THE INSTRUCTIONAL EFFECTS OF DIAGRAMS AND TIME-COMPRESSED INSTRUCTION ON STUDENT ACHIEVEMENT AND LEARNERS’ PERCEPTIONS OF COGNITIVE LOAD

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ABSTRACT

The purpose of this study was to examine the effects of visual representations and time-compressed instruction on learning and learners’ perceptions of cognitive load. Time-compressed instruction refers to instruction that has been increased in speed without sacrificing quality. It was anticipated that learners would be able to gain a conceptual understanding of technical material at normal and moderately compressed (25%) speeds while instruction presented at 50% compression would depress it. Visual representations (images/diagrams) have been shown to support learning from a multimedia environment when presented with verbal representations. Thus, it was anticipated that visuals would support learning in a time-compressed environment.

This study employed 216 undergraduate students from a medium sized university in a 2x3 factorial design. The independent variables were visuals (visual, no-visual) and compression rates (0%, 25%, 50%). Participants listened to audio instruction of the heart and those in the visuals condition also viewed 19 diagrams that corresponded to the verbal instruction. The dependent variables consisted of four achievement tests: drawing, identification, terminology, and comprehension. Total test, Review Behaviors (back and replay buttons), time-on-task, and perceptions of cognitive load served as additional dependent variables. Prior knowledge of biology was also measured and considered for use as a covariate.

Overall, scores on the knowledge-based posttest measures indicate that learning is not significantly affected at the 25% rate, but it is depressed at the 50% compression rate. Participants who listened to compressed instruction at the 50% rate obtained lower scores on the total, drawing, and identification tests than did those in who listened to either
uncompressed instruction or instruction at the 25% compression rate. There was also an
affect of visuals on learning. Participants who viewed visuals obtained higher scores than
those who did not view visuals for the total, drawing, identification, and terminology
tests. Additionally, there was visual by compression interaction for the comprehension
test, which indicated that at 25% compression, high-level knowledge is depressed unless
visuals are presented.

The cognitive load measure indicated that normal and moderately compressed
(25%) instruction use a similar amount of cognitive load, however this is increased at
50%. Participants who viewed visuals indicated they used less cognitive load than did
those participants who were not presented visuals. Although participants could review the
material, the uncompressed version took the greatest amount of time. The 25%
 compression group took longer than the 50% compression group.

In sum, the results of this study indicate that listening to normal or moderately
compressed (25%) instruction in a multimedia environment supports learning. At these
speeds, cognitive load is not increased thus allowing learners to gain a conceptual
understanding of the material.
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Within the last decade, the use of auditory instruction and communication has dramatically increased, due in part to an increasing interest and growth in technology, the Internet, and online education. A report by Bridge Ratings (2006) revealed that at least 6.3 million Americans had listened to or downloaded a digital audio file in 2006 and estimates that this number will increase to 21.7 million by 2010. These numbers represent a cultural shift to adopt audio technology and suggest a substantial increase in the use of audio in the future. This impact has influenced educators to experiment with and implement digital audio technology in both classroom and online-based environments (Descy, 2005). This interest creates a corresponding need for research that will lead to the development of instructional strategies to guide the effective use of audio technology.

In light of new advances in technology, audio is becoming easier to use and create. It has become a popular form of communication due to podcasting, audio and video conferencing tools, and websites such as youtube.com and itunes.com. The term podcast refers to a digital mp3 file that can be in the form of audio, video, and/or audio and static images (Pastore and Pastore 2007; Lucking, Purcell, and Christmann, 2006). Not only is audio becoming popular, but it has also become mobile with mp3 players, laptops, and other portable devices, giving users the ability to play podcasts anywhere and anytime (Stoten, 2007).
Although auditory instruction has gained popularity, its use in the past has not been viewed as practical because of the time needed to listen to an auditory representation, in contrast to the time needed to read it (Goldstein, 1940). Consequently, attention has turned to increasing the speed of auditory instruction, otherwise known as time-compressed instruction. Time-compressed instruction refers to audio speech that has been increased in speed without sacrificing quality of output (Arons, 1992). However, scant research has focused on the use of time-compressed instruction because there wasn’t a need for it as it wasn’t convenient to reproduce. For instance, in the past, speech needed to be compressed at recording studios. This made it extremely difficult for the everyday user to create and almost impossible to employ in a classroom setting without advanced technology and funding. Today, the technology to create, use, and implement it are widely available. Speech compression technology is now available to everyone, is easy to implement, and today’s fast paced digital world encourages it.

Since this technology is now only recently viable for broad-scale use, research needs to catch up. Indeed, Hill, Wiley, Nelson, and Han (2004) have noted, “…we have yet to develop a clear understanding of the impact these technologies have had and are having on the processes of learning. Theoretical and research foundations have not kept pace with technological growth and use.” (p. 434). Consistent with a design-based research perspective (The Design-Based Research Collective, 2003), both research and theory are needed for classroom-based implementations of these new technologies. Additionally, the prevalence of podcasting has certainly increased interest in time-compressed instruction.
Although the research base is thin, there is some empirical evidence suggesting that time-compression can be applied to instructional materials without diminishing learning. Past research has shown that instruction, presented as audio can be compressed up to 50% without sacrificing intelligibility and recall (Heiman, Leo, & Leighbody, 1986). Intelligibility refers to the ability to repeat what was heard. However, much of this past research has focused on recall and has not addressed higher-level learning. Additionally, this research has failed to examine time-compression within different learning environments i.e., multimedia/computer-based environments. In sum, early research on time-compressed instruction focuses on factual learning but does not address high-level learning or learning in computer-based environments. Thus, many questions remain on the conditions for its use in learning environments.

The advantages of the technology that can be used to deliver instruction today are not limited to time-compression. One particularly important advantage is the ease with which visual representations can be incorporated with audio instruction (Mayer, Heiser, & Lonn, 2001). The substantial body of research on the multimedia principle consistently demonstrates that knowledge acquisition increases when learners study visuals along with verbal representations (Schnotz & Lowe, 2003; Mayer, 2001). Multimedia learning refers to a combination of verbal (text or narration) and non-verbal (diagrams, symbols, and images) representations that are designed to aid learning (Mayer, 2005). A study by Mayer and Anderson (1992) examined multimedia learning and found that participants presented verbal and non-verbal representations concurrently performed better on problem solving measures than participants who were presented only a single representation. Similar results can be found throughout the multimedia literature.
The multimedia effect has also been explored in relation to less traditional instructional contexts. Eilam and Poyas (2008), for instance, investigated the effects of multimedia instruction (text and pictures) to text only instruction on cell phones. Learners in the multimedia condition scored significantly higher on recall and transfer measures demonstrating that the multimedia effect transfers to the cell phone delivery system.

While research on multimedia has focused on audio and visual representations, rarely has it examined the use of compressed audio (time-compressed instruction). Most of the studies on time-compressed instruction were conducted before multimedia was a common form of content delivery. Current multimedia literature focuses on verbal representations comprised of text, audio, or spoken words, not time-compressed instruction. A purpose of this study is to examine if the multimedia effect transfers to time-compressed audio instruction and if the effects of these visual representations are the same at different rates of compression. Examining visual representations in a time-compressed environment is important given the impacts of visuals on multimedia. The use of visuals in conjunction with verbal representations has been shown to reduce cognitive load by effectively utilizing working memory channels (Tindall-Ford, Chandler, & Sweller, 1997). Thus, there is a potential for visuals to have an impact on time-compressed instruction given that cognitive load is expected to increase as compression increases.

In addition, presenting learners with audio and visuals is preferred to presenting text and visuals (Low & Sweller, 2005). When learners are presented with text and images they need to split their attention between representations. This leads to an increase
in cognitive load. Presenting learners with audio and images does not require learners to split their attention between representations (Mayer, Heiser, and Lonn, 2001; Jeung, Chandler, & Sweller, 1997). Thus, utilizing a combination of audio and visual representations in multimedia results in a better use of cognitive resources. This has important implications for the use of multimedia, comprised of time-compressed audio and visual representations, in the classroom environment.

Instructional design recommendations for time-compressed instruction are scarce. Not only that, but also the technology, compression methods, and student comfort level with technology have drastically changed since much of the original research on time-compressed instruction was conducted. This creates a need to re-explore this topic. Many questions remain regarding the use of time-compressed instruction in different learning environments (Olsen, 1985). New research in this area could lead to instructional design recommendations for its use and application.
Purpose Statement

The purpose of this study is to investigate the effects of visual representations and time-compressed instruction on student achievement. The following design factors, visuals (visuals and non-visuals) and time-compressed instruction (0%, 25%, and 50%) were presented to university students to analyze learning in a multimedia environment. Instructional materials were originally developed by Dwyer (1965) and consist of a 2,000-word script with 19 simple line drawings on the human heart and its parts. Criterion measures include a pre-test, four posttests (drawing, terminology, identification, and comprehension), time-on-task, Review Behaviors (back and replay buttons pressed during condition), and cognitive load. It is anticipated that the results will lead to instructional recommendations on time-compressed instruction in a multimedia-learning environment as well as contribute to the literature base on multiple external representations (MERs).
Research Questions

1. How does time compressed instruction affect learning?
2. How do visuals affect learning?
3. How do visuals and time-compression interact to affect learning?
4. How does time compressed instruction affect cognitive load?
5. How do visuals affect cognitive load?
6. How do visuals and time-compression interact to affect cognitive load?
Hypotheses

1. There will be an effect of compression. Participants who listen to 0% (regular speech) and 25% compressed instruction will perform better on knowledge-based posttests measuring different educational learning objectives than will participants given 50% compressed instruction.

2. There will be an effect of visuals. Participants who view visuals will perform better on knowledge-based posttests measuring different educational learning objectives than will participants who do not view visuals.

3. There will be a visual by compression interaction on knowledge-based posttests measuring different educational learning objectives. Visuals will support learning for the uncompressed and moderately compressed (25%) groups but will not for the 50% group.

4. There will be an effect of compression. Learners’ perceptions of cognitive load will increase as compression increases.

5. There will be an effect of visuals. Participants who are provided visuals will perceive lower levels of cognitive load than will participants who are not provided with visuals.

6. There will be a visual by compression interaction on learners’ perceptions of cognitive load. Visuals will depress cognitive load at 0, and 25% compression yet will not have an effect at 50% compression.
Rationale for Hypotheses

Previous research has shown that participants who learn from multimedia (verbal and non-verbal representations) score higher on problem solving measures than those who receive a single media representation. As a result, participants in the visual condition are expected to obtain higher scores on measures of problem solving but not on measures of factual recall. Additionally, participants in the visual condition are expected to score higher on the drawing test than those in the non-visual condition. Previous research has rarely, if ever, examined the effects of time-compressed instruction on different types of knowledge outcome measures. However, around the 50% compression marker, recall and intelligibility have been shown to significantly decrease. Thus, participants in the 50% compression condition are expected to score lowest on post-test measures.

The literature indicates that cognitive load is decreased when participants are presented with a multimedia presentation rather than a single media representation. Hence, it is expected that learners presented with visuals will have lower cognitive load scores than participants presented non-visuals. Furthermore, as compression is increased cognitive load is expected to increase. Tests for these differences will be conducted as indicated by the initial analyses of data.
**Definition of Terms**

**Time-compressed Speech** – Speech that has been recorded, and then modified by changing the tempo, without changing pitch, to an increased speed without sacrificing quality (Arons, 1992).

**Time-compressed Instruction** – Time-compressed speech designed to promote and enhance learning.

**Compression** – Amount or percentage that an audio file’s speed has been increased. An example of a time-compression percentage ratio would be a podcast that is 10:00 minutes in length at normal speed (0% compression) with 150 words per minute, would be 5:00 minutes in length with 300 words per minute when compressed 50%.

**Words per minute (WPM)** – The average amount of spoken words per minute of an audio file.

**Representation** – Described by Palmer (1978) as “something that stands for something else” (p.262). Representations are verbal and/or non-verbal forms of content. Examples include text, images, diagrams, and spoken words.

**External Visual Representation** – Representation comprised of images, pictures, graphs, or charts.
**External Verbal Representation** – Representation comprised of audio, text, or spoken words

**Multiple External Representations (MERs)** – The use of more than one representation at a given time in a multimedia-learning environment.

**Multimedia** – Representations presented together as words (text, words, audio) and visuals (images, video, animations, and graphs) (Mayer, 2005).

**Modality Effect/Principle** – Presenting spoken words and images better support learning than presenting text and images in a multimedia environment (Low & Sweller, 2005).

**Split-Attention Principle** – Describes a situation where learners are not required to split their attention between two representations. For instance presenting both text and images requires learners to view both sources. This increases cognitive load because they are trying to integrate two sources of information that are required for comprehension (Jeung, Chandler, & Sweller, 1997).

**Podcast** – A digital mp3 file that contains audio, video, or static images and audio (Pastore and Pastore, 2007; Lucking, Purcell, and Christmann, 2006).

**Auditory Instruction** – The use of spoken words to promote learning that were recorded electronically and delivered electronically via computer or mp3 player.
**Invariant Timing Hypothesis** - Learners cannot distinguish between the quality of audio when there is a tempo change (Honing, 2007).
CHAPTER 2

LITERATURE REVIEW

Overview

This study seeks to examine the effects of time-compressed instruction and visual representations on learning in a multimedia environment. The following chapter develops a theoretical justification for the questions posed in this study by reviewing the literature on information processing, cognitive load theory, dual-coding theory, levels of achievement, multiple representations, the multimedia effect, audio technology, time-compressed speech and technology, and time-compressed instruction. The chapter begins by explaining how we process verbal and non-verbal representations in a multimedia environment. Then a review of the multiple representation literature is presented along with a justification for using audio and visual representations in a multimedia environment. This is followed with a section addressing the need for compressed instruction. The chapter concludes by reviewing the compression literature, which reveals that there are limited studies on the manipulation of audio presentation speed on different types of outcome measures in a multimedia-learning environment. The study proposed here will explore the effects of compression when compressed audio presentations are combined with a multimedia-learning environment. Specifically, the study seeks to understand how compression affects learning and if the multimedia effect influences learners’ abilities to learn from compressed audio.
Theoretical Framework

*Information Processing*

Research on information processing began around 50 years ago when cognitive psychologists began studying the ways that humans and computers processed data. These psychologists created a model that illustrated how humans processed information. This model was later modified into levels of cognitive processing by Craik and Lockhart in 1972.

The study of information processing explores the way humans encode, store, and retrieve information from different levels of our memory, which helps to account for our cognitive processes. These levels range from shallow, sensory information, with a weak memory trace that may be received by short-term memory but not transferred to long-term memory to deep meaningful information, with a strong memory trace that is stored in our long-term memory and connected with prior knowledge.

The information-processing model suggests that when we first receive information it must be encoded. Encoding information is simply a way to code information so that it can be remembered. Once information is encoded, it must be stored in long-term memory so that it is not forgotten. After the information is stored, the learner will be able to retrieve it at a later date.

In 1968 Atkinson and Shiffrin developed a model theory of information processing (Huiit, 2003). This theory is based on three stages, or memory types that relate to the way we sense, process, and output information through sensory, short-term, and long-term memory. In the sensory memory stage the learner receives information and
immediately, must decide how to handle it so that it can be transferred to short-term memory or forgotten. A memory produced in this stage is short, “less than 1/2 second for vision; about 3 seconds for hearing” and is vital to entering the next stages of the process (Huitt, 2003, p. 1). The learner must attend to content that is vital to understanding the material in order to transfer it into short-term memory for use. As a result, when the speed of content presentation is increased, learners will have less time to decide what to attend to. This could limit the amount of content they deem important to remember.

Short-term memory, also referred to as “working memory”, is the next stage in the process (Atkinson & Shiffin, 1968, p. 92). In this stage, information can be used, processed into long-term memory, or forgotten. According to Miller (1956), we can store seven units of information, plus or minus two, in our short-term memory at any one time. The size of these units varies, however, depending on how meaningful the information is to the learner. The memory trace for the units in short term memory memories “will initially last somewhere around 15 to 20 seconds unless it is repeated (called maintenance rehearsal) at which point it may be available for up to 20 minutes” (Huitt, 2003, p. 1). There is not a lot of time to process content from short-term into long-term memory. As new information is being seen or heard it must be rehearsed in order to be remembered. Otherwise, working memory can become overloaded with content and thus the information forgotten. Thus information must be rehearsed/repeated in order for the information to be stored long-term memory. The last stage described in this theory is long-term memory, which is refers to memory that is held for a long period of time. Once knowledge is stored in long-term memory, it can be retrieved later.
Craik and Lockhart took a different approach to information processing in their levels of processing theory, which focuses on the thought process rather than stages of memory (Craik and Lockhart, 1972). The levels range from shallow to deep, where processing begins as structural processing. In structural processing we encode the physical properties and identify words and images leaving a weak memory trace. In the next level, the phonemic level, information is processed from sounds and rehearsal methods. Deep processing occurs from relationships that are formed from meaningful information units. This information has a strong memory trace. We begin to remember information in this level using elaboration rehearsal and relationship building strategies that help create a strong memory trace. This differs from information in the shallow levels that has a weak memory trace and can be easily forgotten.

In the 1960’s, researchers found that auditory instruction was processed differently than visual-based instruction. This led to multiple theories on audio and visual processing such as the dual coding and cognitive load theories. Similar to Atkinson & Shiffin’s (1968) levels theory, Baddley (1998) suggests that auditory memory can also be divided into three types of memory. These include echoic, working memory, and long-term. Baddley (1998) explains that the processing of sound begins with echoic memory, which can last around 250 milliseconds. This type of memory is an initial trace that is encoded and then placed into working memory for use. Short-term memory or working memory is defined as “a brain system that provides temporary storage and manipulation of the information necessary for such complex cognitive tasks as language comprehension, learning, and reasoning.” (Baddley, 1992, p. 556) and can last anywhere from 5-10 seconds. Finally, information in long-term memory can be stored for an
unlimited amount of time so that it can be used later. Long-term memory is stored more “…in terms of its meaning than its sound.” (Baddley, 1998, pg. 23).

Baddley’s memory model expands working memory to encompass a dual channel system. According to Baddley, audio and visual information enters the information processing system through separate channels and is processed in different memory systems. This theory of working memory expands the single processing system model and supports a dual channel processing system where representations (verbal and non-verbal) are processed in separate memory channels. The dual channels are connected through associative and referential connectors. The associative connections are based on meaningfulness and experience. Thus when the nodes are used more often, the links between them become stronger making them more likely to be retrieved. Schunk (2007) explains that these associative connections are made when “the more often that a fact, event, or idea is encountered, the stronger is its representation in memory. Furthermore, two experiences that occur closely in time are apt to be linked in memory, so that when one is remembered the other is activated” (p. 151). Referential connections link the verbal and visual systems together by connecting their units. Together these representations will then be activated when needed for use.

Sadoski, Paivio, and Goetz (1991) explain that these memory channels are organized into verbal and non-verbal systems or channels that are connected but can act independently. Baddley and Hitch (1974) suggest that working memory consists of two independent slave systems and a governing central executive. These two slave systems are comprised of a visual/spatial sketch pad (images/space) and a phonological loop (auditory/verbal/text). Each operates and functions independently and has a limited
capacity for storage and processing but is controlled by the central executive. The central executive controls how information units are processed, stored, and retrieved (Barron, 2004).

**Cognitive Load Theory**

The amount of information being processed in working memory at one time is referred to as cognitive load (Chandler & Sweller, 1991). Cognitive load theory (Sweller & Chandler, 1991) attempts to explain that there is a certain amount of information that can be used and stored in our working memory at one time without exceeding our processing capacity. This theory stems from the information-processing model that suggests that we have a limited working memory and unlimited long-term memory (Brunken, Plass, & Leutner, 2003). When cognitive load is increased, learning is depressed because our working memory channels are overloaded. Thus designers aim to decrease the amount of cognitive load in working memory so that learners understand the content presented and can put it into long-term memory for later use.

Cognitive load is comprised of three types of load that are referred to as extraneous, intrinsic, and germane (Sweller, Van Merrienboer, & Paas, 1998). Each of these types can be manipulated and affects learning separately. Intrinsic cognitive load refers to the instructional materials’ level of difficulty, such that information that is hard for the learners to interpret increases cognitive load. For instance, information that has high element interactivity can increase intrinsic load. Sweller (1994) suggests, "Information may be difficult to learn because it consists of many elements, but may impose a low cognitive load because the elements do not interact greatly. High element interactivity results in a high cognitive load, even if the total number of elements is
small” (p. 192). So if information has high element interactivity, for instance complex images, the elements may be more difficult to learn because they produce a high cognitive load. On the other hand, when the materials have low element interactivity and each element can be learned or presented on its own, there will be a low cognitive load placed on working memory. Pollock, Chandler, and Sweller (2002) demonstrated this in an experiment which sought to establish that students’ cognitive load would be more greatly affected when presented with either isolated interacting elements (low element interactivity) or interacting elements (high element interactivity). They presented industrial trade school students with material on electrical safety. After going through each treatment, participants were asked to rate their mental effort using a seven-point Likert-scale questionnaire. Learners in the low element interactivity instruction group scored higher on tests measuring recall and transfer than did learners in the high element interactivity condition. The authors indicated that participants’ cognitive load was reduced resulting in the higher scores. In sum, presenting learners with complex/high element activity representations can increase cognitive load and depress learning.

Extraneous cognitive load is affected by the design of the instruction. Thus, irrelevant information results in high cognitive processing. So reducing irrelevant activities will reduce cognitive load and increase comprehension. This is exhibited by Chandler and Sweller’s (1991) experiment that found reducing and/or eliminating unnecessary and redundant material decreased cognitive load and increased comprehension. Trade apprentices were given material on installation testing and then placed into groups of split source or integrated instruction. Participants in the integrated instruction condition obtained higher scores on recall and problem solving measures.
However, it should be noted that there was not a specific mental load measure used in this experiment other than the interpretation of the achievement tests. The authors suggested that the split format group performed worse because learners had to go back and forth between representations creating an increase in mental load. Instruction should be designed to reduce cognitive load. Representations should not contain irrelevant information, otherwise they may overburden working memory and increase cognitive load (Paas, Renkl, & Sweller, 2003).

Germane cognitive load refers to load that is generated by instructional activities that lead to schema development and automation (Moreno, 2006; Mayer, 2005). This takes place when learners’ working memory is not overburdened by intrinsic and extraneous cognitive load and they are able to use metacognitive and cognitive strategies to form schema that are placed into their long-term memory structure (Gerjets, Scheiter, & Catrambone, 2004). This is both desired and beneficial for learners who will be able to use the schemas when they are needed in working memory to reduce cognitive load.

Research on cognitive load theory has shown that reducing working memory burden will increase learner comprehension. Cognitive load theory suggests that instructional designers should focus on trying to reduce the load due to intrinsic and extraneous factors to allow for an increase in germane cognitive load. Thus learners are able to retain and store the information in their long-term memory for later use. Several specific recommendations have followed from these findings including, for example, Sorder’s (2005) caution that “activities should remain focused on the concepts to be learned, rather than trying too much to entertain” (p. 265). As a result, designers should focus on reducing redundant materials, such as unnecessary text/graphics/animations,
created for entertainment purposes that do not aid instruction and focus on strategies that support working memory capabilities. However, how do designers know what types of representations can be used in order to support learning? Paivio’s dual coding theory offers the explanation that different types of representations, verbal and visual, are processed differently in working memory because our memory is comprised of more than one processing channel (Paivio, 1986). Therefore, by utilizing these channels, comprehension can be improved.

**Dual Coding**

Verbal and non-verbal information is processed differently in our working memory suggesting a dual modal system (Penney, 1975). This dual modal system, also known as dual coding, implies that our memory is comprised of two memory channels that process information separately in working memory. The Dual Coding Theory (DCT) hypothesizes that our cognitive processes handle verbal (logogens) and visual (imagens) content in separate memory channels and that each has a certain capacity for information processing (Paivio, 1979). Paivio (1991) describes this as, "...a multiple coding theory, with a special emphasis on the fundamental importance of the verbal/nonverbal symbolic contrast" (p. 257). In Dual Coding Theory, verbal information can be described as text and words while visual information can be described as graphics and images. Paivio (1991) explains that, "Verbal and Nonverbal systems are assumed to be functionally independent in that one system can be active without the other or both can be active in parallel" (p. 259). As associative and referential connections are activated within and between the verbal and nonverbal systems, learning is improved. Thus if the memory channels complement one another, then working memory can be maximized in each
mode at the same time, hence the name, dual coding (Paivio, 1986). This helps decrease the load on working memory.

Mayer has applied Paivio’s DCT to understand learning from multimedia (Mayer & Sims, 1994). The result is the Cognitive Theory of Multimedia Learning (CTML) is comprised of three assumptions that are based on the memory models of both Baddley and Paivio: (1) working memory is made up of a dual modality input channel system, (2) there is a limited capacity in working memory, and (3) that learners engage in active processing. Dual modality is described as information that is processed in verbal and non-verbal channels. CTML assumes that each channel has a certain capacity for information processing in working memory. Therefore, the verbal and visual channels can each only process a certain amount of information at one time. Mousavi, Low, and Sweller (1995) state, "Effective cognitive capacity may be increased if both auditory and visual working memory can be used. Instruction may be enhanced by expanding working memory limits by simultaneous visual and aural presentation of information" (p. 321). When learners engage in active processing, they organize and process information in order to transfer it into their long-term memory. The underlying assumption in this theory is that learning is superior in a dual channel presentation (i.e., verbal and non-verbal) than in a single channel (Mayer & Moreno, 2003). Tindall-Ford, Chandler, and Sweller (1997) tested dual modality in a series of experiments that found audio-visual techniques improved achievement significantly over just a visual form. They note that:

If learners are required to split their attention between multiple sources of information that must be mentally integrated, a cognitive load is generated
that may result in working-memory capacity being exceeded. If visual and auditory working memories are partially distinct, total available working memory may be increased by using both processors rather than just the visual processor. An increase in the effect in size of working memory may only have consequences if the material being processed places a burden on working memory (p. 283).

Thus it appears that utilizing dual channels to complement one another is more effective than one channel because it reduces cognitive load. However, each of these channels must complement one another, otherwise working memory may become overburdened. Although text is a verbal representation when it is printed it is processed through the visual channel. Thus, images and text will both compete for the visual channel unless text is spoken. The modality effect demonstrates that presenting spoken words and images are more effective than text and images because working memory channels are not overburdened due to the split attention principle (Low & Sweller, 2005). Ayres & Sweller (2005) describe the split-attention principle as when, “…learners are required to split their attention between and mentally integrate several sources of physically or temporally disparate information, where each source of information is essential for understanding the material” (p. 135). When learners split their attention between text and visuals, they are increasing cognitive load because they are trying to integrate two sources of information that are required for comprehension (Jeung, Chandler, & Sweller, 1997). Mousavi, Low, and Sweller (1995) tested this assumption in a study, which found that presenting geometry content as spoken words and images was
more effective than presenting text and images. They suggest that participants presented
spoken words and images did not need to split their attention between representations
thus resulting in higher scores on problem solving measures. They found that when
effectively utilizing working memory, cognitive load was decreased, and comprehension
increased. Mayer and Anderson (1992) found that presenting spoken text and visuals
together increased comprehension as long as the two representations complement one
another. In two experiments conducted by Mayer, Heiser, and Lonn (2001) students were
presented with animation and narration or animation, narration, and text and then
presented with content on the formation of lightning. They were then assessed via
retention and transfer. In the first experiment, the text summarized the narration and in
the second experiment it duplicated the narration. In both experiments students scored
significantly higher in the no-text group than students who received the text. The authors
suggested that students who received the text had to split their attention between the two
visual sources requiring a high working memory load. This finding was replicated in a
study by Moreno and Mayer (1999b), which investigated the modality effect and spatial
contiguity with college students learning how lightning works. In the first experiment,
students were presented with narration and animation, animation with close (spatially)
text, and animation with far (spatially) text. In Experiment 2, students were presented
with concurrent text or narration or text or narration before or after animation. Then the
participants were assessed via recall, transfer, and matching ability. In both experiments
the groups who received the narration and animation scored higher on all measurements
than the other treatments supporting the modality effect. Brunken, Plass, and Leutner
(2004) uncovered similar findings in two experiments that sought to discover how
instruction presented to students, through verbal and pictorial, and textual and pictorial methods, affected their comprehension. In both experiments, the audio and pictorial groups obtained higher scores on problem solving measures. Multiple studies have revealed similar conclusions that support the modality effect (Mayer & Anderson, 1992; Mayer, Dow, & Mayer, 2003). In sum, eliminating irrelevant information and using verbal and non-verbal representations that complement each other, reduced cognitive load and increases comprehension increases.

Many studies have recommended the use of multiple representations in instruction because our working memory is comprised of a dual channel system where verbal and non-verbal information is processed in different working memory channels (Paivio & Csapo, 1969; Paivio, 1979; Clark & Paivio 1991). Therefore, when users are presented with visuals and auditory instruction, they are able to process both forms of information in separate memory channels. This reduces the strain on working memory. What is not clear, however, is how compression of audio may affect cognitive load. It is likely, for example, that increasing the speed of the instruction will also increase learners’ perception of cognitive load. Adding visuals to this compressed instruction may offset the effects of this load increase, however, so that learners who listen to compressed audio instruction while also viewing visuals will not be negatively affected by the compression rate. The current study seeks to investigate these relationships to understand how different compression rates and visuals interact to influence knowledge acquisition.

*Levels of Achievement*

In order to create effective instruction, information must be structured to promote comprehension and decrease cognitive load capacity. To accomplish this task, theorists
have developed learning taxonomies. Learning taxonomies attempt to organize levels of information that are processed differently in a hierarchal order to increase learner comprehension of the material presented (Gagne, 1985). The purpose of a learning taxonomy is to order learning objectives in a hierarchal structure where facts and concepts are presented as a prerequisite to problem solving. Nitko (2004) states “To assess higher-order thinking abilities, it is often necessary to develop tasks for which the solutions or answers depend on a particular piece(s) of introductory material presented along with them” (p. 232). Presenting information in the hierarchal structure allows designers to effectively align objectives in a structured way that complements instruction and augments comprehension. While there are several theorists who hold their own version of the learning hierarchal structure, they all share the same basic theoretical paradigm. Examples include the levels of complexity, the instructional consistency/congruency model, and the component display theory.

Gagne’s levels’ of complexity is a hierarchal learning taxonomy that aligns information in categories of facts, concepts, rules, and high-order rules or problem solving techniques (Gagne, Wagner, & Briggs, 1998). Gagne explains that in order for learners to be able to perform high-level tasks, such as rules and problem solving, they must first have the prerequisite facts and concepts. Gagne states:

In solving problems for which instruction has prepared them, learners are acquiring some higher-order rules (that is, complex rules). Problem solving requires that they recall some simpler, previously learned rules and defined concepts. To acquire these rules, learners must have
learned some concrete concepts, and to learn these concepts, they must be able to retrieve some previously learned discriminations. (Gagne et al., 1992, p. 54).

Dwyer (1978) encourages the use of an instructional consistency/congruency model that introduces prerequisite objectives prior to presenting information that is required to process high-level learning tasks, i.e., problem solving strategies. The instructional consistency/congruency model is structured similarly to Gagne’s levels and presents itself as levels of facts, concepts, rules/principles, and problem solving objectives. The model helps ensure that learning objectives, instructional content, and assessment items are congruent to each other so that information is both presented and assessed within the same level. Other models with similar theoretical foundations have been proposed as well. For example, Merrill’s Component Display Theory classifies “learning objectives (or capabilities) along two dimensions: performance level (remember, use, or find) and content type (facts, concepts, principles, or procedures)” (Ragan and Smith, 2004, p. 632). The purpose of these models is to ensure that instruction is designed in such a way as to promote learning. This helps ensure that the instructional methods and strategies being implemented are structured in a way that benefits learners' processing abilities.
Representations in Instruction

Multiple Representations

The use of multimedia in education has become increasingly important as the technology to design, develop, and use it are becoming more popular. Multimedia refers to a combination of verbal (text, words, audio) and non-verbal (images, video, animations, and graphs) representations (Mayer, 2005). The use of multiple external representations (MERs) in multimedia learning environments is an effective way to support learning and increase comprehension (Schnotz & Lowe, 2003). This directly relates to the CTML, where we can process more than one representation at the same time in working memory (Mayer, 2001). Processing of MERs in multimedia learning environments (MLE) begins in working memory where learners, with the aid of prior knowledge, create internal representations and store them into long-term memory (Seufert, 2003).

A representation is “something that stands for something else” and has been described by Palmer (1978) as (1) the represented world, (2) the representing world, (3) the aspects of the represented world being modeled, (4) the aspects of the representing world doing the modeling, and (5) the correspondences between the two worlds (p. 262). Markman (1999) describes the represented world as “the domain that the representations are about” (i.e., knowledge/information) and the representing world as “the domain that contains the representations” (i.e., visual/textual) (p. 5). Representations can be formed internally as mental representations and externally as external representations, both of which are understood as verbal (text/narration) and non-verbal (images/animations). Verbal and non-verbal representations are described as descriptions or depictions.
Descriptive representations are symbols, such as text, numbers, and narration; depictive representations are images, icons, or models (Schnotz & Bannert, 2003). Each of these forms has its advantages and thus they can be used to complement and/or hinder one another.

Ainsworth (1999a) proposed a taxonomy that describes the potential functions of MERs in instructional material. This taxonomy is based on three functions that MERs serve to accomplish in the learning process, which are to complement, constrain, and construct (Ainsworth, 1999b). In the complementary role, representations contribute to, support, and complement one another. The constraint function is served when the learner uses information from representation to constrain their understanding of a second representation. Text and pictures are symbolically different types of representations. So the text, “the man sits at the computer” does not describe what he is wearing, if he is typing, what color his hair is, etc. A picture of a man sitting at a computer will provide this information. Thus when using these two representations together, the image will interpret for the text. Constructing aids learners’ deep understanding and helps them form relationships among other mental representations. If multimedia-learning environments comprised of complementary external representations that support one another are presented to learners, such as static visuals and text, working memory can be utilized in a more effective capacity (Ainsworth, 2006).

This is consistent with findings that the type of representation presented influences learners’ processing. For example, Ainsworth and Th Loizou (2003) examined differences in college students’ verbalizations when students studied either text or a diagram describing the human circulatory system. Students presented diagrams generated
more explanations than those who were not. Results of posttests, which included drawing, multiple choice, and short answer questions, revealed that participants presented with the diagrams obtained higher scores than did those who studied the text on all measures.

Butcher (2006) extended this research by studying the self-explanations that learners generate when studying text. In this research, college students learned about the human circulatory system by studying text alone, text with simple images, or text with complex images. Participants in the simple image with text treatment obtained higher scores on drawing, memory, and inference tasks than the complex image with text and text only treatments. The author concludes that presenting images with text is better than text alone and recommends that the image should contain only relevant information. Otherwise, as was seen in the complex image group, cognitive load will be increased to a point that the image no longer helps learning but inhibits it. Similar studies have shown that multiple representations, when used properly in instruction, can increase comprehension and achievement (Dwyer, 1978; Mayer & Anderson 1991). This suggests that using multiple representations appropriately in multimedia instruction can increase the amount of content that can be processed in working memory, increase comprehension, and reduce cognitive load.

**The Multimedia Effect**

Previous research has demonstrated that presenting learners with verbal and non-verbal representations in a multimedia environment is better than presenting a single representation. This is referred to as the multimedia principle (Mayer, 2001) and has been demonstrated in a myriad of experiments (Tindall-Ford, Chandler, & Sweller, 1997;
Mousavi, Low, & Sweller 1995). The multimedia principle suggests that using a combination of verbal and non-verbal representations can improve learning (Schnotz & Lowe, 2003; Eilam & Poyas, 2008). However, research has shown that not all combinations of verbal and non-verbal representations equally support learning in a multimedia environment. According to the modality effect, presenting learners with spoken words and images promotes learning better than text and images (Low & Sweller, 2005). When learners are presented with text and images they are required to split their attention between representations often referred to as the split-attention principle. This causes an increase in cognitive load. When learners are presented with audio and images they do not need to split their attention between representations, which means that the load is not increased. For that reason, presenting a combination of visual and audio representations in multimedia instruction reduces cognitive load and increases learning.

In sum, the use of multiple representations in a multimedia environment improves learning over just a single representation. In accordance with the modality effect, presenting learners with spoken words and visual representations appears to better utilize cognitive resources. This method of multimedia presentation is recommended as an instructional delivery format as it utilizes cognitive resources and supports learning. These instructional design recommendations should be taken into consideration when developing multimedia instruction.
Time-Compressed Instruction

Audio Technology

The use of auditory instruction and communication is becoming increasingly popular in the online world due to new technology, convenience, and learner preference (Newberry, 2001). However, auditory technology was not always convenient. When audio instruction first began to appear online it was not manageable, there were quality issues, and the audio was difficult to produce. As the Internet grew in popularity in mid 1990’s, auditory technology was still uncommon on the world-wide-web. The sound files required a great deal of memory, audio editing software was expensive and uncommon, and internet connections were very slow, which meant that it took a long time to download or upload these files.

Today, however, auditory technology is easy to use. It has become a common form of expression and communication on the Internet due to technologies such as the mp3 player and the popularity of podcasting. The term podcasting is used to describe digital-voice sound files that are available for download onto a computer, mp3 player, or other mobile device. The most common way to play these popular sounds files is on Apple’s iPod. In addition to being used for personal use, podcasts are being widely used in classrooms (Descy, 2005). This increase in use for both persons and educational institutions is mainly due to the ease that audio podcasts are to create and distribute. All computers have the ability to record sound files and podcasts for online use. The software to create and edit these files is free and is included on many computers. Not only that, but Internet speeds have dramatically increased so that they can handle the transfer of large audio files quickly.
While iPods and podcasts are becoming popular, it takes longer to listen to a podcast than to read the same dialogue in text format. Consequently, several models of Apple’s iPod include a feature that allows the user to increase the speed of the audio file (podcast) without changing the quality of the sound. Most free sound-editing programs include this feature as well. This time-saving (compression) feature gives users the ability to listen to the audio file at least as quickly as the information could be read. As a result, there has been a growing interest in compressing audio in a learning environment to understand if it is an effective means of content delivery. Despite the increase in popularity of these delivery systems, little research has been conducted that would help us to understand how compression affects learning and if multimedia learning principles hold when learners study audio material that is presented at a more rapid pace.

Time-Compressed Speech and Technology

When researchers first began experimenting with compressed sound they increased the speed of the audio, which changed both the pitch and tempo. This changed the sound quality and gave the audio a fast paced chipmunk-like effect that could not be understood and/or was very distracting. In order to solve this problem, more sophisticated algorithms were applied so that tempo could be changed without altering the pitch. Orr and Friedman (1967) explain that time-compressed speech means changing the beats per minute, otherwise known as the tempo, without changing the quality of the speaker or the pitch. In other words, time-compression with the technology that is widely available today means speeding up the audio without sacrificing quality.

Most time compression techniques involve tempo changes. The act of changing the tempo while preserving the pitch is referred to as the invariant timing hypothesis.
(Honing, 2007). This hypothesis states that one cannot distinguish between the quality of audio when there is a tempo change. This hypothesis makes time-compressed instruction a feasible method of instruction. Honing (2006) conducted a series of experiments to test this hypothesis. It was revealed that while users could distinguish between the original and modified versions, they could not find significant differences in the quality. This suggests that a tempo change can be used to increase or decrease audio speed, without sacrificing quality. Similar results were uncovered by Reed (2003) who investigated whether users could identify when tempo was changed. It was discovered that users could not distinguish between the original piece and a 20% compression rate. Although it was noted that users seemed to prefer the original. Therefore, it appears that a change in tempo is an acceptable way to compress speech.

Early studies on time-compressed instruction were forced to use professional audio services for compression. Today, one can change the tempo of an audio file in a matter of minutes with very little audio technology experience. Not only is it simple to do but the software to carry out task is available for free. For example, Audacity™, a free sound editor can change the tempo of a 10-minute sound file in seconds.

Many methods and algorithms have been developed to compress speech without sacrificing sound quality. The most popular and recognized methods include synchronized overlap-add method (SOLA) (Barron, 2004) and its variations, which include Pitch Synchronous Overlap Add Method (PSOLA) and Waveform Similarity Overlap Add (WSOLA). SOLA can be described as a method that “consists of shifting the beginning of a new speech segment over the end of the preceding segment to find the point of highest cross-correlation. Once this point is found, the frames are overlapped and
averaged together, as in the sampling method” (Arons, 1992, p. 4). WSOLA, an updated version of SOLA, is described as an efficient method of compressing speech with very high quality (Roelands & Verhelst, 1993). Roelands and Verhelst (1993) state that, “WSOLA algorithm produces high quality speech output, is algorithmically and computationally efficient and robust, and allows for on-line processing with arbitrary time scaling factors that may be specified in a time-varying fashion and that can be chosen over a wide continuous range of values.” (p. 1). Although there are many different methods and algorithms currently being used to compress speech, one has yet to stand out above the rest because they all reach a ceiling effect and produce equal quality (Janse, Nooteboom, & Quene, 2001; Roelands & Verhelst, 1993)

**Time-Compressed Instruction**

Research on time-compressed instruction began in the 1940’s when the technology to develop quality-compressed sound became available. Initial research on time-compressed instruction looked at comprehension, intelligibility, efficiency, and learner characteristics (Duker, 1974). Early interest in time-compressed instruction began when researchers started looking at the rate in which people read and spoke. They found that auditory speech could be sped up to a certain extent without sacrificing comprehension. Literature shows that normal speech rate is between 120-180 words per minute (Monroe & Ehninger, 1974) and averages around 150 words per minute (Benz, 1971). The average reading speed for adults is around 280 wpm (Taylor, Frankenpohl, & Pettee, 1960). As a result, researchers concluded that we may be able to listen as fast as we read, if not faster.
It has been established that learners can understand and comprehend compressed speech up to a certain compression ratio just as well as normally-paced speech (Orr, 1968). Results of the studies on time-compressed speech comprehension can be seen in Table 2.1. For example, Foulke and Sticht (1967) conducted a study at the University of Louisville that sought to measure student comprehension of compressed speech. Auditory instruction was recorded by a professional speaker at a rate of 175 words per minute and was compressed using a tempo regulator to 225, 275, 325, 375, and 425 words per minute. This corresponds to compression rates of 22%, 36%, 46%, 53%, and 59%. The 0% or no compression marker was not analyzed or measured in this study. Students listened to five different recordings with a tape recorder and headsets and then were given 35 multiple-choice questions. The study revealed that there was a 6% difference in comprehension from the 22% compression marker to the 46% marker. There was a 17% overall loss in comprehension when rates were increased from 22% to 53%. Hence, this study suggests that comprehension is adversely affected when the compression rate reaches the 50% marker. It is important to note that this is one of the few studies on time-compressed instruction that used compression ratios instead of words per minute, as this point will be brought up later in this paper.

Similar findings were uncovered by Foulke (1968) who studied the effects of compressed instruction on comprehension. Participants in this study listened to a 2,925-word script that was designed for the college population and then completed a 50 item multiple-choice test. However, the content of the script and knowledge level tested was not revealed. The instruction consisted of 12 time-compressed recordings ranging from 125 to 400 words per minute that were recorded by a professional speaker. Foulke found
that after 275 words per minute, comprehension (recall) significantly decreased from the normal paced recording. Similar results were revealed in a study by Sticht (1968) who found that comprehension holds constant and then rapidly deteriorates after 36% compression. Thus research has shown that student comprehension does not decrease significantly until around 36% to 50% compression (He & Gupta, 2001) or 275 to 325 words per minute (Olsen, 1985).

In most cases, previous research on time compression used words per minute to describe time compression. These studies found that at around 275 wpm, comprehension is significantly decreased (Foulke, 1968; Sticht, 1968). While it is possible to calculate the compression if several words per minute calculations are provided, the compression ratios were not discussed in many of these studies. The problem with the words per minute descriptor of time-compressed instruction is that the past studies relied on the speakers to pace themselves at a certain words per minute rate, even though normal speech can vary from 120 to 180 (Monroe & Ehninger, 1974). The results of these studies recommend that a speaker read at a certain wpm ratio and that instruction can be compressed up to 275 wpm without sacrificing a significant loss in comprehension. This proves to be very difficult, as most people do not know their wpm speaking rate. What is lacking in these studies is that they do not describe or identify any of the compression ratios used, for instance 50% compression. More recent studies on time compression have shown that time compression percentage determines recall, comprehension, and intelligibility and not words per minute (He & Gupta, 2001; Heiman, Leo, & Leighbody, 1986). Consequently there are two plausible explanations why the researchers did not provide the compression ratios (1) outside vendors were the ones compressing the audio,
not the researchers, (2) they focused on speaking rate, not compression ratios. In light of that, current technology relies on compression percentages rather wpm. Thus research is needed to support new technology now available.

For instance, Heiman et al. (1986) found that compression, not words per minute, determines comprehension. Their study presented university students in an introductory psychology course with material at rates of 0% 33%, 43%, 50%, and 60%. They discovered that comprehension decreased slowly from the compression rates of zero to 50% but decreased rapidly from 50 to 60%. They found that at the 275 wpm indicator, there was not a significant loss of comprehension as was revealed in the previous literature (Foulke, 1968; Sticht, 1968). At 262 (33%), 306 (43%), and 350 (50%) wpm there was not a significant loss in comprehension. They concluded that after 50% compression, comprehension is lost no matter how many words per minute are being spoken. They state, “It is also incorrect to argue that comprehension declines dramatically beyond 275 wpm regardless of the compression rate employed” (Heiman et al., 1986, p. 407). This is reiterated by Arons (1992) in a meta-analysis on audio compression methods. Arons states, “Note that in much of the literature the limiting factor that is often cited is word rate, not compression ratios. The compression required to boost the speech rate to 275 words per minute is both talker and context dependent (e.g., read speech is typically faster than spontaneous speech)” (Arons, 1992, p. 6). Thus it can be concluded that compression ratios are the limiting factor in the comprehension of time-compressed instruction and that words per minute should not be taken into consideration. Time-compressed instruction is a viable means to deliver instruction. The WPM ratio appears not to be significant factor in time-compression as it is speaker dependent. Rather, the
compression ratio determines learning and intelligibility. The literature has shown that comprehension and recall remain steady up to around 50% compression and then deteriorates rapidly. Nonetheless, few studies have attempted to examine the role of time compression in a multimedia learning environment.

One study that does address this question was conducted by Olsen (1985). In this research 40 graduate students were divided into groups of 10 and given technical instruction of the human heart developed by Dwyer (1965). Individuals were excluded if they had any prior knowledge of physiology and/or a hearing or visual impairment, and then placed into one of four treatments that consisted of: (1) no compression (control), (2) a compressed version, (3) a compressed version with text, (4) and a compressed version with visuals. The control group was set at 150 words per minute and the compressed groups were set at 250 words per minute. Visual materials consisted of 39 simple hand line drawings identified by Dwyer (1972) that were placed in the instruction where students had most difficulty. Measurements consisted of drawing, where students were asked to draw a picture of the heart and its parts, and three multiple-choice tests of identification, terminology, and comprehension, were given to each group to measure facts, concepts, rules/principles, and problem solving objectives. The tests reliability for this study produced a KR-20 of .87, .75, .77, .59, and the total was .90. Participants in the visuals/compressed treatment scored higher on the drawing task than those in the compressed/no augmentation treatment. On the terminology test, neither text nor visual representation with compression treatment was as effective as the control group (no compression). The other tests revealed insignificant differences, which could be caused by the limited number of people (10) utilized in each treatment. However, the means for
the visuals/compressed treatment, although not significantly different, indicated that participants scored higher on the terminology and identification tests than the group presented the compressed/no augmentation treatment. Since there were only 10 students in each treatment group it is difficult to generalize the results of this experiment. The author notes that future research should explore different rates of compression using visuals and the effects of color on visual representations within time-compressed instruction.

The literature on MERs supports the use of visuals in instruction (e.g., Low & Sweller, 2005; Ayres & Sweller, 2005). The literature on visuals within time-compressed instruction remains unclear. This is mostly due to limited studies on the topic and limited technology at the time of the studies. However, it appears that using visuals with time-compressed instruction may aid comprehension better than no visuals as visuals help to reduce cognitive load. The question remains whether the combination of visuals and time-compressed instruction are a viable means to effectively deliver and present instruction. When discussing the notion that images aid in the comprehension of time-compressed instruction Olsen (1985) states “If such a difference does occur, it is necessary to identify which type of visual augmentation, if any, is more effective in providing for this difference. No research to date has investigated this aspect of comprehension of rate-modified speech.” (p. 193). Further investigation is warranted to see if the use of visuals presented with time-compressed instruction will increase comprehension.
## Table 2.1

**Comprehension of Time-compressed instruction Studies**

<table>
<thead>
<tr>
<th>Author/Year</th>
<th>Treatments</th>
<th>Dependent Variables</th>
<th>Participants</th>
<th>Content</th>
<th>Results</th>
</tr>
</thead>
<tbody>
<tr>
<td>Heiman, Leo, and Leighbody (1986)</td>
<td>0%, 33% (262 wpm), 43% (306 wpm), 50% (350 wpm), 60%</td>
<td>Comprehension (Multiple Choice Test)</td>
<td>200 undergrad students</td>
<td>Narrative</td>
<td>Comprehension decreased slowly (insignificantly) from 0% to 50% then rapidly (significantly) from 50% to 60%</td>
</tr>
<tr>
<td>Olsen (1985)</td>
<td>No Compression – 150 wpm (audio), Compressed 250 wpm, compressed with text, compressed with visuals</td>
<td>Identification, Terminology, Drawing, Comprehension, Total Tests</td>
<td>40 Graduate students</td>
<td>Biology - Heart</td>
<td>Drawing – Compressed with Visual &gt; Compressed Terminology – No compression &gt; Compression</td>
</tr>
<tr>
<td>Foulke (1968)</td>
<td>125 wpm, 150, 175, 200, 225, 250, 275, 300, 325, 350, 375, 400</td>
<td>Comprehension (Multiple Choice Test)</td>
<td>360 Undergrad students</td>
<td>College appropriate selection</td>
<td>After 275 wpm comprehension significantly decreased Comprehension reduced 60% from 125 wpm to 400 wpm</td>
</tr>
<tr>
<td>Sticht (1968)</td>
<td>0% compression (175 wpm) and Low/Medium/High aptitudes, 36% (275 wpm) and Low/Medium/High aptitudes, 59% (425 wpm) and Low/Medium/High aptitudes</td>
<td>Comprehension (Fill in the blank test)</td>
<td>135 army inductees</td>
<td>Use of carbon for estimating age of prehistoric remains</td>
<td>Compression increases as mental aptitude increases for all compression rates Comprehension decreases slightly from 0% to 36% compression then decreases rapidly to the 59% compression marker</td>
</tr>
<tr>
<td>Foulke and Sticht (1967)</td>
<td>225 wpm (22%), 275 (36%), 325 (46%), 375 (53%), 425 (59%)</td>
<td>Comprehension (Multiple Choice Test)</td>
<td>100 Undergrad students</td>
<td>Scientific and Literary content</td>
<td>6% decrease in comprehension from 22%-46% compression 20% decrease in comprehension from 22% to 59% compression</td>
</tr>
</tbody>
</table>
Summary

The literature has helped build a foundation for the questions presented in this study. It has shown that presenting learners with multiple representations in a multimedia environment improves learning more than if just one modality was presented. This is explained via the dual coding theory, which suggests that information is processed via two channels (verbal and non-verbal). Therefore, it is more efficient to design instruction that utilizes both channels in multimedia instruction to improve cognitive processing. When presenting multiple representations in a multimedia format they should be in audio and visual formats rather than text and visual formats. Text and visual formats require learners to split their attention between two representations and increases cognitive load. Additionally, designing instruction that is interactive (self-paced/navigated) rather than continuous leads to a deeper understanding of the material.

While this literature has examined a variety of manipulations to multimedia, little has focused on the potential manipulation of audio presentation speed. This study will examine the effects of how time-compressed instruction effects learning in the context of a multimedia environment. Specifically, this study seeks to find out how different rates of compression (0%, 25%, and 50%) and visual representations (visuals and non-visuals) affect achievement of knowledge posttests in a multimedia environment. It is predicted that learners presented with 0% and 25% compressed instruction will obtain similar scores on dependent measures and higher scores than those presented with 50% compressed instruction. Learners presented with visuals should score higher on all dependent measures than those who do not. Learners who are provided both representations may be less affected by compression because the visual representation
supports processing of the auditory message. Thus, it is expected that the effects of time-compression are moderated by the presence of visual representations. It is anticipated that the results of this study will lead to recommendations on the use of time-compressed instruction in a multimedia environment and contribute to the literature on multiple representations.
CHAPTER 3

METHODOLOGY

The purpose of this study was to explore the effects of visuals (visual and non-visuals) and time-compressed instruction (0%, 25%, and 50%) on learning in a multimedia-learning environment. This chapter will describe the methods used including a description of the participants, materials, criterion measurements, experimental design, procedures, and analysis procedure.

Participants

Participants in this study were 216 undergraduate education majors at Bloomsburg University located in central Pennsylvania. There were 78 males (36%) and 138 females (64%). The participant pool included 58 freshmen (27%), 65 sophomores (30%), 65 juniors (30%), and 28 seniors (13%). The mean GPA was 3.24 out of 4.0. Two hundred of the participants were 18-22 years old, thirteen were 23 to 30 years old, and three indicated they were older than 31. All but one participant was a full time student. Students were recruited from several education technology classes: Interactive Multimedia Authoring Systems for Teaching and Learning Environments (1 section) and Educational Computing and Technology (9 sections). Participants were recruited during both over Fall 2008 (7 sections) and Spring 2009 (3 sections) semesters. The researcher performed the study as part of the regular class requirements and experimental materials were incorporated into a unit on educational research and test development. Although all
students went through treatments as part of the regular class activities, only data from students who signed informed consent were included in the study. No extra credit was provided, and students were not graded on their performance on the study activities. Standard, classroom participation points were provided for completion of the study activities.

Because participants were selected from similar courses for Education majors, it was expected that participants would have similar levels of prior knowledge. Participants were assigned to conditions through random assignment. A moderate effect size was expected and thus, a minimum of 180 participants was necessary to achieve adequate power to detect treatment effects.

**Materials**

*Instruction*

The instructional material, which was originally developed by Dwyer (1965), consisted of a 2,000-word script covering the physiology and function of the human heart. A later version, used in this study, was revised by Dwyer and Lamberski (1983) and consists of a modified 2,000-word script and 19 simple line drawings with arrows and color-coded shaded regions to highlight the concepts being discussed. The script was developed using the instructional congruency/consistency matrix (Dwyer, 1991) so that information would be structured in a hierarchal order, in the form of facts, concepts, rules/procedures, and problem solving (Dwyer, 1978).
**Demographics Survey**

All participants completed a demographics survey in which they indicated their gender, academic status (graduate/undergraduate), year in school (freshmen/sophomore/junior/senior/graduate), enrollment status (full/part-time), age, major, and GPA. Responses to this survey described the study population and provided assurance that groups were equivalent on these characteristics.

**Prior Knowledge Pretest**

The pretest measured students’ general knowledge of physiology. The test consists of 36 multiple-choice questions and measures students’ factual knowledge in the subject area as identified by Dwyer (1972). The test was used to ensure that participants’ prior knowledge was equivalent across the treatments. Sample prior knowledge questions are displayed in Table 3.2.

Table 3.1

*Prior knowledge sample questions*

<table>
<thead>
<tr>
<th>Question</th>
<th>Answer</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. The part of the tooth which contains the hardest substance in the body is the</td>
<td>a. root</td>
</tr>
<tr>
<td>a. root</td>
<td>a. stomach</td>
</tr>
<tr>
<td>b. dentine</td>
<td>b. small intestine</td>
</tr>
<tr>
<td>c. cement</td>
<td>c. mouth</td>
</tr>
<tr>
<td>d. enamel</td>
<td>d. large intestine</td>
</tr>
<tr>
<td>2. The digestion of food occurs principally in the</td>
<td>a. stomach</td>
</tr>
<tr>
<td>a. stomach</td>
<td>b. small intestine</td>
</tr>
<tr>
<td>b. small intestine</td>
<td>c. mouth</td>
</tr>
<tr>
<td>c. mouth</td>
<td>d. large intestine</td>
</tr>
<tr>
<td>3. Contraction of the smooth muscle of the alimentary canal is called</td>
<td>a. peristalis</td>
</tr>
<tr>
<td>a. peristalis</td>
<td>a. heart</td>
</tr>
<tr>
<td>b. digestion</td>
<td>b. lungs</td>
</tr>
<tr>
<td>c. absorption</td>
<td>c. kidneys</td>
</tr>
<tr>
<td>d. assimilation</td>
<td>d. liver</td>
</tr>
</tbody>
</table>
**Knowledge Post Test**

The instrument was developed to coincide with the script described above to measure student achievement (Dwyer, 1965). The instrument consisted of four tests: Drawing, Identification, Terminology, and Comprehension. The total test consists of 60 multiple-choice items and a 20 item-drawing test. Together these tests measure facts, concepts, rules/procedures, and problem solving objectives. Dwyer (1978) analyzed over 100 experimental studies to determine the reliability of these tests and produced an average Kuder-Richardson Formula 20 (KR-20) reliability score of: .83 drawing test, .81 identification test, .83 terminology test, .70 comprehension test, and .94 total criterion test.

The descriptions of each test provided below are adapted from Dwyer (1978, pp. 45-47). Total test scores were derived by adding scores from all 80 items across the four subtests described in the following sections.

**Drawing Test.** The drawing test asked students to physically draw a diagram of a human heart and label 20 items that are given to them in a list format. It was designed to measure students’ conceptual and rule/procedural understanding of the heart. This test was scored based on the relative location of each labeled item. Each item was scored objectively and was worth 1 point.

**Identification Test.** The identification test contains 20 multiple-choice questions designed to measure students’ recall of factual knowledge. Each item was scored
objectively and was worth 1 point. This test provides a diagram of the heart and requires participants to identify the position of each part. This test uses visual cues and requires participants to place structures in the correct position on the diagram. Example questions are placed in Table 3.3.

Table 3.2

*Two Sample Questions from Identification Test*

<table>
<thead>
<tr>
<th>21. Arrow number one (1) points to the</th>
<th>22. Arrow number two (2) points to the</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Septum</td>
<td>A. Superior Vena Cava</td>
</tr>
<tr>
<td>B. Aorta</td>
<td>B. Inferior Vena Cava</td>
</tr>
<tr>
<td>C. Pulmonary Artery</td>
<td>C. Pulmonary Artery</td>
</tr>
<tr>
<td>D. Pulmonary Vein</td>
<td>D. Tricuspid Valve</td>
</tr>
<tr>
<td>E. None of These</td>
<td>E. Aorta</td>
</tr>
</tbody>
</table>

**Terminology Test.** The terminology test contains 20 multiple-choice questions. Each item was scored objectively and worth 1 point. The test measures students’ understanding of concepts and rules/procedures. Test items require participants to recall facts and definitions from the instruction. The concepts and rules/procedures assessed in
the terminology test are a prerequisite to understanding higher order knowledge presented throughout the instruction. Sample questions are displayed in Table 3.4.

Table 3.3

**Terminology Sample Questions**

<table>
<thead>
<tr>
<th>41. _____ is(are) the thickest walled chamber(s) of the heart.</th>
<th>42. The contraction of the heart occurs during the _____ phase.</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Auricles</td>
<td>A. Systolic</td>
</tr>
<tr>
<td>B. Myocardium</td>
<td>B. Sympathetic</td>
</tr>
<tr>
<td>C. Ventricles</td>
<td>C. Diastolic</td>
</tr>
<tr>
<td>D. Pericardium</td>
<td>D. Parasympathetic</td>
</tr>
<tr>
<td>E. Endocardium</td>
<td>E. Sympatric</td>
</tr>
</tbody>
</table>

**Comprehension Test.** The comprehension test contains 20 multiple-choice items. Each item was scored objectively and worth 1 point. The test measures students’ transfer of problem solving. Thus in order to perform well on this portion of the test, students had to have an understanding of facts, concepts, rules/procedures, and problem solving objectives. This test required students to thoroughly understand the heart, its functions, and processes in both the systolic and diastolic phases. Sample questions are displayed in Table 3.5.
Table 3.4

Comprehension Test Sample Questions

<table>
<thead>
<tr>
<th>61. Which valve is most like the tricuspid in function?</th>
<th>62. When blood is being forced out the right ventricle, in which position is the tricuspid valve?</th>
</tr>
</thead>
<tbody>
<tr>
<td>A. Pulmonary</td>
<td>A. Beginning to open</td>
</tr>
<tr>
<td>B. Aortic</td>
<td>B. Beginning to close</td>
</tr>
<tr>
<td>C. Mitral</td>
<td>C. Open</td>
</tr>
<tr>
<td>D. Superior Vena Cava</td>
<td>D. Closed</td>
</tr>
</tbody>
</table>

Cognitive Load

All participants reported perceived cognitive load by responding to a single question asking how easy or difficult the materials were to understand i.e., how much mental effort was required (Brunken, Plass, & Leutner, 2003). Participants responded to this question on a seven-point Likert-scale. This direct, subjective measure of cognitive load permitted testing of how compression rates and visuals affected students’ mental load. Previous research has successfully used this measure and it is considered to be a reliable indicator of mental load (Kalyuga, Chandler, & Sweller, 1999; Mayer & Chandler, 2001; Pollock, Chandler, & Sweller, 2002).

Review Behaviors (Back and Replay Buttons)

Students in each treatment had the opportunity to review earlier content either by pressing either the ‘Back’ button, which would return to an earlier slide, or a ‘Replay’ button, which would repeat the most recently completed slide. This allowed participants to review the content and was designed to simulate a real learning environment. The review behaviors were tracked during the instruction by the program used to develop it,
Adobe Flash. When students were finished, the number was displayed on the monitor for the researcher to record. When participants raised their hand to receive the first posttest, the researcher recorded the number on the participants’ manila file folder.

**Time-on-task**

The time it takes to complete each treatment was recorded at the end of each instruction treatment. The instruction was set up to display the time when the participant was finished with their instruction. When the researcher gave students the first posttest, they wrote the time on the participants’ manila folder. Although different compression ratios result in instruction that requires different amounts of time across conditions, students can affect the total instructional time by using either of the two review options.

**Audio Narration**

Recording was completed by the researcher. The recording took place on an iMac using Audacity™ to record in Mp3 format. Only a 0% compression (normal speed) recording was completed. Words per minute rates can be found in Table 3.6. That 0% recording was then compressed to 25% and 50% as described in the following section using Audacity™. The Mp3 files were then used in the instructional treatments as required.

**Compression.** Tempo was adjusted using a free sound editor called Audacity™ available at (http://audacity.sourceforge.net/) using the ‘Tempo Change’ feature. Audacity™ is a free open-source software package. The ‘Tempo Change’ feature was designed by a company called SoundTouch (http://www.surina.net/soundtouch/) by Olli
Parviainen. It is described as an open-source audio processing tool that uses Waveform Similarity based Overlap-Add (WSOLA) processing techniques to transform the tempo without changing the pitch. Compression was set at 0%, 25%, and 50% of the total time. Time was measured in seconds. In addition to time compression, the tempo percentage compression was stated. Tempo compression refers to the percentage of tempo that had to be modified.

**Design**

This study used a 2x3 factorial design, as displayed in Figure 3.1. The independent variables are Visuals and Compression ratio. Visuals contained two levels - visuals and no visuals while compression contained three levels – 0, 25, and 50% compression ratios. The dependent variables were scores on the achievement tests, time-on-task, review behaviors, and cognitive load. In addition, the pretest assessed prior physiology knowledge. This measure tested for potential prior knowledge differences between conditions and was also considered for use as a covariate during data analysis.
A computer with headphones delivered the instructional materials to participants. Instructional materials for each condition were developed with Adobe Flash CS3, which can be used on both Mac and PC platforms. The treatments were presented on a 650x450 screen size so that they could be played on all desktop computers regardless of monitor size. Each treatment contained 21 different still pages. The design of the computer modules allowed participants to control the instruction by pressing buttons to move forward or review material. An example screen is shown in Figure 3.2. Each of the visual treatments was exactly the same but the compression of the audio was different.
Participants viewed 19 simple line drawings with color codes on the current concept being reviewed. In the no visuals conditions, participants saw the control buttons and a blank screen displaying the message ‘Please listen to the instruction’. An example is displayed in Figure 3.3.

The first and last page of the instruction included directions and was the same in all six conditions. The first slide informed the participants how to navigate through the module. The last screen directed participants to raise their hand to receive the knowledge posttests.

_Treatment Times and Corresponding Compression Times_

Table 3.6 contains information about the time and counts for each compression ratio used in the three compression conditions. The times were calculated by playing the narration all the way through without going back or replaying.

_Table 3.5_

Treatment Times and Corresponding Compression Times

<table>
<thead>
<tr>
<th>Compression Percentage – Time</th>
<th>Time</th>
<th>Words Per Minute</th>
<th>Tempo Percentage Change</th>
</tr>
</thead>
<tbody>
<tr>
<td>0%</td>
<td>12:10</td>
<td>164</td>
<td>0%</td>
</tr>
<tr>
<td>25%</td>
<td>9:08</td>
<td>219</td>
<td>33%</td>
</tr>
<tr>
<td>50%</td>
<td>6:05</td>
<td>328</td>
<td>100%</td>
</tr>
</tbody>
</table>
Figure 3.2

Screenshot of computer-based instruction with visuals
A pilot study was conducted during Spring 2008. The purpose of the study was to identify procedural problems and to observe the amount of time needed to complete the treatments. Twenty-six students from an educational technology class at Bloomsburg University participated in the pilot.

The study was conducted during a single 50-minute class period as an in-class activity the last day of the semester. When students arrived at class, they were given directions for the study and completed the IRB consent form. Only one student did not sign the form. After signing the informed consent and receiving instructions, students
completed the prior knowledge assessment. Participants then received a CD, which contained one of the six treatments. CDs were labeled one through six to mark the condition and were randomly distributed. Participants wrote the number of the CD onto a manila file folder, which was also handed out, to identify participants’ treatment conditions. After participants completed the instructional materials, the time-on-task and review data was displayed on the computer screen. Participants recorded these numbers on their folders.

After completing the instructional materials, participants raised their hand to receive the first posttest. Participants placed this assessment in the manila folder when it was completed and received the identification, comprehension, and terminology tests. Once completed, participants returned the folder to the researcher.

It is important to note that this study was conducted on the last day of the semester. Many students were anxious to complete in order to be finished with their classes. Some were frustrated that they were participating in a study their last day of class. This led to multiple incomplete files as some students did not complete all measures or did not record the treatment number on the file folder with their tests. Therefore, only observations and procedural changes will be described.

**Pilot Study Procedure Problems and Solutions**

1. Time. Although most students had enough time to complete the study, some indicated that they did not. Several students actually had to spend a few minutes after class to finish. Not only that, but the directions presented to the students were brief, without much time for questions. Therefore, the explanation of the study, demographics survey, and pre-test will be completed the class before the
treatments are given. This will give students ample time to ask questions and complete the instructional materials.

2. Demographics Survey. A demographics survey was not given to the participants during the pilot study. This survey was created for the main study.

3. Recording. Students were responsible for recording the CD number, the time for completing the instructional materials, and the number of times the back or replay buttons were pressed. This information was provided either on the CD itself or the last page of the treatment materials and participants were instructed to write this information on the provided manila folder. In the pilot study, however, several participants failed to write some or all of this information. Consequently, the procedures were revised so that the researcher will record this information. The researcher will record this information when a participant is given the first posttest. The classroom instructor will assist in this data collection to reduce the amount of time participants may have to wait for assistance.

**Main Study Procedures**

The study was conducted in a lab/classroom at Bloomsburg University located in McCormick building room 1148. The classroom contained 30 PCs each with headphones. Each PC is a Gateway Desktop that is 2.5 GHz with 2 MB ram. Each computer includes a CD drive, mouse, and keyboard. The experiment was conducted during two regular class meetings and was used as a learning activity for the students. The experiment took approximately 1.5 class periods or 90 minutes.
The first experimental session, held during a class meeting, lasted 30 minutes. The researcher introduced participants to the study and overviewed of the procedures and then solicited volunteers. Participants received the consent form, demographics survey, and prior knowledge test. After signing the consent form and completing both the demographics survey and pretest, participants placed everything into a manila file folder labeled with an ID number. This was the ID number on their computer. Each computer has a piece of tape on the monitor with an ID number (1-40). The researcher placed these folders at each computer before students entered the classroom. In addition to labeling each folder with a computer ID number, participants choose a meaningful identification code that could be remembered later (e.g., mothers maiden name, last 4 digits of social security number, pet’s name etc.). Participants wrote this code onto the folder so that folders could be returned to the appropriate participant during the experimental session. Participants then returned the file folders to the researcher. This concluded the first class (30 minutes) of the experiment.

When students arrived at the following class, the researcher directed participants to sit at the same computer as the previous class. The researcher had placed the appropriate file folders at each computer and participants were able to check the identification code to ensure correspondence with the previous session. A CD, which contained one of the experimental treatments, was also placed with their folder. There were six versions of the CDs, labeled 1-6 to correspond to the six treatments. CDs were placed randomly at students’ workstations. The researcher recorded the CD number on the file folder before students arrived at the experimental session.
The researcher directed participants to place the CD into the computer’s CD drive and begin the instructional material. Each participant raised his or her hand after completing the instructional material. The researcher or course instructor recorded the time-on-task and review behaviors for the replay and back buttons. Since each of the treatments were several minutes apart, only one third of the participants in each class finished around the same time. Each participant then received the cognitive load Likert-scale questionnaire and the drawing test. Participants first answered the Likert-scale question and then completed the drawing test. To signal completion of the drawing test, each participant again raised his or her hand. The researcher placed the cognitive load response and drawing test in the folder and handed out the remaining knowledge posttests. Once students completed all tests, the folder was returned and participation was completed. It should be noted that upon handing in their folders, several students in the 50% conditions indicated to the researcher that their instruction was very fast and difficult to understand.

Data Analysis of Criterion Measures

Hypotheses

This study sought to test the following hypotheses as described in Chapter 1:

1. There will be an effect of compression. Participants who listen to 0% (regular speech) and 25% compressed instruction will perform better on knowledge-based posttests
measuring different educational learning objectives than will participants given 50% compressed instruction.

2. There will be an effect of visuals. Participants who view visuals will perform better on knowledge-based posttests measuring different educational learning objectives than will participants who do not view visuals.

3. There will be a visual by compression interaction on knowledge-based posttests measuring different educational learning objectives. Visuals will support learning for the uncompressed and moderately compressed (25%) groups but will not for the 50% group.

4. There will be an effect of compression. Learners’ perceptions of cognitive load will increase as compression increases.

5. There will be an effect of visuals. Participants who are provided visuals will perceive lower levels of cognitive load than will participants who are not provided with visuals.

6. There will be a visual by compression interaction on learners’ perceptions of cognitive load. Visuals will depress cognitive load at 0, and 25% compression yet will not have an effect at 50% compression.

**Analysis of Criterion Measures**

All criterion measures were analyzed via SPSS version 13.
**Prior Knowledge Assessment**

A reliability measure, Kuder-Richardson Formula 20 (KR-20), was first calculated to establish reliability. The pre-test was assessed via a 2x3 ANOVA to ensure that there were not differences in prior knowledge between the six treatment groups.

**Achievement Tests (Drawing, Identification, Terminology, Comprehension, and Total)**

A reliability measure, KR-20, was first calculated for each individual test and then the total test to establish reliability. Each of the criterion measures (drawing, identification, terminology, comprehension) was moderately correlated (Tabachnick & Fidell, 2001), therefore a factorial MANOVA was used for analysis to help eliminate false positives (Garson, n.d.). The interaction effect followed by the main effect for each independent variable was analyzed for significance. Univariate factorial analysis was conducted where significant main effects were found for each dependent variable (Enders, 2003) and followed by Tukey’s HSD post hoc test to identify where the significant differences occurred.

**Review behaviors (Back and Replay Buttons)**

The back and replay buttons were analyzed as one button since they essentially perform the same task, which is review of material. This data was collected by the researcher and/or instructor. Each participant raised his or her hand once the learning material was completed. The researcher or instructor then went to that student and recorded the number of times that either of the buttons was used. These review behaviors were analyzed via a 2x3 ANOVA.
Time-on-task

Total time on the learning material was analyzed to better understand time differences across conditions. Once students completed their treatment, they raised their hands and the researcher and/or instructor recorded the time on the students’ folder. Time recordings were in seconds. Time was measured via a 2x3 ANOVA. A Tukey’s HSD was conducted to identify significant differences.

Cognitive Load

The cognitive load measure consisted of a seven-point Likert-scale question that asked participants to rate how easy or difficult the condition was to understand. Each participant provided this rating immediately after completing the learning materials. Participants raised their hands after they went through their condition and the researcher or instructor recorded the time-on-task and review behaviors. The researcher or instructor then gave participants a questionnaire with the cognitive load measure. Cognitive load was measured via a 2x3 ANOVA. A Tukey’s HSD was conducted to identify significant differences.
CHAPTER 4

RESULTS

The purpose of this study was to examine the effects of visuals and time-compressed instruction on student learning. As described in the previous chapter, participants in this study completed a prior knowledge pretest, studied instructional material, and completed knowledge-based posttests. Participants were 216 college students, all of whom were included in the data analysis. Data were analyzed using SPSS 13. First, a 2x3 ANOVA tested the pretest measure to ensure groups did not differ on prior knowledge and to consider the potential of prior knowledge as a covariate. A 2 X 3 ANOVA also compared total tests scores across conditions. A 2 X 3 MANOVA then analyzed the four learning variables: Drawing, Identification, Terminology, and Comprehension. The dependent variables cognitive load, time-on-task, and review behaviors: Back and Replay buttons were also analyzed by a 2 X 3 ANOVA. The following section will describe the results of each of these measures.

Participants: Fall and Spring Semesters

Data was collected from courses spanning both the Fall and Spring to ensure robustness of the multivariate tests. The scores of participants from each semester were compared to determine that the populations were comparable. These scores are shown in Table 4.0. As can be seen from the scores in Table 4.0, mean and standard deviations
across semesters is similar for each dependent variable. Participants from each semester were randomly assigned into one of the six treatments. Once the fall and spring totals were added together, each condition had between 34-38 participants per group.

Table 4.0

*Descriptive statistics from participants in the fall/spring semester on learning variables*

<table>
<thead>
<tr>
<th></th>
<th>Drawing</th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fall</td>
<td>N = 152</td>
<td>M 7.34</td>
<td>10.48</td>
<td>7.71</td>
</tr>
<tr>
<td></td>
<td>SD 5.49</td>
<td>4.70</td>
<td>3.69</td>
<td>3.56</td>
</tr>
<tr>
<td>Spring</td>
<td>N = 64</td>
<td>M 6.81</td>
<td>10.06</td>
<td>7.61</td>
</tr>
<tr>
<td></td>
<td>SD 5.51</td>
<td>4.415</td>
<td>4.124</td>
<td>3.625</td>
</tr>
</tbody>
</table>

**Prior Knowledge Pretest**

A 2x3 ANOVA analyzed scores on the prior knowledge pretest across conditions. The independent variables were Visual (visuals and no visuals) and Compression (0%, 25%, and 50% compression). Prior knowledge was assessed to ensure that participants did not have prior knowledge in biology and to assess the viability of this measure as a covariate. In addition, consistent with randomly assigning participants to treatments, prior knowledge was assessed to be sure that there were not prior knowledge differences between groups.

There were not any significant violations of the assumptions of independent observation, normal distribution, or homogeneity of variance (Pallant, 2007; Stevens,
Thus a 2x3 ANOVA compared pretest group means. Table 4.1 shows the descriptive statistics for visual and compression groups on the pretest.

Table 4.1

*Scores could range from 0-36 possible points*

The 2 X 3 ANOVA revealed no differences on the pretest as indicated in Table 4.2. There were no significant differences between the pretest scores of participants in the two visuals groups, visual $F(1, 210) = .048; \ p = .828$, or compression, $F(2, 210) = .149; \ p = .862$. The interaction effect was also not significant, $F(2, 210) = .485; \ p = .617$. Thus, there were no differences between pretest scores across conditions.
Table 4.2

Factorial ANOVA results for the prior knowledge test

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III</th>
<th>Source</th>
<th>Type III</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of</td>
<td></td>
</tr>
<tr>
<td>Corrected Model</td>
<td>15.994</td>
<td>Squares</td>
<td>5</td>
</tr>
<tr>
<td>Intercept</td>
<td>82615.553</td>
<td>df</td>
<td>1</td>
</tr>
<tr>
<td>Visual</td>
<td>.590</td>
<td>.590</td>
<td>1</td>
</tr>
<tr>
<td>Compression</td>
<td>3.687</td>
<td>1.843</td>
<td>2</td>
</tr>
<tr>
<td>Visual x Compression</td>
<td>12.033</td>
<td>6.016</td>
<td>2</td>
</tr>
<tr>
<td>Error</td>
<td>2606.668</td>
<td>12.413</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>85421.000</td>
<td>126</td>
<td>216</td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2622.662</td>
<td>215</td>
<td></td>
</tr>
</tbody>
</table>

Knowledge Posttests

Total Test

The total test scores were calculated by adding the scores from each of the four subtests (i.e., drawing, identification, terminology, and comprehension). Table 4.3 shows the descriptive statistics for visual and compression groups on the total test. The total test score was analyzed via a 2x3 ANOVA. The independent variables were visual and
compression. Analysis of assumptions revealed no major violations of the ANOVA assumptions: independent observation, normal distribution, and homogeneity of variance (Pallant, 2007; Stevens, 2002).

Table 4.3

*Descriptive statistics for visual and compression groups on total test score*

<table>
<thead>
<tr>
<th>Visual</th>
<th>Compression</th>
<th>Mean</th>
<th>Std. Deviation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Compression</td>
<td>32.66</td>
<td>12.465</td>
<td></td>
</tr>
<tr>
<td>25% Compression</td>
<td>23.78</td>
<td>9.221</td>
<td></td>
</tr>
<tr>
<td>50% Compression</td>
<td>21.68</td>
<td>7.031</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>26.24</td>
<td>10.958</td>
<td></td>
</tr>
<tr>
<td>0% Compression</td>
<td>43.00</td>
<td>13.733</td>
<td></td>
</tr>
<tr>
<td>25% Compression</td>
<td>42.09</td>
<td>16.149</td>
<td></td>
</tr>
<tr>
<td>50% Compression</td>
<td>33.83</td>
<td>13.583</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>39.73</td>
<td>14.957</td>
<td></td>
</tr>
<tr>
<td>0% Compression</td>
<td>37.83</td>
<td>14.028</td>
<td></td>
</tr>
<tr>
<td>25% Compression</td>
<td>32.80</td>
<td>15.942</td>
<td></td>
</tr>
<tr>
<td>50% Compression</td>
<td>27.84</td>
<td>12.397</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>32.99</td>
<td>14.724</td>
<td></td>
</tr>
</tbody>
</table>

* Scores could range from 0-80 possible points

As indicated by Table 4.4, there was no significant interaction for Visual by
Compression groups, $F(2, 210) = 2.04; p = .133$. There was a significant effect of Visuals on the total test scores, $F(1, 210) = 64.480; p < .001; \text{partial eta squared}=.235$.

Participants in the visual conditions scored significantly higher than did participants in the no visual conditions.

There was also an effect of compression on the total test scores, $F(2, 210) = 11.873; p < .001; \text{partial eta squared}=.102$. Tukey’s HSD post hoc analysis (Table 4.5) was used to determine where the differences were between compression groups for the total test score. Participants in the 0% compression group scored significantly higher than did participants in the 25% and 50% compression groups. Participants in the 25% compression group scored significantly higher than did participants in the 50% compression group. Table 4.5 shows the Tukey’s post hoc analysis to examine the differences in compression on the total test.
Table 4.4

Factorial ANOVA results for the total test

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III</th>
<th>Partial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of</td>
<td>Mean</td>
</tr>
<tr>
<td></td>
<td>Squares</td>
<td>df</td>
</tr>
<tr>
<td>Corrected Model</td>
<td>14139.028</td>
<td>5</td>
</tr>
<tr>
<td>Intercept</td>
<td>232501.729</td>
<td>1</td>
</tr>
<tr>
<td>Visual</td>
<td>9971.102</td>
<td>1</td>
</tr>
<tr>
<td>Compression</td>
<td>3672.142</td>
<td>2</td>
</tr>
<tr>
<td>Visual x Compression</td>
<td>630.960</td>
<td>2</td>
</tr>
<tr>
<td>Error</td>
<td>32473.930</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>281639.000</td>
<td>216</td>
</tr>
<tr>
<td>Corrected Total</td>
<td>46612.958</td>
<td>215</td>
</tr>
</tbody>
</table>
Table 4.5

Tukey’s Post hoc analysis for total test

<table>
<thead>
<tr>
<th></th>
<th>Mean Difference (i-j)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>(i) Compression</td>
<td>(J) Compression</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0% Compression</td>
<td>25% Compression</td>
<td>5.03*</td>
<td>2.052</td>
<td>.040</td>
<td>.18</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>9.99*</td>
<td>2.068</td>
<td>.000</td>
<td>5.11</td>
</tr>
<tr>
<td>25% Compression</td>
<td>0% Compression</td>
<td>-5.03*</td>
<td>2.052</td>
<td>.040</td>
<td>-9.87</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>4.96*</td>
<td>2.102</td>
<td>.050</td>
<td>.00</td>
</tr>
<tr>
<td>50% Compression</td>
<td>0% Compression</td>
<td>-9.99*</td>
<td>2.068</td>
<td>.000</td>
<td>-14.87</td>
</tr>
<tr>
<td></td>
<td>25% Compression</td>
<td>-4.96*</td>
<td>2.102</td>
<td>.050</td>
<td>-9.92</td>
</tr>
</tbody>
</table>

Drawing, Identification, Terminology, and Comprehension tests

The Multivariate Analysis of Variance (MANOVA) tested scores on each of the subtests to determine if there were significant differences before proceeding to analysis of the four individual tests. A MANOVA seeks to examine the effects of one or more independent variables on multiple dependent variables. If one were to run a statistical test and had one or more independent variables (IV) but two dependent variables (DV) they could run two ANOVAs on each of the DVs. However, doing so would increase statistical Type 1 error. The MANOVA helps control the Type 1 error and tests whether the effects of the DVs occurred by chance. The advantage of a MANOVA is that it helps avoid Type 1 error by testing all of the DVs at one time. For this study, a 2x3 MANOVA
examined the effects of the independent variables (Visuals and Compression) on the learning variables (Drawing, Identification, Terminology, and Comprehension).

The Kuder-Richardson Formula 20 (KR-20) revealed adequate score reliability for each of the four posttests. Reliability for the drawing subtests was .905, .807 for the identification subtest, .756 for the terminology subtest, and .701 for the comprehension subtest.

Prior to conducting the MANOVA the following assumptions were checked for each of the four learning variables (Tabachnick & Fidell, 2007): normality, homogeneity of variance-covariance matrices, linearity, and multicollinearity and singularity. Multivariate normality means that each dependent variable and combinations of them are normally distributed. Univariate normality can be assessed via skewness and kurtosis values as well as through histograms (Meyers, Gamst, & Guarino, 2005; Tabachnick & Fidell, 2007). There were no major violations of univariate normality. Outliers were examined via boxplots in SPSS. There were eight outliers discovered in the analysis. Tabachnick and Fidell (2007) recommend examining each outlier individually to determine if they are caused by an incorrect data entry, a value that is not part of the population, or a case that is from the population but has an extreme value. Each case was examined by looking at the results of the tests for each of the outlying participants. Examination of each case revealed that these outliers were from the target population and were the results of a participant performing better or worse than other participants. As a result, the outliers could be retained, transformed, or deleted. Neither transforming or eliminating the cases had an impact on the inferences made in the analysis so they were retained (Wiggins, 2000). There were no multivariate outliers according to the
Mahalanobis test in SPSS.

The homogeneity of variance-covariance matrices assumes that the variance-covariance from all outcome variables is the same across populations (Warner, 2008). The Box’s M test was significant ($p < .001$) failing the homogeneity of variance-covariance matrices assumption. Tabachnick and Fidell (2007) suggest that when sample size is equal, MANOVA is robust to the homogeneity of variance-covariance matrices. Stevens (2002) recommends that cell sizes must be within 1.5 times of each other in order to be considered equal. In this study, cell sizes are within 1.5 times of each other and thus, the MANOVA is robust to the homogeneity of variance-covariance matrices assumption.

Linearity is described as a straight-line relationship between the dependent variables and can be assessed via scatterplots in SPSS (Pallant, 2007). A straight-line relationship is described as points that are scattered around a straight line (regression line) not forming an elliptical (curvilinear) shape (Lomax, 2000). There were no signs of non-linearity (curvilinearity) in the scatterplots.

Multicollinearity occurs when variables are highly correlated and can result in analyzing redundant variables. Singularity occurs when one of the variables is a combination of two or more of the variables. MANOVA is most appropriate when correlations amongst dependent variables are moderately correlated. French and Poulsen (2002) describe correlations that range from .3 - .7 as moderate. Correlations above .9 can result in multicollinearity or singularity (Haworth, 1996; Tabachnick & Fidell, 2007). Table 4.6 shows the correlations between dependent variables.
Table 4.6

Correlations between dependent variables.

<table>
<thead>
<tr>
<th></th>
<th>Identification</th>
<th>Terminology</th>
<th>Comprehension</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>Pearson</td>
<td>.818**</td>
<td>.514**</td>
</tr>
<tr>
<td></td>
<td>Correlation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>Pearson</td>
<td>.558**</td>
<td>.536**</td>
</tr>
<tr>
<td></td>
<td>Correlation</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td>Pearson</td>
<td></td>
<td>.666**</td>
</tr>
<tr>
<td></td>
<td>Correlation</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

** .3-.7 indicate moderate correlations.

Preliminary analysis revealed no major violations of the normality, homogeneity of variance-covariance matrices, linearity, and multicollinearity and singularity assumptions. As a result a 2x3 MANOVA was conducted to examine the effects of visuals and compression levels on the drawing, identification, terminology, and comprehension variables.

Additionally, prior knowledge was assessed as a potential covariate in the 2x3 MANOVA. The pretest was moderately correlated with dependent variables drawing (.3), identification (.36), terminology (.43), and comprehension (.39). As a result, the homogeneity of regression assumption was checked to further examine the potential use of pretest as a covariate. This was assessed via an interaction between the independent
variables and covariates (Pallant, 2007; Weinfurt, 1995). An interaction was found for both the drawing and terminology variables ($p < .05$), violating the assumption. As a result the pretest was not used as a covariate.

Table 4.7 shows the descriptive statistics for visual and compression groups on the drawing, identification, terminology, and comprehension tests.

The drawing test was worth 20 points. Students were asked to physically draw a diagram of a human heart and was designed to measure students’ conceptual and rule/procedural understanding of the heart. This test was scored based on the relative location of each labeled item.

The identification test was worth 20 points. It was designed to measure students’ recall of factual knowledge. This test provides a diagram of the heart and requires participants to identify the position of each part.

The terminology test was worth 20 points. It was designed to measure students’ understanding of concepts and rules/procedures.

The comprehension test was worth 20 points. It was designed to measure students’ transfer of problem solving.

Table 4.7

Descriptive statistics for visual and compression groups on the drawing, identification, terminology, and comprehension tests

<table>
<thead>
<tr>
<th></th>
<th>0%</th>
<th>25%</th>
<th>50%</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>M</td>
<td>12.11</td>
<td>11.23</td>
<td>8.51</td>
</tr>
<tr>
<td></td>
<td>SD</td>
<td>4.25</td>
<td>4.86</td>
<td>5.61</td>
</tr>
<tr>
<td></td>
<td>N</td>
<td>38</td>
<td>35</td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Median</td>
<td>Range (min/max)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>----------------</td>
<td>--------</td>
<td>-----------------</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>11</td>
<td>4 - 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>12</td>
<td>0 - 20</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>8</td>
<td>0 - 19</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>5.37</td>
<td>3.48</td>
</tr>
<tr>
<td>SD</td>
<td>3.56</td>
<td>2.71</td>
</tr>
<tr>
<td>N</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>Median</td>
<td>5</td>
<td>3.5</td>
</tr>
<tr>
<td>Range (min/max)</td>
<td>0 - 15</td>
<td>0 - 11</td>
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<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Identification</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>8.74</td>
<td>13.74</td>
</tr>
<tr>
<td>SD</td>
<td>5.13</td>
<td>3.91</td>
</tr>
<tr>
<td>N</td>
<td>76</td>
<td>38</td>
</tr>
<tr>
<td>Median</td>
<td>14</td>
<td>14</td>
</tr>
<tr>
<td>Range (min/max)</td>
<td>4 - 20</td>
<td>2 - 20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>No</th>
<th>Visual</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>9.68</td>
<td>3.82</td>
</tr>
<tr>
<td>SD</td>
<td>7.89</td>
<td>3.43</td>
</tr>
<tr>
<td>N</td>
<td>9.68</td>
<td>36</td>
</tr>
<tr>
<td>Median</td>
<td>7.18</td>
<td>8</td>
</tr>
<tr>
<td>Range (min/max)</td>
<td>7 - 18</td>
<td>0 - 20</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Total</th>
<th>Terminology</th>
</tr>
</thead>
<tbody>
<tr>
<td>M</td>
<td>11.71</td>
<td>8.79</td>
</tr>
<tr>
<td>SD</td>
<td>4.39</td>
<td>3.8</td>
</tr>
<tr>
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<td>76</td>
<td>38</td>
</tr>
<tr>
<td>Median</td>
<td>8.65</td>
<td>8</td>
</tr>
<tr>
<td>Range (min/max)</td>
<td>8.65</td>
<td>3 - 18</td>
</tr>
<tr>
<td>Condition</td>
<td>M</td>
<td>SD</td>
</tr>
<tr>
<td>-----------</td>
<td>-------</td>
<td>-------</td>
</tr>
<tr>
<td>No</td>
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<td>6.08</td>
</tr>
<tr>
<td>Visual</td>
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<td>2.69</td>
</tr>
<tr>
<td>N</td>
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<td>36</td>
</tr>
<tr>
<td>Median</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Range (min/max)</td>
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<td>1 - 11</td>
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<tr>
<td>Total</td>
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<td>7.25</td>
</tr>
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<td>SD</td>
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<td>4.02</td>
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<td>71</td>
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<tr>
<td>SD</td>
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<td>N</td>
<td>38</td>
<td>35</td>
</tr>
<tr>
<td>Median</td>
<td>7</td>
<td>8</td>
</tr>
<tr>
<td>Range (min/max)</td>
<td>3 - 18</td>
<td>4 - 18</td>
</tr>
<tr>
<td>No</td>
<td>8.89</td>
<td>6.11</td>
</tr>
<tr>
<td>Visual</td>
<td>3.44</td>
<td>2.98</td>
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<td>N</td>
<td>38</td>
<td>36</td>
</tr>
<tr>
<td>Median</td>
<td>8</td>
<td>6</td>
</tr>
<tr>
<td>Range (min/max)</td>
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<td>1 - 16</td>
</tr>
<tr>
<td>Total</td>
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<td>7.58</td>
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<tr>
<td>SD</td>
<td>3.66</td>
<td>3.75</td>
</tr>
<tr>
<td>N</td>
<td>76</td>
<td>71</td>
</tr>
</tbody>
</table>

*Drawing, Identification, Terminology, and Comprehension posttests could range from 0-20 possible points.

Analysis of the Levene’s test, shown in Table 4.8, indicated that identification ($p = .392$) meets the assumption of equal variances. The drawing ($p < .001$), terminology ($p < .001$), and comprehension ($p = .033$) tests failed to meet the assumption. Tabachnick and Fidell (2007) suggest changing the alpha level to .025 if this assumption is not met.
As a result, the drawing, terminology, and comprehension alpha will be set at .025 rather than .05.

Table 4.8

_Levene’s Test_

<table>
<thead>
<tr>
<th></th>
<th>F</th>
<th>Df1</th>
<th>Df2</th>
<th>Sig.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>7.184</td>
<td>5</td>
<td>210</td>
<td>.000</td>
</tr>
<tr>
<td>Identification</td>
<td>1.045</td>
<td>5</td>
<td>210</td>
<td>.392</td>
</tr>
<tr>
<td>Terminology</td>
<td>5.017</td>
<td>5</td>
<td>210</td>
<td>.000</td>
</tr>
<tr>
<td>Comprehension</td>
<td>2.480</td>
<td>5</td>
<td>210</td>
<td>.033</td>
</tr>
</tbody>
</table>

The multivariate tests, shown in Table 4.9, indicate that there is a significant difference among groups on a linear combination of the dependent variables (Pallant, 2007). Pillai’s trace was significant for the independent variable visual, $F(4, 207) = 46.482; p < .001$; partial eta squared = .473 and compression at $F(8, 416) = 3.830; p < .001$; partial eta squared = .069. The visual by compression interaction was not significant at $F (8, 416) = 1.687; p = .099$; partial eta squared = .031.

Table 4.9

_Multivariate Tests_

<table>
<thead>
<tr>
<th>Effect</th>
<th>Pillai’s Trace</th>
<th>Hypothesis DF</th>
<th>Error DF</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Value</td>
<td>F</td>
<td>DF</td>
<td>DF</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Univariate analyses were then conducted to examine the effects of independent variables on each of the knowledge subtests (Bray & Maxwell, 1982). There was a significant interaction of visuals and compression for the comprehension knowledge subtest, $F(2, 210) = 4.219$, $p = .016$. This subtest will be discussed further below. The interaction was not significant for any other subtest. The effects of each independent variable are addressed in the sections below.

Table 4.10

Tests of Between-Subject Effects

<table>
<thead>
<tr>
<th>Source</th>
<th>DV</th>
<th>Type III</th>
<th>Partial Eta</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Sum of Squares</td>
<td>df</td>
</tr>
<tr>
<td>Corrected</td>
<td></td>
<td>3057.398</td>
<td>5</td>
</tr>
<tr>
<td>Model</td>
<td>Drawing</td>
<td>1323.19</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Identification</td>
<td>262.264</td>
<td>5</td>
</tr>
<tr>
<td></td>
<td>Terminology</td>
<td>325.677</td>
<td>5</td>
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<td></td>
<td>Comprehension</td>
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<td></td>
</tr>
<tr>
<td>Term</td>
<td>Effect</td>
<td>Drawings</td>
<td>p-value</td>
</tr>
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<td>---------------------</td>
<td>--------</td>
<td>----------</td>
<td>---------</td>
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<tr>
<td>Intercept</td>
<td>Drawing</td>
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<td>.000</td>
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<td>22938.648</td>
<td>.000</td>
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<tr>
<td>Terminology</td>
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<td>12622.124</td>
<td>.000</td>
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<td>Comprehension</td>
<td></td>
<td>12981.561</td>
<td>.000</td>
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<td>Visual</td>
<td>Drawing</td>
<td>2614.874</td>
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<td>.000</td>
</tr>
<tr>
<td>Terminology</td>
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<td>80.761</td>
<td>.016</td>
</tr>
<tr>
<td>Comprehension</td>
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<td>108.187</td>
<td>.002</td>
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<tr>
<td>Compression</td>
<td>Drawing</td>
<td>438.563</td>
<td>.000</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td>348.966</td>
<td>.000</td>
</tr>
<tr>
<td>Terminology</td>
<td></td>
<td>137.404</td>
<td>.007</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>127.230</td>
<td>.005</td>
</tr>
<tr>
<td>Visual x Compression</td>
<td>Drawing</td>
<td>13.861</td>
<td>.425</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td>55.591</td>
<td>.169</td>
</tr>
<tr>
<td>Terminology</td>
<td></td>
<td>48.336</td>
<td>.172</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>96.858</td>
<td>.016</td>
</tr>
<tr>
<td>Error</td>
<td>Drawing</td>
<td>3425.195</td>
<td>210</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td>3250.361</td>
<td>210</td>
</tr>
<tr>
<td>Terminology</td>
<td></td>
<td>2861.694</td>
<td>210</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>2410.527</td>
<td>210</td>
</tr>
<tr>
<td>Total</td>
<td>Drawing</td>
<td>17634</td>
<td>216</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td>27741</td>
<td>216</td>
</tr>
<tr>
<td>Terminology</td>
<td></td>
<td>15867</td>
<td>216</td>
</tr>
<tr>
<td>Comprehension</td>
<td></td>
<td>15834</td>
<td>216</td>
</tr>
<tr>
<td>Corrected Total</td>
<td>Drawing</td>
<td>6482.593</td>
<td>215</td>
</tr>
<tr>
<td>Identification</td>
<td></td>
<td>4573.551</td>
<td>215</td>
</tr>
</tbody>
</table>
As shown in the Table 4.10 there was a significant interaction for the comprehension test, $F(2, 210) = 4.219; p = .016$; partial eta squared = .039. A graph of the interaction (Figure 4.1) indicates a disordinal interaction and thus the main effects will not be examined (Cohen & Lea, 2004).

Figure 4.1 shows that the effects of compression depress test scores for the comprehension test at the 25% compression rate and these remain low for the 50% compression rate. However, participants who listened to the instruction at the 25% compression rate yet also viewed visuals, scored as well on the comprehension test as did participants who listened to uncompressed instruction. In sum, it seems that learners’ comprehension is affected by compression at even the 25% rate when visuals are not available.
82

**The Effect of Visuals on Learning**

**Drawing.** There was a significant main effect of Visuals on drawing scores, $F(1, 210) = 160.319; p < .001; \text{partial eta squared} = .433$. As indicated by Table 4.7 the visual group scored significantly higher than the no visual group. Thus, participants who were...
provided both representations obtained higher scores than did participants who were provided only one.

**Identification.** The main effect of Visuals was also significant on the Identification subtest, $F(1, 210) = 59.377; p < .001; \text{partial eta squared} = .22$. As indicated by Table 4.8 the visual group scored significantly higher than the no visual group. Thus, participants who were provided both representations obtained higher scores than did participants who listened to the audio instruction without the aid of visuals.

**Terminology.** There was a significant main effect of Visuals on the Terminology test, $F(1, 210)=5.927; p=.016; \text{partial eta squared} = .027$. As shown in Table 4.9, participants in the visual group scored significantly higher than did participants in the no visual group. Thus, participants who were provided both representations obtained higher scores than did participants who were provided only one.

**The Effect of Compression on Learning**

**Drawing.** There was a significant main effect of Compression on drawing test scores, $F(2, 210) = 13.444; p < .001; \text{partial eta squared} = .114$. Means and standard deviations for this variable can be found in Table 4.7. Tukey’s Honestly Significant Difference test (HSD) post hoc analysis was completed to determine where the differences occurred. The post hoc analysis results are displayed in Table 4.14. The 0% and 25% compression groups’ means were not found to be significantly different.
Participants in the 0% and 25% compression groups scored significantly higher than did participants in the 50% compression group.

**Identification.** The main effect of Compression was also significant for the identification test $F(2, 210) = 11.273; \ p < .001; \ \text{partial eta squared} = .097$. Means and standard deviations for this variable can be found in Table 4.8. Tukey’s HSD post hoc analysis was conducted to examine the differences between group means as shown in table 4.14. The 0% and 25% compression groups’ means were not found to be significantly different from one another. The scores of participants in the 0% and 25% compression groups were significantly higher than were scores of participants in the 50% compression group.

**Terminology.** There was also a significant main effect of Compression on the terminology test $F(2, 210) = 5.042; \ p = .007; \ \text{partial eta squared} = .046$. Means and standard deviations for this variable can be found in Table 4.9. Tukey’s HSD post hoc analysis was used to determine if there were differences between group means as shown in Table 4.11. Participants in the 0% compression group scored significantly higher than did participants in the 50% compression group. The scores of participants in the 25% compression group were not found to be statistically different than the scores of participants in either the 0% or 50% compression groups.
Table 4.11

*Tukey’s HSD for Compression*

<table>
<thead>
<tr>
<th>DV</th>
<th>(i) Compression</th>
<th>(J) Compression</th>
<th>Mean Difference (i-j)</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>95% Confidence Interval</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>Drawing</td>
<td>0%</td>
<td>25% Compression</td>
<td>1.4</td>
<td>.667</td>
<td>.093</td>
<td>-.17</td>
<td>2.97</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>3.42*</td>
<td>.672</td>
<td>.000</td>
<td>1.83</td>
<td>5.00</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>0% Compression</td>
<td>-1.4</td>
<td>.667</td>
<td>.093</td>
<td>-2.97</td>
<td>.17</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>2.02*</td>
<td>.683</td>
<td>.010</td>
<td>.41</td>
<td>3.63</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0% Compression</td>
<td>-3.42*</td>
<td>.672</td>
<td>.000</td>
<td>-5.00</td>
<td>-1.83</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>25% Compression</td>
<td></td>
<td>-2.02*</td>
<td>.683</td>
<td>.010</td>
<td>-3.63</td>
<td>-.41</td>
<td></td>
</tr>
<tr>
<td>Identification</td>
<td>0%</td>
<td>25% Compression</td>
<td>1.15</td>
<td>.649</td>
<td>.183</td>
<td>-.39</td>
<td>2.68</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>3.06*</td>
<td>.654</td>
<td>.000</td>
<td>1.51</td>
<td>4.60</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>0% Compression</td>
<td>-1.15</td>
<td>.649</td>
<td>.183</td>
<td>-2.68</td>
<td>.39</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>1.91*</td>
<td>.665</td>
<td>.012</td>
<td>.34</td>
<td>3.48</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0% Compression</td>
<td>-3.06*</td>
<td>.654</td>
<td>.000</td>
<td>-4.60</td>
<td>-1.51</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>25% Compression</td>
<td></td>
<td>-1.91*</td>
<td>.665</td>
<td>.012</td>
<td>-3.48</td>
<td>-.34</td>
<td></td>
</tr>
<tr>
<td>Terminology</td>
<td>0%</td>
<td>25% Compression</td>
<td>1.5</td>
<td>.609</td>
<td>.039</td>
<td>.06</td>
<td>2.93</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>1.81*</td>
<td>.614</td>
<td>.010</td>
<td>.36</td>
<td>3.26</td>
<td></td>
</tr>
<tr>
<td></td>
<td>25%</td>
<td>0% Compression</td>
<td>-1.5</td>
<td>.609</td>
<td>.039</td>
<td>-2.93</td>
<td>-.06</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>50% Compression</td>
<td></td>
<td>.31</td>
<td>.624</td>
<td>.872</td>
<td>-1.16</td>
<td>1.78</td>
<td></td>
</tr>
<tr>
<td></td>
<td>50%</td>
<td>0% Compression</td>
<td>-1.81*</td>
<td>.614</td>
<td>.010</td>
<td>-3.26</td>
<td>-3.36</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>25% Compression</td>
<td></td>
<td>-.31</td>
<td>.624</td>
<td>.872</td>
<td>-1.78</td>
<td>1.16</td>
<td></td>
</tr>
</tbody>
</table>

*Significance \( p < .05 \) for identification; \( p < .025 \) for drawing and terminology
Cognitive Load

Cognitive load was measured via a 7-point Likert-scale question that asked participants how easy or difficult the material was to go through (i.e., how much mental effort they put forth during their instructional treatment). This Likert-scale question was given to participants immediately following instruction, prior to posttests. A 2x3 ANOVA was conducted to examine the effects of visuals and compression levels on cognitive load. Preliminary analysis revealed no major violations of assumptions: independent observation, normal distribution, and homogeneity of variance (Pallant, 2007; Stevens, 2002).
Table 4.12 shows the descriptive statistics for visual and compression groups on cognitive load.

Table 4.12

*Descriptive statistics for cognitive load*

<table>
<thead>
<tr>
<th>Visual</th>
<th>Compression</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Compression</td>
<td>5.63</td>
<td>1.364</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>No</td>
<td>25% Compression</td>
<td>5.97</td>
<td>1.028</td>
<td>36</td>
</tr>
<tr>
<td>Visual</td>
<td>50% Compression</td>
<td>6.32</td>
<td>1.093</td>
<td>34</td>
</tr>
<tr>
<td>Total</td>
<td>5.96</td>
<td>1.199</td>
<td></td>
<td>108</td>
</tr>
<tr>
<td>0% Compression</td>
<td>4.39</td>
<td>1.685</td>
<td></td>
<td>38</td>
</tr>
<tr>
<td>Visual</td>
<td>25% Compression</td>
<td>4.77</td>
<td>1.239</td>
<td>35</td>
</tr>
<tr>
<td>50% Compression</td>
<td>5.74</td>
<td>1.358</td>
<td></td>
<td>35</td>
</tr>
<tr>
<td>Total</td>
<td>4.95</td>
<td>1.543</td>
<td></td>
<td>108</td>
</tr>
<tr>
<td>0% Compression</td>
<td>5.01</td>
<td>1.645</td>
<td></td>
<td>76</td>
</tr>
<tr>
<td>Total</td>
<td>5.38</td>
<td>1.280</td>
<td></td>
<td>71</td>
</tr>
<tr>
<td>50% Compression</td>
<td>6.03</td>
<td>1.260</td>
<td></td>
<td>69</td>
</tr>
<tr>
<td>Total</td>
<td>5.46</td>
<td>1.468</td>
<td></td>
<td>216</td>
</tr>
</tbody>
</table>

*Likert Scale question ranged from 1-7 points. 1 being the easiest and 7 being the hardest.

Table 4.13 indicates a significant effect for the visual condition, $F(1, 210) =$
Participants who viewed visuals while listening to instructional material reported lower levels of cognitive load than did participants who did not view visuals. There was an effect of compression on cognitive load, $F(2, 210) = 11.04; p < .001; \text{partial eta squared} = .095$. A significant visual by compression interaction was not found, $F(2, 210) = 1.38; p = .254$.

Table 4.13

*Factorial ANOVA results for the cognitive load measure*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III</th>
<th>Partial Eta Squared</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>98.433</td>
<td>.212</td>
<td>5</td>
<td>19.687</td>
<td>11.321</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Intercept</td>
<td>6457.837</td>
<td>.946</td>
<td>1</td>
<td>6457.837</td>
<td>3713.518</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Visual</td>
<td>54.564</td>
<td>.130</td>
<td>1</td>
<td>54.564</td>
<td>31.376</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Compression</td>
<td>38.390</td>
<td>.095</td>
<td>2</td>
<td>19.195</td>
<td>11.038</td>
<td>.000</td>
<td></td>
</tr>
<tr>
<td>Visual x Compression</td>
<td>4.801</td>
<td>.013</td>
<td>2</td>
<td>2.401</td>
<td>1.380</td>
<td>.254</td>
<td></td>
</tr>
<tr>
<td>Error</td>
<td>365.192</td>
<td></td>
<td>210</td>
<td>1.739</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>6899.000</td>
<td></td>
<td>216</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>463.625</td>
<td></td>
<td>215</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Post Hoc Analysis of Compression on Cognitive Load

A Tukey’s HSD post hoc analysis was used to compare the means between the compression groups as shown in table 4.14. Post hoc analysis revealed that participants in both the 0% and 25% compression groups reported lower levels of cognitive load than did participants in the 50% compression group. There were no differences between the mean scores for the 0% and 25% compression groups. In sum, learners perceive instruction presented at 0% and 25% compression to require less mental effort than instruction presented at 50%. Thus learners indicated that presenting instruction at 50% uses more mental effort than presenting instruction at either 0 or 25% compression rates.

Table 4.14

Tukey’s Post hoc analysis for cognitive load

<table>
<thead>
<tr>
<th>(i) Compression</th>
<th>(J) Compression</th>
<th>Difference</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Compression</td>
<td>25% Compression</td>
<td>-.37</td>
<td>.218</td>
<td>.213</td>
<td>-.88</td>
<td>.15</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>-1.02*</td>
<td>.219</td>
<td>.000</td>
<td>-1.53</td>
<td>-.50</td>
</tr>
<tr>
<td>25% Compression</td>
<td>0% Compression</td>
<td>.37</td>
<td>.218</td>
<td>.213</td>
<td>-.15</td>
<td>.88</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>-.65*</td>
<td>.223</td>
<td>.011</td>
<td>-1.17</td>
<td>-.12</td>
</tr>
<tr>
<td>50% Compression</td>
<td>0% Compression</td>
<td>1.02*</td>
<td>.219</td>
<td>.000</td>
<td>.50</td>
<td>1.53</td>
</tr>
<tr>
<td></td>
<td>25% Compression</td>
<td>.65*</td>
<td>.223</td>
<td>.011</td>
<td>.12</td>
<td>1.17</td>
</tr>
</tbody>
</table>
Review Behaviors: Back and Replay Buttons

The dependent variable review behaviors measured the number of times a participant hit either the back or replay buttons to review an earlier portion of the material. These counts were taken from all participants in all conditions to determine if conditions affected participants’ reviewing behavior. A 2x3 ANOVA was used to analyze the effects of the visual and compression groups on review behaviors. This data met the ANOVA assumptions of independence of observations, normality, and homogeneity of variance (Pallant, 2007; Stevens, 2002).
Table 4.15 shows the descriptive statistics for visual and compression groups on frequency count.

Table 4.15

*Descriptive statistics for Review Behaviors*

<table>
<thead>
<tr>
<th>Visual</th>
<th>Compression</th>
<th>Mean</th>
<th>Std. Deviation</th>
<th>N</th>
<th>(Min – Max)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0% Compression</td>
<td>.79</td>
<td>1.833</td>
<td>38</td>
<td>0 – 9</td>
</tr>
<tr>
<td>No</td>
<td>25% Compression</td>
<td>2.31</td>
<td>5.047</td>
<td>36</td>
<td>0 – 22</td>
</tr>
<tr>
<td>Visual</td>
<td>50% Compression</td>
<td>1.76</td>
<td>3.465</td>
<td>34</td>
<td>0 – 14</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.60</td>
<td>3.689</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0% Compression</td>
<td>1.61</td>
<td>2.737</td>
<td>38</td>
<td>0 – 12</td>
</tr>
<tr>
<td>Visual</td>
<td>25% Compression</td>
<td>1.57</td>
<td>3.310</td>
<td>35</td>
<td>0 – 18</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>3.66</td>
<td>5.821</td>
<td>35</td>
<td>0 – 20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>2.26</td>
<td>4.217</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td></td>
<td>0% Compression</td>
<td>1.20</td>
<td>2.350</td>
<td>76</td>
<td>0 – 12</td>
</tr>
<tr>
<td>Total</td>
<td>25% Compression</td>
<td>1.94</td>
<td>4.266</td>
<td>71</td>
<td>0 – 22</td>
</tr>
<tr>
<td></td>
<td>50% Compression</td>
<td>2.72</td>
<td>4.865</td>
<td>69</td>
<td>0 – 20</td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>1.93</td>
<td>3.966</td>
<td>216</td>
<td></td>
</tr>
</tbody>
</table>
As indicated by Table 4.16, visuals did not have effect on frequency count, $F(1, 210) = 1.525; p = .218; \text{ partial eta squared } = .007$. Additionally, there was not a significant effect of compression rate on review behaviors, $F(2, 210) = 2.707; p = .069; \text{ partial eta squared } = .025$. The interaction was also not significant, $F(2, 210) = 1.998; p = .138; \text{ partial eta squared } = .019$. These results indicate that there were no significant differences between groups on the frequency of reviewing the instructional material.

Table 4.16

*Factorial ANOVA results for Review Behaviors*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III</th>
<th>Mean</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Sum of Squares</td>
<td>Df</td>
<td>Mean Square</td>
</tr>
<tr>
<td>Corrected Model</td>
<td>168.350</td>
<td>5</td>
<td>33.670</td>
</tr>
<tr>
<td>Intercept</td>
<td>818.976</td>
<td>1</td>
<td>818.976</td>
</tr>
<tr>
<td>Visual</td>
<td>23.341</td>
<td>1</td>
<td>23.341</td>
</tr>
<tr>
<td>Compression</td>
<td>82.862</td>
<td>2</td>
<td>41.431</td>
</tr>
<tr>
<td>Visual x compression</td>
<td>61.143</td>
<td>2</td>
<td>30.572</td>
</tr>
<tr>
<td>Error</td>
<td>3213.608</td>
<td>210</td>
<td>15.303</td>
</tr>
<tr>
<td>Total</td>
<td>4187.000</td>
<td>216</td>
<td></td>
</tr>
<tr>
<td>Corrected Total</td>
<td>2281.958</td>
<td>215</td>
<td></td>
</tr>
</tbody>
</table>
Time-on-task

Time-on-task was assessed to determine if there was a difference in the amount of time that participants in the experimental groups spent studying the instructional material. Time-on-task was analyzed via a 2x3 ANOVA. Prior to conducting the analysis the following assumptions were tested with no major violations: independence of observations, normality, and homogeneity of variance (Pallant, 2007; Stevens, 2002).

Table 4.17 shows the descriptive statistics for visual and compression groups on the time-on-task variable.

Table 4.17

Descriptive statistics for time-on-task

<table>
<thead>
<tr>
<th>Visual</th>
<th>Compression</th>
<th>Mean (seconds)</th>
<th>Std. Deviation</th>
<th>Means converted to minutes</th>
<th>N</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Compression</td>
<td>810.24</td>
<td>74.108</td>
<td>13.50</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>No 25% Compression</td>
<td>660.94</td>
<td>113.273</td>
<td>11.01</td>
<td>36</td>
<td></td>
</tr>
<tr>
<td>Visual 50% Compression</td>
<td>491.21</td>
<td>96.635</td>
<td>8.19</td>
<td>34</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td>660.04</td>
<td>161.387</td>
<td>11.00</td>
<td>108</td>
<td></td>
</tr>
<tr>
<td>0% Compression</td>
<td>830.79</td>
<td>93.386</td>
<td>13.85</td>
<td>38</td>
<td></td>
</tr>
<tr>
<td>Visual 25% Compression</td>
<td>657.09</td>
<td>149.444</td>
<td>10.95</td>
<td>35</td>
<td></td>
</tr>
</tbody>
</table>
Consistent with the means shown in Table 4.18, the 2 X 3 ANOVA revealed that there was not a significant main effect of visuals, $F(1, 210) = .882; p = .349$; partial eta squared = .004. However, there was a significant main effect for compression, $F(2, 210) = 142.955; p < .001$; partial eta squared = .577. There was not a significant interaction effect, $F(2, 210) = .362; p = .697$; partial eta squared = .003.

Table 4.18

*Factorial ANOVA results for time-on-task*

<table>
<thead>
<tr>
<th>Source</th>
<th>Type III Sum of Squares</th>
<th>df</th>
<th>Mean Square</th>
<th>F</th>
<th>Sig.</th>
<th>Partial Eta Squared</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrected Model</td>
<td>3634814.856</td>
<td>5</td>
<td>726962.971</td>
<td>57.442</td>
<td>.000</td>
<td>.578</td>
</tr>
<tr>
<td>Intercept</td>
<td>94299453.271</td>
<td>1</td>
<td>94299453.271</td>
<td>7451.212</td>
<td>.000</td>
<td>.973</td>
</tr>
<tr>
<td>Visual</td>
<td>11163.913</td>
<td>1</td>
<td>11163.913</td>
<td>.882</td>
<td>.349</td>
<td>.004</td>
</tr>
<tr>
<td>Compression</td>
<td>3618368.113</td>
<td>2</td>
<td>1809184.056</td>
<td>142.955</td>
<td>.000</td>
<td>.577</td>
</tr>
</tbody>
</table>
A Tukey’s HSD post hoc analysis located the differences in compression levels. As indicated by Table 4.19, participants in the 0% compression group spent more time studying the instructional materials than did participants in either the 25% and 50% compression groups. Additionally, participants who studied material at the 25% compression rate spent more time studying the materials than did those who studied the material at the 50% compression rate.

Table 4.19

Post hoc analysis for time-on-task

<table>
<thead>
<tr>
<th>(i) Compression</th>
<th>(j) Compression</th>
<th>Difference</th>
<th>Std. Error</th>
<th>Sig.</th>
<th>Lower Bound</th>
<th>Upper Bound</th>
</tr>
</thead>
<tbody>
<tr>
<td>0% Compression</td>
<td>25% Compression</td>
<td>161.47*</td>
<td>18.568</td>
<td>.000</td>
<td>117.64</td>
<td>205.3</td>
</tr>
<tr>
<td>50% Compression</td>
<td>25% Compression</td>
<td>315.88*</td>
<td>18.707</td>
<td>.000</td>
<td>271.72</td>
<td>360.03</td>
</tr>
<tr>
<td>25% Compression</td>
<td>0% Compression</td>
<td>-161.47*</td>
<td>18.568</td>
<td>.000</td>
<td>-205.3</td>
<td>-117.64</td>
</tr>
<tr>
<td>25% Compression</td>
<td>50% Compression</td>
<td>154.40*</td>
<td>19.017</td>
<td>.000</td>
<td>109.51</td>
<td>199.29</td>
</tr>
</tbody>
</table>

A Tukey’s HSD post hoc analysis located the differences in compression levels.
Summary of Results

This study sought to examine the effects of time-compressed instruction and visual representations on knowledge based posttests. Prior to analysis, a 2x3 ANOVA tested scores on the prior knowledge pretest. A separate 2 X 3 ANOVA tested the effects of independent variables on total test scores. The learning variables, drawing, identification, terminology, and comprehension were then assessed via a 2x3 MANOVA. Independent variables included visuals (visual or no visual groups) and compression (0%, 25%, and 50%). Additionally, cognitive load, frequency count (back and replay buttons), and time-on-task were assessed.

Prior knowledge was assessed before the knowledge-based posttests were examined. Results of the analysis revealed that there was not a difference in visual or compression groups on the pretest. The total test scores were comprised of all four knowledge-based posttests. Results indicated that participants who were presented visuals scored higher on the total test than did participants who were not provided visuals. Post hoc analysis of the compression groups revealed that participants in the 0% compression group scored higher than did participants in either the 25% or 50% compression groups. Participants in the 25% compression group scored higher than did participants in the 50% compression group.

The effects of visuals and compression were then examined via a 2x3 MANOVA
on the drawing, identification, terminology, and comprehension variables. There were significant main effects of both the Visual and Compression variables on the drawing, identification, and terminology subtests. Inline with the multimedia principle, the use of visuals was shown to improve learning for the drawing, identification, and terminology tests. In sum, participants presented with visuals obtained higher scores than did those who were not presented visuals on the drawing, identification, and terminology tasks.

There was an effect of compression on the learning variables drawing, identification, and terminology. On both the drawing and identification tasks participants in both the 0% and 25% compression groups had similar scores. These scores were significantly higher than were the scores of participants in the 50% group. Analysis of the terminology test revealed that participants in the 0% compression group scored higher than did participants in the 50% compression group. However, the scores of participants in the 25% compression group were not statistically different from the scores of participants in either the 0% or 50% compression groups.

There was a visual by compression interaction on the comprehension learning variable. Compression was found to lower test scores at both 25% and 50% compression rates. Participants who viewed visuals in the 25% condition scored as well as the participants presented with uncompressed instruction. As a result, scores were depressed at the 25% compression rate unless visuals were presented.

There were effects of visuals and compression on the cognitive load variable. Participants presented with visuals had lower cognitive load scores than did participants presented with only a verbal representation. Participants presented with 0% and 25% compression had lower cognitive load scores than did participants presented with 50%
compression. There were no differences between the 0% and 25% compression groups on the cognitive load measure. There was not an effect of visuals on time-on-task, however, there was an effect of compression. The 0% condition took longer than did both the 25% and 50% conditions. The 25% condition took longer than did the 50% condition. There was not an effect of compression or visuals on review behaviors (back and replay buttons).
CHAPTER 5

DISCUSSION

The purpose of this study was to examine the effects of visuals and time-compressed instruction on learning in a multimedia environment. A total of 216 participants were utilized in this study. Each completed a pretest, studied instructional materials, provided cognitive load ratings, and responded to knowledge posttests. In addition measures of frequency count and time-on-task were collected as indicators of participants’ study behaviors during their treatment. The following chapter begins by summarizing the results of the previous chapter and discussing the effects of visuals and compression on each dependent variable. Instructional recommendations are then made. The chapter ends with a discussion of conclusions, limitations, and recommendations for future research.

Summary of Results

A 2 X 3 ANOVA with prior knowledge scores as the dependent variable indicated that there were no significant differences between conditions before the study began. A 2 X 3 ANOVA with total test score as the dependent variable did reveal significant differences. The total test consisted of each posttest measure: drawing, identification, terminology, and comprehension. There were effects of visuals and compression on total test. First, participants presented with visuals scored significantly higher than did those who were not provided with visuals. In addition, post hoc analysis comparing participants
at different levels of compression indicated that participants presented uncompressed instruction performed better than did participants in the 25% and 50% conditions. Participants in the 25% group performed better than did those in the 50% compression group.

A 2x3 MANOVA was then conducted to investigate the effects of visuals and time-compressed instruction on the learning variables: drawing, identification, terminology, and comprehension. There were effects of visuals and compression on the drawing, identification, and terminology tests. Furthermore, there was a significant visual by compression interaction effect on comprehension. Participants who viewed visuals obtained higher scores on the drawing, identification, and terminology groups performed better than did participants who did not view visuals. This finding supports the multimedia principle, which suggests that students who study both a verbal and pictorial representation acquire more knowledge than do students who study only one of these representations. There were effects of compression on the drawing, identification, and terminology tests. Results of the drawing and identification tests suggested that participants in the uncompressed groups obtained similar scores to participants in the 25% compression groups. However, participants in the 0% and 25% groups scored significantly higher than did participants in the 50% compression conditions. However, the terminology variable yielded different results. Participants in the uncompressed condition scored higher than did participants in the 50% condition. Scores of participants in the 25% condition, however, were not significantly different from either the 0% or 50% compression groups.

There was an interaction effect of visuals by compression on the comprehension
test. Participants in the 25% and 50% conditions obtained the lowest scores overall. Participants in the 25% condition with visuals performed as well as both uncompressed conditions. These results indicate that learners’ comprehension is lowered at 25% if visuals are not presented. Comprehension is lowered at 50% compression even if visuals are presented.

There was an effect of visuals and compression on cognitive load. Consistent with the Cognitive Theory of Multimedia Learning, learners presented with verbal and nonverbal representations reported lower load levels than did learners presented only verbal instruction. There was an effect of compression on cognitive load. Participants presented 50% compression reported higher cognitive load scores than participants in both the 25% and uncompressed conditions. Participants in the 0% and 25% conditions obtained similar load scores.

There was no effect of compression on participants review behaviors. This is consistent with the time-on-task variable. There was not an effect of visuals on time-on-task, yet there was for compression. The uncompressed condition took longer than the 25% condition, which took longer than the 50% condition. If each of these conditions were allowed to play through, each condition (0%, 25%, and 50%) would be longer than the next. For that reason, even though participants could use the back and replay buttons (review behaviors), the uncompressed condition still took the longest. Thus higher rates of compression had no effect on participants’ use of the back and replay buttons.
Findings

Visuals and Learning

Prior research indicates that learners who study multiple representations (verbal and non-verbal) acquire more knowledge than learners who study just one representation in a multimedia environment (Mayer, 2001). The results of the drawing, identification, and terminology tests uncovered a similar conclusion. These tests were designed to examine learners’ understanding of the material by measuring different types of knowledge (facts, concepts, and rules/procedures). These assessments revealed that presenting learners with visual representations did improve learning beyond providing learners with only the verbal instruction. These findings are consistent with the Cognitive Theory of Multimedia Learning (CTML) and multimedia principle, which will be discussed further below. In sum, presenting learners with visuals was found to increase learning from a multimedia environment.

Compression and Learning

Results of the drawing, identification, and terminology tests indicate that participants who studied normally-paced (0%) and moderately-compressed instruction (25%) obtained similar scores on knowledge posttests. Learners presented with 50% instruction on the drawing and identification tests, however, scored significantly lower than did the 0% and 25% compression groups. This finding is inline with previous research that found learners’ factual understanding of material is decreased at 50%
compression. For instance, Heiman, Leo, & Leighbody (1986) found that learner comprehension decreased slowly from 0% to 50% then rapidly at 50%. In short, students who listen to instruction compressed at 50% are not able to learn from this material. Scores for this condition on the comprehension posttest were significantly lower in comparison to the other conditions, which suggests that this compression rate is too fast for learners to gain a conceptual understanding of the material. Presenting material at 50% does not give learners sufficient time to make the correct connections and inferences in the instruction. Additionally, scores from this condition were also significantly lower on both the drawing and terminology posttests, which assess knowledge of specific, individual concepts explained in the instructional material. Scores on these assessments indicate that it is not only students’ ability to understand the material that is harmed at the 50% compression rate. These participants were also unable to learn basic definitions of the concepts presented in the instruction.

Although there were not significant differences in the posttest scores of participants in the 0% and 25% conditions, there was an overall decrease in scores from 0% to 25% compression. Thus, at some point between 25% and 50% compression, comprehension is significantly decreased for the drawing, identification, and terminology tasks.

*Multimedia Learning in a Compressed Environment*

The Cognitive Theory of Multimedia Learning assumes that working memory consists of a dual channel system, each channel has a limited processing capacity, and that learners engage in active processing during learning (Mayer & Sims, 1994). This
theory suggests that presenting learners with multiple representations (verbal and non-verbal) is better than presenting learners with only one representation as long as they are not competing for the same channel resources (Mayer, 2001; Tindall-Ford, Chandler, & Sweller, 1997). Current multimedia literature has not focused on the use of compressed instruction. For that reason, the findings from this study contribute a unique perspective to the multimedia learning literature.

Results of the drawing, identification, and terminology tests support the CTML and multimedia principle. Thus, learners who were presented with both the visual and verbal representations were able to make the appropriate connections that led to a deeper understanding of the material. Learners who were provided only a verbal representation were not able to make those connections. Furthermore, the multimedia principle held even when learners were presented with compressed instruction. Participants presented with visuals performed best in the 0% and 25% compression conditions. Hence, the use of verbal and non-verbal representations supported learning even when a time-compression instructional strategy was used. When instruction was moderately compressed learners were still able to make the appropriate connections between representations required for learning but only when visuals were included. As a result, when instruction is moderately compressed (25%) learners working memory channels are still able to function as they would when presented normal-paced instruction. Thus, each channel in working memory (verbal and non-verbal) is not being overloaded at 0% or 25% compression. Therefore, using moderately compressed (25%) multimedia instruction results in a 25% user timesavings and does not decrease learning. In sum, compressing instruction up to 25% supports learning from a multimedia-learning
The benefits of the visual representations were most strongly indicated on the comprehension posttest. This assessment measures students’ comprehension (problem solving ability) of the material. At moderate levels of compression (25%), comprehension was decreased unless visuals were included in the instruction. The 25% compression group performed as well as the normal paced instruction groups when visuals were presented. Hence, if even moderately compressed instruction is to be used with high-level learning tasks, both visual and verbal representations should be included. Otherwise, if only a single representation is presented when instruction is moderately-compressed (25%), learners will have a limited conceptual understanding of the material. This suggests that moderately compressed (25%) high-level knowledge instruction may overload working memory unless multiple representations (visual and verbal) are presented, although learners do not indicate sensitivity to this effect. Thus, moderately compressed instruction (25%) is only effective in a multiple representation environment (verbal and non-verbal) for the comprehension measure. If high-level knowledge is desired, compressed material must contain visuals otherwise learning will decrease.

The multimedia principle did not hold for participants in the 50% compression condition. Thus, participants presented multimedia instruction at 0% and 25% compression obtained higher scores on knowledge posttests than did those participants who were presented with 50% compression. This finding was not surprising for the comprehension test, which was designed to measure high-level knowledge. Both the visuals and verbal instruction were required to understand the material. However, 50% compression is too fast for high-level learning even if instructional design strategies are
implemented. Findings from the comprehension test suggest that moderately-compressed instruction (25%) should only be used with a strategy designed to support learning, such as using multiple representations (verbal and nonverbal).

In sum, presenting learners with instruction that is moderately compressed (25%) supported learning for drawing, identification, and terminology tests. However, the comprehension test revealed that high-level knowledge should only be compressed if a multimedia strategy is implemented. At 50% compression, participants performed poorly on comprehension measures even if visuals were used. Thus, the multimedia principle did not hold when instruction was compressed at 50% for high-level knowledge tasks. Therefore, the multimedia principle only holds true when instruction is moderately-compressed (25%).

*Cognitive Load in a Compressed Environment*

The findings of this study support cognitive load theory and reiterate conclusions made in the multimedia literature. Providing learners with well-designed multiple representations reduces cognitive load by effectively using both processing channels (Paivio, 1986; Mayer & Sims, 1994; Mousavi, Low, and Sweller, 1995). Consistent with this assertion, the results of this study indicate that learners who were provided visual representations felt they used less mental effort to study the contents than did participants who did not have these additional representations. Thus, using multiple representations (verbal and non-verbal) reduces cognitive load by effectively using multiple processing channels in working memory.

Furthermore, as the speed of instruction increased from 25% to 50% compression,
learners’ cognitive load also increased. The cognitive load measure indicated that learners did not believe that they were using additional mental effort when presented with moderately-compressed instruction (25%). This is inline with the invariant timing hypothesis, which suggests that learners cannot tell the difference in audio quality when tempo is changed up to a certain point (Honing, 2007; Reed, 2003). Therefore, the 50% compressed instruction is too fast for participants to learn from. At this speed, cognitive load was increased substantially. Participants had to use more mental effort to understand the material and make connections among concepts in the instruction. Participants’ reported mental effort was consistent with performance on the posttests. At 50% compression, participants not only reported high levels of cognitive load, they also performed poorly on the posttests. Thus, 50% compression is too fast for learning to take place.

In sum, the findings of this study supported cognitive load theory. Prior research indicates that presenting well designed multiple representations reduces cognitive load and does not overload working memory. The current study revealed that learners who were presented with multiple representations indicated that they used less mental effort than did participants who were presented with only one representation. Thus, presenting well designed multiple representations reduces cognitive load by efficiently using both working memory processing channels. Posttest results, which found that visual groups outperformed the no visual groups, supported this finding. In addition, learners in the normal-paced (0%) and moderately-paced (25%) compression groups indicated that they used similar amounts of mental effort during the instructional treatments. Therefore, compressing audio up to 25% should not increase the amount of load on technical
material. Learners in the 50% compression groups indicated that they used more effort than both the 0% and 25% compression groups. Not only did they indicate that they used more mental effort in the 50% compression condition but they also performed worse on posttest measures. Thus, 50% compression overloads working memory and inhibits learning.

**Instructional Recommendations**

The findings on the drawing test indicate that audio can be compressed up to 25% without significant declines in student learning. 50% appears too fast and reduces learning from the materials. Participants presented with visuals in the 0% and 25% conditions performed best. Thus, presenting learners with instruction at 0% to 25% with visuals is recommended for the drawing task. Students who study materials at these speeds are able to adequately learn.

Similar to the drawing test, findings of the identification test suggest that instruction can be presented up to 25%. Increasing compression beyond 25% decreases learners’ understanding of factual material. Additionally, participants will perform better on posttests if visuals are used. As a result, presenting learners with visuals at 0% to 25% appear to be the best methods to deliver instruction.

Findings of the terminology task indicate that participants will perform best on posttests if visuals are used. Additionally, instruction can be compressed up to 25% compression without sacrificing learners’ understanding of concepts and rules/procedures. Therefore, students who study instruction presented at 25% compression with visuals are able to adequately learn.
Visual inspection of the means for the comprehension test revealed that participants performed best in the 25% compression with visuals. This indicates that compressing audio up to 25% in a multimedia environment may yield higher scores on problem solving measures than presenting instruction at normal speed. However at 0% compression without visuals, participants performed nearly as well. As such, designers will need to decide what is more important to them: spending time and money developing visuals for a user time-savings of 25% or cutting development time/costs and use 0% compression without visuals.

Based on results of the total test, presenting learners with visuals appears to increase learner comprehension on all tests. Additionally, presenting learners with visuals at 0% and 25% led to the highest scores on all four measures combined. Therefore compressing audio up to 25% will lead to higher scores if the instruction includes strategies designed to support learning, such as the use of visuals.

Presenting instruction at 0% to 25% leads to similar amounts of mental effort. This was indicated by the cognitive load measure. By including visuals, cognitive load was decreased. Therefore presenting instruction that is compressed up to 25% with visuals appears to be the best method of instructional delivery. At 25% compression cognitive load remains decreased and results in learner timesavings. This timesavings is revealed on the time-on-task variable. Time-on-task revealed that participants took different times at each level of compression. Thus time-compression will result in timesavings even if participants can control the pace of instruction. As a result, presenting higher rates of compression can save time. Even though 50% compressed instruction increased cognitive load, participants were not more inclined to replay
instruction. This indicates that instruction was too fast for participants and they may have given up paying attention rather than constantly replaying instruction. Additionally, several participants in the 50% compression indicated to the researcher, upon handing in their folders, that their instruction was too fast for them to follow.

**Conclusions**

The multimedia principle indicates that participants who view multiple representations in a multimedia environment will outperform those who do not when presented with high-level knowledge tasks. Findings in this study confirmed the multimedia principle and suggest that combining verbal and nonverbal representations benefited learning for all dependent variables: drawing, identification, terminology, and comprehension. Furthermore, the results imply that when the representations are used correctly to support learning cognitive load is reduced.

The research on time-compressed instruction has been limited and thus, there is little research available to consider how the multimedia principle might interact with compression. However, there has been a considerable amount of research on the multimedia principle and high-levels of learning utilizing normal-paced instruction. This study expands prior research and examines time-compressed instruction in a multimedia environment on high-levels of learning. Hence, this study fills an important gap in the multimedia literature.

The drawing, identification, and terminology tasks revealed that instruction could be compressed up to 25% without sacrificing learning. Results of the comprehension test indicate that instruction could be compressed up to 25% if visuals are utilized. Visuals
did not support learning at 50% compression when learners were presented with the comprehension task. These findings are important given that designers, instructors, and students have the ability to compress instruction on their own.

For that reason, designers should consider compressing audio instruction up to 25% compression with visuals where timesavings are a concern. However, designers will need to consider if the user timesavings are worth the extra development time/costs of producing quality visual images. Ultimately, it will be up to the designer to decide where time compression is appropriate based on the guidelines outlined in this paper.

The range of possibilities for the application of time-compressed instruction is numerous. Thus, the findings in this study are vital to both corporate and academic institutions who wish to save time when delivering podcasts and/or computer based instruction. Nonetheless, the reader should be aware that presenting instruction above 25% could decrease learning and increase cognitive load to undesirable levels. Therefore caution should be exercised if compressing audio above 25% time compression.

**Limitations**

There were four main limitations in this study. First, the results of this study should not be generalized to the entire college undergraduate population. Participants in this study were education majors from a medium sized state university. Second, this study did not test the effects of prior knowledge on learning from compressed instruction. On the whole, participants in this study had little prior knowledge of the topic. The effects of visuals and compression on learning may be different for learners with higher levels of prior knowledge. Third, participants in this study were not allowed to choose how fast
they listened to instruction. If they thought the instruction was too fast or slow, they could not change it. Finally, this study used a computer to play/display instruction. Results may differ on other devices used to play audio i.e. the mp3 player. When multimedia is played on small devices with screens that are less than a few inches, visual representations may not be visually appealing.

**Future research**

Future research should be conducted on the effects of compression on different populations to confirm the results of this study. Examining different populations would add to the current literature on time-compressed instruction in a multimedia environment. This could lead to a clear set of guidelines for utilizing compressed instruction.

Learners with different prior knowledge levels might comprehend time-compressed speech differently. Learners with high prior knowledge may be able to listen to a higher rate of compression. Therefore examining the effects of compression on prior knowledge could lead to different recommended rates of compression for learners with different prior knowledge levels.

A qualitative approach to understanding learners’ experiences with time-compression could lead to a deeper understanding of the time-compression phenomenon. Learners’ preferences from a qualitative perspective would indicate how learners feel towards compressed speech. This would reveal if learners enjoy/prefer time-compressed speech.

Delayed retention of time-compressed instruction could lead to different
instructional recommendations than were given for immediate posttest retention. This would indicate if there are differences in normal paced and 25% compressed instruction after a delay in instruction and assessment.

Finally, analyzing time-compressed instruction on portable devices (mp3 player) in a multimedia environment would broaden the scope of generalization in the time-compression literature. Current time-compression literature focuses on the computer. Portable devices have smaller screens and technological limitations. These devices may yield different results and lead to recommendations based on the device used.
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SoundTouch audio processing library v1.3.1  SoundTouch library Copyright (c) Olli Parviainen 2002-2006  Retrieved April 1st, 2007, from http://www.surina.net/soundtouch/README.html.


APPENDIX A

Instructional Script

Instructional Script as developed by Dwyer (1965) and edited by Dwyer and Lamberski (1983)
The Parts of the Heart

In order to better comprehend the following instruction, it will be helpful to visualize a cross-sectional view of a human heart in a position such that you are facing a person. Therefore, the right side of the person's heart is to your visual left, as shown in the above diagram. Likewise, the left side of the person's heart would be illustrated on the right side in the diagram.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weights about 11 ozs. And a woman's heart weighs about 9 ozs.

The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the apex and is the part that you feel beating.

The human heart is really two pumps combined in a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the septum, between them.

Each half of the heart is divided into an upper chamber and a lower chamber. The upper chambers on each side of the septum are called auricles; the lower chambers are called ventricles. Auricles have thin walls and act as receiving rooms for the blood, while the ventricles having thicker walls act as pumps moving the blood away from the heart. Although there is no direct communication between the right and left sides, both sides function simultaneously.

The heart contains several layers of membranes and muscle. The first set of membranes enclose the heart in a thin double-walled sac. The layer which forms the outer wall of the sac is called the pericardium. It is composed of a tough, transparent elastic tissue. It protects the heart from rubbing against the lungs and the walls of the chest. The inner portion of the double-walled sac is called the epicardium. It is attached to the heart muscle.

The heart muscle is called the myocardium; it controls the contraction and relaxation of the heart. The myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood through the body. The muscle varies in thickness; for example, the muscle in the auricle walls are thin when compared
to the thickness of the muscle in the ventricle walls.

Finally the endocardium is the name given to the membrane lining inside of the heart wall.

Blood enters the heart through veins. Only veins carry blood to the heart. The superior and inferior vena cava are the two veins which deposit blood in the right auricle; there are no valves at the opening of these veins.

The superior vena cava deposits blood into the right auricle from all body parts above heart level, for example, the head and arms. The inferior vena cava carries blood from parts of the body below heart level, for example, the trunk and legs, depositing the blood in the right auricle.

As blood from the body fills the right auricle, some of it begins to flow into the right ventricle immediately, through a common opening.

This common opening, between the right auricle and right ventricle, is called the tricuspid valve. This valve consists of three triangular flaps on thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender tendons.

Thus, blood passes from the right auricle through the tricuspid valve into the right ventricle. As the right ventricle is filled with blood, both ventricles begin to contract creating pressure.

While the blood pressure behind the tricuspid valve brings the flaps together and prevents the flow of blood between the right auricle and the right ventricle, the contraction of the right ventricle continues until the blood presses hard enough to open the pulmonary valve.

The pulmonary valve, located between the right ventricle and the pulmonary artery, consists of three flaps like the tricuspid valve. As soon as the right ventricle begins to relax from its contraction, the valve flaps are filled with blood backing up from the pulmonary artery. The flaps are pressed together stopping the blood flow back into the right ventricle. The pulmonary valve only opens when the pressure in the right ventricle is greater than the pressure in the pulmonary artery, forcing the blood into the artery.

In the pulmonary artery the blood is carried away from the heart to both the left and right lungs where it is cleansed and oxygenated. Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle; these vein openings, like the vena cava, have no valves. The
left auricle then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left auricle and the left ventricle, is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the valve thereby closing the passageway back to the left auricle. Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by slender tendons.

The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle is filled with blood, it contracts resulting in the pressure opening the aortic valve. The aortic valve is similar to the other flap like valves; the valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta.

The aorta is the large artery which carries the blood away from the heart back to the various parts of the body.

**The Circulation of Blood Through the Heart**

The directional flow of blood in the heart is determined by valves which allow the blood to flow in only one direction. These sets of valves are the tricuspid and mitral valves, which control the flow of blood from the auricles to the ventricles, and the pulmonary and aortic valves which control the flow of blood from the ventricles to the arteries.

Both auricles receive blood simultaneously through vein openings which have no valves. The right auricle receives its blood through the superior and inferior vena cava, while the left auricle receives its blood through the pulmonary veins.

A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously, over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale and in doing so the blood in their chambers is subjected to increased pressure which forces blood to the ventricles through the opened tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.

The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract. This contraction increases the pressure in the ventricle chambers forcing the tricuspid and mitral valves completely closed, thereby preventing blood from
being forced backwards into the auricles.

The auricles, relaxing from their contraction, receive a continuous blood flow from the vena cava and the veins.

As the ventricles continue to contract, pressure in these chambers force the pulmonary and aortic valves to open. The pulmonary valve, leading from the right ventricle, guards the entrance to the pulmonary artery. The aortic valve, leading from the left ventricle, guards the entrance to the aorta or aortic artery.

Both are 3 flapped valves, and are together known as the semi-lunar valves. Prior to ventricle contraction, the valves are closed by back pressure provided by blood already in the exit arteries. When pressure in the ventricles becomes greater than that in the exit arteries due to ventricle contraction, the semi-lunar valves open.

With the semi-lunar valves open, blood flows from the right ventricle into the pulmonary artery on route to the lungs for cleaning and oxygen. Simultaneously, blood flows from the left ventricle into the aorta for distribution throughout the entire body.

Immediately following the pumping of blood into the arteries, the ventricles begin to relax. This relaxation lowers the pressure within their chambers and the greater pressure in the arteries close the semi-lunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.

As the ventricles relax further, pressure within them rapidly decreases. At the same time blood flowing into the auricles from the veins increases the auricle pressure. Due to the differential pressure between the auricles and ventricles, the tricuspid and mitral valves are forced partially open.

The circulation of blood through the heart begins again with the next auricle contraction. Auricle pressure fully opens the tricuspid and mitral valves resulting in a rapid flow of blood into the ventricles.

**The Cycle of Blood Pressure in the Heart**

The cycle of blood pressure in the heart consists of two distinct phases. One of these phases is called the diastolic or relaxation phase.

In the diastolic phase, the heart relaxes between contractions. Blood flows into the heart, filling both auricles. While blood is flowing into the auricles, the arteries still maintain part of the pressure developed by a prior ventricle contraction. This is the time of lowest
pressure in the arteries, or what is called the diastolic pressure.

During this phase the ventricles are also relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially opened tricuspid and mitral valves.

The second phase, the systolic or contraction phase, begins when the auricles contract. The blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles then contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries.

The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is greatest; we refer to this pressure as the systolic pressure.

The heart begins to relax again. The semi-lunar valves are closed; blood flows into the auricles from the veins; and the tricuspid and mitral valves are forced partially open.

The diastolic phase begins, and the cycle of blood pressure starts again.
APPENDIX B

Instruction with Visuals

Instruction with visuals as identified by Dwyer and Lamberski (1983)
The Parts of the Heart

In order to better comprehend the following instruction, it will be helpful to visualize a cross-sectional view of a human heart in a position such that you are facing a person. Therefore, the right side of the person's heart is to your visual left, as shown in the above diagram. Likewise, the left side of the person's heart would be illustrated on the right side in the diagram.

The human heart is a hollow, bluntly conical, muscular organ. Its pumping action provides the force that circulates the blood through the body. In the average adult, the heart is about five inches long and about two and one half inches thick. A man's heart weighs about 11 ozs. And a woman's heart weighs about 9 ozs.
The heart lies toward the front of the body and is in a slanting position between the lungs, immediately below the breastbone. The wide end points toward the right shoulder. The small end of the heart points downward to the front of the chest and toward the left. The lower portion of the heart is called the Apex and is the part that you feel beating.

The human heart is really two pumps combined in a single organ which circulates blood to all parts of the body. The heart is divided longitudinally into two halves by the Septum. The two halves may be compared to a block of two houses, which are independent of each other but have a common wall, the Septum, between them.
Each half of the heart is divided into an upper chamber and a lower chamber. The upper chambers on each side of the septum are called Auricles; the lower chambers are called Ventricles. Auricles have thin walls and act as receiving rooms for the blood, while the Ventricles having thicker walls act as pumps moving the blood away from the heart. Although there is no direct communication between the right and left sides, both sides function simultaneously.
The heart contains several layers of membranes and muscle. The first set of membranes enclose the heart in a thin double-walled sac. The layer which forms the outer wall of the sac is called the Pericardium. It is composed of a tough, transparent elastic tissue. It protects the heart from rubbing against the walls of the chest. The inner portion of the double-walled sac is called the Epicardium. It is attached to the heart muscle.

The heart muscle is called the Myocardium; it controls the contraction and relaxation of the heart. The Myocardium constitutes by far the greatest volume of the heart and its contraction is responsible for the propulsion of the blood through the body. The muscle varies in thickness; for example, the muscle in the auricle walls is thin when compared to the thickness of the muscle in the ventricle walls.

Finally, the Endocardium is the name given to the membrane lining inside of the heart wall.
Blood enters the heart through veins. Only veins carry blood to the heart. The Superior and Inferior Vena Cavas are the two veins which deposit blood in the right auricle; there are no valves at the opening of these veins.

The Superior Vena Cava deposits blood into the right auricle from all body parts above heart level, for example, the head and arms. The Inferior Vena Cava carries blood from the parts of the body below heart level, for example, the trunk and legs, depositing the blood in the right auricles.

As blood from the body fills the right auricles, some of it begins to flow into the right ventricle immediately, through a common opening.
This common opening, between the right auricle and the right ventricle, is called the Tricuspid Valve. This valve consists of three triangular flaps on thin, strong, fibrous tissue. These flaps permit the flow of blood into the right ventricle, but prevent it from flowing backward into the right auricle because the ends of the flaps are anchored to the floor of the right ventricle by slender Tendons.

Thus, blood passes from the right auricle through the Tricuspid Valve into the right ventricle. As the right ventricle is filled with blood, both ventricles begin to contract creating pressure.
While the blood pressure behind the tricuspid valve brings the flaps together and prevents the flow of blood between the right auricle and the right ventricle, the contraction of the right ventricle continues until the blood presses hard enough to open the Pulmonary Valve.

The Pulmonary Valve, located between the right ventricle and the Pulmonary Artery, consists of three flaps like the tricuspid valve. As soon as the right ventricle begins to relax from its contraction, the valve flaps are filled with blood backing up from the Pulmonary Artery. The flaps are pressed together stopping the blood flow back into the right ventricle. The Pulmonary Valve only opens when the pressure in the right ventricle is greater than the pressure in the Pulmonary Artery, forcing the blood into the artery.

In the Pulmonary Artery the blood is carried away from the heart to both the left and right lungs where it is cleansed and oxygenated.
Returning from the lungs, the blood enters the heart through four pulmonary veins and collects in the left auricle; these vein openings, like the vena cava, have no valves. The left auricle then contracts when it is full, squeezing blood through the mitral valve into the left ventricle.

The mitral valve, located between the left auricle and the left ventricle, is similar in construction to the tricuspid valve. As the left ventricle contracts simultaneously with its mate, the right ventricle, it forces blood behind the flaps of the valve thereby closing the passageway back to the left auricle. Like the tricuspid valve, the ends of the mitral valve flaps are anchored to the floor of the left ventricle by slender tendons.
The contraction of the left ventricle pumps the blood through the entire body. For this reason it is the largest, strongest, and most muscular section of the heart. When the left ventricle is filled with blood, it contracts resulting in the pressure opening the aortic valve. The aortic valve is similar to the other flap-like valves; the valve stops the backward flow of blood to the left ventricle and opens for the forward flow of blood to the aorta.

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A wave of muscular contraction starts at the top of the heart and passes downward, simultaneously, over both sides of the heart; that is, both auricles contract at the same time and then relax as the contraction passes down to the ventricles. When the auricles are caused to contract, they become small and pale and in doing so the blood in their chambers is subjected to increased pressure which forces blood to the ventricles through the opened tricuspid and mitral valves.

As the ventricles fill, eddies of the blood float the flaps on both the tricuspid and mitral valves back to a partially closed position.
The instant that the contraction of the auricles has been completed, the ventricles are stimulated to contract. This contraction increases the pressure in the ventricle chambers forcing the tricuspid and mitral valves completely closed, thereby preventing blood from being forced backwards into the auricles.

The auricles, relaxing from their contraction, receive a continuous blood flow from the vena cavas and veins.
As the ventricles continue to contract, pressure in these chambers forces the pulmonary and aortic valves to open. The pulmonary valve, leading from the right ventricle, guards the entrance to the pulmonary artery. The aortic valve, leading from the left ventricle, guards the entrance to the aorta or aortic artery.

Both are 3-flapped valves, and are together known as the semi-lunar valves. Prior to ventricle contraction, the valves are closed by back pressure provided by blood already in the exit arteries. When pressure in the ventricles becomes greater than that in the exit arteries due to ventricle contraction, the semi-lunar valves open.
With the semi-lunar valves open, blood flows from the right ventricle into the pulmonary artery on route to the lungs for cleaning and oxygen. Simultaneously, blood flows from the left ventricle into the aorta for distribution throughout the entire body.
Immediately following the pumping of blood into the arteries, the ventricles begin to relax. This relaxation lowers the pressure within their chambers and the greater pressure in the arteries closes the semi-lunar valves. Pressure within the ventricles is sufficient, however, to maintain closure of the tricuspid and mitral valves against the already increasing auricle pressure.
As the ventricles relax further, pressure within them rapidly decreases. At the same time blood flowing into the auricles from the veins increases the auricle pressure. Due to the differential pressure between the auricles and ventricles, the tricuspid and mitral valves are forced partially open.

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The cycle of blood pressure in the heart consists of two distinct phases. One of these phases is called the diastolic or relaxation phase.

In the diastolic phase, the heart relaxes between contractions. Blood flows into the heart, filling both auricles. While blood is flowing into the auricles, the arteries still maintain part of the pressure developed by a prior ventricle contraction. This is the time of lowest pressure in the arteries, or what is called the diastolic pressure.

During this phase the ventricles are also relaxing. The ventricles are slowly being filled with blood, due to the full auricles and partially opened tricuspid and mitral valves.
The second phase, the systolic or contraction phase, begins when the auricles contract. The blood is forced through the tricuspid and mitral valves into the ventricles. The ventricles then contract forcing the blood through the semi-lunar valves into the pulmonary and aortic arteries.

The blood leaves the ventricles under terrific pressure and surges through the arteries with a force so great that it bulges their elastic walls. At this point, arterial blood pressure is greatest; we refer to this pressure as the systolic pressure.
The heart begins to relax again. The semi-lunar valves are closed; blood flows into the auricles from the veins; and the tricuspid and mitral valves are forced partially open.

The diastolic phase begins, and the cycle of blood pressure starts again.
APPENDIX C

Pre-Test
Physiology Pre-test

DIRECTIONS TO THE SUBJECTS: In the following 36 multiple-choice questions, select the answer which you feel best completes the sentence and place it on your answer sheet.

1. The part of the tooth which contains the hardest substance in the body is the
   a. root
   b. dentine
   c. cement
   d. enamel

2. The digestion of food occurs principally in the
   a. stomach
   b. small intestine
   c. mouth
   d. large intestine

3. Contraction of the smooth muscle of the alimentary canal is called
   a. peristalis
   b. digestion
   c. absorption
   d. assimilation

4. Worn-out red blood cells are decomposed in the
   a. heart
   b. lungs
   c. kidneys
   d. liver

5. "Swollen" glands means an enlargement of the
   a. lymph nodes
   b. heart valves
   c. vena cava
   d. portal vein

6. The chief value of perspiration is that it
   a. eliminates body odors
   b. opens the pores
   c. reduces weight
   d. regulates body temperature

7. Endocrine glands produce
   a. enzyme
   b. endoplasm
   c. hormones
d. serums

8. The body is stimulated to usual activity by increase secretion from the
a. pancreas
b. adrenal glands
c. thyroid gland
d. thymus gland

9. The spinal cord is made up of
a. bone tissue
b. cartilage tissue
c. connective tissue
d. nerve tissue

10. Nerves from the eyes and ear are connected to the
a. cerebellum
b. cerebrum
c. medulla
d. spinal cord

11. The chromosome number of the body cells of identical human twins is
a. 12
b. 24
c. 46
d. 92

12. The person who can give blood to another person but can receive only his own type of blood has blood type
a. A
b. 0
c. AB
d. B

13. The ribs are attached to the spine and meet in the front of the body at, the
a. skull
b. limbs
c. joints
d. breastbone

14. The ribs protect the
a. stomach
b. breastbone
c. spinal cord
d. lungs

15. The hollow interior of the long bones is filled with
a. marrow
b. minerals
c. red and white corpuscles
d. Haversian canals

16. The windpipe is located _______ the esophagus
   a. in front of
   b. behind
   c. to the left of
   d. to the right of

17. The carbon dioxide-oxygen exchange with the atmosphere occurs in the
   a. nose
   b. trachea
   c. lungs
   d. bronchi

18. Blood is oxygenated in the capillaries of the
   a. air sacs
   b. heart
   c. muscle
   d. liver

19. During inspiration, the ribs
   a. do not move
   b. move downward
   c. move inward
   d. move upward

20. The part of the brain that controls respiration is the
   a. medulla
   b. cerebellum
   c. cerebrum
   d. spinal cord

21. A defense of the body against bacteria is
   a. haemoglobin
   b. phagocytes
   c. red blood cells
   d. blood platelets

22. The disease haemophilia is associated with
   a. the bone structure
   b. blood clotting
   c. the structure of nervous tissue
   d. the formation of red corpuscles
23. The liquid that bathes every cell and acts as a medium of exchange is
a. cell sap
b. fibrinogen
c. lymph
d. fibrin

24. Urine is stored in an organ called
a. diaphram
b. kidney
c. bladder
d. lungs

25. Secretions of the ductless glands pass
a. into tubes or ducts
b. directly into the blood stream
c. directly into the organs where they are used
d. out of the body

26. Inactivity of the thyroid gland from infancy may produce a condition known as
a. diabetes
b. beriberi
c. cretinism
d. addison’s disease

27. The concentration of sodium and potassium in the blood is controlled by
a. adrenin
b. cortin
c. insulin
d. secretin

28. Diabetes is caused by the improper functioning of the
a. parathyroids
b. thyroids
c. pancreas
d. adrenals

29. The adult human heart is said to beat approximately ____ times a minute.
a. 85
b. 72
c. 60
d. 58

30. Growth and repair of body tissue involves
a. protein
b. fats
c. starch
d. sugar

31. Blood enters the heart through
   a. arteries
   b. vena cava
   c. the aortic arch
   d. pulmonary veins

32. Blood leaves the heart through the
   a. tricuspid valve
   b. aorta
   c. superior vena cava
   d. mitral valve

33. The portion of the heart which divides it longitudinally into 2 halves is called the
   a. myocardium
   b. tendons
   c. pericardium
   d. septum

34. A blood vessel which carries deoxygenated blood is the
   a. aorta
   b. pulmonary artery
   c. hepatic artery
   d. pulmonary vein

35. The backward flow of blood in the veins is prevented by
   a. muscles
   b. valves
   c. the heart beat
   d. lymphatics

36. The chamber of the heart which pumps oxygenated blood to all the parts of the body is the
   a. left auricle
   b. right ventricle
   c. right auricle
   d. left ventricle
APPENDIX D

Drawing Test
DRAWING TEST

Directions: This is the first part of a four part test. Draw a simple line picture of a heart in the space provided on the right and place the corresponding number of the 20 identified parts (see list at the bottom), where they would be located on the heart.

1. Superior Vena Cava
2. Aorta
3. Tricuspid Valve
4. Pulmonary Veins
5. Septum
6. Epicardium
7. Aortic Valve
8. Pulmonary valve
9. Inferior Vena Cava
10. Pulmonary Artery
11. Myocardium
12. Endocardium
13. Mitral Valve
14. Right auricle
15. Right ventricle
16. Left auricle
17. Left ventricle
18. Apex
19. Tendons
20. Pericardium
When you are finished with this section, put it in the folder provided and raise your hand
APPENDIX E

Identification Test
IDENTIFICATION TEST

Directions: Select the answer you feel best identifies the part of the heart indicated by the numbered arrows.

21. Arrow number one (1) points to the
   A. Septum
   B. Aorta
   C. Pulmonary Artery
   D. Pulmonary Vein
   E. None of These

22. Arrow number two (2) points to the
   A. Superior Vena Cava
   B. Inferior Vena Cava
   C. Pulmonary Artery
   D. Tricuspid Valve
   E. Aorta

23. Arrow number three (3) points to the
   A. Right Ventricle
   B. Right Auricle
   C. Left Ventricle
   D. Left Auricle
   E. Heart Muscle

24. Arrow number four (4) points to the
   A. Pulmonary Valve
   B. Pulmonary Vein
   C. Aortic Valve
   D. Tricuspid Valve
E. Mitral Valve

25. Arrow number five (5) points to the
   A. Aorta
   B. Pulmonary Artery
   C. Superior Vena Cava
   D. Inferior Vena Cava
   E. Pulmonary Vein

26. Arrow number six (6) points to the
   A. Aortic Valve
   B. Pulmonary Valve
   C. Mitral Valve
   D. Tricuspid Valve
   E. Semi-Lunar Valve

27. Arrow number seven (7) points to the
   A. Left Ventricle
   B. Right Ventricle
   C. Right Auricle
   D. Left Auricle
   E. Vascular Spac

28. Arrow number eight (8) points to the
   A. Myocardium
   B. Ectoderm
   C. Pericardium
   D. Endocardium
   E. Epicardium

29. Arrow number nine (9) points to the
   A. Endocardium
   B. Myocardium
   C. Pericardium
   D. Ectoderm
   E. Septum

30. Arrow number ten (10) points to the
   A. Endocardium
   B. Pericardium
   C. Septum
   D. Myocardium
   E. Aortic Base

31. Arrow number eleven (11) points to the
   A. Epicardium
   B. Pericardium
   C. Endocardium
   D. Myocardium
E. None of These

32. Arrow number twelve (12) points to the
A. Pericardium
B. Myocardium
C. Endocardium
D. Endoderm
E. Apex

33. Arrow number thirteen (13) points to the
A. Pericardium
B. Endocardium
C. Ectocardium
D. Endoderm
E. Myocardium

34. Arrow number fourteen (14) points to the
A. Right Ventricle
B. Left Ventricle
C. Left Auricle
D. Right Auricle
E. Apex

35. Arrow number fifteen (15) points to the
A. Pulmonary Veins
B. Tendons
C. Aortas
D. Pericardium
E. None of These

36. Arrow number sixteen (16) points to the
A. Venic Valve
B. Pulmonary Valve
C. Tricuspid Valve
D. Mitral Valve
E. Aortic Valve

37. Arrow number seventeen (17) points to the
A. Superior Vena Cava
B. Tricuspid Valve
C. Aortic Valve
D. Pulmonary Valve
E. Mitral Valve

38. Arrow number eighteen (18) points to the
A. Right Auricle
B. Right Ventricle
C. Left Auricle
D. Left Ventricle
E. Semi-lunar Chamber

39. Arrow number nineteen (19) points to the
   A. Inferior Vena Cava
   B. Superior Vena Cava
   C. Aortas
   D. Pulmonary Veins
   E. Pulmonary Arteries

40. Arrow number twenty (20) points to the
   A. Inferior Vena Cava
   B. Aorta
   C. Pulmonary Artery
   D. Septum
   E. Superior Vena Cava
APPENDIX F

Terminology Test
TERMINOLOGY TEST

Directions: Select the answer you feel best completes the sentence.

41. _____ is(are) the thickest walled chamber(s) of the heart.
   A. Auricles
   B. Myocardium
   C. Ventricles
   D. Pericardium
   E. Endocardium

42. The contraction of the heart occurs during the ______ phase.
   A. Systolic
   B. Sympathetic
   C. Diastolic
   D. Parasympathetic
   E. Sympatric

43. Lowest blood pressure in the arteries occurs during the _____ phase.
   A. Sympatric
   B. Sympathetic
   C. Diastolic
   D. Systolic
   E. Parasympathetic

44. Blood from the right ventricle goes to the lungs through the _____.
   A. Tricuspid Valve
   B. Aortic Artery
   C. Pulmonary Artery
   D. Pulmonary Veins
   E. Superior Vena Cava

45. The ______ is(are) the strongest section(s) of the heart.
   A. Left Ventricle
   B. Aorta
   C. Septum
   D. Right Ventricle
   E. Tendons

46. When blood returns to the heart from the lungs, it enters the _____.
   A. Left Auricle
   B. Pulmonary Valve
   C. Left Ventricle
   D. Right Ventricle
   E. Pulmonary Artery

47. Vessels that allow the blood to flow from the heart are called the _____.
   A. Veins
   B. Arteries
   C. Apex
D. Tendons
E. Valves

48. Blood passes from the left ventricle out the aortic valve to the ______.
   A. Lungs
   B. Body
   C. Aorta
   D. Pulmonary Artery
   E. Left Auricle

49. The chamber of the heart which pumps oxygenated blood to all parts of the body is
    the _____.
   A. Right Auricle
   B. Left Auricle
   C. Aorta
   D. Left Ventricle
   E. Right Ventricle

50. The _____ is another name for the part of the heart called the heart muscle.
   A. Apex
   B. Epicardium
   C. Endocardium
   D. Myocardium
   E. Septum

51. ______ is(are) the part(s) of the heart which controls its contraction and relaxation.
   A. Myocardium
   B. Endocardium
   C. Ventricles
   D. Auricles
   E. Septum

52. The _____ is the name given to the inside lining of the heart wall.
   A. Epicardium
   B. Endocardium
   C. Pericardium
   D. Myocardium
   E. Septum

53. Blood from the body enters the heart through the ______.
   A. Aortic Artery
   B. Pulmonary Veins
   C. Pulmonary Artery
   D. Superior and Inferior Vena Cavas
   E. Superior Vena Cava Only

54. The membrane which borders on the inside lining of the pericardium and is connected
to the heart muscle is called the ______.
A. Extoxim
B. Epicardium
C. Endocardium
D. Myocardium
E. Ectocardium

55. The _______ allow(s) blood to travel in one direction only.
A. Septum
B. Valves
C. Arteries
D. Veins
E. Tendons

56. The _______ is the common opening between the right auricle and the right ventricle.
A. Mitral Valve
B. Tricuspid Valve
C. Septic Valve
D. Pulmonary Valve
E. Aortic Valve

57. The _______ is the triangular flapped valve between the left auricle and the left ventricle.
A. Aortic Valve
B. Pulmonary Valve
C. Septic Valve
D. Tricuspid Valve
E. Mitral Valve

58. The semi-lunar valves are located at the entrance to the ______.
A. Pulmonary Veins
B. Superior and Inferior Vena cavas
C. Pulmonary and Aortic Arteries
D. Mitral and Tricuspid Valves
E. ventricles

59. The outside covering of the heart is called the ______.
A. Endocardium
B. Epicardium
C. Pericardium
D. Myocardium
E. None of These

60. Immediately before entering the aorta, blood must pass through the ______.
A. Left Ventricle
B. Mitral Valve
C. Lungs
D. Superior Vena Cava
E. Aortic Valve
APPENDIX G

Comprehension Test
COMPREHENSION TEST

Directions: Select the answer you feel best answers the question.

61. Which valve is most like the tricuspid in function?
A. Pulmonary
B. Aortic
C. Mitral
D. Superior Vena Cava

62. When blood is being forced out the right ventricle, in which position is the tricuspid valve?
A. Beginning to open
B. Beginning to close
C. Open
D. Closed

63. When the blood is being forced out the aorta, it is also being forced out of the.
A. Pulmonary Veins
B. Pulmonary Arteries
C. Superior Vena Cava
D. Cardiac Artery

64. The contraction impulse in the heart starts in
A. The Right Auricle
B. Both ventricles simultaneously
C. Both Auricles Simultaneously
D. The Arteries

65. In the diastolic phase the ventricles are
A. Contracting, full of blood
B. Contracting, partially full of blood
C. Relaxing, full of blood
D. Relaxing, partially full of blood

66. During the first contraction of the systolic phase, in what position will the mitral valve be?
A. Beginning to open
B. Open
C. Beginning to close
D. Closed

67. During the second contraction of the systolic phase, blood is being forced away from the heart through the
A. Pulmonary and Aortic Arteries
B. Superior and Inferior Vena Cavas
C. Tricuspid and Mitral Valves
D. Pulmonary Veins
68. When blood is entering through the vena cavas, it is also entering through the
A. Mitral Valve
B. Pulmonary Veins
C. Pulmonary Artery
D. Aorta

69. When the heart contracts, the
A. Auricles & Ventricles contract simultaneously
B. Ventricles contract first, then the auricles
C. Right side contracts first, then the left side
D. Auricles contract first, then the ventricles

70. While blood from the body is entering the superior vena cava, blood from the body is
also entering through the
A. Pulmonary Veins
B. Aorta
C. Inferior Vena Cava
D. Pulmonary Artery

71. When the blood leaves the heart through the pulmonary artery, it is also simultaneously
leaving the heart through the
A. Tricuspid Valve
B. Pulmonary veins
C. Aorta
D. Pulmonary Valve

72. When the pressure in the right ventricle is superior to that in the pulmonary artery, in
what position is the tricuspid valve?
A. Closed
B. Open
C. Beginning to Close
D. Confined by pressure from the right auricle

73. When the ventricles contract, blood is forced out the
A. Superior and Inferior Vena Cavas
B. Pulmonary veins
C. Tricuspid and Mitral Valves
D. Pulmonary and Aortic Valves

74. Blood leaving the heart through the aorta had left the heart previously through the
A. Vena cavas
B. Pulmonary veins
C. Pulmonary artery
D. Tricuspid and Mitral Valves

75. When the blood in the aorta is exerting a superior pressure on the aortic valve, what is
the position of the mitral valve?
A. Closed
B. Open
C. Beginning to open
D. Confined by pressure from the right ventricle

76. When the tricuspid and mitral valves are forced shut, in what position is the pulmonary valve?
A. Closed
B. Beginning to open
C. Open
D. Beginning to close

77. During the second contraction of the systolic phase, in what position is the aortic valve?
A. Fully open
B. Partially open
C. Partially closed
D. Fully closed

78. Blood is being forced out the auricles simultaneously as blood is
A. Entering only the vena cavas
B. Being forced out the pulmonary and aortic valves
C. Passing through the tricuspid & mitral valves
D. Being forced out through the pulmonary artery

79. If the aortic valve is completely open, the
A. Second contraction of the systolic phase is occurring
B. Diastolic phase is occurring
C. Tricuspid & mitral valves are completely open
D. Blood is rushing into the right & left ventricles

80. When the heart relaxes, the
A. Auricles relax first, then the ventricles
B. Right side relaxes first, then the left side
C. Left side relaxes first, then the right side
D. Ventricles relax first, then the auricle
APPENDIX H

Visual Treatment
THE HUMAN HEART:

Parts of the Heart, Circulation of Blood and Cycle of Blood Pressure

Directions

You are about to participate in an instructional lesson and study which is attempting to investigate the relative effectiveness of visual representations and time-compressed instruction on achievement. This particular program is one of 6 different types being used.

The subject matter deals with the heart, its parts and functions. The content material for each program is the same. The differences are in the type of visual being used: that is, some programs have pictures, others do not and the rate of speech compression: 0%, 25%, and 50%.

On the basis of this instruction, you will be given a test consisting of several parts. The results of this test will provide us with information assessing the effectiveness of this instruction.

It will be to your advantage to make sure you understand the instructional material to each part before advancing to the next page. There is no time limit.

Click 'Next' to Continue
DO NOT CLOSE THIS PROGRAM YET!

PLEASE RAISE YOUR HAND AND WAIT FOR THE INSTRUCTOR TO COME TO YOUR DESK. THE INSTRUCTOR WILL CLOSE THE PROGRAM.
DO NOT CLOSE THIS PROGRAM YET!

PLEASE RAISE YOUR HAND AND WAIT FOR THE INSTRUCTOR TO COME TO YOUR DESK. THE INSTRUCTOR WILL CLOSE THE PROGRAM.

PLEASE ALLOW THE INSTRUCTION TO RECORD BOXES A, B, AND C BELOW ON YOUR FOLDER.

A: 
B: 
C: 369.6
APPENDIX I

Non-visual Treatment
THE HUMAN HEART:

Parts of the Heart, Circulation of Blood and Cycle of Blood Pressure

Directions

You are about to participate in an instructional lesson and study which is attempting to investigate the relative effectiveness of visual representations and time-compressed instruction on achievement. This particular program is one of 6 different types being used.

The subject matter deals with the heart, its parts and functions. The content material for each program is the same. The differences are in the type of visual being used: that is, some programs have pictures, others do not and the rate of speech compression: 0%, 25%, and 50%.

On the basis of this instruction, you will be given a test consisting of several parts. The results of this test will provide us with information assessing the effectiveness of this instruction.

It will be to your advantage to make sure you understand the instructional material to each part before advancing to the next page. There is no time limit.

Click ‘Next’ to Continue

Please listen to the instruction

Replay
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction
Please listen to the instruction

Please listen to the instruction
Please listen to the instruction

- END OF INSTRUCTIONAL MATERIALS -

DO NOT CLOSE THIS PROGRAM YET!

PLEASE RAISE YOUR HAND AND WAIT FOR THE INSTRUCTOR TO COME TO YOUR DESK. THE INSTRUCTOR WILL CLOSE THE PROGRAM
DO NOT CLOSE THIS PROGRAM YET!

PLEASE RAISE YOUR HAND AND WAIT FOR THE INSTRUCTOR TO COME TO YOUR DESK. THE INSTRUCTOR WILL CLOSE THE PROGRAM

PLEASE ALLOW THE INSTRUCTOR TO RECORD BOXES A, B, AND C BELOW ON YOUR FOLDER.

A: 

B: 

C: 306.394
APPENDIX J

Summary of Results
### Summary of Results

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<th>Independent Variables</th>
<th>Finding</th>
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<tr>
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<td>Visual, Compression</td>
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</table>
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EDUCATION  
Ph.D. - Penn State University, State College, PA – 08/2009 - Instructional Systems with a minor  
Eduational Psychology  
M.S. - Bloomsburg University, Bloomsburg, PA – 05/2003- Instructional Technology  
B.A. - Bloomsburg University, Bloomsburg, PA – 12/2001 - Political Science  

ACADEMIC EXPERIENCE  
Penn State University – Adjunct Instructor (2006 – 2009) - College of Education, University Park, PA  
University of Phoenix – Faculty Member (2005 - 2009) - College of Information Sciences & Technology  

PROFESSIONAL EXPERIENCE  
Instructional Designer (2006 – 2007) - Penn State University – PBS, State College, PA  
Senior Consultant (2004 – 2005) - Booz Allen Hamilton, McLean, VA  

CONSULTING EXPERIENCE  
Course Design and Development (2008) - Penn State University, State College, PA  
Online Strategy Consultant (2007 – 2008) - Subaru of America, Cherry Hill, NJ  
Instructional Designer (2006) - Saint Barnabas Health Care System, West Orange, NJ  

SELECTED PUBLICATIONS (* peer reviewed)  
*Pastore, R. S., & Carr-Chellman, A. A. (accepted). Undergraduate resident students motivation to enroll in online classes. Quarterly Review of Distance Education.  

SELECTED PRESENTATIONS (* peer reviewed)  
*Pastore, R. (accepted – 2009, October). The effects of diagrams an time-compressed instruction on students’ achievement and perceptions of cognitive load, To be presented at the Association for Educational Communications and Technology conference, Louisville, KY.  

SERVICE AND LEADERSHIP  
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AECT Cochran Internship (2008, November) - AECT’s 2008 Conference, Orlando FL  
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Ralph T. Heimer Award (2008) - Penn State University College of Education