THE EFFECTS OF MULTIPLE-CHANNEL TECHNOLOGIES AND LEARNING STYLES ON PROCEDURALIZED INSTRUCTION IN A VIRTUAL ENVIRONMENT

By

GARY PAUL DOTTERER

Bachelor of Science in Mechanical Design Engineering
Technology
Oklahoma State University
Stillwater, OK
1989

Master of Science in Teaching, Learning, and Leadership
Oklahoma State University
Stillwater, OK
2002

Submitted to the Faculty of the
Graduate College of the
Oklahoma State University
in partial fulfillment of
the requirements for
the Degree of
DOCTOR OF PHILOSOPHY
December, 2011

THE EFFECTS OF MULTIPLE-CHANNEL

TECHNOLOGIES AND LEARNING STYLES

ON PROCEDURALIZED INSTRUCTION

IN A VIRTUAL ENVIRONMENT

Dissertation Approved:

Dr. Lynna Ausburn

Dissertation Adviser

Dr. Belinda McCharen

Dr. Ji Hoon Song

Dr. Floyd Ausburn

Dr. Pasha Antonenko

Outside Committee Member

Dr. Sheryl A. Tucker

Dean of the Graduate College

TABLE OF CONTENTS

Chapter Page

Chapter Page

Chapter Page

LIST OF TABLES

Table Page

LIST OF FIGURES

CHAPTER I

INTRODUCTION

Technical advancements in affordable personal computers, associated technology (e.g., software, hardware, connectivity), and web servers have bridged online learning and virtual environments to form new educational learning opportunities (Barron & Kysilka, 1993; Beccue, Vila, & Whitley, 2001; Brashears, Akers, & Smith, 2005; Evans, Mulvhill, & Brooks, 2008; Ford & Chen, 2000). The way in which individuals learn from these opportunities depends on human cognition, information processing, cognitive styles, and cognitive controls. These variables focus on an individual's memory system and how information is acquired, transformed, compacted, encoded, and retrieved through observation or a stimulus (Moore, Burton, & Myers, 1996). Instructional designs are now using multiple-sensory modality models within online course content. The increase of these modality models invokes the human senses to process content-rich material. Visual, auditory, and interactive stimuli are enhanced using 21st century technologies (e.g., video, imagery, simulation, virtual reality) and have been integrated into virtual learning environments (VLEs) delivered by hypermedia or interactive multimedia. In the context of this study virtual learning environments refer to course management systems or learning management systems (e.g., Moodle, Blackboard, or WebCT).

Sensory modality can be defined as one of the five human senses of vision, hearing, smell, taste, and touch used to perceive and process information. According to Meriam-Webster's online dictionary (n.d.), sensory modality is "One of the main avenues of sensation." For the human memory system to successfully and effectively process cues through sensory modalities, the input stimuli must be harmonious, succinct, relevant, and sequential in nature (Dwyer, 1978), in order to prevent interference known as extraneous cognitive load (Sweller, 1988). Historically, research has shown mixed results as to the effectiveness of multiple-sensory inputs based on performance outcomes. Several studies over the past few decades have supported the contention that when applied simultaneously in specific conditions, multiple-stimuli were likely to increase learning opportunities (Drew & Grimes, 1987; Hanson, 1989; Rolandelli, 1989; Severin, 1968; Yang, 1993). However, other findings have concluded that multiple-stimuli cause information jamming or extraneous cognitive load which can hinder learning (Broadbent, 1958). Instructional strategies used by designers are also differentiated by the design type such as proceduralized knowledge. A derivative of procedure knowledge, a proceduralized instructional design can be defined as a method of training or teaching a skill that requires a sequential flow of tasks that are performed in the same order each time (Clark, Nguyen, & Sweller, 2006; DaCosta & Seok, 2010). As more complex strategies are employed, instructional designers or educators are tapping more heavily into sensory modalities using 21st-century technology, matching instructional strategies with individual learning styles as a dimension of individual differences could create complex learning activities that cater to individual learning needs and preferences (Beccue et al., 2001; Ford & Chen, 2000). Numerous research studies have examined learning styles and the effect on performance outcomes when instructional strategies (e.g. proceduralized instruction) are matched to specific styles of learning. However, three factors have emerged from research in this field that suggest additional research is needed:(1) mixed results from research that examined performance outcomes when learning styles were matched with specific modalities, (2) poor experimental design methodologies cited by Pashler, McDaniel, Rohrer, and Bjork (2008) that may have adversely affected findings, and (3)research by Dotterer (2010a)examining the effect of performance outcomes when using multiple-channel technologies in a proceduralized instructional design and suggesting need for research on the roles of learning styles in such an environment. These factors provided the impetus for this study.

Individual Differences

Although synonymous to some, individual differences and learning styles differ in definition. Individual differences can be defined as dimensions or factors on which individuals differ in their behaviors or characteristics; they can cover a broad range of behaviors. Learning styles, according to Fleming and Mills (1992), can be summarized more narrowly as the preferred learning approach for each individual. Jonassen and Grabowski (1993) specifically addressed individual differences in cognitive processing and divided individual differences into four distinct categorizes in relation to technology as shown in Table 1: cognitive controls, cognitive styles, learning styles, and personality types.

Table 1

Categories and Subcategories of Cognitive Processing

Category	Subcategory
Cognitive Controls	Field Dependence/Independence
	Cognitive Flexibility
	Impulsivity/Reflectivity
	Focal Attention
	Category Width
	Automization
Cognitive Styles	Information Gathering
	Visual/Haptic
	Visualizer/Verbalizer
	Leveling/Sharpening
	Information Organizing
	Serialist/Holist
	Analytical/Relational
Learning Styles	Hill's Cognitive Style Mapping
	Kolb's Learning Styles
	Dunn and Dunn Learning Styles
	Gregorc Learning Styles
	Visual, Aural, Read/Write, Kinesthetic Survey
Personality Types	Attention and Engagement Experiences
	Anxiety
	Tolerance for Unrealistic Experiences
	Ambiguity Tolerance
	Frustration Tolerance
	Expectancy and Incentive Styles
	Locus of Control
	Extroversion and introversion
	Achievement Motivation
	Risk Taking versus Cautiousness

Note. Categories and subcategory items relevant to this study are italicized. Adapted from "Individual differences, computers, and instruction," by D. Jonassen, and B. Grabowski, 1993, *Individual differences and instruction*. New York: Allen & Bacon.

Studies have shown that individual differences exist and are significant variables in aptitude treatment interactions (ATIs) (Cronbach & Snow, 1977). Because hypertext, hypermedia, and interactive multimedia require underlying skills to extract information, learner individual differences can be expected to interrelate with technology to influence learning outcomes (Ausburn & Ausburn, 1978; Ayersman & Minden, 1995; Cronbach & Snow, 1977; Gagnon, 1986). Although instructional designers and educators create and implement strategies for successful learning activities with technology, attempting to match instructional designs with every learning style would be a daunting task.

Educators have long accepted the notion that learners have preferred learning styles. They have asserted that individual differences are at the epicenter of the learning process (Dunn & Dunn, 1979; Gardner, 1983; Kolb, 1984). However, recent research conducted in the field of neurological psychology questions the concept of learning styles and its usefulness for educators. Mathews (2010) stated in an article, printed in the *Washington Post*, studies were conducted at the University of California at San Diego, Washington University in St. Louis, University of South Florida, and University of California at Los Angeles, examined the benefits of learning styles and concluded that the learning style research had no rigorous randomization, lacked scientific merit, or showed no significant advantages for students who were taught with their preferred learning style (para. 6). In regard to learning styles, the lack of rigor is problematic, but it should also be noted that there are more conceptual problems with learning style research. Riener and Willingham (2010) supported this contention, reporting that students who stated that they preferred to learn when information was presented visually or through an auditory channel, when tested in a controlled environment, showed no significant benefits when taught using their preferred modality. Although there are mixed reviews as to the importance of learning styles on performance outcomes, a study with a sound theoretical framework and solid experimental design should add to the learning styles knowledge base by addressing the conceptual research problems. This emerging debate on learning styles is discussed in more detail in Chapter 2.

Learning Styles Instrument

This research focused on performance outcomes based on preferred learning styles through proceduralized instructional design. Learning styles in this study were measured by an instrument that draws upon shared information, personal observations, and a model design. The model known as the Visual, Auditory, Read/Write, Kinesthetic (VARK) survey was developed by Fleming and Mills (1992) and was constructed using the three common sensory modalities of visual, aural, and kinesthetic. A fifth learning style, multi-modal, were identified if an individual preferred two or more modalities. The VARK model and questionnaire divide the visual preferences into two separate styles (visual and read/write) as shown in Table 2, both of which are conceptualized as different for preference from spoken/heard verbalization. The visual preference relates to graphical and symbolic forms such as graphs, charts, models, flow charts, etc. The read/write preference refers to the affinity for printed words.

Table 2

Visual, Aural, Read/Write, and Kinesthetic (VARK) Learning Styles

Preferred Modality	Assessed preferred learning style
Visual* (V)	Preference of graphical & symbolic ways of representing information
Aural (A)	Preference of "heard" information
Read/Write* (R)	Preferences of information printed as words
Kinesthetic (K)	Preference related to the use of experience & practice (simulated or real)
**Multi-Modal	Two or more preferred modalities are recognized, thus no one modality is recognized as dominant.

Note. * Refers to the visual preference division between symbolized information and the printed word. Adapted from "Not another inventory, rather a catalyst for reflection," by N. Fleming, and C. Mills, 1992, *Improve the Academy*, 11, p. 129.
** Individuals who were identified to having more than one preferred modality.

To examine multiple-sensory learning in this new age of technology, it is important to discuss how this type of learning is made accessible to individuals. Hypertext, hypermedia, and interactive multimedia produce auditory, visual, and kinesthetic (i.e., hands-on sensory input) modalities in instructional designs. These modality inputs are introduced in special forms of media known as virtual reality (VR) and virtual learning environments. To be considered hypermedia the media must be interconnected by a hyperlink and two of the following elements must be present: text, graphics, audio, interactive video, animation, or other data delivered primarily through some type of electronic device (Beccue et al., 2001; Burton, Moore, & Holmes, 1995; Chen, 2002; Chen & Ford, 1998; Chen & Macredie, 2002; Donovick, 2001; McKnight, Dillion, & Richardson, 1996; Reeves, 1998).

In hypermedia, these elements must be used to incorporate intensely engaging instructional design (Daniels, 1993; Gates, 1993). Interactive multimedia presented online within a virtual environment uses large amounts of bandwidth resources for accessing large amounts of information in many sensory modes or cues that learners can work actively rather than observe passively. Interactive multimedia is not just the merging of video with other digital media but also other media combinations (Burton et al., 1995; DeBloois, 1982). Media-rich instructional designs are more engaging and are able to stimulate multiple senses at one time, thus the media may be more attention-grabbing and desirable (Ayersman & Minden, 1995; Beccue et al., 2001; Reeves, 1998). Recent trends in education technology literature have shown that hypertext, hypermedia, and interactive multimedia provide flexible modalities that can adapt to individual differences.

To access hypertext, hypermedia, or interactive multimedia learners with physical or sensory impairment use assistive technologies to access online learning content through specialized input devices and software. Netherton and Deal (2006) defined assistive technologies (ATs) as, "…any piece of equipment or device that may be used by a person with a disability to perform specific tasks, improve functional capabilities, and become more independent. It can help…people with a wide range of cognitive, physical, or sensory disabilities" (p.11). ATs are used primarily for input and output processes such as oral communication between user and computer, user interaction with programs and software, and user accessing online content. ATs have been demonstrated to aid learners with disabilities (Day & Edwards, 1996; Netherton & Deal, 2006; Weir, 2005).

However, to date there has been no research on learning outcomes when assistive devices are combined with new interactive multimedia in VLEs. As the use of VLEs increases in technical quality and appeal, the lack of data on their ability to support ATs is problematic. The combination of VLEs and multi-channel ATs can appeal to learners who prefer reading information, learning by auditory input, and learning through tactile modality (Moore et al., 1996). This researcher's interest and research history in the efficacies of ATs, VLEs, and the results of combining them in complex multi-sensory learning experiences for all learners prompted this study. Specifically the study tested the effects on learning performance of a proceduralized instructional task when ATs are added to an online VLE. For the purpose of this study, ATs will be referred to by the synonymous term multiple-channel technologies. The terms Closed Caption® (text), audio, and video will be referred to as cues.

Theoretical and Conceptual Framework

The framework constructed for this study is underpinned by five related information-processing theories: (a) Miller's Information Processing Theory (1956), (b) Severin's Cue Summation Principle of Learning Theory (1968), (c) Paivio's Dual Coding Theory (1990), (d) Sweller, van Merrienboer, & Paas Cognitive Load Theory (1998), and (d) Broadbent's Single Channel Theory (1958). Theories used to construct research frameworks are supportive of the concepts of interest through documented facts that compliment the research problem and guide the study by synthesizing and inter-relating the various facts of the research (Wiersma, 2000). The proposed conceptual framework for this study draws upon human cognitive processing and the external influences that affect learning when multiple-sensory inputs are used in proceduralized instructional design. Findings, conclusions and recommendations from previous studies involving multiple-channel communications (Beccue et al., 2001; Brashears et al., 2005), integrating ATs in

VLEs (Dotterer, 2010a), and cognitive processing (Ford & Chen, 2000) informed the development of the framework and helped guide the study.

Examining each theory applied in the conceptual framework and considering the key recommendations from previous studies, the relationships are shown diagrammatically in Figure 1. The conceptual framework is expected to offer both a solid foundation for the study and a vocabulary and logic structure for discussing the findings. The positive and negative influences on learning outcomes identified in the framework represent the findings based on research examining multiple-sensory input that form the theoretical foundations for this study.

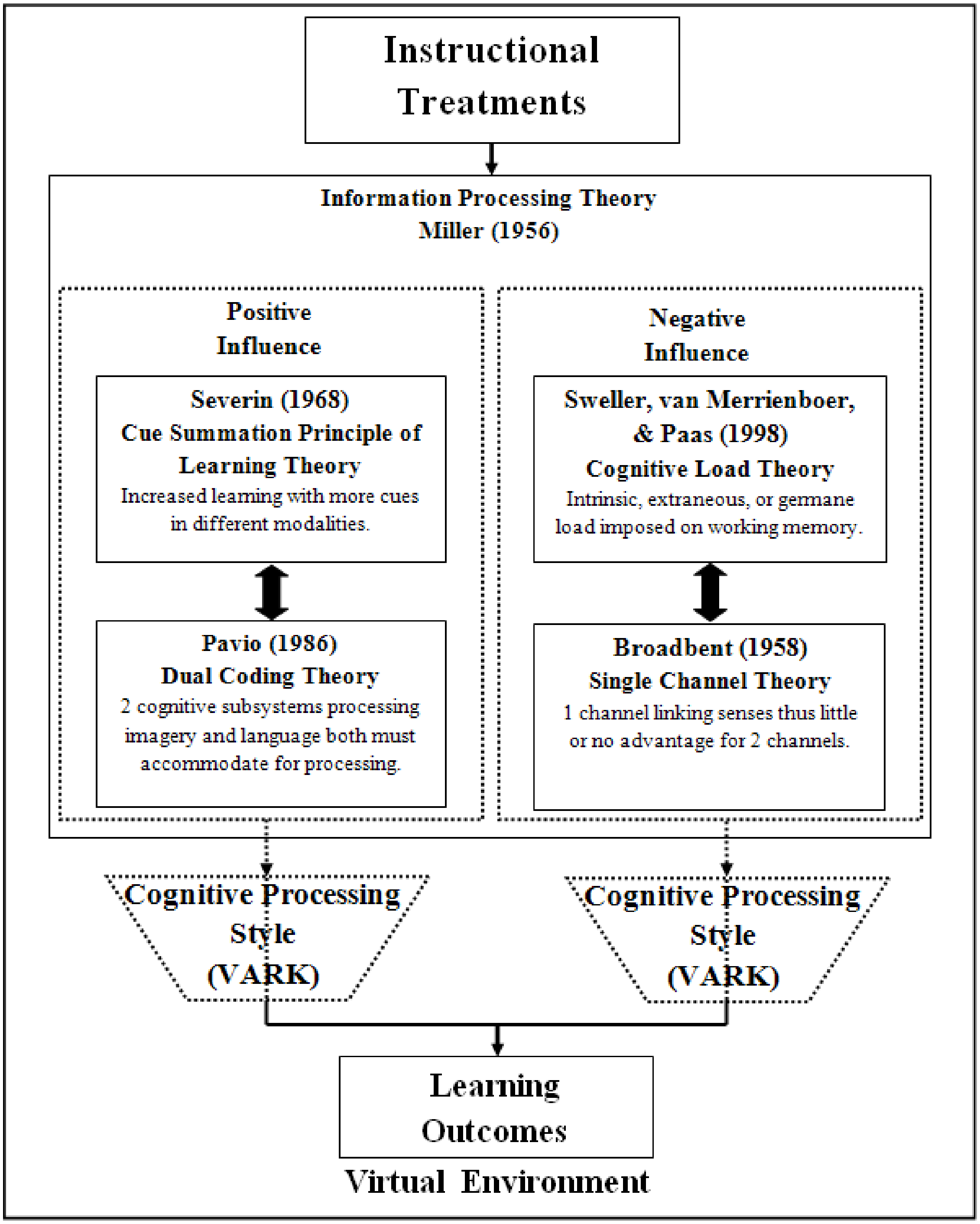

Figure 1. Theoretical/Conceptual Framework for the Effectiveness of Multiple-Channel Technologies in a Proceduralized Instructional Design in a Virtual Environment.

A recent study by this researcher (Dotterer, 2010b) addressed variables relevant to the present study. This study found that individuals immersed in VLEs combined with multiple-channel technologies in a proceduralized instructional design experienced four key obstacles: (1) extraneous cognitive load, (2) orientation obstacles, (3) wayfinding obstacles, and (4) a lack of proceduralized instructional design. This study indicated when merging VLEs and multiple-channel technologies in VLEs, it is imperative that instructional developers be skilled in designing and evaluating how this technology combination is applied for learning online (Dotterer, 2010a). In research examining multiple-channel learning, Brashears et al. (2005) subjected students to three treatments: (a) text only materials, (b) text-audio/video component, and (c) audio/video-imagery in an instructional unit. They concluded that students performed better with treatments containing an audio/video component and recommended further studies incorporating cue summation in instructional development. Other research conducted by Beccue, Vila, and Whitley (2001) examined learning outcomes based on multiple-channel learning when audio cues were integrated into existing text-based and graphic-based multimedia lab exercises. They recommended assessing extraneous loads when adding multiple cues.

Information Processing Theory

George Miller's (1956) information processing theory determined that short-term memory, also known as working memory, can hold about five to nine discrete chunks of information. This concept is known as "chunking" (Burton et al., 1995; Lohr, 2008; Moore et al., 1996; Wilson & Cole, 1996). The term chunking, also known as 'The Rule of Seven' refers to a strategy design in education used to reduce large amounts of information into smaller manageable bits of information (Johnson & Aragon, 2003; Lohr, 2008). Miller (1956) stated, “There is a finite span of immediate memory and…for a lot of different kinds of test materials this span is about seven items” (p. 347). Cowan (2001) states, this is a rough estimate and rhetoric, but does not represent short-term memory capacity. Cowan suggests that memory storage is limited to three to five chunks (Cowan, Elliott, Saults, Morey, Mattox, Hismjatullina, & Conway, 2005), while others claim that there is no capacity limits per se, but the time an item remains active without being recognized or rehearsed is limited (Baddeley, 1986; Richman, Staszewski, & Simon, 1995).

The human cognitive system is divided into three storage structures: sensory registers, short-term memory (STM), and long-term memory (LTM). Environmental stimuli entering the human cognitive system are processed within these three storage chambers. The sensory registers, also known as sensory memory, acquire raw sources of information that are transformed into a readable/writeable language (i.e., similar to a computer processor) that can be interpreted by memory processes that encode and store information (Burton et al., 1995; Moore et al., 1996). The memory’s lifespan at this stage is about three seconds for hearing and one-half second for vision. Within this short lifespan, if interesting stimuli elicit a response, then pattern recognition through STM can evoke previously acquired knowledge from LTM (Ericsson & Kintsch, 1995; Sweller, 2003, 2004). Pattern recognition, sometimes referred to as assigning meaning, occurs in working memory and generally has a short lifespan, usually lasting 15 to 20 seconds unless the material recycles (i.e., maintenance rehearsal) through memory over and over at which the life expectancy is extended upwards to 20 minutes (Burton et al., 1995; Huitt, 2003; van Merrienboer & Sweller, 2005; Moore et al., 1996; Paas, Renkl, & Sweller, 2003; Paas, Tuovinen, Tabbers, & Gerven, 2003; Sweller, 1988; Wilson & Cole, 1996). Without maintenance rehearsal the working memory will drop the information, thus the transfer to LTM will not take place. The general information processing theory forms a background for the more specific processing theories that frame this study and lays the groundwork for understanding how humans process and interpret information. However, stimuli introduced through sensory channels require attention before being processed and moved to permanent cognitive storage. Severin and Paivio, proponents of multiple-sensory stimuli, theorized that learning is reinforced when two or more senses are induced simultaneously.

Cue Summation Principle of Learning Theory

The cue summation principle of learning theory provides a foundation for the modalities found within the multiple-channel technologies. Severin's (1968) cue summation principle of learning theory refers to simultaneous stimuli introduced through sensory channels such as sight, sound, or touch that, according to this learning principle or theory, provide more stimulus reinforcement (Barron & Kysilka, 1993; Barron & Varnadoe, 1992; Burton et al., 1995; Dwyer, 1978; Severin, 1967, 1968; Severin & Tankard, 1979). As cited in the literature, instructional designers must be able to determine how many simultaneous stimuli can be processed when presented through multiple-channels before extraneous cognitive load occurs (Moore et al., 1996; Worley, 1999). Severin's (1968) cue summation principle of learning theory has been both supported and refuted by researchers. The dispute between researchers regarding Severin's theory has been based on cited differences in the types of cues, stimuli or modalities, and how the cues were integrated or infused in the respective studies.

Dual Code Theory

Paivio's dual code theory (DCT) proposes that human cognition is split between two distinct but partially interconnected subsystems that encode, organize, store, and retrieve information (Paivio, 1971, 1990). Unlike Miller's general information processing theory, Paivio's dual cognitive system proposes that imagery (i.e., pictures, sound, taste, events) is processed within a visual memory and verbal language (i.e., linguistics, generic speech) within a verbal memory (Lohr, 2008; Paivio & Desrochers, 1980). This dual system can work as one processing unit or each component can function independently of one another, but both are given equal weight in information processing (Paivio, 1971, 1990). Although Paivio's DCT represents a system that transfers information through a learning process, it contradicts Broadbent's (1958) earlier claim that multiple-sensory channels leads to cognitive jamming or a bottleneck effect.

Single Channel Theory

Broadbent's (1958) single channel theory, also known as the bottlenecking theory, proposes that only one sensory channel can processes information at a time. If more than one channel competes for attention, a jamming, extraneous cognitive overload, or bottlenecking occurs (Barron & Kysilka, 1993; Burton et al., 1995; Jesky & Berry, 1991; Moore et al., 1996). The cue summation principle of learning theory and the dual code theory both acknowledge that STM (i.e., visual and verbal memory) must recognize cues or give attention (pattern recognition) to the cues before the information can be passed onto LTM. This attention is the key to human cognitive processing. Research by Anderson (1985) concluded that the recognition of one stimulus in a channel does not hinder a second stimulus being recognized. All stimuli are recognized by sensory registers and retained for a short time span, but performing two tasks simultaneously is difficult. Only the information that is recognized or given attention can be processed into LTM (Anderson, 1985). Cognitive research supports the information processing theory but relies heavily on the attention or pattern recognition given to stimuli in order for procedural knowledge (i.e., prior knowledge stored in LTM) to be retrieved (Anderson, 1985).

Cognitive Load Theory

Sweller, van Merrienboer, and Paas's (1998) cognitive load theory was based on instructional theory that describes the load created on a learner's cognitive system while performing a particular task (Lohr, 2008; van Merrienboer & Sweller, 2005). There are three distinguishable types of cognitive load; intrinsic, extraneous, and germane (Mayer, 2001). Intrinsic cognitive load is defined by the inherent difficulty of the instructional material, how many elements are present, and how those elements interact with one another. Extraneous cognitive load is externally imposed and is dependent on how the instructional information is designed, organized, and presented. Germane cognitive load is caused by instructional design processes that assist in meaningful learning controlled by the instructional designer (Mayer, 2001). To lower the load on working memory, designers must chunk information in meaningful units and automate procedural knowledge.

Sweller and Chandler (1994) were critical of Severin's theory and provided evidence of extraneous cognitive load issues caused by interactive stimuli that required high numbers of sensory channels and by designs that required students to split their attention. They refuted the efficacy of redundancy effects and cue summation. Instructional design materials that cause individuals to divide their attention between multiple sources of information and then integrate that information is known as split attention (Smith, 2001), which Sweller and Chandler felt was problematic because of the load created when information-processing requirements exceed cognitive capacity. Sweller, van Merrienboer, and Paas's cognitive load theory provides a strong argument against instructional designs incorporating multiple-channel technologies if not properly designed. This argument may help designers develop instructional processes that successfully incorporate multiple-channel technologies.

Framework Summary

The set of cognitive processing theories as related to the theoretical/conceptual framework support and guide the study through interrelations based on human cognition. Each theory independent from one another are substantiated by their classical nature and historical premise. The theories support the framework by establishing an interconnection of how information is processed, how much information can be processed at one time, and the different modalities at which the information is presented. The framework proposes that the effects of instructional treatments are filtered through human information-processing governed by general information processing theory. Information processing may be either positively or negatively affected by use of multiple-sensory input channels, and the path of effect on learning outcomes may be related to an individual's cognitive processing style as defined by the VARK model. This study tested this framework in the context of a virtual learning environment.

Statement of the Problem

The use of virtual learning environments (VLEs) is gaining acceptance in the delivery of instructional content in education, but the successes of VLEs to produce meaningful learning and knowledge creation has yet to be established. Online learning content in the form of multiple-channel or multiple-sensory technologies must be accessed by all learners via computer-based assistive technologies (ATs) on which learners with disabilities are particularly reliant. VLEs are web-based platforms that offer an interface where learners can input or access multiple-sensory content that can be delivered through ATs. However, there has been little research on the compatibility of assistive devices in VLEs. The compatibility of ATs used in VLEs to deliver high-impact learning has yet to be examined to assess the positive or negative effects of multiple-channel ATs. Thus, educators and instructional designers have limited knowledge of how effective multiple-sensory technologies are in VLEs or how to design multiple-channel VLEs to facilitate learning. This situation may be even more complex when individual learning styles are introduced into multiple-sensory VLEs.

Purpose of the Study

The purpose of this study was to examine through experimental research methodology the effects of multiple-channel technologies and learning styles on learning performance in an online VLE with a proceduralized learning task. Dotterer (2010b) conducted research using multiple-channel technologies in the following forms: text only, image only, integrated technologies (i.e., audio and video multimedia components combined with closed captioning and QuickTime virtual reality), and hands-on instruction in a proceduralized instructional design. Dotterer concluded that subjects experienced extraneous cognitive load when multiple-channel technologies were combined with a QuickTime VR movie. The present study expanded on Dotterer's (2010a, 2010b) research. It specifically examined learning of proceduralized instruction in basic cardiopulmonary resuscitation

(CPR) using three separate but distinct multiple-channel treatments: image with supportive text instruction, audio with supportive text instruction, and interactive multiple-channel technologies (i.e., audio, video, and interactive modalities combined with closed caption). The interactive multiple-channel technologies were delivered as an online component within a course management system comprised of virtual simulations and pedagogical agents. The proceduralized instructional designs were identical in content and differed only in respect to the multiple-channel modality formats.

Research Hypotheses

The conceptual framework for this study was formulated based on recommendations from prior research; theories included Miller's (1956) Information Processing Theory, Severin's (1968) Cue Summation Principle of Learning Theory, Sweller's (1988) Cognitive Load Theory, Paivio's (1990) Dual Code Theory, and Broadbent's (1958) Single Channel Theory; and human cognitive processing as defined by Fleming and Mills in their VARK definitions of learning styles. These foundations led to the following two-tailed null hypotheses which were tested in the study:

> $H0_1$: There is no difference in the performances on a basic cognitive test of CPR procedures of learners who receive image with text support, audio with text support, and multiple-channel proceduralized instructional presentations in an online virtual learning environment.

> $H0_2$: There is no difference in the performance on a basic cognitive test of CPR procedures of learners having visual, aural, read/write, kinesthetic, and multi-modal learning styles in a proceduralized instructional presentation in an online virtual learning environment.

$H0_3$: There is no interaction of media format and learning styles on a basic cognitive test of CPR procedure in a proceduralized instructional presentation in an online virtual learning environment.

In addition to participant preferred learning style and CPR test, demographic data were also collected. However, for this study, the demographic data were used only to describe the sample; they were not used in hypothesis testing. The study's research hypotheses, data sources, and data analyses are summarized in Table 3.

Table 3

Research Hypothesis, Data Sources, and Data Analyses

Hypothesis Purpose	Data Source	Data Analysis
Description of Study sample	Demographic questions on online test of CPR procedures	Descriptive Statistics
$H0_1$	Online test of CPR procedures	Factorial ANOVA (Main effects for treatment)
$H0_2$	Online test of CPR procedures	Factorial ANOVA & VARK questionnaire (Main effects for learning styles)
$H0_3$	Online test of CPR procedures and VARK questionnaire	Factorial ANOVA (Interaction of treatment and learning styles)

Definitions of Key Terms

Conceptual Definitions

A Generative Theory of Multimedia Learning: Richard E. Mayer's early theory (1997) blending sensory modalities and multimedia instructional messages with the medium best suited for a learner's individual cognitive processes.

Animation: a series of static images that are linked together through authoring software that produce a mini-movie clip. These animations promote motion, trajectory, or change over time.

Aptitude Treatment Interaction: A theory and research model that suggests the effectiveness of instructional treatments for individuals can be related to their specific abilities or characteristics (Cronbach & Snow, 1977).

Articulatory Rehearsal System: The speech production component of the phonological loop proposed by Alan Baddeley and Graham Hitch (1974). The system acts a rehearsal stage to recycle auditory information while converting visual information into an auditory code.

Assistive Technology: Multi-channel or multi-sensory devices that provide individuals with learning, communication, and physical access difficulties the necessary hardware and software solutions to lead more productive and independent lives. These techniques can also be used by individuals without learning, communication, or physical difficulties to access complex environments.

Central Executive: The most important component of the Model of Working Memory proposed by Alan Baddeley and Graham Hitch (1974). The central executive component deals with attention and how priority is assigned to some stimuli over other stimuli.

Chunking: A term used to describe the grouping of information in smaller bits of information (Miller, 1956).

Closed Caption Video: Text that scrolls through a digital video file that gives auditory-impaired individuals the opportunity to read informational dialogue.

Cognitive Controls: Patterns that display an individual's way of thinking and processing information (Jonassen & Grabowski, 1993).

Cognitive Styles: The way an individual thinks and processes information (Jonassen & Grabowski, 1993).

Coherence Principle: A principle that proposes that the addition of text, imagery, or auditory cues irrelevant to the instructional design is detrimental in the learning process (Mayer, 2005d).

Connectivity: The systems that create the connection between multiple computers and servers across distance. Connectivity can refer to dial-up, digital subscriber line, satellite, T-carrier lines, and fiber optic lines.

Contiguity Principle: A principle proposed by Mayer and Anderson (1992) that comprises two effects: spatial and temporal. Spatial contiguity proposes that learners learn more deeply when pictures are accompanied with relevant text located in the same proximity to one another. Temporal contiguity, similar to spatial contiguity, deals with the amount of time before pictorial modes are presented with supportive text.

CPR: Cardiopulmonary Resuscitation, an emergency procedure used on a person who is not breathing and/or whose heart has stopped beating.

Cue Summation Principle Learning Theory: Theory developed by William Severin (1968) proposing that several sensory modalities presented in a redundant fashion should increase learning.

Digitization: Technological advances that allow for higher quality text, graphics, video color and motion at increased speeds.

Dual Code Theory (DCT): Paivio's (1986) theory that divides the cognitive process into two distinct subsystems: visual memory and verbal memory.

Egocentric: The relationship of oneself to its surroundings in a mapped environment.

Extraneous Cognitive Load: Limitations on learning due to ineffective or poorly designed instructional content (Sweller, van Merrienboer, & Paas, 1998).

Germane Cognitive Load: Germane cognitive load is caused by instructional design processes that assist in meaningful learning when new knowledge is integrated with existing knowledge.

Human Cognition: The study of how the human brain works (Miller, 1956).

Hypermedia: Links that act as portals or gateways to other locations within the same document/media or documents and media in another location. The structure of the linking can be linear (pre-determined navigation) or non-linear (subject controls navigation).

Hypertext: Links that act as portals or gateways to other locations within the same document or documents in another location. The structure of the linking can be linear (pre-determined navigation) or non-linear (subject controls navigation).

Hyper Text Markup Language (HTML): the programming code that allows a hypertext or hypermedia action to take place.

Individual Differences: Dimensions or factors on which individuals differ in their behavior or characteristics.

Information Processing: how information or cues are processed through the human memory system.

Information Processing Theory: Miller's (1956) theory breaking the human cognitive process into three levels of memory: sensory registry, short-term memory, and long-term memory.

Interactive Media: Forms of media that can be actively engaged by an individual to produce an action or response.

Intrinsic Cognitive Load: Intrinsic cognitive load is defined by the inherent difficulty of the instructional material, how many elements are present, and how those elements interact with one another.

Kinesthesia: A sense used by the body to detect movement of muscles, tendons, and joints.

Learning Styles: An individual's preferred approach to learning (Fleming & Mills, 1992).

Linear: Instructional content created by educators that has a pre-determined pathway that is linked through a series of hypertext or hypermedia.

Long-term Memory: a component of human cognition that holds and stores knowledge, skills, experience for long periods of time.

Modality Principle: A principle that proposes to lessen cognitive load when two or more modalities are used within instructional design materials by sharing both visual and auditory loads in working memory (Mayer & Moreno, 1998).

Model of Working Memory: A theoretical model of working memory conceptualized by Allan Baddeley and Graham Hitch (1974). The model introduces a three component model of working memory that divides visual and auditory stimuli into separate stores for processing.

Moodle: An open source course management system used to store and contain instructional content.

Multi-Component Working Memory Model: A hybrid model design of the Model of Working Memory proposed by Alan Baddeley (2000). This model introduces the fourth component known as the Episodic Buffer. The buffer acts as a filter between the visuospatial sketchpad, phonological loop, and episodic long term memory (Baddeley, 2000).

Multi-Store Model: Conceptualized by Richard Atkinson and Richard Shiffrin (1968) based on short-term memory and how information is retrieved, transferred, and stored in the human memory system.

Multimedia Instructional Messages: Presenting instructional materials through a combination of the written word and imagery for the purpose of learning.

Multimedia Principle: A theory used to describe how people learn better with pictures and words than from just words alone (Mayer, 1997).

Multiple Channel Technologies: Technologies that use multiple channels or sensory modalities in instructional design such as audio, video, and interactive elements through an online learning management system; includes assistive technologies.

Non-linear: Learners are given the freedom to navigate within digital content without a pre-determine path. Individuals take a learner-centered approach to learning at the speed and pace they desire.

Phonological Loop: A component found within Allan Baddeley and Graham Hitch (1974) Model of Working Memory. The phonological loop is comprised of two subcomponents known as the phonological store and the articulatory rehearsal system. The store acts as a storage unit and processor of verbal and acoustic stimuli.

Phonological Store: A subcomponent of the phonological loop proposed within Allan Baddeley and Graham Hitch (1974) Model of Working Memory. The phonological store holds auditory stimuli for a brief period of time.

Proceduralized Instructional Design: A method used to teach or train a skill that must be performed in a hierarchical set of sequential steps (e.g., hooking up an electrocardiograph machine or changing oil in an automobile).

Redundancy Principle: Conceptualized by Kalyuga, Chandler and Sweller (1999) proposes to reduce the amount of working memory load when additional redundant modalities are used in instructional design.

Scaffolding: Supporting materials used to help introduce new concepts within learning. Forms of scaffolding include by not limited to resources, tasks, templates, and guides.

Schema: Relationships or connected ideas; also procedures or structures used to organize parts of specific experiences into meaningful systems (Cherry, 2011).

Sensory Memory: A component of the human cognitive process used to filter unanalyzed sensory modalities.

Sensory Modality: One of the five human senses (visual, auditory, smell, taste, touch) used to perceive and process information.

Short-Term Memory: Also known as working memory, takes raw data from sensory memory then comprehends, rehearses, encodes, or drops recognized stimuli within the cognitive process.

Single Channel Theory: Broadbent's (1958) theory that only one channel can be processed in at one time during the cognitive process.

Spatial Contiguity Principle: A principle that proposes that individuals have better learning outcomes when related text are located near the pictures they represent not located elsewhere on another page (Mayer, 2005d).

Split Attention Principle: The split attention principle forces learners to split their attention between two instructional elements due to images placed in separate locations within instructional materials (Sweller & Chandler, 1994).

Stimulus: An external element or bit of information that promotes an activity.

Temporal Contiguity Principle: A principle that proposes that individuals have better learning outcomes when related texts are presented within a short time after the picture has been displayed (Mayer, 2005d).

Uniform Resource Locator (URL): a uniform resource identifier (URI) that relocates to another place within a document or to a different source of media in another location. URLs and URIs are only found within computer based environments, Intranets, or the Internet.

Verbal Memory: Stimuli that has been encoded verbally or in words through human cognitive processing.

Visual, Aural, Read/Write, Kinesthetic Survey (VARK): A questionnaire instrument that deals with only one dimension of the complex amalgam of preferences that make up a learning style. The VARK questions and their results focus on the ways in which individuals like information to come to them and the ways in which they like to deliver their communication. The questions are based on situations in which there are choices and decisions about how that communication might take place (Fleming & Mills, 1992).

Virtual Learning Environment: A computer-produced real or simulated imagery-based "world" that is displayed on a desktop computer screen (Ausburn, Martens, Dotterer, & Calhoun, 2009).

Virtual Reality: Technologies used to immerse individuals in a realistic computer-simulated environment for training; technologies used to create virtual environments.

Visuospatial Sketchpad: Proposed by Baddeley & Hitch (1974), the visuospatial sketchpad handles visual and spatial information and the relation of an object to the environment. This component interacts with the phonological loop and the central executive components of the model of working memory.

Operational Definitions

Audio/Text Based Proceduralized Instructional Presentation: A text-based set of instructions combined with redundant audio media used to teach CPR procedures. The instructions are constructed in a step-by-step procedural order.

Aural Learning Style: This perceptual mode as identified by the VARK describes a preference for information that is "heard or spoken." Students with this modality preference report that they learn best from lectures, tutorials, tapes, group discussion, using mobile phones, speaking, web chat and talking things through. It includes talking out loud as well as talking to yourself. Often people with this preference want to sort things out by speaking, rather than sorting things out and then speaking (Fleming & Mills, 1992).

Demographic Data: Data collected to describe the sample in this study. Data collected will include age, gender, race, education level, career field, job title, visual status, auditory status, computer skill level, and past virtual training experience.

Image Only Proceduralized Instructional Presentation: A series of images used to teach CPR procedures. The instructions are constructed in a step-by-step procedural order.

Kinesthetic Learning Style: This modality as identified by the VARK refers to the "perceptual preference related to the use of experience and practice (simulated or real)" (p. 139). Although such an experience may invoke other modalities, the key is that people who prefer this mode are connected to reality, "either through concrete personal experiences, examples, practice or simulation" (p. 140). It includes demonstrations, simulations, videos and movies of "real" things, as well as case studies, practice and applications (Fleming & Mills, 1992).

Learning Styles: Preferred preferences of learning and processing information as measured by the Visual, Aural, Read/Write, Kinesthetic (VARK) Learning Styles survey.

Multiple Channel Proceduralized Instructional Presentation: A multi-media set of instruction to teach CPR procedures. The instructions are constructed in a step-by-step procedural order. Media used can include hypermedia, closed caption with audio, animated imagery, video, and textual based information.

Performance on Basic Cognitive Test of CPR Procedures: An assessment of 15 multiple-choice questions administered to subjects after they received an instructional treatment. The questions are adopted from the American Heart Association's cognitive test bank which is used to assess an individual's pass or fail on CPR procedures. Score is the number of correctly answered questions on this 15-item test. This score was the learning performance measure and dependent variable in this study.

Proceduralized Instructional Design: A skill set or set of instructions to be followed by a learner in a specific sequential order.

Read/Write Learning Style: This preference as identified by the VARK is for information displayed as written words. This preference emphasizes text-based input and output - reading and writing in all its forms. According to Fleming & Mills (1992), "People who prefer this modality often like PowerPoint, the Internet, lists, dictionaries, thesauri, quotations and words, words, words..." (p. 3).

Text Only Proceduralized Instructional Presentation: A text-based set of instructions used to teach CPR procedures. The instructions are constructed in a step-by-step procedural order.

Visual Learning Style: This preference as identified by the VARK includes the depiction of information in maps, spider diagrams, charts, graphs, flow charts, labeled diagrams, and all the symbolic arrows, circles, hierarchies and other devices, which instructors use to represent what could have been presented in words. It could have been called Graphic (G) Style, as that better explains what it covers. It does NOT include movies, videos or PowerPoint. It does include designs, whitespace, patterns, shapes and the different formats that are used to highlight and convey information (Fleming & Mills, 1992).

Limitations and Assumptions of the Study

The following limitations and assumptions were accepted for this study:

Limitations

1. The population was limited to students from CareerTech technology centers and two-year associate degree trade community colleges in Oklahoma, which limits generalization of its findings.
2. The non-random obtained sample was composed of volunteers and may not accurately represent the population.
3. Assignment of subjects to treatment groups was purposive rather than random. While this supports the study's theoretical/conceptual model, it may have resulted in non-equivalences among the groups that could have biased the outcomes in unknown ways.
4. CPR represents only a single task, and results may not generalize to other proceduralized tasks.
5. Experimental control was limited because the research was conducted outside a laboratory setting.
6. The post-test only research design prevented a "rehearsal" effect on subjects' learning performance, but it also failed to provide a comparative measure for post-treatment performance results. This could have introduced inaccurate interpretation of the study's findings. However, avoidance of rehearsal effect was viewed as the more important consideration for this study.
7. Subjects may not have selected responses that were accurate on the VARK survey, and therefore their preferred learning style would not have been accurately recorded.

8. Some subjects may have had some experience with CPR and not have revealed this to the researcher, which could have biased their learning performance and invalidated interpretation of the study's findings.

Assumptions

1. It was assumed that participants understood all instruments correctly and answered truthfully. This assumption is typical of field-based studies with volunteer participants.

Significance of the Study

Virtual learning environments (VLEs) have demonstrated viability as a means of training in many industries, businesses, and professional environments (Ausburn & Ausburn, 2004, 2008; Ausburn, Ausburn, & Kroutter, 2010; Dotterer, 2010a; Kroutter, 2010). As a learning tool, VLEs have demonstrated distinct benefits across the educational spectrum (Dickey, 2005; Neel, 2006; Revenaugh, 2006; Shim, Kim, Kim, Park, Park, & Ryu, 2003; Smedley & Higgins, 2005; Vogel, Bowers, Meehan, Hoeft, & Bradley, 2004).

Because VLEs are new in training and teaching, the addition of multiple-channel technologies introduce more possibilities for learners in technology centers and in workforce training. VLEs have also proved beneficial in professional occupational training in the medical field and engineering. In general, recent research supports the assertion that an abundance of possibilities exist for VLEs as a training tool within the vocational and technical education field (Ausburn & Ausburn, 2008; Park, Jang, & Chai, 2006; Seth & Smith, 2004; Tiala, 2007). Because many individuals employed in business, industry, and specialized fields have some type of impairment, whether it is considered a minor impairment or severe, technology has provided the necessary tools for those individuals to perform in the workforce. These new multi-channel technologies can be applied to VLEs to give all learners equal opportunity to access information with multiple-sensory stimuli within the learning environment. The contribution to new knowledge in technology centers and in workforce training using VLEs combined with multiple-channel technologies creates the ability to immerse individuals in a safe environment while training for more dangerous or hazardous work areas. Individuals can take virtual tours, visit far away countries, and even explore new frontiers from the safety of their own desktop.

It is important that trainers consider this multi-channel VLE technology because it removes constraints of time and space and, through properly constructed and developed instructional procedures, allows desktop computers to affordably provide many training options. While effective use of multi-channel tools in VLEs can aid all learners, they can be particularly important to those who have disabilities and need assistive multimedia technologies. These individuals should be given the same opportunities as others to experience the benefit of VLEs through multiple-channel technology devices. Both ethical and legal considerations support this observation. This situation supports the importance of evaluating the effects of combining multi-channel assistive technologies in VLEs, which was the purpose of this study.

According to Rehabilitation ACT of 1973, Congress amended the Rehabilitation Act of 1973 in 1998, as amended by the Workforce Investment Act of 1998 requiring Federal agencies to make their electronic and information technology (EIT) accessible to people with disabilities. Inaccessible technology interferes with an individual's ability to obtain and use information quickly and easily (para. 1). VLEs with multiple-channel technology devices provide alternative solutions for all learners that can be more beneficial if properly implemented. The strong learning potential of VLEs has been shown through many training procedures, yet many people assume this technology cannot work for people with disabilities. However, this may not be true, given new multiple-channel technologies that can be integrated into VLEs. These technologies may combine effectively with VLEs to open virtual learning opportunities for everyone. This study tested this possibility and examined the efficacy of various proceduralized instructional designs for optimizing the outcomes for learners with various learning style preferences.

CHAPTER II

REVIEW OF LITERATURE

Introduction

Classical theories were used as the theoretical/conceptual framework that served as the foundation for this study. However, throughout history the classics have transformed into more modern theories or conceptual models used as frameworks to support advancements in technology, multimedia, and virtual learning environments. New discoveries in the field of neuropsychology have opened lines of inquiry regarding how the human cognitive system processes stimuli, while educators and instructional designers tap into more media-rich content by applying more effective strategies to create effective performance-based materials. These content areas will be discussed in further detail throughout this chapter to provide theoretical and empirical support for this study.

Many of the citations referenced in this study date back to the 1950s and have been used to validate the use of classical theories in the theoretical framework of this study. Resources as recent as 2011 pertaining to theories/models and other subject content were also included as part of the review of literature to introduce the more modern theories used in human cognitive processing integrated with 21st century technology. It can be argued that this literature review was written from the context of how education practices become more effective and beneficial by applying what has been learned from past studies.

The logical flow of this chapter guides the reader through several areas of content that have been cited with opposing views based on prior literature and empirical research. Some of the content areas such as human cognitive processing deserve a much more in-depth study than given here, but those areas are far beyond the scope of this study and as such have been introduced in their comprehensive form. Other content areas such as learning styles, multiple-channel or multiple-sensory modalities, 21st century web-based tools (i.e., course management systems and assistive technology devices), and virtual learning environments (VLEs) are re-introduced and expanded upon in this chapter. With recent advancements in technology, the ability to deliver multiple channel modalities of instructional content in a virtual environment may show positive benefits for learners. Individual differences and learning styles are how individuals learn, and the styles that learners may prefer as the means of delivering engaging, interesting and captivating content.

Individual Differences and Learning Styles

During this review, the researcher discovered a growing debate among scholars, educators, and researchers in in-depth studies and investigations into the legitimacy of learning styles theories. These studies offered opposing views as to the benefits of knowing one's preferred learning style based on the premise of performance gains in the learning process. As for this study, the growing debate emerging over the effectiveness of learning styles combined with instructional design practices became a center of attraction or key component of this study. Individual differences and learning styles are quite often interchanged, synonymous with some but quite different to others in regard to actual meaning. Table 1, in Chapter 1, presented Jonassen and Grabowski's (1993) basic layout design of learning differences into several categories (i.e., cognitive controls, cognitive styles, learning styles, and personality types), one of those being learning styles. For the purpose of this study, the focus of learning styles was examined in two areas: (1) preferences, (i.e., the preferred delivery method of content) and (2) aptitude, (i.e., learners' perceptions of how they learn best; aural, visual, or kinesthetic). Leite, Svinicki, and Shi (2009) reported that disagreements have been voiced as to the difference between individual differences and learning styles. Individual differences cover a broad range of categories and subcategories that define different behaviors, characteristics, dimensions, or elements in which individuals differ.

What Are Learning Styles?

Literature cited a multitude of definitions of learning styles. Kolb (1984) in the context of learning styles described knowledge creation as a transformational process based on understanding our own experiences. According to Dunn (2003), "According to learning-style theory, learners' cognitive, affective, and physiological patterns contribute substantially to their academic outcomes. These patterns are relatively stable indicators of how individuals perceive, interact with, and respond to their instructional environment" (p.1). More recently, Leite, Svinicki, and Shi (2009) defined learning styles as perceptual preferences, while others have defined them as any preferences that affect performance outcomes. Felder and Spurlin (2005) have defined learning styles by stating that, "Students have different strengths and preferences in the way they take in and process information – which is to say, they have different learning styles" (p. 103). Others have based their definitions' of learning styles as an integration of learner preferences and delivery methods. These researchers have asserted that individuals have different modes of how information and content are learned, and the learning process can be enhanced if teaching methods are matched with these preferred modes (Barron, 2004; Dunn & Dunn, 1979; Felder & Spurlin, 2005; Mayer, 2001; Pashler et al., 2008; Riener & Willingham, 2010; U.S. Department of Education, 1998).

There are numerous assessments, surveys, and questionnaires that claim to pinpoint an individual's learning style, but to prescribe a matching delivery method to specific sensory modality preferences is impossible (Szabo, 2002). From the view point that performance outcomes can be increased if an individual's learning styles are aligned with delivery methods does make logical and plausible sense (Olsen, 2006), but there are those who refute these benefits based on the lack of scientific evidence or research backing these claims.

Theorists, educators, and other enthusiast have long been inundated with learning styles, and the benefits associated with the different learning styles and how information is processed. Many of these individuals have claimed that individual styles are at the epicenter of the learning process, but research conducted in the field of neurological psychology, distance education, human cognition, and other studies have refuted the myth of learning styles and their usefulness. Stossell's (2006) controversial book, *Myths, Lies, and Downright Stupidity*, has created a stir within the education community and those who embrace learning style theories. Stossell refutes the myth that individuals learn best when learning styles are matched with information delivered in the same modality. Similarly, Henry (2007) claimed that methods of classifying individuals based on learning styles are nonsense and a waste of time and valuable resources.

As both sides debate their case, key questions must be answered that may help resolve this controversial topic: (1) are learning styles assessment tools valid and reliable? (2) will learners benefit from matching delivery methods with learning styles? and (3) does understanding ones preferred learning style improve memory, concentration, confidence level, or anxiety leading to increased performances (Dembo & Howard, 2007)? To answer these questions, several studies have been conducted and reviews of prior research have been evaluated addressing the questions pertaining to learning style instrument reliability and validity, benefits of matching delivery methods, and preferred learning styles improving memory.

Commonality Between Proponents and Non-Proponents of Learning Styles

Reiner and Willingham (2010) have asserted that proponents and non-proponents of learning style theory have commonalities across their beliefs: (1) individuals are unique and differ from one another, which directly affects learning performances and teachers should recognize these differences, (2) individuals differ in their interests, (3) prior knowledge within domains differ from one individual to another, and that background knowledge influences the way they learn. In reference to Reiner and Willingham's first and second claims, scientists explore and discover principles behind learning while educators, design specialist, and others agree that differences do exist. Some of the differences do coincide with the learning process. Most individuals do have the capacity to learn different content areas, and they may possess talents, abilities, or intelligences that are suited to their particular interests (Reiner & Willingham, 2010). When discussing individual interests, the mere thought of having an attraction or fascination with subject content or an object within the environment would create a stronger focus to concentrate on what appeals to the senses.

Lastly, Reiner and Willingham (2010) stated that background or prior knowledge enhance the learning process through connections that were constructed with long-term memory (LTM) that lead to new ideas and concepts. For example, basic mathematical functions and formulae pave the way for more advanced math skills such as operands in algebraic, trigonometry, or complex quadratic formulae. Background knowledge and prior knowledge are also beneficial when considering skills (Pashler et al., 2008; Reiner & Willingham, 2010). A proceduralized set of instructions such as changing the oil in a vehicle or replacing worn out brake pads requires previous or background knowledge. When changing the oil, an individual should master a skill of knowing how to remove the oil drain plug, or if changing brakes, to remove the tire by loosening the lug bolts before changing the brake pads.

Research on Learning Styles

Proponents of learning styles have conducted many research studies. While many of the studies were literature reviews, several empirical studies have shown measurable gains in performance outcomes based on the overall effectiveness of learning styles as an instructional variable. One notable study conducted by Zywno and Waalen (2002) examined the effect on student learning outcomes using hypermedia instruction when compared to conventional methods of instruction. Ninety-four subjects were randomly assigned to one of two treatments; 49 subjects were assigned to the hypermedia group, and 45 were assigned to the traditional instructional method. Each subject was administered the Index of Learning Styles (ILS) formulated by Felder and Silverman (1988). According to Felder and Silverman, the ILS classifies individuals into one of four dimensions: sensing, visual, active, or sequential. Engineering students' academic performance records was compiled and used to measure achievement (Zywno & Waalen, 2002). Upon completion of the treatment, each subject completed a 41 item survey used to measure learning outcomes. Zywno and Waalen concluded that subjects administered the hypermedia instruction out performed subjects as compared to conventional teaching methods in all four dimensions of the ILS based on overall academic achievement and survey results.

A recent study conducted by Tie and Umar (2010) examined the effects on subject recall and retention performances when administered a cooperative learning approach to teaching paired programming language compared to conventional direct instructional design. Eighty-three subjects were randomly assigned to one of two treatments. Subjects were asked to complete the ILS survey by Felder and Silverman (1988) and to complete three assessments: pre-test, post-test, and a delayed post-test. Tie and Umar concluded that both visual and verbal preferred styles of learning performed equally on performance recall. However, visual subjects adapted to other learning approaches as compared to individuals with verbal preference learning style. Verbal preference learners formulated better schemata in long-term memory than visual preference learners due to experiencing oral and written statements from the treatment (Tie & Umar, 2010). Other advocates of learning styles have encouraged learners to know their own learning styles as part of their metacognitive development.

Nolting (2002) stated, "Research has shown that students who understand their learning styles can improve their learning effectiveness in and outside of the classroom" (p. 46). Van Blerkom (2006) advised students to look closely at their preferred learning style:

> Understanding how you learn best can also improve your concentration. When you're working in your preferred learning mode, you probably find that you are better able to concentrate on your study tasks. Approaching a task from your preferred style results in a better fit or match-studying feels right. (p. 14)

Sprenger (2003) suggested that students have preferred methods of learning and these preferences become dominate sensory modalities leading to increased learning performances. Jenkins (2005) stated, "If you discover that your learning style and the instructor's model of teaching clash, speak with your instructor about it" (p. 91). Jenkins went on to say, if you are a linear learner (i.e., left-brain) you are an active listener, thus lectures are your best delivery method of learning, but if you are right-brained, you are a global learner, and you should be reading any assigned materials before you attend the classroom lecture. Several researchers have addressed this discussion deals by pointing out the large amounts of money that are made by individuals and companies that have created a whole industry around selling learning styles assessments, surveys, questionnaires, books, tapes, DVDs, SCORM compliant LMS courses, and consulting contracts (Dembo & Howard, 2007; Pashler et al., 2008). As an example, in June of 2008, Kolb's (1984) learning styles inventories were sold in booklets of 10 for approximately $100.00 by the Hay Group (Pashler et al., 2008). At that same time Observational Primary Assessment of Learning Style (OPAL) sold assessment tools to a range of age groups costing $5.00 per assessment, while groups such as International Learning Styles Network charged $1,225 per trainee to attend a summer certification program (Pashler et al., 2008). Many other companies are also currently cashing in on the popularity of learning styles, but the important concept to take from the discussion is that the learning styles debate may have financial as well as research implications.

Theorists, practitioners, educators, and instructional designers have developed their own spin as to how learning styles should be individually assessed and identified. A study conducted by Coffield, Moseley, Hall, and Ecclestone (2004) examined 70 different models of learning styles assessments or instruments that measured learner attributes, traits, and characteristics (Pashler et al., 2008). Several of the well-known assessments, surveys, or questionnaires include: Kolb's (1984) Learning Styles; Dunn and Dunn (1975) Learning Styles Inventory (LSI); Gardner's (1983) Multiple Intelligence; Honey and Mumford's

(1992), Learning Styles Questionnaire; Gregorc's (1977) Mind Styles Delineator; and Myers-Briggs (1962) Type Indicator (Coffield, Moseley, Hall, & Ecclestone 2004; Dembo & Howard, 2007; Pashler et al., 2008). Coffield et al., (2004) concluded:

> Some of the best known and widely used instruments have such serious weaknesses (e.g., low reliability, poor validity and negligible impact on pedagogy) that we recommend that their use in research and practice should be discontinued. On the other hand other approaches emerged from our rigorous evaluations with fewer defects and, with certain reservations we suggest that they deserve to be researched further. (p. 55)

Low reliability and poor validity could be attributed to the design of the instrument, forcing individuals to choose responses that are narrowed into one particular style (Dembo & Howard, 2007). As the debate continues on validity and reliability of learning styles assessment instruments, a larger concentrated group focus is emerging on matching identified learning styles with particular instructional delivery designs.

The concept of matching preferred learning styles with a specific method of instructional delivery sounds like a good practice, but more than 90 studies spanning 14 years were examined by Stahl (1999), and according to Dembo and Howard (2007) and Coffield et al. (2004), failed to find any empirical evidence that showed that matching delivery methods with learning styles improved learning. Coffield et al. (2004) concluded the empirical evidence was, "…equivocal at best, and deeply contradictory at worst" (p. 40). They went on to say that proponents deliberately mismatched learning styles with delivery methods in an attempt to reverse the outcomes to show negative gains to those who demanded empirical evidence. Dembo and Howard (2007) commented by stating, "With such a long and storied history of different approaches, one would expect that if matching learning styles could produce measurable and consistent improvements in learning we would have ample evidence to this effect" (p. 105).

Research over the years examining performance outcomes has had mixed results based on matching learning styles with delivery methods. Research conducted in the late 1990s found that individual styles showed beneficial outcomes when students engaged in linear and non-linear hypermedia systems based on processing and the acquisition of information (Chen, 2002; Chen & Macredie, 2002). Leite et al. (2009) found that conversations in research and educational circles are beginning to see the need for more valid empirical research examining learning styles and encouraging teachers to embrace these varied instructional methods to help students become better prepared with learner-centered learning strategies. Others have based their criticism on the lack of an experimental foundation coupled with non-rigorous randomization, lack of scientific merit, or no significant advantages to these enhanced outcomes (Feldon, 2005; Mathews, 2010; Mayer & Massa, 2003). Others have challenged the use of learning styles for many years (e.g., Curry, 1990; Gutierrez & Rogoff, 2003; Salomon, 1984; and Stahl, 1999) as cited by (Dembo & Howard, 2007; Olson, 2006). Another empirical failure was reported by Riener and Willingham (2010) who found that although students who reported that they preferred to learn when information was presented visually or through an auditory channel, when they were tested, in a controlled environment, there were no differences reported.

Research conducted by Hartley (2001) examined the effect on learning strategies when instructional content was integrated with a non-linear hypermedia medium based on a pre-test/post-test content measure. Subjects were randomly assigned to one of two conditions, a control group and the strategy instruction group. All participants were asked to complete the Meta-cognitive Awareness Inventory (MAI) before being administered the treatment. The MAI measured knowledge about individual learning strategies, specifically cognitive and meta-cognitive strategies. Hartley (2001) concluded that the strategy instruction did not impact student's cognition that was initially measured by MAI. There was no positive impact on students' regulation of cognition between the two groups. There was no evidence that strategies improved performance or that there was an increased awareness that improved student performance.

In conclusion, individual differences and learning styles differ as to the context of their meaning. While the debate continues as to the benefits or myth of learning styles, proponents on both sides agree on three common areas: (1) individuals are unique and differ from one another and teachers should recognize these differences which directly affect learning performances, (2) individuals differ in their interests and prior knowledge, and (3) background knowledge influences the way they learn.

Human Cognitive System

Human memory has been described as a complex and intricate set of processes that acquire, transform, interpret, encode, store, and retrieve information and are synonymous with one of the memory compartments (Atkinson & Shiffrin, 1968; Brashears et al., 2005; DaCosta & Seok, 2010; Healy & McNamara, 1996). Collectively, the three memory storage compartments have long been used within various models, subsequently producing several theoretical frameworks used to guide research today. Psychologists Richard Atkinson and Richard Shiffrin were best known for their research that examined how information was processed and stored.

Two-Stage Model

Conceptualized by Atkinson and Shiffrin (1965), the two-stage model, offered a simplistic human cognitive model that illustrated how stimuli were retrieved, transferred, and stored in memory. This model of cognition is shown in Figure 2.

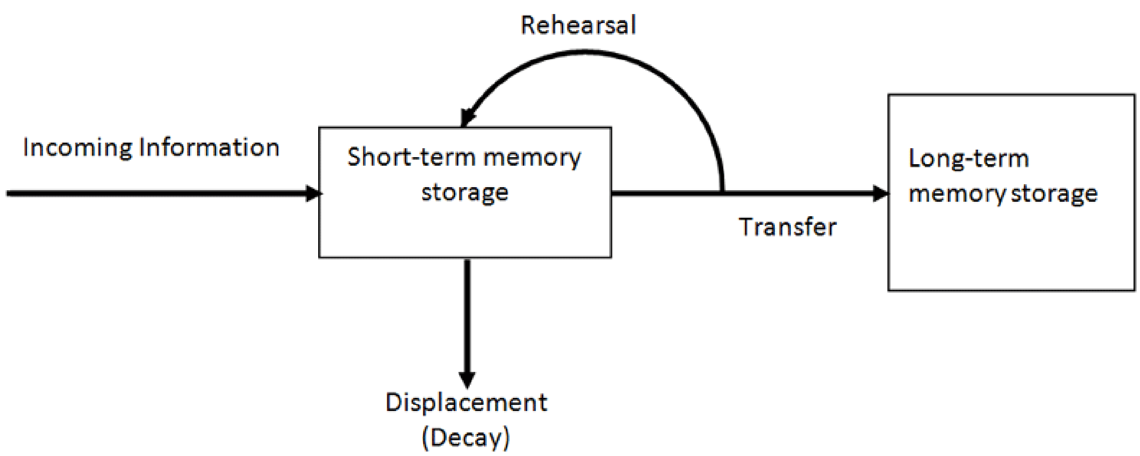

Figure 2. Atkinson and Shiffrin's original "two stage model". Adapted from *Mathematical Models for Memory and Learning (Technical Report No. 79)* by R. L. Atkinson and R. M. Shiffrin, 1965, Stanford University, Institute for Mathematical Studies in the Social Sciences, p. 4.

Atkinson and Shiffrin's early model recognized only two types of memory, short-term memory (STM) and long-term memory (LTM). In 1968, Atkinson and Shiffrin expanded their model and introduced three separate but distinct memory components: (1) sensory memory, (2) STM, and (3) LTM, as shown in Figure 3. In this cognitive model, known as the multi-store model, each memory component operated as a discrete function that worked harmoniously in the cognitive process (Atkinson & Shiffrin, 1968; DaCosta & Seok, 2010; Healy & McNamara, 1996; Huitt, 2003; Lohr, 2008).

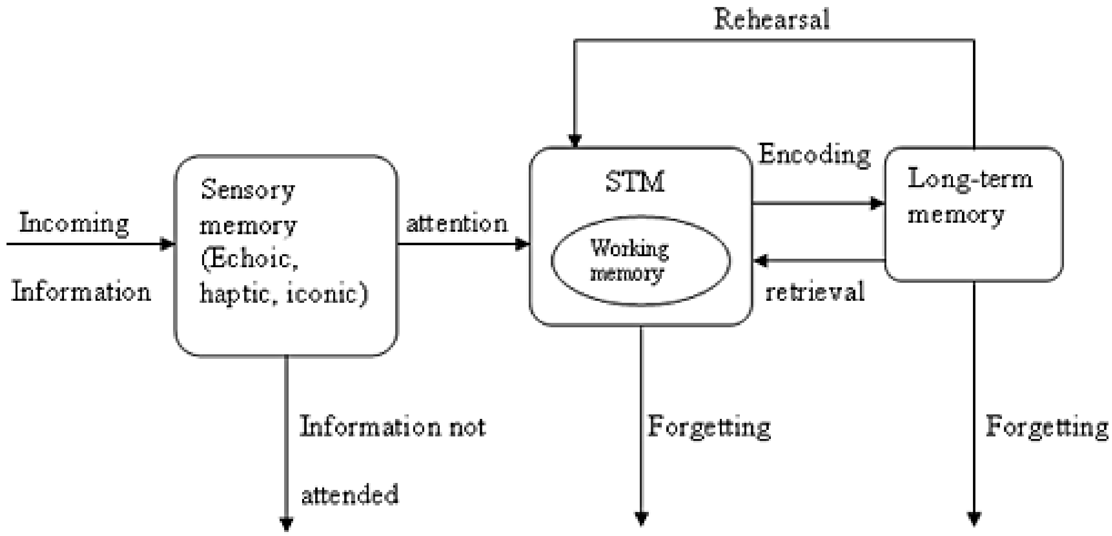

Figure 3. An illustration of the "multi-store model" conceptualized by Atkinson and Shiffrin. Adapted from "Human memory: A proposed system and its control processes" by R. L. Atkinson and R. M. Shiffrin, 1968, in K. W. Spence and J. T. Spence *The psychology of learning and motivation: Advances in research and theory* (p. 195). New York: Academic Press.

Multi-Store Model

The multi-store model illustrated a simplistic human cognitive system. For learning to take place, environmental stimuli must be retrieved and recognized by sensory memory store. Stimuli that are given attention are passed on to STM for further processing, while other un-attended information is permanently discarded and lost forever. These processes occur instantaneously as each bit of stimulus is processed. Stimuli associated with prior knowledge or experiences are connected to relevant information that has been permanently encoded and stored in LTM (DaCosta & Seok, 2010; Lohr, 2008). Although there are many variations of memory models, researchers generally agree that stimuli are passed through memory stages based on a series of encoding and retrieval processes (DaCosta & Seok, 2010).

As the present study focuses on how multiple-channel technologies are used in procedural instructional design, a general understanding of how information is processed in the human cognitive system plays a key role. Research in cognitive psychology warrants a detailed and in-depth discussion, as this particular study covered basic components of cognitive processing as it pertained to education and instructional design. The following sections cover the functions of each memory component of the human cognitive system, and the processes used to transfer stimuli into human memory.

Sensory Memory

The environment provides a large amount of information in the form of sounds, light, smells, taste, and temperature, but the human brain can only interpret electrical signals. The human body has been equipped with receptors that transform environmental stimuli into electrical signals that can be decoded by the brain (Huitt, 2003). The receptors act as transducers and convert raw environmental stimuli into a readable form of energy. The transformed stimuli are passed into sensory memory, also known as sensory registry.

Sensory memory, through perception analysis, filters unanalyzed stimuli by buffering and holding information for a short period of time. Known as selective attention, this filtering or buffering of stimuli is the primary function of sensory memory (Barron, 2004; DaCosta Seok, 2010; Lohr, 2008; Pashler, 1998). This filter siphons unimportant stimuli (e.g., sights, sounds, smells, tastes) and blocks the unwanted information, reducing overload in sensory memory while simultaneously giving attention to important stimuli and acquiring pattern recognition of information to be processed into STM (Burton et al., 1995; Lohr, 2008).

Attention and pattern recognition (i.e., assigning meaning), rely on matching newly acquired stimulus with previously encoded knowledge from LTM (Burton et al., 1995;

Moore et al., 1996). Attention is a cognitive process involved in the selection and focus on relevant information while ignoring non-pertinent information (DaCosta & Seok, 2010). Pattern recognition integrates information from a complex interaction using sensory information within the context of general information (Burton et al., 1995). Attention and pattern recognition are what gives information meaning (Lohr, 2008). During attention and pattern recognition, a memory's lifespan is limited in duration and capacity, thus it is critical that relevant information not be permanently lost. The lifespan of visual information is less than ½ second and auditory information about three seconds (DaCosta & Seok, 2010; Huitt, 2003; Moore et al., 1996; Pashler, 1998; Ware, 2004), therefore attention and pattern recognition play a key role in human cognitive processing. Huitt (2003) reported two major occurrences when information was transferred from sensory memory into STM: (1) individuals are more likely to pay attention to stimuli that are interesting or meaningful, and (2) information that has a known pattern (i.e., relevant information from prior knowledge) has a higher likelihood of recognition.

Sensory memory is responsive to three types of modalities: (1) iconic memory - handles visual stimuli, (2) echoic memory - handles auditory stimuli, and (3) haptic - handles the sense of touch and smell (DaCosta & Seok, 2010; Rehaag & Szabo, 1995). Sensory memory's main functions are to process information and stimuli as shown in Figure 3. Almost all learning stems from the five senses. As environmental stimuli are recognized, the information is passed on to short-term memory (STM).

Short-Term Memory

The second memory, also known as working memory, has been called the "work space" of cognitive processing in which resources are allocated to various senses that are manipulated for reasoning and meaningful learning to take place (Atkinson & Shiffrin, 1968; Baddeley, 2000; Barron, 2004; DaCosta & Seok, 2010; Lohr, 2008; Miller, 1956). STM has been synonymous in many circles with a Freudian term, conscious memory. According to Huitt (2003), memories are created by, "…our paying attention to an external stimulus, an internal thought, or both" (para. 13). Being selective of what information is relevant and focusing on pertinent information maximizes our ability to process information in a meaningful way (DaCosta & Seok, 2010). Interesting stimuli that promote attention and pattern recognition within STM allows individuals to recall prior knowledge from LTM (Ericsson, & Kintsch, 1995; Sweller, 2003, 2004). Unlike sensory memory, STM does not store information in a raw form but in a recognizable form. For example, the number 4 is recognized as a number instead of three lines (Moore et al., 1996). STM holds information between 15 to 20 seconds unless information is recycled. This recycled occurrence is known as maintenance rehearsal.

The information is recycled through working memory, extending the lifespan to 20 minutes (Huitt, 2003; van Merrienboer & Sweller, 2005; Paas, Renkl, & Sweller, 2003; Paas et al., 2003). Information begins to deteriorate if maintenance rehearsal is delayed. However, some studies have pointed at interference caused from a constant bombardment of new information (Green, 1992; Solso, 2001). Although maintenance rehearsal helps to extend the lifespan of information in STM, newly acquired stimuli still must be recognized and processed within the first few seconds before being permanently lost (Burton et al., 1995). Huitt (2003) proposed two concepts for instructional designers to incorporate into content material to extend the lifespan of information in STM: organization and repetition. Huitt went on to describe four types of organization and the advantages of repetition:

> (1) Component (part/whole)—classification by category or concept (e.g.. the components of the teaching/learning model): (2) Sequential – chronological; cause/effect; building to climax (e.g., baking a cake, reporting on a research study): (3) Relevance – central unifying idea or criteria (e.g., most important principles of learning for boys and girls, appropriate management strategies for middle school and high school students): (4) Transitional (connective) – relational words or phrases used to indicate qualitative change over time (e.g., stages in Piaget's theory of cognitive development or Erikson's stages of socioemotional development). Repetition or rote rehearsal is a technique we all use to try to "learn" something. However, in order to be effective this must be done after forgetting begins. Researchers advise that the learner should not repeat immediately the content (or skill), but wait a few minutes and then repeat. For the most part, simply memorizing something does not lead to learning (i.e., relatively permanent change). (p. 3)

Like sensory memory, STM has limitations with both capacity and duration in regard to holding information. STM limitations have been well noted throughout cognitive psychology research with very few stimuli processed at any one time (Kalyuga et al., 1999; Miller, 1956). Processing multiple chunks of information at one time can overload working memory, decreasing the overall learning process. Some cognitive psychologists believe that several cues can be processed simultaneously up to a certain point then a bottleneck occurs (Barron, 2004; DaCosta & Seok, 2010; Miller, 1956; Moore et al., 1996). The funneling effect occurs when information has been given attention and pattern recognition assigned in STM and has received synaptic cues from LTM (DaCosta & Seok, 2010; Fried, Polson, & Dafoe, 1988; Low & Sweller, 2005; Spear & Riccio, 1994; Sweller & Chandler, 1994). New information can overload STM capacity and diminish the learning process (Kalyuga et al, 1999; Sweller, van Merrienboer, & Paas, 1998). To overcome capacity issues, cognitive resources must be allocated for efficient learning to take place. STM has been considered "the working memory" or "work space" of the human cognitive processing system, but for learning to take place information has to be stored in long-term memory (LTM). In the next section, LTM will be introduced as the final stage of the human cognitive processing system.

Long-Term Memory

LTM's main functions are to store knowledge in an organized manner. The function and structure of LTM are complex in nature and by definition provide storage for several types of knowledge (Baddeley, 1999; Barron, 2004; Burton et al., 1995; DaCosta & Seok, 2010; Lohr, 2008; Moore et al., 1996). To access LTM and to measure the storage capacity has been difficult, but most researchers assume that the storage capacity and duration are quite large and possibly unlimited (Barron, 2004). LTM stores a vast array of knowledge and experiences over a human lifetime.

LTM stores three different yet distinct types of knowledge: (1) declarative, (2) procedural, and (3) conditional (DaCosta & Seok, 2010; Hartley, 2001; Huitt, 2003; Moore et al., 1996; Schraw, 1998). Declarative knowledge is factual knowledge or what we know about our surroundings and the objects within our environment that can be evoked and explicitly articulated (Brunning, Schraw, Norby, & Roonning, 2004; DaCosta & Seok, 2010; Huitt, 2003). Declarative knowledge has been categorized into two different types of memory: episodic and semantic (Squire, 2008; Tulving, 2002). Episodic memories are associated with personal experiences from the past (DaCosta & Seok, 2010; Huitt, 2003; Tulving, 1983) and may date back as far as childhood as recently as today. It could be seen as autobiographical in nature (Tulving, 1983). Unlike episodic memory, semantic memory refers to general knowledge and factual information based on our surroundings (e.g. concepts, principles, rules, problem-solving strategies, learning strategies) (Huitt, 2003). The concepts, principles, and rules that govern our surroundings provide a framework in which we think, interpret, and reason. Knowledge representation and reasoning facilitate inference from what is known and how we think (Davis, Shrobe, & Szolovits, 1993). Huitt (2003), listed eight knowledge representations associated with semantic memory:

> (1) Schema / Schemata – networks of connected ideas or relationships; data structures of procedures for organizing the parts of a specific experience into a meaningful system (like standard or stereotype), (2) Proposition – interconnected set of concepts and relationships; if/then statements (smallest unit of information that can be judged true or false), (3) Script -- "declarative knowledge structure that captures general information about a routine series of events or a recurrent type of social event, such as eating in a restaurant or visiting the doctor", (4) Frame -- complex organization including concepts and visualizations that provide a reference within which stimuli and actions are judged (also called "Frame of Reference"), (5) Scheme -- an organization of concepts, principles, rules, etc. that define a perspective and presents specific action patterns to follow, (6) Program -- set of rules that define what to do in a particular situation, (7) Paradigm -- the basic way of perceiving, thinking, valuing, and doing associated with a particular vision of reality, and (8) Model -- a set of propositions or equations describing in simplified form some aspects of our experience. Every model is based upon a theory or paradigm, but the theory or paradigm may not be stated in concise form. (p. 4)

The concept of schema/schemata merits further discussion. These terms are categorized as cognitive structures within a semantic memory. Schemata, singular for schema, are viewed as simple or very complex individualized elements that form relationships between one another called slots (Brunning et al., 2004) and act as one single unit in LTM (Kalyuga, Chandler, & Sweller, 1999, 2004). Schemas are used to help organize knowledge that helps make meaningful interpretations of the world around us (DaCosta & Seok, 2010). According to DaCosta & Seok (2010), “Think of these slots as ‘place holders’ that house information associated with schemata. As you might expect, schemata can be composed of any array of slots” (p.11). A schemata is dependent on whether individuals are considered expert or novice, and personal experiences play a role as to how complex schemas are formulated. In other words, the more an individual knows about something the more complicated the schema. This is critical for novice learners who experience new domains while subsequently building schema patterns stored in LTM. As our schemata becomes highly developed, the more information can be chunked within working memory (Baddeley, 2000; DaCosta Seok, 2010; Johnson & Aragon, 2003).

LTM feeds previously encoded memory structures to sensory memory and STM; in turn, both reciprocate information back to LTM. Encoding information is considered a constructive process, and the human cognitive system relies heavily on this interaction between all three components and is crucial in the learning process (Brunning et al., 2004; Burton et al., 1995). Once a stimulus has been recognized, LTM activates previously stored schema (Burton et al., 1995; Moore et al., 1996). The success of the activation is dependent on the strength of how the information was encoded, organized, and stored (Burton et al., 1995). Although at this time, cognitive psychologists do not completely understand how information is encoded and stored in LTM, they do agree that encoding information is directly related to the amount of elaboration and maintenance rehearsal that has occurred in STM (Barron, 2004). To be effective and efficient LTM memory relies on a hierarchal organization structure that systematically encodes schema to reduce the demands of working memory during the retrieval process (Burton et al., 1995; Kalyuga et al., 1999, Kalyuga, Chandler, & Sweller, 2004; Lohr, 2008). As the new stimuli are integrated with the retrieved schema, the stimuli and schemas are blended together to form a new conceptualized memory and then recoded to LTM (Anderson, Greeno, Kline, & Neves, 1981). While declarative knowledge is factual in nature, procedural knowledge is looked upon as the "how to" perform a task.

Procedural knowledge is implied knowledge about the skills one has acquired (DaCosta & Seok, 2010; Huitt, 2003). Procedural knowledge is hard to communicate because it is implicit in nature. For example, if you were to clearly explain how to ride a horse, would the explanation be understood as to how to accomplish the task? When instructions are proceduralized, human cognition is not consciously aware of the step-by-step processes involved in performing these type tasks; thus we have trouble communicating a clear and concise explanation of the procedure (DaCosta & Seok, 2010). The last type of knowledge held within LTM is known as conditional learning.

Conditional learning is knowing when and why to use the other two types of knowledge declarative and procedural (Brunning et al., 2004). According to DaCosta and Seok (2010), "Conditional learning is knowledge about why we should use certain strategies, under what conditions to use them, and why we should use them over our strategies we have" (p. 10). It has been argued that conditional knowledge is most important because this type of knowledge extends beyond facts and skills but is the most difficult to learn (DaCosta & Seok, 2010). Unlike learning facts or having a skill, learning to make a decision causes hesitation due to anxiety caused by "making the wrong decision".

The three components of the human cognitive process have been introduced in this chapter as a framework. This study was designed to examine multiple-channel technologies and how individuals perform on a proceduralized instructional design based on treatments centered on a multiple modality design. The human cognitive system is much more in depth and requires more elaborate discussion for full understanding, but for the purpose of this study, an introduction in this area was essential. This literature review discussion has thus far covered individual differences and learning styles and how human cognitive systems process environmental stimuli into memory. The theories discussed in further detail in the next section are directly related to how individuals learn and process information that leads to the foundation of this study's framework.

Theoretical/Conceptual Framework

The classical theories used to construct the conceptual framework for this study are historic in nature. These theories also serve as a framework for more modern derivatives within cognitive processing and multi-sensory input research. Although current research has adopted these models, the use of the classic theories in this study serves a dual purpose. One purpose is to substantiate notable research that makes up part of the literature review while serving as the corner stone for the more modern theories used today in cognitive processing and multi-modal research. The literature review will cover the classical theories and the development of the new models that have evolved as advancements in technology have enriched individual learning experiences.

Information Processing Theory

Background

Since the early 1950s many studies have been conducted on the human cognitive processing system and the memory components. This research continues today, examining how the brain processes information. Three early pioneers researched in the field of human cognitive processing deserve recognition. Richard Atkinson and Richard Shiffrin were influenced; however, in the field of psychology related to human memory the most significant and influential work has been done by George Miller.

Miller's most influential contribution to cognitive psychology was first published in 1956. Miller discovered that absolute judgment can only handle five to nine units of information at one time before errors occur during recall (Miller, 1956; Niaz & Logie, 1993). More recently Cowan (2001) and Cowan, Elliott, Saults, Morey, Mattox, Hismjatullina, and Conway (2005) suggested that memory capacity is limited to three to five chunks. Others have claimed there is no limit as to the amount of storage in working memory, but items that have not been given attention are disregarded within a short duration of time (Baddeley, 1986; Richman, Staszewski, & Simon, 1995). Capacity can be reached when one-dimensional or multi-dimensional stimuli overwhelm the visual, auditory, or taste channels. Miller examined several studies conducted in the early 1950s based on recall, and the levels that capacity limits were exceeded when stimuli introduced in visual, auditory, and taste stimuli were processed.

Imagine a communication system consisting of three components: (1) left circle, the amount of input information, (2) right circle, the amount of output information, and (3) overlapping circle, the amount of information that is transmitted (Miller, 1956) as shown in Figure 4.

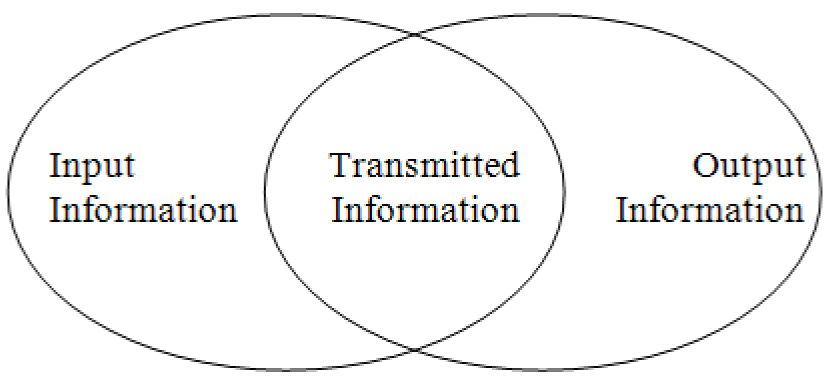

Figure 4. Communication system as proposed by George A. Miller Adapted from "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information," by G. Miller, 1956, *Psychological Review*, 101(2), p. 2.

When the amount of input information is increased, the transmitted information will also increase, but eventually will reach a point of saturation. Confusion caused by this over abundance of information would affect an individual's ability to recall information. The points of saturation are known as channel capacity or the threshold at which an individual can comprehend (Miller, 1956).

Examining the data collected from these studies, Miller constructed a conversion process to convert information units into bits. According to Miller (1956), “One bit of information is the amount of information that is needed to make a decision between two equally likely alternatives” (p. 3). Miller went on to say that two bits of information produce four likely alternatives, three bits produce eight alternatives, and four bits produce 16 alternatives and so on. Based on his analogy, 32 alternatives would equate to five binary decisions in succession. Each time the likely alternatives increase by two, one bit of information is added in this binary system. This is referred to as the simple general rule of thumb (Miller, 1956). The data from the absolute judgment studies were plotted on a graph, and Miller surmised that the asymptotic value (channel capacity) of the one-dimensional (one independent variable) stimuli resulted in the following: auditory channel 2.5 bits, visual channel 3.25 bits, and taste channel 1.9 bits. Converting bits to units, the auditory channel can handle five units, visual channel nine units, and taste channel four units respectively. The multidimensional (i.e., two or more independent variables) stimuli studies had shown increases in channel capacity but at decreasing rates (i.e., differences between attributes based on two or more independent variables). The auditory channel capacity increased to 3.1 bits (eight units), the visual channel 4.6 bits (25 units), and the taste channel 2.3 bits (five units). Results of the studies found that working memory can hold four to nine units of information and is noted by “7 plus or minus 2” regardless of the information per item (Miller, 1956; Broadbent, 1956; Burton et al., 1995; DaCosta & Seok, 2010; Huitt, 2003; Lohr, 2008). Recent research has suggested that the channel capacity is more like “5 plus or minus 2” due to the variability of the amount individuals can retain. It has been noted that some individuals can only retain three units while others can retain upwards to seven units. (Cowan, 2001; Huitt, 2003). Seven units equate to about 23 bits one; English word is represented by 10 bits. If the goal is to stay consistent with 23 bits, individuals should only be able to retain two or three words. The difference between a bit and chunk of information has not been established, but the term unit has been described as information that has been chunked together (Miller, 1956; Cowan, 2001) although what constitutes a chunk of information has never been established. Miller (1956) went on to say:

> In order to capture this distinction in somewhat picturesque terms, I have fallen into the custom of distinguishing between bits of information and chunks of information. Then I can say that the number of bits of information is constant for absolute judgment and the number of chunks of information is constant for immediate memory. The span of immediate memory seems to be almost independent of the number of bits per chunk… (p. 13)

A chunk can be any meaningful measured unit such as digits, symbols, words, people’s faces, or even chess positions (Kearsley, 2011a), but as information becomes more organized and individuals are more experienced the number of bits per chunk increases (Huitt, 2003; Miller, 1956). For example, the letters “a b t” are considered three units comprised of symbols while the word “bat” constitutes one word even though the individual symbols are the same (Huitt, 2003).

It is important to discuss the background that substantiates the conceptualization of a classic theory. The foundation of the information processing theory begins with understanding how absolute judgment and immediate memory require input of information to be administered within boundaries that do not over extend channel capacity (Lohr, 2008; Miller, 1956). The theory itself describes how information travels through memory.

Theory

Miller's information processing theory has been adopted as the general theory of human cognition (Kearsley, 2011a). The theory identifies how information flows and is stored in memory (Lohr, 2008). This flow and storage process is similar to how a computer system works (Donovick, 2001). The information processing theory was made up of three components: (1) sensory memory, (2) short-term memory (STM), and (3) long-term memory (LTM). Miller determined that STM, also known as working memory, can hold about five to nine discrete chunks of information (Huitt, 2003; Johnson & Aragon, 2003).

For this study, Miller's 1956 work was cited in the conceptual framework as the theorist behind the information processing theory. The information processing theory lays the groundwork for understanding how humans process and interpret information; however, stimuli when introduced through sensory channels, require attention before being processed and moved to permanent storage. Severin and Paivio, proponents of multi-sensory stimuli, theorized that learning is reinforced when two or more senses are introduced simultaneously. Later in this chapter, information processing is examined in further detail by expanding on the human cognitive processing system. The information processing theory introduces the concept of how information is processed without regard to the type of stimuli. The second classic theory introduced expands on a dual code process in memory, taking into account two types of information.

Dual Code Theory

Theory

The framework of the Dual Code Theory (DCT) conceptualized that there are three stages of memory that were based on the information processing theory. The DCT has broken down STM into two separate but distinct systems: verbal and non-verbal (Barron, 2004; Brunye, Taylor, & Rapp, 2007; Donovick, 2001; Höffler & Leutner, 2007). Illustrated in Figure 5, these dual systems encode, organize, store, and process information and work independently of one another or in some cases as an interconnected unit, but both are given equal weight when processing stimuli (Clark & Paivio, 1991; Höffler & Leutner, 2007; Kearsley, 2011b; Paivio, 1971, 1983, 2006). Touch, taste, and smell are other stimuli that are processed in Paivio's theory (Lohr, 2008).

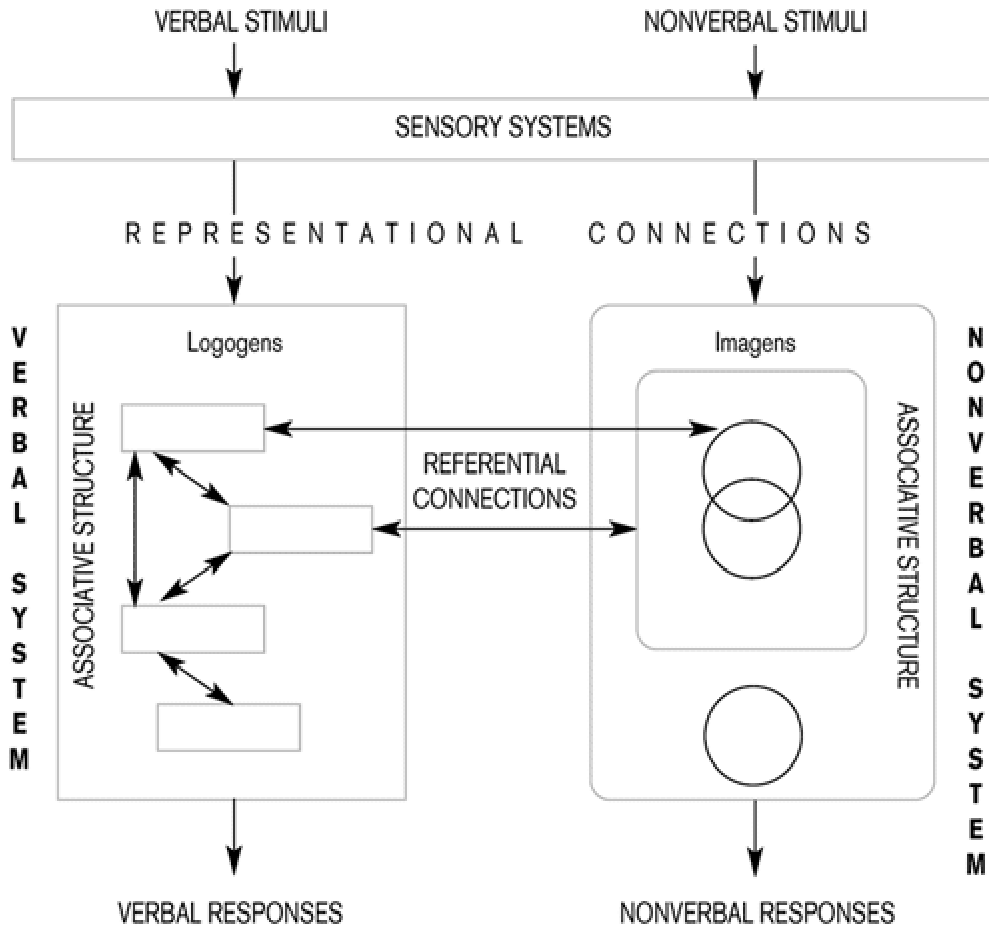

Figure 5. Verbal and non-verbal symbolic systems of Dual Coding Theory. A. Paivio (1990). *Mental Representations: A dual coding approach*, p. 67 New York: Oxford University Press

<u>Background</u>

The human cognition processing system can process multiple forms of stimulus simultaneously, such as language, events, and non-verbal objects. Language itself is a complex system that must be interpreted through linguistic input and output, both the written and spoken word, while concurrently processing symbolic functions with respect to events and behaviors, and non-verbal objects (Paivio, 1990). As hypothesized by Paivio, the DCT model consists of hypothetical networks of verbal and non-verbal representations that are independent and interconnected utilizing three levels of processing that contribute to performance based on past and present events, stimulus characteristics, task, and individual differences (Clark & Paivio, 1991).

The first level of processing is known as representational processing, also known as representational connections. As stimuli are recognized by the sensory memory, representational connections are made between corresponding systems. Stimuli induce verbal and visual representations, from long-term memory. Thus spoken words will activate verbal representations, whereas objects and pictures will activate visual representations (Paivio & Desrochers, 1980).A second level of processing, known as referential connections, interconnects the verbal system with the non-verbal system. Verbal representations interplay with corresponding visual representations from LTM and vice versa (Burton et al., 1995; Clark & Paivio, 1991; Kearsley, 2011b; Mayer & Anderson, 1991; Paivio & Desrochers, 1980). The third level of processing, known as associative structure, refers to the links made between verbal representations or visual representations through associative meaning. In the verbal system, words are connected to other related words and in the non-verbal system images are joined to other corresponding representations (Clark & Paivio, 1991). The interconnections within the systems and between one another are assumed to be one-to-many relationships that any connections made are activated from past experiences (Paivio & Desrochers, 1980). As verbal or non-verbal stimuli enter sensory memory, processing may require only one or all three levels (Kearsley, 2011b).

Verbal System

Clark and Paivio (1991) stated that the verbal system contains, "…visual, auditory, and articulatory, and other modality-specific verbal codes (e.g., representations for such words as book, text, livre, school, teacher, learn, strategy, mathematics, and worry)" (p. 151).

In the verbal system, stimuli in the form of linguistics or generic speech are intercepted by sensory systems. The stimuli are organized into a higher-order structure that invokes the auditory-motor functions that control hearing and speech (Lohr, 2008; Mayer & Anderson, 1991; Moore et al., 1996; Paivio & Desrochers, 1980).

Non-verbal system

The non-verbal system processes visual stimuli in the form of pictures, sounds, taste, events, or non-verbal representations (i.e., imagination) that are introduced into sensory memory and processed into the non-verbal system of STM. The stimuli can be processed synchronously or in parallel with verbal memory (Burton et al., 1995; DaCosta & Seok, 2010; Kalyuga et al., 1999; Lohr, 2008; Thomas, 2010). Non-verbal representations include: image specific, (e.g., an atomic model); environmental sounds, (e.g., emergency vehicle siren); actions, (e.g., sketching characters or pressing keys on a keyboard); bodily, or instinctive movement related to emotion, (e.g., breathing, teeth grinding); and other non-verbal or nonlinguistic objects or actions (Clark & Paivio, 1991). An image according to Paivio (1971) refers to:

> …concrete imagery, that is, non-verbal memory representations of concrete objects and events, or non-verbal modes of thought (e.g., imagination) in which such representations are actively generated and manipulated by the individual. This will usually be taken to mean visual imagery, although it is clear that other modalities (e.g., auditory) could be involved and when they are, this must be specified. Imagery, so defined, will be distinguished from verbal symbolic processes, which will be assumed to involve implicit activity in an auditory-motor speech system. (p. 1 2)

Paivio argued that images are remembered more often than verbal cues (Pressley & Miller, 1987), especially concrete words such as people, places, objects, tastes, touch, and smell (Lohr, 2008). For example, the spoken-word horse may induce a mental image of a horse. Imagery can represent real-world situations during knowledge creation by using effective pictures, diagrams, models, and other illustrations (Clark & Paivio, 1991). Mental images are not reproductions in memory, but instead are bits of information that were previously encoded during attention and pattern recognition (Burton et al., 1995; Moore et al., 1996). Images are thought to be organized into subunits (i.e., synchronous hierarchy) during recognition, the process of encoding visual scenes or objects (Burton et al., 1995; Moore et al., 1996; Paivio & Desrochers, 1980).

Logogens and Imagens

DCT introduced two representational units known as logogens (verbal entities) and imagens (mental images) found in the verbal and non-verbal systems respectively. Logogens and imagens are activated when an individual recognizes, manipulates, or thinks of an object or words (Clark & Paivio, 1991; Kearsley, 2011b). Imagens are understood to be perceptual in the sense that the representations are made up of separate modality-specific information. Logogens are also considered to be perceptual in the sense that the framework of the information is sequentially and systematically related to the particular stimuli and responses (Paivio & Desrochers, 1980). Kearsley (2011b) stated, “Logogens are organized in terms of associations and hierarchies while imagens are organized in terms of part-whole relationships” (para. 2). Imagens and logogens are referred to as “chunks” similar to Miller’s term (Paivio, 1990, 2006). The representations are different and specific to each modality. Visual, auditory, haptic, and motor skills each have their own imagens and logogens in relation to objects and language. The sensory input and response output systems are connected to these representations and are interconnected with each other and can work concurrently or as a standalone system to oversee non-verbal or verbal behavior.

Representational activity is not always experienced consciously as with imagery and inner speech (Paivio, 2006). Verbal input can invoke imagens (i.e., creating representational imagery in memory) creating an inter-link between the verbal and non-verbal systems (Paivio & Desrochers, 1980; Thomas, 2010). DCT asserts that it is more likely that individuals can learn material when the information is encoded in both visual and verbal systems (Barron, 2004; Lohr, 2008; Mayer & Anderson, 1991).

Empirical Research

Paivio's dual coding theory has evolved over a 30-year period while withstanding decades of criticism from others who refute the theory (Morris & Hampson, 1983; Thomas, 1987, 2010; Richardson, 1980, 1999). Early in information processing theory development, Broadbent (1958) disagreed with the possibility that dual coding existed and claimed that multi-sensory channels lead to a bottleneck effect. A bottlenecking occurs when two tasks using the same code interfered with one another (Daniels, 1993; Thomas, 2010). Strong evidence supporting dual coding was established through observed evidence that explained how mental processing was directly influenced by stimuli (Clark & Paivio, 1991). Paivio (1971, 1990) argued that, "DCT theoretical mechanisms and associated empirical phenomena are relevant to various aspects of human cognition, as well as emotion, motor skills, and other psychological domains" (p. 150). Several studies concurred that the recall of mental imagery is more effective than memory of words (Moore et al., 1996). Since the initial inception of the DCT, Paivio has continued to develop, refine, and defend the foundation of the theory (Paivio, 1971, 1977, 1983, 1990, 1991, 1995, 2007; Paivio & Begg, 1981; Sadoski & Paivio, 2001). In 1994 Paivio and Thompson examined three stimulus lists: (1) pictures, (2) sounds, (3) and picture-sound pairs. The dual modality (picture-sound) pairs were found to be more consistent in recall (Barron, 2004). Similar to Paivio's DCT, Severin's (1967) Cue Summation Principle of Learning Theory encourages the use of multiple modalities to deliver instructional content.

The Cue Summation Principle of Learning Theory

Theory

The cue summation principle of learning theory provides a foundation that has supported the use of numerous modalities integrated with multiple-channel technologies. The term cue summation refers to stimuli presented simultaneously through sensory channels such as sight, sound, or touch that according to this principle of learning theory provides more stimulus reinforcement (Barron & Kysilka, 1993; Barron & Varnadoe, 1992; Burton et al., 1995; Moore et al., 1996; Weiss, Knowlton, & Morrison, 2002). Visual and verbal cues, when accurately combined to create mental representations, are more effective during knowledge creation (Brunye et al., 2007; Paivio, 2006). However, conflicting cues interfere with one another and hinder the learning process (Severin, 1967). As cited in the literature, instructional designers must be able to determine the number of stimuli that an individual can process at one time before cognitive load takes over (Moore et al., 1996; Worley, 1999). Severin's cue summation principle of learning theory (1968) has been both praised and criticized by researchers. The dispute among researchers has been based on the types of cues, stimuli or modalities, and how the cues were integrated or infused in the respective studies.

Background

Miller (1956) expressed the need to increase the amount of cues across a presentation. If a stimulus supported or reinforced another channel, the learning experience was more likely to be enhanced (Brunye et al., 2007; Burton et al., 1995; Jesky & Berry, 1991). During many research studies the auditory and visual channels were loaded when examining performance outcomes using multiple-channel technologies. Researchers increased the amount of cues, although additional cues could cause interference or bottlenecking (Barron, 2004; Burton et al., 1995, DaCosta & Seok, 2010) if the second channel cues were not related to the first channel (Beccue et al., 2001).

Severin's theory differs from other multiple modality models due to the addition of relevant cues. If the second channel adds no new information to the first channel, there would be no summation, thus the information would be redundant (Cushman, 1973; Kalyuga et al., 2004; Szabo, 2002). The general theory of cue summation stated that adding modalities increase learning, however multiple-channel information tends to reach an overloading point much quicker than using a single channel alone (Hsia, 1969). Severin's theory also focuses on the need to add cues such as words that are closely related or relevant to pictorial images or illustrations within presentations (Barron, 2004; Burton et al., 1995; Dwyer, 1978; Moore et al., 1996).

Empirical Research

Severin (1968) conducted several studies examining task recognition using numerous multiple cue treatment conditions. In one notable study, 246 seventh-grade students were randomly assigned to one of six treatments; audio with relevant images, an audio, a visual, audio with redundant text, and audio with unrelated images. Figure 6 illustrates eight rank-order comparisons and the relationship for each treatment. Severin (1968) stated that the higher positions are read as "greater than".

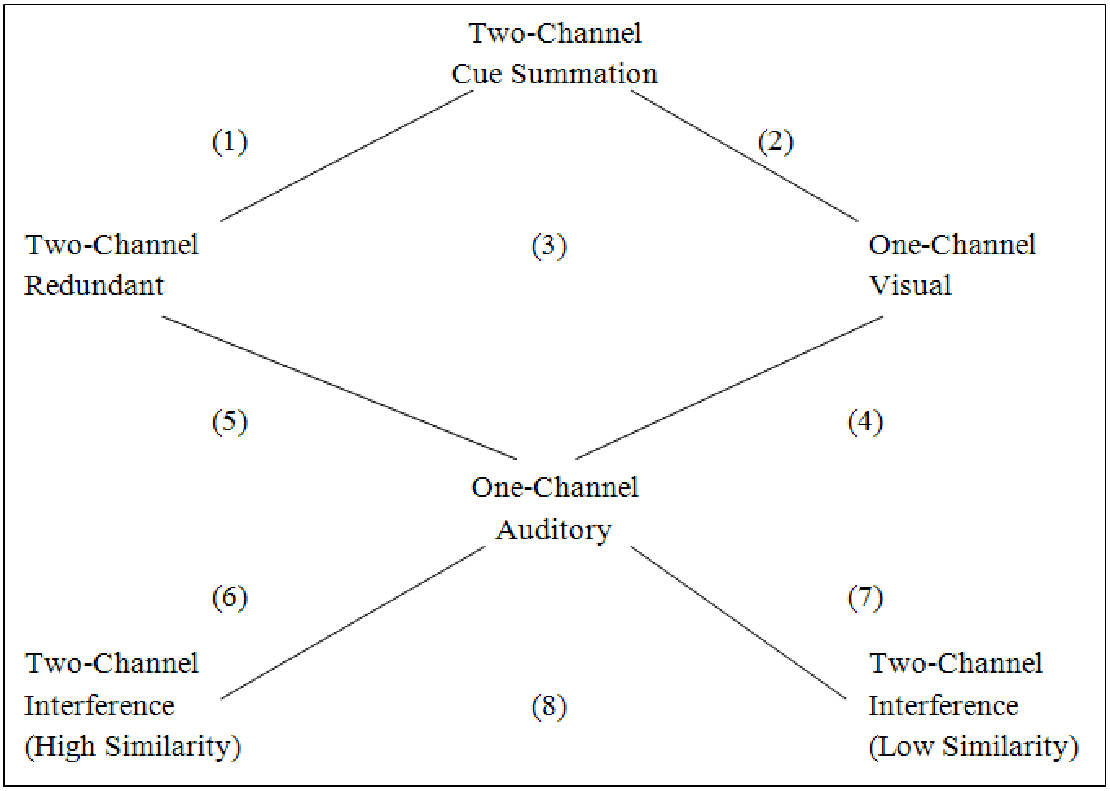

Figure 6. An illustration of the rank order comparisons conceptualized by Severin. Adapted from "Cue summation in multiple-channel communication" by W. Severin, 1968, (ERIC Report ED021463). Retrieved from University of Wisconsin, Media and Concept Learning Project Technical Report.

The first three rank-order comparisons are based on the cue summation theory: (1) cue summation should be a superior treatment in contrast to the redundant cues, (2) two-channel cue summation should be superior to the visual channel only, and (3) there should be no difference between redundant and single channel cues. Predictions 4 and 5 were based on research discussed later in this chapter. Predictions 6 and 7 proposed that stand alone single visual or auditory channels produce better learning outcomes over competing cues presented simultaneously. Prediction 8 proposed that there would be no significant difference between the cues. Severin (1968) concluded that the cue summation and the audio with relevant images treatments were superior to redundant and the audio with text-based treatment in the rank-order comparison. The visual treatment was superior to audio (Barron, 2004; Severin, 1968). An example would be an image of a moose and the written word moose or an image of a moose and the spoken-word moose (Moore et al., 1996). Severin went on to say that multiple-channel communications are far superior to single channel communications when the cues are relevant in nature. Redundant and irrelevant cues, the addition of irrelevant effects, leads to interference in the channel (Barron, 2004; Burton et al., 1995; Moore et al., 1996; Severin, 1967, 1968). The strength of the cue summation theory, and the potential interference effects, occur at all levels of communication skills, intelligence, work study skills, and reading comprehension (Severin, 1968).

Several studies have been conducted on the integration of multiple-channel cues, stimuli or combinations of modalities, within multimedia environments bringing together information, communication, instructional content, and other materials used in training and education. Researchers have debated the effect on performance outcomes when adding multiple cues in presentation mode. Advocates of the cue summation theory have asserted that learning increased in multimedia environments while those who refute the theory claimed that bottlenecking interfered with processing of auditory, visual, or taste channels (Kalyuga et al., 2004). Others have questioned the following delivery methods; (1) multiple-cues presented simultaneously, (2) relevant information presented in both verbal and visual channels, or (3) redundant information presented in both channels. Multiple-channel cues when combined offer several variations such as audio-text (i.e., narration-printed), audio-visual (i.e., images, pictures, and video), visual-text, taste-text, taste-audio, and taste-image. For this study, the taste channel has been excluded.

Some researchers examined the cue summation theory and concluded that adding images related to text-based information improved the effectiveness of recall over text alone (Burton et al., 1995). Other studies reported that redundant information in an audio and print channel presented simultaneously produced better and deeper meaningful outcomes than either channel individually. However; unrelated and contradictory information caused interference between the channels (Burton et al., 1995; Hanson, 1989). An example would be the spoken word moose and the written word moose (Moore et al., 1996). Several studies reported no increase in learning when redundant print and audio were presented. In some cases, the addition of multiple-channels provided no benefits, although poor readers were more likely to benefit from redundancy (Szabo, 2002; Rehaag & Szabo, 1995; Wu & Dwyer, 1990). Audio combined with print was not significantly better than print alone (Severin, 1967). Hanson (1989) reported that redundant audio and visual messages complimented each other and improved learning, while Beccue et al. (2001) concluded that audio cues integrated into existing text-based and graphic-based multimedia lab exercises affected learner outcomes. They recommended assessing a cognitive load when adding multiple cues.

Based on 55 research studies that examined multiple-channel modalities, strategies considered were: (1) incorporate eye-catching imagery to increase attention; (2) add imagery to text to increase learning and reading memorization; (3) add imagery to evoke enjoyment and affective reaction to text-based material; (4) add images to assist poor readers; (5) add illustrations to text which is generally more useful than the creation of mental imagery (Levie & Lentz, 1982). Two other suggested points are: (1) During the learning process include the same media when testing, and (2) If sensory modalities are used simultaneously, make sure the content of different sources are consistent and complementary (Szabo, 2002).

Hsia (1971) reviewed studies that examined how multiple cues were processed and at what point channels reached memory capacity. Hsia found that the combination of the audio and imagery cues were more effective on performance outcomes than either cue presented alone although information processing was susceptible to bottlenecking.

Severin recognized the extensive reviews of research and indicated that mixed and contradictory results frequently occurred (Severin, 1967). Severin pointed out that many of the studies were poorly designed. Studies lacked hypotheses, were test-channel biased, lacked relationship content in the channels, and some studies lacked experimental control. Interference between channels was not sufficiently reported in the context of unrelated or opposing information (Barron & Kysilka, 1993; Burton et al., 1995; Moore et al., 1996). Severin (1967) suggested that educators tend to combine multiple cues that are only processed in one channel. Although the cue summation principle of learning theory can be described as a classic model, Severin's theory presents a strong framework when numerous stimuli are presented within instructional procedures delivered via 21st century technologies. Unlike Severin's theory, using two or more modes, Broadbent's single channel theory refutes multiple stimuli and asserts that only one cue can be processed at any one time.

Single-Channel Theory

Theory

Broadbent's single-channel theory, also known as the bottlenecking theory, proposed that only one channel can process information at any one time. Any additional information would cause interference (Broadbent, 1958; Huitt, 2003). If the audio and visual stimuli arrive at the central nervous system at the same time, a jamming, cognitive load, or bottlenecking occurs (Barron, 2004; Barron & Kysilka, 1993; Broadbent, 1958; Burton et al., 1995; Jesky & Berry, 1991; Moore et al., 1996, Severin, 1967; Szabo, 2002). According to Donovick (2001) if Broadbent's theory was true, then additional cues render multimedia computer-based training useless. The theory itself posed that there are no advantages to using multiple-channels (Szabo, 2002).

Background

The single-channel theory proposed that multiple inputs from the senses are funneled down into a one-channel input in the central nervous system (Severin, 1967). The system was hypothesized to contain a filter that prevented an excessive rate of material or information to exceed the memory capacity (Severin, 1967). For example, an individual can hear multiple auditory messages at any one time, but only one sound is filtered (Moore et al., 1996). However, a few of those unattended sounds could penetrate this bottleneck (Burton et al., 1995). The filter blocks unwanted content that was presented in more than two modalities simultaneously and the extra information is discarded (Moore et al., 1996). When information is transmitted at high speeds or two or more high-order messages are sent simultaneously a "jamming" occurs, particularly if the information is not related. Research examined the single-channel theory, confirming Broadbent's theory on system jamming when responding to 10 multiple-channels, especially when information was unrelated (Beccue et al., 2001; Severin, 1967). Information that arrives simultaneously in separate channels will also cause interference due to the inability to switch back and forth from one channel to another (Broadbent, 1956, 1958, 1965; Moore et al., 1996). Broadbent stated that interference introduced into the system depends upon the distractions from non-redundant information (Severin, 1967).

Research

Broadbents's single-channel theory has been cited in numerous research studies. Many of these studies advocated Broadbent's theory as a centralized system and confirmed that multiple-channel information was less likely to be processed than information from a single-channel. Early research concluded that redundant information added to presentations caused interference (Severin, 1967). Some studies have been questioned based on Broadbent's use of verbal materials presented in two channels. In these studies, Broadbent used pictorial information as a relevant modality (Severin, 1967). Broadbent's filter hypothesis was based on the premise that information not attended to would be discarded. Other research studies concluded that predisposed information could be recalled (Barron, 2004; Hawkins & Presson, 1986). Severin and Broadbent's classic theories oppose one another, but both agree that too much information presented at one time lead to jamming or cognitive load.

Cognitive Load Theory

Theory

Sweller, van Merrienboer, and Paas's cognitive load theory (1998) has been categorized as both a learning theory and an instructional theory that describes the load created on a learner's cognitive system during knowledge acquisition (DaCosta & Seok, 2010; Sweller, 1988; van Merrienboer, & Sweller, 2005). According to Lohr (2008), the theory described as "mental energy needed to think about or process information" (p. 51).

Depending on the type of information and in what mode the materials are presented, energy expended on knowledge acquisition can create a large demand on working memory. There are three distinguishable types of cognitive load: (a) intrinsic, (b) extraneous, and (c) germane (Höffler & Leutner, 2007; Lohr, 2008; Mayer, 2001; Paas et al., 2003; Pollock, Chandler, & Sweller, 2002; Sweller 2005a). Intrinsic load is measured by the difficulty of the material, how many elements are present, and how those elements interact with one another (DaCosta & Seok, 2010). The presence of extraneous load is determined by how the content was designed, organized, and the mode of delivery (Mayer, 2001). The germane load is dependent on the instructional designer to include scaffolding that optimizes learning processes (Clark et al., 2006). In the following sections, an in-depth description of each type of cognitive load and the effects on instructional content are discussed.

Background

Human memory systems have limited capacity, thus processing information is constrained. The cognitive load theory requires that information be designed, constructed, and organized in a manner that limits the load on working memory (Kalyuga et al., 1999). At any one point in time, the human cognitive system can only hold information momentarily before being processed, passed onto long-term memory, and in many instances forgotten (Lohr, 2008). If information held in working memory is subjected to cognitive load, the likelihood of storing or processing the information is jeopardized and forgetting occurs. Content designers must be cognizant of loads on working memory and develop instructional materials organized and presented without unnecessary loads.

Cognitive load can also be viewed as the amount of energy needed to think about and process information. Learning diminishes when the load is too high. Having too much information, unrelated information, and complex information causes an overload on memory (Johnson & Aragon, 2003; Lohr, 2008), however there are also adverse effects on learning if the load is low. The lack of abundant or effective information or the presence of non-engaging information can lead to poor learning outcomes (Lohr, 2008). Although a high or low cognitive load challenges instructional designers, cognitive load theory suggests that developers should consider best practices and processes when incorporating multiple-channel modalities by limiting the burden on working memory (Barron, 2004; DaCosta & Seok, 2010).

Sweller, van Merrienboer, and Paas's theory provides a strong argument against poorly designed content when incorporating multiple-channel modalities. This argument has helped designers prepare instructional designs that are beneficial when different modes are used. As mentioned above cognitive load takes on three separate forms. Understanding these three types of cognitive load provide understanding of effective instructional strategies when using multiple-channels.

Intrinsic Load

Intrinsic cognitive load refers to the instructional content in relation to the degree of complexity of the information to be processed. If the content is complex, individuals would experience a higher inherent load (Barron, 2004). Complexity is an element of interactivity or a learner's ability to understand content and how it interacts with additional content (DaCosta & Seok, 2010; Höffler & Leutner, 2007; Lohr, 2008; Sweller, 2005a). An element refers to a single unit of information that is processed within working memory. Interactivity can be categorized as high or low content. According to Lohr (2008):

> High content interactivity describes content that can be understood or studied only when an understanding of many different factors are taken into account. Low content interactivity describes content that is more easily understood in isolation, because it requires an understanding of fewer elements. (p. 52)

Some learning cannot occur in isolation and was meant to be processed simultaneously with other content (Sweller, 2005a). This simultaneous learning has consequences. A load on working memory occurs when one source of information is waiting while another source of information is processed. The processing system becomes overwhelmed when both sources are processed during their integration (Kalyuga et al., 2004; Mayer & Anderson, 1991; Mayer & Sims, 1994). Low content interactivity can be learned in isolation. For example, learning a foreign language and identifying simple nouns in a new language demonstrate isolated learning. Take, for instance, the noun "cat" can be learned independent of the noun "dog". The interactivity between the two nouns is low because working memory only processes one element at a time (DaCosta & Seok, 2010). An example of high content interactivity can be best be explained by looking at sentence construction. Sentence structure requires that individual words be understood while rules governing grammar and syntax play an important part in sentence meaning. Understanding the meaning of each word can be accomplished in isolation, but to comprehend the structure and meaning of the sentence is a more complex task (Clark et al., 2006). To further clarify high content interactivity, consider an electrical circuit board. Every circuit board consists of an intricate wiring structure connected to various capacitors, resistors, and inductors. Each component can be learned in isolation but the circuit board, components, and wiring system as a whole must be understood as a complex unit (Polluck et al., 2002). The high content interactivity causes working memory to process vast amounts of information simultaneously. It is critical for instructional designers to understand that in some instances, intrinsic load cannot be controlled due to the element interactivity. However, this type of load can be managed through pre-training. Research examining intrinsic load has shown that pre-training and segmenting principles limit the load on working memory when best practices are applied to instructional design (Clark et al., 2006; DaCosta &Seok, 2010). Pre-training reduces the load on working memory by chunking smaller units of information and simplifying the concepts into more manageable content, while segmenting gives learners more control of their learning (i.e., what to learn and when to learn) (DaCosta & Seok, 2010).

Extraneous Load

Extraneous cognitive load, known as irrelevant load, refers to extra immaterial sources or tasks added to instructional materials or procedures (Barron, 2004; Höffler & Leutner, 2007). Content that contains unrelated information leads to inefficient cognitive processing and is thus detrimental to learning due to design and organization flaws that ignore working memory limits (Barron, 2004; DaCosta & Seok, 2010; Höffler & Leutner, 2007). Extraneous load extends the time on task, produces unsatisfactory learning outcomes, or both (Clark et al., 2006). Extraneous load is the least desirable of the three load types due to the time wasted filtering through excessive information and the increase load on working memory (DaCosta & Seok, 2010). Extraneous load can be controlled by excluding unnecessary information and elements (Moore et al., 1996). Sweller and Chandler proposed the following assumptions: (1) major learning mechanisms include schema acquisition and automation, (2) verbal and visual content delivered simultaneously can increase the load on working memory, (3) multiple-channel content must be interactive, (4) content and delivery methods are responsible for high levels of interactivity, and (5) when intrinsic elements are kept to a minimum, extraneous load can be negligible (Moore et al., 1996; Smith, 2001). Other studies suggest incorporating principles that have been shown to limit cognitive load such as worked examples, split-attention, modality, and redundancy principles (Clark et al., 2006).

Germane Load

Germane cognitive load, known as effective load, is caused by instructional design practices that aid in meaningful learning (DaCosta & Seok, 2010; Höffler & Leutner, 2007; Lohr, 2008). Clark et al. (2006) described germane load as relevant load caused by the development, processing, construction, schema acquisition, and automatic processing that leads to better learning. Examples include textual based information that provides scaffolding for content, chunking of information, proceduralization, and providing analogies that allow learners to pick up information quickly. All of these techniques can reduce the mental integration that causes a cognitive load (Kalyuga et al., 1999; Lohr, 2008). Clark et al. (2006) defined a germane load as, "…relevant load imposed by instructional methods that lead to better learning outcomes" (p. 11). Germane load aides in the overall learning process and can prove to be advantageous to skilled learners when demonstrating learned tasks known as transfer of learning (DaCosta & Seok, 2010). Designers who are cognizant of cognitive load are more likely to manage any intrinsic load by incorporating design principles that avoid extraneous loads and promote germane load (Clark et al., 2006, DaCosta & Seok, 2010; Paas et al., 2003; van Merrienboer & Ayres, 2005). For an instructional designer, educator, or practitioner developing instructional materials, the following principles represent best practices and processes to lower intrinsic and extraneous loads.

Worked Examples Principle

The worked examples principle, known as the worked-out-examples principle, proposes that worked examples of a problem are more beneficial to learners than studying the example practice problem (Sweller, 2005a). Worked examples are step-by-step problems that are used in proceduralized training requiring the learner to demonstrate the problem-solving techniques (Clark, 2006). Worked examples reduce the extraneous load while counterbalancing loads that are created when new schemata are formed (DaCosta & Seok, 2010).

Worked examples help individuals create knowledge and a better understanding of the content during the initial acquisition (Renkl, 2005). This is prevalent when novice learners are first exposed to new information due to the lack of experience and prior knowledge. This inexperience can impose cognitive load in other areas such as speed of the material being presented, organization, and learner decision making (DaCosta & Seok, 2010). For novice learners, constructing instructional materials by chunking small units of information are beneficial in knowledge creation (Lohr, 2008). Experience and knowledge decrease the need for worked examples, however; worked examples for expert learners impede the learning process and increase the extraneous load (Clark et al., DaCosta & Seok, 2010; Paas et al., 2003; van Merrienboer & Ayres, 2005). Instructional designers must be cognizant of the skill levels needed for any particular content while experienced learners are able to handle larger chunks of information such as one or two pages comprised of longer sentences and paragraphs (Lohr, 2008). Worked examples may include problem formation, solutions steps, and a final solution. However, worked examples must be studied in depth to be of any value when limiting extraneous loads (Renkl, 2005). Similar to the worked examples principle, the split-attention principle also limits an extraneous load by building on prior knowledge.

The Pre-Training Principle

The pre-training principle can manage intrinsic load within instructional content. Conceptualized by Mayer (2005a), the pre-training principle proposed that learners are more engaged in the learning process when the familiarity of the content such as names, terminology, or behaviors have been previously experienced (DaCosta & Seok, 2010; Mayer, 2005a; Mayer & Moreno, 2003). The theoretical underpinning of this principle is based on how learners build upon schema or prior knowledge from concepts or components that were applied during a later time, thus lowering cognitive load (DaCosta & Seok, 2010). This strategy aids those who are unable to process continuous chunks of information. Clark et al., (2006) described this process as segmenting.

According to Clark et al., (2006) process knowledge and procedural knowledge are defined as: (1) “a flow of events that summarize the operations of business, scientific, or mechanical systems” (p.168), and (2) “knowledge underpinning performance of a task that is completed more or less the same way each time” (p.163). For example, the inner-workings of a refrigerator and how the refrigerant circulates within the condenser coils are considered process knowledge, while procedural knowledge is the step-by-step processes use to hook up an Electro-Cardio Graph machine or the procedure to administer Cardio Pulmonary Resuscitation. To overcome loads when using process knowledge, the teaching methods should employ pre-training principles. When addressing procedural knowledge, instructional designers and educators should incorporate scaffolding elements. These strategies are discussed further in detail in the next section.

To eliminate cognitive load in process knowledge, the individual components of the system should be introduced before unveiling the whole system (Clark et al., 2006; DaCosta & Seok, 2010). Research by Mayer, Mathias, and Wetzell (2002), provided empirical support for this pre-training principle. Three strategies were proposed to initiate a pre-training design: (1) deconstruct the whole system into individual components, (2) separate the components and add labels identifying each part, and (3) represent any action that may require a state of change (e.g. an animation that shows the master piston in a car brake system moving back and forth) (DaCosta & Seok, 2010; Mayer, Mathias, & Wetzell, 2002).

Lowering the cognitive load in procedure knowledge requires alternative strategies. First, teach the steps in order to complete the task, then give the student the opportunity to practice the steps, followed by re-teaching the procedural step again, but during this step provide supporting scaffolding of the procedure the second strategy is to provide the support information followed by teaching each step (Brunye et al., 2007; Clark, 1999; Clark et al., 2006; Pollock et al., 2002). These strategies have both advantages and disadvantages. Both strategies break down intricate information into two segments, steps, and support information. However; when implementing the first strategy, individuals may not fully comprehend the steps because information is taught out of sequence and context (Clark et al., 2006; DaCosta & Seok, 2010; Solomon, 2004). In the second strategy, the hands-on practice is delayed until supporting information can be introduced (Clark et al., 2006). Depending on the type of procedure, designers are given the option to choose between the strategies because neither has been identified as the better practice (Clark et al. 2006). Similar to the pre-training principle, the segmenting principle also alleviates some of the intrinsic load created from the difficulty of the content. The segmenting principle will be covered in more detail as applied to cognitive load.

The Segmenting Principle

The segmenting principle suggests learning can be enhanced if the learner controls the pace of the instruction (Mayer, 2005a; Mayer & Moreno, 2003). This allows learners to process information within the scope of their individualized learning process. This particular principle can be advantageous by allowing learners to choose what materials can be processed and at what rate (DaCosta & Seok, 2010). According to Clark et al. (2006) there was a potential pitfall in utilizing the segmenting principle; for a novice learner, deciding the order in which information was to be presented, which may create a cognitive load issue due to unfamiliarity of subject content (Clark et al., 2006). However, researchers do agree that allowing students to move at their own pace is beneficial (DaCosta & Seok, 2010). From a virtual environment standpoint, instructional material should include "continue" or "next" navigation buttons for self-paced learning. Several studies have been conducted on the segmenting principle including Mayer and Chandler, (2001) and Mayer, Dow, and Mayer, (2003).

Mayer and Chandler (2001) concluded that the group receiving the segmented presentation outperformed the group that viewed a continuous presentation on a problem-solving test. The group subjected to the continuous presentation treatment viewed a 140 second narrated animation on lightning formation; while the segmented presentation group viewed the same animation divided into 16 segments each lasting about 10 seconds sequenced by a "Continue" button to advance the presentation (DaCosta & Seok, 2010). In the Mayer et al. (2003) study, two groups experienced different media formats: (1) interacted with an avatar in a simulation game learning about electric motors and (2) were given a segmented version of the game that displayed questions corresponding to the narrated animation. The first group engaged the avatar with a click of the mouse while the animation involved no engagement to play the media (DaCosta & Seok, 2010). Like the Mayer and Chandler study, the group receiving the segmented presentation outperformed the group subjected to a continuous narrated presentation. Mayer was quick to say that further research in this area is warranted (Mayer, 2005b). Another strategy known as transfer of skills and knowledge eliminated cognitive load. Further detailed discussions are covered in the following section.

Transfer of Skills and Knowledge

This type of learning can be beneficial when newly acquired skills are applied to new settings and situations to transfer skills and create knowledge. There are two types of transfer learning, near and far (DaCosta & Seok, 2010). These two types of learning are both beneficial in education. Near transfer of skills and knowledge is essentially applied the same way each time a new task and knowledge are performed. Near transfer skill and knowledge can be best described as a procedural instructional design that follows a hierarchical order of sequential events. Far transfer skill and knowledge are applied under different and changing conditions. This type of transfer may have more advantages but is more difficult to teach (DaCosta & Seok, 2010). Clark et al., (2006) suggested that far transfer learning may benefit from worked examples. Although schemata are formed when far transfer learning takes place, this new information adds to the load on working memory (Clark et al., 2006).

As mentioned above, cognitive load theory has been viewed as a limitation of working memory and can impede learning. Intrinsic loads are most difficult to control when overloading the learner with unfamiliar or new content. Instructional designers and educators must consider pre-training or segmenting principles and apply best processes and practices when designing or teaching with content that is complex for novice learners. However, when avoiding extraneous load when using multiple modalities, the loads on working memory are more prominent when contiguity (i.e., both temporal and spatial), redundancy, or a split-attention issues occur.

The framework for this study was constructed from classic theories, but more modern models of memory processing have become popular with the introduction of 21^{st} century technologies. These newer theories are reviewed in the next sections.

Baddeley's Model of Working Memory

Considered one of the leading contributors to working memory, Alan Baddeley was a British psychologist working with Graham Hitch. He proposed a three-component model of working memory. Baddeley and Hitch (1974), referring to Atkinson and Shiffrin's (1968) multi-store model, argued that STM in their model was far too simple (McLeod, 2007, "Working Memory," para. 3). According to McLeod (2007), "…STM holds limited amounts of information for short periods of time with relatively little processing. It is a unitary system. This means it is a single system (or store) without any subsystems. Working memory is not a unitary store" ("Working Memory," para. 3). Figure 7 illustrates Baddeley and Hitch's (1974) model of working memory, a three-component model, comprised of a central executive center that controls and coordinates the operation of two subsidiary slave components: the phonological loop and the visuospatial sketchpad (Baddeley, 1986, 1998, 1999, 2000, 2002; Baddeley & Hitch, 1974; Cowan, 1998; Huitt, 2003; Kalyuga et al., 1999).

Figure 7. An illustration of the three component model of working memory conceptualized by Baddeley & Hitch (1974). Adapted from "Episodic Buffer: A New Component of Working Memory" by A. D. Baddeley, 2000. *Trends in Cognitive Sciences*, 4(1), p.418.

Figure 8 illustrates each component of the model of working memory in detail. The most important and versatile component of the model is the central executive (McLeod, 2007, "The Central Executive," para. 1). Although little is known about this component, the central executive component drives and manages two subsidiaries while focusing, filtering, and dividing attention to recognize stimuli before information enters working memory (Baddeley, 2000; DaCosta & Seok, 2010; Lohr, 2008; Moore et al., 1996) while conducting cognitive tasks such as mental arithmetic or problem solving as it relates to LTM (McLeod, 2007, "The Central Executive," para. 3).

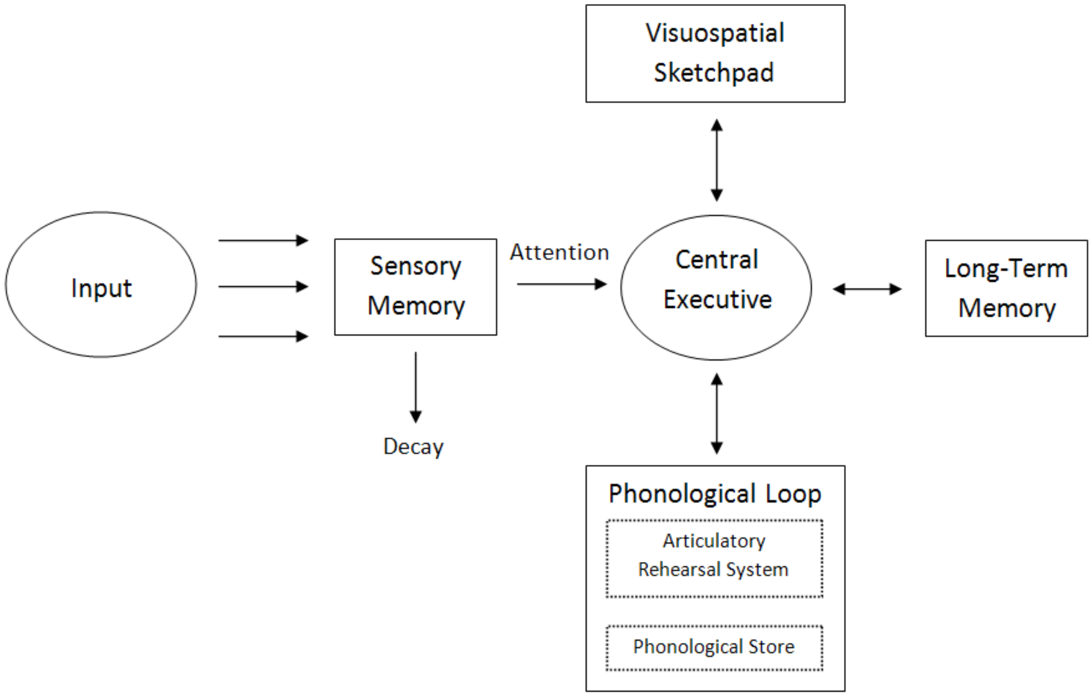

Figure 8. The components of Baddeley & Hitch's (1974) Model of Working Memory. Adapted from "Working Memory (Baddeley and Hitch, 1974)" by S. McLeod, 2007. Retrieved from http://www.simplypsychology.org/working%20memory.html

The central executive component operates as a controller for attention processing by enabling working memory to selectively attend to stimuli while ignoring non-relevant cues (Baddeley, 1986, 1992, 1999). The central executive determines the priority that is given to particular activities. The central executive has two subsidiaries, the phonological loop and the visuospatial sketchpad. These components serve as active storage units that combine visual and acoustic stimuli integrated with information from the central executive component (Baddeley, 1992, 2000; Baddeley & Hitch, 1974; Huitt, 2003; DaCosta & Seok, 2010). According to Baddeley (1986, 1992, 1998, 1999, 2000, 2002), the elements of the memory system are dependent on each component's functionality to work as a cohesive system to process stimuli in working memory.

The phonological loop temporarily stores several linguistic forms while processing verbal and acoustic information received from auditory cues (Baddeley, 1986, 1992, 1998, 1999, 2000, 2002; Baddeley & Hitch, 1974; DaCosta & Seok, 2010; McLeod, 2007, "The Phonological Loop," para. 4). The loop is divided into two sub components: (1) phonological store and (2) articulatory (sub vocal) rehearsal system. The phonological store temporarily stores cues or verbalizations until they are recognized by the rehearsal system (Baddeley, 1992, 2003). Storage is limited in duration, thus any non-relevant information is permanently discarded unless the stimuli are recognized by the articulatory rehearsal system (Baddeley, 2000).

The phonological store acts as an inner ear and holds speech perception (i.e., spoken word) for no more than two seconds. Therefore, the store relies on the system to recall or activate previously stored information from LTM (Baddeley, 1992, 1996). According to Baddeley (2000), the phonological store is efficient in serial recall, "…adult subjects typically opt to name and subvocally rehearse visually presented items, thereby transferring the information from a visual to an auditory code" (p.419). A memory trace (i.e., stimuli received by sensory input) in the store receives stimuli from auditory input or sub vocal articulation (i.e., a symbol or letter visually presented) (Baddeley, 2000). According to McLeod (2007), "Spoken words enter the store directly. Written words must first be converted into an articulator (spoken) code before they can enter the phonological store" ("The Phonological Store," para. 2). The conversion is conducted by the articulatory rehearsal system.

The second sub component of the phonological loop, known as the articulatory rehearsal system, acts as an inner voice that circulates auditory information in an indefinite loop or cycle. This recycling effect similar to rehearsal (e.g., repeating a person's name or phone number that we have just learned) and helps to retain information in working memory (McLeod, 2007, "The Phonological Store," para. 3). The phonological loop sub components process both acoustic and verbal information while converting written materials into a readable code (i.e., letters or symbols) for storage. The loop has been identified as a key element of the model of working memory, but one more element of this model known as the visuospatial sketchpad will be introduced.

The third component of Baddeley's model, the visuospatial sketchpad, acts as an inner eye handling both visual information (i.e., what things look like) and spatial information (i.e., the positioning of one's self in relation to objects in the environment). Visual information is considered to be tangible in nature and is recognized as: diagrams, imagery, and pictures. Spatial information refers to how we move around in the surrounding environment in relation to objects (Baddeley, 1992, 2002; Kalyuga et al., 1999; Lohr, 2008; McLeod, 2007, "The Visuo-Spatial Sketchpad," para.3). According to Baddeley (2000), the sketchpad stores, processes, organizes, and integrates three types of components: (1) visual, (2) spatial, and (3) kinesthetic, while displaying and manipulating the information from LTM (Baddeley, 2002; Mayer, 2002). For example, the spatial layout of your living room is held in LTM. If you were asked how many chairs are in your living room, more than likely a representation appears in your mind allowing you to count the number of chairs. This mental image would be stored and then retrieved from LTM and placed on the visual sketchpad (McLeod, 2007, "The Visuo-Spatial Sketchpad," para.4).

Since the inception of the Baddeley and Hitch (1974) Model of Working Memory, research conducted within the field of human cognition has suggested that a backup store needs to be integrated within the model (Baddeley, 2000). Evidence for this integrated storage is based on visual similarity of verbal recall from different modalities and systems. Baddeley (2000) assumed, “a process or mechanism for synergistically combining information from various subsystems into a form of temporary representation” (p.421). The representation offers a solution and takes on the role of consciousness (Baddeley, 2000). Baddeley’s (2000) concluded that modifications to the original framework where necessary to reflect how phonological processing reflected distinct cognitive systems based on data from adults and neuropsychological patients (Alloway, Gathercole, Adams, Willis, Eaglen, & Lamont, 2005; Baddeley, 2000). The term episodic buffer has been proposed by Baddeley to represent the fourth component of the working memory model (Baddeley, 2000).

The current version known as the Multi-Component Working Memory Model includes the episodic buffer as illustrated in Figure 9.

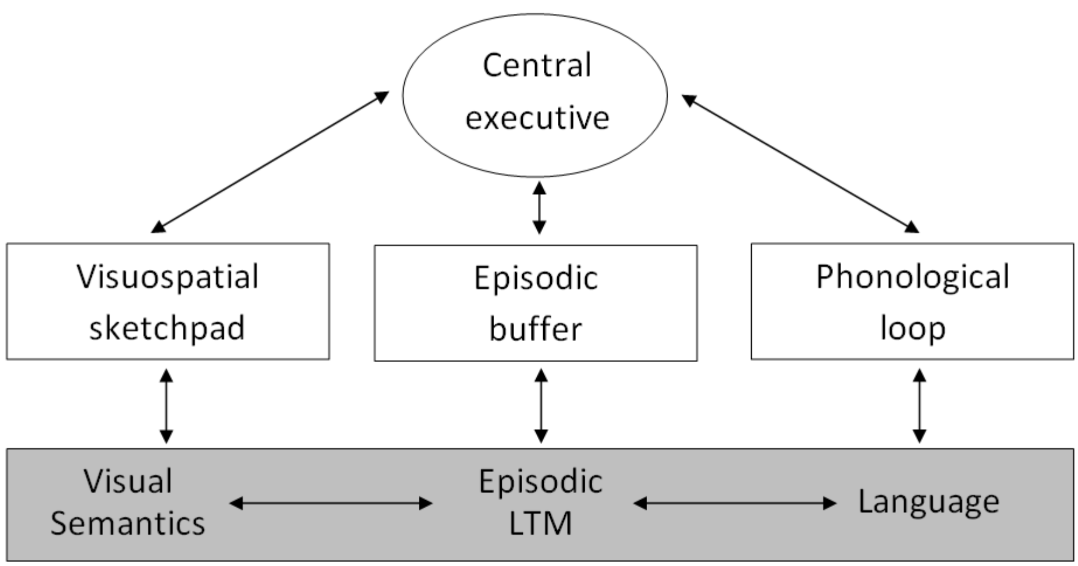

Figure 9. An illustration of the current multi-component working memory model conceptualized by Baddeley (2000). Adapted from “Episodic Buffer: A New Component of Working Memory” by A. D. Baddeley, 2000. *Trends in Cognitive Sciences*, 4(1), p.421.

The loop has since been recognized as a critical component in the functionality of STM and LTM. According to Baddeley (2000), “It became clear that the phonological loop plays an important role in long-term phonological learning, in addition to short-term storage. As such it is associated with development of vocabulary in children, and with the speed of acquisition of foreign language vocabulary in adults” (p.418).

The episodic buffer is capable of integrating stimuli from various sources and is limited temporary storage capacity for multiple dimensional codes. It acts as an interface between the sketchpad, loop, and LTM (Baddeley, 2000; Lohr, 2008). Baddeley (2000) stated, “The buffer is episodic in the sense that it holds episodes whereby information is integrated across space and potentially extended across time” (p.421). The buffer is assumed to be controlled by the central executive component and capable of: (1) retrieving information through the medium of conscious awareness, (2) reflecting on the stimuli, and when necessary (3) modifying and manipulating information. The buffer serves as an interface between working memory (i.e., visuospatial sketchpad and phonological loop), retrieving a multitude of information each containing unique but different code while simultaneously retrieving stored information from episodic LTM (Baddeley, 2000, 2003). Referring to the latest model, Baddeley (2000) stated, “The shaded areas of the model represent ‘crystallized’ cognitive systems capable of accumulating long-term knowledge (e.g., language and semantic knowledge), and the unshaded areas represent ‘fluid’ capacities (such as attention and temporary storage)” (p.421). This blending may explain the inter-workings of a problem-solving task and creativity through the juxtaposition of information held within the buffer (Baddeley, 2000; Lohr, 2008). The buffer plays a vital role within this complex processing structure by creating an interface between the components of working memory and blending existing knowledge with newly formed representations in memory and cognition. Since Baddeley's conceptualization of the multi-component working memory model, the elements and components of his system have widely gained acceptance as a strong theoretical model. In the next section, Baddeley's model is introduced as one of the main components of Mayer's cognitive theory of multimedia.

Mayer's Cognitive Theory of Multimedia

Background

Richard E. Mayer is best known for his research in the area of multimedia and human cognitive processing using multiple modalities within educational materials. Mayer has conducted several research studies based on multimedia instructional messages delivered via two or more modalities (Barron, 2004; DaCosta & Seok, 2010; Mayer, 1997; Mayer & Moreno, 2003; Moreno, 2006; Mayer, 1997; Szabo, 2002). Mayer (1997) defined multimedia instructional messages as, "…presentations involving words (such as spoken or printed text) and pictures (such as animation, video, illustrations, and photographs) in which the goal is to promote learning" (p. 56). During the late 1980s and early 1990s, researchers formulated a new hypothesis based on research that examined performance outcomes when using multimedia (DaCosta & Seok, 2010; Szabo, 2002). Researchers found evidence that meaningful learning took place when visual and verbal representations were administered through multimedia applications (Brunye et al., 2007; Mayer, 1997, 2001, 2002). The use of multimedia technology has developed at a faster pace than the research examining how people learn with multiple-channel technologies and virtual environments (Mayer, 2001; Szabo, 2002). Various aspects of learning are strongly influenced by different characteristics of media in relation to technology, symbol systems, and an individual's ability to process information (Kozma, 1991). Kozma (1991) asserted that learning was influenced by the type of media in relation to an individual's processing abilities combined with prior knowledge and cognitive skills. In the context of learning, multimedia is comprised of three key components: (1) delivery media, (2) presentation mode, and (3) sensory modalities (Moore et al., 1996). Each component is unique and distinguishable and requires that best practices and processes be used when planning, designing, and implementing the use of multimedia in instructional design. Delivery media refers to the way content is presented (i.e., textbooks-printed word, audio modules, or computer-based medium); the presentation mode refers to the technology used to present instructional materials (e.g., words, sound, imagery, or video) (DaCosta &Seok, 2010; Mayer, 1997, 2001; Moore et al., 1996). The third component, sensory modalities, refers to visual, auditory, smell, taste, and touch; and how individuals process modalities.

Theory

Conceptually, the Generative Theory of Multimedia Learning proposed that learners construct their own knowledge by selecting, organizing, and integrating information from two or more modalities (Craig, Gholson, & Driscoll, 2002; Lohr, 2008; Mayer, 1997; Mayer & Anderson, 1991). Mayer (1997) hypothesized that multimedia instruction has had an influence on the degree to which individual cognitive processes engage meaningful learning. The theory was constructed with a culmination of notable theories, conceptual designs, and other research extensions such as Information Processing Theory, Dual Code Theory, Multi-Component Working Memory Model, and Generative Theory (Brunye et al., 2007; DaCosta & Seok, 2010; Höffler & Leutner, 2007; Mayer, 1997). Other research extensions include the work of Sternberg (1985) and Mayer (1984, 1992, 1993a, 1993b, 1993c). According to

Brunye, Taylor, and Rapp (2007), the dual coding principle suggested that, "…active mental integration of multimedia components across steps should impart memory advantages. Because multimedia necessitates further integration activities, we predicted that interleaved presentations should lead to better memory compared to traditional, repetitious multimedia" (p.887). According to Mayer (1997):

> From generative theory, I take the idea that meaningful learning occurs when learners select relevant information from what is presented, organize the pieces of information into a coherent mental representation, and integrate the newly constructed representation with others. From dual coding theory, I take the idea that these cognitive processes occur within two separate information processing systems: a visual system for processing visual knowledge and a verbal system for processing verbal knowledge. (p. 4)

The illustration in Figure 10 represents three processes in Mayer's model.

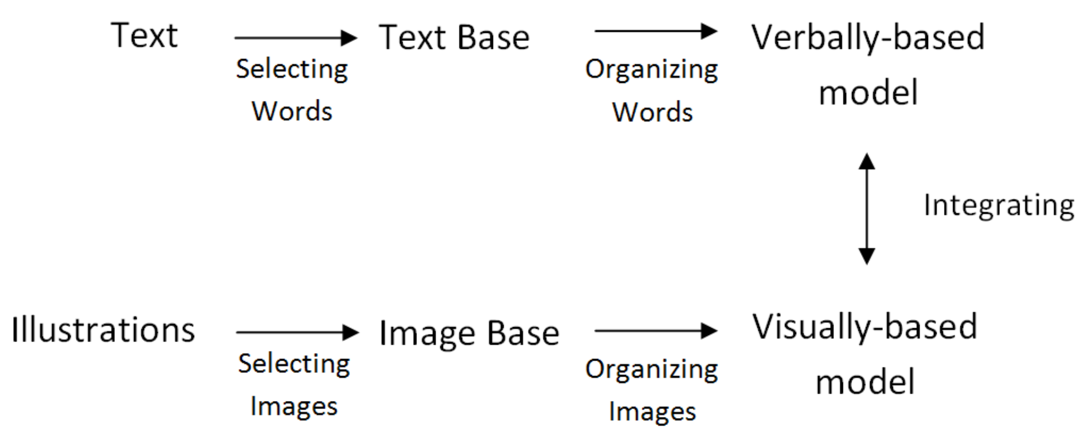

Figure 10. Representative illustration of the processes from the generative theory of multimedia learning by Mayer (1997). Adapted from "Multimedia Learning: Are We Asking the Right Questions?" by R. E.. Mayer, 1997. *Educational Psychologist*, 32(1), p.5.

The arrows represent the course of action that takes place as raw stimuli are converted and transformed into a format that is stored as new schema in LTM (Brunye et al., 2007; Clark & Paivio, 1991; DaCosta & Seok, 2010; Kalyuga et al., 1999; Lohr, 2008; Mayer, 1997, 1999, 2001, 2002; Wittrock, 1989).The first process, known as selecting, recognizes and gives attention to relevant text and illustrations that have entered the system through sensory receptors (i.e., the eyes and ears). The process of selecting transfers briefly stored text and illustrations that are converted to text and image based representations placed in working memory (Barron, 2004; Mayer, 1984, 2002). Selecting can take place in a conscious or unconscious manner. For example, driving in the country side, our perceptual view identifies an octagonal shape; in the distance, as the shape becomes more distinct, other cues are recalled from LTM (prior knowledge) such as color and text that are present on the sign.

Based on these cues, we visualize a stop sign, thus we prepare to stop (Lohr, 2008). The visual stimulus is intercepted by the rods, cones, and optic nerve of the eye. The eye extracts the information into a meaningful object (Moore et al., 1996). The selection process works on an unconscious level in the case of the octagonal shape, but also works at a conscious level as imagery and textual based stimuli are moved from sensory memory into working memory. As mentioned earlier, STM is limited in capacity and duration, thus the process of selecting relevant information has to occur in a short period of time (Lohr, 2008). In Paivio's (1990) dual code theory, the selecting process was referred to as representational processing, where stimuli are activated to construct verbal and non-verbal representations. In Baddeley's model, the selecting process occurs in the visuospatial sketchpad and the phonological loop (Baddeley, 2000, 2002; Mayer, 2001, 2005a). Sternberg (1985) refers to the selecting process as selective encoding that adds a filtering mechanism to sift through relevant and irrelevant information. In Miller's (1956) information processing theory, this process was referred as selecting relevant information, a process where cues are moved from sensory memory to STM.

According to Mayer (1997), the second process known as organizing is described as, “organizing the selected information in working memory into a coherent whole” (p. 5). Verbal and visual memories are ordered and categorized by the learner to make more sense of the information (Lohr, 2008). Text and image based information are organized into verbally and visually based mental representation models. Lohr (2008) gave an example of this process, stating that “…learners may try to structure the information sequentially, hierarchically, or according to past experiences. They might arrange things in a list or imagine parts of an image in a certain format” (p.63). Rehearsal is a critical process if learning is to take place. The learner organizes the information in a manner that is more likely to promote learning (Lohr, 2008). Dual code theory refers to organizing as an associative process that involves connecting visual and verbal information to respective systems, while the information processing theory transforms verbal and visual knowledge into the STM compartments. Sternberg (1985) refers to organizing as a selective combination, where information is organized and built into newly formed visual or verbal mental representations before being passed on to working memory.

The final process of Mayer’s (1997) generative model of multimedia learning was referred to as integrating; integrating builds connections between two representations. The visually and verbally based mental models are stored in working memory and integrated with previously stored knowledge recalled from LTM (Lohr, 2008; Mayer, 1984, 1997). When combined, the likelihood of these models being transferred to LTM is due to the meaningful learning that has taken place (Lohr, 2008). The dual code theory refers to integration as a referential process based on connections that are formed between representations within verbal and non-verbal systems. Miller’s (1956) information processing system related this process to building referential connections, while Sternberg (1985) referred to the integrating process as the selective comparison, (i.e., relating new knowledge to prior knowledge to form new schema). Through extensive research, Mayer and his colleagues have identified different strategies that extend memory using multimedia instructional design principles (Lohr, 2008; Mayer, 2001).

Mayer's (1997) generative model of multimedia learning illustrated how the human cognitive system processes information based on his research. The true conceptual framework model (i.e., representative illustration) is known as the cognitive model of multimedia learning shown in Figure 11.

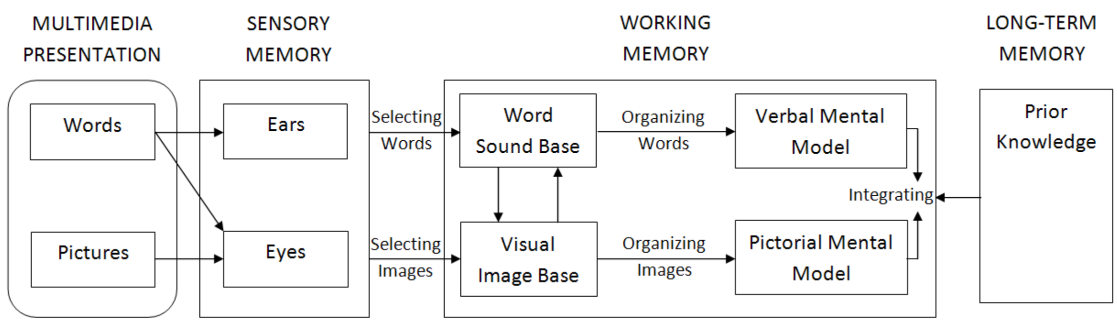

Figure 11. Illustration of the Cognitive Theory of Multimedia Learning by Mayer (2001). Adapted from *Multi-media learning* by R. E. Mayer, 2001. New York: Cambridge University Press.

Multiple citation dates were listed as to when Mayer first published his model. For this study, the 2001 date was used when referencing this design. The Cognitive Theory of Multimedia focuses on best practices and processes proposing six instructional design principles used when two or more modalities in multimedia learning environments are used: the modality principle, the split-attention principle, the contiguity principle, the redundancy principle, and the coherence principle (Craig et al., 2002; Mayer, 2001; Moreno & Mayer, 1999, 2000). These principles are discussed in the following sections.

The Modality Principle

Researchers, content designers, and educators have long supported the use of multiple-channel technologies incorporated into instructional materials to influence learning outcomes. The modality principle proposed when information was presented in two or more modes this would limit cognitive load through sharing visual and auditory loads across working memory (Craig et al., 2002; DaCosta & Seok, 2010; Kalyuga et al., 1999, 2004; Low & Sweller, 2005; Moreno, 2006; Rummer, Schweppe, Fürstenberg, Scheiter, & Zindler, 2011). The modality principle occurs when one form of instruction is replaced with another (e.g., replacing text-based instruction with an auditory component) while integrating non-verbal modalities such as; video, imagery, animation, photos, or illustrations (DaCosta & Seok, 2010; Rummer et al., 2011; Sweller et al., 1998; Tindall-Ford, Chandler, & Sweller, 1997). The modality principle proposed that learning will be maximized if non-redundant information were presented simultaneously by both visual and auditory channels (DaCosta & Seok, 2010). According to Clark et al. (2006) instructional material presented in an audio channel has been shown to benefit novice learners or those with limited prior knowledge (Clark et al., 2006). The modality principle has been shown to be beneficial when new information was presented to novice learners, but experienced learners can experience capacity loads exceeding working memory (DaCosta & Seok, 2010; Low & Sweller, 2005, Sweller & Chandler, 1994).

Early research conducted by Mayer and his associates was criticized for the lack of environmental control. Although Rieber (2005) was skeptical about Mayer's conclusions, Mousavi, Low, and Sweller (1995) and Tindall-Ford et al. (1997) conducted research within educational institutions. To date, the most influential research conducted on the modality principle was Mousavi, Low, and Sweller's (1995) study. Three groups were exposed to different treatments based on geometry worked problems: (1) simultaneous group, subjects who were given examples of a diagram supported by statements presented visually with a redundant audio component; (2) visual-visual group, were given worked examples of the same diagram with only visual support statements; (3) visual-auditory group, received the diagram in a visual modality while supported by audio statements only (Mousavi et al., 1995). Findings indicated that subjects administered the visual and auditory modes performed significantly better on transfer tests than the visual mode only group (Barron, 2004; DaCosta & Seok, 2010; Kalyuga et al., 1999; Mousavi et al., 1995).

Research conducted by Tindall-Ford et al. (1997) examined the effect on test scores using mixed auditory and visual modes of presentation based on introductory electrical engineering material. The modality principle and split attention principles were the main emphasis for this particular study. Thirty trade apprentices were assigned to one of three treatments. All three treatments contained a diagram with complementary text presented in different modes. In treatment one (i.e., visual instruction) contained bulleted textual statements located below the schematic diagram. Neither mode was intelligible as a standalone instructional piece that required mental integration. Treatment two (i.e., integrated instruction) the text was placed within the diagram, creating a sequential and proceduralized instructional design. Treatment three (i.e., audio/visual instruction) used the same diagram, but the text was presented in an auditory format (Tindall-Ford et al., 1997). Based on the findings, groups receiving the integrated and audio/visual instruction were far superior in performance on transfer tasks and a recall test than those receiving the visual only instruction. Tindall-Ford's et al. (1997) referred to extraneous load in their claim that "When students are faced with intellectually difficult material requiring mental integration between multiple sources of information, results suggest that mental integration may be easier if written information is transferred into an auditory form. Alternatively, when information is not intellectually challenging, the mode of presentation may be of less importance" (p. 285).

More recent research, consisting of two experiments, was conducted by Rummer, Schweppe, Fürstenberg, Scheiter, and Zindler (2011). They examined the effect of the modality principle and the contiguity principle based on a comprehensive recognition test. In each study, subjects were randomly assigned to one of six treatments: simultaneous presentation, imagery supported with narration and imagery supported with text; sequential presentation, imagery supported with narration and imagery supported with text; text-only presentation, text and narration. The studies differ in regard to content related within the treatments: experiment one, text about fictitious constellations and their depictions; experiment two, text describing geometric shapes of the constellations. According to Rummer et al. (2011) for subjects exposed to printed text rather than voice narration during a simultaneous presentation of modalities, the scores on the image recognition test decreased which was attributed to time constraints. When examining the contiguity principle, subjects receiving voice narration outperformed those receiving printed text when presented simultaneously. Rummer et al. (2011) recommended that instructional designers refrain from using auditory narration when larger amounts of text are associated with images based on the spatial contiguity principle.

Harskamp, Mayer, and Suhre (2007) conducted two experiments examining the effect of the modality principle utilizing two multimedia treatments. In both experiments, subjects were randomly assigned to one of two treatments and were asked to complete both a pre-test and post-test to measure performance gains. In the first experiment, both treatments contained identical illustrations but differed in modality support; treatment one was supported with textual statements and treatment two was supported with a voice-over narration. Both treatments were identical in respect to content. The text was placed to the left of the illustration to maintain spatial contiguity. In the second experiment, the instructional materials were modified to include more interactivity. According to Harskamp et al. (2007), unlike the first experiment, subjects were required to answer questions that were embedded into the treatment slides before moving to the next slide. Times were recorded to determine the time on a task when viewing instructional material. Harskamp et al. concluded that the modality principle was supported in both experiments (i.e., students learn better from graphics and spoken text than from graphics and printed text) particularly held true when tests measured learner understanding (i.e., transfer rather than retention) and learners who did not require more than the average time to learn. Harskamp et al. went on to say that the results recommend that multimedia instructional designs should incorporate spoken words instead of printed words when meaningful learning is to take place.

Other notable studies (e.g., Jeung, Chandler, & Sweller, 1997; Kalyuga et al., 1999; Mayer & Moreno, 1998) examined topics such as math problems, formation of lightning, car brake system, electrical engineering, aircraft simulation, environmental science game, and mechanics behind a motor car. Findings indicated that individuals receiving imagery animation with simultaneous narrated multimedia presentations performed better during transfer tests than learners receiving text-based presentations only (DaCosta & Seok, 2010; Mayer, 2000).

Future Research

As different forms of advanced technologies are discovered in the future, alternative delivery methods will take place. Instructional design processes and practices must adapt to the ever-changing way in which individuals create knowledge and learn new skills. Researchers examining the modality principle are encouraged to explore ways that modalities could be combined to ease the burden on working memory. Future studies using advanced multimedia technologies within virtual environments should examine performance outcomes when visual or auditory modes are presented sequentially.

Other studies should examine human cognition and the exact mental mechanisms that drive the modality principle and their effect on memory performance and meaningful learning (Barron, 2004). As discussed above, the modality principle supports multiple-channel technologies as long as the information is new to the learner. The split attention principle augments this concept by asserting that pictorial or imagery and the textual information that supports these modalities should be located within a relatively close spatial area.

Split Attention Principle

Split attention occurs when learners divide their attention between two instructional elements due to poor spatial design. Spatial design refers to the location of an image in respect to the placement of supporting text (Barron, 2004; Kalyuga et al., 1999, 2004; Lohr, 2008; Moreno & Mayer, 2000; Smith, 2001). Although research has provided evidence of increased extraneous cognitive load when learners split their attention between two modalities, the capacity of working memory can be extended using dual-modalities by stretching both visual and auditory memories (DaCosta & Seok, 2010; Kalyuga et al., 1999, 2004; Sweller & Chandler, 1994). Research concluded that concurrent uses of two modalities are superior although the working memory load was increased (Brunye et al., 2007; Craig et al., 2002; Kalyuga et al. 1999, 2004).

Although Jeung et al.'s (1997) research initially examined the modality principle, split attention occurred due to the spatial contiguity effect (discussed later in the chapter). The research examined the effects on test scores when multiple modalities were integrated in a geometric instructional design. Sixty subjects were divided into six groups: two, visual-visual instructional designs; two, audio-visual instructional designs; and two, audio-visual flashing (i.e., relevant parts of the instructional design would flash when matching audio coincided with a diagram). Each treatment administered was rated as either high or low in search complexity based on spatial location of supporting visual or auditory documentation. Jeung et al. (1997) concluded that an extensive search for supportive documentation located elsewhere within the material caused a split attention effect that hampered the beneficial effects of dual modalities.

Another research study examining split attention was Chandler and Sweller's (1991) study. They found that individuals examining textual and pictorial integrated instructional materials (i.e., a diagram illustrating the flow of blood through the heart, lungs, and body) performed no differently than those who were exposed to materials that caused split attention They concluded that the extraneous load caused by the division of visual and auditory cognitive processes can be controlled if designers follow best processes and practices, especially when integrating supportive modalities.

The Contiguity Principle

Mayer and Anderson (1992) proposed the contiguity principle an element of instructional design related to the placement of images relative to the supporting text. Moreno and Mayer (1999) added that there are two separate and distinct effects: spatial (i.e., printed text and pictures) and temporal (i.e., visual and spoken materials) contiguity (Barron, 2004; Craig et al., 2002). Moreno and Mayer's rationale behind these contiguity effects were to ease the integration process in STM when two stimuli are presented simultaneously (Barron, 2004).

Spatial contiguity proposes that learners learn more deeply when pictures accompanied with relevant texts are located within the same space or proximity to one another (Brunye et al., 2007; DaCosta & Seok, 2010; Donovick, 2001; Levie & Lentz, 1982; Levin, Anglin, & Carnay, 1987; Kalyuga et al., 1999; Lohr, 2008; Mayer, 2005c; Moreno & Mayer, 1999). The goal of spatial contiguity is to create instructional materials that eliminate the search for accompanying components (i.e., the image with supportive text or vice versa) (Craig et al., 2002; DaCosta & Seok, 2010; Mayer, 1997; Moreno & Mayer, 1999, 2000). Non-contiguous text and images may cause learners difficulty when integrating the two components, thus leading to cognitive load and a disruption in the learning process (Brunye et al., 2007).

Some instructional content may be presented concurrently such as a text-based statement that supports an image or picture. The time that elapses between exposing both text and imagery is known as temporal contiguity (Craig et al., 2002; Lohr, 2008; Mayer, 1997; Mayer & Sims, 1994; Moreno & Mayer, 1999). Related animation and narration modalities experience the same temporal contiguity. According to the cognitive theory of multimedia learning, both contiguity principles increase the opportunity for information to be processed in visual and verbal stores, unlike a successive presentation, when the learners must hold the information in working memory until the complement is unveiled (Craig et al., 2002; DaCosta & Seok, 2010). Based on the cognitive theory of multimedia learning, several studies have been conducted examining spatial and temporal contiguity.

The most notable study conducted by Mayer and Moreno (1998) examined the dual-processing theory of working memory. Two studies were conducted with treatment content on lightning formations and a car's brake system. Seventy-eight college students were assigned to one of two groups: (1) known as the AN group (i.e., animation with concurrent auditory narration, and (2) known as the AT group (i.e., animation with corresponding on-screen text) (Mayer & Moreno, 1998). Subjects were administered their assigned treatment followed by a retention test that measured recall and skill transfer. According to Mayer and Moreno (1998), the results extended previous research of contiguity effects in their finding that, "…students learned better when an animation depicting the workings of a scientific system and the corresponding narration were presented concurrently rather than successively" (p. 318). They went on to say that the contiguity principle (temporal) was advantageous to learners when presenting words with corresponding pictures (Barron, 2004; Mayer & Moreno, 1998; Moreno & Mayer, 1999).

Research conducted by Mayer (1989) examined the effect on recall and transfer tests based on adding explanative text labels to static illustrations on an automotive brake system procedure. Subjects were asked to recall text associated with pictorial labels and demonstrate transfer skills to maintain a brake system. Mayer concluded that recall and transfer skills were improved by the addition of contiguous labels (Mayer, 1989; Moore et al., 1996). Similar to Mayer's (1989) study, Mayer, Steinhoff, Bower, and Mars (1995) examined the effects on problem solving solutions when text-based information was added to illustrations. Subjects were assigned to one of two treatments: (1) integrated group, text was placed adjacent to illustrations that contained annotations repeating verbal cause and effect information and (2) separated group, integrated text with illustrations placed on separate pages without annotations. Mayer et al. (1995) found that subjects administered the integrated group treatment generated 50% more creative solutions on transfer problems than those given the separate group treatment. Positive effects were attributed to the contiguous integrated illustrations incorporating annotations (i.e., captions and labels).

Other studies examining the contiguity principle were conducted by Mayer et al. (1995), Chandler and Sweller, (1997), Sweller, Chandler, Tierney, and Cooper, (1990), and Tindall-Ford et al. (1997).

Redundancy Principle

The redundancy principle was originally conceptualized by Kalyuga, Chandler, and Sweller (1999). The rationale behind this principle was to offer students a choice of various formats within multimedia presentations that best fit their particular learning style (Mayer, 2002). It was hypothesized that the addition of redundant modalities would increase performance (Aarntzen, 1993; DaCosta & Seok, 2010; Kaiser, 2004, 2005), although van Merrienboer & Ayers (2005) stated the redundancy principal promoted the consolidation and condensation of multiple sources into one, thus reducing the cognitive load. However, other researchers have repeated the redundancy principle, asserting that adding several redundant forms of information with a learner's schematic knowledge; the overall effect can cause an extraneous load on working memory, consequently hindering the learning process (Kalyuga et al., 1999, 2004; Moore et al., 1996; Sweller, 2005b). Under this condition, the load placed on working memory was not caused by split attention but by the existence of multiple sources (Aarntzen, 1993; Kalyuga, 2000; Kalyuga et al., 1999, 2004; Moore et al. 1996). Attending to unnecessary information required extensive amounts of resources allocated for processing. These resources are normally reserved for schema acquisition (Kalyuga et al., 1999, 2004). The concepts of the redundancy principle are based on "less is more" (Nguyen & Clark, 2007; DaCosta & Seok, 2010). The redundancy principle advocates that instructional design must be self-contained within single modes or sources of information (DaCosta & Seok, 2010; van Merrienboer & Ayres, 2005). In other words, minimize the amount of information by including only the necessary information that meets instructional objectives and distinguishes between the "need to have" verses the "nice to have" (DaCosta & Seok, 2010).

More recent studies examining the redundancy principle were conducted by Mayer and Johnson, (2008), Kalyuga et al. (2004), Mayer, Heiser, and Lonn (2001), and Sweller (2005a). Mayer and Johnson (2008) conducted two research studies that examined the effects on transfer and retention tests when adding redundant on-screen text to multimedia presentations. The first study consisted of 90 subjects assigned to one of two multimedia lesson treatments. Subjects received a non-redundant multimedia lesson designed with diagrams supported with simultaneous narration, while others were administered the same multimedia lesson only action keywords were added to the diagrams in the form of on-screen text. Mayer and Johnson (2008) found that the redundant text fostered generative processing (i.e., deep cognitive processes) contrary to previous research. Although past research has shown that the addition of a redundant modality is detrimental to knowledge creation, extraneous loads were limited by chunking the content into small phrases instead of reproducing all the narrations in a text form (Mayer & Johnson, 2008). A second experiment was conducted to determine if the results obtained could be replicated with a different proceduralized instructional design.

Mayer and Johnson's (2008) second study randomly assigned 62 subjects to one of two multimedia lessons on the inner-workings of a car brake system using diagrams and simultaneous narration as the modes of delivery. However, the redundant treatment contained short keyword actions in the form of on-screen text labels placed within a close proximity of the visual display (Mayer & Johnson, 2008). Findings duplicated the results of the first experiment when small bits of information produced favorable outcomes when the instructional design best practices and processes were used when redundant information was added.

Kalyuga et al. (2004) conducted a series of three studies examining the effects of redundant auditory and visual modalities through multimedia presentations. The first study compared concurrent and sequential (i.e., auditory followed by visual) modes of presentation of textual statements of a diagram without any time restrictions. The second experiment compared the same presentations under a time constraint. Kalyuga et al. (2004) described the treatments of the study: "In the third experiment, we compared simultaneous presentation of audio and visual text with an audio-alone condition without a diagram and predicted again that the elimination of the redundant visual mode would facilitate learning" (p. 569).

Subjects were randomly assigned to either the concurrent or sequential mode treatment used in the first study. The treatments were delivered using computer-based training modules. A seven-point scale collected difficulty ratings (i.e., extremely easy to extremely difficult) from each subject. According to Kalyuga et al. (2004) this type of rating scale has become popular when measuring subjective mental cognitive load related to learning tasks. Each subject was administered a performance outcomes test that measured transfer skills. In both the non-concurrent and concurrent presentations Kalyuga et al. (2004) concluded that there was no significant effect on the test scores of the multiple-choice test. However, subjects were allowed to view visual instructions without any time constraints and thus could compensate for the load during the learning process. Kalyuga et al. (2004) went on to say that redundancy may have resulted in cognitive load without affecting performance. Based on their findings, Kalyuga et al. (2004) conducted a follow-up study to confirm their findings, but felt it necessary to change the content and add a time limit to view the instructional materials.

In the second study, instructional materials were used to train subjects in the area of fabrication. The content focused on soldering and blueprint readings. Kalyuga et al. (2004) randomly assigned subjects to one of two treatments. The first group received a concurrent presentation containing animated components (i.e., diagrams) with integrated textual statements and supportive audio narration. The second group received the same content, but the text was presented immediately after the auditory explanation rather than simultaneously. Both treatments were delivered using computer-based systems that controlled the timing of the animation and textual statements. Auditory narration and the step-by-step procedure were allotted the same time constraints, although experiment one had no restrictions on time to view the diagrams and integrated text (Kalyuga et al., 2004). In experiment one, researchers used two collection methods, a nine-point scale to measure the difficulty rating (i.e., 1 being extremely east to 9 extremely difficult) and a ten question multiple-choice test to measure transfer skills. Kalyuga et al. concluded that the concurrent group performed significantly worse on the multiple-choice test while the non-concurrent group reported a higher mental load based on the rating scale. They went on to say that a redundancy effect caused the load based on time constraints when both text and narration were presented simultaneously. The subjects administered the redundant information experienced cognitive load, thus decreasing performance and efficiency of the concurrent presentation. Kalyuga et al. stated, "Delayed presentation of visual text in the non-concurrent format, which does not require additional working memory load, may also effectively transform this presentation into a form of revision of previously learned auditory presented material" (p. 576). They suggested that a third study be conducted to examine possible distractions caused by animated imagery distracting a subject from reading textual statements, which could cause a perceptual load rather than a cognitive load.

The third study conducted by Kalyuga et al. (2004) examined the redundancy effect when delivering content in a concurrent presentation featuring text and narration simultaneously, while the second treatment administered was an audio-text treatment. Researchers hypothesized that integrating visual and auditory elements would impose a cognitive load based on redundant materials (Kalyuga et al., 2004). Participants were randomly assigned to one of the two groups. Both treatments contained identical auditory narrations in a concurrent treatment. The textual statements and narrations contained the same content. Both the visual and auditory modalities were simultaneously presented. Time constraints were introduced into this experiment; the animated diagrams with supporting textual statements and narration were presented in the same time frame. Eight multiple-choice test questions were administered to each subject measuring performance outcome. Kalyuga et al. concluded that the redundancy effect was obtained with the concurrent text group, while the auditory text group reported performance gains when the pacing of the instruction was controlled. Results obtained from those three studies concurred with previous studies examining the redundancy effect found within the cognitive load of multimedia theory.

Kalyuga et al. (2004) concluded the first two experiments indicated textual and auditory instructional content presented simultaneously were detrimental and hindered the learning process. It was hypothesized that the human cognitive processing system would be overloaded, thus inadequate when audio and visual modes were presented concurrently. Sequential presentations of both modes handled the information without placing any extraneous loads on the learning process, although results from the subjective ratings consistently demonstrated that the presentations were seen as a strain on the mental efforts contrary to the non-concurrent presentations. Based on these conclusions, future research must examine redundant multimedia modalities used in instructional design. Mayer and Anderson (1991, 1992) and Mayer and Sims (1994), found that audio and visual components within a multimedia presentation presented simultaneously were far superior to those presented sequentially. These results were conflicting with previous research when split attention and redundancy principles were examined. Kalyuga et al.

(2004) suggested that future research studies provide information describing effects encountered or observed related to both principles.

Research by Chandler and Sweller (1991) examined the effects on performance skills and test outcomes based on using redundant modes of instructional content in the wiring of electrical circuits. Two groups consisting of 14 subjects were randomly assigned to one of two treatments. The first group received a conventional split-source format guide (i.e., supporting sequential text and diagram divided on a page); the others were administered a modified version of treatment number one containing identical content in a form (i.e., textual sequential steps were placed within the diagram). Chandler and Sweller (1991) concluded that integrated instructional materials involving diagrams and text increased interactivity, causing a cognitive load. This appeared to support the statement by Kalyuga et al. (2004) that when adding redundant text, "…the need to attend to, coordinate, and process both modes of text simultaneously, and to relate them to graphic information, consumed additional resources" (p. 3).

Kalyuga (2000) conducted a study examining the effect of additional modalities used to teach novice apprentices soldering skills. Using fusion diagrams, three treatments were administered to subjects: diagram with visual-text, diagram with audio-text, and diagram with visual-text plus audio-text. Higher test performance scores were achieved by groups administered the diagram with audio text over the other two treatments. Kalyuga (2000) concluded that redundant information added to stand alone instructional materials caused a cognitive load on working memory.

Based on the studies reported above, the research has shown that the redundancy principle caused a cognitive load, and designers should be aware of the pitfalls if redundant information is introduced to learners. Novice and expert learners are not immune to the redundancy principle when poor practices are used to create instructional material, although information presented to experts within a domain can invoke a cognitive load due to conflicting prior knowledge or schema construction (Kalyuga, Chandler, & Sweller, 1998). Best practices and processes when designing content can eliminate loads when redundant information is presented, thus freeing up resources for processing (DaCosta & Seok, 2010; Kalyuga et al., 2004; van Merrienboer & Ayres, 2005). To limit load in instructional content, the designer should develop pre-training principles that lower extraneous load (van Merrienboer & Ayres, 2005).

Coherence Principle

The final multimedia instructional design principle used to eliminate or limit loads on working memory is known as the coherence principle. This principle identifies irrelevant material added to instructional content (i.e., bells and whistles). Moreno and Mayer (2000) stated, "Students learn better when extraneous material is excluded rather than included in multimedia explanations" (p. 6). Unnecessary words and pictures added to multimedia presentations disrupt the learning process (Lohr, 2008; Mayer, 2002; Moreno & Mayer, 2000; Morey & Cowan, 2004). As discussed earlier, the visual and auditory channels, according to the cognitive theory of multimedia learning, are limited in capacity (Mayer, 2002). Although adding audio has been shown to be useful in providing instruction or verbal feedback (Aarntzen, 1993), irrelevant audio (e.g., music, sounds, narration, or other digital auditory), text, and pictorial cues overload a channel (Kalyuga et al., 1999, 2004; Moreno & Mayer, 2000). Expanding on their 1998 research, Moreno and Mayer's (2000) study has been cited as the most notable research conducted on the coherence principle. Mayer and Moreno

(1998) originally examined the dual coding process of working memory using animation and narration as the modes of presentation. Moreno and Mayer (2000) then added irrelevant background music and environmental sounds to multimedia presentations using the same instructional content from their 1998 study. Seventy-five college students were assigned to four treatment groups: (1) NEM group (i.e., narration combined with environmental sounds and music), (2) N group (i.e., concurrent narration), (3) NM group (i.e., narration with background music, and (4) NE group (i.e., narration with environmental sounds). Subjects were administered one of the four treatments and then a transfer test. Findings supported "…the hypothesis derived from the cognitive model of multimedia learning. Adding extraneous auditory --material in the form of music--tended to hurt students' understanding of the lighting process. Adding relevant and coordinated auditory material--in the form of environmental sounds—did not hurt students' understanding of the lightning process" (p. 5). Moreno and Mayer went on to say that the extra load on working memory was created by adding irrelevant material (Barron, 2004; DaCosta & Seok, 2010; Moreno & Mayer, 2000).

As discussed in this section, several principles were introduced to inform content designers or educators about possible pitfalls that could be encountered when developing instructional content. In conclusion, research has shown that irrelevant text, imagery, and auditory cues cause a load on working memory. Eliminating unnecessary content within the instructional material through best practices and processes promote meaningful learning and knowledge creation. In the next section, 21st century technologies including web tools within virtual-learning environments used to construct multimedia are discussed.

21st Century Technology in Education

Some researchers are concerned and argue that the future of education is bleak due to dogmatic ways of thinking about how education and instructional content should be designed, created, delivered, and implemented. Some administrators and instructors who are unwilling to adopt advanced technologies in education throw blame only in the opposite direction from the true problem. They blame the lack of funding, understanding new practices, processes, and professional development as an excuse to postpone integrating technology into the classroom (Dotterer & Washburn, 2009). Slaughter (2002) wrote that education is stuck in the industrial era of instruction. Others argue that education has been experiencing drastic changes over the last decade similar to those changes from oral to printed text, a “technological revolution” per se (Best & Kellner, 2001). These rapid advancements in technology have outpaced research conducted on the effectiveness of media infused into current instructional processes and designs (Mayer, 2005a; Gidley & Hampson, 2005; Hartley, 2001; Sheehy & Bucknall, 2008). Innovative technologies are constantly evolving and changing. The advancements of hardware, software, and connectivity are still developing while new ways of integrating mobile applications (APS), Web 2.0 tools, and cloud computing into multimedia are being discovered. With these advancements, the use of technology in science, research, communication, medicine/health, and education are evolving at such a rapid pace that the future holds exciting and unimaginable opportunities. Optimistic researchers believe that the technological developments employed today provide a clear lens on the future of education and give educationalists a means to reflect what is important and necessary in the 21st century classroom (Kellner, 2004; Sheehy & Bucknall, 2008).

Despite its potential benefits, educators designing and implementing instructional content face several obstacles when trying to integrate new technology. In blending content with technology to produce meaningful learning outcomes, educators must overcome deficient technology, lack of funding resources, limited training with advanced technology, and student accessibility (Dotterer & Washburn, 2009). Although these obstacles present challenges for educators, the integration of technology provides the ability to digitize, personalize, and create interactive virtual environments. Digitization as defined by Tu (2005) is “Technological advancements that permit better sound and picture quality and information transmission at higher speeds. The improved quality of digitized information permits the transmission of higher quality text, graphics, motion and colors at increased speed” (p. 196). Technology can also provide a personalized experience for students by providing choices with media, social interaction, and a learner-centered approach to learning. Interactive communication/socialized learning can improve student performance by eliminating the feelings of isolation within linear or non-linear content structure (Tu, 2005). Educators must be able to successfully create environmental stimuli and cues that are strategically embedded within instructional content to invoke the sensory modalities through segmented information that is interesting and relevant to the learning process.

As stated earlier in this chapter, sensory modalities are, in essence, cues or stimuli that are received by the visual, auditory, smell, taste, and touch senses. A transformative process changes environmental cues from one form to another one that is understandable through the human cognitive processing system. The basis for this study examines an individual’s preferred learning style mixed or matched with an instructional medium (i.e., modality form to transfer information) while demonstrating the ability to recall information and to transfer learned skills. Twenty-first century education/training media currently used include components calling upon visual, auditory, and motor based skills requiring hand-eye coordination (i.e., kinesthesia movement) senses.

<u>Multimedia, Hypertext, and Hypermedia</u>

Multimedia, an integration of technologies, is a combination of two or more of the following; digital sound, animation, photographic imagery, video, and other data delivered via computer or other electronic means and are capable of delivering massive amounts of information (Azevedo & Hadwin, 2005; Barron, 2004; Beccue et al., 2001; Chen & Ford, 1998; Craig et al., 2002; Donovick, 2001; Hartley, 2001; Mayer, 2005b; Reed, 2006). Multimedia can be used as a delivery method for instructional materials, integrated into a presentation, as an App (i.e., shorthand for application), or hybrid interactive medium. Multimedia becomes active when hypertext and hypermedia links are embedded within media. Through active multimedia educators are able to deliver instructional materials that are engaging to students in rich sensory activities that promote inquiry and exploration (Beccue et al., 2001; Chen, 2002; Chen & Ford, 1998; Donovick, 2001; Weiss et al., 2002).

Hypertext and hypermedia links are portals or gateways to other locations within the same document/media or to documents and media in another location (Beccue et al., 2001; Burton et al., 1995; Chen, 2002; Chen & Ford, 1998). Engaging hypertext or hypermedia links can be initiated by “clicking” text (i.e., letters, numbers, words, a series of words, or a Uniform Resource Locator (URL)) or an image. Hyperlinks can usually be easily identified. The links are usually underlined, and the text is formatted in a different color. Image-based links may have a blue border around the image, but both hypertext and hypermedia links are identified when the pointing cursor changes shape and engage an alternative box (i.e., a text box describing the link used mainly by screen readers). Also known as “hot words”, “hot links”, or nodes, these links allow the relocation action to take place through Hyper Text Markup Language (HTML). This relocation action is better known as navigation. According to Szabo (2002), navigation is a means to access rich multimedia content in an organized or non-organized structure and can be structured in a linear or non-linear approach to learning.

One advantage of hypertext and hypermedia linking is the ability to control flow in two ways: (1) linear flow, with pre-define linked pathway between content sources; (2) non-linear flow, in which students take on a learner-centered approach by determining their own pathway and speed to access linked instructional material (Chen & Ford, 1998; Vass, 2008). According to Dillion and Jobst (2004), a linear hyper-based system guides users through a sequential progression of chunked information linked to other information Non-linear linking allows the student to browse through content that is interesting and relevant to their learning needs (Azevedo & Hadwin, 2005). For the scope of this study, linear and non-linear approaches were only defined in the context of the associations found with hypertext and hypermedia.

The depth of hyperlink approaches warranted a more detailed and in-depth review of their potentials in future technology research designs, particularly in light of the lack of student preparation for dealing with learner-centered non-linear formats. Mixed reviews have surfaced on which linking approach produces better learning outcomes. Some researchers believe that there are direct relationships between linear and non-linear hyperlinking approaches with learning styles (Burton et al., 1995), although Chen and Ford (1998) suggests that more research be conducted examining these possible relationships. Chen (2002) also suggested conducting research to examine the possibility of integrating both linear and non-linear approaches into a single hypermedia program to accommodate different individual learning styles. Further discussion pertaining to learning styles will be introduced in greater detail later in this chapter.

Research has shown that some individuals are at a disadvantage when using non-linear learning formats. Some users have reported becoming confused and disoriented in relation to location (Ausburn, Martens, Washington, Steele, & Washburn, 2009; Darken & Peterson, 2002; Dotterer, 2010b; Dotterer, Calhoun, Kroutter, Jennings, Burkett, & Braithwaite, 2008; Kroutter, 2010). Some subjects experienced extraneous and intrinsic cognitive loads when asked to navigate through non-linear virtual learning environments (VLEs) (Chen, 2002; Dotterer 2010b). Dotterer (2010b) went on to say that lacking navigational skills or egocentric presence caused orientation issues, thus individuals were not able to understand how to work on the task at hand as indicated in comments such as “Where do I start?", “What do I do next?", or “This was frustrating!” (Dotterer, 2010b). To overcome extraneous and intrinsic loads within VLEs, educators and designers must incorporate and embed scaffolding to increase learner success (Azevedo & Hadwin, 2005). Before initiating non-linear formats, students should be introduced to learner-centered strategies, personal goal setting and reflection, and benchmarking tasks through interactive media (i.e., embedded animation, pedagogical agents) or other experienced learners (Azevedo & Hadwin, 2005; Hartley, 2001; Johnson & Aragon, 2003; Mayer et al., 2003; Pang, 2009; Tu, 2005). Educators or self-pace programs must also be able to offer instantaneous feedback or some type of reward system designed to foster best practices and processes when learners are successful in using non-linear designs.

Virtual Learning Environments and Web Based Instructional Design

VLE systems are becoming a more relevant and significant part of online delivery systems and flexible e-learning. The benefits of using virtual learning environments include integration, access, improved motivation, and learning opportunities (Ajlan & Zedan, 2007; Berry, 2008; Dougiamas, 2007, “Moodle in Education,” para. 1), VLEs can provide interactive learning that provides automatic feedback to activities, assessments, and other learning modules (Ajlan & Zedan, 2007; Mecella, Ouzzani, Paci, & Bertino, 2006). They provide a platform for web-based instructional design that is housed and managed through course management systems (i.e., Blackboard, Web CT, Desire2Learn, Angel, and Moodle) and are offered in hybrid forms (i.e., partial face-to-face with online component) or without a physical presence (Becker & Haugen, 2004; Johnson & Aragon, 2003). Course management systems contain multiple modules, interactive forums, discussions, chat rooms, conditional activities, video, blogs, assessment tools, and built-in elements that aid in scaffolding, real-time progress, and feedback reports (Becker & Haugen, 2004; Pang, 2009). As an extension of human knowledge and power, these systems contain the capacity to do so much more than just being a storage house for mundane documents. Because Web 2.0 tools and web authoring software, enhanced interactive elements should be included as more robust tools that promote meaningful learning and knowledge creation (Tu, 2005). These course management systems are numerous and broad in scope, and can offer course content in K-12 schools, technical and trade centers, private and community colleges, and universities (Johnson & Aragon, 2003; Pang ,2009; Sumiyoshi, Yamada, & Yagi, 2002). The participatory nature, social constructs, and cognitive nature of web-based training through advancements in technology have provided resources and activities that have fundamentally changed the way education, and training is offered today (Sumiyoshi et al., 2002; Tu, 2005; Vass, 2008).

VLEs are seen as powerful media but need to address instructional design issues that could be detrimental if not attended to through best practices and processes. According to Johnson and Aragon (2003), VLEs should contain a combination of the following principles: (1) address individual differences, (2) motivate individuals, (3) eliminate extraneous, intrinsic loads while promoting germane loads, (4) provide realism, (5) use social constructs, including interaction, (6) provide hands-on components, and (7) foster feedback and student reflection. The lack of basic design considerations is problematic due to the understanding that instructional materials are only being delivered through another framework (Carr-Chellman & Duchastel, 2001), and designers frequently spend more time developing eye-appeal information that promotes extraneous and intrinsic cognitive loads (Barron, 2004). As mentioned before, best practices and processes should be taken into consideration when developing multimedia or hybrid media, recognizing methodologies that promote behavioral and social constructs through group interaction, peer assessment, personal feedback, and encouraging self-reflection (Johnson & Aragon, 2003). However; in corporate training or professional development, too much emphasis is placed on "getting something up and running" instead of cognitive and constructivist models of design to produce measurable meaningful learning (Pang, 2009). A more common concern in web-based training stems from unprepared learners who are asked to take the initiative and responsibility to regulate their own learning.

According to Azevedo and Hadwin (2005), studies have shown that students have difficulties regulating aspects of their cognitive system (e.g., lack of prior knowledge), understanding features of hypermedia (e.g., coordinating and accessing multiple forms of instruction and sequencing), lack of mediation of learning processes (e.g., knowing how to plan, formulate goals and timelines, engage in meta cognitive monitoring to understand topics and content, and using effective strategies). Numerous studies have pointed to the lack of preparation or skill sets that learners need to be successful with this new learning delivery method. Azevedo, Cromley, and Seibert's (2004) study provided additional evidence that inferior learning occurs for some students due to the lack of self-regulated learning of key concepts.

With all the advantages of utilizing multiple-channel technologies in hybrid media and course content delivered through online course management systems, hypertext and hypermedia also present roadblocks for a student-centered user. The hyper environment notably causes navigation issues due to the large extensive layers and options (Chen, 2002; Johnson & Aragon, 2003). Furthermore, "drilling down" (i.e., the act of navigating through multiple layers of content) with a poor design of "bread crumb" trails leaves students disoriented from a geocentric stand point. Scaffolding in the form of course structure, whether graphical or textual in nature, act as a mapping system for students to navigate and map their way through vast amounts of information (Johnson & Aragon, 2003). If properly constructed, these mapping organizers can also contain hypertext or hypermedia links to connect content, repositories of information, or even site maps (i.e., used as mapping organizers on web sites).

Multiple-channel technology training tools provide a vast array of tantalizing visual, auditory, and haptic sensory appeal and are becoming more affordable (Ausburn & Ausburn, 2008; Dotterer, 2010a, Dotterer & Washburn, 2009) and a viable and effective means to train in technical and medical fields. Multiple-channel modalities are integrated technological components used as media (e.g., virtual reality, augmented reality, pedagogical agents, virtual worlds/environments, simulators) for providing realistic sensory experiences (Ausburn, Martens, Dotterer, & Calhoun, 2009) and are constructed using rudimentary audio, visual, and kinesthetic multimedia elements. Until recently, educational delivery methods have not strayed far from the basic auditory, visual, or kinesthetic instruction. However, with recent technology developments, the integration of instructional content with online virtual environments has formed new hybrid media that are affordable, workable, and feasible and are currently under examination as to their effectiveness.

Auditory Modalities

Oral instruction (i.e., speech) was one of the earliest delivery methods along with textual-based materials used in education and communication (Barron, 2004). Auditory media are found in much instructional content and can be broken down into three elements: speech, sound effects, and music (Barron, 2004; Beccue et al., 2001; Mayer, 2002). Through these elements, audio modalities can be used to inform and motivate students from an instructional design perspective and have become an integral part of multimedia and online hybrid media (Barron, 2004; Johnson & Aragon, 2003).

Mayer (2002) and Szabo (2002) defined verbal modes as instruction based on spoken words (i.e., narration, lectures, discussion) and printed text. Printed text includes textual-based documentation, on-screen text, or content within a textbook. For the purpose of this research, verbal mode will refer to audio modalities and to printed text. Verbal media can provide stand-alone instruction, play a support role to other cues (i.e., dual mode), or provide redundant information to textual, visual, or kinesthetic movement.

Verbal cues can be presented in a temporal contiguity form (i.e., concurrent or non-concurrent), a contextual form (i.e., related or unrelated), or as an enhancement (Aarntzen, 1993; Szabo, 2002).

The research literature has noted several appropriate uses of verbal media, including adult literacy, early childhood education and reading, learning a second language, study of music, using sound effects (i.e., heartbeats, sonar signal), and audio stream feeds for distance learning in remote areas (Beccue et al., 2001; Rehaag & Szabo, 1995). When discussing the advantages of verbal media, one of the most significant uses has been shown to be the interaction between user and computer. Individuals with disabilities (i.e., visual and motor skill impairment) are able to utilize verbal media assistive technologies. These technologies include screen reader software that converts web-based code to audible narration or describes imagery using HTML tags and Braille readers that utilize a special keyboard that produces Braille code to the finger tips of an individual (Aarntzen, 1993). More recently, advancements in speech recognition software, web 2.0 tools, interactive intelligent agent software, wearable computers, virtual reality, PDAs, and IPad devices can make readable and audible interactive interfaces for users (Sycara, Giampapa, Langley, & Paolucci, 2003).

Barron (2004) listed three specific instructional activities well suited for the integration of the audio medium: (1) Adding audio to assessments meets the need for non-readers, visually impaired, and can be used to test listening skills; (2) Audio can provide mainstream instruction as a narrative; and (3) Audio can be used to provide feedback and prompts within multimedia and online instructional content. Audio modalities can also be fused with other modalities such as visual media to form a formidable combination when applied to multimedia and hybrid designs. In the following combination modes, an assumption by Barron (2004) makes clear that the listed hybrid media contain only static imagery and animated graphics: (1) full text mirrored by redundant audio, (2) full text integrated with audio highlights, and (3) partial text with full audio integrated. Barron also included two other combinations: stand alone audio and stand alone text (to be discussed later). Several researchers have pointed out that when hybrid media are designed and used within instructional content, best practices and processes should be taken into account. Redundant narration and textual material should be presented non-concurrently, especially in time-limited pace instruction (Kalyuga et al., 2004; Severin, 1967) because vision dominates hearing in the cognitive domain (Aarntzen, 1993). However, both audio and print combinations have been shown to be more effective than either mode alone (Kalyuga et al., 1999; Mayer, 2002). Researchers have also mentioned that extended sections of text should be chunked into segmented portions that include line breaks for a more effective design practice. Looking at audio and print as two separate media, audio has advantages over print because monotonous repetition of reading words can be broken up by adding intonation, pacing, sequence, and phrasing. However, Aarntzen, (1993) and Beccue et al., (2001) disagreed and maintained that printed text is the most proficient medium for conveying verbal information. Some researchers have asserted that visual information is more advantageous than auditory information (i.e., transient in nature) due to STM lapses because auditory information is difficult to retrieve once heard unless controls are provided to allow individuals to replay the audio component (Aarntzen, 1993; Kalyuga et al., 1999). At this time, it is impossible to find any guidelines that would aid in the development of adding verbal modes into instructional design (Barron, 2004). Empirical research conducted in the area of audio and visual media are quite scarce (Barron, 2004; Donovick, 2001; Lai, 2000; Solomon, 2004). Most available research is extensive reviews of literature with little or no data to validate how effectively audio contributes to education (Moreno & Mayer, 2000; Rehaag & Szabo, 1995). Figure 12 illustrates the history of audio technology dating back to the 1850s through 2010. Research throughout this timeline is extensive and has examined audio or sound, but more specifically has been studies conducted in film and television.

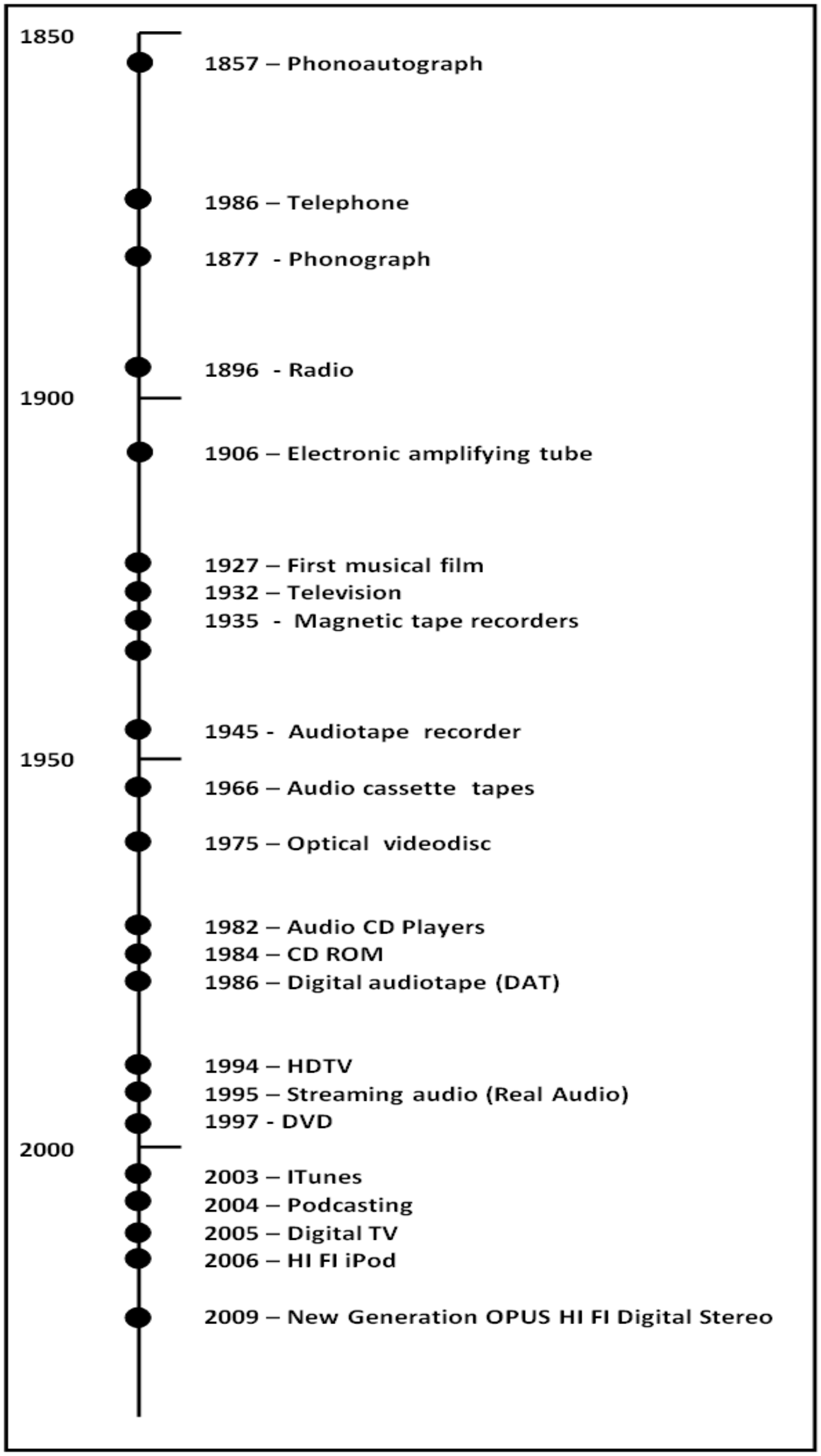

Figure 12. Illustration of the History of Audio Technology by Barron (2004). Adapted from "Audio Instruction" by A. E. Barron, 2004. In: Jonassen DH, ed. *Handbook of Research on Educational Communications and Technology*. 2nd ed. Mahwah NJ: Lawrence Erlbaum Associates, Inc. p. 950.

Allen (1956) noted the most ambitious audio research undertaking was Hoban and van Ormer's research conducted from 1918-1950 with instructional film. Although notable research has been conducted since the 1950s, for the purpose of this study, discussion will be limited to research conducted from the mid 1990s to date.

Rehaag and Szabo (1995) conducted research examining the effects of redundant audio added to computer-based instruction measured by achievement tests; they found no significant difference when compared to a textual based on-screen version. Mentioned above, Kalyuga et al., (1999) examined the redundant instructional design and found that an audio-text group outperformed a visual plus audio-text group.

Beccue et al. (2001) examined the effects of adding audio to a computer-based training multimedia presentation measured by gains in a pre-test/post-test design. The multimedia presentation contained text, static graphics, and animated imagery. Eighty subjects were divided into two groups receiving one of two treatments: (1) the multimedia presentation and (2) the same presentation with the addition of audio. The researchers reported that there were no significant differences in performance between the two treatment groups.

Tabbers (2002) also studied the effects of adding audio. He randomly assigned 111 subjects to one of 4 treatments: group one VN (i.e., visual text, no cues in diagram); group two VC (i.e., visual text, cues in the diagram); group three AN (i.e., audio, no cues in the diagram); and group four AC (i.e., audio, cues in the diagram). Tabbers' study further examined the effects of verbal information when presented in an audio format in contrast to visual media measured by retention and transfer tests. This study was to add plausibility and increase the generalizability of both Mayer's and Sweller's empirical studies on the modality effect. Tabber found that replacing on-screen text with an audio format was only beneficial when the instructional design was paced by a linear design. If subjects were allowed to proceed at their pace, results showed no difference between treatments. Tabber went on to recommend that if the pace is set by the multimedia and not by the student, only then should designers consider using narration within an instructional design. Although verbal modes of instruction have had mixed reviews, visual modes are included as a broad spectrum of media found within multimedia formats and hybrid mediums. Research on these media has also yielded mixed results.

Static and Dynamic Imagery

In the scope of this research, non-verbal modalities refer to visual stimuli in the form of pictures, sounds, tastes, and mental representations. Twenty-first century technologies in the form of visual media - whether they are used in print such as visual displays or through other media such as: imagery, animation, or even video - are now enhanced and more detailed in composition and can be delivered through high-definition (HD) signals or 3D representations. Inclusion of digitized modalities that are integrated into instructional design can combine visual appeal, texture, surface shape, and subsurface hidden features (Chen, Wactlar, Wang, & Kiernan, 2005). Instructional design content can include static graphics (e.g., photographs, figures, symbols, illustrations, and charts) and dynamic graphics (e.g., animation, video, simulations, virtual reality, games, and virtual worlds) and also sound segments (Dotterer, 2010a; Mayer, 2000). If utilized properly, advanced visual stimuli should be incorporated into instructional design content, which adds more realism or real world learning environments and tasks that foster meaningful learning (Chen et al., 2005; Johnson & Aragon, 2003; Michas & Berry, 2000; Tu, 2005; Vass, 2008). However, Tversky, Morrison, and Betrancourt (2002) concluded that animations should lean toward schematics in contrast to realistic. These media are finding their way into instructional content. Some designers and educators have added these elements for pure aesthetics and eye appeal without taking into account best practices and processes related to learning (Weiss et al., 2002). However, research has shown that complex assembly tasks, procedural /declarative knowledge, or problem solving knowledge benefit from static or dynamic imagery (Brunye et al., 2007). According to Wiener (1991), using a combination of both verbal and non-verbal modalities would be superior to just a visual presentation for those with impairments. Adding both modalities together can assist those who may be unable to tap into either of the modes separately.

Visual representation has a long history in human history and education. In 1994, animal paintings, engravings and drawings (i.e., static imagery) were discovered in Chauvet Cave in France dating back some 35,000 years (Clottes, 2001; Cutting & Massironi, 1998). Traditional educational practices relied on oral media in early education but this changed. Smith and Elifson (1986) compared history books from the 1960s with those in the 1980s and found a huge increase in the amount of supportive illustrations. Levin (1982) introduced five functions of imagery when supporting textual statements: decorational, representational, organizational, interpretational, and transformational. Decorational pictures simply decorate the page; representational, by far most common function, mirrors all or part of the text; organizational pictures provide a structural framework (e.g., illustration map of a nature trail, or a series of procedural steps such as cardiopulmonary resuscitation); interpretational pictures support textual content that is extraneous in nature (e.g., illustrating air pressure within an air tank system); and transformational pictures help enhance meaningful learning through elements that improve a reader's recall with textual content (Carney & Levin, 2002). Levin and Mayer (1993) suggested that imagery improves learning from text-only content. They proposed the seven "Cs" of picture facilitation; concentrated (i.e., focus, gaining learner attention); compact/concise (i.e., self- explanatory), concrete (i.e., representational function), coherent (i.e., organizational function), comprehensible (i.e., interpretation function), correspondent (i.e., connecting unfamiliar text to prior knowledge), and code-able (i.e., transformational function). According to Brunye et al. (2006), representational pictures act as a repetitious element when supporting textual content and leads to memory advantages for learners.

Early animation was simply a set of multiple frames of static pictures (Hegarty, 2004; Höffler & Leutner, 2007) sequenced together using authoring software that added a timeline between each frame very similar to that of a motion picture film. According to Hegarty (2004) as the animation completes the frame-by-frame sequence the animation is no longer available to the viewer unless set up as a continual loop. This can place heavy demands on working memory if the animation is to be used later, causing a temporal contiguity issue leading to an extraneous load (Hegarty, 2004). More recent animation includes podcasts, flash files (i.e., shockwave flash movie (SWF), flash video file (FLV), and any MPEG-4 file formats. Similar to early animations, each of these newer forms of animation still uses a frame-by-frame sequencing or chunking segments (Rieber, 1990a, 1990b, 1991), but Podcasts and MPEG file formats are video-related files compressed and condensed for manageable access and smaller load times. More recent versions of animation files are embedded with user-control toolbars. Learners can play, pause, stop, fast forward, rewind and control most aspects of the animation to match their comprehension speed (Hegarty, 2004; Tversky, Morrison, & Betrancourt, 2002). As with all instructional content, gaining attention of the learner can sometimes be a daunting task. An obvious advantage of animation is the "attention grabbing" feature that can capture the user's imagination by focusing on important points (Weiss et al., 2002). For animations to be useful, the concepts should be relatively complex (Weiss et al., 2002). They are also useful when illustrating motion, trajectory, or changes occurring over time to reinforce human cognitive processing (Höffler & Leutner, 2007; Weiss et al., 2002). Animations can facilitate teaching abstract relationships (e.g., in an economic lesson explaining the relationship between a number of factory workers and units produced coming off an assembly line) or a procedure such as setting up an Electrocardiogram Machine (Dotterer, 2010a, Weiss et al., 2002). Static and dynamic imagery play a key role in multiple-channel technologies as a single format but when supportive modalities such as narrations or printed text are added, a rich deposit of research opportunities are available (Brunye et al., 2007).

Previous studies that examined multimedia used as a component in instructional designs are quite extensive, especially research conducted by Mayer and his associates. The following studies were introduced earlier in this chapter, but are listed here to generalize findings related to this specific core group of research conducted on multimedia: Mayer (2001, 2002), Mayer and Anderson (1991), Mayer and Chandler, (2001), Mayer, Dow, and Mayer, (2003), Mayer and Johnson, (2008), Mayer, Mathias, and Wetzell (2002), Mayer and Moreno (2002, 2003), Mayer, Heiser, and Lonn (2001), and Mayer and Sims (1994). All these studies examined the use of static or dynamic imagery as the primary modality with supportive narration or printed text in instructional content. They found that when multiple-channel technologies are processed in the human cognitive system, learners visualize mental model representations that promote deeper and meaningful learning. These studies also concluded that the multiple-channel modalities were more effective on performance outcomes than single modes presented alone (Brunye et al., 2007). In particular, one study noted that when on-screen text, narration, and animation were presented simultaneously, non-verbal systems were overloaded by both text and animations due to these modes competing for processing time in working memory (DaCosta & Seok, 2010; Mayer, 2002; Lohr, 2008). According to Mayer (2001), when animation and text are presented visually the non-verbal system can become overloaded, but when the text is narrated both verbal and non-verbal systems function simultaneously, eliminating capacity loads on working memory. Mayer went on to say that animations are meaningless if the learners are unable to make a connection as to the elements or action. Mayer and Anderson (1991) stated that students reading explanative illustrations linked to on-screen text performed better on problem solving transfer tests than those who were given textual words followed by images. DaCosta and Seok (2010) identified other instructional design media researched by Mayer and his associates: pedagogical agents (Moreno, 2005); virtual reality (Cobb and Frasier, 2005); games, simulations, and virtual worlds (Rieber, 2005).

Over two decades ago Rieber (1990a, 1990b) stated that technological advances in computer-based graphics, including text-based animation graphics and the use of illustrations, were not matched by corresponding scientific advances in understanding how individuals learn from both pictures and words. Rieber's more recent research stemming from Baddeley's (2000) and Mayer's (2001) studies have closed the gap on multiple-channel technologies embedded in instructional content. However, literature pointed to the grounded framework of human cognitive processing of modalities even though advanced technologies have enhanced audio and graphic capabilities. Often research comparing the effects of using static and dynamic imagery on retention and problem-solving tasks concluded that deeper learning occurred when individuals solved complex problems using animation (Mayer & Moreno, 2002). Other studies have shown mixed results (e.g., Catrambone & Seay, 2002; Höffler & Leutner, 2007; Yang, Andre, & Greenbowe, 2003). Most of the research examining non-verbal modalities originated from Baddeley and Mayer's concepts.

Hegarty, Kriz, and Cate (2003) conducted three experiments examining: (1) the effectiveness of adding static diagrams to a proceduralized instructional design, (2) comparison of an animation accompanied by commentary to a static diagram accompanied by on-screen text, and (3) comparison of comprehension following the viewing of a phase diagram to the viewing of a static and animated diagram without supporting modalities. Subjects in each experiment were classified as either high or low spatial based on performance scores of a paper folding test. Subjects in each experiment were assigned to conditional treatments: experiment one had a control, prediction, animation, and combination of all three; experiment two contained static media, a prediction plus static media, animated media, and a prediction plus animation media; and experiment three had a control, a diagram only, a three-phase diagram, and animation. The researchers found that the non-verbal modalities increased comprehension in a procedural instructional design, whether the imagery was static or animated in nature. They also found that subjects exposed to voice narration or supportive text outperformed subjects who were only exposed to a non-verbal modality. Subjects assigned the static non-verbal modality with supportive text and narration outperformed subjects given animation non-verbal modalities with supportive text and narration. Future research was suggested to include higher-quality animation due to the nature of the visual and detailed illustrations that comprised the animation used in their research.

Höffler and Leutner (2007) conducted a meta-analysis of multiple studies conducted on learner performance outcomes comparing animation to static images. Several databases were searched using keyword and descriptors criteria associated with animation, imagery, etc. Databases that contained unpublished dissertations, diploma theses, and conference proceedings were searched. Twenty-six studies were included as part of the final analysis. Studies were coded to identify variable characteristics based on several features of animation. Höffler and Leutner concluded that animations were far superior to static pictures when the motion was the key learning objective. However, Carney and Levin (2002) asserted that when decorative animation was perceived as the primary focus, animations were not superior to static images. Furthermore, it was concluded that animation was more realistic and more effective when acquiring procedural-motor skills, acquiring declarative knowledge, and during problem-solving activities.

As discussed above, researchers had mixed results as to the effects of static and dynamic imagery when examining student performance outcomes. What were not examined were effective uses of animation as it pertains to learner performance (Mayer

& Anderson, 1991; Weiss et al., 2002), although Szabo (2002) recommended the following for using static and dynamic imagery in multimedia:

> (1), Analyze the relevance of graphics/animation cues to the learning outcome and use those cues appropriately in the instructional, practice, and testing situations relative to the particular learning objectives; (2), Examine graphics/animations for these criteria: (a), sense of perspective (e.g., relative size, speed, and path of motion); (b), ability to convey the time-or motion-based aspects of animation in a single viewing; (c), alternatively provide the learner with multiple opportunities to replay the animation; (d), clarity of representation, which may be effectively enhanced by the use of text labels; (e), the desirability of showing the animation from multiple perspectives; and (g), the ability of the learner to interact with and modify the graphic/animation; (3), Seek the advice/development expertise of a graphics/animation specialist; (4), Test out prototype lessons using different graphics/animations with your target population of learners; (5), Test prototype lessons on the complete range of target delivery machines because, various machines are capable of running the animation at different speeds or drawing the graphic can give rise to different effects which can be quite different from that intended; (6), Complex animations may not be optimal for beginning learners; (7), The real contribution of animation may be in the realm of interactive graphics however, few have been constructed for general education due to the enormous complexity and expense involved; (8), Enhance the encoding power of graphics or animations by engaging the learners in the creation and use of mental imagery during instruction; (9), Enhance the decoding power of graphics or animations by using the same graphics and animations in testing situations as were used in the instruction.

Twenty-first century technologies have been evolving at a rapid pace. As the future holds new possibilities in the way individuals are able to send and receive information or even expand the need for socialization and communication on a global level, research and a more in-depth understanding of how technology impacts the future would be beneficial. As the world uses more advanced technologies through realistic virtual-learning environments, the need to integrate and blend better and more effective instructional designs with multiple modalities in education are essential. This literature review has examined and reported a broad range of research and theory related to multiple modalities and their processing in the human cognitive systems.

CHAPTER III

METHODOLOGY

Research Design

This study used a quasi-experimental research design to compare performance outcomes by learners with various learning styles using dual- and multiple-channel technologies in a proceduralized instructional design presented in a virtual learning environment (VLE). Specifically, this research compared the learning effects on learners with four learning styles as defined by the VARK questionnaire instrument on three different types of procedural treatments in a VLE. In experimental research designs, theories or hypotheses are tested by measuring relationships among variables, at least one of which is manipulated or controlled. The nature of this particular study required participants to be volunteers and to have not been previously exposed or trained in basic CPR techniques. The age requirement of the subjects was limited to between 18-55 years of age. This criterion defined and limited the population and sample and constrained the research design to quasi-experimental options. The lower limit age requirement (i.e., 18) was chosen to eliminate the need to obtain assent of the child or minor and permission of the parents instead of the consent of subject form. The upper limit age requirement (i.e., 55) was chosen to eliminate information technology (IT) road blocks. According to Kirk (2006), the technology has changed so rapidly that the *old guard* prefers a rigid approach to IT, while the younger sectors are more *cutting edge*, thus more responsive to newer technology. Telco2.0 (2009) states that Older Boomers (i.e., 55-63) only 13% of the population uses the Internet while the Younger Boomers (i.e., 45-54) usage increase to 22%. As the age of the population increases especially after those who are 45-54, Internet usage drastically decreases (Telco2.0).

Experimental research implies that at least one variable is manipulated or altered by the researcher to determine the outcomes or effects of that variation (Weirsma, 2000). It is necessary for the researcher to maintain as much control of the study as possible in order to correctly interpret the findings. This study drew upon the experimental research model as its methodological foundation. Experimental research can be divided into true experimental and quasi-experimental designs (Gay & Airasian, 2003). Given the sampling constraints of this study, the quasi-experimental model best fit based on a non-random purposive set of subjects. Creswell (2003) stated, "…quasi-experiments use control and experimental groups but do not randomly assign participants to groups" (p. 167). Another characteristic of quasi-experimental designs is non-random selection of the subjects, which introduces issues with the internal and external validity (Campbell & Stanley, 1966; Gay & Airasian, 2003; Weirsma, 2000). However, it is generally recognized that in many educational studies, random sampling of subjects and/or random assignment to treatments are just impossible (Weirsma, 2000). This was the situation in this field-based study, which resulted in the use of a quasi-experimental research design.

The quasi-experimental model for this study based on a volunteer purposive sample but randomly assigned treatments are shown in Figure 13.

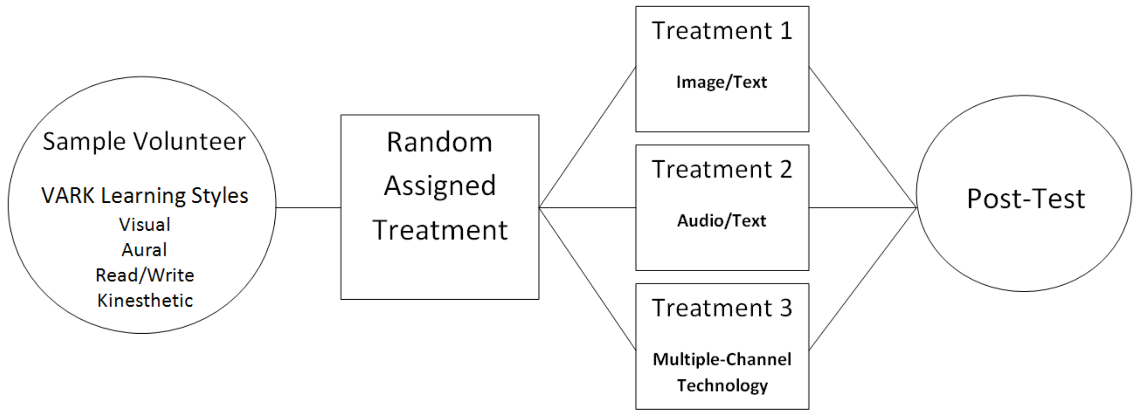

Figure 13. Quasi-Experimental Design with Purposive Volunteer Sample and Randomly Assigned Treatments.

The non-random sample for this study consisted of subjects recruited from a group of technology centers and a two-year associate-degree-granting post-secondary trade school. The subjects were restricted to a range of 18-55 years of age, and each subject could not have been previously exposed to CPR training or have taken courses related to treating individuals under cardiac arrest. The age restriction restricted the subjects to similar age groups, eliminated underage issues, and also eliminated individuals who less likely to be familiar with current multiple-channel technologies. The CPR experience restriction avoided any pre-training or pre-exposure to performing the procedure.

Volunteers were randomly assigned to one of three instructional treatments based on the Flemings and Mills (1992) Visual, Auditory, Read/Write, Kinesthetic (VARK) learning styles survey. A 12-question post-test was administered to determine performance outcomes upon completion of the assigned treatment. Thus, the research design was post-test only.

The post-test research design used in this study has been open to criticism because it provides no baseline measure of subject performance (Campbell & Stanley, 1966; Garson, 2009). Garson (2009) stated "quasi-experimental post-test only design lacks a pretest baseline or a comparison group, making it impossible to come to valid conclusions about a treatment effect because only posttest information is available" (para. 5). In this study, while a pretest was not administered, multiple experimental groups provided a comparison basis across treatments, thus overcoming one limitation of the post-test only design. Although a pretest has the advantage of setting a baseline measure, naïve subjects was felt to be critical to this study's internal validity. Subjects for this study would have been exposed to a "rehearsal" effect for both the treatment content and technology delivery media if a pretest was used, which could have affected performance outcomes. Thus, for this study, the disadvantages of a pretest would have outweighed the advantages; therefore, the post-test only design was selected to preserve the need for naïve subjects.

In the volunteer-sample, quasi-experimental design, it is generally recognized that the internal and external validity are jeopardized by the lack of random sampling. Internal validity refers to the degree to which the results of a study can be accurately interpreted, while external validity refers to the generalizability to the population based on the situations and conditions of the study (Felder & Spurlin, 2005; Gay & Airasian, 2003; Wiersma, 2000). However, as is often the case with field experiments and studies restrained by IRB requirements, in this study, the sample was volunteer rather than random. Although many researchers find themselves in this situation, the limitations of the study should be well defined, the possible non-equivalence of groups should be noted, and the generalizability should be discussed (Weirsma, 2000). These cautions have been acknowledged and are discussed in this study.

Population and Sample

A population can be defined as a set or group of all individuals of interest for a specific study (Gravetter & Wallnau, 2007; Salkind, 2008; Wiersma, 2000), and to which the results of the study are generalizable (Gay, & Airasian, 2003). A sample has been defined as a subset of a population (Salkind, 2008) and according to Gravetter and Wallnau (2007) is "a set of individuals selected from a population, usually intended to represent the population in a research study" (p. 5). Fraenkel and Wallen (2006) defined the act of sampling as "the process of selecting a number of individuals (a sample) from a population, preferably in such a way that the individuals are representative of the larger group from which they were selected" (Glossary p. G-7).

Demographic data for gender, ethnicity, and age compiled by the National Center for Educational Statistics (2008) based on students who were enrolled in career education or a two-year sub-baccalaureate degree programs are shown in Table 4-6.

Table 4

National Gender Demographics (n = 3,517,000)

	Frequency	%
Male	2,202,627	62.6
Female	1,314,373	37.4
Total	3,517,000	100.0

Note. Demographic data adapted from the National Center of Educational Statistics. (2008). *Career/Technical Education (CTE) Statistics*. Retrieved from http://nces.ed.gov/surveys/ctes/tables/P46.asp

Table 5

National Ethnicity Demographics (n = 3,528,479)

	Frequency	%
Caucasian	2,057,333	57.3
Native American	N/A	N/A
Hispanic	527,041	16.9
African American	606,378	17.5
Asian	214,008	5.8
Other	112,238	2.5
Total	3,517,000	100.0

Note. Demographic data adapted from the National Center of Educational Statistics. (2008). *Career/Technical Education (CTE) Statistics*. Retrieved from http://nces.ed.gov/surveys/ctes/tables/P46.asp

Table 6

National Age Demographics (n = 3,528,479)

	Frequency	%
Age		
18-24	1,795,327	51.1
25-34	926,238	26.3
35-55	795,436	22.6
Total	3,517,000	100.0

Note. Demographic data adapted from the National Center of Educational Statistics. (2008). *Career/Technical Education (CTE) Statistics*. Retrieved from http://nces.ed.gov/surveys/ctes/tables/P46.asp

These data were used for comparison with the study's sample. The data were drawn from career programs that were representative of the sample from this study: business and marketing, communications, computer and information sciences, engineering and architecture, manufacturing, construction, transportation, and protective services students. Due to the naïve subjects restrictions placed on sampling, health sciences students trained in CPR or having had prior knowledge of learning CPR procedures were excluded from the data.

Description of the Sample

Drawing from a population of CareerTech technology centers and a two-year associate degree trade college in Oklahoma, this study solicited samples from four large technology centers and one trade/technology college/institute. The obtained volunteer sample size was N = 284. Only volunteers from 18-55 years of age with no prior exposure to CPR were accepted as participants. Detailed information such as participation criteria, scope and nature of the study, timeline, and requirements were read to the participants during a brief solicitation and introduction at each testing location.

Descriptive statistics were collected from each subject using a questionnaire after treatments were administered. Data collected included gender, ethnicity, age, visual status, auditory status, computer skill level, and experience with virtual training programs. To describe the sample's demographics characteristics, frequency distribution descriptive analyses were performed and are reported in Tables 7 – 12. Gender demographics for this study are shown in Table 7, and ethnicity is shown in Table 8.

Table 7

Gender Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Cumulative %
Male	201	70.8	70.8
Female	83	29.2	100.0
Total	284	100.0	

Table 8

Ethnicity Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Cumulative %
Caucasian	193	68.0	68.0
Native American	59	20.8	88.7
Hispanic	7	2.5	91.2
African American	13	4.6	95.8
Asian	6	2.1	97.9
Other	3	1.0	100.0
No Response	3	1.0	
Total	284	100.0	

The frequency distributions for male and female participants were quite different in this study's sample, but are not out of line with the national gender distributions show in Table 4. Comparing the frequency distributions from Table 4 and Table 7, the gender percentages are somewhat elevated for males but are not strongly dissimilar. Participants who were ineligible to participate, due to restrictions (i.e., participants that had been trained or exposed to CPR procedures), were enrolled in health related fields or nursing.

These career fields are predominately female students, thus the elevated frequency counts for males was not illogical.

Ethnicity demographics for this study's sample indicated that the majority of subjects were Caucasian while Native Americans represented a distant second and Hispanics, African Americans, and Asians were under represented when compared to the national data reported in Table 5. However, a predominance of Caucasian students, a representation of Native Americans above national values, and under representation of African Americans, Hispanics, and Asians is typical for Career and Technical programs in Oklahoma.

Age demographics for this study's sample are shown in Table 9.

Table 9

Age Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Mean	Min	Max	Std. Dev.
Age *			23.02	18	55	7.898
18-24	218	76.7				
25-34	38	13.3				
35-55	28	10.0				
Total	284	100.0				

Note: * Age variable was grouped for comparison with the Institute of Education Sciences National Center of Educational Statistics.

The age ranges were divided into three groups to facilitate direct comparison with the National Center of Education Statistics data: 18-24, 25-34, and 35-55. Age limits were used to delimit this study's volunteers to serve several purposes. First, the subjects were from a specified age range; second, subjects at least 18 years of age eliminated underage issues (i.e., requiring parental permission), and third, upper age limits eliminated individuals who were not likely to be up to date with current multiple-channel technology. A comparison of Table 9 with Table 6 indicates the subjects in this study were younger than the national group, with a majority 76.7% in the 18-24 interval and only 10% aged 35-55.

In addition to descriptive data for gender, ethnicity, and age, four other demographic characteristics were collected and used to describe physical characteristics and computer experiences of the study's sample. These variables were felt to be important, given the nature of the technology-based characteristics of the treatments used in the study.

The visual and auditory statuses of the subjects are shown in Table 10 and 11 respectively.

Table 10

Visual Status Demographic Variable Frequencies for the Sample (n = 284)

	Frequency	%	Cumulative %
Do you have any uncorrected visual problems that you are aware of	9	3.2	3.2
Do you have any known visual problems that prevent you from seeing the computer screen well	5	1.8	4.9
Do you currently wear glasses or contact lens	124	43.7	48.6
I do not have any visual problems	146	51.4	100.0
Total	284	100.0	

Table 11

Auditory Status Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Cumulative %
Do you have any uncorrected auditory problems that you are aware of	9	3.2	3.2
Do you have any known auditory problems that prevent you from hearing audio files	3	1.1	4.2
Do you currently use any hearing assistive devices	4	1.4	5.6
I do not have any auditory problems	268	94.4	100.0
Total	284	100.0	

These participant characteristics were important because uncorrected visual or auditory impairment could negatively affect learning from the multimedia treatments used in this study. Tables 10 and 11 indicate that very few subjects reported visual or auditory problems that might have affected the findings of this study.

Subjects were also asked to report their self-assessed computer skill level based on four defined categories: (a) novice user, new to computers and have limited skills such as using the Internet; (b) fairly skilled user, can perform basic operations such as using the Internet, email, and use several different computer programs well; (c) skilled user, can use advanced features of the Internet and email, including, downloading and installing plug-ins, can use multi-media features, can install software, can use numerous programs skillfully; (d) power user, can use advanced features of the Internet and email, use advanced multi-media features, install software and learn new software frequently and easily, can install new hardware components and drivers, can tune up and optimize a computer's functioning. Table 12 shows the distribution of these computer skill levels.

Table 12

Computer Skills Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Cumulative %
Novice	12	4.2	4.2
Fairly Skilled	75	26.4	30.6
Skilled	94	33.1	63.7
Power User	103	36.3	100.0
Total	284	100.0	

Note. For definition of skill categories, see Appendix B, p. 227, question 24.

The study participants felt themselves to be relatively skilled in using computers. The majority of participants rated their computer skill level as power users or skilled users (i.e., 36.3% and 33.1% respectively). Only 4.2% considered themselves to be novice users. Thus, lack of adequate computer skills to successfully use the treatment in this study was not likely to be a limitation.

Finally, subjects were asked to report their experiences with virtual reality training programs. The results are shown in Table 13.

Table 13

Experience with Virtual Training Demographic Variable Frequencies for Sample (n = 284)

	Frequency	%	Cumulative %
Do you know what a virtual training program is	37	13.0	13.0
Know what a virtual training program is, but have never used one	101	35.6	48.6
Have used a few virtual reality training programs	91	32.0	80.6
Have used several virtual training programs	33	11.6	92.3
Have used numerous virtual training programs	22	7.7	100.0
Total	284	100.0	

Table 13 indicates that over 80% of the sample had little or no previous experience with VR training programs; less than 20% had previously experienced several or numerous

VR training programs. Thus, only a relatively small number of participants were likely to have had their performance outcomes positively affected by prior VR experience.

Instrumentation and Treatments

The study used two instruments completed by each volunteer subject: (a) the Visual, Aural, Read/Write, Kinesthetic Survey (VARK) learning styles assessment survey, and (b) a CPR cognitive test integrated with a participant demographic information sheet. The instruments were administered in the sequence as listed above. A pilot study was conducted to test the instruments and adjustments were made accordingly. This pilot study is discussed in greater detail later in this chapter.

The VARK Survey

The VARK preference of learning styles survey was developed by Neil Fleming (1995). Fleming's research of neurolinguistic programming influenced further studies examining how individuals receive information through sensory modalities and the preference by which they are used (Leite, Svinicki, & Shi, 2009). The VARK survey measures four different preferred styles of perceiving input information: visual (V), aural (A), read/write (R), and kinesthetic (K). VARK identifies preferred style by assessing the learner's preferences for learning and teaching (Fleming & Baume, 2006). The survey measures a learner's level of preference on four dichotomies, not just the one single preferred style of learning. It identifies individual information-processing strategies that are independent of personality characteristics while measuring users' social interaction strategies within their learning environment (Fleming, 2001; Fleming & Mills, 1992; Leite et al., 2001). The VARK is composed of 16 testlets of four distinct dichotomies. According to Lee, Brennan, and Frisbie (2000), testlets are defined as, "A subset of the items in a test form that is treated as a measurement unit in test construction, administration, and/or scoring” (p. 10). The unique design of the VARK instrument does not limited it to selecting only one item or the ‘best fit” which tends to narrow an individual to one learning style as mentioned in Chapter 2. The VARK instrument was chosen because individuals are profiled based on preferences of receiving and giving information. The popularity of the VARK survey comes from its simplicity, ease of use, and especially its face validity (Leite et al., 2009). A copy of the VARK presented in Appendix A. According to Leite, Svinicki, and Shi (2010) the correlated trait-correlated uniqueness (CTCU), correlated trait-correlated method (CTCM), correlated trait-uncorrelated method (CTUM), and correlated traits-correlated methods minus one (CT-C(M-1)) model were compared to evaluate the dimensionality of the VARK instrument. The estimated reliability coefficients and the preliminary support for the validity of the VARK were determined (Leite et al., 2010). Although the reliability estimates for the visual, aural, read/write, and kinesthetic subscales were .85, .82, .84, and .77 respectively, researchers should be cautious because the use and interpreted VARK scores have not had a comprehensive validation (Leite et al., 2010).

The CPR Cognitive Test and Participant Information Sheet Questionnaire

The second instrument, in the form of a questionnaire, was used to collect two specific sets of data: (a) the American Heart Association’s CPR cognitive test, and (b) a participant information sheet. This combination performance and learner characteristics instrument was administered upon completion of the randomly assigned instructional treatment. The CPR cognitive test was adapted from the virtual reality simulation program offered by the American Heart Association’s online Basic Life Support (BLS) system. The cognitive test consisted of 12 multiple-choice questions that were delivered through a virtual learning environment (VLE) and used to assess an individual's ability to recall basic CPR procedures presented in an instructional treatment. Through the VLE, each subject's scores were tabulated per question and were scored accordingly. A correct answer was scored as a numerical value of one point while an incorrect answer was scored as a zero. A database containing each subject's response (i.e., whether the answer was correct or incorrect) was stored within the VLE system. Score results were electronically submitted as a back-up if data were lost within the system due to uncontrollable technical factors. The numbers of correct answers were tabulated and recorded as the subject's CPR cognitive test score. This score was used to measure learner performance based on the hypothesis test for this study.

The participant information sheet (i.e., the demographic and characteristics data) was used to collect descriptive information that was used to describe the study's sample. The data included age, gender, ethnicity, visual status, auditory status, computer skill, and experience with virtual environment training programs. These data are shown in Tables 7 – 13.

Treatments

Subjects were randomly assigned to one of three instructional treatments of the CPR content (i.e., audio-text, imagery-text, and multiple channel technologies treatment). The automated random assigning to a treatment was possible by embedding a Personal Home Page (php) syntax code, known as a shuffle array. This php syntax was integrated with other scripting code that tabulated the results from the VARK survey. Upon submission of the VARK survey, a dynamically generated web page displayed the following results: (a) a Visual learning style score, (b) an Aural learning style score, (c) a Read/Write learning style score, (d) a Kinesthetic learning style score, and (e) a hypertext link to the randomly assigned instructional treatment. The treatments are described below.

Multiple-Channel Technologies Treatment

The American Heart Association (AHA) offers a CPR online interactive training program known as the HeartCode™ BLS Part 1 (80-1470) system. The CPR certification program is comprised of two independent procedural designs: a basic cognitive portion and a hands-on component. Permission was granted by the AHA to use the online component as one of the three treatments for this study. Several modalities were integrated into this multiple-channel technologies including verbal, non-verbal, and hypermedia based interactive systems (i.e., interactive virtual reality) and were interconnected with hypertext and hypermedia links delivered in a linear proceduralized design. A hierarchical structured navigation block containing hypertext jumps allowed subjects to move around (i.e., jump to different components of the training system) within the CPR course as shown in Figure 14.

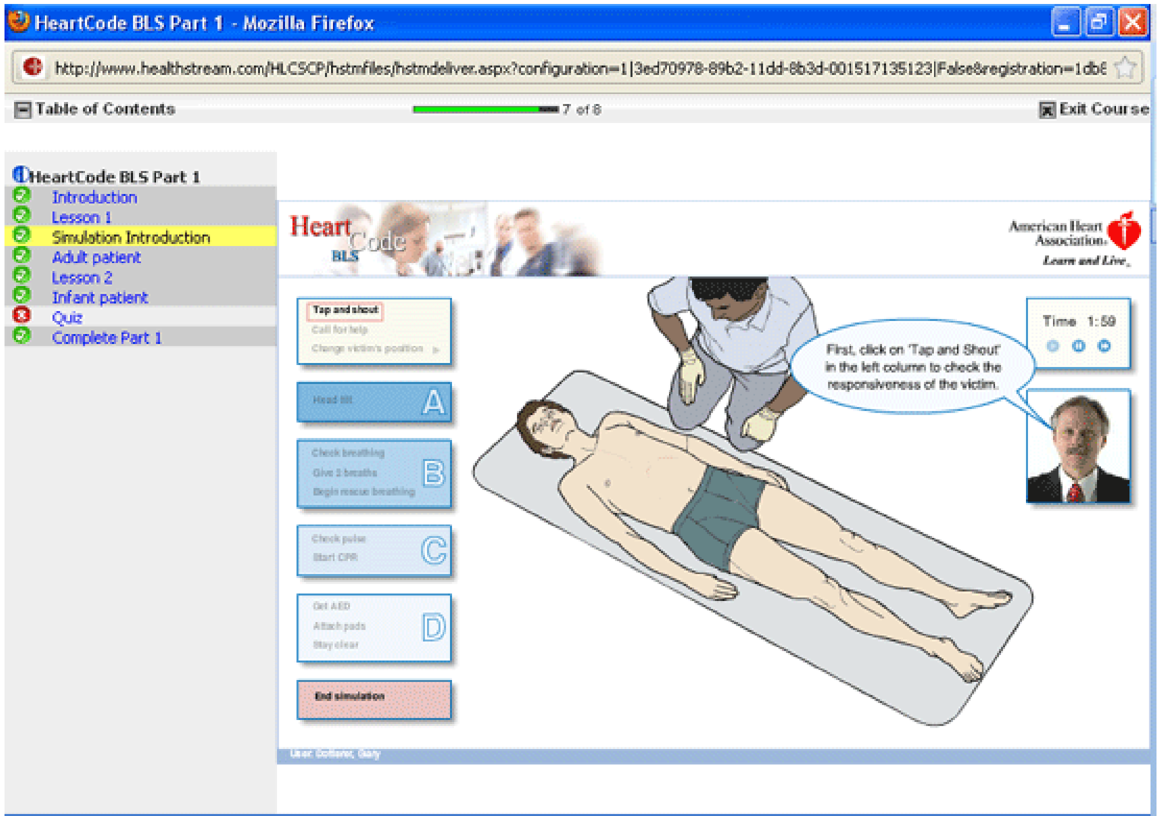

Figure 14. Screen shot of the HeartCode™ BLS Part 1 (80-1470) system used as the multiple channel technologies treatments. The American Heart Association (2011). Available at http://www.onlineaha.org

The HeartCode™ BLS Part 1 (80-1470) system content was duplicated for the other two treatments with the permission of the AHA. The sequence and proceduralized layout was duplicated in audio-text and image-text treatments.

<u>Audio-Text Treatment</u>

The audio-text treatment was constructed using two-channel modalities delivered as auditory and visual components. The auditory component was a digital audio file that had been embedded into the page containing the textual information as shown in Figure 15.

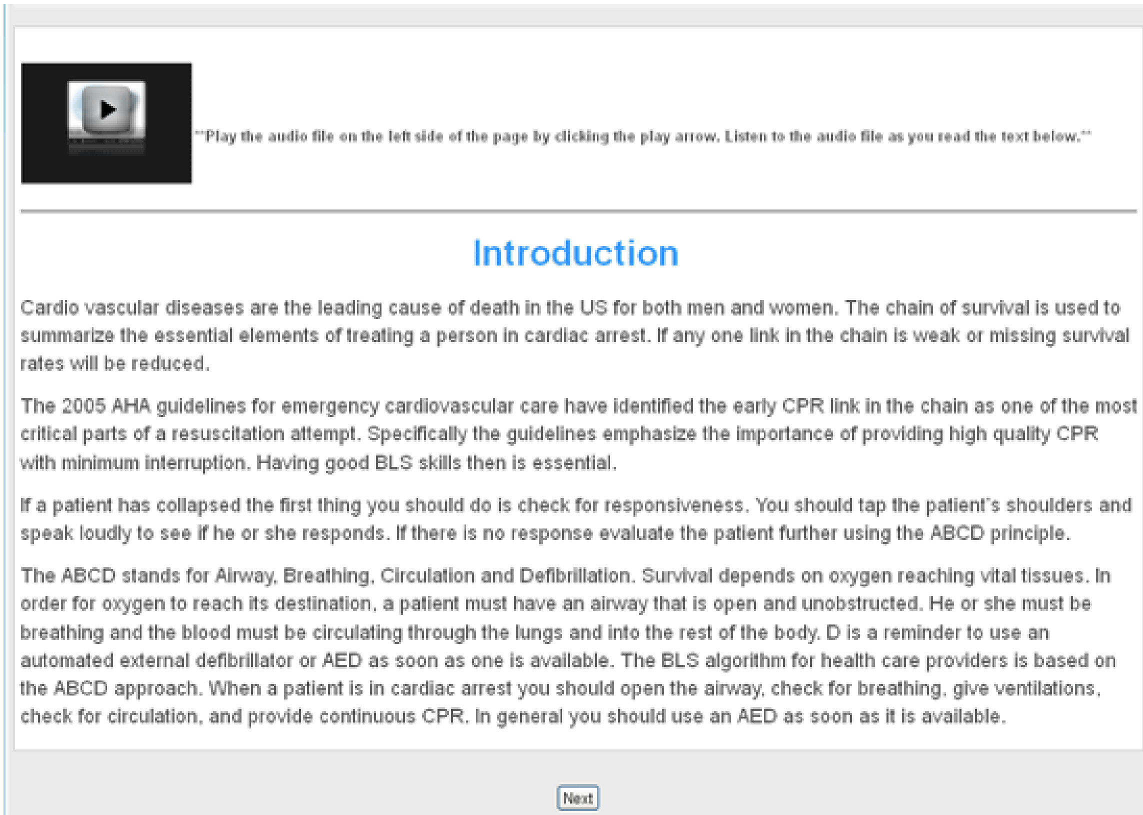

Figure 15. Screen shot of one of the audio-text treatment web pages. Available at http://www.netech.edu/mod/lesson/view.php?id=9212&pageid=91

According to Paivio's (1986) Dual Code Theory and Baddeley's (2000) Multi-Component Working Memory Model, the digital audio file (i.e., a narrated version of the text) and the printed texts are considered to be verbal modes. For the purpose of the study, the content was read (i.e., the textual print) as a narration and recorded using Camtasia 6.0 Recorder. Because the content of the audio file and the textual print are identical, according to Kalyuga et al., (1999), the modalities are considered redundant.

<u>Image-Text Treatment</u>

The image-text treatment was constructed using one channel modalities delivered as visual components. The imagery components used within the image-text treatments were embedded into the web pages using both static and dynamic image types as shown in Figure 16.

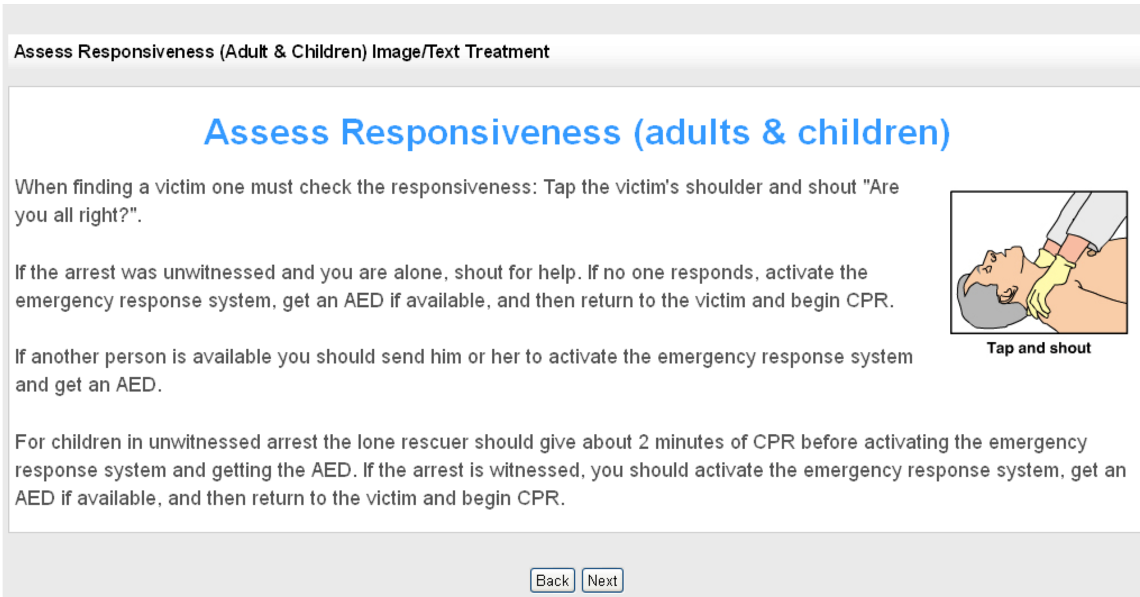

Figure 16. Screen shot of one of the image-text treatment web pages. Available at http://www.netech.edu/mod/lesson/view.php?id=9212&pageid=66

The imagery and textual based content are considered to be non-verbal modes according to Paivio's (1986) Dual Code Theory and Baddeley's (2000) Multi-Component Working Memory Model. The imagery in this treatment provides support to the printed text and was placed strategically on the web page according to Mayer and Anderson's (1992) contiguity principle.

Procedures

A formal letter was drafted and sent by electronic mail to superintendents of technology centers and to presidents of two-year sub-baccalaureate degree or career education universities and colleges in the state of Oklahoma. Permission to conduct the research was given by six campuses of four large CareerTech technology centers and one trade/technology college/institute. Meeting dates, and times were established with various administrators to visit programs and classrooms to recruit volunteers who were willing to participate in the research study.

Potential subjects met at designated times and locations and were given a brief overview of the study, requirements to volunteer, and an incentive to participate in the study in the form of a drawing to win a smart phone. Participants who completed the study submitted their randomly assigned identification number and email address for the purpose of a drawing. Those willing to participate in the study were given a flier containing the overview of the study, detailed incentive documentation, and specific instructions on how to navigate to the research website, including login and password information.

The research was administered online through a learning management system (LMS) known as Moodle. Strict controls were used according to IRB guidelines to ensure subject anonymity and confidentiality. The LMS stored all documentation, subject information, and subject data (i.e., demographics, VARK results, and CPR test scores). Volunteers who gave their consent were directed to complete the VARK survey. The participant ID and VARK scores were stored in a log file within the LMS and duplicate copies were emailed to the researcher. Subjects were randomly assigned to one of the three treatments: image/text, audio/text, or interactive multiple channel technology. Upon completing the instructional treatment, subjects were asked to complete the CPR post-test and the demographics questionnaire.

Pilot Studies

Two pilot studies were conducted with samples of 14 and 10 volunteer participants. The first pilot study was conducted to evaluate the overall processes and specific tasks required of each participant. They were asked to read through the documentation for clarity while commenting on any information that was not clear and concise. During the pilot study, the consent form, instruments, and treatments were assessed for flaws. The logical flow of the study was also tested to make sure that the study could be completed without any assistance. Upon completion of the pilot study, the 14 participants were asked to discuss their experiences during the study and to comment on any processes that were ambiguous, challenging, or areas that need to be examined further. The participants reported several problems such as misspelled words, elements out of sequential order, broken links, and confusing instructions. Various adjustments were made to the appropriate content by correcting misspelled words, unclear content, and repairing any broken links. The researcher conducted a final thorough examination and test for the flow and accessibility. A second pilot study was administered using 10 new volunteer subjects to verify that all processes, documentation, instruments, and treatments were in good working order before the actual study began. No further problems were reported.

Data Analysis

Data collected from 284 volunteer subjects were analyzed using the SPSS/PASW statistical software package version 16.0 graduate student version. A two-stage analysis approach was used in this study: (a) descriptive statistics were collected and reported as demographic data to describe the sample, (b) factorial analysis of variance (ANOVA) on post-test data was conducted to test the research hypotheses. According to Salkind (2008), a factorial ANOVA, "…tests the means of more than one independent variable" (p. 388). The independent variables were the results of the VARK learning styles and the randomly assigned instructional treatments; while the dependent variable was the post-test score from the CPR cognitive test. To operational the learning style independent variable, the highest score in one of four VARK learning styles categories (visual, aural, read/write, or kinesthetic) was determined to be the participants preferred style of learning. If two or more high scores were identical the participant was considered to have a multi-modal learning style.

Research Questions Hypothesis Data

The first null hypothesis for this study (i.e., there is no difference in the performances on a basic cognitive test of CPR procedures of learners who receive an image with text support, audio with text support, and multiple-channel proceduralized instructional presentations in an online virtual learning environment) was addressed by running a Factorial Analysis of Variance to determine main effect statistical significance among treatment groups.

The second null hypothesis for this study (i.e., there is no difference in the performance on a basic cognitive test of CPR procedures of learners having visual, aural, read/write, kinesthetic, and multi-modal learning styles in a proceduralized instructional presentation in an online virtual learning environment) was also addressed in the same Factorial Analysis of Variance to determine main effect statistical significance among learning style groups.

The third hypothesis for this study (i.e., there is no interaction of media format and learning styles on a basic cognitive test of CPR procedure in a proceduralized instructional presentation in an online virtual learning environment) was addressed by the interaction term in the Factorial Analysis of Variance to determine statistical significance of the interaction of VARK learning style by instructional treatment.

CHAPTER IV

FINDINGS

Introduction

To address the two-tailed hypotheses that guided this study, statistical analyses were conducted on: (a) one dependent variable, post-test scores from a CPR cognitive test and (b) two independent variables, randomly assigned instructional treatment and preferred learning style as measured by the VARK learning style preferences survey. Descriptive statistics, Levene's Test of Equality of Error Variance, and factorial analysis of variance (ANOVA) were used to test the independent variable normality, homogeneity of variance, and the study's null hypotheses respectively. ANOVA was chosen as the test of significance for this study because it is appropriate to "…evaluate whether or not there is a difference between at least two means in a set of data for which two or more means can be computed" (Sheskin, 2007, p. 867). The factorial ANOVA was selected to "…simultaneously evaluate the effect of two…independent variables on a dependent variable" (p. 1119). For the factorial ANOVA, the fixed-effects model was used, because it "…assumes that the levels of the independent variables are the same levels that will be employed in any attempted replication of the experiment…." (p. 944). An alpha level of .05 was used for all statistical tests.

ANOVA Assumptions

Factorial ANOVA is based on several assumptions about its data and is therefore a parametric statistic. To the extent that these assumptions are violated, the reliability of the test statistic may be compromised (Sheskin, 2007). It is first assumed that the data to be analyzed are interval/ratio and that each sample group has been randomly drawn from the sample it represents (Sheskin, 2007). For this study the first assumption was met. However, the samples were not random and this is an ANOVA assumption violation. This is a nearly universal limitation of field-based experiments that must use quasi-experimental designs to meet real-world conditions.

Other assumptions underlying factorial ANOVA include univariate normality and homoscedascity (Sheskin, 2007; UCLA Academic Technology Services, n.d.). While the assumptions about data distributions' normality and equality of variance refers to the samples' underlying populations (Sheskin, 2007), this is difficult to ascertain. However, it was possible to examine these properties in this study's dependent variable. The CPR post-test scores were examined for distributional assumptions, univariate normality, and homoscedascity using statistical tests that examined distribution normality and of equality of variance in the sample sub-sets. The normality assumption was measured and analyzed by measures of skewness and kurtosis as reported in Table 14. Visual confirmation was provided in a histogram of a frequency distribution of the post-test scores from the CPR cognitive test, shown in Figure 17.

Table 14

Descriptive Statistics, Skewness, and Kurtosis of Post-test CPR Cognitive Test (*n* =284)

Valid Cases	284.000
Missing Cases	0.000
Mean	7.366
Median	7.000
Std. Deviation	1.865
Skewness	-.172
Std. Error of Skewness	.145
Kurtosis	.099
Std. Error of Kurtosis	.288

Note: The descriptive statistics were computed based on the frequency distribution.

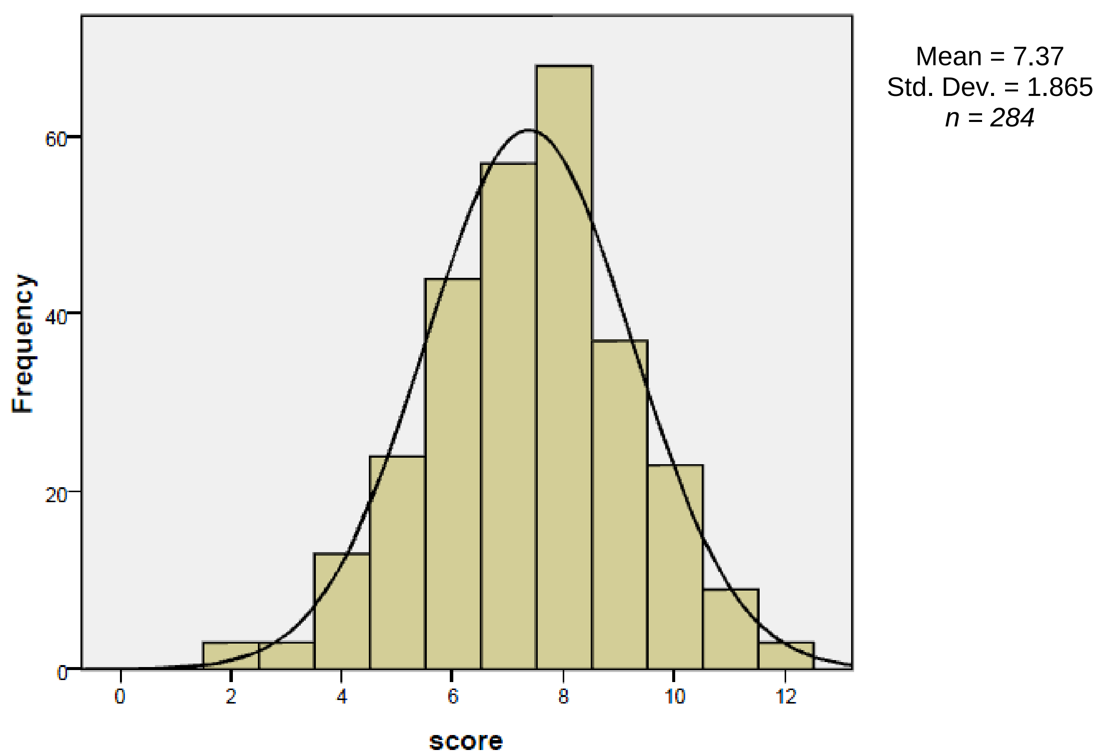

Figure 17. Frequency distribution of post-test scores from the CPR cognitive test.

The frequency distributions were plotted in a histogram illustration with an overlaying normal curve shown in Figure 17. The overlaying curve represents a typical normal bell curve shape and form for the dependent variable distribution. Distribution normality was also found in the coefficient for skewness and kurtosis. Sheskin (2007) stated that skewness and kurtosis determine "goodness of fit" of data to a specific distribution such as the normal distribution (p. 17). He defined skewness as "…reflecting the degree for which a distribution is asymmetrical" (p. 17). According to Crewson (2008), "Skewness provides an indication of how asymmetric the distribution is for a given sample...Values greater than 1 or less than -1 indicate a non-normal distribution" (p. 30). The critical value for skewness is $Sk = 0.277$ when $n = 300$ and $\alpha = 0.05$ (Petrovich, 2011). For the CPR scores, a $Sk = -0.172$ was calculated. This value fell well within the minimum and maximum limits and nears the value of zero, thus indicating the CPR scores distribution can be considered to be normal. Sheskin (2007) identified kurtosis as a measurement of the curvature or "peakedness" of a distribution, with the classic normal distribution being "mesokurtic" or moderately peaked relative to its standard deviation (p. 24). According to Petrovich (2011), "For kurtosis, if the kurtosis value is greater than or equal to the high critical value, or is less than or equal to the low critical value, reject the assumption of normality" (para. 4). The critical values for kurtosis are $K_{high} = 0.64$ and $K_{low} = -0.46$ when $n = 300$ and $\alpha = .05$ (Petrovich, 2011). The results of a kurtosis test for the CPR scores showed the kurtotic value nearing the accepted mesokurtic value of zero (Sheskin), at $K = 0.099$. Thus, a normal distribution for the post-test CPR cognitive test scores was found for both skewness and kurtosis.

A Levene's test was used to test equality of variance or homogeneity of variance in the dependent variable among the sample sub-groups, and the results are illustrated in Table 15. Differences in variances from the Levene's test were not significant ($p = .07$). While the Levene's test was not significant, it did approach significance. The reason for this was probably a considerable difference in group sizes. However, despite the sample group sizes being considerably different, the F test for homogeneity of variance did not attain significance, which allows the ANOVA homogeneity assumptions to be met.

After completing these analyses, the researcher decided to proceed with factorial ANOVA as the statistical test of significance. Two reasons informed this decision. First, data on this study's dependent variable met most of the assumptions underlying factorial ANOVA. The second reason was the "robustness" of ANOVA to violation of its assumptions. Sheskin (2007) defined a test as "robust" if it will still provide reasonably reliable information even if its assumptions are violated and declared that in most cases the choice of a parametric or non-parametric test is "…of little consequence" because when both tests are used to evaluate a data set, "…they lead to identical or similar conclusions" (pp. 108-109). Thus, the researcher saw no reason to replace the ANOVA with a non-parametric analogue.

Table 15

Levene's Test of Equality of Variances[a]

F	df1	df2	Sig.
1.651	14	269	.066

a: Tests the null hypothesis that the error variance of the dependent variable is equal across groups.

Treatment and Preferred VARK Distributions

Before proceeding to the factorial ANOVA to test the null hypotheses for this study, descriptive statistics were calculated to define the data set. Frequency tables were calculated for the three treatment groups. This showed the distribution of subjects randomly assigned to one of the three treatments: (1) audio-text, (2) image-text, and (3) multiple channel modes. The frequency distribution is shown in Table 16.

A frequency distribution was also calculated for the subjects' preferred learning style as measured by the VARK survey: (1) visual, (2) aural, (3) read/write, (4) kinesthetic, and (5) multi-modal. The distribution is shown in Table 17.

Table 16

Frequency Distribution for Treatments (*n* = 284)

Treatment	Frequency	Percent	Cumulative Percent
Audio-Text	99	34.9	34.9
Image-Text	99	34.9	69.7
Multiple Channel	86	30.3	100.0
Total	284	100.0	

Note: Treatments randomly assigned to subjects

Table 17

Frequency Distribution for Preferred VARK Styles (*n* = 284)

VARK Style	Frequency	Percent	Cumulative Percent
Visual	17	6.0	6.0
Aural	44	15.5	21.5
Read/Write	77	27.1	48.6
Kinesthetic	95	33.5	82.0
Multi Modal	51	18.0	100.0
Total	284	100.0	

Descriptive statistics were calculated for each treatment based on the CPR test post-test scores, as shown in Table 18. VARK style descriptive statistics were also calculated based on post-test scores on the CPR cognitive test, as shown in Table 19.

Table 18

Descriptive Statistics by Treatment for CPR Post-test Scores (*n* = 284)

Treatment	*n*	Mean	Median	Min	Max	SD
Audio-Text	99	7.32	7	4	10	1.596
Image-Text	99	7.23	8	2	11	1.754
Multiple Channel	86	7.57	7	2	12	2.242
Total	284					

Table 19

Descriptive Statistics by VARK Style for CPR Post-test Scores (*n* = 284)

VARK Style	*n*	Mean	Median	Min	Max	SD
Visual	17	7.59	8	3	10	1.770
Aural	44	7.48	7.50	4	12	1.691
Read/Write	77	7.18	7	2	12	1.869
Kinesthetic	95	7.34	8	2	12	1.877
Multi Modal	51	7.53	7	2	11	2.043
Total	284					

Finally, additional descriptive statistics were calculated for the dependent variable, post-test CPR cognitive test scores, as shown in Table 20.

Table 20

Descriptive Statistics for Dependent Variable, CPR Post-test Scores (n = 284)

Variable	*n*	Min	Max	Mean	SD
Test Scores	284	2	12	7.37	1.865

Note: Test scores were the post-test scores from the American Heart Association's CPR Cognitive test

After completion of descriptive statistics calculations, a factorial ANOVA was computed for the dependent variable, post-test CPR cognitive test scores, to test the study's null hypotheses. The independent variables were treatment and preferred VARK learning style. Table 21 presents the data from the factorial ANOVA using the fixed effects model. A graph illustrating five group mean scores of VARK learning styles of each treatment were attempted. The differences of VARK learning style group mean scores on treatments were not graphically significant to plot.

Table 21

Factorial Fixed Factor ANOVA for Post-Test CPR Cognitive Test Scores (*n* = 284)

Source	Type III Sum of Squares	*df*	Mean Square	*F*	*p*
Corrected Model	24.180	14	1.727	.484	.941
Intercept	8671.185	1	8671.185	2430.407	.000
Treatment	4.656	2	2.328	.652	.522
Preferred VARK	4.086	4	1.022	.286	.887
Treatment* Preferred VARK	14.223	8	1.778	.498	.857
Error	959.736	269	3.568		
Total	16394.000	284			
Corrected	983.915	283			

Note: Selected alpha level was $p = .05$
R Squared = .025 (Adjusted R Squared = -.026)

Results for Three Null Hypotheses

$H0_1$: There is no difference in the performances on a basic cognitive test of CPR procedures of learners who receive image with text support, audio with text support, and multiple-channel proceduralized instructional presentations in an online virtual learning environment.

CPR cognitive post-test scores were subjected to a factorial ANOVA having three levels of treatment (audio-text, image-text, and multiple channels). Main effect for treatment would be considered statistically significant $p = .05$ level.

The main effect for treatment yielded an F ratio of $F(2, 281) = .652$; $p = .522$, indicating that there was no main effect for treatment on post-test CPR cognitive scores. Therefore, null hypothesis one was retained.

$H0_2$: There is no difference in the performance on a basic cognitive test of CPR procedures of learners having visual, aural, read/write, kinesthetic, and multi-modal

learning styles in a proceduralized instructional presentation in an online virtual learning environment.

The factorial ANOVA had five levels of preferred VARK styles (visual, aural, read/write, kinesthetic, and multi-modal). Main effect for learning style would be considered statistically significant at the p = .05 level.

The main effect for learning styles yielded an F ratio of $F(4, 279) = .286$; p = .887, indicating that there was no main effect for preferred VARK style on post-test CPR cognitive scores. Therefore, null hypothesis two was retained.

$H0_3$: There is no interaction of media format and learning styles on a basic cognitive test of CPR procedure in a proceduralized instructional presentation in an online virtual learning environment.

There was no interaction of treatment by preferred VARK style on post-test CPR cognitive scores ($F_{7, 276}$ =.498; p=.857). Therefore, null hypothesis three was retained.

Based on R^2 = .025 and the adjusted R squared = -.026, only 3% of the variance, on the dependent measure (CPR post-test score) from the factorial ANOVA, was accounted for in this particular model. The other 97% was influenced by some other variables. Because high alpha (p) values and low F test values were reported a smaller percentage adjusted R squared value was expected.

CHAPTER V

CONSLUSIONS, DISCUSSION, AND RECOMMENDATIONS

Summary of the study

Purpose and Conceptualization

As technology and education merge in the 21^{st} century, the need to create robust and media-rich content that is accessible, interactive, and beneficial to learners is critical. One approach to meeting this need is to develop friendly and accessible virtual learning environments (VLEs). The advancements in virtual reality technology have given developers and educators an opportunity to incorporate complex modalities that capture the user's attention and promote an interest within the instructional materials (Dotterer, 2010a; Dotterer & Washburn, 2009). Multimedia, in the form of imagery, audio, video, and other interactive elements can provide extremely realistic learning experiences that promote inquiry and exploration (Ausburn et al., 2009; Tversky et al., 2002; Weiss et al., 2002). These creative forms of multimedia are becoming more popular and widespread as designers, developers, and educators transfer media-rich content to online environments.

As a learning tool, these VLEs have demonstrated themselves to be beneficial to learners by providing an engaging interactive storage repository for instructional materials (Dickey, 2005; Dougiamas, 2007; Neel, 2006; Revenaugh, 2006; Shim et al., 2003; Smedley & Higgins, 2005; Vogel et al., 2004). Although more multimedia are becoming integrated with VLEs, combining both could lead to accessibility obstructions for those with impairment. Some forms of media are not compliant with current accessibility laws due to the characteristics of the media. Adding multimedia content to VLEs would create an even more complex, challenging, and problematic set of circumstances. Although every individual must be given equal access to instructional content, there are those who have voiced skepticism towards the benefits or an accessible coexistence between these technologies for people with disabilities. However, this skepticism may not be justified, given the new advancements in technology and the ability to incorporate best practices and processes when developing instructional materials, the successful merging of multimedia content with online virtual training environments may be attainable. A need to examine this possibility was an impetus for this study.

Some theorists, educators, and instructional developers have maintained that knowing an individual's preferred style of learning is beneficial. Matching a person's learning preference to specific modalities may enhance or increase performance outcomes as well. Ausburn and Ausburn (2003) argued that past research tended to "focus on comparing instructional treatments and designs as main effects rather than on examining interactions between treatments and specific types of learners" (p. 2). In its conceptual model, this study hypothesized that the integration of multiple-channel technologies into a VLE using several proceduralized instructional designs would optimize performance-based outcomes for learners with various learning style preferences.

The purpose of this study was to examine through experimental research methodology the effects of multiple-channel technologies and learning styles on learning performance in an online VLE with a proceduralized learning task. There are few studies on the effects of learning style preferences when matched with specific delivery methods (Kahn, 2007; Krichen, 2007; Ritschel-Trifilo, 2009). However, Akdemir and Koszalka's (2004) and Aragon, Johnson, and Shaik's (2002) studies found learning style preferences when matched with delivery method strategies, produced no significant difference in learning performance outcomes. Data for this study contributed to the knowledge base for learning styles when matched with delivery methods in a proceduralized instructional design in a virtual learning environment. The following null hypotheses were developed to guide this study:

> $H0_1$: There is no difference in the performances on a basic cognitive test of CPR procedures of learners who receive image with text support, audio with text support, and multiple-channel proceduralized instructional presentations in an online virtual learning environment.
>
> $H0_2$: There is no difference in the performance on a basic cognitive test of CPR procedures of learners having visual, aural, read/write, kinesthetic, and multi-modal learning styles in a proceduralized instructional presentation in an online virtual learning environment.
>
> $H0_3$: There is no interaction of media format and learning styles on a basic cognitive test of CPR procedure in a proceduralized instructional presentation in an online virtual learning environment.

<u>Research Design and Data Analysis</u>

This study used a post-test only quasi-experimental design. Drawing from a population of CareerTech technology centers and a two-year associate degree trade college in Oklahoma, this study solicited samples from four technology center districts and one trade-college located in NE Oklahoma. Volunteer participants (*n* = 284) completed the VARK learning style preference survey and based on the highest score were classified into one of five preferred learning style categories; (1) visual, (2) aural, (3) read/write, (4) kinesthetic, and (5) multi-modal (i.e. two or more equal scores) as shown in Appendix A. Upon completion of the survey, subjects were randomly assigned into one of three treatments in which various multimedia components were integrated in an online virtual environment: (1) audio-text, (2) image-text, and (3) multiple-channel technologies (i.e. video with closed caption, audio, imagery, textual, and interactive virtual reality). Participants were administered a 25-question fill-in-the-blank and multiple-choice questionnaire shown in Appendix B. Thirteen questions were related to demographics data while the remaining 12 questions made up the cognitive CPR post-test. Upon participants' completion of the data collection process, individual VARK learning style preference survey results and CPR cognitive test scores were electronically tabulated through .php script and Moodle's questionnaire module respectively. The data were exported, organized, and digitally stored as a comma separated file (CSV) (i.e., a Microsoft Office Excel file type). The data were transferred into SPSS/PASW version 16.0 graduate student version for analysis. The dependent variable analyzed was the CPR cognitive test score. The two independent variables were (1) VARK learning style preference and (2) treatment type. The data analysis was quantitative in nature using descriptive statistics, Levene's Test of Equality of Error Variance, and a Factorial Analysis of Variance (ANOVA). These procedures were used to test normality, homogeneity of variance, and the research hypotheses respectively.

<u>Findings</u>

The three null hypotheses were accepted for this study and the two-tailed alternate hypotheses were rejected. Findings reported for the three null hypotheses indicated that:

(1) there was no main effect for the three treatments of audio-text, image-text, and multiple-channel technologies on CPR cognitive test scores; (2) there was no main effect for preferred VARK learning styles of visual, aural, read/write, kinesthetic, and multi-modal on CPR cognitive test scores; and (3) there was no interaction between the three treatments and the five VARK learning style preferences.

Conclusions

While this study did yield significant results, the "significance of non-significance" phenomenon was important in the study's findings. Almost nothing is known at this time about what instructional and learner variables affect learning outcomes when new multimedia assistive technologies are used in complex learning environments. At this point in the research history of these technologies, information about variables are *not* relevant contributes to the body of knowledge as information about what *is* relevant. Several conclusions can be drawn from the findings of the study.

$H0_1$: Effect of Treatment on CPR Cognitive Test Scores

Conclusion #1: Multimedia components can be used effectively regardless of the specific combination of media.

The mean scores on the 12-item CPR post-test for the audio-text treatment (n = 99; *M* = 7.23; SD = 1.754), the image-text treatment (n = 99; *M* = 7.23; SD = 1.754), and the multiple-channel technology treatment (n = 86; *M* = 7.57; SD = 2.242) were really identical (not significantly different) and relatively high. This suggests that all three multimedia combinations were very similar in their relatively positive effects on learning in a virtual environment. The magnitude of the three means also suggests that none of the three multimedia combinations produced extremely strong learning performances. Thus, some other variable may influence performance in virtual environments with multimedia components add, but it is probably not the nature and complexity of the multimedia combinations.

Conclusion #2: The design of multimedia components may be more important than the specific media combination or its complexity.

Conclusion #3: Multimedia components should be designed according to "best practices" multimedia principles.

As discussed in the theoretical/conceptual framework, there are opposing views when environmental stimuli or cues are processed through the human cognitive system. However, the research literature has shown that multimedia instructional design materials that have been designed according to best practices and processes "multimedia principles", increase learning performance outcomes (Brunye et al., 2007; DaCosta & Seok, 2010; Harskamp et al., 2007; Mayer, 2002). All multimedia components used in this study were designed by applying specific principles, and all were found to be relatively effective.

The audio-text treatment content was redundant and was constructed using audio narrative with supportive text. This design was constructed based on implementing the redundancy principle (DaCosta & Seok, 2010; Kaiser, 2004, 2005; Kalyuga et al., 1999; Kalyuga et al., 2004; Mayer & Johnson, 2008) discussed earlier in Chapter 2.

The image-text treatment was comprised of static, dynamic animation, or a combination of both supported with complimentary text. Following design guidelines in accordance to the contiguity principle (Brunye et al., 2007; DaCosta & Seok, 2010;

Donovick, 2001; Lohr, 2008; Mayer, 2005c; Moreno & Mayer, 1999), the placement of the image relative to the text were both spatial and temporal in nature.

The multiple-channel technology treatment used several multimedia components such as interactive virtual reality, video with closed caption, imagery (i.e. static and dynamic animation), audio, and text-based information. The multimedia elements delivered through a virtual learning environment and were combined producing a visual, aural, and kinesthetic interactive instructional content as described in the modality principle. Implementing the modality principle, learning is maximized when information is presented in both visual and auditory channels simultaneously (Clark et al., 2006; DaCosta & Seok, 2010 Low & Sweller, 2005).

Conclusion #4: Multi-modality presentations may be more effective than single modality for teaching procedures.

The research literature offers both theoretical and empirical support for two opposing views of modalities in designing instruction: Single channel and dual channel. Some theorists have warned that too much information presented simultaneously in more than one modality can cause a cognitive load (Broadbent, 1958; Burton et al., 1995; Moore et al., 1996; Sweller, 2005b), while others agree that multiple delivery methods lead to performance gains when processed by the verbal and non-verbal memory components (Baddeley, 2003; Mayer, 2005b; Paivio, 2006, 2007; Severin, 1968). In a pilot for this study, Dotterer (2010a) found that single-mode proceduralized instructional content *hindered* performance outcomes when compared to multiple-modality designs. Therefore, for this study, supported by research literature and the pilot findings, the treatments were constructed using two or more delivery methods based on Dotterer's

(2010b) recommendations and the theoretical underpinnings that guided this study. All multi-modal treatments were effective in this study as they were in the pilot study. Taken together, the results of the pilot and the present study lend support to the dual channel theory of information processing.

$H0_2$: Effect of VARK learning style preferences on CPR cognitive test scores

Conclusion #5: Learning styles as conceptualized and defined by VARK are not relevant in a virtual environment.

The research literature shows that the VARK learning style preference survey instrument classifies a learner's preference based on choices and decisions as to how the individual prefers to receive and send information (Fleming & Mills, 1992). According to Dunn (2003), knowing an individual's preferred learning style helps increase performance outcomes. However, others oppose this view; Mathews (2010) pointed out there are growing debates about the benefits of knowing one's learning style preferences based on lack of any empirical data supporting claims of increased performance outcomes.

In this study, means on the CPR post-test were very similar (not significantly different) and relatively high for all VARK learning style groups: (1) visual learning preference (M = 7.59, SD = 1.770), (2) aural learning preference (M = 7.48, SD = 1.691), (3) read/write learning preference (M = 7.18, SD = 1.869), (4) kinesthetic learning preference (M = 7.34, SD = 1.877), and (5) multi-modal learning preference (M = 7.53, SD = 2.043). This finding suggests that the VARL learning styles are not a relevant learner variable in researching sources of performance variance in multimedia environments. While it would be premature to conclude that learning styles in general are irrelevant as argued by Mathews (2010), it is appropriate to conclude that learning styles as defined by VARK are not relevant in the context of multimedia virtual environments.

$H0_3$: Interaction between treatment and learning style.

Conclusion #6: Multimedia elements do not interact with learning styles as defined by VARK to produce differentiated learning outcomes of a procedure.

The research literature reported opposing views on benefits of learning styles matched to instructional methods. There are those who support the claim that performance outcomes are increased when learning styles are matched with respective delivery methods (Nolting, 2002; Sprenger, 2003; Tie & Umar, 2020; Zywno & Waalen, 2002). On the other hand, those who oppose this claim assert that learning styles are a myth and reports of increased performance gains are based on no empirical evidence to support these claims (Coffield, 2004; Dembo & Howard, 2007; Henry, 2007; Stossell, 2006; Szabo, 2002). ANOVA results of no significant interaction between treatment and learning style, in this study supports the "opposition" view in the specified context of learning styles as defined by VARK and multimedia in virtual environments.

Discussion

Several points of discussion arise from the study. This discussion covers several key areas that were influential in regard to the study's research and treatment designs. The study's line of inquiry was established through a relationship between previous studies' recommendations, historical theoretical framework, modern conceptual theories, and best practices and process principles.

Determining Constructs for This Study

A prior study conducted by the researcher (Dotterer, 2010a, 2010b) examined the effects of four treatments on learner performances in a proceduralized instructional design within virtual learning environments (VLEs). Two of the treatments were delivered in single modalities: text-only and image-only. The third treatment, multiple channel technologies (i.e., desktop virtual reality with assistive technologies) was constructed using audio and video multimedia components combined with closed captioning and virtual reality. The final treatment, hands-on instructional design, served as a control treatment or base to compare performance outcomes with the media treatments. With no experience with the procedure, or prior knowledge, the novice learners were unable to rely on prior understanding or schema recalled from long-term memory.

Results from that study showed that there were significant differences in performance outcomes of subjects administered the multiple-channel treatment compared to the single mode text-only treatment on a post-test demonstration proceduralized test. There were no differences on image-only treatment scores. Dotterer (2010b) concluded that subjects receiving the text-only treatment had difficulty performing the proceduralized task based on their demonstration scores. The results supported multi-modal theories of instructional design to increase overall learning performances.

Subjects administered the hands-on control treatment outperformed subjects given the multiple channel technologies treatment. Dotterer (2010b) concluded that the subjects experienced extraneous cognitive load due to navigational and orientation issues within the virtual reality environment and the loss of egocentricity. Although the results showed no differences between the multiple-channel technology and image-only treatments, the assumption that alternative text (i.e., supportive text coded to imagery read by assistive technology devices) provided the necessary scaffolding.

Dotterer (2010b) recommended that future research examine the effects on performance test scores when instructional content was delivered in a virtual learning environment by reducing the extraneous cognitive load. It was recommended to eliminate the navigational and orientation cognitive load factors that hindered performance outcomes. This recommendation was implemented in the present study.

Dotterer (2010b) also recommended following best practice and process principles when designing proceduralized instructional materials. For the present study, an approach to inquiry was established based on traditional theories while incorporating multimedia design principles based on modern concepts such as the modality and redundancy principle.

The Modality Principle

According to the modality principle, information shared across verbal and non-verbal working memory components limit cognitive load (DaCosta & Seok, 2010; Low & Sweller, 2005; Moreno, 2006; Rummer et al., 2011). The instructional content within each treatment in the present study was presented using two or more delivery methods. Content between treatments was inter-changed by replacing text-based instruction with narrative verbal modalities, and non-verbal modalities were substituted with video, imagery, or animation (DaCosta & Seok, 2010; Rummer et al., 2011). According to the literature, new information presented to novice learners or those with a limited knowledge benefit from content delivered as an auditory narrative (Clark et al., 2006). Based on the results of the present study, subjects administered audio-text content scored slightly higher on learning test scores than those given the image-text treatment. The results of the study and research literature both support the modality principle when novice learners are presented new information.

The Redundancy Principle

The redundancy principle proposed that two or more types of instructional content, containing redundant material, were available for learners to choose the best presentation mode suited for their particular learning style (Mayer, 2002). Additional modalities increase performance outcomes (DaCosta & Seok, 2010; Kaiser, 2004, 2005), but adding redundant information could cause an extraneous load on working memory (van Merrienboer & Ayers, 2005). In the present study, the audio-text and multiple-channel treatments contained redundant content, while the image-text treatment only contained supporting imagery with text. The post-test CPR scores were slightly elevated for those administered the audio-text and multiple-channel treatments over those receiving the image-text treatment. Although the research literature cited conflicting views as to performance outcomes, the results from this study reported increase performance outcomes, supporting the redundant principle.

Implications of the Study

General Implications

New technology has directly affected how education, businesses, services, information, and communication are conducted on a global scale. The ability to integrate innovative technology into viable learning strategies is beneficial and promising. However, adopting technology into current practices and processes without clearly identifying benefits may lead to little or no advantages and could become quite costly. Within the field of education, integrating media-rich content into instructional designs without evidence that contribute to the literature base could be detrimental and waste valuable time and resources. This study added to the knowledge base of instructional content delivered through virtual environments for educators and designers. By studying the effects on performance outcomes when individual's learning style preferences are matched with respective multiple-channel technologies, the benefits to educators and designers can effectively incorporate best practices and processes that can be carried over into other educational domains. The results of this study showed no main effect by treatment or VARK learning style preferences, but various instructional design principles proved to be advantageous in regard to limiting cognitive load based on the performance test scores. The overall general implications of this study recommend further research within specific areas outlined later in the chapter. The study also had implications for research in the benefits of learning styles as on important variable in instructional design research.

Implications for Career and Technical Education

Career and technical educators have used a multitude of platforms and software to deliver instructional content and to train individuals in skilled areas. Although various forms of multimedia have been used in the classroom for many years, the combination of both media-rich content and virtual learning environments are relatively new. Educators and instructional designers use virtual learning environments as a storage device to house instructional content, deliver assessment tools, and display various imagery and videos, but educators have not fully utilized the potential of these environments when training or providing specialized skill training. The advancements in technology, especially derivatives of virtual reality and simulation training components, provide real-time and realistic environments, which are beneficial to educators and the student faced with budgetary constraints, confined areas, or dangerous occupational hazards. As educators and instructional designers rely heavily on these advanced technologies, knowing the benefits in regard to performance gains or increased skill sets are key to utilizing these technologies. Although the results of this study revealed no main effect for media treatments or VARK learning styles and no interaction between these variable, the "significance of non-significance" was the impact of this study. What was found not to be true was highly revealing. Thus, a line of inquiry on learning style preferences matched with respective modalities should continue.

Implications in Business and Commercial Training

As stated earlier, advancements in technology have opened doorways to exciting, new opportunities and innovative practices that incorporate media-rich content. Business, industry, or corporate trainers are able to train and educate workers new skill sets or enhance professional development opportunities. According to Friedman (2006), the flattened world requires bridging the gap between continents with technology and the Internet. Globalization has forced a paradigm shift in the way companies conduct business, exchange goods and services, and educate individuals with new tools of collaboration (Dotterer & Washburn, 2009). These training tools use multimedia in various forms to train, educate, and provide professional development on a global scale. Effectively integrating instructional content using these medias in a virtual learning environment would benefit business and commercial industries by decreasing travel expenses and training costs while eliminating time and location constraints.

Implications Theoretical

The implications of this studies theoretical framework support multiple channel modalities over information presented in a single channel. In a previous study Dotterer (2010a, 2010b), examined the effects on performance outcomes based on single-channel and multiple-channel modalities. Two single channel treatments (i.e., text-only and image only), multiple-channel treatment, and control treatment group were instructed on a proceduralized instruction. The results of the study concluded that the multiple-channel group outperformed a single-channel group on demonstration post-test scores (Dotterer, 2010b). The results of that study were used to formulate the theoretical framework of this study. Broadbent's (1958) Single Channel Theory and Severin's (1968) Cue Summation Principle of Learning Theory were considered negative and positive influences for this study respectively. It was recommended by Dotterer (2010b) to further examine Sweller, Van Merrienboer, and Paas's (1998) Cognitive Load Theory when using multiple-channel technologies combined with assistive technologies in virtual learning environments in a proceduralized content design. Using the modality and redundancy principles in the design of multimedia instructional content, the implications of these practices benefit learners by limiting extraneous load.

Recommendations

Recommendations for Further Research on Learning Style Preferences

Additional research is needed to examine the effects on performance outcomes when multiple-channel technologies are matched with an individual's preferred learning styles in a proceduralized instructional design. When discussing learning style preferences, this study used the VARK learning style preference survey to identify and classify how individuals prefer to send and receive information. The five classifications of this survey recognize visual, aural, read/write, kinesthetic, and multi-modal preferences. Based on the results from this study, it is recommended that other learning style assessment tools based on different constructs be used to study the effects of learning styles in multimedia learning. This would help to advance the knowledge base related to learning styles and their effects on performance outcomes. Using multiple learning style assessment tools simultaneously might be advantageous in identifying relevant styles with a minimum number of studies.

Recommendations for Further Research on Individual Differences

Future research needs to examine a broader range of individual differences as defined by Jonassen and Grabowski (1993) as illustrated in Table 2. Individual differences were comprised of numerous categories and subcategories identifying elements and characteristics of how individuals' best learn taking into account cognitive controls, cognitive styles, learning styles, and personality traits that encompass a variety of learner characteristics. This recommendation would broaden the research base that would be beneficial not only to educators and designers but to all individual learners on a global scale.

Recommendations for Further Research on Multiple-Channel Technology

Further research is recommended examining performance outcomes when multiple-channel technologies are used to deliver instructional content and integrated into online virtual learning environments. As new advancements in technology are discovered, research examining the benefits to education should remain current and up to date. As mentioned in Chapter 2, research is currently trailing in regard to how effective and beneficial new technologies are in regard to performance gains for learners.

Recommendations for Further Research on Assistive Technology Devices

Future research is recommended to test the compatibility of hardware when using multiple-channel technologies in virtual learning environments. As new advancements in technology are discovered, new hardware used to access content are being developed. The benefits of these hardware technologies are not limited to those with disabilities, and research should maintain a reasonable effort to maintain the most current and update information. As the age of the population increases and more and more people are coping with physical limitations and other impairments, expanding the knowledge base is necessary.

Recommendations for Further Research on Other Types of Learning

Proceduralized instruction is only one domain of learning, but further research should be conducted examining the effect of multiple-channel technologies and learning styles in virtual environments when the preferred methods of learning are cognitive and affective domains. Cognitive learning takes place when individual's listen, watch, touch, read, or experience newly acquired information. Affective domain learning includes how emotion, feelings, values, appreciation, enthusiasm, motivation, and attitudes engage and reinforce learning. As more and more instructional content are stored and managed in virtual environments, the use of multi-media which includes several modalities of delivery would need to be examined based on performance outcomes.

Conclusion: Final Thoughts

This study examined the effect of several multiple-channel technologies and one type of learning styles on proceduralized instruction in a virtual environment. When VARK learning style preferences were examined with multiple-channel delivery methods, performance test scores were similar across both treatment and learning style preference. Although test scores were slightly different, the statistical analysis revealed in no significant differences on test scores, whether participants received the audio-text, image-text, or multiple-channel treatments, or if they were classified as visual, aural, read/write, kinesthetic, or multi-modal learning style preferences. There was also no significant interaction between multimedia treatment type and VARK learning style.

Findings of the study were beneficial to the research base by providing a pathway for future research in the areas of learning style preferences, individual differences, multiple-channel technology, and assistive technology devices. The idea of matching learning style preferences with specific delivery methods warrants further research to help educators and instructional designers better prepare instructional content for online learning. Adding to the literature base for career and technical training, education, and business and industry benefits all stakeholders as research expands and broadens across several disciplines.

The ability to provide multiple instructional strategies that match various learning styles may be productive and could help educators, trainers, and designers become more efficient and effective when delivering or designing instructional content for today's learning environments, whether individuals meet in a classroom or within virtual learning environments. The success of each student or individual in any educational setting, who has the desire and willingness to succeed, should be given equal access and equal opportunity to learn.

REFERENCES

Aarntzen, D. (1993). Audio in courseware: Design knowledge issues. *Educational and Training Technology International, 30*(4), 354-356. doi:10.1080/0954730930300406

Ajlan, A. A., & Zedan, H. (2007). The web services selection of virtual learning environment services. Paper presented at the IADIS International Conference WWW/Internet, Vila Real, Portugal. Retrieved from http://www.cse.dmu.ac.uk/STRL/research/publications/pubs/2007/2007-24.pdf

Akdemir, O., & Koszalka, T. (2004). Investigating the relationships among instructional strategies and learning styles in online environments. *Association for Educational Communications and Technology, 50*(4)*,* 1451-1461. doi:10.1016/j.compedu.2007.01.004

Allen, W. H. (1956). Audio-visual communication research. *The Journal of Educational Research, 49*(5), 321-330.

Alloway, T., Gathercole, S., Adams, A., Willis, C., Eaglen, R., & Lamont, E. (2005). Working memory and phonological awareness as predictors of progress towards early learning goals at school entry. *British Journal of Developmental Psychology, 23*(3), 417-426. doi:10.1348/026151005x26804

Anderson, J. R. (1985). *Cognitive psychology and its implications*. New York, NY: Worth Publishers and W. H. Freeman and Company.

Anderson, R. C., Greeno, J. G., Kline, P. J., & Neves, D. M. (1981). Acquisition of problem solving skill. In J. R. Anderson (Ed.), *Cognitive skills and their acquisition* (pp. 125-153). Hillsdale, NJ: Lawrence Erlbaum.

Aragon, S., Johnson, S., & Shaik, N. (2002). The influence of learning style preferences on student success in online versus face-to-face environments. *American Journal of Distance Education, 16*(40), 227-245.

Atkinson, R. C., & Shiffrin, R. M. (1965). *Mathematical models for memory and learning* (Technical Report No. 79). Retrieved from Stanford University, Institute for Mathematical Studies in the Social Sciences website: http://suppes-corpus.stanford.edu/techreports/IMSSS_79.pdf

Atkinson, R. C., & Shiffrin, R. M. (1968). Human memory: A proposed system and its control processes. In K. W. Spence & J. T. Spence (Eds.), *The psychology of learning and motivation: Advances in research and theory* (pp. 89-195). New York, NY: Academic Press.

Ausburn, L. J., & Ausburn, F. B. (1978). Cognitive styles: Some information and design implications for instructional design. *Educational Communication & Technology Journal*, *26*(4), 337-354. doi:10.1007/BF02766370

Ausburn, L. J., & Ausburn, F. B. (2003). A comparison of simultaneous vs. sequential presentation of images in a visual location task to learners with visual and non-visual perceptual styles: A study of supplantational instructional design. *The Journal of the Oklahoma Association of Teacher Educators, 7*, 1–20.

Ausburn, L. J., & Ausburn, F. B. (2004). Desktop virtual reality: A powerful new technology for teaching and research in industrial teacher education. *Journal of Industrial Teacher Educators*, *4*(4), 33-58.

Ausburn, L. J., & Ausburn, F. B. (2008). Effects of desktop virtual reality on learner performance and confidence in environment mastery: Opening a line of inquiry.

Journal of Industrial Teacher Education, 45(1), 54-87.

Ausburn, L. J., Ausburn, F. B., & Kroutter, P. (2010). An exploration of desktop virtual reality and visual processing skills in a technical training environment. *i-manager's Journal of Educational Technology, 6*(4), 44-56.

Ausburn, L. J., Martens, J., Dotterer, G., & Calhoun, P. (2009). Avatars, pedagogical agents, and virtual environments: Social learning systems online. *Journal of Educational Technology, 5*(4), 1-13.

Ausburn, L. J., Martens, J., Washington, A., Steele, D., & Washburn, E. (2009). A crosscase analysis of gender issues in desktop virtual reality learning environments. *Journal of Industrial Teacher Education, 46*(3), 51–89. Retrieved from http://scholar.lib.vt.edu/ejournals/JITE/v46n3/pdf/ausburn.pdf

Ayersman, D., & Minden, A. (1995). Individual differences, computers, and instruction. *Computers in Human Behavior, 11*(3-4), 371-390.

Azevedo, R., Cromley, J. G., & Seibert, D. (2004). Does adaptive scaffolding facilitate students' ability to regulate their learning with hypermedia? *Contemporary Educational Psychology, 29*, 344–370. doi:10.1016/j.cedpsych.2003.09.002

Azevedo, R., & Hadwin, A. (2005). Scaffolding self-regulated learning and metacognition: Implications for the design of computer-based scaffolds. *Instructional Science 33*(5), 367-379. doi: 10.1007/s11251-005-1272-9

Baddeley, A. D. (1986). *Working memory*, New York, NY: Oxford University Press.

Baddeley, A. D. (1992). Working memory. *Science, 255*(5044), 556-559. doi: 10.1126/science.1736359

Baddeley, A. (1996). Exploring the central executive. *The Quarterly Journal of*

Experimental Psychology A: Human Experimental Psychology, 49A(1), 5-28. doi:10.1080/027249896392784

Baddeley, A. D. (1998). *Human memory: Theory and practice*. Boston, MA: Allyn and Bacon.

Baddeley, A. D. (1999). *Essentials of human memory*. East Sussex, UK: Psychology Press Ltd.

Baddeley, A. D. (2000). The episodic buffer: A new component in working memory? *Trends in Cognitive Sciences, 4*(1), 417-423. doi:10.1016/S1364-6613(00)01538-2

Baddeley, A. D. (2002). Is working memory still working? *European Psychologist, 7*(2), 85-97. doi:10.1027//1016-9040.7.2.85

Baddeley, A. (2003). Working memory and language: An overview. *Journal of Communication disorders, 36*(3), 189-208. doi:10.1016/S0021-9924(03)00019-4

Baddeley, A. D., & Hitch, G. J. (1974). Working memory. In G. A. Bower (Ed.), *Recent advances in learning and motivation* (pp. 47–90). New York, NY: Academic Press.

Barron, A. E. (2004). Auditory instruction. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 949-978). New York, NY: MacMillan.

Barron, A., & Kysilka, M. (1993). The effectiveness of digital audio in computer-based training. *Journal of Research on Computing in Education, 25*(3), 277-290.

Barron. A., & Varnadoe, S. (1992). Digital audio: A sound design element. *Instructional Delivery Systems*, *6*(1), 6-9.

Beccue, B., Vila, J., & Whitley, L. (2001). The effects of adding audio instructions to a multimedia computer based training environment. *Journal of Educational Multimedia & Hypermedia*, *10*(1), 47-67.

Becker, D., & Haugen, S. (2004). Wireless instruction: a new dimension in course delivery. *Management Accounting Quarterly, 6*(1), 41-46.

Berry, M. (2005). An investigation of the effectiveness of Moodle in primary education. *Proceedings of the IADIS International Conference WWW/Internet 2005 Lisbon, Portugal.* 51-58.

Best, S., & Kellner, D. (2001). *The postmodern adventure*. New York, NY: Guilford Press.

Brashears, T., Akers, C., & Smith, J. (2005). The effects of multimedia cues on student cognition in an electronically delivered high school unit of instruction. *Journal of Southern Agriculture Education Research*, *55*(1), 5-18.

Broadbent, D. E. (1956). Successive responses to simultaneous stimuli. *Quarterly Journal of Experimental Psychology, 8*(4), 145–152. doi:10.1080/17470215608416814

Broadbent, D. E. (1958). *Perception and communication*. New York, NY: Pergamon Press.

Broadbent, D. E. (1965). Information processing in the nervous system. *Science, 150*(3695), 457–462. doi:10.1126/science.150.3695.457

Brunning, R. H., Schraw, G. J., Norby, M. M., & Roonning, R. R. (2004). *Cognitive psychology and instruction*. Upper Saddle River, NJ: Pearson/Merrill/Prentice Hall.

Brunye, T. T., Taylor, H. A., & Rapp, D. N. (2007). Repetition and dual coding in procedural multimedia presentations. *Applied Cognitive Psychology, 22*(7), 877-895. doi:10.1002/acp.1396

Burton, J., Moore, M., & Holmes, G. (1995). Hypermedia concepts and research: An overview. *Computers in Human Behavior*, *11*(3-4), 345-369. doi:10.1016/0747-5632(95)80004-R

Campbell, D., & Stanley, J. (1966). *Experimental and quasi-experimental designs for research.* Chicago, IL: Rand McNally & Company.

Carr-Chellman, A., & Duchastel, P. (2001). The ideal online course. *Library Trends, 50*(1), 145-158. doi:10.1111/1467-8535.00154

Carney, R. N., & Levin, J. R. (2002). Pictorial illustrations still improve students' learning from text. *Educational Psychology Review, 14*(1), 5-26. doi:10.1023/A:1013176309260

Chandler, P., & Sweller, J. (1991). Cognitive load theory and the format of instruction. *Cognition and Instruction, 8*(4), 293-332. doi:10.1207/s1532690xci0804_2

Chen, C. C., Wactlar, H. D., Wang, J. Z., & Kiernan, K. (2005). Digital imagery for significant cultural and historical materials. *International Journal on Digital Libraries, 5*(4), 275-286. doi:10.1007/s00799-004-0097-5

Chen, S. (2002). A cognitive model for non-linear learning in hypermedia programmes. *British Journal of Educational Technology*, *33*(4), 449-460. doi:10.1111/1467-8535.00281

Chen, S. Y., & Ford, N. J. (1998). Modeling user navigation behaviours in a hypermedia-based learning system: An individual differences approach. *Knowledge Organization*, *25*(3), 67-78.

Chen, S., & Macredie, R. (2002). Cognitive styles and hypermedia navigation: Development of a learning model. *Journal of the American Society for Information Science and Technology*, *53*(1), 3-15. doi:10.1002/asi.10023

Cherry, K. (2011). What is Schema? [About.com. Psychology a guide to psychology]. Retrieved from http://psychology.about.com/od/sindex/g/def_schema.htm

Clark, R. C. (1999). *Developing technical training: A structured approach for developing classroom and computer-based instruction materials,* (2nd ed.). Silver Spring, MD: International Society for Performance Improvement (ISPI).

Clark, R. C., Nguyen, F., & Sweller, J. (2006). *Efficiency in learning: Evidence-based guidelines to manage cognitive load.* San Francisco, CA: Pfeiffer.

Clark, J. M., & Paivio, A. (1991). Dual coding theory and education. *Educational Psychology Review, 3*(3), 149-210. doi: 1040-726X;1573-336X

Clottes, J. (2001, August). France's magical ice age art. *National Geographic, 200*(2), 104-121.

Cobb, S., & Frazier, D. S. (2005). Multimedia learning in virtual reality. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 525-549). New York, NY: Cambridge University Press.

Coffield, F., Moseley, D., Hall, E., & Ecclestone, K. (2004). *Learning styles and pedagogy in post-16 learning: A systematic and critical review*. Retrieved from http://www.lsrc.ac.uk/

Cowan, N. (1998). Visual and auditory working memory capacity. *Trends in Cognitive Sciences, 2*(3), 77-78. doi:10.1016/S1364-6613(98)01144-9

Cowan, N. (2001). The magical number 4 in short-term memory: A reconsideration of mental storage capacity. *Behavioral and Brain Sciences, 24*(1), 87-114. doi: 75513066

Cowan, N., Elliott, E. M., Saults, J. S., Morey, C. C., Mattox, S., Hismjatullina, A., & Conway, A. (2005). On the capacity of attention: Its estimation and its role in working memory and cognitive aptitudes. *Cognitive Psychology, 51*(1), 42-100. doi:10.1016/j.cogpsych.2004.12.001

Craig, S. D., Gholson, B., & Driscoll, D. M. (2002). Animated pedagogical agents in multimedia educational environments: Effects of agent properties, picture features, and redundancy. *Journal of Educational Psychology, 4*(2), 428-434. doi:10.1037//0022-0663.04.2.428

Creswell, J. W. (2003). *Research design: Qualitative, quantitative, and mixed methods approaches* (2nd ed.). Thousand Oaks, CA: Sage Publications.

Crewson, P. (2008). *Applied statistics handbook version 1.4*. Leesburg, VA: Acasoft Software.

Cronbach, L. J., & Snow, R. E. (1977). *Aptitudes and instructional methods: A handbook for research on interactions*. New York, NY: Macmillan.

Curry, L. (1990). A critique of research on learning styles. *Educational Leadership*, *48*(2), 50-53, 54-56.

Cushman, D.R. (1973). The cue summation theory tested with meaningful verbal information. *Visible Language, 7*(3), 247-261.

Cutting, J. E., & Massironi, M. (1998). Pictures and their special status in perceptual and cognitive inquiry. In J. Hochberg, & E. Carterette (Eds.), *Perceptions and cognition at the century's end: Handbook of perception and cognition,* (2nd ed., pp. 137-168). San Diego, CA: Academic Press.

DaCosta, B., & Seok, S. (2010). Managing cognitive load in the design of assistive technology for those with learning disabilities. In S. Seok, E. Meyen, & B. DaCosta (Eds.), *Handbook of research on human cognition and assistive technology: Design, accessibility and transdisciplinary perspectives* (pp. 1-20). Hershey, PA: Medical Information Science Reference (an imprint of IGI Global).

Daniels, L. (1993). Audio vision: Audio-visual interaction in desktop multimedia. *Journal of Educational Television*, *19*(2), 81-93.

Darken R. P., & Peterson, B. (2002). Spatial orientation, wayfinding, and representation. In K. M. Stanney (Ed.), *Handbook of virtual environments: Design, implementation, and applications* (pp. 493–518). Mahwah, NJ: Erlbaum.

Davis, R., Shrobe, P., & Szolovits, P. (1993). What is knowledge representation? *AI Magazine, 14*(1), 17-33.

Day, S., & Edwards, B. (1996). Assistive technology for postsecondary students with learning disabilities. *Journal of Learning Disabilities*, *29*(5), 486-503. doi: 10.1177/002221949803100104

DeBloois, M. L. (1982). *Videodisc/microcomputer courseware design*. Englewood Cliffs, NJ: Educational Technology.

Dembo, M. H. & Howard, K. (2007). Advice about the use of learning styles: A major myth in education. *Journal of College Reading and Learning*, *37*(20), 101-109.

Dickey, M. (2005). Brave new (interactive) worlds: A review of the design affordances and constraints of two 3D virtual worlds as interactive learning environments. *Interactive Learning Environments, 13*(1-2), 121-137. doi:10.1080/10494820500173714

Dillion, A., & Jobst, J. (2005). Multimedia learning with hypermedia. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 569-588). New York, NY: Cambridge University Press.

Donovick, J. (2001). *The effects of audio on multimedia computer-based learning in undergraduate studies in the humanities*. Retrieved from the University of South Florida http://www.coedu.usf.edu/itphdsem/eme7938/2001/donovickj.pdf

Dotterer, G. (2010a). Effects of assistive technologies combined with desktop virtual reality in instructional procedures (1). In S. Seok, E. Meyen, & B. DaCosta (Eds.), *Handbook of research on human cognition and assistive technology: Design, accessibility and transdisciplinary perspectives* (pp. 209-305). Hershey, PA: Medical Information Science Reference (an imprint of IGI Global).

Dotterer, G. (2010b). Effects of assistive technologies combined with desktop virtual reality in instructional procedures (2). In S. Seok, E. Meyen, & B. DaCosta (Eds.), *Handbook of research on human cognition and assistive technology: Design, accessibility and transdisciplinary perspectives* (pp. 306-312). Hershey, PA: Medical Information Science Reference (an imprint of IGI Global).

Dotterer, G., Calhoun, P., Kroutter, P., Jennings, C., Burkett, R., & Braithwaite, P. (2008, December). *Preparing learners for desktop virtual reality training in career and* *technical education.* Poster session presented at ACTE Research and Professional Development Conference, Charlotte, NC.

Dotterer, G., & Washburn, E. (2009). Technical issues, affordability, and skilled educators to utilize advanced technology in the classroom. *OATE Journal: Journal of the Oklahoma Association of Teacher Educators*, *13*, 24-30.

Dougiamas, M. (2007). Re: Moodle [Online forum comment]. Retrieved from http://docs.moodle.org/20/en/Moodle_in_education

Drew, D. G., & Grimes, T. (1987). Audio-visual redundancy and TV news recall. *Communication Research*, *14*(4), 452–461. doi:10.1177/009365087014004005

Dunn, R. (2003). The Dunn and Dunn learning-style model and its theoretical cornerstone. In R. Dunn & S. Griggs (Eds.), *Synthesis of the Dunn and Dunn learning styles model research: Who, what, when, where and so what: The Dunn and Dunn learning-style model and its theoretical cornerstone*. New York, NY: St. John's University.

Dunn, R. S., & Dunn, K. J. (1979). Learning styles/teaching styles: Should they...can they...be matched? *Educational Leadership, 36*(4), 238-244.

Dwyer, F. M. (1978). *Strategies for improving visual learning*. State College, PA: Learning Services.

Ericsson, K. A., & Kintsch, W. (1995). Long-term working memory. *Psychology Review, 102*(2), 211–245. doi:10.1037/0033-295X.102.2.211

Felder, R. M. & Silverman, L. K. (1988). Learning and teaching styles in engineering education. *Engineering Education*, *78*(7), 674-681.

Felder, R., & Spurlin, J. (2005). Applications, reliability and validity of the index of learning styles. *International Journal of Engineering Education, 21*(1), 103-112.

Feldon, D. F. (2005). Dispelling a few myths about learning. *UrbanEd, 1*(4), 37-39.

Fleming, N. D. (2001). *Teaching and learning styles: VARK strategies*. Christchurch, New Zealand: Author.

Fleming, N., & Baume, D. (2006). Learning styles again: VARKing up the right tree! *Educational Developments, SEDA Ltd.*, *7*(4), 4-7.

Fleming, N., & Mills, C. (1992). Not another inventory, rather a catalyst for reflection. *To Improve the Academy, 11,* 137-143.

Ford, N., & Chen, S. (2000). Individual differences, hypermedia navigation, and learning: An empirical study. *Journal of Educational Multimedia and Hypermedia*, *9*(4), 281-311.

Fraenkel, J. R., & Wallen, N. E. (2006). *How to design and evaluate research in education* (6th ed.). New York, NY: McGraw-Hill.

Freidman, T. (2006). *The world is flat a brief history of the twenty-first century*. New York, NY: Farrar, Straus, and Giroux Union Square West.

Fried, A., Polson, M. C., & Dafoe, C. G. (1988). Dividing attention between the hands and the head: Performance trade-offs between rapid finger tapping and verbal memory. *Journal of Experimental Psychology. Human Perception and Performance, 14*, 60-68. doi:10.1037/0096-1523.14.1.60

Gagnon, D. (1986). *Interactive television: The influence of user control and interactive structure*. (ERIC Document Reproduction Service No. ED 283 512)

Gardner, H. (1983). *Frames of Mind,* (1st ed.) New York, NY: Basic Books.

Garson, G. (2009). *Notes for a lecture on quantitative research in public administration*. Research Designs. North Carolina State University, Raleigh, NC. Retrieved from http://faculty.chass.ncsu.edu/garson/PA765/pa765syl.htm

Gates, W. (1993). The promise of multimedia. *The American School Board Journal*. *180*(3), 35-37.

Gay, L. R., & Airasian, P. (2003). *Educational research: Competencies for analysis and application*. Upper Saddle River, NJ: Prentice-Hall.

Gidley, J. M., & Hampson, G. P. (2005). The evolution of futures in school education. *Futures, 37*(4), 255-271. doi:10.1016/j.futures.2004.07.005

Gravetter, F., & Wallnau, L. (2007). *Statistics for the behavioral sciences*. Belmont, CA: Thomson Wadsworth.

Green, R. L. (1992). *Human memory: Paradigms and paradoxes.* Hillsdale, NJ: Lawrence Erlbaum.

Gutierrez, K. D., & Rogoff, B. (2003). Cultural ways of learning: Individual styles or repertoires of practice. *Educational Researcher, 32*(5), 19-25. doi: 10.3102/0013189X032005019

Hanson, L. (1989). Multichannel learning research applied to principles of television production: A review and synthesis of the literature. *Educational Technology*, *29*(10), 15–19.

Harskamp, E. G., Mayer, R. E., & Suhre, C. (2007). Does the modality principle for multimedia learning apply to science classrooms? *Learning & Instruction, 17*(5), 465-477. doi:10.1016/j.learninstruc.2007.09.010

Hartley, K. (2001). Learning strategies and hypermedia instruction. *Journal of Educational Multimedia and Hypermedia, 10*(3), 285-305.

Hawkins, H., & Presson, J. (1986). Auditory information processing. In K. R. Boff, L. Kaufman, & J.P. Thomas (Eds.), *Handbook of perception and human performance* (pp. 1-64). New York, NY: Wiley.

Healy, A. F., & McNamara, D. S. (1996). Verbal learning and memory: Does the modal still work? *Annual Review of Psychology, 47*(1), 143-172. doi:10.1146/annurev.psych.47.1.143

Hegarty, M. (2004). Dynamic visualizations and learning: getting to the difficult questions. *Learning and Instruction, 14*(3), 343-351. doi:10.1016/j.learninstruc.2004.06.007

Hegarty, M., Kriz, S., & Cate, C. (2003). The roles of mental animations and external animations in understanding mechanical systems. *Cognition and Instruction, 21*(4), 325-360. doi:10.1207/s1532690xci2104_1

Henry, J. (2007, July). Re: Professor pans 'learning style' teaching method [Online News Website]. Retrieved from http://www.telegraph.co.uk/news/uknews/1558822/Professor-pans-learning-style-teaching-method.html

Höffler, T., & Leutner, D. (2007). Instructional animations versus static pictures: A meta-analysis. *Learning and Instruction, 17*(6), 722-738. doi:10.1016/j.learninstruc.2007.09.013

Hsia, H. J. (1969). Intelligence in auditory, visual, and audiovisual information processing. *AV Communication Review, 17*(3), 272–282. doi:10.1007/BF02767637

Hsia, H. J. (1971). The information processing capacity of modality and channel performance. *A V Communication Review, 19*(1), 51-75. doi:10.1007/BF02768431

Huitt, W. (2003). *Educational psychology interactive: The information processing approach*. Valdosta State University, Valdosta, GA. Retrieved from http://chiron.valdosta.edu/whuitt/col/cogsys/infoproc.html

Jenkins, C. (2005). *Skills for success: Developing effective study strategies.* Belmont, CA: Wadsworth/Thompson Learning.

Jesky, R., & Berry, L. (1991). The effects of pictorial complexity and cognitive style on visual recall memory. *Proceedings of the Annual Convention of the Association for Educational Communications and Technology*. Orlando, FL.

Jeung, H. J., Chandler, P., & Sweller, J. (1997). The role of visual indicators in dual sensory mode instruction. *Educational Psychology, 17*(3), 329-343. doi: 10.1080/0144341970170307

Johnson, S. D., & Aragon, S. R. (2003). An instructional strategy framework for online learning environments. *New Directions for Adult & Continuing Education*, *2003*(100), 31-43. doi: 10.1002/ace.117

Jonassen, D., & Grabowski, B. (1993). *Individual differences and instruction.* New York, NY: Allen & Bacon.

Kahn, P. (2007). *Teaching to learning styles: A study of learning outcomes for the adult learner*. (Doctoral dissertation) Capella University. (UMI No. 3288732)

Kaiser, E. C. (2004). *Dynamic new vocabulary enrollment through handwriting and speech in a multimodal scheduling application. Making pen-based interaction intelligent and natural.* Paper presented at the 2004 AAAI Symposium, Arlington, VA.

Kaiser, E. C. (2005). Multimodal new vocabulary recognition through speech and handwriting in a whiteboard scheduling application. *Proceedings of the International Conference on Intelligent User Interfaces* (pp. 51-58). New York, NY: ACM Press.

Kalyuga, S. (2000). When using sound with a text or picture is not beneficial to learning. *Australian Journal of Educational Technology, 16*(2), 161–172. Retrieved from http://www.ascilite.org/ajet/ajet16/kalyuga.html

Kalyuga, S., Chandler, P., & Sweller, J. (1998). Levels of expertise and instructional design. *Human Factor, 40*(1), 1-17. doi:10.1518/001872098779480587

Kalyuga, S., Chandler, P., & Sweller, J. (1999). Managing split-attention and redundancy in multimedia instruction. *Applied Cognitive Psychology, 13*(4), 351-371. doi: 10.1037/0022-0663.93.3.579

Kalyuga, S., Chandler, P., & Sweller, J. (2004). When redundant on-screen text in multimedia technical instruction can interfere with learning. *Human Factor, 46*(3), 567-581. doi: 10.1518/hfes.46.3.567.50405

Kearsley, G. (Ed.) (2011a). *The theory into practice database.* Retrieved from http://tip.pshychology.org/miller.html

Kearsley, G. (Ed.) (2011b). *The theory into practice database.* Retrieved from http://tip.pshychology.org/paivio.html

Kellner, D. (2004). Technological transformation, multiple literacies, and the re-visioning of education. *E-Learning*, *1*(1), 9-37. doi:10.1007/978-14020-3803-7_9

Kirk, J. (2006). *Age gap hampers technology adoption*. Retrieved from http://www.infoworld.com/t/architecture/age-gap-hampers-technology-adoption-527

Kolb, D. A. (1984). *Experiential Learning*. Englewood Cliffs, NJ: Prentice-Hall.

Kozma, R. B. (1991). Learning with media. *Review of Educational Research, 61*(2), 179-211. doi:10.3102/00346543061002179

Krichen, J. (2007). *Learning styles in the online context: Can learner selection of instructional activities improve the quality of learning?* (Doctoral dissertation) Capella University. (UMI No. 3288855)

Kroutter, P. J. (2010). *The influence of field dependence / independence, gender, and experience on navigational behavior and configurational knowledge acquisition in a desktop virtual environment* (Unpublished doctoral dissertation). Oklahoma State University, Stillwater, OK.

Lai, S. (2000). Influence of audio-visual presentations on learning abstract concepts. *International Journal of Instructional Media, 27*(2), 199–206.

Lee, G., Brennan, R. L., & Frisbie, D. A. (2000). Incorporating the testlet concept in test score analyses. *Educational Measurement: Issues and Practice, 19*(4), 9-15. doi: 10.1111/j.1745-3992.2000.tb00041.x

Leite, W., Svinicki, M., & Shi, Y. (2009). Attempted validation of the scores of the VARK: Learning styles inventory with multitrait-multimethod confirmatory factor analysis models. *Educational and Psychological Measurement, 70*(2), 323-339. doi:10.1177/0013164409344507

Levie, W. H., & Lentz, R. (1982). Effects of text illustrations: A review of research. *Educational Communication and Technology Journal, 30*(4), 195-232. doi:10.1007/BF02765184

Levin, J. R. (1982). Pictures as prose-learning devices. *Advances in Psychology, 8*, 412-444. doi:10.1016/S0166-4115(08)62709-0

Levin, J. R., Anglin, G. J., & Carnay, R. N. (1987). On empirically validating functions of pictures in prose. In H. A. Houghton, & D. A. Willows (Eds.), *The psychology of illustration.* (pp. 51-86). New York, NY: Springer-Verlag.

Levin, J. R., & Mayer, R. E. (1993). Understanding illustration in text. In B. K. Britton, M. Binkley, & A. Woodward (Eds.). *Learning from textbooks* (pp. 95-113). Hillsdale, NJ: Erlbaum Associates, Inc.

Lohr, L. (2008). *Creating graphics for learning and performance: Lessons in visual literacy*. Cleveland, OH: Prentice-Hall.

Low, R., & Sweller, J. (2005). The modality principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 147-158). New York, NY: Cambridge University Press.

Mathews, J. (2010, February, 11). Some say learning styles are myth, others magic. *The Washington Post*, p. T18.

Mayer, R. E. (1984). Aids to text comprehension. *Educational Psychologist, 19*(1), 30-42. doi:10.1080/00461528409529279

Mayer, R. E. (1989). Systematic thinking fostered by illustrations in scientific text. *Journal of Educational Psychology, 81*(2), 240-246. doi:10.1037/0022-0663.81.2.240

Mayer, R. E. (1992). Guiding students' cognitive processing of scientific information in text. In M. Pressley, K. R. Harris, & J. T. Guthrie (Eds.), *Promoting academic competency and literacy in school.* (pp. 243-258). San Diego, CA: Academic Press.

Mayer, R. E. (1993a). Comprehension of graphics in text: An overview. *Learning and Instruction, 3*(3), 239-246. doi: 10.1016/0959-4752(93)90007-M

Mayer, R. E. (1993b). Illustrations that instruct. In R. Glaser (Ed.), *Advances in instructional psychology*, (Vol. 5, pp. 253-284). Hillsdale, NJ: Lawrence Erlbaum Associates, Inc.

Mayer, R. E. (1993c). Problem-solving principles. In M. Fleming, & W. H. Levie (Eds.), *Instructional message design: Principles from the behavioral and cognitive sciences* (2nd ed., pp. 253-282). Englewood Cliffs, NJ: Educational Technology Publications.

Mayer, R. E. (1997). Multimedia learning: Are we asking the right questions? *Educational Psychologist, 32*(1), 1-19. doi:10.1207/s15326985ep3201_1

Mayer, R. E. (2001). *Multimedia learning.* New York, NY: Cambridge University Press.

Mayer, R. E. (2002). Cognitive theory and the design of multimedia instruction: An example of the two-way street between cognition and instruction. *New Directions in Teaching in Learning, 2002*(89), 55-71. doi:10.1002/tl.47

Mayer, R. E. (2005a). Introduction to multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 1-16). New York, NY: Cambridge University Press.

Mayer, R. E. (2005b). Principles for managing essential processing in multimedia learning: Segmenting, pretraining, and modality principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 169-182). New York, NY: Cambridge University Press.

Mayer, R. E. (2005c). Cognitive theory of multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31-48). New York, NY: Cambridge University Press.

Mayer, R. E. (2005d). Principles for reduction extraneous procession in multimedia learning: Coherence, signaling, redundancy, spatial contiguity, and temporal contiguity principles. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 183-200). New York, NY: Cambridge University Press.

Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology, 83*(4), 484-490. doi: 10.1037/0022-0663.83.4.484

Mayer, R. E., & Anderson, R. B. (1992). The instructive animation: Helping students build connections between words and pictures in multimedia learning. *Journal of Educational Psychology, 88*(), 444-452. doi: 10.1037/0022-0663.84.4.444

Mayer, R. E., & Chandler, P. (2001). When learning is just a click away: Does simple user interaction foster deeper understanding of multimedia messages? *Journal of Educational Psychology, 93*(2), 390-397. doi: 10.1037/0022-0663.93.2.390

Mayer, R. E., Dow, G. T., & Mayer, S. (2003). Multimedia learning in an interactive self-explaining environment: What works in the design of agent-based microworlds? *Journal of Educational Psychology, 95*(4), 806-812. doi: 10.1037/0022-0663.95.4.806

Mayer, R. E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more materials results in less understanding. *Journal of Educational Psychology, 93*(1), 187-198. doi:10.1037/0022-0663.93.1.187

Mayer, R. E., & Johnson, C. I. (2008). Revising the redundancy principle in multimedia learning. *Journal of Educational Psychology, 100*(2), 380-386. doi:10.1037/0022-0663.100.2.380

Mayer, R. E., Mathias, A., & Wetzell, K. (2002). Fostering understanding of multimedia messages through pre-training: Evidence for a two-stage theory of mental model construction. *Journal of Experimental Psychology: Applied, 8*(3), 147-154. doi: 10.1037/1076-898X/8.3.147

Mayer, R. E., & Massa, L. J. (2003). Three facets of visual and verbal learners: Cognitive ability, cognitive style, and learning preference. *Journal of Educational Psychology, 95*(4), 833-841. doi:10.1037/0022-0663.95.4.833

Mayer, R. E., & Moreno, R. (1998). A split-attention effect in multimedia learning: Evidence for dual processing systems in working memory. *Journal of Educational Psychology, 90*(2), 312-320. doi:10.1037/0022-0663.90.2.312

Mayer, R. E., & Moreno, R. (2002). *A cognitive theory of multimedia learning: Implications for design principles*. Unpublished manuscript, Department of

Psychology, The University of New Mexico, Albuquerque, NM. Retrieved from http://www.unm.edu/~moreno/PDFS/chi.pdf

Mayer, R. E., & Moreno, R. (2003). Nine ways to reduce cognitive load in multimedia learning. *Educational Psychologist, 38*(1), 43-52. doi: 10.1207/S15326985EP3801_6

Mayer, R. E., & Sims, V. K. (1994). For whom is a picture worth a thousand words? Extensions of a dual-coding theory of multimedia learning. *Journal of Educational Psychology, 86*(3), 389-401. doi:10:1037/0022-0663.86.3.389

Mayer, R. E., Steinhoff, K., Bower, G., & Mars, R. (1995). A generative theory of textbook design: Using annotated illustrations to foster meaningful learning of science text. *Educational Technology Research and Development, 43*(1), 31-43. doi:10:1007/BF02300480

McKnight, C., Dillion, A., & Richardson, J. (1996). User centered design of hypertext/hypermedia for education. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 979-1005). New York, NY: MacMillan.

McLeod, S. A. (2007). *Working memory (Baddeley and Hitch, 1974)*. Retrieved from http://www.simplypsychology.org/working%20memory.html

Mecella, M., Ouzzani, M., Paci, F., & Bertino, E. (2006). Access control enforcement for conversation-based web services. *Proceedings of the 15th International Conference on World Wide Web*. doi:10.1145/113577.1135818

Michas, I. C., & Berry, D. C. (2000). Learning a procedural task: Effectiveness of multimedia presentations. *Applied Cognitive Psychology, 14*(6), 555-575. doi:10.1002/1099-0720(200011/12)14:6<555::AID-ACP677>3.0.CO;2-4

Miller, G. (1956). The magical number seven, plus or minus two some limits on our capacity for processing information. *Psychological Review*, *101*(2), 343-352. doi: 10.1037/0033-295X.101.2.343

Moore, D. M., Burton, J. K., & Myers, R. J. (1996). Multiple-channel communication: The theoretical and research foundations of multimedia. In D. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 979-1005). New York, NY: MacMillan.

Moreno, R. R. (2005). Multimedia learning with animated pedagogical agents. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 507-523). New York, NY: Cambridge University Press.

Moreno, R. R. (2006). Does the modality principle hold for different media? A test of the method-affects-learning hypothesis. *Journal of Computer Assisted Learning, 22*(3), 149-158. doi:10.1111/j.1365-2729.2006.00170.x

Moreno, R., & Mayer, R. E. (1999). Cognitive principles of multimedia learning: The role of modality and contiguity. *Journal of Educational Psychology, 91*(2), 358-368. doi:10.1037/0022-0663.91.2.358

Moreno, R., & Mayer, R. E. (2000). A learner-centered approach to multimedia explanations: Deriving instructional design principles from cognitive theory. *Interactive Multimedia Electronic Journal of Computer-Enhanced Learning, 2*(2), 1-6.

Morey, C. C., & Cowan, N. (2004). When visual and verbal memories compete: Evidence of cross-domain limits in working memory. *Psychonomic Bulletin & Review, 11*(2), 296-301.

Morris, P. E., & Hampson, P. J. (1983). *Imagery and consciousness*. London, UK: Academic Press.

Mousavi, S. Y., Low, R., & Sweller, J, (1995). Reducing cognitive load by mixing auditory and visual presentation modes. *Journal of Educational Psychology, 87*(2), 319-334. doi:10.1037/0022-0663.87.2.319

National Center for Education Statistics. (2008). *Career/Technical Education (CTE) Statistics*. Retrieved from http://nces.ed.gov/surveys/ctes/tables/P46.asp

Neel, R. (2006). Consider the opportunities: A response to no child left behind. *Education and Treatment of Children*, *29*(4), 533-548.

Netherton, D., & Deal, W. (2006). Assistive technology in the classroom. *Technology Teacher*, *66*(1), 10-15.

Nguyen, F., & Clark, R. C. (2007, November). Efficiency in e-learning: Proven instructional methods for faster, better, online learning. *E-guild's Journal, November*. Retrieved from http://www.clarktraining.com/content/articles/Guild_E-Learning.pdf

Niaz, M., & Logie, R. H. (1993). Working memory, mental capacity and science education: Towards an understanding of the 'working memory overload hypothesis'. *Oxford Review of Education, 19*(4), 511-525. doi:10.1080/035498930190407

Nolting, P. D. (2002). *Winning at math: Your guide to learning mathematics through successful study skills* (4th ed.). Bradenton, FL: Academic Success Press.

Olson, J. K. (2006). The myth of catering to learning styles. *Science and Children, 44*(2), 56-57.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist*, *38*(1), 1-4. doi:10.1207/S15326985EP3801_1

Paas, F., Tuovinen, J., Tabbers, H., & Gerven, P. (2003). Cognitive load measurements as a means to advance cognitive load theory. *Educational Psychologist*, *38*(1), 63-71. doi:10.1207/S15326985EP3801_8

Paivio, A. (1971). *Imagery and verbal processes*. New York, NY: Holt, Rinehart & Winston.

Paivio, A. (1977). Mental comparisons involving abstract attributes. *Memory & Cognition, 6*(3), 199-208. doi:10.3758/BF03197447

Paivio, A. (1983). The mind's eye in arts and science. *Poetics, 12*(1), 1-18. doi:10.1016/0304-422X(83)90002-5

Paivio, A. (1986). *Mental representations: A dual-coding approach.* New York, NY: Oxford University Press.

Paivio, A. (1990). *Mental representations: A dual coding approach.* New York: Oxford Press.

Paivio, A. (1991). Dual coding theory: Retrospect and current status. *Canadian Journal of Psychology, 45*(3), 255-287. doi:10.1037/h0084295

Paivio, A. (1995). Imagery and memory. In M. S. Gazzaniga (Ed.), *The cognitive neurosciences* (pp. 977-986). Cambridge, MA: MIT Press.

Paivio, A. (2006, October). *Dual coding theory and education.* Paper presented at the meeting of Pathways to Literacy Achievement for High Poverty Children, University of Michigan School of Education, Lansing, MI.

Paivio, A. (2007). *Mind and its evolution: A dual coding theoretical approach*. Mahwah, NJ: Erlbaum.

Paivio, A., & Begg, I. (1981). *Psychology of language.* Englewood Cliffs, NJ: Prentice Hall.

Paivio, A., & Desrochers, A. (1980). A dual-coding approach to bilingual memory. *Canadian Journal of Psychology Revue canadienne de psychologie*, *34*(4), 388-399. doi:10.1037/h0081101

Pang, K. (2009). Video-driven multimedia, web-based training in the corporate sector: Pedagogical equivalence and component effectiveness. *International Review of Research in Open and Distance Learning, 10*(3), 1-14.

Park, C. H., Jang, G., & Chai, Y. H. (2006). Development of a virtual reality training system for live-line workers. *International Journal of Human-Computer Interaction*, *20*(3), 285-303. doi:10.1207/s15327590ijhc2003_7

Pashler, H. E. (1998). *Psychology of attention*. Cambridge, MA: The MIT Press.

Pashler, H., McDaniel, M., Rohrer, D., & Bjork, R. (2008). Learning styles: Concepts and evidence. *Psychological Science in the Public Interest, 9*(3), 105-119. doi:10.1111/j.1539-6053.2009.01038.x

Petrovich, M. V. (2011). *MVP programs*. Retrieved from http://mvpprograms.com/help/mvpstats/distributions/SkewnessKurtosis

Pollock, E., Chandler, P., & Sweller, J. (2002). Assimilating complex information. *Learning and Instruction, 12*(1), 61-86. doi:10.1016/SO959-4752(01)00016-0

Pressley, M., & Miller, G. (1987). Effects of illustrations on children's listening comprehension and oral prose memory. In D. M. Willows & H. A. Houghton (Eds.), *The psychology of illustration* (pp. 87-114). New York, NY: Springer-Verlag.

Reed, S. K. (2006). Cognitive architectures for multimedia learning. *Educational Psychologist, 41*(2), 87-98. doi:10.1027/s1532698Sep4102_2

Reeves, T. (1998). *The impact of media and technology in schools*. Retrieved from University of Georgia: http://it.coe.uga.edu/~treeves/Bertlesmann_Impact_Report.pdf

Rehaag, D., & Szabo, M. (1995, February). *An experiment on effects of redundant audio in computer based instruction on achievement, attitude and learning time in 10th grade math.* Paper presented at the annual meeting of the Association for Educational Communications and Technology, Anaheim, CA.

Rehabilitation ACT, 29 U.S.C. § 794d (1973). Retrieved from http://www.section508.gov/index.cfm?fuseAction=stdsdoc#Web

Renkl, A. (2005). The worked-out examples principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 229-245). New York, NY: Cambridge University Press.

Revenaugh, M. (2006). K-8 virtual schools: A glimpse into the future. *Educational Leadership*, *63*(4), 60-64.

Richardson, J. T. E. (1980). Concreteness, imagery, and semantic categorization. *Journal of Mental Imagery, 4*(1), 51-58.

Richardson, J. T. E. (1999). *Mental imagery*. Hove, U.K: Psychology Press.

Richman, H. B., Staszewski, J. J., & Simon, H. A. (1995). Simulation of expert memory using EPAM IV. *Psychological Review, 102*(2), 305-330. doi: 10.1037/0033-295X.102.2.305

Rieber, L. P. (1990a). Animation in computer-based instruction. *Educational Technology Research and Development, 38*(1), 77-86. doi:10.1007/BF02298250

Rieber, L. P. (1990b). Using computer animated graphics in science instruction with children. *Journal of Educational Psychology, 82*(1), 135-40. doi:10.1037/0022-0663.82.1.135

Rieber, L. P. (1991). Animation, incidental learning, and continuing motivation. *Journal of Educational Psychology, 83*(3), 318-328. doi:10.1037/0022-0663.83.3.318

Rieber, L. P. (2005). Multimedia learning in games, simulations, and micro worlds. In R. E. Mayer (Ed.), *Cambridge handbook of multimedia learning* (pp. 549-568). New York, NY: Cambridge University Press.

Riener, C., & Willingham, D. (2010). The myth of learning styles. *Change, 42*(5), 32-35. doi:10.1080/00091383.2010.503139

Ritschel-Trifilo, P. (2009). *The effect of learning styles on cognition and satisfaction in online biology laboratories for nonscience major undergraduates*. (Doctoral dissertation) Capella University. (UMI No. 3355873)

Rolandelli, D. R. (1989). Children and television: The visual superiority effect reconsidered. *Journal of Broadcasting & Electronic Media*, *33*(1), 69–81. doi:10.1080/08838158909364062

Rummer, R., Schweppe, J., Fürstenberg, A., Scheiter, K., & Zindler, A. (2011). The perceptual basis of the modality effect in multimedia learning. *Journal of Experimental Psychology: Applied, 17*(2), 159-173. doi:10.1037/a0023588

Sadoski, M., & Paivio, A. (2001). *Imagery and text: A dual coding theory of reading and writing*. Mahwah, NJ: Erlbaum.

Salkind, N. J. (2008). *Statistics for people who think they hate statistics*. Thousand Oaks, CA: Sage Publications Inc.

Salomon, G. (1984). Television is "easy" and print is "tough": The differential investment of metal effort in learning as a function of perceptions and attributions. *Journal of Educational Psychology*, *76*(4): 647-658.

Schraw, G. (1998). Promoting general metacognitive awareness. *Instructional Science, 26*(1-2), 113-125. doi:10.1023/A:1003044231033

Sensory Modality. (n.d.). In *Meriam-Webster's online dictionary*. Retrieved from http://www.merriam-webster.com/dictionary/modality

Seth, A., & Smith, S. (2004). PC-based virtual reality for CAD model viewing. *The Journal of Technology Studies*, *30*(4), 32-37.

Severin, W. J. (1967). *Cue summation in multiple channel communication*. (Unpublished doctoral dissertation). The University of Wisconsin, Madison, WI.

Severin, W. J. (1968). *Cue summation in multiple-channel communication*. (Report No. 37). Washington, DC: U.S. Department of Health, Education & Welfare Office of Education.

Severin, W. J., & Tankard, J. W. (1979). *Communication theories -- origins, methods and uses.* New York, NY: Hastings House.

Sheehy, K., & Bucknall, S. (2008). How is technology seen in young people's visions of future education systems? *Learning, Media and Technology, 33*(2), 101-114. doi:10.1080/17439880802097642

Sheskin, D. J. (2007). *Handbook of parametric and nonparametric statistical procedures* (4th ed.). Baca Raton, FL: Chapman Hall/CRC Taylor and Francis Group.

Shim, K., Kim, H., Kim, J., Park, J., Park, Y., & Ryu, H. (2003). Application of virtual reality technology in biology education. *Journal of Biological Education*, *37*(2), 71-73. doi:10.1080/00219266.2003.9655854

Slaughter, R. (2002). From rhetoric to reality: The emergence of futures into the educational mainstream. In J. Gidley, & S. Inayatullah (Eds.), *Youth futures: Comparative research and transformative visions* (pp. 175-86). Westport, CT: Praeger.

Smedley, T., & Higgins, K. (2005). Virtual technology: Bringing the world into the special education classroom. *Intervention in School and Clinic*, *41*(2), 114-119.

Smith, K. (2001). *New designs for multimedia learning.* Unpublished manuscript, Virginia Tech University, Blacksburg, VA.

Smith, B. D., & Elifson, J. M. (1986). Do pictures make a difference in college textbooks? *Reading Horizons, 26*(4), 270-277.

Solomon, H. (2004). The impact of spoken instructions on learner behavior following multimedia tutorial instruction. *Association for Educational Communications and Technology, 1*, 753-758.

Solso, R. L. (2001). *Cognitive psychology* (Vol. 6). Needham Heights, MA: Allyn & Bacon.

Spear, N. E., & Riccio, D. C. (1994). *Memory: Phenomena and principles.* Boston, MA: Allyn & Bacon.

Sprenger, M. (2003). *Differentiation through leaning styles and memory.* Thousand Oaks, CA: Corwin Press.

Squire, L. R. (2008). *Memory and brain.* New York, NY: Oxford University Press.

Stahl, S. A. (1999). Different strokes for different folks? A critique of learning styles. *American Educator, 23*(3), 27-31.

Sternberg, R. J. (1985). *Beyond IQ: A triarchic theory of human intelligence*. Cambridge, England: Cambridge University Press.

Stossell, J. (2006). *Myths, lies, and downright stupidity: Get out the shovel – why everything you know is wrong*. New York, NY: Hyperion.

Sumiyoshi, H., Yamada, I., & Yagi, N. (2002). Multimedia education system for interactive educational services. *Proceedings of the (ICME) IEEE International Conference on Multimedia*, *2*, 385-388. doi:10.1109/ICME.2002.1035612

Sweller, J. (1988). Cognitive load during problem solving: Effects on learning. *Cognitive Science, 12*(1), 257-285. doi:10.1016/0364-0213(88)90023-7

Sweller, J. (2003). Evolution of human cognitive architecture. In B. Ross (Ed.), *The psychology of learning and motivation* (pp. 215–266). San Diego, CA: Academic Press.

Sweller, J. (2004). Instructional design consequences of an analogy between evolution by natural selection and human cognitive architecture. *Instructional Science, 32*(1/2), 9–31. doi:10.1023/B:TRUC.0000021808.72598.4d

Sweller, J. (2005a). Implications of cognitive load theory for multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 19-30). New York, NY: Cambridge University Press.

Sweller, J. (2005b). The redundancy principle in multimedia learning. In R. E. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 159-168). New York, NY: Cambridge University Press.

Sweller, J., & Chandler, P. (1994).Why some material is difficult to learn. *Cognition and Instruction*, *12*(3), 185–233. doi: 10.1207/s1532690xci1203_1

Sweller, J., Chandler, P., Tierney, P., & Cooper, M. (1990). Cognitive load as a factor in the structuring of technical material. *Journal of Experimental Psychology: General*, *119*(2), 176-192. doi:10.1037/0096-3445.119.2.176

Sweller, J., van Merrienboer, J. G., & Paas, F. C. (1998). Cognitive architecture and instructional design. *Educational Psychology Review, 10*(3), 251-296. doi:10.1023/A:1022193728205

Sycara, K., Giampapa, J. A., Langley, B. K., & Paolucci, M. (2003). The RETSINA MAS, a case study, In A. Garcia, C. Lucena, F. Zambonelli, A. Omici, J. Castro (Eds.), *Software engineering for large-scale multi-agent systems: Research issues* *and practical applications* (Vol. LNCS 2603, pp. 232-250). Heidelberg, Germany: Springer-Verlag.

Szabo, M. (2002). *If instructional technology effectiveness were a crime, would there be enough evidence to convict it?* Retrieved from University of Alberta, Center for educational media: http://www.quasar.ualberta.ca/edmedia/readingsnc/Nrefsza.html

Tabbers, H. K. (2002). *The modality of text in multimedia instructions: Refining the design guidelines* (Unpublished doctoral dissertation). Open University of the Netherlands, Heerlen, Netherlands.

Telco2.0. (2009, March). Re: Defining the digital generation: Young today, grey tomorrow [Web log message]. Retrieved from http://www.telco2.net/blog/2009/03/defining_the_digital_generatio_1.html

Thomas, N. J. T. (1987). *The psychology of perception, imagination and mental representation, and twentieth century philosophies of science*. (Doctoral thesis, Leeds University, Leeds, United Kingdom). Retrieved from http://www.imagery-imagination.com/thesis.htm

Thomas, N. (2010). *Dual coding and common coding theories of memory*. Unpublished manuscript, Metaphysics Research Lab, Stanford University, Stanford, CA.

Tiala, S. (2007). Integrating virtual reality into technology education labs. *The Technology Teacher, 66*(4), 9-13.

Tie, H., & Umar, I. N. (2010). The impact of learning styles and instructional methods on students' recall and retention in programming education. In S. L. Wong, S. C. Kong, & F. Y. Yu (Eds.), Proceedings of the 18th International Conference on

Computers in Education. Putrajaya, Malaysia: Asia-Pacific Society for Computer in Education.

Tindall-Ford, S., Chandler, P., & Sweller, J. (1997). When two sensory modes are better than one. *Journal of Experimental Psychology. Applied, 3*(4), 257-287. doi:10.1037/1076-898X.3.4.257

Tu, C. (2005). From presentation to interaction: New goals for online learning technologies. *Educational Media International, 42*(3), 189-206. doi:10.1080/09523980500161072

Tulving, E. (1983). *Elements of episodic memory.* Oxford, UK: Oxford University Press.

Tulving, E. (2002). Episodic memory: From mind to brain. *Annual Review of Psychology, 53*, 1-25. doi:10.1146/annurev.psych.53.100901.135114

Tversky, B., Morrison, J. B., & Betrancourt, M. (2002). Animation: Can it facilitate? *International Journal on Human-Computer Studies, 57*(4), 247-262. doi:10.1006/ijhc.1017

U.S. Department of Education. (1998). *Learning styles and vocational education practice.* Office of Educational Research and Improvement. Washington, DC: Brown, B. L. Retrieved from http://www.melta.org.my/ET/2009/The_English_Teacher_2009.pdf

UCLA Academic Technology Services. (n.d.). *Regression with SPSS*. Retrieved from http://www.ats.ucla.edu/stat/spss/webbooks/reg/chapter2/spssreg2.htm

Van Blerkom, D. L. (2006). *College study Skills: Becoming a Strategic Learner* (5th ed.). Boston, MA: Thompson Higher Education.

van Merrienboer, J., & Ayres, P. (2005). Research on cognitive load theory and its design implications for e-learning. *Educational Technology Research and Development, 53*(3), 5-13. doi:10.1007/BF02504793

van Merrienboer, J., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, *17*(2), 147-177. doi:10.1007/s10648-005-3951-0

Vass, E. (2008). *New technology and habits of mind*. Retrieved from http://www.beyondcurrenthorizons.org.uk/wp-content/uploads/final_vass_newtechnologyhabitsofmind_20081201_jb.pdf

Vogel, J., Bowers, C., Meehan, C., Hoeft, R., & Bradley, K. (2004). Virtual reality for life skills education: Program evaluation. *Deafness and Education International*, *6*(1), 39-50. doi:10.1002/dei.162

Ware, C. (2004). *Information visualization: Perception for design*. San Francisco, CA: Morgan Kaufmann Publishers.

Weir, L. (2005). Raising the awareness of online accessibility: The importance of developing and investing in online course materials that enrich the classroom experience for special needs students. *T H E Journal*, *32*(10), 30-33.

Weiss, R. E., Knowlton, D. S., & Morrison, G. R. (2002). Principles for using animation in computer-based instruction: Theoretical heuristics for effective design. *Computers in Human Behavior, 18*(4), 465-477. doi:10.1016/S0747-5632(01)00049-8

Wiener, R. (1991). Computerized speech: A study of its effect on learning. *Technological Horizons in Education, 18*(7), 100-102.

Wiersma, W. (2000). *Research methods in education and introduction.* Needham Heights, MA: A Pearson Education Company.

Wilson, B., & Cole, P. (1996). Cognitive teaching models. In D. H. Jonassen (Ed.), *Handbook of research for educational communications and technology* (pp. 601-621). New York, NY: MacMillan.

Wittrock, M. C. (1989). Generative processes of comprehension. *Educational Psychologist, 24*(4), 345-376. doi:10.1207/s15326985ep2404_2

Worley, G. M. (1999). *The effects of highlight color on immediate recall in subjects of different cognitive styles*. (Unpublished doctoral dissertation). Virginia Polytechnic and State University, Blacksburg, Virginia.

Wu, M., & Dwyer, F. M. (1990). The effect of varied instructional strategies (visual and verbal) in complementing printed text. *International Journal of Instructional Media, 17*(1), 41-50.

Yang, C. S. (1993). *Theoretical foundations of hypermedia.* Unpublished manuscript, Virginia Polytechnic Institute and State University, Blacksburg, VA.

Zywno, M. S., & Waalen, J. K. (2002). The effect of individual learning styles on student outcomes in technology-enabled education. *Global Journal of Engineering Education, 6*(1), 35-44.

APPPENDICES

APPENDIX A

VARK a guide to learning styles

The VARK Preference of Learning Styles Survey (Version 7)

How Do I Learn Best?

Choose the answer which best explains your preference and click the checkbox(es) next to it. Please check more than one if a single answer does not match your perception. Leave blank any question that does not apply.

Participant ID: 346

1.You are helping someone who wants to go to your airport, town centre or railway station. You would:

- ☐ a. go with her.
- ☐ b. tell her the directions.
- ☐ c. write down the directions.
- ☐ d. draw, or give her a map.

2. You are not sure whether a word should be spelled "dependent" or "dependant." You would:

- ☐ a. see the words in your mind and choose by the way they look.
- ☐ b. think about how each word sounds and choose one.
- ☐ c. find it in a dictionary.
- ☐ d. write both words on paper and choose one.

3. You are planning a holiday for a group. You want some feedback from them about the plan. You would:

- ☐ a. describe some of the highlights.
- ☐ b. use a map or website to show them the places.
- ☐ c. give them a copy of the printed itinerary.
- ☐ d. phone, text or email them.

4. You are going to cook something as a special treat for your family. You would::

- ☐ a. cook something you know without the need for instructions.
- ☐ b. ask friends for suggestions.
- ☐ c. look through the cookbook for ideas from pictures.
- ☐ d. use a cookbook where you know there is a good recipe.

APPENDIX A (continued)

5. A group of tourists want to learn about the parks or wildlife reserves in your area. You would:

- ☐ a. talk about, or arrange a talk for them about parks or wildlife reserves.
- ☐ b. show them internet pictures, photographs or picture books.
- ☐ c. take them to a park or wildlife reserve and walk with them.
- ☐ d. give them a book or pamphlets about the parks or wildlife preserves.

6. You are about to purchase a digital camera or mobile phone. Other than price, what would most influence your decision?

- ☐ a. Trying or testing it.
- ☐ b. Reading the details about its features.
- ☐ c. It is a modern design and looks good.
- ☐ d. The salesperson telling me about its features.

7. Remember a time when you learned how to do something new. Try to avoid choosing a physical skill, eg. riding a bike. You learned best by:

- ☐ a. watching a demonstration.
- ☐ b. listening to somebody explaining it and asking questions.
- ☐ c. diagrams and charts - visual clues.
- ☐ d. written instructions - e.g. a manual or textbook.

8. You have a problem with your knee. You would prefer that the doctor:

- ☐ a. gave you a web address or something to read about it.
- ☐ b. used a plastic model of a knee to show what was wrong.
- ☐ c. described what was wrong.
- ☐ d. showed you a diagram of what was wrong.

9. You want to learn a new program, skill or game on a computer. You would:

- ☐ a. read the written instructions that came with the program.
- ☐ b. talk with people who know about the program.
- ☐ c. use the controls or keyboard.
- ☐ d. follow the diagrams in the book that came with it.

10. I like websites that have:

- ☐ a. things I can click on, shift or try.
- ☐ b. interesting design and visual features.
- ☐ c. interesting written descriptions, lists and explanations.
- ☐ d. audio channels where I can hear music, radio programs or interviews.

11. Other than price, what would most influence your decision to buy a new non-fiction book?

- ☐ a. The way it looks is appealing.
- ☐ b. Quickly reading parts of it.
- ☐ c. A friend talks about it and recommends it.
- ☐ d. It has real-life stories, experiences and examples.

12. You are using a book, CD or website to learn how to take photos with your new digital camera. You would like to have:

- ☐ a. a chance to ask questions and talk about the camera and its features.
- ☐ b. clear written instructions with lists and bullet points about what to do.
- ☐ c. diagrams showing the camera and what each part does.
- ☐ d. many examples of good and poor photos and how to improve them.

13. Do you prefer a teacher or a presenter who uses:

- ☐ a. demonstrations, models or practical sessions.
- ☐ b. question and answer, talk, group discussion, or guest speakers.
- ☐ c. handouts, books, or readings.
- ☐ d. diagrams, charts or graphs.

14. You have finished a competition or test and would like some feedback. You would like to have feedback:

- ☐ a. using examples from what you have done.
- ☐ b. using a written description of your results.
- ☐ c. from somebody who talks it through with you.
- ☐ d. using graphs showing what you had achieved.

15. You are going to choose food at a restaurant or cafe. You would:

- ☐ a. choose something that you have had there before.
- ☐ b. listen to the waiter or ask friends to recommend choices.
- ☐ c. choose from the descriptions in the menu.
- ☐ d. look at what others are eating or look at pictures of each dish.

16. You have to make an important speech at a conference or special occasion. You would:

- ☐ a. make diagrams or get graphs to help explain things.
- ☐ b. write a few key words and practice saying your speech over and over.
- ☐ c. write out your speech and learn from reading it over several times.
- ☐ d. gather many examples and stories to make the talk real and practical.

Submit

APPENDIX B

CPR Cognitive Test

*1 Enter the Participant ID number assigned to you from the VARK survey results.

*2 Enter your "Visual" score from the VARK survey results.

*3 Enter the "Aural" score from the VARK survey results.

*4 Enter the "Read/Write" score from the VARK survey results.

*5 Enter the "Kinesthetic" score from the VARK survey results.

*6 **What would you do if you feel a pulse or more than 60 beats per minute, but the child is not breathing?**

- Attach the AED
- Give 1 breath every 3 to 5 seconds. Each breath should make the child's chest rise
- Shake the child vigorously
- Sweep the mouth for 2 minutes before giving breaths

*7 **What is the first step in relieving severe choking in a responsive adult?**

- Perform blind finger sweeps for 2 minutes
- Use abdominal thrusts to relieve the obstruction
- Provide breaths that make the chest rise
- Perform chest compressions that are fast and deep

*8 **What is the first thing you do if the arrest was unwitnessed and you are alone and find an unresponsive adult?**

- Activate the Emergency Response System after checking the adult's pulse
- Activate the Emergency Response System as soon as the adult is found
- Activate the Emergency Response System after 5 cycles of CPR
- Shout for help

*9 **What would you do when finding an unresponsive child with no pulse?**

- Sit up the child and leave to activate the emergency response system
- Give rescue breaths for at least 2 minutes before starting chest compressions
- Start chest compressions and ventilations in a ratio of 30:2. If two rescuers are present use 15:2 ratio
- Perform blind finger sweeps followed by 10 rescue breaths

*10 **What would you do to check for adequate breathing in an unresponsive adult victim with agonal gasps, before giving breaths?**

- ◯ Listening carefully for gasps because they are signs of adequate breathing
- ◯ Sweep the mouth with a finger for anything blocking the airway
- ◯ Look. Listen and feel for breathing with your face near the victims nose and mouth. Agonal gasps are not signs of adequate breathing
- ◯ Place one hand over the mouth of the victim to feel signs of airflow

*11 **What should you do if an adult victim becomes unresponsive while you are doing abdominal thrusts for severe choking?**

- ◯ Keep the victim upright and perform 5 chest thrusts
- ◯ Give chest thrusts for 2 minutes, then begin CPR
- ◯ Lay the victim on the floor and continue abdominal thrusts
- ◯ Begin CPR. When you open the airway, look for and remove any object (if seen) before giving rescue breaths

*12 **When should you start chest compressions with breaths for an adult?**

- ◯ The victim is responsive but is complaining of chest discomfort lasting more than 15 minutes
- ◯ The victim has a pulse but cannot breathe adequately
- ◯ The victim shows signs of severe choking
- ◯ The victim is unresponsive, is not breathing, and does not have a pulse.

*13 **What might happen if you touch the victim while the AED is delivering a shock?**

- ◯ The AED is not able to deliver shock if you touch the victim
- ◯ The AED could shock you while it is shocking the victim
- ◯ The AED might mistake any movements as the victim's pulse and not deliver a shock
- ◯ The AED will always start analyzing the rhythm if you touch the victim

*14 **What is the best way to open an unresponsive victim's airway when cervical spine injury is not suspected?**

- ◯ Use the thumb to lift the chin
- ◯ Use a mask while giving breaths to the victim
- ◯ Use the Head tilt-chin lift
- ◯ Use the tongue lift-finger sweep

*15 **What would be the next step when finding an unresponsive victim with agonal gasps, and you have sent someone to activate the emergency response system?**

- ◯ Place the victim in recovery position as agonal gasps are signs of adequate breathing
- ◯ Open the airway and give 2 breaths
- ◯ Open the victim's mouth and look for a foreign object
- ◯ Give rescue breaths for at least 2 minutes before starting chest compressions

*16 **What should you do when using and AED on an adult victim and the AED gives a "no shock indicated" (or "no shock advised") message?**

- ◯ Place the victim in recovery position and wait for advanced care personnel to arrive
- ◯ Start CPR beginning with chest compressions
- ◯ Give 8-10 breaths per minute
- ◯ Check if the victim has a pulse or normal breathing

*17 **Why is it important to deliver early defibrillation to an adult?**

- ◯ The most effective treatment for sudden cardiac arrest is synchronized cardioversion
- ◯ The most frequent initial rhythm in witnessed sudden cardiac arrest is atrial fibrillation
- ◯ The probability of successful defibrillation diminishes rapidly over time
- ◯ Early defibrillation can improve spontaneous breathing

The remaining questions are demographic questions about you the subject. Please complete the questions to the best of your ability.

*18 **Your age is**

[ ]

*19 Your gender is

Choose...

*20 **Your Race is**

- ◯ Caucasion
- ◯ Native American
- ◯ Hispanic
- ◯ African American
- ◯ Asian
- ◯ Other

21 **If other please write your race**

[ ]

*22 **Visual Status**

- ◯ Do you have any uncorrected visual problems that you are aware of
- ◯ Do you have any known visual problems that prevent you from seeing the computer screen well.
- ◯ Do you currently wear glasses or contact lens
- ◯ I do not have any visual problems

*23 **Auditory Status**

- ◯ Do you have any uncorrected auditory problems that you are aware of
- ◯ Do you have any known auditory problems that prevent you from hearing audio files
- ◯ Do you currently use any hearing assistive devices
- ◯ I do not have any auditory problems

*24 **How would you describe your overall skills in using computers:**

- ○ Novice user: New to computers and have limited skills such as using the Internet, email, and basic functions of a few computer programs.
- ○ Fairly skilled user: Can perform basic operations such as using the Internet, email, and use several different computer programs well.
- ○ Skilled user: Can use advanced features of the Internet and email including downloading and installing plug-ins; can use multi-media features; can install software; can use numerous programs skillfully.
- ○ Power user: Can use advanced features of the Internet and email; use advanced multi-media features; install software and learn new software frequently and easily; can install new hardware components and drivers; can tune-up and optimize my computer's functioning.

*25 **Which of these best describes your past experience with virtual training programs**

- ○ Do not know what a virtual training program is
- ○ Know what a virtual training program is, but have never used one
- ○ Have used a few virtual reality training programs
- ○ Have used several virtual training programs
- ○ Have used numerous virtual training programs

Submit questionnaire

VITA

Gary Paul Dotterer

Candidate for the Degree of

Doctor of Philosophy

Dissertation: THE EFFECTS OF MULTIPLE-CHANNEL TECHNOLOGIES AND LEARNING STYLES ON PROCEDURALIZED INSTRUCTION IN A VIRTUAL ENVIRONMENT

Major Field: Education (Occupational Studies)

Biographical:

Education: Completed the requirements for the Doctor of Philosophy in Education (Occupational Studies) at Oklahoma State University, Stillwater, Oklahoma in December, 2011.

Completed the requirements for the Master of Science in Teaching, Learning, and Leadership at Oklahoma State University, Stillwater, Oklahoma in May, 2003.

Completed the requirements for the Bachelor of Science in Mechanical Design Engineering Technology at Oklahoma State University, Stillwater, Oklahoma in May, 1989.

Experience: Northeast Technology Center, 2000 – present
Tulsa Community College, 1998 – 2000
GDMD Inc, 1995 – 2001
World Connect Communications, 1996 – 1999
Butala Construction Co., 1995 - 1996
Stan Clark Companies, 1987 - 1995

Professional Memberships: Omicron Tau Theta, Academy of Human Resource Development, Rocky Mountain Educational Research Academy, National Association of Industrial Technical and Teacher Educators, OKC Webmasters Group, Skills USA, National Education Association, Oklahoma Education Association, Association of Career and Technical Education, Oklahoma Association of Career and Technical Education

Name: Gary Paul Dotterer Date of Degree: December, 2011

Institution: Oklahoma State University Location: Stillwater, Oklahoma

Title of Study: THE EFFECTS OF MULTIPLE-CHANNEL TECHNOLOGIES AND LEARNING STYLES ON PROCEDURALIZED INSTRUCTION IN A VIRTUAL ENVIRONMENT

Pages in Study: 231 Candidate for the Degree of Doctor of Philosophy

Major Field: Education – Occupational Studies

Scope and Method of Study:

No research has examined the effects on performance outcomes when learning style preferences and multiple-channel interactive media integrated with assistive technologies are delivered through an online virtual learning environment (VLE). When innovative multi-channel technologies are introduced in online virtual environments to deliver instructional content, this media-rich content may not be accessible for all learners unless assistive technologies can be successfully included. As online VLEs increase in popularity and are able to handle sophisticated and complex media, the lack of effectiveness data and the ability to support multi-channel assistive technology devices are problematic. This quasi-experimental study examined the effects on performance outcomes when the cognitive portion of the cardiopulmonary resuscitation certification process were delivered using three multiple-channel treatments with assistive technologies through an online VLE. A purposive sample of 284 CareerTech technology center and two-year associate degree trade community college students were administered the VARK (visual, aural, read/write, kinesthetic) learning styles survey and were then randomly assigned to one of three multi-channel treatments followed by a CPR cognitive post-test. Post-test data were analyzed with 2-way factorial ANOVA.

Findings and Conclusions:

No main effects for treatment or for VARK learning style, or interaction of these two factors, were found. Based on these findings plus those from a pilot study and literature review, several conclusions were drawn, including:

1. Learning style as defined by VARK (i.e., related to preferred stimulus input modality) is not a contributor to performance in an online VLE using multi-channel assistive technologies. This supports a growing literature contention that learning styles may not be as important as many believe. Further, these styles do not appear to interact with specific combinations of media.
2. Many combinations of multi-channel media can contribute equally well to learning. This supports the effectiveness of assistive technologies in VLEs to provide access for all learners. It also suggests that instructional *design* may be more important for learning than specific combinations of media.

ADVISER'S APPROVAL: Lynna J. Ausburn, Ph.D.