subjective mental load and instructional effectiveness estimates by Pass and Van Merrienboer (1993, 1994) were used to support the suggestion that the effect is due to cognitive load factors.

Jeung, Chandler and Sweller (1997) demonstrated that the additional processing capacity provided by using dual-mode (audio/video) presentations enhanced learning only if mental resources were not devoted to extensive visual search involved in the coordination of auditory and visual information. Experimenting with primary school, computer-based geometry instructional materials, they found that if visual search was high, then audio-visual instruction was only beneficial if visual indicators in the form of electronic flashing were incorporated into the instructional format. In contrast, when instructional materials low in visual search were used, a standard audio/visual format resulted in superior learning to a visual-only format. There was no beneficial effect of electronic flashing, suggesting that the effectiveness of visual indicators depended on the cognitive load imposed by visual search (Kalyuga, Chandler & Sweller, 1999).

Mayer (1997) and his associates have conducted a number of experiments demonstrating the superiority of audio/visual instructions. Mayer and Anderson (1991, 1992) and Mayer and Sims (1994) demonstrated that audio/visual instructions may only be superior when the audio and visual information are presented simultaneously rather than sequentially – referred to as the *contiguity effect*. This effect could be interpreted within a cognitive load approach as providing an example of split-attention effect (Kalyuga, Chandler & Sweller, 1999).

2.7. Learning Styles

In addition to the instructional environment, sensory preferences have been found to influence information processing. Miller (2001) identified that one way to improve student motivation and performance is to adapt teaching approaches to meet the different learning style preferences of students. Learning styles are broadly described as “cognitive, affective, and physiological traits that are relatively stable indicators of how learners perceive, interact with, and respond to the learning environment” (Keefe, 1979). Research by Dunn, Dunn, and Price (1975, 1979, 1981, 1985, 1989) repeatedly documented that, when students were taught with approaches that matched their preferences, they demonstrated statistically higher achievement and attitude test scores – even on standardized tests – than when they were taught with approaches that mismatched their preferences.

Educationalists introduced the concept of learning style as a —description of the attitudes and behaviors that determine our preferred way of learning (Honey & Mumford, 1992; 2001). Many studies of the learning styles have been conducted in the field of higher education (Duff & Duffy, 2002; Lohri-Posey, 2003; Coffield et al., 2004; Demirbas & Demirkan, 2007; Li et al., 2008).However, despite being half a century old, first cited in literature over 50 years ago (Thelen, 1954), there still isn’t a precise definition of learning styles (Anderson & Adams, 1992), Furthermore, researchers also disagree about the relationship and overlap between concepts of learning styles, cognitive styles, and learning ability. Most modern style theories focus more on the cognitive process aspects of learning styles with a analytical approach to learning on one hand and a visual/verbal approach to learning on the other (Riding, 2001). The disagreement on the definition of learning styles has resulted in a body of research that is fragmented, using different instruments to measure different constructs under the heading of learning styles (Sternberg & Zhang, 2001).

According to Jonassen and Grabowski (1993), learning styles can also be seen as applied cognitive styles in the domain of learning, removed one more level from pure processing ability. As evidence of this removal, learning styles are usually based on self-reported learning preferences. For measuring them, instruments are used that ask learners about preferences. In contrast, cognitive styles are identified by task-relevant measures, which test the actual ability or skill.

Many learning style models exist in the literature today, each proposing different descriptions and classifications of learning types. Research by Coffield et al (2004) identified 71 models of learning styles and categorized 13 of them as major models with respect to their theoretical importance in the field, their widespread use, and their influence on other learning style models. Kolb (1984) conceded, “Individual styles of learning are complex and not easily reducible into simple topologies – a point to bear in mind as we attempt to describe general patterns of individuality in learning.”

2.7.1. VARK Survey

One characterization of learning styles is to define the learner’s preferred mode of learning in terms of the sensory modality by which they prefer to take in new information. The VARK Model (Fleming, 2001), is a sensory model that is an extension of the earlier neuro-linguistic model (Eicher, 1987). The acronym VARK stands for Visual (V), Aural (A), Read/Write (R), and Kinesthetic (K). Fleming (2001) defines learning style as “an individual’s characteristics and preferred ways of gathering, organizing, and thinking about information. VARK is in the category of instructional preference because it deals with perceptual modes. It is focused on the different ways that we take in and give out information.”

The VARK inventory is, technically, not a learning styles questionnaire. The questions and their results focus on the ways in which people like information to come to them and the ways in which they like to deliver their communication (Fleming & Baume, 2006). The strength of VARK is that its questions and options are drawn from real life situations and that people identify with the results that they receive. The acceptance of VARK is shown in the percentage of students who say that their VARK results match what they perceive as their learning preferences. In September 2008 (n=59443) this

"Match" statistic was 55.3% of the total respondents and the "No Match" was 6.2%. The remaining respondents (38.6%) chose "Don't Know" and of that total 41.4% were under 18 years of age.

When comparing the VARK questionnaire to other learning styles inventories, such as the Myers-Briggs Personality Type Inventory and Kolb's Learning Style Inventory, the differences are in the outcomes and purposes for usage. Looking more closely at each inventory, the Myers-Briggs Personality Type Inventory indicates individual preferences based on four dimensions: extraversion/introversion, judging/perceiving, sensing/intuition, and thinking/feeling (Morgan, Richard, & Rushton, 2007). Lastly, Kolb's Learning Style Inventory is a learning model of cognitive processes also based on a four-stage learning cycle. The learning cycle includes concrete experiences-feeling, reflective observations-watching, active experimentation doing, and abstract conceptualization-thinking (Hay Group, 2005). Although each inventory has common characteristics that could be used for organizing and developing instructional materials, the VARK questionnaire lends itself more than the others for improving teaching and learning strategies (Fleming, 2007). This is because the VARK questionnaire looks to measure instructional preferences independent of personality characteristics, information processing strategies, or social interaction strategies in the classroom. Fleming (2001; Fleming & Mills 1992) utilize research in neurolinguistic programming, suggesting that individuals receive information through sensory modalities and have sensory modality preferences, which is the primary area of disagreement between Cognitive Load Theory and Information-Delivery Theory.

Research on the validity of the VARK learning styles inventory through psychometric analysis has shown that it fits a four-factor correlated trait-correlated uniqueness model and that the reliability estimates were good, however, estimated factor loading of the VARK items were small to moderate.

The VARK Inventory provides metrics in each of the four perceptual modes, with individuals having preferences for anywhere from one to all four.

Individual students have relative preferences along each of the four perceptual modes, but can learn to function in the other modes. Figure 2.3 presents the VARK model (adapted from Fleming, 2001).

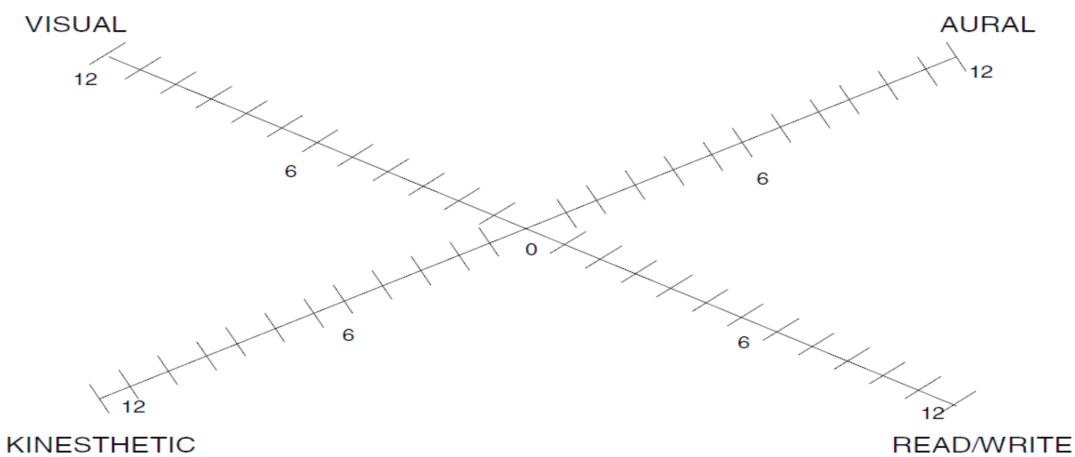
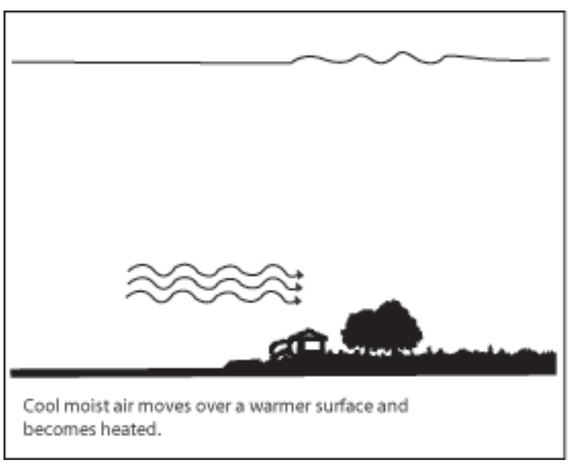


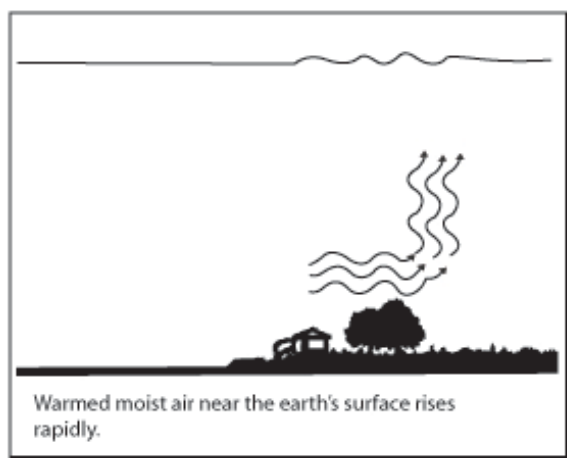
Figure 2.3. VARK Learning Model (Fleming, 2001)

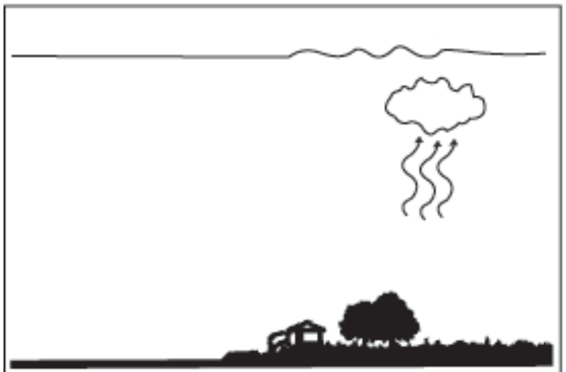
CHAPTER 3. FRAMEWORK AND METHODOLOGY

This experimental study focused on replicating a previously constructed multimedia lesson within a computer-based environment(Mayer & Chandler, 2001). Figure 3.1 presents the frames from the computer-based multimedia lesson on lightning formation. The lesson consists of a 120-second animation, separated into 16 individual segments (4-9 sec, in duration), depicting the key steps in lightning formation, along with a corresponding 287-word narration spoken by a male voice, describing each key step in lightning formation. The animation, constructed in Adobe Flash, uses simple line drawings consisting of only a few essential elemental elements and event. This is a multimedia lesson because it contains both words (narration) and pictures.

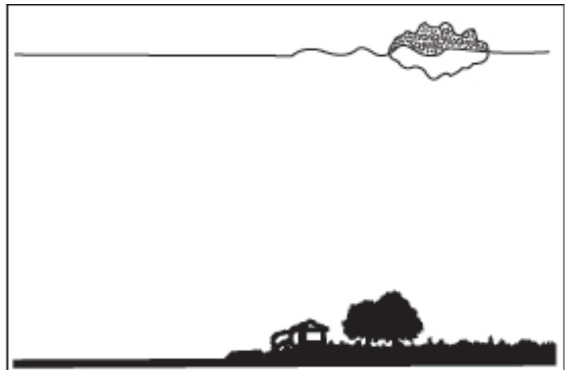
3.1. Multimedia Instructional



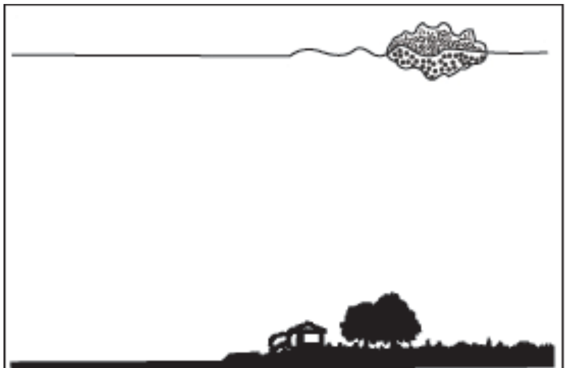




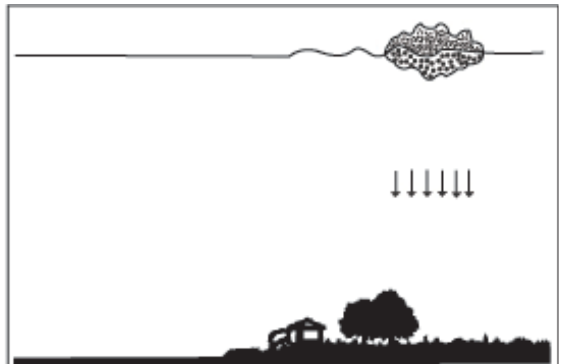
As the air in this updraft cools, water vapor condenses into water droplets and forms a cloud.



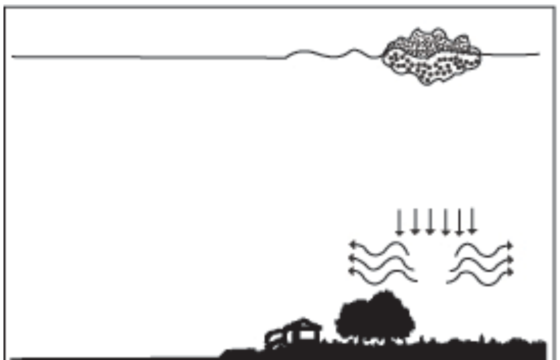
The cloud's top extends above the freezing level, so the upper portion of the cloud is composed of tiny ice crystals.



Eventually, the water droplets and ice crystals become too large to be suspended by the updraft.

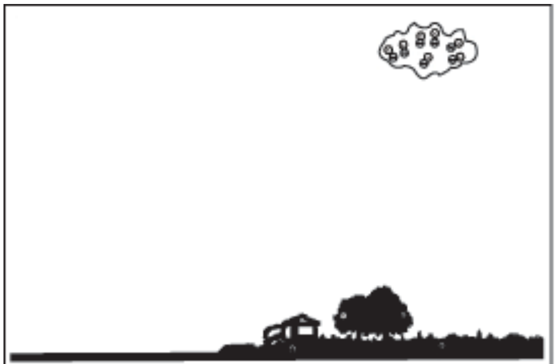


As raindrops and ice crystals fall through the cloud, they drag some of the air in the cloud downward, producing downdrafts.

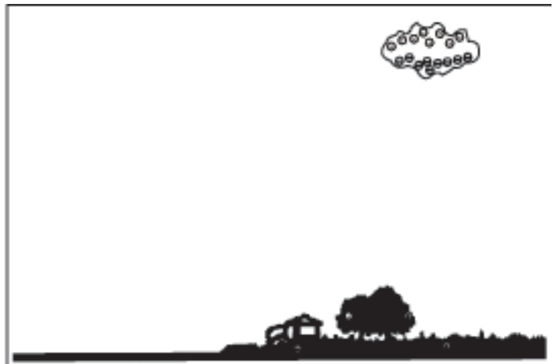


When downdrafts strike the ground, they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain.

Within the cloud, the rising and falling air currents cause electrical charges to build.

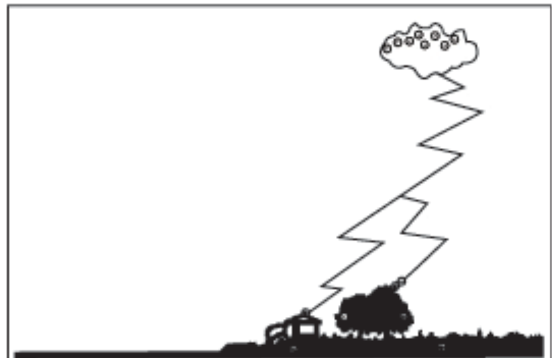


The charges results from the collision of the cloud's rising water droplets against heavier, falling pieces of ice.

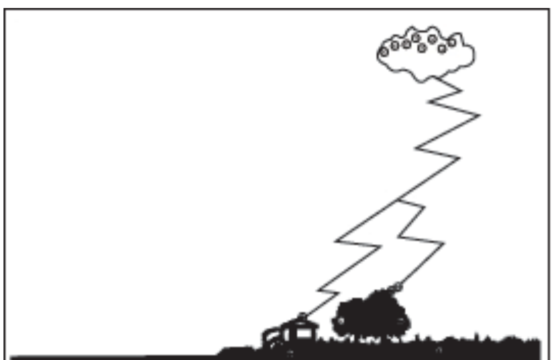


The negatively charged particles fall to the bottom of the cloud, and most of the positively charged particles rise to the top.

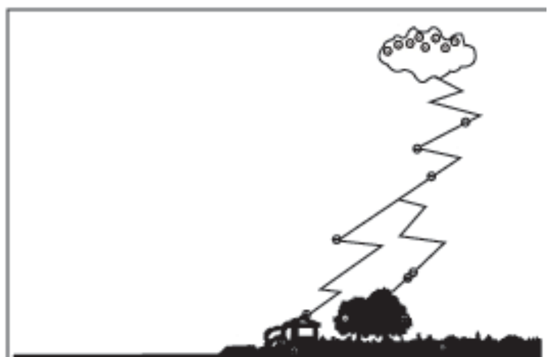
A stepped leader of negative charges moves downward in a series of steps. It nears the ground.



A positively charged leader travels up from such objects as trees and buildings.



The two leaders generally meet about 165-feet above the ground.



Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. It is not very bright.

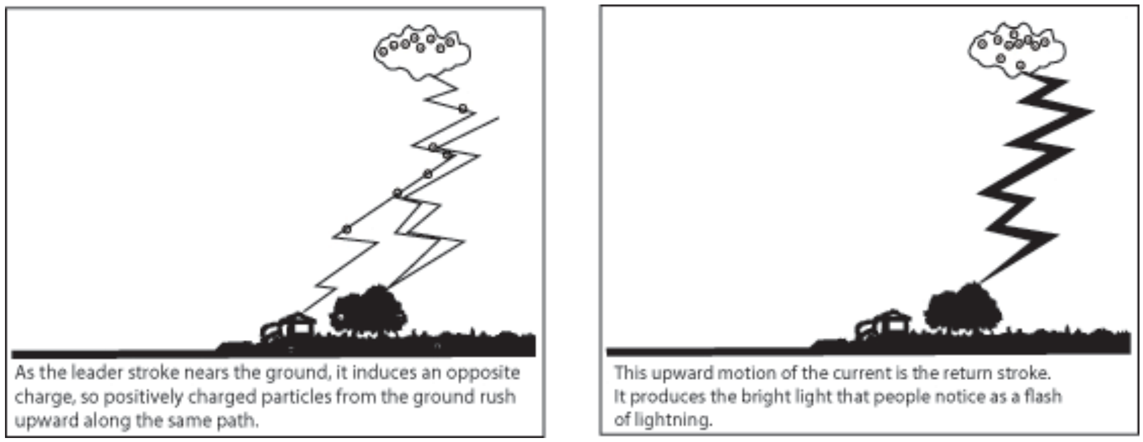


Figure 3.1. Lightning Formation Instructional

3.2. Methodology Design

The experiment in this study is designed to investigate individualization of learning environments in order to minimize the extraneous cognitive load place on an individual. This study looks at an individual's modality preferences and their effect on split-attention and redundancy, as outlined in Mayer's Theory of Multimedia Learning (Mayer & Moreno, 2003), in an effort to determine if there is a significant difference between perceived cognitive load for individuals who's modality preferences match the method of instruction versus those who's preferences do not.

Previous studies of computer-based multimedia instructions (Mousavi, Low & Sweller, 1995; Jeung, Chandler & Sweller, 1997; Tindall-Ford, Chandler & Sweller, 1997; Kalyuga, Chandler & Sweller, 1999) show a modality effect supporting audio narration of test being superior to visual test. These studies concluded that the inclusion of the visual text simultaneously with the same text in an audio form imposed an additional cognitive load due to redundancy. However, it is hypothesize that the effects of split-attention and redundancy will be minimized or compounded for individuals who's learning style modality preferences match or mismatch with the instructional format they receive.

All participants were tested individually, and all tests were conducted in a single session. The experiment consisted of a pre-assessment phase, one instruction phase, a test phase, and a post-assessment phase.

3.2.1. Pre-Assessment Phase

During the pre-assessment phase each subject was given five minutes to complete a demographic information survey reporting their (1) Gender, (2) Age, (3) Undergraduate classification, and (4) Previous science background, and then 10 minutes to complete a knowledge assessment of their meteorological knowledge.

Meteorology knowledge was assessed by using a six-item knowledge checklist and a five-item self-rating (Mayer & Moreno, 1998). The self-assessment asked participants to rate their knowledge of weather by placing a check mark next to: very little, between very much and average, average, between average and very much, or very much. The checklist consisted of instructions to “please place a check mark next to the item that applies to you” followed by a list of six items: “I regularly read the weather maps in the newspaper,” “I know what a cold front is,” “I can distinguish between cumulous and nimbus clouds,” “I know what a low pressure system is,” “I can explain what makes the wind blow,” “I know what this symbol means: [symbol for cold front],” and “I know what this symbol means: [symbol for warm front].”

3.2.2. Instructional Phase

The instruction phase included an introduction to the subject matter (lightning formation) in the form of an instructional multimedia. The material was presented to the subject in a computer-based visual plus audio text format. The visual plus audio text format contained sixteen sequentially introduced animated components (4 – 9 sec. in duration) with written explanations for newly appearing elements. The same explanations were simultaneously presented in an auditory format (via headphones) concurrently with the corresponding animations. This computer-based presentation was self-paced with the learner proceeding to each component by clicking the “continue” button at the end of each segment.

3.2.3. Cognitive Learning Phase

During the test phase participants were given ten minutes to complete a matching questionnaire (See Appendix C) in which participants were asked to number the events in the order they occur. A retention score was computed for each participant by counting the number of correctly labeled elements (out of ten possible) on the matching test. Participants received one point for each event correctly labeled in the sequence.

3.2.4. Post-Assessment Phase

Once participants have completed the cognitive learning phase they were given five minutes to fill out a post-assessment survey assessing how difficult it was for them to perceive the information presented in the informational multimedia. The Subjective Mental Effort Questionnaire (SMEQ) also referred to as the Rating Scale for Mental Effort by Zijlstra (1993) and Zijlstra and Doorn (1985) consists of a single scale with nine labels from “Not at all hard to do” to “Tremendously hard to do” (See Figure 3.2). In the paper version, participants drew a line through a vertical scale to indicate how much mental effort they had to invest to execute a task. The item positions in a paper format are shown as millimeters above a baseline and the line of the scale runs from 0 to 150, thus leaving quite a large distance above “Tremendously hard to do,” which is sometimes used by participants. Scoring the paper version of SMEQ requires measuring the distance in millimeters from the nearest vertical line marking. In previous studies, SMEQ has been shown to be reliable and easy for participants to use. For the SMEQ, an online version shown will be used (available at www.usablesurveys.com). In its paper version, the vertical scale is standardized at 15 centimeters high, filling most of a printed page. In the online version, each millimeter was made to equal 2.22 pixels resulting in a scale large enough to fill most of the browser widow on a 1224x768 pixel resolution monitor. Participants will move the slider with a mouse to the point in the scale that represented their judgment of difficulty. The slider "widget" provides the researcher with the scale value to the thousandth decimal. A more difficult task should be given a higher value.

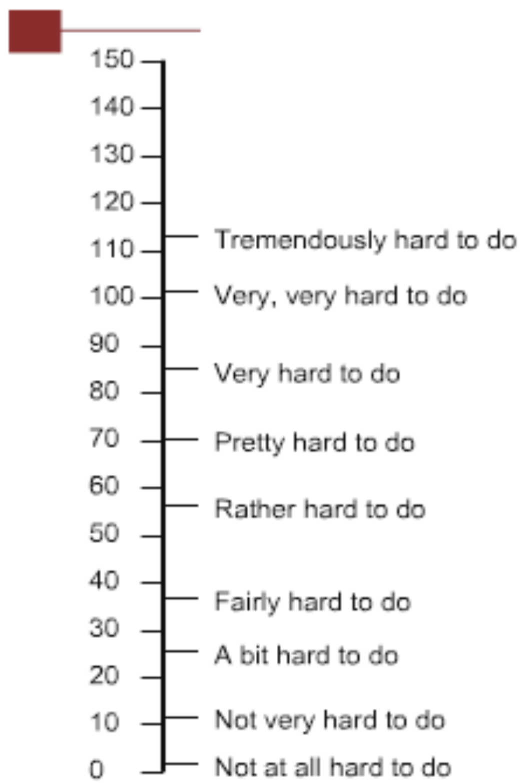


Figure 3.2. Subjective Mental Effort Questionnaire

Once the participant selected their level of mental effort, by clicking and dragging the "widget" to the proper point on the line, they clicked the "submit" button to receive their SMEQ score. Participants self recorded their score on the survey and then proceeded to the second part of the post-assessment.

Participants were given ten minutes to take the online VARK questionnaire. Users completed the questionnaire online. They could have had more than one answer per question, so they get a profile of four scores – one for each modality. VARK is a catalyst for metacognition, not a diagnostic or a measure. The questionnaire is deliberately kept short in order to prevent student survey fatigue. It encouraged respondents to reflect and answer from within their experience, rather than from hypothetical situations (Fleming & Baume, 2006). Upon completion of the questionnaire, subjects were asked to self record their individual visual, aural, read/write, and kinesthetic scores on the post-assessment printout.

3.3. Hypothesis

H_1: The lower the cognitive load, the higher the gain score should be.
H_2: There is a negative correlation between the perceived cognitive load and the read/write preference score.

3.4. Subjects

This study was conducted using students taking an introductory computer graphics course at Purdue University during the spring semester of the 2009-2010 academic school year. All participants had limited or no practical experience with the subject matter. None of the participants had any previous exposure to instructions and the instructional materials presented to the participants were part of the class.

3.5. Data Collection and Analysis

Instructional effectiveness measures were calculated using the Paas and Van Merrien-boer's (1993, 1994) procedure. This approach allows measures of cognitive load (obtained by participants' subjective ratings) to be combined with measures of performance (obtained from the measure of test performance multiple-choice responses) in order to derive information on the relative effectiveness of instructional conditions and estimate the cognitive cost of instruction. High effectiveness occurs under conditions of low cognitive load and high test performance and low effectiveness under high cognitive load and low test performance. Effectiveness values can be calculated by converting cognitive load and performance measures into Z-scores (R and P, respectively) and combining those scores using the formula:

$$E = (P - R) / /SQRT(2)/$$

In order to depict effectiveness, the cognitive load Z-scores (R) and performance Z-scores (P) are represented in a cross of axes (see Figure 3.3). In this coordinate system, the relative effectiveness of an instructional condition as a point (R,P) on the diagram can be measured as the distance from this point to the line of zero effectiveness (E . 0) and calculated using the above formula. The high-effectiveness area (relatively lower cognitive load with higher performance) is above the line E= 0. The low-effectiveness area (higher cognitive load with lower performance) is located below this line.

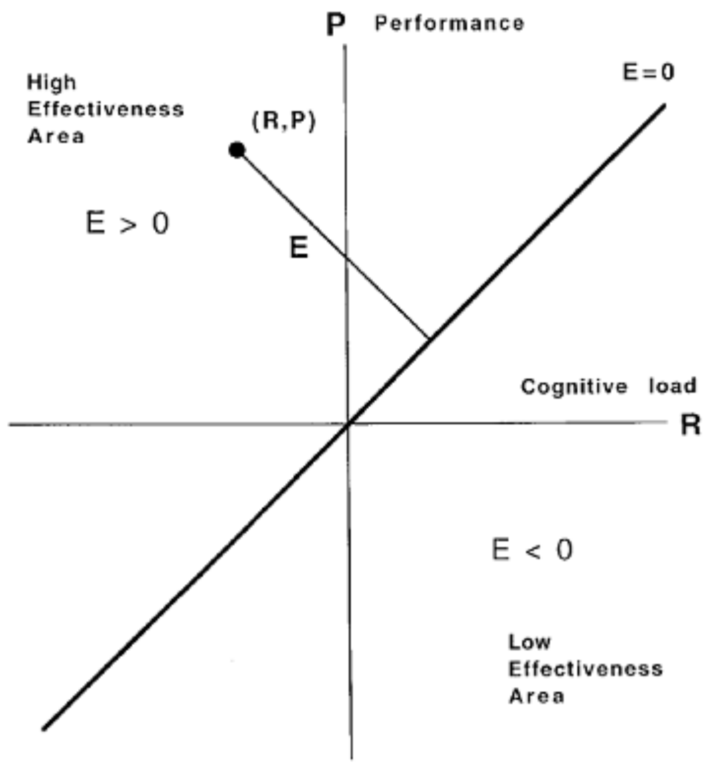


Figure 3.3. Instructional Effectiveness Measurement

The variables under analysis were: (1) the subjective ratings of mental load, (2) the test performance scores from the matching questionnaire, and (3) the Visual, Aural, Read/Write, and Kinesthetic scores from the VARK Survey. The subjective mental effort and gain scores were graphed and through Linear Regression a correlation between the subject's modality preference and the instructional's effectiveness was calculated. The strength of the correlation will also be assessed to see how well the model fits the data.

The hypothesis is that as the learner's modality preference better matches the method of instruction the perceived mental load will decrease (producing a negative sloping graph) while the gain scores will increase (producing a positive sloping graph) thus illustrating a higher instructional effectiveness and lower cognitive load.

Because previous studies have demonstrated that some instructional effects were stronger for low-experience learners than for high-experience learners (Mayer & Gallini, 1990; Mayer & Sims, 1994), this study will only include low-experience students. Experience scores were computed by tallying the number of domain related activities that the participant checked on the Meteorological Knowledge Questionnaire and adding that number to the level of experience the participant checked on the five-level self-assessment (with very little counted as 0 points less than average as 1, average as 2, more than average as 3, and very much as 4). Data was eliminated for any student who scored above 5 and replaced with the data of a new student.

CHAPTER 4: PRESENTATION OF DATA

For each obtained VARK score regression analysis (linear regression) was conducted to determine the relationship between the dependent variable (Visual, Aural, Read/Write, or Kinesthetic scores) and independent variables (Matching and Subjective Mental Effort scores). Alpha was set at .05 when evaluating tests of significance.

4.1. Visual

Table 4.1 shows the Visual scores obtained from the VARK Survey and subsequent Matching and SMEQ scores associated with each individual score.

Linear regression revealed a significant interaction between the level of retention (Matching Score) and a subject's perceived level of cognitive load (SMEQ Score). Figure 4.1. shows a negative correlation with approximately nine percent of the variation in "y" (Matching Score) being explained by "x" (SMEQ Score), $r^2 = 0.096$, $p = .03$. No significance interaction between the Visual score and the Matching score or the Visual Score and the SMEQ score.

Table 4.1.
Visual Score, Matching Score, and Subjective Mental Effort Questionnaire Score

V	Matching	SMEQ	V	Matching	SMEQ	V	Matching	SMEQ
1	3	23.86792	7	7	22.95605	8	10	10.32668
2	8	10.8738	7	8	19.28578	8	8	7.021159

Table 4.1 (continued).

Visual Score, Matching Score, and Subjective Mental Effort Questionnaire Score

2	2	11.28414	7	5	18.07755	8	4	25
2	4	4.536319	7	3	58.1	9	8	56.67237
3	2	99.2566	7	5	13.06228	9	0	9.96
5	8	25.16733	7	10	53.11608	10	6	29.86345
5	4	30.09141	7	10	10.75981	10	0	39.8256
5	6	9.64278	7	7	18.76145	10	5	11.10176
5	5	70.28199	7	2	83.16213	11	8	3.350891
5	3	44.54	7	8	25	11	8	10.98778
5	7	30.11421	7	2	49.21784	11	8	4.901
6	7	10.50905	7	5	25.14453	11	6	17.7584
6	6	20.15205	8	8	7.021159	11	0	28.63243
6	4	60	8	4	19.37697	11	5	7
6	5	18.51069	8	3	5.01505	11	0	20.67638
6	7	11.5121	8	6	25.69165	13	5	43.13724

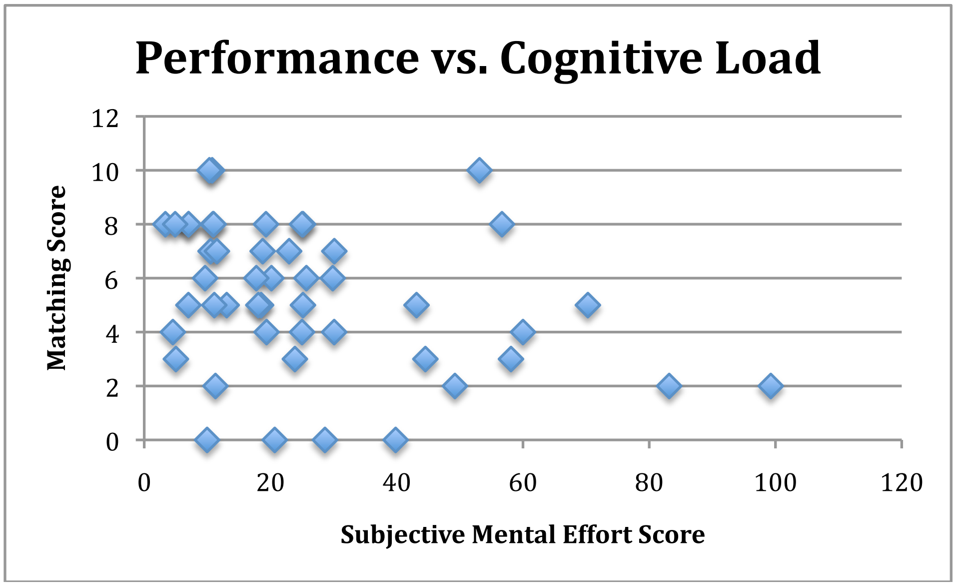


Figure 4.1. Relationship between Matching Score and Subjective Mental Effort Score

4.2. Aural

Table 4.2 shows the Aural scores obtained from the VARK Survey and subsequent Matching and SMEQ scores associated with each individual score.

Linear Regression revealed a significant interaction between the level of retention (Matching Score) and a subject's Aural Score. Figure 4.2. shows a positive correlation with approximately 11 percent of the variation in "y" (Matching Score) being explained by "x" (Aural Score), $r^2 = 0.1107$, $p = .02$.A significant interaction between the level of retention (Matching Score) and a subject's perceived level of cognitive load (SMEQ Score) was also observed. Figure 4.3. shows a negative correlation with approximately nine percent of the variation in "y" (Matching Score) being explained by "x" (SMEQ Score), $r^2 = 0.096$, $p = .03$. No significant interaction was found between Aural score and Subjective Mental Effort Score as illustrated by Figure 4.4.

Table 4.2.

Aural Score, Matching Score, and Subjective Mental Effort Questionnaire Score

A	Matching	SMEQ	A	Matching	SMEQ	A	Matching	SMEQ
1	7	22.95605	6	3	44.54	9	6	29.86345
2	5	7	7	8	3.350891	9	5	43.13724
2	0	9.96	7	4	19.37697	9	0	28.63243
3	3	23.86792	7	8	4.901	9	5	13.06228
3	6	20.15205	7	10	10.32668	9	5	18.51069
3	2	83.16213	7	5	70.28199	10	8	7.021159
3	4	60	7	2	99.2566	10	6	17.7584
3	4	4.536319	8	8	19.28578	11	8	56.67237
4	4	30.09141	8	7	10.50905	11	5	18.07755
4	7	11.5121	8	3	58.1	11	10	53.11608
5	2	11.28414	8	10	10.75981	11	8	25
5	0	20.67638	8	7	30.11421	11	5	11.10176
6	6	9.64278	8	2	49.21784	12	3	5.01505
6	0	39.8256	8	4	25	12	6	25.69165
6	8	7.021159	8	5	25.14453	13	8	10.98778
6	8	10.8738	9	8	25.16733	14	7	18.76145

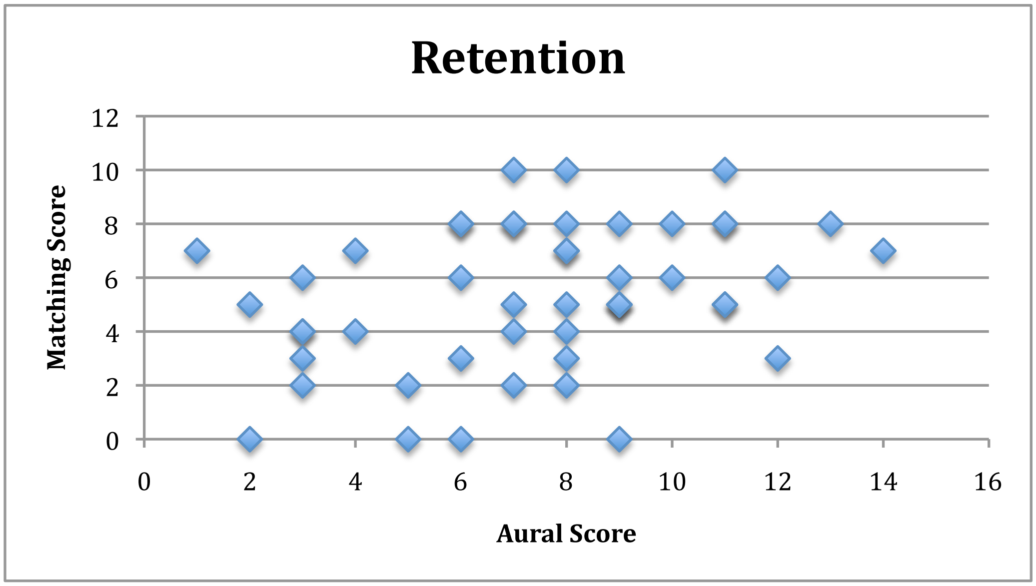


Figure 4.2. Relationship between Aural Score and Matching Score

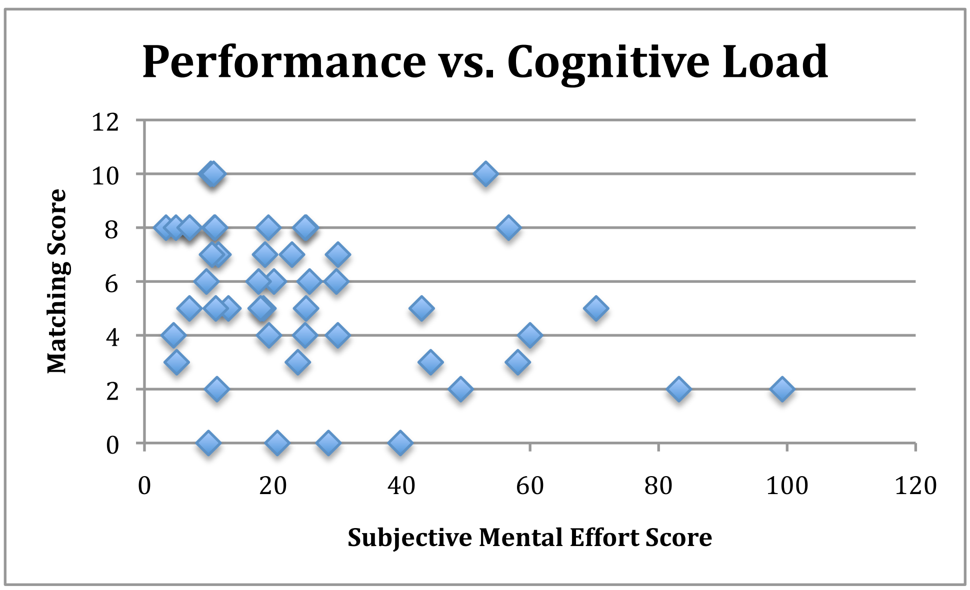


Figure 4.3. Relationship between Matching Score and Subjective Mental Effort Score

4.3. Read/Write

Table 4.3. shows the Read/Write scores obtained from the VARK Survey and subsequent Matching and SMEQ scores associated with each individual score.

Linear regression revealed a significant interaction between the level of retention (Matching Score) and a subject's perceived level of cognitive load (SMEQ Score). Figure 4.1. shows a negative correlation with approximately nine percent of the variation in "y" (Matching Score) being explained by "x" (SMEQ Score), $r^2 = 0.096$, $p = .03$. No significance interaction between the Read/Write score and the Matching score or the Read/Write Score and the SMEQ score were found

Table 4.3.
Read/Write Score, Matching Score, and Subjective Mental Effort Questionnaire Score

R	Matching	SMEQ	R	Matching	SMEQ	R	Matching	SMEQ
1	6	20.15205	5	4	60	7	7	30.11421
2	6	29.86345	5	8	25	7	2	49.21784
2	10	10.32668	6	8	7.021159	7	4	4.536319
2	2	99.2566	6	4	30.09141	8	8	19.28578
2	7	11.5121	6	6	25.69165	8	10	53.11608
3	7	22.95605	6	0	39.8256	9	8	10.98778
3	3	23.86792	6	5	18.07755	9	8	56.67237
3	6	9.64278	6	7	10.50905	9	6	17.7584
3	3	58.1	6	5	70.28199	9	5	11.10176

Table 4.3. (continued).

Read/Write Score, Matching Score, and Subjective Mental Effort Questionnaire Score

3	7	18.76145	6	3	44.54	9	0	20.67638
3	0	9.96	7	8	3.350891	10	8	4.901
3	8	10.8738	7	4	19.37697	10	0	28.63243
3	4	25	7	3	5.01505	10	5	13.06228
4	8	25.16733	7	5	7	12	10	10.75981
4	2	83.16213	7	2	11.28414	4	2	83.16213
4	5	25.14453	7	5	18.51069	4	5	25.14453

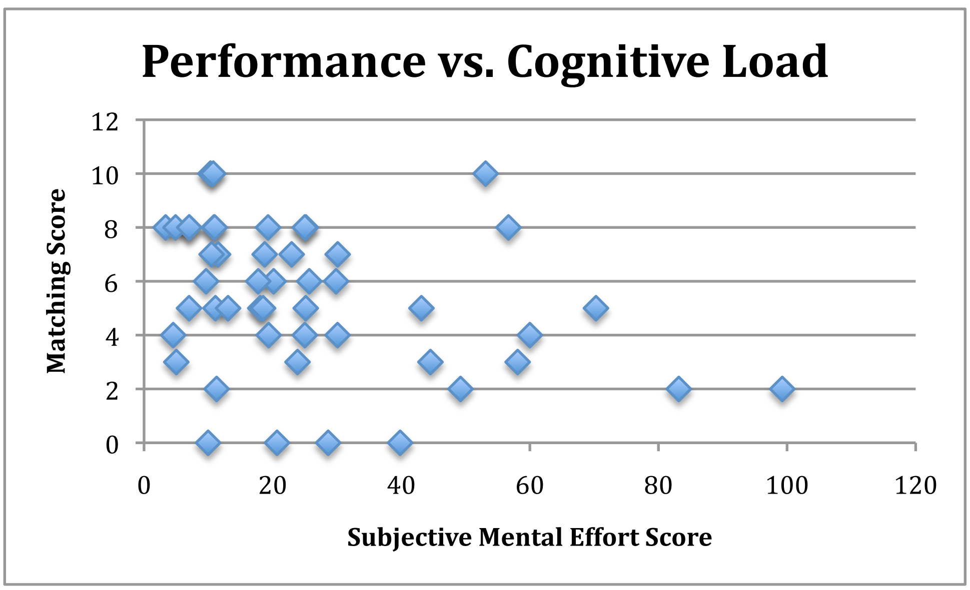


Figure 4.4. Relationship between Matching Score and Subjective Mental Effort Score

4.4. Kinesthetic

Table 4.4. shows the Kinesthetic scores obtained from the VARK Survey and subsequent Matching and SMEQ scores associated with each individual score.

Linear regression revealed a significant interaction between the level of retention (Matching Score) and a subject's perceived level of cognitive load (SMEQ Score). Figure 4.1. shows a negative correlation with approximately nine percent of the variation in "y" (Matching Score) being explained by "x" (SMEQ Score), $r^2 = 0.096$, $p = .03$. No significance interaction between the Kinesthetic score and the Matching score or the Kinesthetic Score and the SMEQ score were found

Table 4.4.
Kinesthetic Score, Matching Score, and Subjective Mental Effort Questionnaire Score

K	Matching	SMEQ	K	Matching	SMEQ	K	Matching	SMEQ
2	2	11.28414	8	6	9.64278	2	2	11.28414
3	0	9.96	8	10	10.32668	3	0	9.96
4	2	99.2566	8	7	18.76145	4	2	99.2566
5	5	7	8	5	25.14453	5	5	7
5	8	10.8738	9	4	30.09141	5	8	10.8738
5	7	30.11421	9	8	56.67237	5	7	30.11421
5	7	11.5121	9	3	23.86792	5	7	11.5121
5	4	4.536319	9	6	17.7584	5	4	4.536319
6	3	58.1	9	8	19.28578	6	3	58.1
6	2	83.16213	9	0	28.63243	6	2	83.16213

Table 4.4. (continued).

Kinesthetic Score, Matching Score, and Subjective Mental Effort Questionnaire Score

7	8	4.901	10	5	43.13724	7	8	4.901
7	6	20.15205	10	3	5.01505	7	6	20.15205
7	5	13.06228	10	6	25.69165	7	5	13.06228
7	5	70.28199	10	0	39.8256	7	5	70.28199
8	8	25.16733	10	8	7.021159	8	8	25.16733
8	4	19.37697	10	10	10.75981	8	4	19.37697

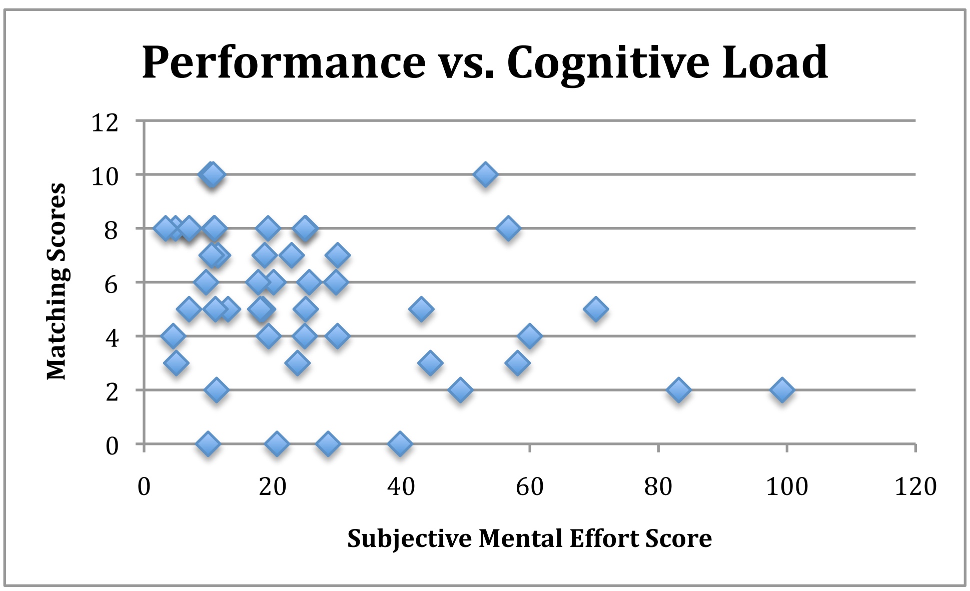


Figure 4.5. Relationship between Matching Score and Subjective Mental Effort Score

4.5. VARK

For each VARK modality preference regression analysis (linear regression) was conducted to determine the relationship between the Visual, Aural, Read/Write, and Kinesthetic scores. Alpha was set at .05 when evaluating tests of statistical significance.

4.5.1. Visual

Regression analysis revealed a significant interaction between the Visual modality preference and Aural modality preference with approximately nine percent of the variation in "y" (Visual preference) being explained by "x" (Aural preference), $r^2 = 0.092$, $p = .03$. Also, a significant interaction between the Visual modality preference and Read/Write modality preference was observed with approximately nineteen percent of the variation in "y" (Visual preference) being explained by "x" (Read/Write preference), $r^2 = 0.199$, $p = .001$, and between Visual modality preference and Kinesthetic modality preference with approximately seventeen percent of the variation in "y" (Visual preference) being explained by "x" (Kinesthetic preference), $r^2 = 0.174$, $p = .003$.

4.5.2. Aural

Regression analysis revealed a significant interaction between the Visual modality preference and Aural modality preference with approximately nine percent of the variation in "y" (Aural preference) being explained by "x" (Visual preference), $r^2 = 0.092$, $p = .03$. Also, a significant interaction between the Aural modality preference and Read/Write modality preference was observed with approximately eight percent of the variation in "y" (Visual preference) being explained by "x" (Read/Write preference), $r^2 = 0.083$, $p = .04$, and between Aural modality preference and Kinesthetic modality preference with approximately twenty five percent of the variation in "y" (Visual preference) being explained by "x" (Kinesthetic preference), $r^2 = 0.25$, $p < .001$.

4.5.3. Read/Write

Regression analysis revealed a significant interaction between the Read/Write modality preference and Visual modality preference with approximately nineteen percent of the variation in “y” (Read/Write preference) being explained by “x” (Visual preference), $r^2 = 0.199$, $p = .001$. Also, a significant interaction between the Read/Write modality preference and Aural modality preference was observed with approximately eight percent of the variation in “y” (Read/Write preference) being explained by “x” (Aural preference), $r^2 = 0.083$, $p = .04$. No significant interaction was found between the Read/Write modality preference and the Kinesthetic modality preference.

4.5.4. Kinesthetic

Regression analysis revealed a significant interaction between the Kinesthetic modality preference and Visual modality preference with approximately seventeen percent of the variation in “y” (Kinesthetic preference) being explained by “x” (Visual preference), $r^2 = 0.174$, $p = .003$. Also, a significant interaction between the Kinesthetic modality preference and Aural modality preference was observed with approximately twenty five percent of the variation in “y” (Kinesthetic preference) being explained by “x” (Aural preference), $r^2 = 0.25$, $p < .001$. No significant interaction was found between the Kinesthetic modality preference and the Read/Write modality preference.

4.6. Discussion

The major conceptual limitation of regression techniques is that one can only ascertain relationships between variables, and never be sure about the underlying causal mechanisms (correlation does not mean causation). Secondly, one cannot predict values outside those observed (outside the data set).

The results of this study suggest a negative relationship between the level of perceived mental effort exerted and the retention of information from a multimedia. As a subject’s Subjective Mental Effort Score (cognitive load) increased, the lower their Matching Score (retention) tended to be. This, in short, provides support for cognitive load theory and parallels results found in previous studies (Mayer & Moreno, 1998).The measurement of instructional effectiveness (Paas & Van Merrien-boer's, 1993, 1994) found no relationship between modality preferences and effectiveness of the multimedia, however, it did highlight that instructional effectiveness was high for subjects that perceived a low level of cognitive load and had a high level of retention.

Secondly, the positive relationship between those subjects with a higher Aural modality preference score and better performance on the retention test could provide evidence for the existence of the visuospatial sketch pad for visual processing and the phonological loop for auditory processing. One could then hypothesize that those who were more efficient at utilizing both channels for processing information would retain more information in working memory.

Lastly, the data suggests a strong relationship between the modality preferences. Stimulus/Response (hearing a noise, seeing an image, touching an object, etc.) based modality preferences (Visual, Aural, Kinesthetic) demonstrated significant relationships to one another, however, more cerebral modalities (Read/Write) elicited less of a relationship and counted for less of the variability in the other modalities.

CHAPTER 5: SUMMARY, OUTCOMES, AND IMPLICATIONS

This study looked to shed light on the relationship between a users' preferred modality for instruction and the effect it had on their perceived level of difficulty in learning from an instructional multimedia. To conclude, this chapter provides a summary of the study; its purpose, questions, significance, and methodology are revisited. The chapter then surmises the observed results given the data gathered and concludes with recommendations for improvement and future studies.

5.1. Summary of This Study

Through a series of quantitative assessments, this study profiled modality preferences in students from an introductory computer graphics course at Purdue University. Its purpose was to determine and analyze the relationship between individuals preferred modality for instruction and the perceived level of difficulty they associated with learning from an instructional multimedia. It is believed that by understanding the users preferred modality and comparing it to the instructional effectiveness of the multimedia provides insight into the users role in the learning process.

Analysis of this study looks to investigate two questions. First, does level of difficulty the user associates with learning from the instructional multimedia have an effect on the amount of information retained by the user? Specifically, does a high association of difficulty result in a lower amount of retention? This core question investigates the observation of cognitive overload, which would be suggested by a negative relationship between the perceived level of difficulty in learning from the multimedia and the subject's retention of information (Mayer & Moreno, 2003). Results of this study support that as the processing demands of the learning task began to exceed the processing capabilities of the subject retention of the information began to decrease.

This study hypothesized a solution to cognitive overload by looking to match modality preferences of the subject to the display of information. The second question which arises from this is; Does a higher Read/Write modality preference (as indicated by the VARK Survey) have a negative effect on perceived level of difficulty associated with learning from the instructional multimedia?” This explores the elements of the multimedia to determine their level of support for specific modality preferences. The multimedia’s design suggest less characteristics in support of those with Read/Write modality preferences; however, no relationship was found to exist between the Read/Write modality preference and level of perceived cognitive load.

5.1.1. Significance of This Study

Based on a review of the literature, it was found that the central argument between Cognitive Load Theory and Information-Delivery Theory stems from their perspective ways of meeting user needs through a multimedia instructional interface. Both recognize that an interface/instructional should be designed with regards to the specific user, however, they differ in whether or not to present information using one or more modalities. The primary argument for Cognitive Load Theory is to reduce the cognitive load placed on a user by presenting the information in only one modality, so as to limit the processing requirements the user needs to understand the information. Whereas, Information-Delivery Theory says to design an interface/instructional utilizing as many modalities as possible so the user can pick the modality that best fits how they learn.

Since the chief argument centers around appropriate modalities for a user this study chose to focus its investigation on the user rather than the interface. It is believed by investigating the users modality preference one can get a more complete picture of the user. With a more detailed user profile one can then more accurately investigate and measure the interactions that exist when a user interacts with a multimedia interface. The hope is that the insights contained in this study will help researchers to better design, and implement instructional interfaces for human-computer interaction.

5.1.2. Data Analysis

Using Regression Analysis (Linear Regression), the strength and relationship between a users modality preference (as determined by the VARK Questionnaire) and the perceived level of difficulty associated with learning from an instructional multimedia was examined. The relationship between retention and cognitive load as well as modality preferences were also investigated and conclusions were formed as themes emerged across the data.

5.2. Recommendations for Future Studies

As with anything study, hindsight and reflection help point out things that could have been done better or more effectively. The following are acknowledgements of these areas in this study.

Further investigation into Learning Styles. Despite being half a century old, first cited in literature over 50 years ago (Thelen, 1954), there still isn't a precise definition of learning styles (Anderson & Adams, 1992), Furthermore, researchers also disagree about the relationship and overlap between concepts of learning styles, cognitive styles, and learning ability. The disagreement on the definition of learning styles has resulted in a body of research that is fragmented, using different instruments to measure different constructs under the heading of learning styles (Sternberg & Zhang, 2001). An agreed upon working definition of the term might provide for a deeper comprehension and better methods of inclusion into future studies.

Further Investigation into Modality Preferences. The VARK Learning Styles Inventory was used not only because of its face validity, simplicity, and ease of use, but more importantly because it looks to measure instructional preferences independent of personality characteristics, information processing strategies, or social interaction strategies in the classroom. However, it was still found to be difficult to separate or group the participants due to the scores being integrated (many multimodal preferences). Perhaps looking into a more categorical measure of modality preferences would allow for more individualization of the groups.

Pre and Post Test Assessments. Though there was a good range of scores on the Matching Questionnaire having the students complete a pre-test evaluation and then a post-test evaluation one would be able to better compare scores and make more conclusive findings as to the instructional effectiveness of the multimedia.

Transfer Test Assessment. To better encompass all aspects of learning as well as look for any relationships between the instructional effectiveness over a long period of time future studies should investigate both transfer and retention of information. It is also important to note that the process of storing information in short-term memory is different than the process for storing information in long-term memory, therefore time delayed tests of long term retention/schema acquisition should be utilized.

Individual Testing Environment. Most previous studies in the field of Cognitive Load Theory and Multimedia Learning have been conducted in a laboratory setting so it would be interesting to see if the laboratory data generalizes to a "real world" environment. At the same time motivation factors both for completion and individual pacing should be investigated. Research has shown that learning takes effort, therefore having similar levels of motivation for completion would be ideal.

Qualitative Feedback. Qualitative feedback on the participant's strategy for recalling information from the multimedia during the assessment as well as their individual strategy for interacting with the multimedia would have added more depth. For instance, researchers could determine if subjects disregard or were distracted by elements in the multimedia (like text when there is concurrent narration). Also, by utilizing Likart assessment researchers could determine if a subject with a visual modality preference is more likely to recall the images they saw when trying to answer transfer and/or retention questions or if a subject with an aural modality preference has a tendency to recall sounds and auditory information.

Development of Teaching Tool and Instruction. By utilizing current methods of instructional design and usability improvements could be made to the multimedia and interface to facilitate better learning. Including control functions such as a "back" button could limit cognitive load by allowing users to rehears and repeat complicated areas of information. Also, by describing or explaining in detail the testing element through the use of a progress bar and/or detailed explanations (explaining to subjects that they will have ten minutes to study a two minute multimedia) one could also decrease the cognitive load the environment places on the subject.

5.3. Summary

This chapter concludes the documentation of this study by revisiting the primary objectives that were a part of it. This chapter also presented an answer to primary research question and the two tertiary questions posed at the beginning of the study. It is hoped that the reader now has a general understanding of the foundation of Cognitive Load Theory and it's implications in the creation and implementation of multimedia applications. As with most ideological young researchers I'd hoped to stumble upon some great new discovery. Some say no significant result is still a result, and to this I agree. I did not come to any new conclusions, and in fact I added to the support of one of the more popular theories of multimedia learning. That said, I believe that the true value of this study comes in the recommendations for future study. It is hoped that this study serves as a framework for exploration into formal methods of modality and learning style evaluation and definition. The hope is that future studies will provide better user profiles to assess the interactions between users and interfaces.

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APPENDICES

Appendix A: Demographics Questionnaire

Demographics Questionnaire

Directions: On the line to the left of each statement, check the answer that best applies to you.

1. What is your gender?

    ____ Male

    ____ Female

2. What is your age?

    ____ 18 - 19

    ____ 20-21

    ____ over 21

3. What is your undergraduate classification?

    ____ Freshman

    ____ Sophomore

    ____ Junior

    ____ Senior

4. Have you had any science courses in high school or college where you learned about the weather?

    ____ Yes

    ____ No

Appendix B: Meteorology Knowledge Questionnaire

Meteorology Knowledge Questionnaire

Directions: Please place an X on the item that comes closest to your answer.

5 = strongly agree 4 = agree 3 = neutral 2 = disagree 1 = strongly disagree

QUESTION	**5**	**4**	**3**	**2**	**1**
1, I regularly read the weather maps in the newspaper.					
2. I know what a cold front is. (If your answer is 5, answer on the back.)					
3. I can distinguish between cumulous and nimbus clouds. (If your answer is 5, answer on the back.)					
4. I know what a low pressure system is. (If your answer is 5, answer on the back.)					
5. I can explain what makes the wind blow. (If your answer is 5, answer on the back.)					
6. I know what this symbol means: 					
7. I know what this symbol means: 					

Appendix C: Matching Questionnaire

Matching Questionnaire

Directions: On the line to the left of each statement, number the events in the order they occur.

.

_____ Negative charges fall to the bottom of the cloud

_____ Positive charges rush up

_____ Negative charges rush down

_____ Air rises

_____ Water and crystals fall

_____The leaders meet

_____ Wind is dragged downward

_____ Electrical charges form

_____ Water condenses and forms a cloud

_____ Cool air moves over warmer surfaces

Appendix D: Subjective Mental Effort and VARK Questionnaire

Subjective Mental Effort Questionnaire

Directions: Please move the slider by clicking and dragging to the point in the scale that represents your judgment of how difficult it was to learn from the multimedia.

Please click "submit" and write your numerical score below.

VARK Questionnaire

Directions: On the line to the left of each category, please write your Visual, Aural, Read/Write, and Kinesthetic Scores.

Visual	Aural	Read/Write	Kinesthetic