THE INFLUENCE OF THEMATIC GRAPHICS IN THE
INTERPRETATION OF NARRATIVE TEXT

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by
Chad C. Mortensen
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DEDICATION

I am truly indebted to my mother and my grandparents for all of their love and support throughout my studies. My mother’s strength and courage is an inspiration for me. Thank you for everything.
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ABSTRACT

THE INFLUENCE OF THEMATIC GRAPHICS IN THE
INTERPRETATION OF NARRATIVE TEXT

by

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This investigation was designed to test the hypothesis that decorative graphics serve to reveal the underlying themes of accompanying text, and are not benign in their influence of deeper comprehension processes. One-hundred-forty undergraduate volunteers read or listened to a classic literary short story (Hills Like White Elephants by Ernest Hemingway) accompanied by either one of two decorative graphics or no graphic at all and wrote an essay of their understanding of the passage and its underlying themes immediately and one week later. Results revealed that decorative graphics enhanced understanding of the passage at both the literal and deep semantic level of the passage but only when the graphic was related metaphorically to the story themes. The effect was apparent immediately following reading and became even stronger one week later. The
results are discussed in terms of the cognitive function metaphor to incur deep processing between graphics and text.
CHAPTER I

INTRODUCTION

Background

Graphics are frequently used to influence what learners understand from an accompanying text. When graphics accompany text, learners learn more from what they read. The finding is ubiquitous across a wide variety of graphic types and texts, as well as knowledge domains and outcome measures (Huk, & Steinke, 2007; Mayer, Hegarty, & Mayer 2005; Veriki, 2002; Zacks, & Tversky, 2003). However, different types of graphics may influence learners’ cognitive processes differentially. Furthermore, some graphics are less reliable in their effect on learning from text than others, particularly when the graphics are employed to decorate a page, rather than to inform. A meta-analytic review by Levin, Anglin, and Carney (1987), revealed moderate to strong effect sizes of learning outcomes when graphics are employed to inform a text by representing all or part of text content, but weak to non-existent effect sizes of learning outcomes for graphics used to adorn a text. Indeed, Elia, Gagatsis, and Demetriou (2007) found that when graphics are used principally for adornment, they fail to increase understanding of related tasks or deepen learner’s comprehension of instructional material. Therefore, the current investigation was designed to demonstrate that decorative graphics function beyond the benign presence of adorning text; instead, they influence learning outcomes based on the thematic relationship they share with text.
However, two specific issues underlie research regarding the influence that graphics have on an accompanying text. First, there are differences in the types and functions that graphics are intended to serve. Secondly, different types of graphics influence different cognitive processes that learners use to derive and construct meaning at varying levels of comprehension from the graphic and text combinations.

Graphic Types and their Functions

Many Graphics populating textbooks and web pages do not necessarily correspond to the text-based concepts they are intended to address; instead, they often convey concepts and ideas that are generally redundant with the text, providing visual stimulation that neither adds to, nor substantially enhances, the meaning of text content. Edens and Potter (2003) noted that while science textbooks typically devote half of their pages to illustrations, only ten percent are capable of explaining the concepts to which they refer. Furthermore, Pozzer and Roth (2003) found that most students rarely even attend to the graphics they see in text—either the graphics designed specifically to help them learn, or the graphics designed to make pages more interesting visually.

It is no wonder that Levin et al. (1987) found moderate to strong effect sizes for some graphic types, but weak to non-existent effect sizes for others. Therefore, it is essential to understand the way learners use different graphics to help them understand an accompanying text. The current investigation examines this problem by looking directly at the way decorative graphics influence learning of an accompanying text when the graphics vary in their degree of thematic representation.
The majority of graphics found in textbooks are either representational or decorative in nature (Levin, et al., 1987). Representational graphics “literally depict or overlap (part or all of) the text content” (Carney & Levin, 2002, p. 11), whereas decorative graphics “simply decorate the page” having “little or no relationship to the text content” (p.7). Levin et al.’s (1987) meta-analysis found a moderate effect size for graphics of the representational type, but no reliable effect for graphics that are decorative. Little is understood about the way both types of graphics influence the meaning learners make of text content. It is also unclear whether there are differences in the way these two types of graphics function when considering that decorative graphics may be visually representative of text content, and representational graphics may also be decorative. Therefore, the purpose of the present investigation was to demonstrate that decorative graphics actually can and do influence the way learners cognitively interact with a narrative text, dictating the learners’ derivation of meaning and subsequent comprehension of text content.

When Graphics Communicate Theme

Although decorative graphics often fail at enhancing learner comprehension (Levin, Anglin, & Carney, 1987; Elia, Gagatsis, & Demetriou, 2007), when a graphic conveys theme, the graphic may serve more than a simple decorative function, such that the graphic’s theme may help to facilitate learner comprehension. Schwartz and Collins (2008, p. 231) define the theme of a graphic as “an aggregated set of features, comprising as a whole, a generalized unifying or dominant concept conveyed as a unitary
display”. Furthermore, Schwartz and colleagues suggest that thematic graphics are different from other graphical displays because they do not portray information that is redundant with the text, but rather depict the underlying theme conveyed within the text. The theme of a graphic is presumably capable of directing a learner’s attention and may help facilitate comprehension of the underlying thematic information embedded within the text.

Thus, theme has been directly implicated in the efficacy of decorative graphics to inform accompanying text. Specifically, when graphics convey information about the theme of a text, they are capable of influencing a learner’s cognitive interaction with a passage (Schwartz, Battinich, Lieb & Mortensen, 2008; Schwartz, Lieb, Battinich & Kuinke, 2007). Furthermore, Schwartz and Collins (2008) demonstrated that, through schema activation, the theme of a graphic creates observable differences in the information learners bring to mind when processing text. Additionally, Battinich and Schwartz (in submission) provided evidence that decorational graphics function to invoke theme, since learners devote cognitive resources to make their graphic interpretations consistent with their interpretations of text content based on their past experiences. Thus, decorational graphics apparently function to stimulate learners to actively construct meaning from an accompanying text, but only when the graphic is able to communicate theme.

And yet, it is still unclear how decorative graphics actually function to invoke theme, and to which level of a passage the graphics exert their effect—the literal level of a text, or the deeper semantic level of a text from which theme is derived. It is
equally unclear if decorative graphics exert a differential influence on text if theme is manipulated for salience.

Metaphorical Graphics and Metaphorical Comprehension

I suggest that when a graphic communicates theme, the graphic acts as a visual metaphor to direct attention to the underlying thematic concepts conveyed in a passage. Thematic graphics act as visual metaphors because, like metaphors, they have a partial similarity to a target (Wonzy, 1989)—in this case a text, and thereby aid a learner’s conception of a text’s content. Thus, thematic graphics function metaphorically in that they are capable of facilitating the comprehension of difficult or ambiguous learning materials because they are capable of highlighting a deeper semantic structure of the text base.

At the same time, it is important to note that, while thematic graphics may assist learners in deep comprehension processes, it is essential that learners are capable of interpreting the graphic at a metaphorical level rather than a literal level (Horn, 1998) to correctly infer the underlying concepts that the graphic conveys. Learners must therefore rely on their prior knowledge and activate relevant schema to correctly draw inferences between the text and graphic. In short, when graphics convey theme, the theme provides learners with a conceptual framework capable of guiding and facilitating comprehension of the accompanying text.

The function of metaphorical interpretation, then, plays a key role when considering theme. Metaphors are critical because they can override categorical
boundaries and combine objects—in this case, graphics and text—by allowing learners to cross conceptual domains from which to derive a common meaning of both (Bowdle & Genter, 2005). Thus, metaphorical understanding is derived by an active process of inference based on a conceptual mapping of domain-related knowledge derived from both referents (Lakoff & Johnson, 1980) in which the subject matter of the text establishes the relevant features for attribution by the non-literal gestalt visual properties of the graphic (Glucksberg, McClone, & Manfredi, 1997). In short, metaphor comprehension involves activating the non-literal meaning while inhibiting meaning that is literal (McClone & Manfredi, 2001).

An investigation by ChanLin (1996) supported this reasoning. ChanLin used metaphorical graphics to teach molecular biotechnology concepts. In this investigation, learners were presented with textual information describing DNA transcription that was accompanied with or without the visual metaphor of a “screwed zipper”. Results revealed that learners who were presented with the text and metaphorical graphic together benefited significantly in their comprehension of the learning materials. Therefore, when learners understood the visual metaphor of the “screwed zipper”, they were able to create associative connections between the verbal and graphical information. Conversely, when learners did not understand the visual metaphor in terms of their prior knowledge, the graphic served to distract them in the learning process; that is, the learners had to exert extra effort in attempting to derive meaning from the graphic and text. It was therefore hypothesized that using metaphorical graphics afforded learners deeper comprehension processes that allowed them to create a connection between the
graphic and text. In short, this investigation revealed that graphical metaphors improved learning for text based concepts.

Theoretical Function of Thematic Graphics

The theoretical foundation regarding the role of theme is based on Schnotz and Bannert’s (1999; 2003) integrated model of text and picture comprehension. According to the model, learners create several mental representations when learning from textual and graphical information.

Specifically, when a learner actively processes textual and graphical information, they subsequently create a mental representation that occurs as a result from the semantic units provided by the propositions of a text in conjunction with the semantically processed gestalt visual elements of a graphic (Schnotz, 2002). Therefore, the construction of the mental representation is determined according to a learner’s ability to understand the relationship that exists between the text and graphic. Most importantly, this understanding occurs as a product of a schema mapping process (Schnotz & Bannert, 2003). In short, graphics and text are semantically processed and understood according to a learner’s existing prior knowledge in the form of schemata.

I contend that when learners understand the thematic relationship shared between a text and a graphic as Schnotz (2002) describes, they are afforded the ability to semantically process and construct meaning of the presented information. However, it is essential for learners to interpret the textual and graphical information at a metaphorical level; otherwise, they may fail to understand the text and graphic at a semantic level that
is necessary for the creation of a meaningful representation. Furthermore, Schnotz (2002, p. 115) suggests that the “semantic processing of verbal and pictorial information requires activation of thematically related prior knowledge”. If learners do not possess the necessary schema for understanding the relationship between the text and graphic, they may fail to correctly interpret and extract theme from the materials.

If themes function in the way that Schnotz suggests, then the thematic elements shared between a graphic and a text should be able to influence learners’ cognitive interaction and understanding of the multimedia information according to the prior knowledge the learners possess. Indeed, two investigations—one by Rittschoff, Kulhavy, Stock, and the other by Hatcher (1993) and Rittschoff, Stock, Kulhavy, Verdi, and Doran (1994) supported this reasoning—but with thematic maps. In the Rittschoff et al. (1993; 1994) studies, participants studied a map of Colonial Ceylon that conveyed three different themes—elevation, agriculture, and rainfall. Participants also read an accompanying passage containing facts that related to the three themes conveyed in the map. After studying the maps, the participants were asked to recall as much as they could about the map and text, and solved theme-related inference questions. Results from both investigations revealed that theme-related information, as well as the theme-related inferences, was facilitated by the thematic maps. In short, the thematic relationship shared between the map and text facilitated learner comprehension. Most importantly, theme operated as a common operator for linking the graphics and text together.
Present Investigation

Carney and Levin (2002) noted that decorational graphics often fail to influence what learners comprehend from a passage. However, I contend that if the decorational graphics are thematically related to information conveyed within the text, then learners will be able to derive meaning as they semantically process both sources of information by way of the prior knowledge they possess.

Thus in the present investigation, I sought to demonstrate that the theme of decorative graphics operate to influence learners’ understanding of an accompanying text in a manner similar to Rittschoff et al.’s map. That is, the theme of a graphic will provide a context for interpreting the theme of a text. Thus, I presented different types of decorational graphics and varied them for their thematic relationship to a narrative text. If I am correct in my assumption that graphics are capable of activating relevant schema as Schnotz and his colleagues suggest, then differences should be observed in the information learners bring to mind when processing the text, depending upon the graphic they view.

I employed two different graphics, each varied in the thematic relationship they shared with a story and chose a narrative that was ambiguous at the surface level of the story, yet rich in several underlying themes. This type of text requires a reader to process the story to derive meaning and understanding of the text at a deep semantic level. I manipulated the task demands of reading (or listening) to the story in such a way as to stimulate learners to process the story as deeply as possible, thereby assisting them to cognitively engage and interact with the passage. I expected to observe differences that
could be attributed to the two types of graphic. In short, I asked learners to read or listen to the story in the presence of one of the two graphics or no graphic at all, then asked the learners to write a reflective essay about the story integrating the meanings, themes and interpretations they understood immediately following reading, and again at a delay, one week later.

Thus, the passage was accompanied by two graphics that were used to prime the passage for the extraction of certain types of themes. Therefore, I expected the graphics to invoke related information to the story. The thematically related graphic would help learners extract the underlying theme of the story by way of the thematic relationship shared between the graphic and the story. Similarly, the non-thematic graphic would help learners extract non-thematic elements conveyed at the literal level of the story by way of the literal relationship shared between the graphic and the story.

I predicted that when the graphic was metaphorical for theme, passage themes would be available for processing; when the graphic had no thematic association, theme would be impossible to derive. When the graphic was metaphorical for setting, literal story meaning would be higher, but thematic material would be suppressed. Graphic absence would result in comparatively little understanding of the passage at both story levels. The influences would be stronger over time.

Finally, I varied the modality of presentation of the passage through the delivery of either a printed text or an auditory narration presented in conjunction with one of the two graphics. Modality of presentation was varied based upon Mayer’s cognitive theory of multimedia learning (Moreno & Mayer, 2000a; Mayer & Moreno, 2002a,
According to this theory, a split-attention effect occurs when learners’ process visually based textual and graphic information. As such, learners’ are forced to divide their attention among separated sources of information that subsequently overloads their working memory space. However, presenting an auditory text with graphics creates a modality effect (e.g., Tindall-Ford, Chandler, & Sweller, 1997) and may prevent the split-attention effect from occurring. In short, presenting graphics with an auditory text reduces extraneous cognitive demands placed on the working memory because processing is distributed across dual-modalities, the phonological loop and the visuo-spatial sketchpad.

Thus, in the present investigation, I manipulated the modality of presentation in accordance with expectations of the split attention effect. As such, I expect that when either of the graphics is presented with an auditory text, processing of the graphics will take up comparatively less cognitive resources than the printed text presentation. Therefore, I predicted that learners will be able to process the graphics more deeply and efficiently in drawing associative links between the passage and graphic. Additionally, the influences will be stronger over time.
CHAPTER II

LITERATURE REVIEW

Introduction

Multimedia involves the presentation of both words and graphics. Words correspond to verbal material in the form of printed text or spoken text. Graphics correspond to pictorial material in the form of static graphics, such as, illustrations, photographs, maps, diagrams or graphs. Multimedia information is often seen as an advantageous technique in learning and instruction because information can be presented using different codes (e.g., verbal and non-verbal) and in different modalities (e.g., visual and auditory) simultaneously. In addition, multimedia learning environments are capable of motivating and engaging learners. These apparent advantages have led to the widely accepted belief that multimedia presentations are superior to traditional learning presentations using text only. However, empirical studies on multimedia learning presentations have produced inconclusive results. Some studies suggest that learning is enhanced with the use multimedia learning, while others show detrimental effects for learning from multimedia information.

While graphics are frequently used in conjunction with texts, many empirical investigations have revealed inconclusive results regarding how graphics guide and influence learners’ comprehension of the textual information. To understand the role that graphics have on the comprehension of textual materials, many researchers have
developed different models offering insight into the processing, comprehension, and memory of multimedia information. Each model offers its own explanation that is both grounded in theory and empirically supported.

The purpose of this paper is to identify and review the empirical and theoretical findings regarding the processing of textual and graphical information. This paper will also identify the function of thematic graphics and how they influence learners’ cognitive interaction with a narrative text.

Mental Representations of Verbal and Pictorial Information

There are several theories regarding the storage of textual and graphical information. However, there are three main theories that have received thorough investigation as to plausible explanations of graphical representations. First, schema theory is widely accepted as an explanation for how verbal information is processed and stored. However, this theory has received criticisms with regard to explaining the nature of how graphics are comprehended and stored. Dual coding theory offers an alternative explanation regarding the processing and storage of verbal and non-verbal sources of information. Lastly, the mental models approach offers one of the most plausible explanations regarding the processing and storage of graphical and verbal information alike.
Schema Theories

Schema theory (e.g. Anderson, Spiro, & Anderson, 1978) suggests that learners create broad based frameworks characterized by a general of knowledge of things and events that they use to learn and understand information about the world. Schema is an organized structure that contains information of our own personal knowledge and expectations about particular domains. Therefore, when people learn or remember new information, they construct meaning based upon prior-knowledge from established schemata. However, if the new information is not compatible with existing knowledge or schema, then distortions are likely to occur.

Schema allows for the encoding, storage, and retrieval of information related to the domain that is to be learned (Alba & Hasher, 1983). Schema also allows learners to make inferences and predictions about new information. Schema-based processing is an interaction between bottom-up and top-down processing, where environmental stimuli activates schema (bottom-up) and thereby sets up expectations (top-down) for additional information (Driscoll, 2005, p. 131). Furthermore, when a learner’s schema matches the incoming information, comprehension is faster, easier, and consumes less cognitive resources. The process of accretion occurs when pre-existing schema is used without alteration in order to understand new information. Yet schema can be adjusted so that learners are able to make sense of unusual, unfamiliar experiences or new information. Additionally, a process of restructuring occurs when learners are repeatedly exposed to unfamiliar experiences where new schema are constructed through bottom-up processing as they replace or are incorporated into existing schema (Vosniadou & Brewer, 1987).
Empirical evidence of schemata was first described by Bartlett (1932) who examined the remembering of complex stories. In his investigations, he exposed participants to the North American Indian folk tale, “War of the Ghosts”. When participants were asked to recall the story, he found that their memories contained inaccuracies involving omissions of information or replacement of unfamiliar information with something that was more familiar to them. In addition, participants typically derived several inferences that went beyond what was stated in the original story. Bartlett hypothesized that people have schemata that contain an individualized account of general information that they have about the world. He further theorized that learners activated relevant schema to remember the story, but when they were asked to recall the story they used their familiar schema to reconstruct information that they had forgotten (Driscoll, 2005). In short, schema influences how new information is learned and understood.

Stemming from the Barlett’s schema theory, Minsky (1975) proposed frame theory. A frame is a schema that that contains information about the structure of a familiar event. An example from Alba and Hasher (1983) demonstrates frame theory by explaining the knowledge that a person possesses about the structure of a short story. “It specifies not the exact contents of the event but rather the general type of information expected in that situation and the order in which it should be encountered (for example, in a story setting information would be followed by theme information and so on)” (Alba & Hasher, 1983, p. 204). Elaborating on Minsky’s frame theory, Rumelhart (1975)
developed the concept of story grammar. Story grammar refers to the rules that describe the structure underlying a story, and thereby, influence how people remember a story.

Similar to that of a frame, a script (Schank & Abelson, 1977) contains information about the sequences and actions of particular social events. Scripts are organized hierarchically and help people to behave appropriately in frequently experienced social interactions. For example, when students attend a class, they retain knowledge regarding the sequences and actions that take place, such as sitting in one’s seat, taking out paper, writing notes, leaving when the bell rings, etc. Additionally, an investigation by Bower, Black, and Turner (1979) revealed that when participants were asked to recall a story that they read, they frequently recalled information that was not specifically stated within the story, yet it was relational with the script. Lastly, several investigations of schema involvement in reading comprehension revealed that learners had difficulty comprehending and remembering a passage when its theme was ambiguous (Bransford & Johnson, 1972; Dooling & Lachman, 1971).

In short, schema theories attempt to explain how knowledge is stored within the long-term memory and how these knowledge structures influence the processing and learning of new information. The functions of schema in information processing and encoding of information include four processes: selection, abstraction, interpretation, and integration. The selection process occurs first, where only information that is relevant and important to the currently activated schemata will be incorporated. The selected information then undergoes abstraction, where the surface structure of the text is lost and only the semantic content is processed. Next, the semantic content is interpreted
according to existing schemata. Lastly, the integration process occurs by which the new information combines with existing schemata (Thorndyke & Yekovich, 1980; Alba & Hasher, 1983).

Additionally, Alba and Hasher (1983), propose a fifth process, reconstruction, that occurs when a person attempts to reproduce a memory of previously learned information. “This process uses whatever details were selected for representation and are still accessible together with general knowledge to essentially fabricate what might have happened” (Alba & Hasher, 1983, p. 204). However, it is widely believed that the process of reconstruction is rare.

As supported by many previous empirical investigations, schema theory offers explanations for understanding reading; however, schema theory is often criticized for its lack of support for explaining the retention of graphics (Alba & Hasher, 1983; Sadoski, Pavio, & Goetz, 1991). Furthermore, schema theory has difficulty explaining the persistence of images after learners studied them (Schwartz & Bruett, 1995).

Paivio’s Dual Coding Theory

Dual coding theory was developed from a series of studies by Paivio (1969, 1971, 1986), in an attempt to address the aforementioned concerns regarding the processing, encoding, and storage of graphical information. Research regarding this theory investigated associative links when learning information from verbal and nonverbal codes. Dual coding theory proposes the involvement of two distinct subsystems for human cognition. One system specializes in the processing and
representation of language; whereas, another system specializes in the processing and representation of nonverbal information. The language system deals with linguistic information in the form of speech and writing, but it also serves as a symbolic function for nonverbal information. The nonverbal system deals with multi-modal information—visual, auditory, haptic, gustatory, olfactory, and affective; however, research was more focused with regard to visual information.

Each of the two systems is comprised of hierarchically organized representational units that vary in size and allow for the interpretation of new information through the activation of mental representations (Sadoski, Paivio, & Goetz, 1991). The representational units for the storage of language-based information are called logogens; whereas, the representational units for the storage of graphically-based information are called imagens (Atteneave, 1974). Logogens are comprised of propositions, and are the smallest single unit of information that represents an idea. Morton (1979) developed the concept of logogens as a template for word-recognition.

The distinguishing feature of dual coding theory was that it provided a framework for which verbal and imaginal codes are related, yet are processed quite differently. The verbal system processes information sequentially and syntactically; whereas, the visual system processes information holistically, simultaneously, and synchronously. The two systems are independent, yet they are also interconnected by referential links where verbal codes can activate imaginal codes; imaginal codes can activate verbal codes; or both systems can activate simultaneously. Furthermore, a representational unit in one system may trigger the activity of the corresponding unit in
another system through the referential connection, and thereby, enhance recall. Moreover, it was noted that “verbal and nonverbal codes corresponding to the same object can have additive effects on recall” (Paivio, 1991, p. 259). In sum, learning with multimedia information consisting of verbal and graphical material occurs as a result of reciprocal activation of verbal and imaginal codes.

The holistic and parallel processing of graphical information, as opposed to the serial processing of verbal information supports the picture superiority effect—that pictures are remembered better than words (cf. Paivio, 1986, p. 62). However, this effect is questionable because it was found that the imaged words were recalled about as well as named pictures (Paivio, 1991). Moreover, the holistic processing of graphical information is special because less space is consumed within the working memory store. Text and graphics are often presented together instructionally in text-books and web-pages. Thus, given that graphics consume comparatively less space in the working memory, there is more room available for the processing of verbal information (Kulhavy, Stock, & Kealy, 1993).

The underlying assumptions for dual coding theory have received support from several empirical investigations; however, it is not without controversy. An investigation examining the recall of imaged words and non-imaged words revealed a concreteness effect; thereby, suggesting that concrete words or sentences is remembered better than abstract words or sentences (Anderson, Goetz, Pichert, & Halff, 1977; Sadoski, Goetz, & Fritz, 1993). According to dual coding theory, the concreteness effect is attributed to the integrative memory induced by imagery. However, Marschark and
Paivio (1977) found that when recall was successful, the memory of abstract sentences was also integrated.

In summary, a substantial amount of investigations have shown support for dual coding theory by substantiating the notion of two separate and distinct cognitive coding systems, one for verbal and one for nonverbal. Empirical support revealed that the comprehension of concrete concepts is enhanced when learners create a mental representation of the concept. Moreover, dual coding theory suggests that comprehension of abstract systems concepts is enhanced when learners make use of verbal and visual cognitive functions. In short, dual coding theory laid the framework for understanding how verbal and nonverbal information is processed and understood through the proposal of two separate, yet interconnected cognitive systems.

Kulhavy’s Conjoint Retention Hypothesis

Similar to Paivio’s dual coding theory, Kulhavy’s conjoint retention hypothesis (Kulhavy, Lee, & Caterino, 1985) proposes two separate models in the processing of information—a verbal mode and a nonverbal mode. According to this hypothesis, when learners process graphical and textual information together, the information is “conjointly retained” within the two separate cognitive systems. Thereafter, learners are capable of constructing mental models based upon the interactions of the two systems.

Kulhavy and Stock (1996) propose that learners utilize two different control processes to construct meaning from graphical or spatial displays. First, learners must
determine the best way to use the information that they are presented. This is largely determined according to the prior knowledge that the learner possesses. Prior knowledge helps learners select appropriate graphical elements for understanding the present task at hand. Secondly, learners must comprehend the information according to the content of the graphic in relation to the demands of the present task. Therefore, the learner must allocate time, attention, and cognitive strategies for understanding present task according to the information presented in the graphical display. The main difference distinguishing these two control processes is that of content versus context.

According to this model, there are two types of graphical elements that influence a learner’s knowledge—structure and feature. Structural elements represent the physical layout of the graphical display. For example, structural elements may include features such as colored lines used to represent rivers or roads on a map as well as symbols used to represent hospitals or schools (Stamn, Johnson, & Verdi, 1999). Moreover, a study by Schwartz and Kulhavy (1981) revealed that learners are more likely to remember graphical elements when they are spaced further apart rather than closely together when depicted on a map.

An investigation by Kulhavy, Stock, Verdi, Rittschoff, and Savenye (1993) revealed that learners retain information presented on a map along with the textual information within the working memory store. This allows learners to inspect and reference the features on a map with the features found in the text. Moreover, given that both verbal and nonverbal information is available for simultaneous processing within the working memory, learners’ comprehension of the information is enhanced.
An important structural element is that of the “edge effect”. This effect proposes that learners typically remember structural information when it is placed near the edge of a graphic or near a line within a map. In an investigation by Rossano and Morrison (1996), learners were presented with a map to study for ten minutes. Afterwards, they were asked to draw the map that they had studied on a blank sheet of paper. Learners returned a week later to redraw the map from memory. Results of this investigation revealed that the structural features found along the edge of the map were remembered with greater accuracy than elements contained elsewhere in the map.

Interestingly, if graphics and maps are processed as holistic and “intact” mental images as Kulhavy, Stock, Woodard, and Haygood (1993) suggest, then all elements regardless of their structural position should be recalled with equivalent accuracy.

On the other hand, feature elements represent discrete locations on a graphic (Kulhavy & Stock, 1996). For example, a map of a hiking trail may have a picture of a tent that symbolizes where the location of a campground, or a water faucet that symbolizes the location of a water source. Lastly, Verdi and Kulhavy (2002) contend that features play a crucial role in the activation of prior knowledge that can help learners interpret and comprehend graphical information.

According to this model, prior knowledge is an important influential factor for the processing, interpretation, and understanding of graphical displays (Verdi & Kulhavy, 2002). Several investigations with regard to map learning have revealed that prior knowledge has a significant influence on learners’ memory of specific markings on maps (Lowe, 1993) and of related passages (Allen, Schwartz, Grahm, Knight, & McLaughlin,
Furthermore, in an investigation by Schwartz, Ellsworth, Graham, and Knight (1998) examined the interaction of map familiarity and prior knowledge. In this investigation, learners were presented with either a familiar or an unfamiliar map in conjunction with a passage that described the game of cricket with regard to the specific places on the map where games and practices were held. Results revealed that a learner’s prior knowledge of the map locations helped facilitate comprehension of the information contained within the map and the passage. In short, when learners possessed high prior knowledge of the map, then their memory of the specific locations mentioned in the text was enhanced.

In sum, when learners are attempting to understand a graphic, they process structure and feature elements differently. Learners’ process feature information based upon the referential connections between the dual informational codes and allows learners to represent a graphic with verbal and imaginal processes (cf. McNamara, Halpin & Hardy, 1992). Whereas, Kulhavy et al. (1993) suggest that because structural information is difficult to process propositionally using verbal codes, learners retain a visually intact image. This intactness provides learners with a visual framework for searching and locating features. Furthermore, these features may be associated with information that is absent in a graphic, but retained propositionally within the verbal store (Kulhavy, Stock, & Kealy, 1993); thereby allowing learners to remember more about a graphic when its structural elements are high (cf. Johnson, Verdi, Kealy, Stock & Haygood, 1995; Johnson, Stamm, Alan & Verdi, 1996). Additionally, graphics whose structural elements are high help learners’ memories for verbal information when it is

Expanding from Paivio’s dual coding theory, Kulhavy’s conjoint retention theory described how learners interpret specific aspects of a graphical display. Additionally, the theory attempts to explain how the design features of graphical displays influence the learning process as well. This theory also takes into consideration the influence of learner characteristics such as prior knowledge for the comprehension of graphics. In short, the conjoint retention theory addresses how learners interpret and understand graphical displays as well as how this graphical information influences the construction of mental models.

Mental Models

Norman (1983) and Johnson-Laird (1983) proposed that schema combine with images, propositions, and memory of events to form representations called mental models. Craik (1943) first described mental models as “mind constructs ‘small-scale models’ of reality to anticipate events, to reason, and to underlie explanation” (Wilson & Keil, 1999, p. 525). Broadly speaking, mental models are schemata that “represent one’s knowledge about specific subject matter that include perceptions of task demands and task performances” (Driscoll, 2005, p.130). In other words, mental models guide and govern performance as learners attempt to complete a task or solve a problem. These models are hypothesized to change and shift when learners create an understanding of new information; thereby, making mental models inherently unstable and inconsistent.
Furthermore, Norman (1983, p. 8) described mental models as having the following attributes: 1) mental models are incomplete; 2) people’s ability to control their models is limited; 3) mental models are unstable; 4) mental models do not have firm boundaries; 5) mental models are unscientific; 6) mental models are parsimonious. While the concept of mental models is widely used, conceptual definitions are often vague and diverse.

According to Rickheit and Sichelschmidt (1999, p. 24) mental models are regarded as “dynamic cognitive representations of the contents of an utterance on the part of the recipient”. Furthermore, they propose that mental models are composed of analogical components, such as “quasi-pictorial images” (cf. Rickheit and Sichelschmidt, 1999). However, unlike mental images, mental models are not bound to specific sensory modalities and are capable of representing abstract notions (Schnotz, 2002) as well as integrate information from different sensory modalities (Schnotz, 2005). In addition, mental models include information from prior knowledge and are also assumed to contain new information that was inferred by a learner.

The mental model approach proposes that text comprehension occurs as a result of the construction of the facts described in the text. In the construction of a mental model, the information given in a text is integrated with a learner’s prior knowledge and plays an important role in text comprehension. That is, a learner’s prior knowledge produces certain expectations regarding the way they interpret a text. In addition, it is assumed that the processes of mental-model construction are incremental. The initially-built mental model is assumed to be constantly modified and elaborated in the course of text processing (cf. Schnotz, 1988). In short, when someone is learning new information,
the mental model undergoes a process of inspection and modification according to the processing of new information.

Overall, the concepts of mental models are favored for understanding the methods by which graphics are represented in memory. Some contend that graphics are stored as intact visually-based images (e.g. Kulhavy et al., 1993). Kulhavy and Stock (1996) proposed that graphics are encoded and stored as similar mental representations to the graphic’s original perceptual display. Furthermore, several other theories attempted to address the empirical concerns stemming from the lack of clarity of schema and mental model theories for addressing how graphics are encoded and stored in memory. For example, Sadoski and colleagues (e.g. Sadoski, Goetz, & Avila, 1995; Sadoski, Goetz, & Fritz, 1993; Sadoski, Paivio, & Goetz, 1991) contend that “…schemata are, by most accounts, abstractions derived from experience that exist in a potential, non-specific state, awaiting input” (Sadoski, et al., 1991, p.467). Additionally, Kulhavy and Stock (1996) voiced similar concerns for the construction of mental models from graphics by stating the lack of information explaining how people learn and retain graphical information mentally.

Several empirical investigations provide support for mental model theories. Some studies provided evidence suggesting that learners were able to remember the surface structure of an ambiguous text without understanding the underlying meaning of the text. On the other hand, learners were able to remember the underlying meaning of an unambiguous text, but not the surface structure of the text (Bryant & Trabasso, 1971; Trabasso, Riley, & Wilson, 1975; Mani & Johnson-Laird, 1982; Perrig & Kintsch, 1985).
In short, learners could only construct an adequate mental model of a text when it was unambiguous; however, when the text was ambiguous learners were not able to construct an adequate mental model due to the several possible models that could be derived from the text (Schnotz, 1988).

Mayer’s Cognitive Theory of Multimedia Learning

Several empirical investigations have explored mental model construction in learners who are exposed to multimedia materials comprising of text and graphics. The cognitive theory of multimedia learning was developed from a series of investigations by Mayer and colleagues (Moreno & Mayer, 2000a; Mayer & Moreno, 2002a, 2002b) on the premise that “people learn more deeply from words and pictures than from words alone” (Mayer, 2005, p. 3). This theory is based upon how people learn from text and graphic combinations according to three underlying assumptions. In line with dual coding theory, this theory proposes that people possess two separate channels for processing verbal and visual material (dual-channels assumption). Secondly, this theory proposes that each channel can only process a limited amount of information at any given time (limited capacity assumption). Lastly, this theory proposes that learners actively engage in cognitive processing in order to construct a meaningful representation through the filtering, organizing, and integrating of information in these two channels (active processing assumption) (Mayer, 1997). The overall assumption is that text and graphic information are processed in different cognitive subsystems that results in the parallel construction of two kinds of mental models that are eventually mapped onto each other.
The model proposes that there are three memory stores involved in the processing of multimedia information. First, multimedia information in the form of words and pictures enter into the sensory memory via the ears and eyes. The visual sensory memory is a temporary storage that allows printed words and pictures to be stored intact for brief periods of time. The auditory sensory memory allows intact auditory images to be stored for brief periods of time. After information enters into the sensory memory, the learner selects relevant words and images to transfer to the working memory. Within the working memory, a learner is able to temporarily hold relevant information for conscious processing and manipulation. Next learners organize the verbal and pictorial information to construct two separate verbal and pictorial models. Subsequently, the verbal and the pictorial mental models are integrated in the working memory along with prior knowledge from long-term memory. Finally, the learner is able to map the verbal model and the pictorial model onto each other in the construction of an integrated representation that contains information from both the text and the graphic.

Schnotz’s Integrated Model of Text and Picture Comprehension

Contrasting with Mayer’s theory, Schnotz and Bannert (1999, 2003) developed an integrated model for understanding text and picture comprehension that provides a detailed explanation about how text and graphical information are mentally represented during learning. In accordance with Paivio’s dual coding theory and Mayer’s cognitive theory of multimedia learning, this theory proposes that text and graphical information is processed in two separate channels. However, the parallel processing of
textual and graphical information assumed in Mayer’s model is problematic because text and graphics are based on different sign systems and use different principles of representation (Schnotz, 2002).

For instance, the mental representation of texts is descriptive in nature; whereas, the mental representation of graphics is depictive in nature. According to the integrated model, the interaction between descriptive representations is based on symbol processing, and the interaction between depictive representations is based on structure mapping. Furthermore, the processing of textual and pictorial information is both “...based on an interaction of bottom-up and top-down activation of cognitive schemata that have both a selective and an organizing function” (Schnotz, 2002, p. 108). While Mayer’s model proposes that a verbal mental model and a pictorial mental model are created separately and then mapped onto each other or integrated, Schnotz’s model proposes the creation of a single mental model that contains information from the two different sources of information.

According to Schnotz and colleagues, (Schnotz, Bannert, & Seufert, 2002; Schnotz & Bannert, 2003) two representational branches are activated when a learner encounters graphical and textual information. The descriptive branch consists of the external text, the internal mental representation, and the propositional representations created by the learner from the text. Processing in this channel occurs as a result of symbol processing. The depictive branch contains the external graphic display, the visual perception of the display, and the mental model of the depicted subject matter. Information in this channel occurs as a result of structure mapping. The combination of
both symbol processing and structure mapping allows a learner to construct a mental representation that contains information from both the graphic and the text. This framework for processing descriptive and depictive information is most closely associated with Paivio’s dual-coding theory; however, unlike dual-coding theory, the integrated model proposes that multiple representations are created in both text and picture comprehension (Schnotz, 2005).

When people learn from textual and graphical information they create several mental representations. When learners read or listen to textual information, they create three different mental representations (Graesser, Millis, & Zwaan, 1997; van Dijk & Kintsch, 1983). Initially, a text-surface representation is constructed and allows the learner to retain the information within the working memory. Based upon the surface representation, a propositional representation is constructed of the semantic content, and then a mental model of what the text is about (Graesser et al., 1997, Schnotz, 2002). The construction of these representations results from an interaction of bottom-up and top-down schema activation. Similarly, when learners view and understand graphical information, they also create multiple mental representations (Kosslyn, 1994; Lowe, 1996; Schnotz, 2005). They first create a mental representation of the picture’s surface structure, then a mental model of the semantic content, and lastly, a propositional representation of the subject matter in the graphic (Schnotz, 2002). In the perceptual processing of graphics, information is selected through top-down schema activation and is organized according to the Gestalt laws.
When learners encounter written or spoken text they first select relevant verbal information from the words and sentences. Next, the learners organize the information and activate related prior knowledge. Lastly, the learners create a coherent propositional representation as well as a mental model. Similarly, when learners encounter pictorial information, they first select relevant pictorial information. Next, the learners organize the information and activate related prior knowledge. Lastly, they construct a coherent mental model that is complemented by the propositional representation. Unique to Schnotz’s integrated model of text and picture comprehension is the notion of auditory pictures. During the process of sound comprehension, learners first select and organize relevant acoustic information. Next, they activate prior knowledge and construct a coherent mental model that is complemented by the propositional representation.

Once the mental model is created it undergoes continuous construction and inspection as a result of the schema mapping process. As learners encounter and process new information, the model undergoes continuous reconstruction. After the final construction of the mental model, learners can externalize new information by combining it with their prior knowledge (Schnotz, 2005).

Categories of Working Memory

Working Memory

The concept of ‘working memory’ was first described by Miller, Galanter, and Pribram (1960). Atkinson and Shiffrin (1968) used the concept of working memory to
describe a unitary short-term store; however, Baddeley and Hitch (1974) used it to refer
to a system comprising of multiple components. Nevertheless, the most central concept
for describing working memory is that it plays a central role in information processing,
and it has a limited capacity for temporary storage and manipulation of information.

Baddeley and Hitch (1974) proposed a simplified model of the working
memory that consisted of three component systems. The central executive component
serves as a “limited capacity attentional controller” (Baddeley, 2001, p. 86). The central
executive system is aided by two subsystems, the phonological loop and the visuo-spatial
sketchpad. Empirical investigations on these two sub-systems are well-explored;
whereas, the role of the central executive control is less clearly understood.

The working memory is a temporary store that is capable of combining and
manipulating new information from the environment with that of the learner’s prior
knowledge so that the information can be stored for later retrieval. However, working
memory is constrained by a limited capacity in both the amount of information that can
be processed at any given point in time as well as the amount of time the information can
be retained without additional processing by the learner. Miller (1956) reported that the
working memory is capable of handling seven, plus or minus two, pieces of information.
Additionally, Atkinson and Shiffin (1971) noted that information in the working memory
will decay within thirty seconds of time unless it is actively processed and retained by the
learner.
The Phonological Loop

According to Baddeley (1997), the phonological loop consists of two components—a phonological store that holds speech-based information for approximately two seconds and an articulatory control processor based on inner speech. The articulatory control processor allows learners to convert printed material into phonological codes, thereby allowing them to refresh the verbal information held in the phonological store through sub-vocal rehearsal.

The Visuo-spatial Sketchpad

The visuo-spatial sketch pad is responsible for setting up and manipulating mental images. The visuo-spatial sketch pad deals directly with incoming visual stimuli with a limited capacity to handle approximately five units of information. This system is responsible for the construction of internal mental representations of graphical information. However, it is widely debated as to whether the internal mental image is comparatively similar to the original perceptual image or rather a propositional representation that is descriptive in nature. Additionally, the sketchpad is proposed to form an interface between visual and spatial information, accessed either through the senses or from the long-term memory store.

The Central Executive

The central executive was first postulated by Baddeley and Hitch (1974) as an attentional controller that regulates the two component systems of the working memory. Baddeley and colleagues focused their research on the attentional control characteristics of the central executive. Baddeley adopted a concept from the supervisory attentional
system model proposed by Norman and Shallice (1986). Accordingly, this model suggests that human actions are controlled by a series of schemata; thereby, allowing learners to deploy well-learned or routine skills automatically. In other words, when learners become skilled or when their actions become familiar, such as when driving a vehicle, the cognitive demands placed on the working memory when carrying out these actions are reduced. However, when a conflict occurs between a learner’s automatic action plan and the stimuli in the environment, the supervisory attentional system helps by combining information from long-term memory with the incoming environmental stimuli.

A prominent feature of the central executive system is in the capacity to focus a learner’s available attention. In addition, the central executive system has the capacity to divide as well as switch attention (Baddeley, Chincotta, & Adlam, 2001). Another capacity of the central executive system allows learners to selectively focus attention on one stimulus while suppressing other or irrelevant stimuli. Additionally, investigations on working memory span suggest that the central executive system allows learners to hold and manipulate information from long-term memory (Daneman & Carpenter, 1980).

In Baddeley’s original working memory model (1986), the central executive is supposed to be capable of combining the information from working memory and long term memory. Yet, the central executive system does not have the capacity for the storage of information (Baddeley 1996; Baddeley & Logie, 1999) and may not have as much involvement in retrieval from long-term memory (Baddeley, Lewis, Eldridge, & Thomson 1984; Craik, Govoni, Naveh-Benjamin, & Anderson, 1996). Therefore, the
premise that the central executive system is strictly an attentional controller and does not have the capacity for storage, poses some problems for understanding the interaction between the working memory and the long-term memory store. Specifically, Baddeley’s (1986) original model does not explain how and where the central executive combines the verbal and the visual information from the two subsystems. Therefore, Baddeley (2001) sought to address this problem by developing a revised model that added a fourth component—the episodic buffer.

The Episodic Buffer

The episodic buffer is the place where information from working memory subsystems and that from the long-term memory store is integrated. “It is assumed to be episodic in the sense that it holds integrated episodes or scenes and to be a buffer in providing a limited capacity interface between systems using different codes” (Baddeley, 2001, p. 858). It is further assumed that the episodic buffer uses a common code to integrate the different codes from the phonological loop and the visuo-spatial sketchpad with that of the long-term memory store. Moreover, the revised model proposes that the episodic buffer depends upon the central executive system because there are currently no direct links between the episodic buffer and the two subsystems. According to this revised model, the central executive system is specifically attentional in nature; whereas, the episodic buffer is specifically mnemonic in nature.

Baddeley’s revised working memory model includes direct links between the phonological loop and the long-term verbal memory and also includes direct links between the visuo-spatial sketchpad and the long-term visual memory. Investigations
with regard to these linkages suggest that the prior knowledge that is stored within the long-term memory is also involved in the processing of information within the systems of the working memory. Another update to Baddeley’s model proposes a direct link between the two subsystems and the long term memory store, thereby suggesting that information transfer can occur without the need to pass through the episodic buffer or the central executive first.

While there are several theories regarding the system of working memory, my concentration focused around Baddeley’s model due to its wide acceptance and support from psychological and neurophysiological data. Furthermore, it is of most relevance to the purpose of my investigation. Moreover, Baddeley’s revised model addresses the interplay between the working memory and the long-term store, which until recently, lacked empirical evidence and support

Sweller’s Cognitive Load Theory

Cognitive load theory was developed by Sweller and colleagues (Sweller, Chandler, Tierney, & Cooper, 1990; Chandler & Sweller, 1991; Sweller, 1993, 1994; Sweller, van Merriënboer, & Paas, 1998) as an instructional theory based upon knowledge of the human cognitive architecture and addresses the limited capacity of the working memory. “Cognitive load refers to the strain that is put on working memory by the processing requirements of a learning task. When learners encounter a task for which they do not have an appropriate schema or automated schema, they must hold in mind all elements of the task individually and simultaneously” (Driscoll, 2005, p. 136). This
ultimately strains the limited capacity of the working memory as the learner attempts to create a new schema for the new information.

Before new information is stored in the long-term memory as schema, it is first processed within the limited capacity of the working memory. Consequently, if the processing of the new information exceeds the capacity of the working memory, then learning will be impaired. Working memory capacity is limited by both amount and time. Working memory is capable of handling seven plus or minus two, pieces of information (Miller, 1956). Additionally, when new information is not rehearsed, it is susceptible to decay within thirty seconds (Atkinson & Shiffrin, 1971; Peterson & Peterson, 1959). Therefore, cognitive load theory addresses these limitations of the working memory and proposes instructional techniques and guidelines for designing learning materials that promote effective learning.

Levels and Types of Cognitive Load

Cognitive load theory differentiates between three types of cognitive load (Sweller, 1999). Intrinsic cognitive load is characterized by the structure and complexity of the learning materials. Intrinsic cognitive load is created when learners process information in the working memory and it cannot be altered through instructional interventions (Sweller et al., 1998). On the other hand, extrinsic cognitive load is unnecessary and is not relevant for learning. Extrinsic cognitive load is created from poorly designed instructional materials and can be controlled for with instructional interventions. Lastly, germane cognitive load is created when learners construct schema
from the processing and comprehension of the learning materials. Germane cognitive load can also be altered through instructional interventions. Additionally, Valcke (2002) proposed a type of germane cognitive load—meta-cognitive load, and is created when learners monitor their cognitive abilities throughout the learning process.

The three types of cognitive load produce an additive effect. Accordingly, cognitive load theory proposes that intrinsic and extraneous cognitive load should be minimized; whereas, germane cognitive load should be increased. This may be accomplished by optimizing the learning materials; however, it is essential that the combination of all three types of cognitive load remain within the limits of the working memory (Bannert, 2002; Kirschner, 2002). In short, increasing germane cognitive load increases learners’ schema construction; whereas, decreasing intrinsic and extraneous cognitive load prevents learners from becoming distracted by irrelevant information.

Measures for Reducing Cognitive Load

Cognitive load theory proposes several methods for reducing or eliminating extraneous cognitive load in multimedia learning materials. Three specific effects are related to the reduction of extraneous cognitive load, and include the redundancy effect, the split-attention effect, and the modality effect.

The Redundancy Principle

According to cognitive load theory, redundant information creates unnecessary cognitive load because learners must devote attentional resources to process the redundant information; thereby, reducing the amount of cognitive resources available
for processing relevant information. The redundancy effect (e.g. Chandler & Sweller, 1991) occurs when different sources of similar information are presented simultaneously. For example, a redundancy effect may occur when printed text is accompanied with spoken text.

An investigation by Kalyuga, Chandler, and Sweller (1999) revealed that learners who received a diagram presented with an auditory text outperformed learners who received the same diagram presented with the text in both auditory and visual format. However, Kalyuga (2000) proposed that the redundancy effect might not occur if the redundant sources of information are presented successively rather than simultaneously. Therefore, when the redundant information sources are separated by time or space, learners are not forced to comprehend all of the information at the same time. Furthermore, an investigation by Kalyuga et al. (1998, 2000) revealed that experienced learners only required diagrams; whereas, novice learners required diagrams integrated with additional textual information.

**Split-Attention Effect**

According to cognitive load theory, when text and graphics that are dependent on each other for comprehension are presented separately in space or time, learners must divide their attention amongst the sources to mentally integrate the information to formulate comprehension of the materials. Therefore, searching for relevant information from separated sources imposes excessive cognitive load and impairs learning. To eliminate this effect, it is therefore suggested that instructional designs integrate text and
graphics or present graphics with auditory text (Chandler & Sweller, 1992; Sweller & Chandler, 1994; Sweller et al., 1990; Kalyuga et al., 1999).

Several empirical investigations explored the split-attention effect in using instructional materials from electrical engineering, biology, and geometry. Results revealed that learners performed significantly better when they were exposed to a diagram that was integrated with textual information over a split-design where text information was shown over, below, or next to the diagram. Mayer and colleagues found similar split-attention effects while examining animations and textual information.

The Modality Effect

As described above, a split-attention effect may occur as a result of presenting both text and graphics visually. However, presenting an auditory text with graphics creates a modality effect (e.g., Tindall-Ford, Chandler, & Sweller, 1997) and may prevent the split-attention effect from occurring. This assumption is based upon Baddeley’s (1986, 1992, 1997) model of working memory, comprising of the central executive, the phonological loop, and the visual-spatial sketchpad. Therefore, graphics and auditory text reduces extraneous cognitive load on the working memory because processing is distributed across dual-modalities, the phonological loop and the visuo-spatial sketchpad (Sweller, 2005). Additionally Low and Sweller (2005, p. 148) suggest that “it may be possible to increase effective working memory capacity by presenting information in a mixed visual and auditory mode rather than a single mode.” Furthermore, Kalyuga et al. (1999, p. 53) noted that, “in a split-attention situation, increasing effective working memory by using more than one modality produced a positive effect on learning, similar
to the effect of physically integrating separate sources of information”. Two experiments by Allport, Antonis, and Reynolds (1972) revealed that working memory capacity increased when information was presented to learners using two modalities as opposed to one. In short presenting graphics with an auditory text distributes processing over two sensory systems; thereby, reducing the cognitive demands placed on learners and affording them additional cognitive resources for the comprehension of the learning materials.

Several empirical investigations on the modality effect revealed inconsistent results. For example, Kalyuga et al. (1999) suggested that a modality effect might not occur when auditory text is too long or complex and would create an increase in cognitive load on the working memory because “auditory information is fleeting and difficult to retrieve once heard” (Kalyuga et al., 1999, p. 368). On the other hand, visual text is permanent, and allows learners to refer to it repeatedly.

Long-term Memory and Learning

The long-term memory is a system that purportedly has the capacity to hold a seemingly infinite amount of information that is accumulated over the life-span. The information stored within the long term memory is comprised of various types of knowledge that includes: semantic knowledge, procedural knowledge, and episodic knowledge. The long-term memory is responsible for the storage and retrieval of information, and additionally, plays an important and active role in information processing.
The comprehension of textual information requires prior knowledge for the graphic pattern of written text, for the sound patterns of spoken text, and for the syntax structures of the text-surface representation. The comprehension of graphical information requires prior knowledge for the perception of the graphic and determines how easily the graphical information is categorized (Schnotz, 2005). Furthermore, prior knowledge may help compensate when there is a lack of external information or low working-memory capacity (Adams, Bell, & Perfetti, 1995; Miller, & Stine-Morrow, 1998). Additionally, it is suggested learners analyze pictures more intensively when the content is difficult and when their prior knowledge is low (Carney & Levin, 2002).

Learning with Text and Pictures

The theories described previously concern the mental representations of verbal and pictorial information, and how the human information processing system encodes, stores, and retrieves this multimedia information. According to the underlying assumptions of dual coding theory, presenting graphics and text should always be beneficial for learning. While several investigations offer support towards this premise, there are studies that have revealed contradictory evidence. This inconsistency of support for whether or not graphics benefit or harm learning is largely due other influential factors, such as nature and design of the learning materials; the instructional methods used; the types of graphics used; the way that the graphics and text are presented together; the prior knowledge that the learner possesses; amongst many other factors.
The results of several empirical investigations suggest that people generally learn better from text and graphic combinations, than from words alone (Levie & Lentz, 1982; Levin, Anglin, & Carney, 1987). This notion is known as the multimedia effect (Mayer, 1997). Additionally, Lewalter (2003) suggests that graphics are frequently integrated with expository texts in order to facilitate and enhance the learning process. Furthermore, the instructional support hypothesis (Tobias, 1976, 1982, 1989) proposed that adding graphical supports to instructional materials is beneficial for learners with limited prior knowledge about the subject domain. In short, when graphics accompany text, people learn more from what they read. This finding received support from several studies that used a wide variety of graphic types and texts, as well as knowledge domains and outcome measures (Huk, & Steinke, 2007; Mayer, Hegarty, Mayer, & Campbell, 2005; Vekiri, 2002; Zacks, & Tversky, 2003).

Several other investigations demonstrate how graphics serve to influence what learners comprehend from the accompanying textual information. For example, graphics have been shown to assist learners with complex concepts in the biological and physical sciences (Cook, Carter, & Wiebe, 2007; Ioannidou, Paraskevopoulos, & Tzionas, 2006; White, 2005). Additionally, Schwartz and colleagues have demonstrated that the use of graphics in hypermedia environments, influence the strategies that learners use to develop comprehension of complex instructional systems (Schwartz, Stroud, Lee, Scott, & McGee, 2006; Schwartz, Verdi, Morris, Lee, & Larson, 2007; Scott & Schwartz, 2007). In short, the use of graphics in instructional materials undoubtedly influences what learners comprehend from an accompanying text.
In short, the integrative model of text and picture processing (Schnotz & Bannert, 1999) and dual coding theory (Paivio, 1986, 1991) propose that presenting textual information with graphical information aid in the learning process because of the facilitative effect that graphics have with helping learners to construct mental models of the information. Although this premise was confirmed by several empirical investigations, several studies revealed that graphics were not beneficial and sometimes even harmed the learning process. Therefore, the effects that pictures have on the learning process are largely determined by other factors that were mentioned previously. Moreover, the type of text and graphics that are used play a central role in determining whether the learning outcomes will yield positive or negative effects.

Types and Functions of Pictures

The functions and effects of graphics depend principally upon the type of text that they are presented with. According to Fang (1996), the graphics that are used in conjunction with storybooks may help learners to “(a) establish the setting; (b) define/develop the characters; (c) extend/develop the plot; (d) provide a different viewpoint; (e) contribute to the text’s coherence; and (f) reinforce the text” (Carney & Levin, 2002, p. 6). In addition, Levin (1981) and Levin, Anglin, and Carney (1987) examined and categorized five different types of pictures used in textbooks. Decorative graphics are used to simply decorate the page and usually have little relationship with the text content. Representative graphics are the most frequently used graphic and correspond to part or to all of the text content. Organizational graphics, such as a map, provide a
structural framework to the text content. Interpretative graphics help clarify particularly difficult text content. Transformational graphics are mnemonic and serve to aid in memory.

Stemming from Levin’s categorization of graphics, Mayer (1993) proposed four types of graphics that include: decorative, representational, organizational, and explanatory. In addition, he calculated the percentage of the use of these four types of graphics in textbooks used to teach scientific concepts.

Additionally, Levin and Mayer (1993) proposed seven principles that explain why graphics improve learning from text. Graphics make the text more concentrated (focused, with respect to directing a reader’s attention), compact/concise, concrete (the representation function), coherent (the organization function), comprehensible (the interpretation function), correspondent (relating unfamiliar text to a reader’s prior knowledge), and codable (the mnemonic transformation function) (Carney & Levin, 2002). In relation to Levin and Mayer’s review, Peeck (1993) describes some of the ways that graphics improve learning from text because they increase motivation, focus attention depth of processing, clarify text content, and decrease interference and decay (Carney & Levin, 2002).

Representational graphics and decorative graphics are the most frequently used type of graphics in textbooks, web pages, and other instructional media; yet it remains unclear how these types of graphics influence how learners comprehend an accompanying text (Perales & Jiménez, 2002; Pozzer & Roth, 2003; Schwartz & Collins, 2008). Edens and Potter (2003) noted that while half of the pages in science textbooks are
reserved for graphics, only ten percent of those graphics are capable of assisting learners in developing their comprehension of the concepts they read.

Some graphics are less reliable in their effect on learning from text than others, particularly when the graphics are employed to decorate a page, rather than to inform. A meta-analytic review by Levin et al. (1987) revealed that decorative graphics produced weak effect sizes with no beneficial text-learning effects; whereas, representational graphics produced moderate effect sizes in benefiting text-learning effects. Additionally, Elia, Gagatsis, and Demetriou (2007) found that when graphics are used for adornment, they often fail to increase a learner’s understanding of related tasks or their comprehension of instructional materials. However, Levie and Lentz (1982) proposed that decorative graphics help organize and improve memory of a text when the graphic depicts the actual setting that is described in the text. Finally, emerging investigations suggest that graphics used to adorn text serve more than a simple decorative function.

Battinich and Schwartz (in submission) and Schwartz and Collins (2008) contend that decorative graphics are capable of being representational with text content, and that representational graphics may also be decorative in nature. While representational and decorative graphics are often defined in terms of their categorical differences, Schwartz and colleagues suggest that these graphics differ in terms of their varying degrees of thematic representation. Accordingly, they propose that thematic representation refers to the ideas portrayed in a graphic that bring out the underlying semantic aspects of an accompanying text. Moreover, they assume that “regardless of the
function that graphics are intended to serve text, both representational and decorative graphics may operate cognitively to influence learners’ perceptions of a text based on the thematic representation the graphics share with the text” (Collins, 2008, p. 4). In short, graphics conveying varying levels of thematic representation will engage and influence learners in varying ways.

Battinich and Schwartz (in submission) and Schwartz and Collins (2008) also revealed that decorative graphics are capable of activating a learner’s prior knowledge. In both investigations, learners summoned personally relevant prior knowledge based on the graphics they viewed, integrating their knowledge in the essays they wrote. Furthermore, Schwartz and Collins (2008) observed that learners' essays contained content from prior knowledge that was thematically related to the graphics they viewed. In short, decorative graphics are more than the benign text adjuncts as Levin et al (1987) suggest; instead, they seem to promote differential processing amongst learners.

This idea concerning the thematic representation of graphics and text is driven by Schnotz’s integrated model of text and picture comprehension (Schnotz & Bannert, 1999; Schnotz, Bannert, & Seufert, 2002). According to the integrated model, when learners are exposed to text and graphics, learners generate an integrated mental representation that contains information from both the text and graphic. This representation is constructed using the semantic units from the propositions of the text as well as the semantically processed Gestalt properties of the graphic. Therefore, the semantic processing of the text and graphic occurs when learners activate thematically related prior knowledge in the form of schema (Schnotz, 2002). In short, the
representation is constructed when a learner understands the relationship between the text
and graphic as a result of a schema mapping process; whereby, information from the
graphic and text is organized, regulated, and monitored by pre-existing schema (Schnotz

If learners are required to understand a graphic rather than merely perceive it,
then it is essential for learners to semantically process the graphical information. The
semantic processing of graphics allows learners to construct a pictorial mental model of
the information by means of a schema mapping process where “graphic entities are
mapped onto mental model entities and spatial relations are mapped onto semantic
relations” (Schnotz, 2002, p. 110). Furthermore, Schnotz (2002) notes that this mapping
process occurs bi-directionally, where learners can construct a mental model through the
bottom-up processing of a graphic, or learners can examine and evaluate an established
mental model through the top-down processing of a graphic. In short, this schema
mapping process “is fundamentally a semantic task applied to both a graphic and a text—
organized, regulated, and monitored by the functions of schemata” (Schwartz & Collins,
2008, p. 228). Furthermore, Schwartz and Collins (2008) suggest that the thematic
relations shared between a graphic and a text allow for the semantic processing to occur,
and thereby, drive the graphic’s influence on a learner’s cognitive representation of the
text.
Metaphors and Metaphorical Graphics

When Graphics Communicate Theme

Although decorative graphics often fail at enhancing learner comprehension, when the graphics convey theme, the graphic may serve to benefit learner comprehension. Thematic graphics are “defined as an aggregated set of features, comprising as a whole, generalized unifying or dominant concept conveyed as a unitary display” (Schwartz & Collins, 2008, p. 231). Furthermore, Schwartz and colleagues contend that thematic graphics are different from other graphical displays because they do not portray information that is redundant with the text, but rather depict the underlying theme conveyed within the text. Accordingly, the theme of a graphic is capable of directing a learner’s attention and may help facilitate comprehension and interpretation of the underlying thematic information embedded within the text.

Thematic graphics help prepare learners for interpreting textual information; thereby, allowing them to predict the underlying concepts (Schriver, 1997). Although thematic graphics may assist learners in deep comprehension processes, it is essential that a learner is capable of interpreting the graphic on a metaphorical level as opposed to the literal level (Horn, 1998). In short, thematic graphics serve as visual metaphors because they have a partial similarity to the target (Wonzy, 1989). Therefore, learners must rely on their prior knowledge to correctly interpret the metaphorical meaning of a thematic graphic.

Metaphor comprehension requires the activation of the non-literal meaning while inhibiting the literal meaning (McGlone & Manfredi, 2001). An investigation by
ChanLin (1996) supported this effect by using metaphorical graphics to teach molecular biotechnology concepts. In this investigation, learners were presented with textual information describing DNA transcription that was accompanied with or without the visual metaphor of a “screwed zipper”. Results revealed that learners who were presented with the text and metaphorical graphic together benefited significantly in their comprehension of the learning materials. Therefore, when learners understood the visual metaphor of the “screwed zipper”, they were able to create associative connections between the verbal and graphical information. Conversely, when learners did not understand the visual metaphor in terms of their prior knowledge, then the graphic served to distract them in the learning process; thereby, requiring the learners to exert extra effort in attempting to derive meaning from the graphic and text. Moreover, ChanLin’s (1996) investigation revealed that novice learners processed graphics in a superficial manner based upon its physical characteristics, such as size, yet ignored the deeper meaning of the graphics. It was therefore hypothesized that using metaphorical graphics afforded learners deeper comprehension processes that allowed them to create a connection between the graphic and text. In short, this investigation revealed that graphical metaphors improved learning for text based concepts.

McKay (1999) investigated the use of textual metaphors versus graphical metaphors for learning computer programming algorithms while accounting for learners’ cognitive style. In this investigation, learners were presented with instructional materials in conjunction with either a textual or graphic metaphor. Irregardless of the learners’ cognitive style of being either a verbalizer or visualizer, results from this investigation
revealed that graphical metaphors produced positive effects on learning. In short, learners who received the text with graphical metaphors performed better than learners who received text with textual metaphors.

A more recent investigation by Stützle and Sajaniemi (2005) revealed the effectiveness of metaphorical graphics in communicating themes for learning computer programming concepts. In this investigation learners were presented with either appropriate metaphorical graphics or inappropriate metaphorical graphics while they worked through a computer program. For example, when learning the concept of a “fixed value”, learners were presented with a metaphorical graphic that depicted a stone to convey the theme that this concept is not easily changed. Results of this investigation revealed that learners who received an appropriate visual metaphor understood the concept better. In sum, presenting learners with an appropriate visual metaphor allowed learners to make a meaningful connection between the graphical and textual information.

Metaphor Comprehension

Although using metaphors can have a positive influence on learning, the inexactness of metaphors can create interpretation and comprehension problems (Carroll & Thomas, 1982). Metaphors can often convey several meanings; therefore, context can help learners clarify and differentiate multiple meanings (Glucksberg, 1989). Context is essential for correctly identifying graphics (Goldsmith, 1984) and guiding comprehension (Gibbs & Gerig, 1989). Several investigations demonstrate how context can allow learners to select appropriate information and suppress inappropriate information for
correctly interpreting ambiguous textual information (Giora, 1999; Katz & Ferretti, 2001; Keysar, 1994). These investigations revealed that context guided learners to interpret ambiguous text at either a figurative or literal level.

Investigations by Biederman (1972, 1981) demonstrated that the characteristics of a particular scene determines the context of an image and thereby guides a learner’s processing and interpretation of the image. Another study by Bloem and La Heij (2003) demonstrated how visual context facilitated semantic processing for learners engaging in a picture naming task. In their investigation, learners were presented with a context picture that was either semantically related or not related to a target picture. Results revealed that naming the target picture was faster when it was related semantically with the context picture. In short, context influences a learner’s cognitive processes by guiding them to correctly construct meaning of the metaphor and thereby facilitating their comprehension of the learning materials.

Learner Characteristics

Prior Knowledge

As described in Schnotz and Bannert’s (1999, 2003) integrated model for text and picture comprehension, a learner’s prior knowledge guides the schema mapping process by which learners form a mental representation of the instructional materials. When learners view a thematic graphic, it influences their cognitive processes of interpretation and comprehension in relationship to their prior knowledge. That is,
learners activate relevant schema based upon the thematic content of the graphic, thereby influencing the learners’ interpretation and comprehension.

When learners already possess schema for a particular domain, new information is processed more easily and efficiently. Mayer and Gallini (1990) investigated a learner’s level of prior knowledge in conjunction with the design of the learning materials. Results revealed that learners who had low prior knowledge of the subject domain benefited from well-designed presentations with text and graphics more than learners with a high prior knowledge of the subject domain who received poorly designed presentations using text only.

Similarly, an investigation by Kalyuga, et al. (1998) revealed that learners with low prior knowledge learned most from a presentation that integrated text and diagrams; whereas, learners with higher prior knowledge learned best from diagrams only. Additionally, another investigation by Kalyuga, et al. (2000) revealed that learners with low prior knowledge learned most when presented with a diagram accompanied by an audio-text. Furthermore, an investigation by Kalyuga, Ayres, Chandler, and Sweller (2003) revealed and interesting and unusual effect—the expertise reversal effect. This effect proposes that learners with low prior knowledge benefit from high levels of instructional support. However, learners with high prior knowledge do not benefit and are sometimes impaired when they receive high levels of instructional support.
CHAPTER III

METHODOLOGY

Design

Three Factors, Graphic Type, Modality of Presentation, and Comprehension Time were crossed to yield 12 experimental cells. The resulting design was a 3 Graphic Type (thematic vs. non-thematic vs. none) x 2 Modality of Presentation (printed text vs. auditory text) X 2 Comprehension Time (immediate vs. delayed) fixed analysis of variance, with repeated measures on the comprehension time variable.

Participants

One-hundred-forty undergraduate volunteers were randomly sampled from a mid-size university in the western United States and assigned to one of the six between-subjects conditions. Participants were 75% male and 25% female, with an average age of 22 years, and generally average academic profiles, as evidenced by GPA (M = 3.23; SD = 2.20). 22% were seniors; 47% were juniors; and 11% and 16% were sophomores and freshman, respectively. All were predominately white with no apparent sensory impairments that would preclude their participation in the investigation.
Experimental Materials

The experimental materials used in the investigation were comprised of two decorative graphics, a classic literary narrative, three self-report inventories, and a demographic data sheet. The materials were assembled in an experimental hypermedia site posted on the web. The website consisted of 16 hypermedia pages, including: (a) one page of informed consent, (b) one page each of general and demographic instructions, (c) four wait pages, (d) an essay prompt and instructions page, (e) a routing page, (f) three pages containing a critical thinking skills test, and (g) one page displaying one of the two graphics, situated at the left two-thirds of the web page, or no graphic at all in conjunction with the narrative either printed (at the right one-third of the web page) or recorded. The last page consisted of a statement of debriefing. The remaining two self-report inventories—one a measure of metacognitive skill and the other a measure of cognitive load were administered as paper and pencil test and were not contained in the website. The critical thinking skills test and the test of metacognition were administered after the presentation of the experimental materials, and were not a part of the present investigation. Figure 1 represents the layout of the website.

Decorative Graphics

Two graphics were designed as visual displays to accompany the experimental narrative. One was a metaphorical depiction of the theme underlying the narrative; the other was a metaphorical depiction of the setting in which the narrative takes place.
Figure 1. Site Map for Website
Metaphorical depiction was defined as an aggregated set of features, comprising as a unitary display, a generalized unifying or dominant concept or idea conveyed in the narrative.

Thus, the graphics were constructed by blending distinctive features of the narrative to reveal either thematic, or non-thematic, elements. When thematic elements were employed, the graphic was comprised of: (a) a railroad track diverging in two directions, (b) a soft blended image of a young woman's face revealing a pensive look, (c) dark foreboding clouds on one side and a bright clear sky on the other, and (d) a barren desert landscape devoid of life on one side and a lush and fertile landscape on the other side. (See figure 2 and 3 for the thematic and non-thematic graphics, respectively). When non-thematic elements were employed, the graphic was comprised of: (a) a pastel colored landscape with hills in the distance, (b) a train stopped at an open-air station featuring a covered platform, (c) a row of tables and chairs next to the railway, and (d) a table with two beers sitting atop. Both displays were digitally painted using Photoshop 7.0 and were 11 cm. x 15 cm. in size.

In order to ensure that the graphics contributed visually to the metaphor conveying either the underlying theme or setting of the story, 43 undergraduate volunteers (22 for the thematic graphic and 21 for the non-thematic graphic) normed the images for their respective metaphorical depiction. Each set of volunteers were instructed to read the story, and scale either of the two graphics for the degree to which the graphic was: (a) related to the story, (b) related to the message of the story at a thematic level,
Figure 2. Thematic Graphic

Figure 3. Non-thematic graphic
(c) related to the setting of the story, (d) confusing, (e) interpretable, (f) easy to understand (comprehensibility), and (g) informative. The judgments were made by placing an 'X' on an eight centimeter line, with one pole labeled "not at all" and the other labeled "completely"; the judgments were then scored by placing a ruler over the line and counting the number of millimeters from the line's left pole to the 'X'. Results of the norming study revealed that the volunteers judged the two graphics to be distinctly different for thematic message, $F(1, 41) = 3.96, p = .05$, setting, $F(1, 41) = 4.17, p = .05$, comprehensibility, $F(1, 41) = 5.57, p = .02$, and the degree to which the graphic was judged to be confusing, $F(1, 41) = 5.88, p = .02$. Specifically, in comparison to the non-thematic graphic, the thematic graphic was judged to be more thematically related to the message of the narrative ($M = 52.09; SD = 23.28$ vs. $M = 36.86; SD = 26.89$), more comprehensible ($M = 45.05; SD = 22.78$ vs. $M = 60.81; SD = 20.92$), and confusing ($M = 42.64; SD = 24.30$ vs. $M = 24.52; SD = 24.66$). On the other hand, the non-thematic graphic was judged as significantly more related to the setting of the narrative ($M = 72.76; SD = 22.49$) than the graphic that was thematic ($M = 57.27; SD = 26.95$). The means, standard deviations, and F-tests for the remaining characteristics are shown in Table 1.

**Passage**

The experimental passage was the classic literary story *Hills Like White Elephants* (1927) by Ernest Hemingway. The story is a 1,445-word text that is 60% dialogue. The passage was chosen based upon its readability, ambiguity, and salience of underlying themes. The readability statistics of the passage are estimated at 93.8 using
the Flesch Reading Ease score, and 2.1 using the Flesch-Kincaid Grade Level index.

Thus, both metrics reveal that the story has a syntactic structure that is easy to read. At a

**TABLE 1.**

*Norming statistics for remaining characteristics*

<table>
<thead>
<tr>
<th>Characteristic</th>
<th>Mean</th>
<th>Standard Deviation</th>
<th>F-value</th>
<th>P-value</th>
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<td>.04</td>
<td>.85</td>
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<td>.93</td>
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<tr>
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<td>2.03</td>
<td>.16</td>
</tr>
<tr>
<td><strong>Non-thematic graphic</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Theme</td>
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<td>22.86</td>
<td>.04</td>
<td>.85</td>
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<tr>
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<td>.93</td>
</tr>
<tr>
<td>Meaning</td>
<td>44.28</td>
<td>25.63</td>
<td>2.03</td>
<td>.16</td>
</tr>
</tbody>
</table>

literal level of meaning, the story reports a conversation between two people waiting for a train; at a semantic level, the story is rich in two themes—deliberation over choice, and conflict over power between female and male. The narrative is written in the third person and reveals little information about the intentions, issues, and relationship between the main characters. It also fails to explicitly state issues that the characters discuss. Therefore, the reader must infer and interpret meaning based upon the limited information that is provided.

The story was also presented in an auditory format. An MP3 file was created from a compact disc containing a narration of the story. The auditory narration is
composed of a male voice using clear English. The length of the narrated story is 8 minutes and 30 seconds. The audio file was embedded into the web page and began streaming automatically upon opening the web page and therefore required no input control from the participants. In addition, the pace and volume of the narration was set and controlled.

Procedure

Participants completed all procedural tasks in a university computer lab in groups ranging from 1 to 20. They were invited to sit at a computer of their choice, where the screen was set to the informed consent page. Each computer was fitted with a folder containing the demographic data sheet and the three self-report inventories. All instructions were read aloud by a proctor while participants read quietly to themselves. If participants chose not to participate they were excused.

The instructions informed participants that the study consisted of two sessions, the first of which would take approximately 90 minutes to complete and the second approximately 20 minutes a week later. Participants who agreed to participate were directed to click the ‘next’ button taking them to a page providing general information on how to complete the study, including where to find further instructions and assistance. The instructions informed them that they would be reading or listening to the short story and would be asked to write an essay about their understanding of it later.

Following the instructions, participants were directed to click the ‘next’ button that took them to a routing page. There, they were directed to select one of the five
numbered links corresponding to the experimental condition to which they were randomly assigned. After clicking, they were allotted 8 minutes and 30 seconds to read or listen to the story and view the experimental materials. When time expired, they were instructed to click the ‘next’ button, which advanced them to the essay prompt. The prompt instructed them to prepare their essays by directing them to: 1) think about the short story they heard or read; 2) think about any underlying themes, meanings, and interpretations that were conveyed within the story; 3) use their thoughts and ideas to write an essay, integrating the meanings, themes and interpretations they gathered from the story; and 4) be as elaborative and as generative as they wished being certain to include any thoughts, feelings, or ideas that came to mind as they wrote. Participants were allotted 15 minutes to write their essay.

Following the essay phase, participants were directed to click the ‘next' button, routing them to a page providing instructions for completing the demographic data sheet. Participants were then instructed to fill out the demographic data sheet and self-assessment cognitive load measure. After completion, they were instructed to complete a measure about the way that they think. They were directed to click the 'next' button again—this time, taking them to a page containing questions for a critical thinking skills test—a 34-item questionnaire for which they were given 45 minutes to complete. Next, they were allotted 10 minutes to complete a 32 item metacognitive skill measure. Finally, they were directed to a link routing them to a web page in which they were asked to rate variations of the graphics used in this study based upon the graphics’ general appeal and beauty. The procedural sequence concluded with a debriefing page. Participants were
thanked for their participation and were asked to sign-up for an available time for session two of the study, and were then excused.

Participants who came back for the second session were asked to write an essay about the story that they read or listened to the week prior. Participants were provided with the original essay prompt and directed to write their essay based upon what they remembered about the story and its themes. They were allotted 15 minutes to write their essay and were then excused.
CHAPTER IV

RESULTS

Data Source

Participant protocols were scored for the quantity, type, and qualitative thematic nature of idea units present in student essays—that is, the number of idea units remembered from the literal level of the story, and the amount and quality of the idea units related directly to the story's themes. Generically, an idea unit was defined as a complete thought contained in a sentence, clause or phrase that revealed a semantically circumscribed and clearly identifiable idea. When the idea units were evaluated for quantity, their frequency was simply summed. When they were evaluated for quality, the idea units were assigned to one of five categories reflecting the nature of the narrative's themes—specifically, the themes of: (a) choices, (b) consequences, (c) doubt, (d) ambiguity, and (e) male and female relationships. The theme of a narrative was defined as a unifying idea or message that is conveyed by a written text, yet it is not explicitly stated. Theme must therefore be inferred and inductively derived by the reader. Specifically, the theme of choices is derived from the text by the dialogue between the characters about making a decision regarding an unplanned pregnancy. The characters must make a choice about whether they will have an abortion and continue on their hedonistic journey that is free from responsibility or they will abandon their current
journey and decide to keep the child. The theme of consequences is derived from the text depending upon the decision that the characters have to make and the resulting consequences based upon that decision. The theme of doubt is derived from the dialogue of the text. For example, the male character attempts to persuade and convince the female character that abortion is safe and that it is the best option; however, the female character doubts that this is option is neither best nor safe. The narrative text is inherently ambiguous by nature as it fails to explicitly state issues that the characters discuss and provides no resolution at the end. Therefore, the reader must infer and interpret the theme of ambiguity based upon their interpretation of the limited information that is provided. Finally, the theme of male and female relationships is also derived from the dialogue regarding the conflict over power between the male character and the female character. The male character focuses on their current situation as having only one solution, and pressures the female to get an abortion; whereas, the female character resists giving into his pressure and looks forward to the future beyond their current situation.

The categories were derived inductively by six raters based on the principles of grounded theory. Thus, the raters read the protocols, identified each idea unit, and then designated the thematic category to which the idea unit belonged. When disagreements occurred, the raters reconciled their discrepancies by discussion and consensus. When reconciliation was impossible, an idea unit was to be left unassigned and omitted from consideration; however, consensus was reached 100% of the time. Next, a scoring rubric was developed to assign point values to each identified theme category present in the protocols. Thematic idea units were allotted a point value of one, with an additional one,
two or three points allocated for one, two, or more than two idea units provided as themerelated evidence, respectively. In short, participants could receive a total of four points in each theme category—three points depending upon the supporting evidence provided, in addition to a point for the presence of the identifying theme. Finally, in order to ensure reliability of the identification of idea units derived from participant protocols, all were redundantly scored by an additional rater. The inter-rater reliability was 95%. All measures were entered as dependent variables into the same design—a 3 Graphic Type (thematic vs. non-thematic vs. none) X 2 Modality of Presentation (printed text vs. auditory text) X 2 Comprehension Time (immediate vs. delayed) fixed analysis of variance, with repeated measures on the comprehension time variable. All tests were evaluated for statistical significance at an alpha level exceeding .05.

Analysis of Passage Comprehension

Literal Comprehension of the Narrative

The number of idea units remembered from the literal level of the narrative was used as the index of narrative comprehension. Thus, the number of idea units present in learners essays immediately, and one week after, exposure were entered into the three factor design. The results revealed a main effect for Comprehension Time, $F(1, 65) = 22.38, MSE = 10.43, p = .001$, and the Graphic Type X Comprehension Time interaction, $F(2, 65) = 5.39, MSE = 10.43, p = .007$. As expected, learners remembered significantly more idea units from the narrative immediately after exposure to the story ($M = 7.60; SD = .5.18$) than after a one week delay ($M = 4.84; SD = 3.89$). However, the decline was
mediated by the type of graphic to which learners were exposed. Figure 4 shows the Graphic Type X Comprehension Time interaction. Specifically, simple effects tests revealed that the interaction was due to a significant decline in the number of literal idea units remembered from immediate testing to the delay for learners reading the narrative without a graphic, \(F(1, 16) = 6.18, p = .02\), and the graphic that was thematic, \(F(1, 28) = 36.70, p = .00\). However, learners reading the narrative in the presence of the non-thematic graphic showed no decline a week following initial testing, \(F(1, 24) = .34\).
Table 3 shows all other main effects, as well as the other primary, secondary, and tertiary interactions failed to reach acceptable levels of statistical significance.

**Analysis of Idea Units from the Thematic Level of the Narrative**

The number of idea units corresponding to the type of themes embedded in the story was entered as indices of learners' comprehension of the narrative's themes.

**Theme: Consequences, Doubt, and Ambiguity**

In the first set, idea units corresponding to the themes of consequences, doubt, and ambiguity were entered into three separate analyses of the same design. In each respective analysis, no main effects or interactions were revealed. Thus the type of graphic learners viewed, $F(2, 66) = .125, MSE = .967, p = .88$, $F(2, 66) = .84, MSE = .33, p = .44$, and $F(2, 66), F = .998, MSE = .528, p = .37$, failed to differentially influence the extraction of consequences, doubt, and ambiguity themes, respectively.

**Theme: Male-Female Relationships**

In the case of the theme of male female relations, the number of idea units were differentially influenced only by the type of graphic $F(2, 66) = 5.92, MSE = .56, p = .004$. Post-hoc Tukey tests revealed that learners exposed to the passage in the presence of the thematic graphic extracted more evidence ($M = 1.68; SD = 1.11$) from the passage to support their induction of the male-female relationship theme than learners viewing the non-thematic graphic ($M = 1.37; SD = 1.05$) or no graphic at all ($M = 1.07; SD = 1.07$). No difference in the extraction of the theme was revealed between the non-thematic graphic and no graphic all. All other main effects and interactions failed to reach an acceptable level of statistical significance.
**Theme: Choices**

With regard to the theme of choices, the number of idea units were differentially influenced by the type of graphic $F(2, 66) = 3.05$, $MSE = .44$, $p = .05$. Post-hoc Tukey tests revealed that learners exposed to the passage in the presence of the thematic graphic extracted more evidence ($M = .73; SD = .86$) from the passage to support their induction of the choices theme than learners viewing the non-thematic graphic ($M = .40; SD = .60$). No difference in the extraction of the theme was revealed between the non-thematic graphic and no graphic at all. However, the analysis did reveal a significant Graphic Type X Presentation X Comprehension Time interaction $F(1, 66) = 4.75$, $MSE = .44$, $p = .03$. Figure 5 shows the Graphic Type X Comprehension Time interaction for the Printed Text Presentation. Figure 6 shows the Graphic Type X Comprehension Time interaction for the Auditory Text Presentation. Specifically, post hoc simple effects tests revealed that learners viewing the thematic graphic ($M = 1.04; SD = 1.07$) extracted significantly more thematic content related to choice than the non-thematic graphic ($M = .42; SD = .70$) during the delay, $p = .017$, and marginally at immediate testing (Thematic $M = .73; SD = .86$; Non-thematic $M = .40; SD = .60$), $p = .075$. No effects were observed for either the main effect of modality of presentation, or the modality of presentation x graphic type interaction at either immediate or delay comprehension time sampling.
Figure 5. Graphic Type X Comprehension Time Interaction for Printed Presentation

Figure 6. Graphic Type X Comprehension Time Interaction for Auditory Presentation
CHAPTER V

DISCUSSION

Results of this investigation support the assumption that, through the construction of an integrated mental model comprised of information from a passage and graphic, learners are afforded a framework for understanding the thematic relationship shared between the two. The manipulation of graphics according to their degree of thematic representation shared with a text creates observable differences in the information learners bring to mind when processing the text. Learners who viewed a graphic thematically related to the text, summoned distinctly different material than learners who viewed a non-thematic graphic or no graphic at all.

While Carney and Levin (2002) suggest that graphics are differentiated according to their categorical function, I suggested that graphics are differentiated according to their degree of thematic representation. While many categorize representational and decorational graphics as being distinctly different based upon the function they serve text (cf. Carney & Levin, 2002; Levin, Anglin, & Carney, 1987; Levin & Mayer, 1993; Mayer, 1993; Pozzer & Roth, 2003), I contended that differentiating graphics in this manner may not be as important as the extent to which the graphics are capable of making certain content of an accompanying passage more salient. I suggested that decorational graphic may be representational in nature and that representational graphics can also be decorational, but it is the theme the graphics convey
that predicts how learners will interpret and understand the passage to which the graphic is assigned.

While many contend that decorative graphics fail at enhancing learner comprehension (Levin, Anglin, & Carney, 1987; Elia, Gagatsis, & Demetriou, 2007), the findings of this investigation show quite the contrary. I expected that the different types of graphics, both thematic and non-thematic, would interact with learners in cognitively different ways to invoke differential processing. This in turn would influence the type and quality of material the learners brought to mind for developing an understanding of the passage. The results of this investigation provide evidence to support this prediction—that learners brought to mind distinctively different material to the essays they wrote based upon the thematic representation of the graphic they viewed while reading or listening to the passage.

The support for this expectation is provided by Schnitz and Bannert’s (1999; 2003) integrated model of text and picture comprehension. According to Schnitz and Bannert, when a learner actively processes textual and graphical information together, they subsequently create a mental representation that occurs as a result of the semantic units provided by the propositions of the text in conjunction with the semantically processed Gestalt visual elements of the graphic (Schnotz, 2002). Thus, the construction of the mental representation is determined according to a learner’s ability to understand the relationship that exists between both referents. Moreover, the differential influence of theme as a metaphorically related bridge between the graphic and text are consistent with
Schnotz and Bannert’s (2003) contention that a schema mapping process is integral to the development of the text-passage representation.

The schema mapping piece is important since I contended that when learners understand the thematic relationship a text and graphic share, they are afforded the ability to semantically process and construct meaning of the presented information in both (Schnotz, 2002). Thus, it is essential for the learners to interpret the textual and graphical information at a metaphorical level because it is the metaphorical structure that allows theme to be revealed so that the graphic and text can be semantically bound together.

Next, I hypothesized that the two different types of decorative graphics in this investigation would enhance understanding of the passage at either the literal or deep semantic level of the passage, depending upon the type of graphic the learners viewed. The results revealed that this hypothesis was supported. Specifically, I found that when there was no graphic, comprehension at both the thematic and the literal levels of the narrative was more difficult to derive. When learners read or listened to the passage in the presence of the non-thematic graphic, they were able to derive meaning at the narrative’s literal level. By contrast, when learners read or listened to the passage in the presence of the thematically related graphic, they were able to derive thematic meaning at a deeper level of comprehension.

Several empirical investigations have established the notion that learners learn more from what they read when graphics are paired with text. In this case, a graphic may serve to activate relevant schema in a learner, and thereby enhance his or her understanding of the relationship between the graphic and text. If this is true, it would be
expected that learners who read the passage in the absence of the graphic would have comparatively little understanding of the passage at either a literal or thematic level because activation of a relevant schema was necessary for processing and making meaning of the rather ambiguous narrative text.

Results from the investigation yielded partial support for this assumption. That is, at the delayed testing interval, learners who read the passage without a graphic remembered less literal meaning in comparison to learners who viewed the graphic void of theme; however, the difference was not revealed when contrasted to the learners who viewed the graphic metaphorically depicting theme. In addition, at the immediate time of testing, learners who read the passage without a graphic, extracted more literal level idea units in comparison to learners who viewed the non-thematic graphic, but not for learners who viewed the graphic depicting theme.

With regard to derivation of theme from the passage, it was expected that learners who read the passage without a graphic would be unable to derive meaning at a thematic level of comprehension. Results supported this prediction at immediate testing, such that learners recalled less thematic idea units in comparison to learners who viewed the thematic or non-thematic graphics. Interestingly, at delayed time of comprehension, learners who read the passage without a graphic remembered slightly more thematic content from the passage than learners who viewed the non-thematic graphic—although, this finding was not significant.

The graphics used in conjunction with the passage were designed to serve as visual metaphors—one relating to the literal level meaning of the passage and one
relating to the thematic level meaning of the passage. Since metaphor comprehension
involves activating the non-literal meaning while inhibiting meaning that is literal
(McClone & Manfredi, 2001), I expected learners who read or listened to the passage in
conjunction with the non-thematic graphic would activate meaning at the literal level
while suppressing meaning at the thematic level. That is, the non-thematic graphic would
direct learners’ attention to the literal elements of the passage and subsequently make
those elements available for processing and understanding. Similarly, I expected learners
who read or listened to the passage in conjunction with the thematic graphic would
activate meaning at the thematic level while suppressing meaning at the literal level. In
short, the thematic graphic would direct learners’ attention to the underlying thematic
concepts conveyed within the passage and subsequently make this content available for
processing and understanding.

The findings borne from this investigation produced only partial support for
this hypothesis. Specifically, contrary to the hypothesis, when looking at the immediate
time of testing, learners who read or listened to the passage with the non-thematic graphic
recalled on average, less idea units from the literal level of the passage in comparison to
learners who viewed the thematic graphic or no graphic at all. At delayed time of testing,
by comparison, the pattern was reversed and supported the hypothesis. In this case,
learners who read or listened to the passage with the non-thematic graphic remembered
more idea units at the literal level of meaning than those who viewed the thematic
graphic or no graphic at all. Most importantly, learners who read or listened to the
passage with the non-thematic graphic showed no difference in recall of idea units at the literal level between both testing intervals of comprehension.

Learners who viewed the non-thematic graphic—the graphic related to the passage at the literal level of meaning—may have been able to suppress the thematic material from the passage. Kulhavy and Stock (1996) suggested that graphics are stored as visually intact mental representations that are similar to a graphics original perceptual display. Thus, when taking this into consideration, it is possible that learners who read or listened to the passage with the non-thematic graphic, did not necessarily remember the text per se, but may have retained a mental representation of the graphic they viewed. Therefore, at the delayed time of recall, the mental representation of the original image would be available for processing and would aid them in the recall of the passage in relationship to that mental representation—in this case, related to the literal level of meaning.

With regard to derivation of theme, as expected, learners who read or listened to the passage in the presence of the thematic graphic identified significantly more themes than learners who viewed the non-thematic graphic or no graphic at all. Even though thematic graphic viewers were presumably able to suppress literal level meaning at immediate time of testing, they were still able to process and extract thematic meaning from the passage at both times of comprehension. In the aggregate, thematic graphic viewers identified more thematic material at the delayed comprehension time over the immediate comprehension time. This finding gives support to Kulhavy and Stock’s suggestion that learners will retain a visually intact representation that is similar to the
graphics original perceptual display. Therefore, at delayed time of comprehension, the passage would not necessarily be remembered in much detail; however, the graphic would be available for processing and would subsequently influence the learner’s derivation of theme.

With regard to the issue of modality of presentation, the passage was varied through the delivery of either a printed text or an auditory narration presented in conjunction with one of the two graphics. As explained by the modality effect (Moreno & Mayer, 2000a; Mayer & Moreno, 2002a, 2002b), it was expected that learners who listened to the passage in opposition to reading it would have less cognitive demands created from the split-attention effect created from processing visually based graphical and textual information together. In turn, less cognitive demands would afford students additional cognitive resources permitting them to process the graphics more deeply and efficiently in drawing associative links between them.

Results from this investigation showed partial support for this prediction, depending upon the presentation of the passage. At the immediate time of testing, no difference for extraction of theme was revealed between the three graphics groups when the text was read. However, when the passage was heard, the thematic graphic viewers showed a 40% to 60% higher extraction of thematic idea units than the control and non-thematic graphic viewers, respectively. This effect was greater at the delayed time of testing when the passage was read. In this case, thematic graphic viewers showed a 50% and 300% improvement in their derivation of passage themes relative to the control and non-thematic graphic groups, respectively. In short, these results suggest that there may
have been a modality effect that may have helped learners process the graphic more deeply and subsequently aided in their derivation of thematic level meaning.

As suggested by Schnotz’s integrated model of text and picture comprehension, when learners read or listened to the passage in the presence of a graphic, they would create a mental model containing the semantically processed textual content and the semantically processed visual elements of the graphic. After learners constructed the representation, through the active processing in working memory, they would be able to store this information as a knowledge structure within the long-term memory store. I therefore hypothesized that at delayed time of testing, learners would not necessarily remember the surface structure of the passage they read or heard per se, but rather they would have an intact mental representation similar to the graphic’s original perceptual display (c.f. Kulhavy & Stock, 1996)—an image available for processing long after learners read the passage in conjunction with the graphic. This theoretical explanation fits the data well.

In the aggregate, Schnotz, Bannert, and Seufert (2002) described two branches of representation—one that is descriptive and one that is depictive. Thus, when learners’ cognitively interact with a text and graphic, both branches of representation combine to produce a mental representation through an active processing of the semantic units provided by the propositions of the text and the thematically selected elements from the graphical display. The representation that is created is thereby influenced according to the graphic that learners view in conjunction with the text. Therefore, the construction of the mental representation is guided by learners’ perception and understanding of the thematic
relationship that is shared between the text and graphic, and is driven by a schema mapping process that is influenced by prior knowledge. Our findings support Schnitz’s integrated model of text and picture comprehension as well as Kulhavy & Stock. This supports the idea that decorational graphics serve more than the function of adornment, but rather influence learners’ cognitive interaction with a passage to help invoke certain passage content and making that content more salient.
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