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Entitled Pictures Versus Text: Modality Effects Across Three Levels of Learning and Study Time

For the degree of Doctor of Philosophy

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PICTURES VERSUS TEXT: MODALITY EFFECTS ACROSS THREE LEVELS OF LEARNING AND STUDY TIME

A Dissertation

Submitted to the Faculty

of

Purdue University

by

Janet M. Beagle

In Partial Fulfillment of the

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of

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West Lafayette, Indiana

For Graduate School.

It’s been fun.

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LIST OF TERMS

Given that terminology is occasionally used with slight variations in meaning across disciplines, and even within disciplines, the following serves as a list of terms as they are used in this dissertation.

Analogical Transfer: a measure of learning involving the application of an abstract schema from a source story to a target problem (Gick & Holyoak, 1983).

Associative Connections: entails activation of mental representations within either the verbal or nonverbal symbolic system, accounting for spread of association among words or among images (Paivio, 1991).

Content Transfer: a measure of learning involving the application of learned content to new scenarios or novel problems, such as problem solving (e.g., Mayer, 1997).

Modality Transfer: the transition of information from one modality to another, specifically from the verbal to the visual and vice versa made possible by dual coding (Paivio, 1971; 2007).

Comprehension/Understanding: the second level of learning according to Bloom's *Taxonomy* (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). As used here, comprehension or understanding reflects the ability to answer questions posed about a text or picture when answers were explicitly stated in the study material.

Comprehension shows a grasp of the idea behind the picture or text rather than merely recognizing or recalling the exact representation.

Depictive Representation: iconic signs associated with the content they represent through common structural features on either a concrete or more abstract level. Pictures are depictive representations (Schnotz, 2002).

Descriptive Representation: a representation consisting of symbols that have an arbitrary structure and that are associated with the content they represent simply by means of a convention. Text is a descriptive representation (Schnotz, 2002).

Task-specific Informationally Equivalent: when two (or more) representations both allow the extraction of the same information required to solve specific tasks (Schnotz, 2002).

Memory: the first level of learning according to Bloom's *Taxonomy*. Includes recognition and recall (Bloom et al., 1956).

Modality Interaction Effect: score suppression that is the result of a modality transfer. A modality interaction effect has been shown for memory, where participants who are asked to recognize information in the opposite modality than their study modality score lower than participants who are asked to recognize information in the same modality (Standing & Smith, 1975).

Picture Superiority Effect: A consistent finding in memory studies where those who study pictures remember more than those who study text that is task-specific informationally equivalent (Standing, 1973).

Referential Connection: the mental connection between visual and verbal mental representations of the same or similar material (Mayer & Sims, 1994).

Representational Connection: the cognitive process of going from an external to an internal representation of material; encoding. Representational connections will be in visual form (imagens) for visual information and verbal form (logogens) for verbal information (Mayer & Sims, 1994; Paivio, 1986).

Representational Transfer: a measure of learning involving the application of a concept or methodology such as diagrams to solve novel problems (Novick, 1990).

Transfer: Synonymous with application, the third level of learning according to Bloom's *Taxonomy* (Bloom et al., 1956). As used here, transfer refers to the ability to apply information to a new context and/or solve novel problems for which answers are not directly supplied. Several types of transfer are briefly explored in the text.

Verbal: as used by dual-coding theory (Paivio, 1971), verbal refers to both written and aural language.

Visual: as used by dual-coding theory (Paivio, 1971), visual refers to pictures, graphs, photos, and other images that are stored as imagens by the brain.

ABSTRACT

Beagle, Janet M. Ph.D., Purdue University, December 2009. Pictures Versus Text: Modality Effects Across Three Levels of Learning and Study Time. Major Professors: Mark A. Balschweid and B. Allen Talbert.

The present study sought to explore the impact of picture and text modality on three levels of learning and study time. Undergraduate students (N=206) who indicated English as their first language studied information on the Emerald Ash Borer in either picture or text format for one, two, or four minutes. They then answered recognition and comprehension questions in picture and text format and two types of transfer questions. At one minute, the picture study condition significantly outperformed the text study condition across recognition and comprehension (p = .016), primarily due to performance on picture recognition questions. At two and four minutes, this picture superiority effect was replaced with a modality interaction effect; those who studied pictures scored higher on picture recognition questions and those who studied text scored higher on text recognition questions (all at p < .01). No significant effect of study condition was found on the comprehension questions at any time (all at p > .1). A study condition x question type interaction showed pictures had an advantage for recognition but not for comprehension (p = .001). This waning of a picture superiority effect was continued at the level of transfer, where the text study condition scored significantly higher on the scenario transfer questions averaged across all time periods (p = .011). No difference between study conditions was seen for the problem solving transfer questions (p = .802). Results suggest a memory advantage for pictures, but a transfer advantage for text. Implications are discussed.

CHAPTER 1: INTRODUCTION

Statement of Problem

This dissertation seeks to investigate whether pictures and text are differentially processed across different levels of learning, and to assess the implications of that processing for science educators.

Pictures and text are frequently used alone or in combination within various educational settings. This is particularly true within science education where precise identification of biological organisms, chemical structures, and biochemical pathways is a core component of student learning (e.g., Atkinson et al., 1999; Patrick, Carter, & Wiebe, 2005; Velázquez-Marcano, Williamson, Ashkenazi, Tasker, & Williamson, 2004). Within science education, photographs, diagrams, graphs and other visuals are used alone or in conjunction with text to aid student learning.

The goals of this learning can be variable. In 1956, Bloom and his colleagues established a *Taxonomy* of learning that is still used to classify learning today (Anderson & Sosniak, 1994; Bloom, 1994.) These levels of learning are evident within science education. For example, consider the first three levels of learning: knowledge (memory), comprehension, and application.

There are times when rote memorization or identification are essential – such as identifying cell types, chemical structures, insect pests, or particular species of plants or animals. In these cases it is most important that students are able to accurately remember the information.

In other situations, the learning goal is more comprehensive. For example, it is important for students to understand why particular chemical reactions are taking place, what is being indicated about plant or animal health by a combination of symptoms, or how biological systems function.

Learning can also extend to the next level of application or transfer. There are times students need to take information they learned in the classroom and apply it to new contexts. If they are identifying plant or animal species from photographs, they also need to be able to identify the living organism in the field. If they are learning why a particular chemical reaction is taking place, they need to be able to predict similar reactions with different compounds.

Despite the prevalent use of pictures and text to achieve these various learning outcomes, limited research has sought to identify how pictures and text are processed for various levels of learning. The present study seeks to identify how pictures and text are remembered, understood, and transferred – and how educators can appropriately use these two modalities to improve learning.

Theoretical Framework

The theoretical framework of the present study rests at the intersection of dual-coding theory (Paivio, 1971) and the taxonomy of learning proposed by Bloom and his colleagues (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). Dual-coding theory proposes there are “two separate coding systems of mental representation, one system specialized for language and one system specialized for dealing with nonverbal objects and events" (Sadoski & Paivio, 2001, p. 43). In other words, pictures are processed one way, while text is processed another way.

The question investigated here is how this differential processing is impacted by the different levels of learning proposed by Bloom and his colleagues (1956). It has been shown that pictures are superior to text for memory tasks (e.g., Paivio & Csapo, 1973; Standing, 1973). So, pictures outperform text at the first level of Bloom's *Taxonomy*. It is unknown, however, whether this "picture superiority effect" will remain for other levels of learning.

The present study seeks to investigate the differential processing of pictures and text across the first three levels of Bloom's *Taxonomy*: memory, comprehension, and transfer (Bloom et al., 1956).

Research Background

Within the field of educational research, investigations into picture and text effects generally operate within a text-centric paradigm. The main goal of these investigations is to enhance textual learning through the addition of pictures (e.g., Carney & Levin, 2002; Mayer, 1997). With few exceptions, most notably within advertising and other persuasion research (e.g., Peracchio & Meyers-Levy, 2005), but occasionally within the field of education (e.g., Weidenmann, 1989), little research has investigated how individuals learn from pictures alone, and how this learning compares to that from text. A basic science investigation comparing pictures and text across different levels of learning is needed to begin to identify the relative strengths and weaknesses of these two modalities. This, in turn, will begin to guide research towards the most effective usage of pictures and text.

A review of existing literature raises an additional point in need of further research: the modality with which learning is assessed. With few exceptions (e.g., Butcher, 2006) learning assessments are almost always conducted textually, particularly for higher levels of learning such as comprehension or transfer (e.g., Mayer, 1997; Mayer & Johnson, 2008). Within the picture memory literature, it has been shown that requiring participants to respond in a modality different than the modality they studied suppresses their test scores (Standing & Smith, 1975). In other words, participants who study pictures but demonstrate their learning in text form or study text but demonstrate their learning in picture form have lower scores than those who study pictures and demonstrate their learning in picture form or who study text and demonstrate their learning in text form. Therefore, the assessment instrument can artificially deflate the learning measure simply by changing the modality.

It is unknown whether a similar modality interaction effect occurs at levels of learning beyond memory. If it does, this effect could be confounding existing research. A study is needed that uses an assessment instrument in both picture and text modality to allow for an investigation into this modality interaction effect.

An additional consideration for pictures and text comparisons is the impact of processing speed. As detailed shortly, the amount of time an individual has to review information can impact the type of processing they undergo and can differentially impact the information obtained from picture vs. text modalities (e.g., Lang, Potter, & Bolls, 1999; Meyers-Levy & Malaviya, 1999; Paivio, 1971). It is possible, then, that different picture and text effects may be exhibited with different study times. There is a need within the literature for the variable of study time to be considered.

In addition to the contributions this study makes to the existing literature base, a basic understanding of picture and text effects also has direct application to education both in and out of the classroom. From a practical perspective, it is not always possible to include both pictures and text in learning materials. There may be limited space within a document, limited time to present the information, or a limited budget with which to produce the materials. In these instances, educators are forced to make a modality decision, and they need to know the best choice to achieve their teaching objective. Thus, a study is needed that directly compares the usage of pictures and text at different levels of learning.

The present study seeks to address these needs by providing a direct, intensive investigation into the effects of visual and verbal modalities across three levels of learning: memory, comprehension, and transfer. The topic of the Emerald Ash Borer was selected as a model for science learning. The Emerald Ash Borer is an invasive insect in Indiana, and was selected as an ideal topic for this study for several reasons.

First, the Department of Natural Resources has been trying to increase awareness about this insect because it has been spreading rapidly from its initial discovery in Michigan through (at the time of the study) seven other states, including Indiana. The Emerald Ash Borer infects ash trees, important both for their wood, their popular use as community shade trees, and their presence in national forests. Once infected, 100% of ash trees die. The spread of the Emerald Ash Borer has been exacerbated by people transporting firewood, nursery stock, and other ash products. Quarantines are being enforced in several Indiana counties, restricting the movement of wood. The proximity of these occurrences and the plea to the general population for assistance makes the Emerald Ash Borer a relevant topic for the participants in this study.

Second, the Emerald Ash Borer has a wealth of concrete imagery associated with it. Many facts concerning this insect can be presented in visual form, making it an ideal topic for this study. Many of the pictures used in the study are currently used in actual university, industry, or governmental publications being distributed to the public. This enhances the ecological validity of the study, since “real life” information is being tested. The use of actual publication photos that may be altered to create various treatment conditions is also a recommended practice in picture research (e.g., Childers & Houston, 1984; Mendelson & Thorson 2004; Wanta, 1988).

Third, despite recent efforts by natural resource officials, including the launching of an Emerald Ash Borer awareness week, student knowledge about the Emerald Ash Borer is expected to be low. A pilot test supports this supposition. When students in the pilot test were asked to rate their familiarity with the material presented with 1 being not at all familiar and 5 being very familiar, they reported an average familiarity of the Emerald Ash Borer of only 2.15 (SE=0.296). Thus, the potential exists to measure actual learning rather than previous knowledge.

Undergraduate students were selected as the study population. While this is frequently viewed as a convenience sample, the researcher was primarily interested in this population because they are key learners. As science educators, it is important to identify the best way to present picture and/or text information to these students.

Research Questions and Hypotheses

This study seeks to expand existing literature in several ways. First, this study seeks to replicate and build upon the picture superiority effect seen in memory studies (Paivio & Csapo, 1973; Standing, 1973; Standing & Smith, 1975) and extend the investigation into comprehension and transfer. While pictures have been shown to be superior to text in memory studies, direct comparisons between pictures and text at deeper levels of learning are limited to problem solving with cause-and-effect pictures (Mayer & Anderson, 1991; Mayer et al., 1996). A study comparing picture and text effects across all three levels of learning will deepen our understanding of verbal and visual effects across learning levels. A direct comparison will also break out of the text-centric paradigm and allow for a fresh perspective on the educational potential of pictures and text. The overarching research question guiding this study may be summarized as follows:

> **RQ1:** As question complexity increases, will performance advantage switch from the picture study condition to the text study condition?

Several related hypotheses were put forth to address details inherent in this overarching question. The first set of hypotheses addresses learning level. Questions to assess each level of learning were used, and these are referred to here as question type.

As question complexity increases, it is believed that test scores will be lower. Of greater interest, however, is the interaction between question type (i.e., learning level) and study condition. Because the picture superiority effect for the level of memory is well established, it is expected that picture superiority for memory will be replicated in the present study. However, previous research could suggest various outcomes for picture vs. text effects on comprehension and transfer questions. Briefly, the superiority of pictures at the level of memory and the fact that adding pictures to text generally improves transfer over text alone (Mayer, 1997) would suggest that pictures would perform better than text for comprehension and transfer. However, other studies suggest otherwise. Animated pictures were better than text in an analogical transfer task, but static pictures were not (Pedone, Hummel, & Holyoak, 2001). Similarly, there was no difference between pictures and text in a problem solving transfer study (Mayer & Anderson, 1991). Thus, hypotheses related to picture and text effects at the levels of comprehension and transfer were left bidirectional. The hypotheses related to learning level are as follows:

H1: Recognition scores will be higher than comprehension scores.

H2: A picture superiority effect will be seen for recognition memory. On recognition multiple choice questions, those who studied pictures will outperform those who studied text.

H3: A study condition effect will be seen for comprehension. On comprehension multiple choice questions, those who studied pictures will perform differently than those who studied text.

H4: A study condition effect will be seen for transfer. On the transfer problems, those who studied pictures will perform differently than those who studied text.

This study will also check for modality interaction effects across both memory and comprehension. Modality interaction effects have been shown for memory, with participants scoring significantly higher when they are tested in the same modality as their study condition (Standing & Smith, 1975). The presence of modality interaction effects could have implications for educational assessments as well as research design. Current testing materials may not be providing accurate representations of student knowledge if the results are compounded by a modality interaction effect. For example, if students are better able to express understanding in the same modality in which the material was learned, using assessments only in text format may be suppressing the impact of pictures. This study will extend previous research by investigating the modality interaction effect for comprehension as well as memory. The following hypothesis was put forth:

H5: A modality interaction effect will be seen for both recognition and comprehension so that within-modality questions will outperform cross-modality questions.

The variable of study time will also be introduced. Overall, it is expected that test scores will increase with study time. Of greater interest, however, are the anticipated interactions between study time, study condition, and learning level. According to dual-coding theory, visual perception is capable of receiving, transmitting, and processing visual information simultaneously, while text must undergo sequential processing (Paivio, 1971). Thus, pictures can elicit a quicker mental snapshot than that which can be obtained with text. In the multimedia television environment, it has also been shown that at high levels of cognitive load, visual recognition was not decreased with increased speed of presentation but verbal recognition was (Lang et al., 1999). These findings suggest that individuals will remember pictures better than text when there is less time to study the material. Therefore, it is expected that shorter study times will favor pictures, but that this advantage will disappear for longer study times.

It has also been suggested that pictures are processed more superficially than text (Weidenmann, 1989). Therefore, the quicker processing of pictures may not result in deeper levels of learning. It is expected that the speed advantage for pictures will not be present for the transfer task.

H6: As study time increases, test scores for recognition and comprehension will increase.

H7: As study time increases, test scores for transfer will increase.

H8: For recognition questions, the picture study condition will outperform the text study condition at shorter study times, but not at longer study times.

H9: For transfer tasks, there will not be a picture advantage at shorter study times.

A participant self-rating of confidence will be included. This approach is an alteration of that used by Archer (2007) who, for multiple choice questions, included an option of "I cannot answer this without guessing." Including confidence score ratings will allow an additional dependent measure to investigate study condition effects. It is expected that confidence scores will follow a similar pattern of results as that of actual test scores, specifically:

H10: Confidence in answers will be higher for recognition questions than for comprehension questions.

H11: Confidence in answers will be higher for within-modality questions than for cross-modality questions.

Confidence ratings will also provide an opportunity to compare participants' self-reported confidence with their actual test scores. A correlation will be run to compare how well confidence and test scores correlate for each study condition. Since the comparison between confidence and actual test scores is exploratory, anticipated results are framed as research questions rather than as hypotheses:

RQ2: For each level of learning, does the pattern of confidence ratings in each study condition follow the same pattern as the test scores?

RQ3: Do the correlations between confidence and actual test scores differ between study conditions?

The effect of various demographic variables on these hypotheses will be analyzed. Because participants will be randomly assigned to study conditions and study times, the impact of any demographic variables should be minimal. However, to make sure the randomization adequately distributes these characteristics across treatments, demographic variables that have previously been shown to impact picture or text learning will be assessed.

In particular, prior knowledge and interest have been shown to impact learning (e.g., Mayer and Gallini, 1990; McKelvie, Standing, St. Jean, & Law, 1993; Schiefele & Krapp, 1996). As a result, a self-reported measure of prior knowledge and interest will be included among the demographic variables. Similarly, because students living in an area affected by the Emerald Ash Borer may have more implicit knowledge of the subject, the student's home location will be collected. Since age and year in school could also impact implicit knowledge, these variables will be collected.

An impact of gender has occasionally been reported in the literature, with recognition memory for pictures differing between males and females. For example, people are generally more accurate at recognizing pictured faces of their same gender (McKelvie et al., 1993) and women are more likely to look at a color photograph compared to men (Garcia & Stark, 1991). To insure gender is not a confounding factor in the analyses, it, too, will be collected as a demographic variable and its effect on test scores assessed.

Participant's visual-verbal learning style will also be included. Of particular interest to this study is the cognitive aspect of learning style, or the way in which individuals process and represent information (Mayer & Massa, 2003). To insure visual-verbal learning style does not skew the results, its impact will be investigated.

Summary

The present study gives pictures and text an equal opportunity to exhibit their learning potential across three levels of learning: memory, comprehension, and transfer. Three study times allow for an assessment of how study time impacts picture and text learning. The assessment instrument allows for modality interaction effects to be tested by including recognition and comprehension questions in both picture and text modalities. For the first time, as far as the researcher is aware, a direct comparison is made between pictures and text across three levels of learning using both picture and text assessment tools for recognition and comprehension. This allows for a more unrestricted investigation into the learning potential of these two modalities. Results provide science educators with guidelines for using pictures and text in their instructional materials and assessment tools. These implications are discussed in the last chapter.

CHAPTER 2: LITERATURE REVIEW

Introduction

From the earliest hieroglyphics to modern multimedia presentations, pictures and text have been foundational elements in written communication. The importance of these elements has not gone unnoticed, and research bases have sprung up within the fields of cognitive psychology, marketing, mass communication, and education in an attempt to better understand both the basic science and the practical applications of pictures and text. Much of this research conjoins in an attempt to answer two main questions: How are pictures and text processed? How can we best use pictures and/or text to meet our communication goals – whether those goals are persuasive or educational in nature?

Some of the key literature as it relates to pictures and text in learning is presented here. The following review is broken into three main sections. In the first section, picture and text processing as it relates to the current study is briefly reviewed. The foundational theory, dual-coding theory, is first introduced. An additional model, the integrative framework, is also briefly explored. The integrative framework suggests there is differential processing of information depending on viewer engagement and that the role of pictures in information processing will vary depending on the type of processing the viewer is engaged in. For the purposes of the present study, it is important to consider these differential pictures and text effects. Out of this discussion come several variables that could impact the way pictures and text are processed, including student interest, study time, and the use of color. Potential impacts of these variables were taken under consideration during the design of the present study.

In the second section, the practical implications of differential picture and text processing as it relates to learning are explored. First, a brief review of the more relevant learning style literature is provided to consider how learning style may impact the present study. This is followed by an identification of the key functions of pictures and text within learning. Levels of learning are then explained, and a closer examination is taken to determine what is already known about picture and text effects for the first three levels of learning. The present study follows from this intersection of picture and text processing at the first three levels of learning.

The third section considers the challenges facing picture and text research and the recommendations for handling these challenges. The review concludes with a brief summary leading into the study.

Picture and Text Processing

When investigating picture and text processing, it is important to consider both the physiological processing and storing of information, as well as the traits of individuals processing the information. Dual-coding theory and the integrative framework of persuasion have proven particularly useful for analyzing how pictures and text are differential processed.

Dual-Coding Theory

Dual-coding theory began to take shape during the 1960s, but was first proposed by Allan Paivio in 1971 (Sadoski & Paivio, 2001). The theory posits that cognition "consists of the activity of two separate coding systems of mental representation, one system specialized for language and one system specialized for dealing with nonverbal objects and events" (Sadoski & Paivio, 2001, p. 43). Paivio (1986) refered to the units of visual memory as "imagens" and the units of verbal memory as "logogens."

In recent years, additions and adaptations to dual-coding theory have been made. See, for example, Wolfgang Schnotz' (2002) suggestions for an integrated model of text and picture comprehension and Richard Mayer's cognitive theory of multimedia learning (Mayer, Bove, Bryman, Mars, & Tapangco, 1996; Mayer & Sims, 1994). However, the foundational concepts of dual-coding theory have remained unchanged.

Dual-coding theory recognizes two main cognitive processing systems in which both aural and written language are grouped together in comparison with nonverbal images and objects (Paivio, 1971; 2007). This grouping was supported by early research which showed aural and written language to be functionally equivalent. Standing and Smith (1975) noted that memory for a word is "little affected by whether the word is presented visually or aurally, and whether the response is made by speaking or writing" (p. 316). In short, pictures are mentally stored and processed one way, while words (whether received visually or aurally) are mentally stored and processed another way.

While the discussion of dual-coding theory as it relates to the present study is centered around the implications of this theory for picture and text processing, it should be noted that dual-coding theory is not only a verbal versus visual theory (Paivio, 1991).

Within dual-coding theory, a distinction is made between sensorimotor and symbolic systems. Sensorimotor systems refer to the way in which information is perceived, while the symbolic systems refer to the way information is mentally processed and stored (Paivio, 1986). Information obtained from the same type of sensorimotor system may be processed under either the verbal or non-verbal symbolic system depending on the object under study. For example, the present study is concerned with pictures vs. text. Both of these are obtained through the visual sensorimotor system, but while text is processed under the verbal symbolic system, pictures are processed under the nonverbal symbolic system (Paivio, 1986). Other examples of the sensorimotor and symbolic system distinctions are displayed in Table 1.

Table 1
Relationships Between Sensorimotor Systems and Symbolic Systems with Examples of Modality-Specific Information. Adapted from Paivio, A. (1986). Mental Representataions: A Dual Coding Approach. New York: Oxford University Press, pp. 57

Sensorimotor	**Symbolic Systems**	
	Verbal	**Nonverbal**
Visual	Written text	Visual objects; pictures
Auditory	Auditory words	Environmental sounds
Haptic	Writing patterns; Braille	“Feel” of objects
Taste	--	Taste memories
Smell	--	Olfactory memories

Functional differences have also been described for the two symbolic systems. Verbal representations are more powerful for expressing general ideas, while visual representations are able to provide greater specificity (Schnotz, 2002). This may be due in part to the type of processing the information undergoes. Verbal information is processed sequentially, while visual information is processed spatially (Paivio, 1971). Under spatial processing, the spatial relationship of components is much more evident.

For example, when shown a series of dots, individuals can visually see a non-random line of dots in an instant, while sequential analysis of the arrangement requires a time consuming process of calculating the distance of each dot to every other dot (Pizlo, Salach-Golyska, & Rosenfeld 1997).

Another example of the difference in specificity may be seen in the concept of the triangle. Schnotz (2002) suggested that while the word triangle can include a wide variety of three-sided objects, a picture of a triangle locks in one specific image with specific geometric properties. Standing and Smith (1975) made a similar statement when they noted the challenge of specificity in mentally encoding text versus images. When someone says the word “dog,” a participant may conjure up any number of images ranging in shape, size, and color. If an image is presented, however, then only that particular image is likely to be stored. This may be particularly true for people with high visual aptitude, since high visualizers perceive and store visual information literally (Paivio, 1971).

As a representation is being processed, it is also networked with existing prior knowledge into one or more mental models. Thus, while a visual representation is a fairly specific encoding of a given picture, the overall mental model incorporating the picture contains both less and more information than the picture itself. The model contains less information because abstraction is necessary to integrate the key elements of the picture into the mental model, but more information because it also includes prior knowledge that is not present in the picture (Schnotz, 2002).

As discussed shortly, dual-coding theory was chosen as this study’s guiding theory for its practical implications to the field of education. However, it is certainly not the only theory used to assess the processing of pictures and text. Pavio (1991) noted: "The dominant opposing position has been that the language of thought is unimodal and abstract, classically viewed as internalized words and sentences and, more recently, as amodal propositional structures and rule-governed (computational) processes" (p. 257).

Under this opposing view, information received in picture or text form is processed and stored within a single system without retaining the visual or verbal properties of the original information. Many proponents of the single-coding system fall within the research realm of artificial intelligence (Molitor, Ballstaedt, & Mandl, 1989). These researchers maintain that "all of our knowledge is stored in a unique memory system in a propositional format independently of whether it was decoded as linguistic or visual information" (p. 7).

The debate between a dual-coding, a single-coding, or some other kind of coding has been in full swing for several decades, with proponents on both sides claiming empirical support (e.g., Paivio, 1991; Te Linde, 1982). While a full review of this debate is outside the scope of this dissertation, a sample discussion may prove useful. One argument for the presence of a single, amodal processing system lies in the ability for pictures and text to be merged into a single memory. For example, Pezdek (1977) suggested information presented pictorially is processed similarly to information presented verbally. She cited Nelson and Reed (1976) who claim that the semantic content of pictures and words is stored comparably, independent of the nature of the original representation. This position was supported by a study showing the integration of visual and verbal information into a single construct. Students read the sentence "The bird was perched atop the tree" and were then shown a picture of an eagle sitting in a tree; these students later believed the sentence was “The eagle was perched atop the tree” (Pezdek, 1977).

It should be noted, however, that the integration of visual and verbal material is not unique to the single-coding theories. Dual-coding theory acknowledges three types of connections between visual-verbal stimuli and the mental representations (Paivio, 1991):

1. Representational processing refers to the relatively direct activation of logogens by linguisitic stimuli and imagens by nonverbal stimuli.
2. Referential processing refers to the cross-system activation required in imaging to words and naming objects.
3. Associative processing entails activation of representations within either system, accounting for spread of association among words or among images. (p. 259)

Thus, dual-coding theory suggests the two symbolic processing systems operate independently, and it is this independence that allows for simultaneous but differential “parallel” processing of pictures and text (Paivio, 1991). However, pictures and text are *not* kept in complete isolation from one another. While *representational* connections are made between the material being studied and the mental representation in working memory in the same modality as the presented material, *referential* connections are made between the visual and verbal representations (Mayer & Sims, 1994). These referential connections allow for a transfer of information from the visual system to the verbal system and vice versa.

For example, when presented with a picture of a dog, an individual will create a representational connection between the picture and the visual mental image of the dog that is stored in memory. At the same time, it is possible for the individual to make a referential connection between the visual mental image and the verbal equivalent "dog." A diagram adapted from Mayer and Anderson (1991) illustrates representational and referential connections and is presented in Figure 1.

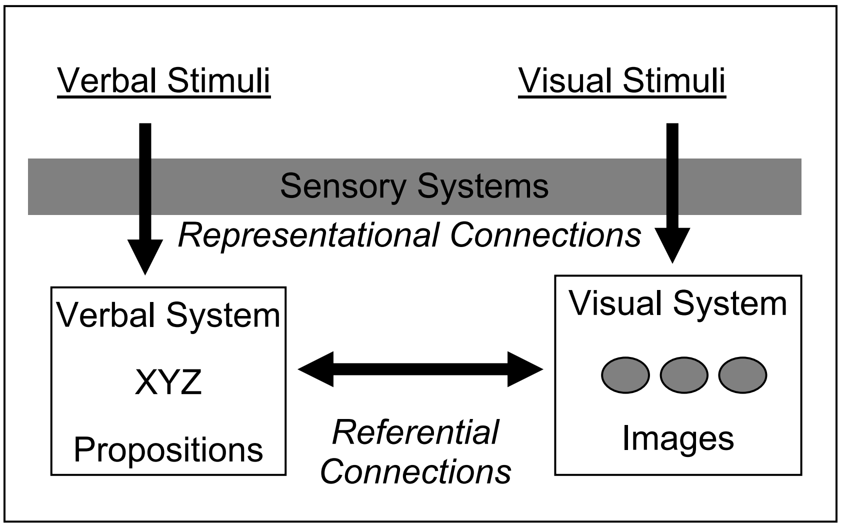

Figure 1. Diagram of representational and referential connections. Adapted from Mayer, R. E., & Anderson, R. B. (1991). Animations need narrations: An experimental test of a dual-coding hypothesis. *Journal of Educational Psychology, 83*(4), 484-490.

Early research also investigated the nature of the referential processing of converting words to pictures and pictures to words. Again, some results were claimed to support the dual-coding premise (Standing & Smith, 1975), while others were claimed to support the single-coding premise (Te Linde, 1982).

For the purposes of the present study, the interest in dual-coding theory lies in the potential for differential picture and text processing to differentially impact learning. As Molitor and her colleagues (1989) noted:

> If the assumption of a possible dual coding in two different knowledge systems is true, then texts and pictures are subject to different processes. It is then also conceivable and probably the case that...the presentation form in the one medium or in the other play an essential role with respect to learning. (p. 9)

The possibility of differential processing of pictures and text impacting learning is worthy of investigation. Indeed, others within the field of education have specifically sought to test a single-coding versus dual-coding model and have found support for dual-coding theory (e.g., Mayer & Anderson, 1991). Dual-coding theory has also been widely used as a theoretical foundation for various tests of learning from pictures and text (e.g., Childers & Houston, 1982; Levie & Lentz, 1982; Mayer, 1997). The present study seeks to expand this literature by assessing if students learn differently from pictures and text at different levels of learning.

To summarize, the possible implications of dual-coding theory on the effects of learning from pictures and text are fundamental. With two different coding systems in place, the opportunity arises for various interactions between words and pictures. These interactions will be explored in more detail in subsequent sections and include both additive effects, where text and pictures together improve learning, as well as competing effects, where text and picture combinations actually inhibit learning either through cognitive overload (e.g., Igo, Kiewra, & Bruning, 2004; Mayer, Heiser & Lonn, 2001) or by detracting from the key message (e.g., Boesch & Standing, 1990; Lee & Ang, 2003;

Wanta & Roark, 1993). The implications of the relative generalizability of pictures and text as they relate to learning will also be further expounded below, particularly in the section on transfer.

Integrative Framework

In 1999, Meyers-Levy and Malaviya published an integrative framework of persuasion. This particular framework is stated to provide a more “parsimonious and comprehensive account” (Meyers-Levy & Malaviya, 1999, p. 50) than some of its predecessors. Although their model was designed for advertising and marketing research, their inclusion of picture processing within this framework makes it an important model to consider for the present study.

According to the integrated framework, pictures will impact viewers differently depending on what type of cognitive processing they are engaged in (Meyers-Levy & Malaviya, 1999). The type of cognitive processing is determined by the allocation of cognitive resources, i.e., the amount of thought that an individual invests during processing. Three levels of cognitive processing are identified. Systematic processing requires the greatest investment of resources, followed by heuristic processing and then experiential processing (Meyers-Levy & Malaviya, 1999). A person who devotes little attention to the content is engaging in experiential processing, while someone who devotes a lot of attention to the content is engaging in systematic processing. If one considers this framework in an educational context, it becomes evident that the time and energy devoted by the student could impact how well they learn from the pictures and text presented.

Allocation of resources is determined by characteristics of the message recipient, the message itself, and the context in which the message is received (Meyers-Levy & Malaviya, 1999). Each of the three levels of the integrated model and the role of pictures at each level are briefly discussed below.

Effects of Pictures on High Cognitive Involvement (Systematic Processing)

Systematic processing has its roots in the cognitive-response, dual-process, and resource-matching models of persuasion. Pulling insights from each of these theories, Meyers-Levy and Malaviya (1999) suggested that systematic processing is an effortful, deliberate, and logical approach to judgment making that uses extensive and critical elaboration of message claims. In other words, individuals engaged in systematic processing take the time and effort to understand and create an opinion about a message.

Although not explicitly noted, systematic processing is also related to the associative-network model. Under the associative network model, memory consists of information nodes linked with different degrees of association so that more strongly associated information is more readily recalled than weakly associated information (Lee & Ang, 2003). The more "pathways" a person has to locate a particular memory, the more easily that memory will be brought to mind.

When using systematic processing, persuasion is a function of people's cognitive responses to the message. In other words, the thoughts that arise during the process of elaboration will directly impact how the viewer perceives the persuasive appeal. At the same time, the balance of cognitive demand needed to process the content and the cognitive supply the viewer has allocated to interpret the content can determine the impact of the content (Meyers-Levy & Malaviya, 1999). If the cognitive supply and demand are equal, people will perceive the message more favorably. However, if the cognitive supply is too low, a communication will not be properly processed and the viewer will not receive the intended message. If the supply is too high, the viewer is likely to engage in elaborative processing beyond the information presented, becoming more critical of the message content and potentially less inclined to agree with the primary message.

Individuals are most likely to engage in systematic processing when they place a premium on forming accurate assessments and are willing and able to devote the time and mental resources (Meyers-Levy & Malaviya, 1999). Within a learning environment, individuals are likely to engage in systematic processing when they are interested in the topic. When an individual views pictures of a topic that interests them, they show improved memory of those pictures (McKelvie et al., 1993). Highly interested readers also process text more deeply and recall more information, even after accounting for prior knowledge and verbal ability (Schiefele, 1996; Schiefele & Krapp, 1996). Thus, interest can be a key trigger for an individual to engage in more systematic processing.

In advertising, it has been shown that when advertisements are processed at a deeper, semantic level, pictures do not improve advertisement recall (Childers & Houston, 1984). However, pictures still play a critical role for systematic processors. At this level of processing, pictures are remembered best when they make sense. When nonsense pictures were given a textual interpretation, recall increased by 65% (Bower, Karlin, & Dueck, 1975).

The use of color can impact how a picture is processed. Full color photos impose greater demands on people's cognitive resources and may therefore be detrimental when viewers are undergoing systematic processing (Meyers-Levy & Peracchio, 1995). In fact, when products were presented in a cognitively demanding advertisement (e.g., including block text of product attributes or intangible claims such as "excitement") participants evaluated the product more favorably, produced more positive thoughts and fewer negative thoughts, and noted more visual elements that were product related when the photographs were in black and white (Meyers-Levy & Peracchio, 1995). Childers and Houston (1984) also found that color depressed recall of words and pictures under semantic, or more cognitively demanding, processing. McCloud (1993) suggested that when pictures are presented in black and white, the ideas behind the pictures are communicated more directly; color objectifies the pictured subject, drawing more attention to the surface of the picture rather than the underlying message.

Images with perceptual ambiguity (like the classic "face or vase" and "young girl or old woman" images) can be very effective at grabbing and holding attention (Barry, 1997). Several reasons may exist for this. First, ambiguous images may form more mental associations. If an image may be seen in two ways, then it is feasible for both of these perspectives to be stored, essentially doubling the potential number of mental associations.

Perceptual ambiguity also begets viewer engagement. Viewers will look longer at a complex image than a simple one (Leckart, 1966). In a sense, ambiguity creates a weak level of cognitive dissonance – a sense that two or more pieces of information don't quite match and need to be reconciled – that encourages viewers to wrestle with the image in an effort to relieve the dissonance (Baran & Davis, 2003). In other words, an ambiguous image is not providing one clear message, and the viewer must take time to study the image and identify the message.

This idea relates to Marshall McLuhan's theory of hot and cool media. Hot media allows for little filling in, while cool media forces viewer participation by leaving gaps in words or images that viewers must complete (Barry, 1997). Cool media only makes sense with insights which the viewer brings.

This need for engagement coincides with the "generation effect" studied by educational researchers. According to this principle, people will remember material better if they have to generate a solution rather than simply read about it. For example, if people generate the partial word in the synonym pair FAST::R___, they will remember the word RAPID better than if they simply read the pair, FAST::RAPID (Slamecka & Graf, 1978).

A precedent for applying the basic premise of the generation effect beyond word generation has been established. For example, the principles of the generation effect have been cited to explain why students learned better through problem solving rather than memorization (Needham and Begg, 1991). Images that similarly require viewer engagement may improve recall of the information. It may even be argued that in generating referential connections, verbal and visual materials are adhering to the "generation effect," but this possibility would need to be empirically tested.

Effects of Pictures on Intermediate Cognitive Involvement (Heuristic Processing)

Individuals engaged in heuristic processing generate simple inferences from the most salient points of the communication, devoting only moderate levels of cognitive resources to the task (Meyers-Levy & Malaviya, 1999). The effects of pictures may be greater for heuristic processing than for any other type of processing. Peracchio and Meyers-Levy (2005) use the rather ambiguous phrase "somewhat extensive processing" (p. 39) to identify the opportune level of cognitive processing necessary for maximum picture effects. They note that extensive processing frequently relegates pictures to a more minor role, with greater emphasis placed on text than on graphics. This idea is fairly well supported, as seen in the discussion above on high cognitive processing and in journalism studies where a picture that piques a reader's interest will cause them to dig deeper into the text for the details (Zillman, Knobloch, & Yu, 2001). On the other hand, if cognitive processing is too low, viewers do not seem to ascertain all aspects of the message, such as the stylistic properties present in images (Meyers-Levy & Peracchio, 1992; Peracchio & Meyers-Levy, 2005).

Stylistic properties are the design components of an image, such as camera angle, orientation of the depicted object, or lighting (Peracchio & Meyers-Levy, 2005). Stylistic properties can be an important aspect of the intended message. For example, an image may be shot with a low, upward looking camera angle to evoke a feeling of power (Peracchio & Meyers-Levy, 2005). Viewers using only low levels of cognitive processing who don't notice such stylistic properties (consciously or otherwise) are missing part of the intended message. Thus, to achieve maximum picture effect, the level of cognitive processing needs to be "somewhat extensive."

In addition to a moderate level of cognitive processing, additional semantic coding is generally needed for the stylistic properties of pictures to be appreciated. Participants who view images with an incompatible caption (e.g., using flirty, fun advertisement copy with a photo empirically shown to elicit feelings of power) or no caption (e.g., using only the brand name and category with a photo) do not notice the stylistic properties of the image (Peracchio & Meyers-Levy, 2005). Adding relevant text to the picture makes the viewer more aware of the picture's message.

The difference between systematic processing and more heuristic processing is that when extensive cognitive processing is used, pictures primarily reinforce the textual message and serve as an additional association in memory storage – ultimately helping with message recall. In other words, under extensive processing, pictures take on a secondary role. Alternatively, under heuristic processing, the role of the picture in interpreting a message becomes more prominent. Elements of the text are used to heighten awareness of the stylistic properties of the image, and these image properties become the readily accessible cues upon which judgment is formed.

During heuristic processing, stylistic properties of images may be perceived even in the absence of textual cues if viewers are cued in other ways. Priming individuals by asking them a series of questions related to the message evoked by the stylistic properties of the image can improve their recognition of these properties (Peracchio & Meyers-Levy, 2005). For example, individuals asked questions related to physical strength (i.e., various exercises) prior to viewing ads had improved brand recall and a more favorable impression of ads shot with a low "strong" camera angle; individuals asked questions related to nature prior to viewing ads had improved brand recall and more favorable impressions of ads shot with a high “natural” camera angle (Peracchio & Meyers-Levy, 2005). Thus, when individuals were primed for a certain trait, they had better memory and more positive feelings of the product when the camera angle also referenced that trait.

There is an important implication to this finding. The positive stylistic property intended by the designer (e.g., showing strength through low camera angles) may not be positively perceived by all viewers. Viewers who are not cued to perceive the image in the manner the designer intended may even view the message more negatively than if it had been designed differently. However, advertisers may be able to improve their chances of positive impact by considering the context in which ads are being placed. Priming experiments such as that by Peracchio and Meyers-Levy (2005) suggest that context will be an important component of heuristic processing.

Unlike participants undergoing high processing motivation, participants in low processing motivation are not adversely affected by the cognitive demand of an advertisement’s design (Meyers-Levy & Peracchio, 1995). In other words, while systematic processors could elicit a negative assessment if the cognitive supply and demand doesn’t match, this does not seem to be the case with heuristic processors. It could be argued that since heuristic processors are relying on more heuristic cues, the cognitive demand needed to fully comprehend the advertisement is irrelevant; heuristic processors are not paying attention to all the details anyway. Thus, for those allocating less cognitive resource to advertisement processing, color has been shown to result in more positive thoughts, fewer negative thoughts, and more favorable attitudes toward the advertised product (Meyers-Levy & Peracchio, 1995). Similarly, images shot low to produce an upward angle are positively viewed when cognitive processing is low or moderate (Meyers-Levy & Peracchio, 1992). Taken together, this suggests that once the stylistic properties of pictures are properly processed, they become important cues for heuristic processors.

Effects of Pictures on Low Cognitive Involvement (Experiential Processing)

It has been said that images are the surest route to the emotions (Barry, 1997), and that makes pictures a critical influencer during experiential processing. Experiential processing relies on serendipitous sensations or feelings to form judgments (Meyers-Levy & Malaviya, 1999). These are quick, low-effort decisions. The use of colors in advertising and marketing is an excellent example. Blue encourages people to browse and shop, red makes people eat faster, and green connotes freshness (Barry, 1997). There is little, if any, cognitive reason for this; people just “feel” like acting a particular way.

In many ways, experiential processing relies on a gestalt phenomenon. Max Wertheimer, who is credited with founding gestalt theory, explained gestalts this way:

> There are wholes, the behaviour of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole. It is the hope of Gestalt theory to determine the nature of such wholes. (Wertheimer, 1925/1967, p. 2)

Gestalt psychologists believe physiological or psychological phenomena do not occur through the summation of individual elements, but through gestalts. In other words, the whole is greater than the sum of the parts.

Gestalt psychology may be particularly applicable to experiential processing of advertisements. In advertising, "the way elements are combined to create a total effect or impression is more important than fact or rational logic" (Barry, 1997, p. 254). The individual elements in an advertisement when viewed separately and summed together do not elicit the same response as the advertisement in its entirety. Viewers tend to see external effects, like colors, lighting, camera angles, editing, etc., as internal attributes of the product or concept being pictured (Barry, 1997). These effects can be extremely powerful. Taste tests have shown that package design can improve or detract from a product's taste, and simple alterations to product packaging – color, shape, graphics – can increase sales by 25%, or more (Barry, 1997; Gladwell, 2005). It has also been shown that visual advertisement claims dominate inference formation when they differ from verbal claims (Smith, 1991). In other words, the feelings or beliefs elicited by an advertisement picture are stronger than the feeling or beliefs elicited by the advertisement text. People believe the message provided by the picture, even if it differs from the message provided by the text (Smith, 1991).

Experiential processing may also "piggyback" onto other types of processing. For example, someone engaged in systematic processing may become frustrated because he is not able to find the information he is interested in or become overwhelmed from too much information (resource-mismatch). He may allow these emotions to override his systematic processing and he may develop a negative connotation of the information based solely on this experiential processing. In education, this effect may be seen in students who have a bad experience with a particular subject and subsequently exhibit learned helplessness anytime they are faced with similar material.

Summary of the Integrative Framework

The three levels of the integrative framework provide a helpful model for understanding picture processing, because they help explain some of the variability seen in picture research. According to this framework, pictures will impact viewers differently depending on what type of processing they are engaged in. From the review above, we see three clear categories. (1) Systematic processors require simple, informational graphics that may be semantically processed and that meet their need for substantiary evidence. (2) Heuristic processors require colorful, stylish photographs closely associated with the message that provide plenty of cues for quick assessment of the product. (3) Experiential processors require emotionally evocative images that blend with the copy into a gestalt that resonates with the viewer.

While many of the studies cited above are advertising studies, it is important to note that the underlying principles are applicable to education as well. If information is created with the intent that it will be processed one way, a different type of processing will not result in maximum learning. For practical applications, the type of processing students are engaged in should be considered when developing instructional materials. Likewise, in experimental settings, the type of processing elicited by the experimental design should be considered.

Inherent in this discussion is also the factor of time. Because systematic processing requires the greatest investment of resources, it likewise will require the greatest amount of time. Individuals need time to gather relevant information and study it. At the other end of the spectrum, experiential processing occurs very quickly – an almost instinctive, reflexive reaction. The level of processing can therefore be manipulated somewhat by controlling time. Individuals given only a short time to learn material will have to identify the message quickly, while individuals given a longer time period may engage in more systematic processing. It may be expected that a student given less time to study information will used the pictures and text differently than a student given ample time to study. This variable of study time became an important component of the study presented here.

Pictures and Text in Learning

The frameworks discussed above provide a theoretical context for picture processing. For educators, however, the practical implications of these theories may hold even greater interest. As discussed, dual-coding theory suggests that pictures and text are processed and mentally stored separately. The integrated framework supports this idea of differential processing by showing how pictures and text take on different roles depending on how an individual engages with the material. The question follows, then, how does the differential processing of pictures and text impact student learning?

In the following sections, some of the more applied picture and text literature is briefly explored. Consideration is given to learning style theory as it relates to visual-verbal learning, which questions whether an individual’s learning style could impact their learning from pictures and text. This is followed with a brief look at the functional categories of pictures and text – some classifications showing how pictures and text are used in learning. Levels of learning and the effects of pictures and text on different levels of learning are then considered.

Learning Style Considerations

In addition to the type of processing an individual is engaged in, it has been suggested that learning style may impact how well individuals access and engage with information (e.g., Dunn, 2000). Learning styles have been studied since the 1800s, but it was not until the latter half of the 1900s that research shifted from trying to find the one best teaching method to finding ways to incorporate pedagogical techniques that appeal to multiple learning styles (Dunn & Dunn, 1975). Of particular interest to researchers investigating picture and text effects are the distinctions between visual and verbal learners. Although visual and verbal learning were some of the earliest aspects of learning styles to be studied (Dunn & Dunn, 1975; Paivio, 1971), the effects of these modalities on learning are still controversial and incompletely understood.

Visualizers are people with a predisposition for learning from visual material while verbalizers are people with a predisposition for learning from verbal or textual material (Mendelson & Thorson, 2004). Although some learning style theorists separate oral and written language (e.g., Dunn & Dunn, 1975; Reiff, 1992), the term verbalizer refers to both oral and written language. Visualizer refers to a preference for pictures, films, and objects. This classification is in agreement with the classification used by dual-coding theory (Paivio, 1971).

Historically, "verbal processes were emphasized while non-verbal imagery was almost totally ignored" (Paivio, 1971, p. 2). This tendency towards the verbal may be seen as persisting today within much of the educational system (Silverman, 2002). This creates difficulties for many learners. Between 33-50% of the population may be considered primarily visual-spatial, or what some refer to as "global" learners (Reiff, 1992; Silverman, 2002; Terregrossa & Englander, 2000). In contrast, 25-30% of students are auditory learners, 15% of students are tactile/kinesthetic learners, and 25-30% of students are mixed-modality learners (Barbe & Milone, 1980).

People's subjective measure of their learning style is a poor predictor of their performance on objective inventories and standardized learning tasks (Krätzig & Arbuthnott, 2006). Alternatively, more objective measures of a person's visual and verbal learning styles are needed. To this end, Mayer and Massa (2003) developed an instrument compiling 14 different measures commonly used to assess visual-verbal learning style. Their results indicated that these measures actually measure four different factors, which they labeled cognitive style, general achievement, learning preference, and spatial ability (Mayer & Massa, 2003).

General achievement is of least relevance to the present study, and utilized such tests as the SAT Mathematics and SAT Verbal tests. The division of other measures of visual-verbal learning style into three distinct categories, however, is an important consideration. This suggests that results may vary among studies because different tests generally believed to measure "visual-verbal learning style" are actually measuring three distinct components: cognitive style, learning preference, and spatial ability. Cognitive style refers to the "ways that people process and represent information," while learning preference refers to the "ways that people like information presented to them" (Mayer & Massa, 2003, p. 833). Spatial ability refers to someone's ability to mentally rotate objects. For example, the card rotation tests require a participant to be able to identify (from a series of choices) which pictured object is the same as another one that has been rotated.

While there are positive correlations between cognitive style, learning preference, and spatial ability, each emerged as a distinct factor during analysis (Mayer & Massa, 2003). While it is possible to assess a person's "complete" visual-verbal learning style by administering all 14 assessments (e.g., Massa & Mayer, 2006), most studies are interested in once aspect of the visual-verbal learning style. It is therefore important when assessing visual-verbal learning style to know which aspect of visual-verbal learning style is of interest, and to use an appropriate measure. For example, if research is interested in assessing how participants' process of information impacts results, then the cognitive style would be of most interest. The verbal-visual learning style rating was shown to be the strongest indicator of cognitive style (Mayer & Massa, 2003), and so this would be an appropriate measure for cognitive style.

Although most students learn with all their modalities or can switch from one to another for certain tasks (Davis, 1993), some students may have particular strengths and weaknesses. Learning style theory posits that individuals should learn best when the instructional material and learning environment match their learning style. While this theory makes intuitive sense, there is limited empirical evidence to support this theory with respect to modality.

It has been shown that in a hypermedia environment, individuals with different learning style preferences access and use materials differently. In one case, the learning style measure looked at field independence. Field-independence is a learning style measure based upon an individual's ability to recognize important details amid a field of distractions (Liu & Reed, 1994). This is related to the "global" learner referred to earlier, which is sometimes used interchangeably with visual-spatial learner because visual learners are generally more “right-brained” and process things in an integrated or global way (Reiff, 1992; Silverman, 2002; Terregrossa & Englander, 2000). Typically, field-independent individuals are more verbal and analytical, while field-dependent individuals approach problems more visually and globally (Liu & Reed, 1994). When given the option, field-independent individuals showed a preference for verbal content and field-dependent individuals showed a preference for visual content (Liu & Reed, 1994). Unfortunately, with no control group to establish base-line scores, this study did not test whether this preference actually explained test scores.

Other studies have shown that students did *not* learn better when their learning style preference matched the instructional modality. There was no correlation seen between students score on the visual, auditory, and kinesthetic Barsch Learning Style Inventory, and their performance on the respective visual, auditory, and kinesthetic task, even when the task was performed at their preferred time of day (Krätzig & Arbuthnott, 2006). Similarly, a series of three experiments with both college students and adults found no evidence that matching instructional materials to a verbal or visual learning style improved learning (Massa & Mayer, 2006).

On the other hand, effects of learning outside a formal classroom have been more pronounced. For example, Schofield and Kirby (1994) found that individuals with a high preference for the visual learning style were quicker at processing topographical maps. A person’s preference for verbal learning did not significantly predict his processing speed. Alternatively, a person’s level of verbalizing was the major predictor for recalling key facts in the text heavy newspaper environment (Mendelson & Thorson, 2004). In general, high verbalizers were more interested in newspaper stories and recalled more about both the stories and the photos than low verbalizers (Mendelson & Thorson, 2004). This was particularly true for high verbalizers who were also low visualizers. Presence of a photo reduced story recall for high verbalizers, but increased story recall for low verbalizers. Interestingly, presence of a photo had no effect on visualizers (Mendelson & Thorson, 2004). This effect of photos on visualizers is in contrast to results obtained by Chatterton (2006) who found that visualizers scored significantly higher on recall tests when reading a novel with pictures rather than without pictures.

Finally, it should be noted that in some instances, an unexpected and overarching effect of the visual has been found. While a “picture superiority effect” for memory has been substantiated in the literature (e.g., Paivio & Csapo, 1973; Standing, 1973), the effects of pictures on other levels of learning is less clear. Early research suggested analytical people performed better when a compatible pedagogy was used; however, more recent research has shown that most people perform better when provided with more visual-spatial learning material (Dunn, 2000). Additionally, both visualizers and verbalizers who had access to more information in picture format while reading a text outperformed those who had access to the same extra information in text format (Massa & Mayer, 2006).

Nearly fifteen years after Davis (1993) summarized the state of research on learning styles, her statement still rings true: “There is no consensus in the research about whether matching teaching methods to learning style increases learning” (p. 189). Many reasons may account for these disparate findings. Part of the difficulty may be in the measures used to assess the individual’s learning style. As discussed above, various measurement instruments have been shown to tap into different aspects of the visual and verbal learning styles; comparisons across studies and general conclusions may therefore be difficult.

As measurements become more accurate, researchers are also learning more about the relationships among different styles, which is changing the way learning styles are viewed. Although visualizers and verbalizers were once thought to be at opposite ends of a single continuum, more recent research suggests visual and verbal ability are independent characteristics (Kirby, Moore, & Schofield, 1988; Mendelson & Thorson, 2004; Paivio, 1971). For example, an individual may be both a high visualizer and a high verbalizer or both a low visualizer and a low verbalizer. In fact, empirical evidence substantiates this. Visualizing and verbalizing have been shown to be positively correlated ($r = .33$), suggesting that people who are high visualizers will tend to also be high verbalizers (Mendelson & Thorson, 2004).

Perhaps, as Dunn (2000) suggested, a comprehensive learning style that accounts for many factors beyond modality (e.g., environmental, emotional, sociological) are an essential component to improving student learning. Many of the inconclusive results on learning style modality may be a result of not accounting for these other factors. For example, if visual learners also tend to learn better in groups, with low light, with multiple breaks, and with intake, merely adjusting the verbal-visual component of the instruction may not be enough. A stronger modality effect may become more evident if other aspects of the individual's learning style are accommodated.

Taken together, these findings suggest that though individuals may have a preferred learning style and choose visual or verbal material when given the opportunity, actual performance does not always suffer if they are faced with methods incompatible with their preferred learning style. In fact, verbal learners may even exhibit improved performance when instructional techniques include visual components (Massa & Mayer, 2006). This is not to imply, however, that a person's visual-verbal learning style is irrelevant. Rather, more precise measures are needed to assess the qualities that compose this learning style.

To summarize, learning style research shows that providing information in a manner other than the learner's dominant verbal or visual style does not reduce test performance (Dunn, 2000; Krätzig & Arbuthnott, 2006; Massa & Mayer, 2006). However, research also shows that outside the classroom, learning style can dictate how quickly individuals process visuals and how well they can recall text (Chatterton, 2006; Mendelson & Thorson, 2004; Schofield & Kirby, 1994). Research is still needed to account for these discrepancies. In particular, Mendelson & Thorson (2004) noted that future research should examine a visual only environment to see if their findings are reversed. They suggested that a person's visualizer level might predict learning in a picture-only environment while the verbalizer level would make no difference. While a great deal of effort has been spent looking at the effect on learning of adding pictures to text passages (e.g., Carney & Levin, 2002; Massa & Mayer, 2006; Mayer, 1997) little attention has been paid to a visual-only environment. As previously mentioned, a shift away from the text-centric paradigm towards a greater emphasis on the visual may provide new insight into the literature on picture and text learning.

Categories of Pictures & Text

It is useful to both the educator and the researcher to consider the various uses of pictures and text within the learning environment. Understanding these different uses allows for a more precise understanding of the kind of picture and text combination being used in the classroom or in a research study. Two different classifications are presented here.

Levin's taxonomy of illustrations (Carney & Levin, 2002; Levin, 1989) provides a useful categorization of pictures that identifies the types of relationships between pictures and text. According to this taxonomy, the five functions of pictures include:

1. Decorational: decorate the page, but have little or no relationship to text
2. Representational: reiterate part or all of the text
3. Organizational: provide a structural framework for the text content, such as a diagram into which text is placed
4. Interpretational pictures: clarify difficult text, for example through analogy like illustrating the cardiovascular system as a pump
5. Transformational: systematic mnemonics used to improve recall.

Levin's taxonomy is primarily focused on the ways pictures can be utilized as a textual aid. This may be seen as the dominant paradigm within much of the picture and text literature, where the focus is largely on how pictures can improve textual understanding (e.g., Butcher, 2006; Levie & Lentz, 1982; Mayer & Gallini, 1990). Carney and Levin (2002) even stated "pictures are intended as text supplements rather than as text substitutes" (p. 9).

The bias towards the textual within picture and text relationships is reminiscent of the issue raised by learning styles theorists, who suggest the verbal style of teaching and learning is favored over other learning styles (Paivio, 1971; Silverman, 2002.) While studies within the "pictures assist text" paradigm provide valuable and practical insight into the use of pictures and text, they do not allow for the full relationship between pictures and text to be explored. Because the focus is primarily on how pictures and other visuals can assist textual learning, the full potential of pictures is left unexplored.

In contrast to this dominant paradigm, a categorization proposed by McCloud (1993) identified seven different relationships between words and pictures:

1. Word specific – pictures highlight certain words
2. Picture specific – words highlight certain pictures
3. Duo-specific – words and pictures contain same info
4. Additive – words add to pictures and pictures add to words
5. Parallel – don't seem to relate
6. Montage – words treated as part of the picture
7. Interdependent – whole is greater than the parts; convey a message neither could convey alone.

In his categorization, McCloud (1993) demonstrated a greater breadth of possible interactions between pictures and words than did Levin (1989; Carney & Levin, 2002). By acknowledging that pictures may at times be the dominant focus, the types of questions that can be asked about the relationship between pictures and text expands. As a researcher shifts away from the text-centric paradigm, it becomes possible to investigate the learning potential of pictures on their own merit. Research surrounding the learning potential of pictures and text is discussed next, beginning with a discussion of the various levels of learning.

Levels of Learning and Picture and Text Effects

In 1956, Bloom and his colleagues published the *Taxonomy of Educational Objectives, The Classification of Educational Goals, Handbook I: Cognitive Domain* (Bloom, Engelhart, Furst, Hill, & Krathwohl, 1956). The volume resulted from the efforts of 34 participants who met through a series of annual conference between 1949 and 1953 (Bloom et al., 1956). Originally intended to assist university examiners, Bloom's *Taxonomy* has become one of the most influential frameworks to be implemented by curriculum planners, administrators, researchers, and teachers at all levels of education (Anderson & Sosniak, 1994; Bloom, 1994).

For purposes of the present discussion, Bloom's *Taxonomy* is particularly relevant to the distinction between the various levels of picture learning. The *Taxonomy* divides the cognitive domain of learning into six major classes arranged hierarchically (Bloom et al., 1956):

1. **Knowledge:** remembering, either by recognition or recall, an idea or phenomenon in a form very close to that in which it was originally encountered (p. 28-29, 62)
2. **Comprehension:** objectives, behaviors, or responses which represent an understanding of the literal message contained in a communication (p. 89)

3. **Application:** the ability to apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation (p. 120)
4. **Analysis:** ability to break down the material into its constituent parts and detect the relationships and organization of the parts (p. 144)
5. **Synthesis:** putting together the elements or parts to form a whole structure not clearly there before (p. 162)
6. **Evaluation:** making judgments about the value of ideas, works, solutions, methods, material, etc. (p. 185)

As with any widely cited conceptualization, Bloom's taxonomy is not without its revisions. Krathwohl (2002), for example, recommended the terms remember, understand and create rather than knowledge, comprehension, and synthesis, and suggested a reorganization such that Evaluate appears before Create (Synthesis). Such changes, however, are largely semantic, and the wide acceptance of Bloom's *Taxonomy* over the last 50 years is a testament to its robustness. Since the original intent of the *Taxonomy* was to provide a pragmatic framework that would facilitate communication (Bloom et al., 1956, p. 10), such alterations are not only seen as acceptable, but are encouraged. In a reflection of their work, one of the co-authors noted, "Our experience with the *Taxonomy* suggests that the framework has been most useful as it is extended and/or modified to fit the purposes for which it is being used" (Krathwohl, 1994).

In this spirit, Bloom's *Taxonomy* provides an excellent framework upon which to tease apart the various levels of learning that may occur with pictures. The first three levels of learning as they relate to visual and verbal learning are briefly examined below.

Picture and Text Effects at the First Level – Knowledge/Remember

The literature is replete with studies looking at the effects of pictures on memory. A bibliography of picture-memory studies compiled by Standing, Bond, Hall, and Weller (1972) shows picture-memory studies dating back to the 1890s. There is even one text, by Gregor von Feinagle, published in 1813. Such a compilation clearly indicates that interest in picture memory is not new. Nor is this interest simply a matter of historical fortitude. In 1985, Kobayashi updated Standing et al.'s bibliography, bringing the total number of known picture memory studies to 1,388. In the twenty-one years since this updated bibliography was published, numerous other studies and reviews have made their way into the literature base.

The work involving pictures and memory fits easily within the first level of Bloom's *Taxonomy*. This literature is based largely on recall or recognition tasks, the definition employed by Bloom and his compatriots to explain the term "Knowledge." In fact, Krathwohl (1994) felt the term "remember" better reflected the nature of this first level.

Memory for pictures has consistently been shown to be superior to memory for words. In a hallmark examination of picture memory capacity, Standing (1973) showed that memory capacity for vivid pictures is almost limitless. In one experiment, participants were randomly assigned to study groups that were shown words, pictures, or vivid pictures (visually remarkable, such as a dog with a pipe in its mouth). Participants were shown either 20, 40, 100, 200, 400, or 1000 stimuli and were tested on 20, 40, or 80 forced recognition pairs (one new, one old) of the same modality as the study condition. Picture memory was consistently superior to word memory, as participants recognized pictures more frequently than words across all six group sizes (Standing, 1973). For 100 stimuli, word recognition was only 70%, while picture recognition was 90% and vivid picture recognition was 96%. For 1000 stimuli, word recognition dropped to 62% while picture recognition was 77% and vivid pictures was 88%. To test the upper limits of visual memory, an additional group was shown 10,000 pictures over several days and given a forced recognition of 160 pictures. Participants still correctly recognized the previously seen picture 66% of the time (Standing, 1973), showing an amazing capacity for visual memory.

Standing (1973) expanded upon this study and found similarly convincing results. When participants had to recognize the picture out of 32 alternatives shown sequentially, the same picture superiority results were obtained. Out of 100 words or picture stimuli, mean recognition rates were 66.5% for words and 90.1% for pictures. If anything, having a larger pool hindered word recognition even more than picture recognition. Likewise, when participants performed a free recall of 200 stimuli, they recalled 88% of pictures but only 67% of visual and 71% of auditory words. Standing (1973) concluded that "pictorial superiority appears to be a robust phenomenon that is found under a wide variety of experimental tasks" (p. 219). This term "picture superiority effect" was adapted in the early memory studies to refer to an individual's ability to remember pictures better than text (e.g., Paivio & Csapo, 1973; Standing, 1973; Standing & Smith, 1975). The term is still referenced in more recent literature (e.g., Weldon & Coyote, 1996).

Dual-coding theory has been used to explain this phenomenon. Pictures arouse both representational and referential connections resulting in both a concrete memory representation and a verbal label (Paivio, 1971). For example, when a student views a picture of a dog, they store that exact image in their memory as a representational connection. But, they also create a verbal tag, "dog," to describe the image and this is stored as a referential connection in the verbal system. Thus, an image evokes memory storage in both the verbal and nonverbal symbolic systems. This "dual-coding" is credited with producing the superior memory for pictures.

Since the early memory studies first uncovered the picture superiority effect, additional empirical research has uncovered some practical applications of picture and text memory. For example, pictures have been shown to be attention-getting within the newspaper environment. This is particularly true for large, emotional, close-cropped, or multiple pictures (Garcia & Stark, 1991; Gibson, 1979; Gibson & Zillman, 2000; Zillman et al., 2001). In some cases, pictures may also be used to draw attention to nearby copy. When images are thematically similar to the accompanying text, there is improved recall of information presented in the text, even when some information present in the text is not present in the picture (Levin, 1989; Wanta & Roark, 1993). Representational pictures (pictures that reiterate information presented in the text) have also been shown to aid in information recall (Edell & Staelin, 1983).

Similarly, people remember advertisements longer if they contain representational pictures rather than just words (Childers & Houston, 1984). Viewers also recall advertisements better if the brand, copy, and picture are all related, but when only two elements are present, related pictures improve recall over related text (Schmitt, Tavassoli, & Millard, 1993). In other words, people remember an advertisement better when the brand is illustrated with a picture than with text. This is particularly true if the picture and the brand name are shown interacting in some way (Childers & Houston, 1984). The importance of this interaction between words and pictures is also seen elsewhere. In education, paired associated learning, where two images are visually connected to improve recall, is an extremely effective mnemonic that has been shown to improve both recall and transfer (Levin, 1989; Levin & Levin, 1990).

Taken together, such empirical evidence suggests that adding representational pictures to text can improve memory of the presented message. Using the associative network model and dual-coding theory as a theoretical foundation, this increased recall for picture and text combinations makes sense. Information presented in picture and text form will be processed and stored separately, but the information will be connected (Paivio, 1971). Thus, not only is the information processed and stored twice, once in visual form and once in verbal form, but the storage units are also referentially connected. By triggering these networks of related information in the brain, representational pictures may excite more neural pathways and improve recall (Edell & Staelin, 1983).

An early study illustrated this visual-verbal connection. Participants who looked at a picture of an eagle sitting in a tree immediately after seeing the sentence “The bird was perched atop the tree” later believed the statement had been “An eagle was perched atop the tree” (Pezdek, 1977). Thus, messages portrayed in pictorial form can blend with messages portrayed in text form, giving educators the opportunity to blend images and text into a single coherent memory with multiple neural pathways for their students.

The advantage of multiple neural pathways can be taken one step further for visual information. The richness of an image itself provides multiple cues that can serve as aids to memory retrieval (Childers & Houston, 1984). Even though the focus of a picture may be on a particular subject, aspects of the scene may also be stored and associated with prior memories. This increases the mental network and makes it more likely that the image will be recalled. In fact, pictures have been shown to be superior to semantically similar words in creating multiple inferences (McQuarrie & Phillips, 2005).

While the review thus far has shown the powerful potential of utilizing pictures to aid memory, several important caveats are important to note. When trying to improve recall of accompanying text, both the syntactic and semantic qualities of the picture must be considered. When improperly used, pictures may actually inhibit message recall by detracting from the accompanying message (Lee & Ang, 2003; Wanta & Roark, 1993). Studies in cognitive psychology have also shown that looking at unrelated pictures before text can suppress the recall of the text (Boesch & Standing, 1990). Every article cited above that showed a positive memory enhancement from pictures employed what Levin (1989, Carney & Levin, 2002) would classify as a representational picture or interpretational picture. The visual was related to the text and portrayed some of the same information as that presented in the text.

Along with relevancy, other aspects of effective pictures have been studied. It has been shown that unexpected but relevant pictures result in the highest level of message recall (Lee & Ang, 2003). Emotional photographs in particular draw readers to accompanying text. Zillman and his colleagues (2001) note, "Those trapped by [a photograph] should want to know the rest of what happened" (p. 306). It may be possible to pique someone's interest with a photograph and provide the "explanation" in the copy. This need to investigate emotional photos seems to be deep-rooted. Shoemaker (1996) argues that people's interest in bad news is genetically programmed. She draws on

Lasswell's (1948) work to suggest that humans monitor their environment in the interest of self preservation. It follows that emotionally arousing photographs are particularly eye-catching. People want to know what the danger is in case they need to protect themselves.

However, using an eye-catching photo that is less relevant to the accompanying text may be detrimental. If the implications of the picture superiority effect (Standing, 1973) are considered, it would follow that because pictures are remembered better than text, text memory could be suppressed in a picture vs. text environment. Indeed, pictures have been cited as inhibiting information processing by drawing attention to themselves at the detriment of accompanying text (Wanta & Roark, 1993). This inhibition is even stronger when the image agrees with some text, but not others. For example, Lee and Ang (2003) used pictures that were similar to one claim in an advertising message, but different than a second claim. As would be predicted by the additive effect of dual-coding theory, participants were better able to recall the message which the picture emphasized than the message which the picture did not emphasize. If a more neutral picture that did not specifically emphasize either message was used, recall of the second message improved (Lee & Ang, 2003).

Readers also appear aware of the intent of the photograph. While photographs have been shown to be the most common points of entry for newspaper stories, photographs within newspaper advertisements were never the point of entry into a page and were frequently ignored altogether (Garcia & Stark, 1991).

From these results, it appears that the ideal photo to maximize retention of the overall message would be an eye-catching, unexpected photo that is relevant to the accompanying text. Expectancy is the “degree to which an item or a piece of information falls into some predetermined pattern or structure” (Heckler & Childers, 1992, p. 477). Relevancy refers to the degree to which an item or a piece of information contributes to the identification of the primary message communicated in the advertisement (Heckler & Childers, 1992). Thus, a relevant, unexpected photo is one that reiterates the concepts presented in the text, but is presented in a less conventional manner. This idea has been substantiated. It was found that unexpected, relevant pictures result in the highest level of message recall (Lee & Ang, 2003). Of particular interest, unexpected-irrelevant pictures were the most remembered pictures, but they reduced recall of the accompanying advertising message (Lee & Ang, 2003). In other words, people remember an unexpected, irrelevant picture, but they probably won’t remember the point the communication was trying to make.

To summarize, the “picture superiority effect” seen in memory studies indicates that memory for pictures far outperforms memory for text (e.g., Paivio & Csapo, 1973; Standing, 1973; Standing & Smith, 1975). Additional empirical work has shown that when properly used, pictures can also improve recall of accompanying text. Questions remain, however, whether similar results are obtainable for higher levels of learning such as comprehension and transfer. Linn and Eylong (2006) note that “recall is not sufficient for solving complex problems” (p. 519). Thus, the picture superiority effect seen at the level of memory cannot be applied to comprehension and transfer without substantiating evidence. The role of pictures in comprehension and transfer is explored in the following sections.

Picture and Text Effects at the Second Level – Comprehension/Understanding

Unlike the picture memory studies discussed in the previous section that directly compared an individual's memory of pictures with their memory of text, no known study has directly investigated an individual's understanding of a picture versus their understanding of equivalent text. Instead, much of the research at this level of learning focuses on comparing picture and text combinations with text alone.

For young children, the use of pictures in picture books to teach learning has been intensely studied. In their review, Carney and Levin (2002) noted that the influence of pictures on young children's ability to gain reading skills has received mixed reviews, with some researchers suggesting that pictures interfere with learning to read and others suggesting the benefits (motivating the child to read, promoting creativity, providing mental scaffolds, etc.) far outweigh any potential negative interference.

For older students, research suggests that adding pictures to text improves learner comprehension. In one recent study, participants learned about the heart and circulatory system from text only, text with simplified diagrams, or text with detailed diagrams (Butcher, 2006). Participants' understanding was assessed by having them draw and explain a model of the heart and its blood flow and then answer multiple choice questions. Results indicate that adding either type of diagram to the text improved the participants' ability to draw and explain their model of the heart, regardless of their prior knowledge. However, students who learned using the simple diagram outperformed both the text-only and the text with detailed diagram treatments on the multiple choice test (Butcher, 2006).

The role of "mental pictures" has also been considered in assessing learning. Students who were asked to draw their own pictures outperformed students who were asked to paraphrase the study material (Alesandrini, 1981). The effect size was small, however, accounting for less than 2% of the variability in test scores, and the author noted that science learning may be better with provided pictures rather than learner-generated pictures (Alesandrini, 1981).

It has also been suggested that learners with high domain knowledge are able to construct a mental model without pictorial support (Mayer, 1997). While this may be true, other research has shown that performance on a multiple choice knowledge test and on an assessment where participants were asked to draw and explain the circulatory system was improved for both low and high knowledge students by adding diagrams to the study material (Butcher, 2006). This suggests that even if students are able to construct a mental model from text alone, the concrete visual may still be beneficial. Although it is possible to create a mental visual from a passage of text, a physical rather than a mental picture may better aid understanding by providing a concrete representation which students can refer back to (Paivio, 2007). Similar predictions regarding a student's ability to create verbal representations from visual materials and how this ability may impact learning are not as evident in the literature.

Despite the apparent benefits of added pictures to aid understanding of textual passages, some researchers have suggested that students frequently do not take advantage of the benefits of the pictures. For example, pictures may be viewed as "easy" material and may be examined only superficially by learners. Weidenmann (1989) noted "Pictures are susceptible to being undervaluated…because the subjective ease of encoding them at a superficial level may lead the learner to the illusion of a full understanding" (p. 163). As discussed under the section on dual-coding theory, pictures are processed spatially, while text is processed sequentially (Paivio, 1971). Weidenmann (1989) was suggesting that by the very nature of this processing, a fuller semantic meaning may be extracted from text, while only a more syntactic visual representation is encoded for the picture.

To correct this undervaluation of pictures, explicit instructions can be provided to encourage students to undergo a more substantial processing of the pictures. For example, when students were told to notice certain features about pictures, they scored 35% higher on learning tests than those who viewed the same materials without instruction (Weidenmann, 1989). Similar benefits of adding text to images has been seen in advertising. As discussed previously, when advertisement copy was compatible with the stylistic properties of an image, viewers noticed the stylistic properties, thereby receiving a fuller message than those who did not ascertain these properties (Peracchio & Meyers-Levy, 2005).

The explicit instruction or textual cues used in these experiments may be viewed as analogous to scaffolding techniques. Scaffolding techniques have been shown to support student motivation to engage in learning opportunities that they might not on their own (Perry, Turner, & Meyer, 2006).

It is also possible that some complex pictures and diagrams may be perceived as too time consuming to process, and so are skipped over. Indeed, pictures have been shown to be less effective at aiding learning when the information is abstract rather than concrete (David, 1998). However, pictures illustrating the usage of abstract words (e.g., accept vs. except) were shown to be more beneficial than usage rules for teaching college students the correct usage, both on a test where they had to describe the rules of usage and on a test where they had to generate proper usage examples (Igo, Kiewra, Bruning, 2004). This shows that when used inventively, pictures can benefit even less concrete information.

It has also been shown that as textual content becomes more difficult, learners will look at adjacent visual displays more frequently (Carney & Levin, 2002). Unfortunately, because the educational system places a greater emphasis on textual reading and oral lectures than on visual learning (Paivio, 1971; Silverman, 2002), students may not be learning the skills they need to truly understand information presented in visual form. There is evidence for this in the literature. Peeck (1993) has suggested that students will not process pictures more deeply if they are simply told to "pay more attention" to them. Instead, explicit instructions, cues, or activities are needed. The use of "contrasting cases" may be one way to encourage students to notice important aspects of pictures. Contrasting cases encourage students to compare and contrast items, thereby extracting the key similarities and differences of the items. For example, Bransford and McCarrell (1974) used contrasting cases of scissors to teach students the relationship between how a pair of scissors looks and what it is used for. A similar comparison among pictures may encourage deeper processing of them. Indeed, the study cited above did not simply tell students to pay more attention to the photos. Instead, students compared and contrasted the way photos presented a message, and this resulted in an increase in learning of the picture's message (Weidenmann, 1989).

The emotional value of information presented in pictures should also be considered. Paivio and Steeves (1967) found that the strength of the connections between words and images is positively correlated with their relevance to a person's interests and values. In other words, the more strongly someone feels about a given topic, the more interconnected that person's mental storage of related text and images is. It has also been shown that participants are more likely to notice problems in a research study when the study is inconsistent with their beliefs, or they may misinterpret relationships between variables if they have preconceived notions (Shah & Hoeffner, 2002). This has implications for picture understanding, since a given picture may be strongly or weakly connected to other mental representations, such as information gathered from text books or lectures, depending on how strongly the person feels about the topic. In short, the more relevant a person feels a pictured topic is, the more mental connections that person will have and the better that person will be able to understand the meaning behind the picture.

As a subset of visual literacy, graph comprehension has also received some attention in the literature. In a review of graph comprehension research, Shah and Hoeffner (2002) offered some suggestions for improving graph understanding. Graphs should always be plotted to make the most important comparisons or data the most salient. For example, students were better able to draw conclusions about population changes when the data were drawn with line graphs showing trends rather than as bar graphs (Shah & Hoeffner, 2002). While line graphs emphasize x-y trends, bar graphs emphasize discrete comparisons. Shah and Hoeffner (2002) also suggested that when using bar graphs, vertically oriented bars are better for quantities while horizontal bars are better for distances. Bar graphs should not be 3-dimensional, as this extra element distracts the reader from the main data. Tables are better for people to get precise point values, but graphs offer more relational data, so the more important point should be considered when deciding which format to use (Shah & Hoeffner, 2002).

Using labels rather than legends helps reduce the load on working memory, making it quicker and easier for readers to interpret the various lines in the graph (Shah & Hoeffner, 2002). The use of labels in other types of pictures has also been explored. The International Pictogram Standard suggests a message or sign legend directly under or to the side of the pictogram can be helpful in improving understanding (Pierce, 1996). Such textual explanation may become even more important when pictures become more complex or abstract. Comments from participants in an unpublished study (Beagle, 2006) on learning from pictures suggest that individuals are not always able to interpret or understand a picture until a textual explanation is provided. Sixty-seven percent of participants who studied pictures with minimal text explanation noted that it was not always clear what information the pictures were trying to portray. One typical participant in the study commented, “I wasn’t sure of what some of the [pictures] were really showing until I read the description in the questionnaire” (Beagle, 2006).

Similar misunderstandings of pictorial content have been seen when news photographs influence a reader’s perception of a topic above and beyond, or even in contrast, to the accompanying text. For example, Zillman, Gibson, and Sargent (1999) had participants assess the economic status of farmers and the safety of amusement parks after reading articles that contained either no image, a positive image, a negative image, or both images. Even though the accompanying text was the same, results showed that positive images evoked a positive assessment and negative images evoked a negative assessment (Zillman et al., 1999).

Gibson and Zillman (2000) also noted that photographs showing disease victims of particular ethnic groups resulted in increased perceptions of risks to those groups even though no textual information suggested that any particular ethnic groups was at greater risk. The result was a miscommunication where the intended message was unduly influenced by the accompanying pictures.

Clearly the "story" which a picture portrays is not something to be taken lightly. As discussed under the section on memory, representational pictures can improve recall of the message. However, additional care must be taken that the remembered message is indeed the intended message. Inappropriately used pictures may unduly influence the reader's understanding of the message.

While the research discussed above has wonderful applications to education, there is a definite need to expand the base of research to include direct comparisons between pictures and text at this level of learning. Until we understand how well individuals can comprehend pictures alone, we will never be able to maximize the learning potential of instructional materials. Research suggests that assessing and improving visual literacy holds great promise for maximizing this learning potential.

Picture and Text Effects at the Third Level – Application

To assess learning at the level of application, researchers frequently will implement transfer tasks. Salomon and Perkins (1989) made some interesting mechanistic distinctions regarding transfer. As a rough definition, they distinguish transfer from memory or understanding in relation to the context. If the context of a future performance is different than the context of the learning instance, then the learning can be said to have occurred at the level of transfer (Salomon & Perkins, 1989). Unfortunately, this definition leaves plenty of room for interpretation of what constitutes a "different" learning context, and the authors acknowledge this grey area.

By focusing on how transfer occurs, these authors also distinguished between "low-road transfer," which they defined as the "spontaneous, automatic transfer of highly practiced skills" and "high-road transfer," which they defined as the "explicit, conscious formulation of abstraction in one situation that allows making a connection to another" (Salomon & Perkins, 1989, p. 118). High-road transfer was then further broken down into (1) forward-reaching transfer which occurs when a general formulation occurs initially and finds new application spontaneously later; and (2) backward-reaching transfer which occurs when someone deliberately searches their existing mental knowledge base to address a present activity or problem (Salomon & Perkins, 1989).

Transfer can vary in other ways as well. A brief review of the literature reveals several different categories based on "what" is transferred. Among these are analogical transfer, representational transfer, content transfer, and modality transfer. Analogical transfer is concerned with the transfer of an abstract schema from one situation to another (Gick & Holyoak, 1983), while representational transfers involve conceptual or methodological transfers such as diagrams (Novick, 1990). The category referred to here as content transfer involves the application of learned content to new scenarios or novel problems. Modality transfer follows from dual-coding theory (Paivio, 1971; 2007) and is the transfer from one modality to another, specifically, from the verbal to the visual modality and vice versa. Each of these categories as they relate to visual and verbal learning is briefly discussed in turn.

Analogical transfer. In their work on analogical transfer, Gick and Holyoak (1983) noted:

> To make the novel seem familiar by relating it to prior knowledge, to make the familiar seem strange by viewing it from a new perspective – these are fundamental aspects of human intelligence that depend on the ability to reason by analogy. (p. 1-2)

The ability to reason by analogy is considered to be a sign of higher learning because analogies require the attributes of "application" as defined by Bloom and his compatriots: the ability to apply the appropriate abstraction without having to be prompted as to which abstraction is correct or without having to be shown how to use it in that situation (Bloom et al., 1956). However, Pedone et al., (2001) noted that relatively little work has explored the use of visual analogies.

Analogical transfer tasks typically involve a "source" story or diagram which study participants are given to read or look at. Participants are then given a different but analogous problem to solve. The percentage of participants who correctly solve the problem on their own are said to have "spontaneously noticed and retrieved" the analog (Pedone et al., 2001). Students are then told to consider the story or picture they just read, and any additional correct answers are recorded as transfer that occurred after the cue.

Several mental processes are needed to successfully complete an analogical transfer task. Participants need to (1) retrieve the source, (2) notice the source's relevance to the target problem, (3) compare the analog to identify relational overlaps, and (4) construct the analogous solution (Pedone et al., 2001). A breakdown in any one of these steps would prevent the respondent from correctly solving the transfer task. Current measurements divide these stages into two major categories – those that can successfully complete all four stages, and those that can complete steps three and four when a hint has been given to carry the participant through steps one and two. Unfortunately, these methods have no way of measuring those individuals who can complete steps one and two without a hint, but are unable to complete steps three and four. These methods also do not measure failure at any one particular step.

A predominant analogical transfer problem is the radiation problem introduced by Duncker (1945). This was used in all of the studies to be discussed here. In this problem, a doctor is attempting to kill a tumor with radiation; the high intensity ray will kill the tumor but also kill the patient, while the low intensity ray will not harm the patient but also not kill the tumor. The solution may be found in a convergence schema: if many low frequency rays are aimed at the tumor from different angles, they will pass through the patient's body as harmless low-frequency rays, but converge into a high frequency ray that kills the tumor.

Perhaps one of the most striking results found among these analogical transfer studies is the role of pictures. When diagrams were used as the source, they were not spontaneously noticed and participants were unable to solve the radiation problem. However, once a hint to use the previously seen diagram was given, participants were able to solve the problem (Gick & Holyoak, 1983). In a separate experiment, diagrams included with two analogs increased the percentage of spontaneous and total solutions compared to conditions that received only the two analogs as a source (Gick & Holyoak, 1983).

One explanation for these findings may be found in the idea stated earlier regarding the undervaluation of pictures and the lack of deeper picture comprehension until a verbal directive or context is provided (Beagle, 2006; Peracchio & Meyers-Levy, 2005; Weidenmann, 1989). The relevance or meaning of the picture may not be appreciated until participants are directed to consider it. In the case of Gick and Holyoak (1983), once participants were given one or two analogs to provide context for the diagram, they were able to understand and apply the picture. This idea has also been stated more succinctly by others: "One general possibility is that without any semantic interpretation, the diagrams are not encoded in terms of concepts that could potentially link them to the verbal target problem" (Pedone et al., 2001).

To address this possibility, Pedone et al. (2001) set out to explicitly test the perceptual properties of diagrams on their effectiveness in analogical problem solving. A previous study by Beveridge and Parkins (1987) found that a visual representation using transparent blue strips hinged at one end that slowly fanned out to show the convergence principle spontaneously generated the correct solution in 95% of the participants. This is nearly double that seen in many of the previous experiments using pictures and/or text as the source (e.g., Gick, 1985; Gick & Holyoak, 1980, 1983). Those results encouraged Pedone et al. (2001) to examine various manipulations of the source diagram.

In a series of experiments, it was found that multiple diagrams showing a sequence of arrows splitting from a single line of arrows to multiple converging arrows did not have any effect on participants' ability to solve the transfer problem (Pedone et al., 2001). However, animation of these same diagrams to show movement of the arrows more than tripled the number of participants who correctly solved the problem prior to the hint compared to the static diagram (55% vs. 15%; Pedone et al., 2001). This percentage approximates that found for a text-based source (e.g., Gick & Holyoak, 1983) and for a static diagram plus a written principle (Pedone et al., 2001) in other studies. Thus, while a picture superiority effect was still not seen, the picture effects were at least equivalent to those seen with text. Like the visual used by Beveridge and Parkins (1987), the animation may have improved semantic encoding of the diagram, allowing participants to better access the source and notice its relevance to the target problem.

In combination with some of the previous discussion on picture comprehension, these analogical transfer studies suggest there is a lack of spontaneous comprehension of some visuals, even when the visual is related to the text. However, once deeper processing of the visual is encouraged either through verbal cues or manipulation of the visual, comprehension of the visual is strengthened and the abstracted principle is transferable to new problems. These studies also support some of the indications discussed under dual-coding theory that verbal representations may be more general and more easily abstracted (and thus more easily transferred) than visual representations.

Representational transfer. This type of transfer is more concerned with a highly abstract but visual representation of information. Representational transfer may be defined as a transfer "in which the primary goal is transfer of a representation in the absence of a common solution procedure" (Novick, 1990). In other words, representational transfer is a "higher level" transfer in which general concepts or a methodological framework is transferred, but the procedures for how to utilize the concept or framework is not. For example, one may transfer a diagrammatic template such as a matrix, a path diagram or network, or a hierarchical tree (Novick & Hurley, 2001).

These representational diagrams are a more conceptual rather than content-driven form of picture. The manner in which one actually uses these templates will vary widely between the source and the target problem, since the framework is merely a structure under which to organize relevant information. For example, informational graphics such as graphs, charts, and tables offer a more visual way to present numerical data. These graphics help reveal data patterns that may otherwise be undetected, help readers view and interpret numerical information, and are effective at attracting and holding people's attention (Lipkus & Hollands, 1999). It has also been shown that tables increase the speed with which readers can acquire information (Peterson, 1983). It may be beneficial, then, to use this type of graphical organization when trying to solve a target problem. In representational transfer, neither the content of the graphic nor the process used to solve the problem is transferred. Instead, only the structure, e.g., the matrix, is transferred. Appropriate information is then inserted into the transferred "template" and this organizational structure is used to solve the target problem. Such representational transfer has been shown to spontaneously occur, even in the absence of a common solution procedure (Novick, 1990).

Representational transfer adds new meaning to traditional transfer problems. Representational transfer relies upon a framework which may be used to push into uncharted territories and solve new problems. This type of transfer is an application of the physical framework rather than the concept or the content – e.g., What other ways can this diagram be used? This more general transfer opens up new venues for visual usage, because by their very nature, these diagrammatic transfers are visual-based.

Problem solving/Content transfer. While the previously described types of transfer provide valuable insight into visual and verbal learning, the category of application tests referred to here as content transfers are the most directly integrated with the present study. As such, some space is devoted here to exploring a few of the more salient studies involving this type of transfer, as well as discussing some of the underlying mental processes that are involved.

As used here, content transfer is concerned with students' abilities to answer novel questions based on the information they received. This could include applying content to new scenarios or solving unique problems. Problem solving requires a level of learning beyond simple recall of the facts presented (Mayer, 1997), and even beyond a direct understanding of the facts presented; instead, learners must assimilate the information in a manner that allows them to answer questions for which the answer is not directly provided.

Research suggests that only representational connections (those between the object and its mental representation) are necessary for recall, but both representational and referential connections (those between two mental representations of different modalities) are important for problem solving (Mayer & Sims, 1994). A contiguity effect has also been noted, where narration and animation presented together or text and pictures presented together allow for greater referential connections than if the narration and animation are presented sequentially or the text and pictures are on separate pages (Mayer, 1997; Mayer & Anderson, 1991).

However, this contiguity effect appears to be true only when the learner has low prior knowledge for the subject. In a series of three experiments, Mayer and Gallini (1990) explored the conditions under which creative problem solving could be improved by adding interpretational pictures to text. They used what they called explanatory illustrations, or illustrations that indicated cause-and-effect, of a braking and pump system. In addition to a recall and recognition component, students had to answer questions not directly supplied in the content they had reviewed. The study found that pictures had the greatest impact on problem solving when the following four conditions were met:

1. Text explains and describes a cause-and-effect system
2. Illustrations explain the cause and effect of the system rather than just labeling parts of the system
3. Learners lack prior knowledge
4. Tests measure conceptual understanding.

Mayer and Sims (1994) built upon this study to find that the contiguity effect was strongest for students with high spatial ability. The authors reason that even when low-spatial ability learners are given coordinated instruction that should allow them to build referential connections, they are spending their cognitive resources on maintaining representational connections in working memory and are unable to devote the necessary resources to build referential connections. High spatial ability learners, on the other hand, have an easier time building the representational connections and are able to devote more resources towards referential connections (Mayer & Sims, 1994).

It is interesting to note that when compared to sequential animation and narration, simultaneous animation and narration improved problem solving but not recall (Mayer & Anderson, 1991; Mayer & Sims, 1994). In other words, the contiguity effect was helpful for transfer but was not helpful for memory. Participants were apparently able to build similar representational connections regardless of whether the information was presented concurrently or sequentially, but were better able to build the referential connections needed for transfer when the information was presented concurrently.

Similar results have been found where recall is better if participants focus on trying to remember stories, but transfer is better if participants focus on trying to explain the stories' solutions (Needham & Begg, 1991). The authors noted that there are apparently different laws underlying memory and transfer (Needham & Begg, 1991). This distinction of learning level and the possible explanation found in the underlying mental processes is important, and deserves continued elucidation in future research.

In addition to adding representational or interpretational pictures to text, mnemonics, or what Levin (1989) refers to as transformational pictures, have also been used to improve content transfer. In a series of plant biology experiments, mnemonics were shown to outperform a free-study group in classifying a novel specimen and in completing a series of comparisons that required an understanding and application of the hierarchical relationship of taxonomy (Levin & Levin, 1990). Combinations of matrix structures and mnemonic illustrations (called a "mnematrix" by the authors) have also been used to help students remember, organize, and compare types of fish in order to make predictions about a new type of fish (Atkinson et al., 1999). These studies suggest that mnemonic techniques have value for higher levels of learning beyond memory.

The cognitive load and the presence of extraneous detail within the instructional materials also must be considered. When narrated text was also visually shown on screen during an animation, students were able to come up with fewer creative problem solutions than when they received only the narration and animation (Mayer et al., 2001). The authors refer to this as a redundancy effect, suggesting the redundant visual text adds unnecessary cognitive load and detracts from a student's ability to process the animation within the visual system.

In addition to this redundancy effect, supplying students with extraneous detail has also been shown to be detrimental to problem solving. In a series of experiments where students read about lightning and had to answer problem-solving questions, results indicated that adding text passages to captioned pictures did not improve problem solving ability (Mayer et al., 1996). In fact, adding longer text to the captioned pictures reduced students' abilities to solve problems, which the authors suggest could be because the extra text reduced students' abilities to identify the key elements from the text and effectively blend them with the pictures (Mayer et al., 1996).

Similar effects have been seen in other studies. In a study where students learned about the circulatory system from text with simple diagrams or text with detailed diagrams, no difference in inference ability was found; but, the author noted participants who studied detailed diagrams "often appeared to be confused about what they had learned and about how to revise their mental models" (Butcher, 2006, p. 188). Similar to the suggestion made by Mayer et al. (1996), it is possible that more complex diagrams could be harder to identify the key elements necessary to apply to new situations and draw appropriate inferences.

Problems with extraneous detail have also been encountered with animations. When interesting but less critical details were added to an animated lesson about lightning, in text form or as short video clips, students had a reduced ability to solve the transfer problems – especially when the details were shown before or during the main instruction (Mayer et al., 2001). This is reminiscent of results in mass communication where images occasionally cause a suppression in learning by drawing attention to themselves and away from the accompanying text (Lee & Ang, 2003; Wanta & Roark, 1993). Further research is needed to assess the level of detail to present in pictures and/or text to optimize problem-solving.

Since picture processing requires less space in working memory than text processing (Schnotz, 2002), it may be possible that greater emphasis on quality pictures could maximize transfer without overloading cognitive resources. A greater emphasis on visuals may also allow more cognitive resources to be allocated towards making referential connections to prior knowledge. On the other hand, because text is better for generalizations (Schnotz, 2002), it may be easier to extract transferable elements. Salomon and Perkins (1989) made a similar statement when they suggested that "perceptual experience accompanied by a verbal narration should… facilitate transfer more than if it is accompanied by pictorials, although the latter might be better for immediate mastery of the material" (p. 129). Only through further empirical research will we better understand how each of these modalities works to facilitate transfer, and through this understanding be able to combine pictures and text into the most effective instructional tools.

Taken together, this brief review suggests that picture and text combinations can improve problem solving under certain conditions. Less attention has been paid to directly comparing the effects of pictures versus text on transfer, although some studies have included picture-only or text-only treatments as part of larger studies. For example, in their study on using visual and verbal summaries in text books, Mayer et al. (2006) found that neither pictures alone nor captions alone were as effective as captioned pictures in producing problem solutions. Unfortunately, it was not reported whether there was a statistical difference between the picture alone or caption alone treatments. In their study of bicycle pump animations, Mayer and Anderson (1991) found that students who received words with pictures generated more problem solutions than the words-only, pictures-only, and no-instruction treatments, which did not differ. Both of these studies used cause-and-effect pictures and text. Additional research is needed to confirm these findings and further test non-cause-and-effect pictures and text.

As demonstrated by the above examples, problem solving is an effective measurement of a student's ability to apply content they have learned to answer novel questions or respond to new scenarios to which they have not been given a direct answer. Content transfer questions are an effective way to test the ability of students to transfer the *content* they have learned.

Modality transfer. Although modality transfer could be classified as a sub-category of content transfer, this researcher has placed it in its own category to better reflect its relationship to the other types of transfer. While modality transfer is here defined as the transfer from one modality to another, "what" is transferred can be viewed very broadly. While content transfer is concerned with the transfer of learned content as presented in the study materials, modality transfer could subsume other types of transfer. For example, a schema that is transferred during analogical transfer could be in either a visual or verbal form, and one could perform a modality transfer on that schema. In fact, this was seen in the presentation of the convergence schema presented as a diagram and as text (Pedone et al., 2001). Thus, it is possible for a “double-transfer” to occur. Students could be asked to perform both an analogical transfer (or representational or content transfer) and a modality transfer.

Modality transfer involves what Paivio (2007) refers to as “symbolic modality.” This refers to the presentation style of the information, for example, whether the information is presented in pictorial or textual form. Transfer at the level of symbolic modality considers how well individuals “transfer” the information presented in a picture into a textual form and vice versa. Transfer at this level is also an assessment of the strength of referential connections which an individual has made between their visual and verbal mental representations.

Transfer appropriate processing theory posits that “performance on a memory task is enhanced to the extent to which cognitive processes engaged at test match those engaged at study” (Park & Gabrieli, 1995, p. 1583). It follows, then, that individuals who study pictures should test better with pictures and individuals who study words should test better with words. In fact, this has been shown to be true. Using pictures and short descriptions of the pictures, Standing and Smith (1975) found that performance was quantifiably poorer in those conditions where participants were shown pictures and had to recognize words (picture-word) or were shown words and had to recognize pictures (word-picture). Participants who were shown pictures and had to recognize pictures (picture-picture) outperformed all other treatments. Specifically, picture-picture performance was the highest followed by picture-word and word-word performance which were equal, and then word-picture (Standing & Smith, 1975). They found that the average performance of the picture-picture and word-picture treatments was the same as the average performance of the picture-word and word-word treatments (Standing & Smith, 1975). In other words, whether participants were tested using pictures or words had no effect, but the interaction between the modality of the learning stimulus and the modality of the test stimulus was significant.

Standing and Smith (1975) proposed a single visual coding system for their results, but it is interesting to note how well their results fit under the dual-coding theory. Under dual-coding theory, though pictures are processed one way and text is processed another, there is a referential connection between the two. It makes sense that some information could be lost in the transfer from text to picture and picture to text so that recognizing information in the opposite modality of the study materials would cause a depression in scores.

Several other studies incorporated modality transfers into their study designs, perhaps unintentionally. For example, several studies that provided study materials in both text and picture format assessed learning with a strictly text-based test (e.g., Igo et al., 2004; Mayer and Anderson, 1991; Mayer et al., 1996).

Consideration of these modality transfers may be even more important to consider when learning style is a key variable in the research. An example may be seen in the work by Mendelson and Thorson (2004). High verbalizers recalled more about pictures than low verbalizers, but no effect was seen between high and low visualizers. The method of assessment had participants write what they could remember about the pictures (Mendelson & Thorson, 2004). It is possible the results may have been different if a picture recognition test was used instead of the written response. Similarly, Massa and Mayer (2006) assessed whether verbalizers and visualizers learn better when they are matched to the appropriate instruction modality. Unfortunately, their learning assessment was only in written (i.e., verbal) form. Follow-up research would be needed to see if this modality transfer impacted the results. This issue could be addressed in future research by using assessments that included both verbal and visual modalities.

Challenges Facing Picture Research

As with any experimental undertaking, investigating the effects of pictures and text on learning presents researchers with some unique challenges. Here, a few of the challenges facing picture and text researchers are discussed, and a few of the standards set forth by previous researchers are established.

When designing experimental manipulations, it is an inherent assumption of the experimental design that participants perceive information from an image similarly to the way the researchers intended. Otherwise, a lack of experimental effect may be due to participants perceiving the picture differently than intended, rather than an actual lack of picture effects. Unfortunately, researchers and participants do not always perceive images the same. As lamented in her essay on archiving images, Finnegan (2006) described how it took her days to locate a particular image in the Farm Security Administration – Office of War Information (FSA-OWI) photo archive simply because she did not view the content of the photograph in the same manner as the archivist. She came to the striking conclusion, “Apparently I am utterly incapable of answering a seemingly simple question: *‘What is this a picture of?’*” (p. 117).

The effects of this challenge are also seen experimentally. Zillman, Gibson, and Sargent (1999) did not describe how the “negative” and “positive” images used in their study were selected. They noted in retrospect, however, that the roller coaster image showing people having fun may not have evoked the feeling of “safety” that they were testing for in their second experiment. Likewise, Mendelson (2001) suggested future research needs to examine what viewers perceive in news photographs. In his experiment on novelty, experienced photographers helped design the study and classified photographs on content and composition. Though reliability of the experienced coders was 100%, study participants were not able to differentiate between the critical elements of photographic content and composition (Mendelson, 2001).

This difficulty may be slightly tempered when more concrete representations are used, since it has been shown that more abstract topics are harder to portray pictorially (David, 1998). Mayer and his colleagues, for example, have relied on cause-and-effect text and illustrations that have been modified from existing encyclopedia entries (e.g., Mayer & Gallini, 1990). Butcher (2006) used diagrams of the heart. These subjects are relatively objective, and allow for concrete representations of physical objects. Thus, relative to the more subjective elements being tested by Mendelson (2001) and Zillman, Gibson, and Sargent (1999) (e.g., “novelty” or “safety”), discrepancies in the interpretation of the image should be minimized. Indeed, neither Mayer and his colleagues (e.g., Mayer & Gallini, 1990) nor Butcher (2006) reported any misinterpretations of their materials.

A related challenge is encountered when direct picture to text comparisons are made, since it is important that the information presented in one is also presented in another. “Two representations are informationally equivalent if all of the information in the one is also inferable from the other, and vice versa” (Larkin & Simon, 1987, p. 67). Taken literally, pictures and text will likely never achieve informational equivalence because of their syntactic differences. No matter how intensely descriptive a text may be, it can rarely – if ever – account for every nuance visually depicted in the picture. As mentioned under the section on dual-coding theory, others have pointed out the specific depictive ability of pictures as compared to text (Schnotz, 2002; Standing & Smith, 1975), as well as the differences in mental encoding (Paivio, 1971; Sadoski & Paivio, 2001).

From a more applied perspective, however, more important than straight informational equivalency is whether or not the information portrayed allows for the practical completion of a required task. As long as the necessary information is present, the additional surface features of the representation are what lend the modality its relative advantage or disadvantage. Thus, for applied purposes, two representations are (in a task-specific sense) informationally equivalent if both allow the extraction of the same information required to solve the specific tasks (Schnotz, 2002). For example, a visual and verbal representation are informationally equivalent in a task-specific sense if they each provide the information necessary to answer a question. However, depending on the situation, one representation may be easier to use than the other. It is this latter part – identifying when and how to utilize various representations – that represents the larger research question to the picture and text literature. Even with an emphasis on task-specific information equivalency, precautions should be taken to improve the likelihood that images are being consistently viewed. A pretest showing that participants can in fact pull similar information from the verbal and visual materials would improve a study's validity.

Much of the early picture memory research (e.g., Goulet & Sterns, 1970; Standing & Smith, 1975) had a group that was exposed to pictures and a group that was exposed to text. When simple line drawings and single words were used (Goulet & Sterns, 1970) no precautions were taken to assure the word and picture matched. When photographs and short statements were used, statements were created by two observers and then a consensus statement created. Information on the reliability between observers or evidence of pretesting of the statements once they were created was not provided (Standing & Smith, 1975). Under these methods, there is no way to accurately determine if in fact participants received the same "message" from the picture as they did from the text.

Beltran and Duque (1993) found no difference in recognition response time between color photographs and line drawings. However, color has been shown to be detrimental during resource demanding tasks (Meyers-Levy & Peracchio, 1995), suggesting that as the level of learning deepens - and the learning tasks become more difficult - color may inhibit learning.

These issues raise the question, what level of specificity is needed to ensure information equivalency? Likewise, how does one balance specificity with equivalency, since more detailed descriptions of images would require lengthier statements? Lengthier statements have been shown to decrease readability (Hartley, Sotto, & Fox, 2004) and may in turn limit learning potential. In the words of Zinsser (1985), "There is no minimum length for a sentence that's acceptable in the eyes of man and God. Among good writers, it is the short sentence that predominates" (p. 113-114). The importance of shorter sentences is also indicated by the research showing extraneous details reduces problem solving ability (e.g., Mayer et al., 2001; Mayer et al., 1996). Lessons from these previous studies therefore seem to indicate that relatively shorter sentences and simpler, black and white pictures would allow for the most accurate comparison.

Finally, caution should be used when determining how to measure recall or recognition, especially if transferring between visual and verbal modalities. As discussed under the section on modality transfer, when switching from one form of processing to another, some information is lost in the translation (e.g., Standing & Smith, 1975). This issue could be addressed by using an assessment tool that is in both verbal and visual form.

Study Rationale

From the review above, it is evident that numerous studies have investigated the impact that visual and verbal modalities have on learning. The complexities of these relationships are both daunting in their intricacy and exhilarating in the promise they hold for educational impact.

Many of the studies discussed fall under a text-centric paradigm, where the primary testing of visuals is to determine how they can most improve textual learning. There are, however, exceptions, and a few studies have actually suggested ways that text can improve visual learning. Further investigation is needed to assess the learning potential of pictures. There remains a lack of a basic understanding of relative visual and verbal semantics and the relative strengths and weaknesses of these modalities at different levels of learning. The better we are able to understand their individual potentials, the better we will be able to utilize them within both instruction and assessment to meet our educational goals.

The following study provides a direct, intensive investigation into the effects of visual and verbal modalities across three levels of learning: memory, comprehension, and transfer. Further details about the materials and methods used for these investigations is described in the next chapter.

CHAPTER 3: MATERIALS AND METHODS

Design

In order to assess the intricacies of picture and text affects across three levels of learning and study time, a relatively complex experimental design was utilized. This experimental design may be best understood as comprising of three distinct sections. Each section addresses specific hypotheses and research questions that have been put forth. When results from all three sections are considered, an overall answer emerges for the primary research question:

RQ1: As question complexity increases, will performance advantage switch from the picture study condition to the text study condition?

To better understand the experimental design used, the explanation here has been broken down into three sections to mirror the three key components of the design as they were conceived. The first section addresses hypotheses related to the first two levels of learning, recognition and comprehension. This includes:

H1: Recognition scores will be higher than comprehension scores.

H2: A picture superiority effect will be seen for recognition memory. On recognition multiple choice questions, those who studied pictures will outperform those who studied text.

H3: A study condition effect will be seen for comprehension. On comprehension multiple choice questions, those who studied pictures will perform differently than those who studied text.

H5: A modality interaction effect will be seen for both recognition and comprehension so that within-modality questions will outperform cross-modality questions.

H6: As study time increases, test scores for recognition and comprehension will increase.

H8: For recognition questions, the picture study condition will outperform the text study condition at shorter study times, but not at longer study times.

To address these hypotheses, the first section of the experimental design followed a split-plot design in a variation of the "Posttest-only Control Group Factorial Design" identified by Campbell and Stanley (1963/1969). A split-plot design includes both repeated measures and between-subject variables. The repeated measures component of the design allows for more accurate comparisons across learning levels because individual differences are experimentally controlled (Kirk, 1995).

Question type (recognition or comprehension) and question modality (picture or text) were within-subjects variables. Thus, there were four dependent, repeated measures: scores on picture recognition, text recognition, picture comprehension, and text comprehension questions. Each of these questions is described in subsequent sections.

There were three between-subjects variables. Two study conditions were created consisting of either picture or text study materials. Three study times (1, 2, or 4 minutes) were used to test for differential processing across time. Four test versions (A, B, C, and D) were created to control for order effects of the questions. Thus, study condition (picture or text), study time (1, 2, or 4 minutes), and test version (A, B, C, or D) comprised the between-subjects variables. Each of these variables is described in greater detail in subsequent sections.

The second section of the experimental design relates to the third level of learning. In order to minimize some of the complexity of the experimental design, the third level of learning (transfer) was tested in only text modality and was analyzed separately from the recognition and comprehension questions. This resulted in a distinct "second section" of the experimental design. This second section addressed hypotheses related to this third level of learning, which included:

H4: A study condition effect will be seen for transfer. On the transfer problems, those who studied pictures will perform differently than those who studied text.

H7: As study time increases, test scores for transfer will increase.

H9: For transfer tasks, there will not be a picture advantage at shorter study times.

To address these hypotheses, two types of content transfer tasks were used that required participants to transfer some of the learned content to unique situations. Details about the two transfer tasks are provided in a subsequent section, but a brief overview is provided here. The first transfer task was a scenario transfer that required participants to apply their learning to a "real-life" scenario and make judgment about the validity of the information provided. The second transfer task was a problem-solving transfer task that required participants to combine their learning with newly presented information and then solve problems related to the Emerald Ash Borer.

Because the transfer tasks were presented only in text modality and were the same on every test version, they were analyzed using two separate general linear model univariate procedures. Transfer score was the dependent variable and study condition and study time were the independent variables.

A third distinct section of the experimental design addressed the hypotheses and research questions related to participants' confidence in their answers. These were:

H10: Confidence in answers will be higher for recognition questions than for comprehension questions.

H11: Confidence in answers will be higher for within-modality questions than for cross-modality questions.

RQ2: For each level of learning, does the pattern of confidence ratings in each study condition follow the same pattern as the test scores?

RQ3: Do the correlations between confidence and actual test scores differ between study conditions?

As participants answered each recognition, comprehension, and scenario transfer question, participants rated their confidence on a Likert scale with 1 being not at all confident and 5 being very confident. For recognition and comprehension questions, confidence rating on the picture recognition, text recognition, picture comprehension and text comprehension questions was used as the dependent variable in a split-plot design. Study condition (picture or text), study time (1, 2, or 4 minutes), and test version (A, B, C, or D) were the independent, between subjects variables. Correlations were also run to compare confidence rating with actual test scores for the recognition and comprehension questions.

For scenario transfer questions, confidence rating on the scenario transfer questions was used as the dependent variable in a general linear model univariate procedure. Study condition (picture or text) and study time (1, 2, or 4 minutes) were the independent variables. Correlations were also run to compare confidence level with actual scenario transfer test scores. More details regarding these variables can be found in subsequent sections.

Participants

A total of 224 undergraduate students at a large, public Indiana university received extra credit in an introductory statistics class for participating in the study. Therefore, the participants volunteered but were, in part, motivated by the prospect of increasing their score in one class. Undergraduate students were chosen as the study population because they are a core population of key learners. It is important to understand how these students learn from pictures and text.

As part of the demographic variables, participants were asked whether English was their first language. Anyone who answered no or left the question blank was excluded from the study. This resulted in a total of 206 participants who were included in the analysis.

Study Conditions

Two study conditions (pictures vs. text) were created to test participants on their ability to learn about the Emerald Ash Borer, an invasive insect, from pictures or text. As detailed in the introduction, the Emerald Ash Borer was chosen as a topic for three main reasons. To reiterate, the Department of Natural Resources has been trying to increase awareness about this insect because it has been spreading rapidly from its initial discovery in Michigan through (at the time of the study) seven other states, including Indiana. The Emerald Ash Borer infects ash trees, important both for their wood, their popular use as community shade trees, and their presence in national forests. Once infected, 100% of ash trees die. The spread of the Emerald Ash Borer has been exacerbated by people transporting firewood, nursery stock, and other ash products. Quarantines are being enforced in several Indiana counties, restricting the movement of wood. The proximity of these occurrences and the plea to the general population for assistance makes the Emerald Ash Borer a relevant topic for the participants in this study.

Second, the Emerald Ash Borer has a wealth of concrete imagery associated with it. Many facts concerning this insect can be presented in visual form, making it an ideal topic for this study.

Third, despite recent efforts by natural resource officials, including the launching of an Emerald Ash Borer awareness week, student knowledge about the Emerald Ash Borer is expected to be low. A pilot test supported this supposition. When students in the pilot test were asked to rate their familiarity with the material presented with 1 being not at all familiar and 5 being very familiar, they reported an average familiarity of the Emerald Ash Borer of only 2.15 (SE=0.296).

All materials used in the study were reviewed for technical accuracy by an entomologist who specializes in the Emerald Ash Borer.

Picture Study Condition

The picture study condition consisted of a four page information packet plus a cover sheet printed single-sided in black and white on 8-1/2”x11” white paper (Appendix A). Because color has been shown to be detrimental under high cognitive processing situations (Meyers-Levy & Peracchio, 1995), only black and white and grayscale images were used. Arguably, limiting the picture study condition to black and white also makes it more syntactically similar to the text study condition, since the text is also printed in black and white.

The picture information packet was created in Microsoft Word. Each page had one or two text headings in Arial size 12 bold font followed by images. The headings were framed in the form of a question, e.g., “What does the ash tree look like?” and the images answered each question. The information needed to complete the test was contained in the images, so while the headings provided a context for the images, it was necessary for students to study and understand the images in order to complete the test.

Images included photographs, graphs, charts, and maps. High resolution photographs and maps were downloaded from the database forestryimages.com and from the image search of Google.com. Photo citations are available in Appendix B. All images were opened in Adobe Photoshop, set to 300 dpi for maximum print quality, and converted to gray scale. Any images too small to meet this resolution were discarded.

All images were saved as high quality .jpg or .tif images and then imported into the MS Word file.

Whenever possible, pictures currently used in university, industry, or governmental publications were used. For example, many of the images on the forestryimages.org Web site are currently used in various publications to educate the public about the Emerald Ash Borer. The use of actual publication photos that may be altered to create various treatment conditions is a common practice in picture research (e.g., Childers & Houston, 1984; Mendelson & Thorson 2004; Wanta, 1988).

To increase saliency of particular aspects of a photograph, for example, to draw attention to the holes in a photograph of bark, circles or arrows were used. Call-out boxes were also used to highlight a detail, for example, showing that an Emerald Ash Borer larva was embedded in wood.

Charts and graphs were created using Microsoft Excel and then imported into the MS Word document. Good graph practices as suggested by Shah and Hoeffner (2002) were used. For example, a pie chart was used to indicate proportion, a horizontal bar graph was used to indicate distance, and no distracting three dimensional effects were used.

The cover sheet of the picture information packet included a large “P” and instructions not to turn the page until instructed to do so and not to write in or markup the packet. The picture information packet was created first, and then a comparable text information packet was created.

Text Study Condition

Like the picture study condition, the text study condition used a four page information packet plus a cover sheet printed single-sided in black and white on 8-1/2”x11” white paper (Appendix C). Each page had the same headings as the picture information packet printed in Arial size 12 bold font. These headings were followed by a series of short statements describing the comparable image in the picture information packet. The equivalency of the text and pictures used was tested as described in the material validation section below. The text statements were printed in Arial font size 14.

The cover sheet of the text information packet included a large “T” and instructions not to turn the page until instructed to do so and not to write in or markup the packet.

Study Times

Three study times were chosen to encourage different levels of processing. As discussed in previous chapters, the type of processing students undergo when reviewing information can impact the information they receive from pictures compared to text (Meyers-Levy & Malaviya, 1999). Because pictures have been shown to be processed faster but more superficially than text (Paivio, 1971; Weidenmann, 1989), it was also believed that study time would impact how students learned from the picture and text study conditions. As a result, three study time conditions were established.

The first condition allowed students enough time to quickly read through the material once. This was intended to mimic the amount of time that someone might spend to quickly flip through a brochure.

The second condition allowed students enough time to slowly read through and think about the material once, or read steadily through the material twice. This condition was intended to mimic an audience that takes the time to read and think about the material, but is not repeatedly studying the material.

The third condition allowed students extra time to really study the material. This condition was intended to mimic the amount of time someone would spend if they were to rehearse it, review it, and/or re-read it several times.

A pilot test was conducted (N=10) and participants were observed and/or questioned at the conclusion of the study to determine the appropriate study time allotments to meet these three conditions. The three study times that were selected for the main study were one minute, two minutes, and four minutes.

Tests

To assess memory, comprehension, and transfer for the studied material, four test versions were created (Appendix D). Each test version contained four sections: recognition questions (12), comprehension questions (12), transfer questions (18), and demographic information. Different test versions were created to switch the order of the recognition and comprehension questions and to allow each recognition and comprehension question to appear in both visual and verbal form. Switching the order of the recognition and comprehension questions allows order effects to be counterbalanced. Having each question answered in both visual and verbal form helps ensure that any effects seen are not due to questions in one modality being easier than questions in the other modality. Transfer questions were in text format and always came third. Demographic questions always came last.

Each test was physically divided into two packets, each printed on one side of each page. The first packet was either recognition or comprehension. The second packet contained whichever question type the first packet did not, plus the transfer questions and demographic questions that were the same on every test.

Thus, the four test versions were as follows:

A – (A1) recognition, opposite modality as C1; (A2) comprehension, opposite modality as C2 – plus transfer and demographics

B – (B1) comprehension, opposite modality as D1; (B2) recognition, opposite modality as D2 – plus transfer and demographics

C – (C1) recognition, opposite modality as A1; (C2) comprehension, opposite modality as A2 – plus transfer and demographics

D – (D1) comprehension, opposite modality as B1; (D2) recognition, opposite modality as B2 – plus transfer and demographics

Under this scenario, tests A and B have identical questions, except in test A, recognition questions are first and comprehension questions are second. In test B, comprehension questions are first and recognition questions are second. Likewise, tests C and D have identical questions, but the order of recognition and comprehension questions are reversed.

Alternatively, tests A and C have the same order of questions, but different question modalities. Any question that is in visual form on test A will be in verbal form on test C. Any question in visual form on test C will be in verbal form on test A.

Likewise, tests B and D have the same order of questions, but the question modalities differ.

Every test had both visual and verbal modalities for recognition and comprehension questions, as indicated in Table 2. Modalities alternated in a random pattern. Modalities are further explained in the sections below regarding each type of question.

Table 2

Question Modality (P=Picture; T=Text) for Recognition and Comprehension Questions.

Test Question	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**	**12**
A1 Recognition	P	P	T	T	P	T	P	T	P	T	T	P
B2 Recognition	P	P	T	T	P	T	P	T	P	T	T	P
C1 Recognition	T	T	P	P	T	P	T	P	T	P	P	T
D2 Recognition	T	T	P	P	T	P	T	P	T	P	P	T
A2 Comprehension	P	T	T	P	P	T	T	P	T	P	T	P
B1 Comprehension	P	T	T	P	P	T	T	P	T	P	T	P
C2 Comprehension	T	P	P	T	T	P	P	T	P	T	P	T
D1 Comprehension	T	P	P	T	T	P	P	T	P	T	P	T

Note: *The letter and number indicates the test and section. For example, A1 is the first section of test A; B2 is the second section of test B, etc.*

Each test had a color cover sheet with instructions to circle the test version on the answer sheet. The same color cover sheet was used for the first and second section (e.g., A1 and A2). This made it easier during administration to make sure participants received the same test version for all test sections.

So that content would not be a confounding factor when comparing recognition scores to comprehension scores, the same general content was tested by both the recognition and comprehension questions. For example, under the recognition section, students had to recognize the pie chart or statement that 40% of the trees in Indiana cities and towns are ash trees. Under the comprehension section, students had to understand this same knowledge to answer the question "A city in Indiana has 200 trees. How many of them are likely ash trees?" Because the same basic content is being tested, any differences in scores seen between recognition and comprehension should be due to the types of questions (i.e., recognition or comprehension) and not because of any differences in content.

Precaution was also taken to ensure there would not be a compounding modality effect when comparing recognition and comprehension questions. Similar content was tested at both the recognition and comprehension levels so that a comparison between recognition scores and comprehension scores could be made. If recognition questions were asked in one modality while comprehension questions were asked in another modality, any differences that were seen between the two question types would raise the question whether the difference was do the question type (recognition vs. comprehension) or a modality effect (picture questions vs. text questions). To eliminate the possibility of a modality effect, any question of the same content was presented in the same modality for a given test. This means any differences seen between recognition and comprehension questions are likely attributable to question type rather than content or modality differences.

For example, consider the sample cited above. Under the recognition section, students had to recognize that 40% of the trees in Indiana cities and towns are ash trees in verbal form for tests A and C and in visual (pie chart) form for tests B and D. Under the comprehension section, students had to answer the question "A city in Indiana has 200 trees. How many of them are likely ash trees?" in verbal form for tests A and C and in visual (graph) form for tests B and D. Thus, recognition and comprehension questions based on the same content were asked in the same modality on a given test.

While the same general content was being tested by both recognition and comprehension questions, the order of the questions under recognition differed from the order of the questions under comprehension. Using our same example, the recognition question that 40% of the trees in Indiana cities and towns were ash trees was question number four in the recognition questions. The corresponding comprehension question was question number six. This extra precaution should prevent students from recognizing a pattern of similar content as they move from one section of the test to another.

All answers were given on an answer sheet (Appendix E). Two answer sheets were created that were identical except that in the header, one was labeled with a "P" for those who received the picture study condition and the other was labeled "T" for those who received the text study condition. For the multiple choice recognition and comprehension questions, participants circled the letter corresponding to their answer and then completed a 5-point confidence scale. For the first transfer question, students circled "correct" or "incorrect" to indicate their answer and completed the 5-point confidence scale. The second transfer questions were short answer.

All materials were used in a pilot test (N=10), and each participant was asked at the end which questions, pictures, or text they found confusing and why. Based upon their feedback, slight modifications were made to improve the materials. For example, one phrase in the text study condition used the term "leaflets," which one participant was unsure of. This was changed to “little leaves.” It was also suggested that the image in the picture study condition of the Emerald Ash Borer flying was not clear. At the participant’s suggestion, motion lines were added to help indicate movement.

Recognition Questions

Twelve recognition questions were created with six questions in visual modality and six different questions in verbal modality. Participants had to choose the previously seen item out of three possible choices. For the visual modality, the correct answer was always the exact image in the exact same size as the image appearing in the picture study condition. Wrong answer choices were images matched in size and were chosen for their perceptual and conceptual similarity. For example, when the correct image was a single tree with no leaves on its top branches, wrong answer choices were similarly sized single trees with similarly plain backgrounds but with differing amounts of leaves.

As in the creation of the picture study materials, picture recognition questions used only black and white and grayscale images set to 300 dpi for maximum print quality. Images included photographs, graphs, charts, and maps and were downloaded from either forestryimages.com or the image search of Google.com, or (in the case of graphs and charts) were created in Microsoft Excel.

For the verbal modality, the correct answer was always the exact statement as the statement appearing in the text study condition. Wrong answer choices were text statements describing the wrong answer choices used for the visual modality questions. Answer choices were always phrased using the same grammatical structure as the correct answer and were printed in Arial font, the same as was presented in the text study condition. Whenever possible, verbal answer choices were also limited to approximately the same number of words. In some instances this was not possible. For example, when listing the states where the Emerald Ash Borer has been found, some answers listed more states than others.

Each test used six recognition questions in visual modality and six different recognition questions in verbal modality so every participant answered questions in both visual and verbal modality. Participants were instructed to choose the picture or phrase that best matched the information they saw and to choose the one that looked "most familiar" to them and circle the corresponding letter on their answer sheet. They were then instructed to indicate on a Likert scale how confident they were that their answer was correct, with 1 being not at all confident and 5 being very confident. The confidence rating was a modification of that used by Archer (2007) who, for multiple choice questions, included an option of "I cannot answer this without guessing."

For students who were in the picture study condition, the six visual recognition questions should have been an exact match with their mental representation. The six verbal recognition questions, however, required a modality transfer. Their mental representation would have initially been in visual form, and they had to match this representation with the corresponding verbal choices on the test.

Similarly, for students who were in the text study condition, the six verbal recognition questions should have been an exact match with their mental representation. However, the six visual recognition questions required a modality transfer. Students who studied text would have created an initial mental representation in verbal form, and they had to match this representation to the correct image on the test.

Comprehension Questions

Twelve comprehension questions were created with six questions in visual modality and six different questions in verbal modality. Participants had to answer multiple choice questions about the information they had studied, and the three answer choices were either in visual or verbal form.

Some comprehension questions required the participant to demonstrate understanding by performing nominal manipulations of the information. In an example referred to previously, students had to understand that 40% of the trees in Indiana and towns are ash trees and calculate how many trees this would be if a town has 200 trees. Other comprehension questions required the participant to demonstrate understanding by answering more direct questions about the information. For example, one question asked participants "When a tree becomes damaged by the Emerald Ash Borer, what part of the tree loses its leaves FIRST?" To answer this, students have to recall the image or the text that says one of the signs of an Emerald Ash Borer infestation is a tree with no leaves on its top branches. This would indicate the tree loses its leaves from the top of the tree first.

Occasionally the exact image and exact phrase from the study packets were used as wrong answers. This tested to make sure the student actually understood the material as opposed to simply recognizing an image or a phrase.

For the visual modality, the correct answer was a different image than the one used in the picture study condition, although it presented similar information. The correct image might be a different photograph of the same type of item (e.g., a different ash tree) or it might contain a different angle or a different zoom. The wrong answers were images matched in size and were chosen for their perceptual and conceptual similarity to the correct answer. For example, in a question asking about the origin of the Emerald Ash Borer, the answer choices are various rotations of a globe, while the image presented to the picture study condition was a rectangular world map. If participants only remember the surface features of the image (e.g., the area on the right was highlighted) they may have no problem with the recognition question, but will have more difficulty answering the comprehension question.

As in the creation of the picture study materials and the picture recognition questions, picture comprehension questions used only black and white and grayscale images set to 300 dpi for maximum print quality. Images included photographs, graphs, charts, and maps and were downloaded from either forestryimages.com or the image search of Google.com, or (in the case of graphs and charts) were created in Microsoft Excel.

For the verbal modality, the correct answer was a slightly different phrase than that used in the text study condition and was printed in Times New Roman font size 12 instead of the Arial font used in the study packet. The correct answer described the correct answer used in the visual modality. The wrong answers described the wrong answer choices used for the visual modality questions. Wrong answer choices were always phrased using the same grammatical structure as the correct answer. Whenever possible, verbal answer choices were also limited to approximately the same number of words.

Each test used six comprehension questions in visual modality and six different comprehension questions in verbal modality so every participant answered questions in both visual and verbal modality. Participants were instructed to answer the questions by choosing the one best answer and circle the corresponding letter on their answer sheet. They were then instructed to indicate on a Likert scale how confident they were that their answer was correct, with 1 being not at all confident and 5 being very confident.

For participants who were in the picture study condition, the six visual comprehension questions were in the same modality as their study materials. Unlike the recognition questions, however, participants could not rely directly on their mental representation to answer the comprehension questions, because the answer choices did not directly match what they had previously seen. Instead, slight abstraction of the studied material and generalization to the possible answer choices was necessary. The six verbal questions would require a modality transfer in addition to this abstraction and generalization.

Similarly, for participants who were in the text study condition, the six verbal comprehension questions were in the same modality as their study materials. However, because the comprehension questions were not an exact duplication of their study materials, participants could not rely directly on their precise mental representation to answer the questions. Instead, the key components of the studied material needed to be understood in order to answer the question. The six visual recognition questions would require a modality transfer in addition to this abstraction and generalization.

Transfer Questions

Two content transfer tasks were created to assess participants' ability to apply their study materials to new situations. Both transfer tasks were presented in text form.

The first transfer task was a scenario transfer task and the second was a problem-solving transfer task.

The scenario transfer questions (Appendix D) were based on actual incidents of fraud; con-artists were falsely informing home owners that their trees were infested with the Emerald Ash Borer and were charging large sums of money to supposedly alleviate the problem for them (Hagen, 2005). In this transfer problem, participants read a scenario where a friend is being approached by an "expert" who tells the friend all about the Emerald Ash Borer. For each sentence in the scenario, participants had to indicate whether what the expert said was correct or not. The concluding statement required participants to assimilate the presented information to decide if a tree was infested with the Emerald Ash Borer. Participants also indicated on a Likert scale how confident they were that each of their answers was correct.

The problem-solving transfer problem (Appendix D & E) had participants read two short paragraphs of new information about the Emerald Ash Borer and then answer problem solving questions. These questions were not directly answered by any of the information participants had seen. Instead, participants needed to combine the new information with previously learned information and creatively apply it to answer the question. For example, one question asked participants why the Emerald Ash Borer would cause more damage to the tree population in cities and towns than to the tree population in remote forests. To answer correctly, participants must combine the new information that ash trees make up about 6% of forest trees and the previously learned information that about 40% of the trees in cities and towns are ash trees. They can then appropriately argue that ash trees make up a larger percentage of the trees in cities and towns, so an Emerald Ash Borer infestation would destroy a larger percentage of the trees in cities and towns than in forests.

Demographic Variables

Because both prior knowledge and interest have been shown to impact picture and text learning (e.g., Mayer & Sims, 1994; Mayer & Gallini, 1990), familiarity and interest were assessed as part of the demographic variables so they could be included in the analysis as necessary. Each was asked on a 5-point Likert scale ranging from 1 (not at all familiar; not at all interesting) to 5 (very familiar; very interesting).

The impact of visual-verbal learning style has received mixed reviews in the literature, with some research suggesting learning style can impact visual-verbal learning (Chatterton, 2006; Schofield and Kirby, 1994) and other research suggesting it does not (Krätzig & Arbuthnott, 2006; Massa & Mayer, 2006).

As discussed in the previous chapter, different measures of visual-verbal learning style have been shown to measure slightly different underlying constructs (Mayer & Massa, 2003). This study was primarily interested in assessing whether cognitive style, or the ways that people process and represent information (Mayer & Massa, 2003), would impact the effectiveness of the picture or text study condition. In their analysis of various measures, Mayer and Massa (2003) identified the Verbal-Visual Learning Style Rating as the highest loading factor for cognitive style. As a result, this single question measure was used in the present study to identify participants' visual-verbal learning style.

Gender, age, and class level (freshman, sophomore, junior, or senior) were also collected to be tested as possible covariates.

Finally, the home county of the participant was collected. It was thought that someone who lived in a county with an Emerald Ash Borer infestation or quarantine may be more familiar with the insect. So whether or not participants lived in an Emerald Ash Borer county was tested as a possible demographic variable. At the time of the test, the Emerald Ash Borer had been detected and/or a quarantine was in place in 20 counties in Indiana, 18 counties in Illinois, all of lower Michigan, and two counties in Maryland. Other states were also affected, but no students were from those states and so they were disregarded. Any student from one of the affected counties was marked “yes” for an Emerald Ash Borer county. All other students were marked as “no.”

Distracter Task

A distracter task was created to reduce mental rehearsal of the study materials between the time of study and the test. In order to use both the visual and the verbal mental systems, a matching task was created where participants had to match 12 ambiguous images and phrases. There were no right or wrong answers. Instead, ambiguity was used to increase the participants’ engagement with the material (Baran & Davis, 2003). For example, the phrase “Look waaay up there.” could match the mountain peak, the hot air balloon, the empire state building, or the airplane. Anecdotally, this distracter was a success, as the majority of participants used the full time allotted to work on the task and the papers frequently showed cross-outs where participants had changed their minds, suggesting they thought about and engaged with their responses. A copy of the distracter task is available in Appendix F.

Procedure

All materials and procedures used in this study were approved by the Purdue University Institutional Review Board, responsible for approving research conducted with human subjects (Protocol #0806007032). Participants were given the choice to sign up for one of nine sessions. The study was administered to groups of participants ranging from 3 to 54 in number, with 18 being the median group size.

Prior to each session, participants were randomly sorted using the Microsoft Excel random number generator and given an assigned seat. Seats were arranged on a grid indicating the study condition and test version. In this way, participants were randomly assigned to treatments. Approximately equal numbers of study conditions and test versions were used at each session to reduce any potential impact of a study condition by session interaction. However, study time was nested within session, with each session using a single study time. All sessions were run by the same researcher and an assistant who helped pass out and collect materials.

Participants signed in as they arrived and took their assigned seats. Any latecomers had to wait until the timed portions of the study were over and then were allowed to begin the study.

The researcher thanked everyone for their participation and provided a brief overview of the study. The written protocol used to guide each session is available in Appendix G. Briefly, the researcher explained to participants they were going to be given a four-page information packet on the Emerald Ash Borer, an invasive insect in Indiana which the Department of Natural Resources was asking everyone to help prevent its spread. They would have one minute (or two or four minutes) to review the information and would be given a 30 second (or one minute) warning when they had 30 seconds (or one minute) left. They would then answer written questions about what they saw.

Information packets were then distributed and once everyone had one, they were told they could begin. A stop watch was used to time the study portion, and an appropriate 30 second or one-minute warning was given. At the end of one minute (or two or four minutes) they were then told to close the packet and pass it to the front of the room.

The distracter task was then passed out face down, and participants were told this was an activity for them to complete and that they should follow the instructions on the paper. Once everyone had a distracter, they were told to begin and were given five minutes to work on the distracter. The distracter was then collected.

Participants were then told a test booklet and answer sheet was going to be distributed. It was explained the test had four sections, and they should follow the instructions printed for each section. For the first three sections, the questions were in the test booklet and participants marked their answers on the answer sheet. For the last section, the questions were printed on their answer sheet. Section one was distributed first. Once they were done, participants raised their hands to have section one collected and the remaining sections given to them. They were told there was no time limit.

Once participants completed the last section, their test booklet and answer sheet were collected, they were thanked for their time, and they were free to go. As the answer sheet was collected, it was checked to make sure the appropriate test version had been circled.

Scoring and Analyses

All tests were scored by a single grader. Participants received one point for each correct answer. For the short answer, problem-solving transfer questions, a list of all possible acceptable answers was compiled; answers not on this list were marked wrong. No partial credit was given. Total possible points were as follows: six picture recognition, six text recognition, six picture comprehension, six text comprehension, 13 scenario transfer, and five problem-solving transfer. Confidence scores were input directly into Microsoft Excel as indicated by the participants and then formatted for SPSS. All analyses were run using SPSS 16.0 for Windows. Specific models used will be provided along with the results in the next chapter, but an overview of the analyses used is provided below.

To test if there were differences among the test versions, two general linear model repeated measure tests were run with the dependent, within-subject variables picture recognition, text recognition, picture comprehension and text comprehension. In the first analysis, the independent, between-subject variables were tests A and C compared to tests B and D. This checked to see if there was an order effect for recognition and comprehension questions, since tests A and C had recognition questions first and tests B and D had comprehension questions first. The second analysis used independent, cross-subject variables tests A and B compared to tests C and D. This checked to see if there was a modality effect, since tests A and B had the same questions in pictures and text format while tests C and D had the same questions in the opposite modality.

Second, the success of participants' randomization was checked. The distribution of the categorical demographic variables (gender, whether their home county was infested by the Emerald Ash Borer, and year in school) across study condition, study time, and test version was checked using a chi-square analysis. The distribution of continuous demographic variables was checked using a series of one-way analysis of variance (ANOVA) tests. Because of the large sample size, the central limit theorem was invoked to meet the assumption of normal distribution necessary for the ANOVA (Kirk, 1995). Dependent variables were familiarity with the Emerald Ash Borer, interest in the study material, visual-verbal learning style, and age. The independent variables (run separately) were study condition, study time, and test version. Any demographic variables that were not evenly distributed as a result of the randomization were used as an independent variable in a general linear model repeated measure to see if they influenced picture recognition, text recognition, picture comprehension, or text comprehension. Similarly, any demographic variables that were not evenly distributed were used as the independent variable in a general linear model to see if they influenced the transfer scores. Any demographic variables shown to impact these test scores ($p < .05$) were included in the main analyses.

Once all possible covariates were considered, the three sections of the experiment were analyzed. For the main analyses, the general linear model repeated measures was run with picture recognition, text recognition, picture comprehension, and text comprehension as the dependent, repeated measures. To assess the effects of study time, study condition and study time were included as independent variables with test version and demographic variables included as covariates as necessary. To further analyze the impact of study condition, repeated measures were run at each study time. Post-hoc planned comparisons using the general linear model were used to assess interactions.

Significance was declared at $p < .05$ and the Bonferroni adjustment was made for all post-hoc comparisons.

As discussed previously, the second "section" of the experiment consisted of the two transfer tasks. All participants received the same two transfer problems in the same order. Transfer problems were analyzed separately from the recognition and comprehension questions using the general linear model. Score was the dependent variable and study condition and study time were the independent variables. Each type of transfer score was analyzed separately. Demographic variables were included as covariates as necessary. A model using study condition as the sole independent variable was run at each study time to further assess the impact of study condition within each study time. Significance was declared at $p < .05$.

Third, students' self-reported confidence was analyzed. Differences in self-reported confidence among question types were assessed using similar models except that self-reported confidence replaced the test score. For recognition and comprehension questions, a general linear model repeated measures was run with picture recognition confidence, text recognition confidence, picture comprehension confidence, and text comprehension confidence as the dependent, repeated measures. Study condition (picture or text) and study time were included as independent variables. Test version and demographic variables were included as covariates as necessary. To further analyze the impact of study condition at each study time on the confidence scores, repeated measures were run for each study time. Post-hoc planned comparisons using the general linear model were used to assess interactions. Significance was declared at $p < .05$ and the Bonferroni adjustment was made for all post-hoc comparisons.

For transfer questions, confidence was analyzed using the general linear model. Self-reported confidence was input as the dependent variable with study condition and study time as the independent variables. Demographic variables were included as covariates as necessary. A model using study condition as the sole independent variable was run at each study time to further assess the impact of study condition within each study time. Significance was declared at $p < .05$.

This approach allowed for a direct comparison between actual test scores and confidence. Correlations were run between test scores and self-reported confidence for both the picture study condition and the text study condition. Additionally, paired sample t-tests were used to identify differences between self-reported confidence scores and actual test scores. Such analyses will show whether students had an accurate assessment of what they knew, whether certain study conditions and/or question types are more prone to guessing, or whether certain study conditions and/or question types promote overconfidence.

Material Validation

To validate the task-specific informational equivalence of the text and images used in the study, a matching test was administered at the time of the study. Participants were drawn from the same pool as the participants used in the main study. They also received extra credit in the same introductory statistics class. Those who did not indicate English as their first language were removed from the analysis, leaving N = 17. The matching test included every image and corresponding text statement that appeared in the study packets or on the tests. The matching test was divided into four sections with 18-

26 images and text statements in each section. A copy of the matching test is available in Appendix H.

The matching test was scored by a single grader. Each question was entered into Excel so that the percentage of participants who correctly matched each image and text statement could be calculated.

CHAPTER 4: RESULTS

The explanation of this study's results begins with the material validation and an assessment of potential covariates to be included in the main analysis, including the different test versions used and the demographic variables. The remainder of this chapter is then devoted to the key results of the study. These key results have been organized according to the three main sections of the experiment as described at the beginning of the previous chapter. Specifically, the first section of the experiment analyzed the first two levels of learning, recognition and comprehension. The second section analyzed the two transfer tasks. The third section analyzed the self-reported confidence of participants as they answered the different types of questions. The hypotheses related to each of these sections are explained.

While this chapter approaches the results as separate sections of the experiment in order to provide clarity to the models used and the individual results obtained, the importance of each of these results should also be considered in relationship to the primary research question, "As question complexity increases, will performance advantage switch from the picture study condition to the text study condition?" The next chapter will take the key points of each of these sections and blend them into a comprehensive discussion of the overall findings of the study.

Material Validation

During the material validation, participants were instructed to match the pictures and corresponding text used in the information packets and tests. Overall, pictures and text were correctly matched 95% of the time, with 61% of participants correctly matching every picture and text phrase, lending support to the task-specific information equivalency of the images and text used. The percentage of participants who correctly matched each picture with its corresponding text ranged from 71%-100%, with a median and mode of 100%. As an extra validation step, a subset of tests from the main study were re-scored after removing any question containing a picture or text with less than 80% correct matches from the validation phase. Removing these images did not alter the results of the study, and so all questions were included in the final analyses. Overall, results of the material validation suggest participants were able to identify the same information from the images and text used. This lends support to the functional information equivalency of the pictures and text used.

In addition to the matching test, several statistical analyses were run on the materials used. As detailed in the next section, the four test versions were collapsed into two versions, A&B vs. C&D, for analysis. To statistically assess the reliability of these instruments, Cronbach's Alpha was used (Santos, 1999). For tests A&B, Cronbach's Alphas were .40 for recognition questions and .40 for comprehension questions. For tests C&D, Cronbach's Alphas were .51 for recognition questions and .52 for comprehension questions.

Cronbach's Alphas were similarly low for the transfer tasks. Since transfer questions were the same on every test version, reliability was computed across test versions. Cronbach's Alpha was .37 for the scenario transfer questions and .27 for the problem solving transfer.

These results suggest that the instrument used was not consistently measuring the same underlying construct. It is possible that this difference may be due to the different types of questions asked within each level of learning. For example, some questions were number-based or required mathematical judgment (e.g., A city in Indiana has 200 trees. How many of them are likely Ash trees?) while other questions required participants to understand physical characteristics (e.g., Which of the following are traits of the tree which the Emerald Ash Borer attacks?) Future research needs to determine if there are differences in the way students approached these questions.

These instruments should be refined though future research to improve their reliability. However, for the purposes of the present study, it should be noted that despite these low reliabilities (which would suggest increased variability in responses and therefore may be expected to reduce significance), significant results were still obtained.

As shown in Table 3, there were weak but positive correlations between scores on the various question types and modalities (e.g., picture recognition questions, text recognition questions, picture comprehension questions, etc.). Such correlations may be expected, since it would make sense for someone scoring higher on one type of question to likewise score higher on another type of question, hence the positive correlation. At the same time, because the questions are assessing different levels of learning and/or employing a different modality, performance on one type of question could vary from performance on another type of question. It is therefore understandable that the scores are not perfectly, or even highly, correlated.

Table 3

Correlations Among Test Question Types and Modalities.

		Picture Recognition	Text Recognition	Picture Comprehension	Text Comprehension	Scenario Transfer	Problem Solving Transfer
Picture Recognition	Pearson Correlation	1.000	.141*	.271**	.338**	.214**	.124
	Sig. (2-tailed)		.043	.000	.000	.002	.076
Text Recognition	Pearson Correlation		1.000	.170*	.389**	.389**	.185**
	Sig. (2-tailed)			.015	.000	.000	.008
Picture Comprehension	Pearson Correlation			1.000	.255**	.305**	.294**
	Sig. (2-tailed)				.000	.000	.000
Text Comprehension	Pearson Correlation				1.000	.301**	.227**
	Sig. (2-tailed)					.000	.001
Scenario	Pearson Correlation					1.000	.184**
	Sig. (2-tailed)						.008
Problem Solving	Pearson Correlation						1.000
	Sig. (2-tailed)						

**Correlation is significant at p < .05 (2-tailed).*

***Correlation is significant at p < .01(2-tailed).*

Test Versions

To assess test effects, a repeated measure general linear model was run using question type and modality as the within-subject variable and test version as the independent variable. As detailed in the materials and methods, tests A and C had the same order of questions using opposite modalities, but the reverse order of questions when compared to tests B and D.

Tests A&C were compared to tests B&D to check for order effects using a repeated measure with picture recognition, text recognition, picture comprehension, and text comprehension as the dependent, repeated measure and test version (A&C vs. B&D) as the independent variable. A significant difference would indicate that whether students answered recognition questions or comprehension questions first affected their scores. No significant difference was found on picture recognition, text recognition, picture comprehension, or text comprehension scores for tests A&C versus tests B&D (p = .588). This suggests the order of question types – whether recognition questions were first or whether comprehension questions were first – does not matter. As a result, the four test versions were collapsed into two: A&B vs. C&D.

To see if test versions could be collapsed further, tests A&B were compared to tests C&D to check for modality effects using a repeated measure with picture recognition, text recognition, picture comprehension, and text comprehension as the dependent, repeated measure and test version (A&B vs. C&D) as the independent variable; a significant difference would indicate that whether questions were asked in picture or text form affected their score. There was no main effect when comparing tests A&B versus tests C&D (p = .838), which suggests that overall, students scored similarly whether a question was in visual or verbal modality. Interestingly however, a significant test x question modality interaction ($p = .007$) and a test x question type x question modality interaction ($p = .002$) was found.

An examination of the means of the 2-way interaction showed that though the interaction was significant, post-hocs for each question type were not. On tests A&B, participants scored numerically higher on the text questions than on the picture questions (72% vs. 70%; $p = .386$), while on tests C&D participants scored numerically higher on the picture questions than on the text questions (74% vs. 69%; $p = .036$, which after the Bonferroni adjustment would not be statistically significant at $p < .05/2 = .025$). It is important to note the similarity in scores between the A&B text questions and the C&D picture questions (72% vs. 74%, $p = .451$) and the similarity in scores between A&B picture questions and C&D text questions (70% vs. 69%, $p = .614$). These were the same questions given in different modalities, and their similarity supports the task-specific informational equivalence of the visual and verbal questions.

The 3-way interaction shows that the 2-way test x question modality interaction is being driven almost exclusively by the recognition questions. Test A&B scored numerically lower than test C&D for picture recognition questions ($p = .046$), but this is not statistically significant after the Bonferroni adjustment of $p < .05/4 = .016$. Test A&B scored higher than test C&D for text recognition questions ($p = .000$). Alternatively, there was no difference between test version for picture comprehension ($p = .425$) or text comprehension ($p = .395$). Mean test scores are shown in Table 4. Again, the similarity between the opposite modalities for the two test versions should be noted. These can be seen by looking at diagonal cells in Table 4, (e.g., picture recognition for test A&B and text recognition for test C&D, etc.).

Table 4

Recognition and Comprehension Test Scores (± SE) by Test Version

Test	Picture Recognition (%)	Text Recognition (%)	Picture Comprehension (%)	Text Comprehension (%)
A&B (N=101)	82.84 ±1.82	87.13* ±1.40	57.83 ±1.81	57.43 ±2.19
C&D (N=105)	88.10 ±1.87	78.41 ±1.76	60.17 ±2.38	60.00 ±2.07

Note. The Bonferroni adjustment was made for these posthoc analyses.

**Test version (A&B or C&D) was greater than other test version at p < .05/4 = .016*

These results suggest that the information in the text recognition questions on tests A&B and in the picture recognition questions on tests C&D (which were the same questions) was easier than the information in the remaining recognition questions. This stresses the importance of using multiple test versions, since if only tests A&B had been used, there would have been a confounding factor with the questions in text format being easier than the questions in picture format. Likewise, if only tests C&D had been used, there would have been a confounding factor with the questions in picture format being easier than the questions in text format. By having both test versions, this confounding factor is being effectively controlled, as demonstrated by the non-significant main effect.

There was also no main effect of the test versions with different modalities. However, since there was an interaction between test version and question modality, a conservative approach was taken and the two test versions (A&B vs. C&D) were not collapsed any further. They were included as a covariate in the main analyses.

Demographics

Categorical demographic variables (gender, year in school, and whether or not students lived in an Emerald Ash Borer infested county) were checked in a series of chi-square analyses to see if they were evenly distributed across test versions, study time, and study condition. Distribution of continuous demographic variables (self-reported familiarity, interest, age, and visual-verbal learning style rating) was checked in a series of ANOVAs using the demographic variable as the dependant variable and test version, study time, or study condition as separate independent variables.

Gender, whether or not students lived in an Emerald Ash Borer infested county, year in school, self-reported familiarity, interest, and age were all evenly distributed across study condition, study time, and test version (all at $p > .05$). Thus the participants' random assignment to condition effectively controlled these demographic variables, and they were not included in the main analyses for recognition, comprehension, or transfer scores.[1]

[1] To answer additional questions beyond those in the study, and to see if any of these demographic variables influenced test scores, a series of repeated measure analyses were run using the General Linear Model Repeated Measure in SPSS (Version 16.0). There were no main effects from gender, whether or not students lived in an Emerald Ash Borer infested county, year in school, self-reported familiarity, or age. There was, however, an effect of interest, with those indicating greater interest in the material scoring higher across all question types ($p = .000$). This agrees with previous research showing those with greater interest in the material tend to create stronger mental representation and perform better than those with less interest (e.g., Pavio and Steeves, 1967; Schiefele & Krapp, 1996). This result emphasizes the importance of controlling for this variable experimentally as was done here. Pragmatically, the influence of interest also indicates the importance of generating as much interest as possible within a learner.

Visual-verbal learning style as measured by the single question verbal-visual learning style rating (Mayer & Massa, 2003) was not effectively controlled by the randomization. Although visual-verbal learning style was evenly distributed across test version and study time (both at $p > .05$), it was not evenly distributed across study condition. Participants in the picture study condition indicated a higher visual preference than those in the text study condition ($p = .000$), although the means of both groups were above the median of the 7-point scale, indicating a slight visual preference overall (5.73 for the picture study condition vs. 4.89 for the text study condition). Because it was not evenly distributed across treatments, a repeated measure was run to see if visual-verbal learning style had an impact on test scores for the picture recognition, text recognition, picture comprehension, and text comprehension questions. No main effect was observed ($p = .252$), but a question modality x visual-verbal learning style interaction ($p = .048$) and a questions type x question modality x visual-verbal learning style interaction ($p = .019$) were observed.

To better understand these complex interactions, visual-verbal learning style was recoded into a 3-point ordinal scale with one being more verbal than visual, 2 being equally verbal and visual, and 3 being more visual than verbal. With this recoding, the question modality x visual-verbal learning style interaction disappeared ($p = .322$) while the 3-way interaction remained ($p = .003$). There was also a trend ($p = .068$) towards a main effect with increasing visual preference resulting in higher scores.

An investigation of the 3-way interaction is illustrated in Figure 2. Recognition scores were higher than comprehension scores. A univariate analysis using the general linear model investigated the interactions at each question type. For the comprehension questions, there was no question modality x visual-verbal learning style interaction ($p = .612$), although there is a trend towards more visual students scoring higher than more verbal students overall ($p = .062$).

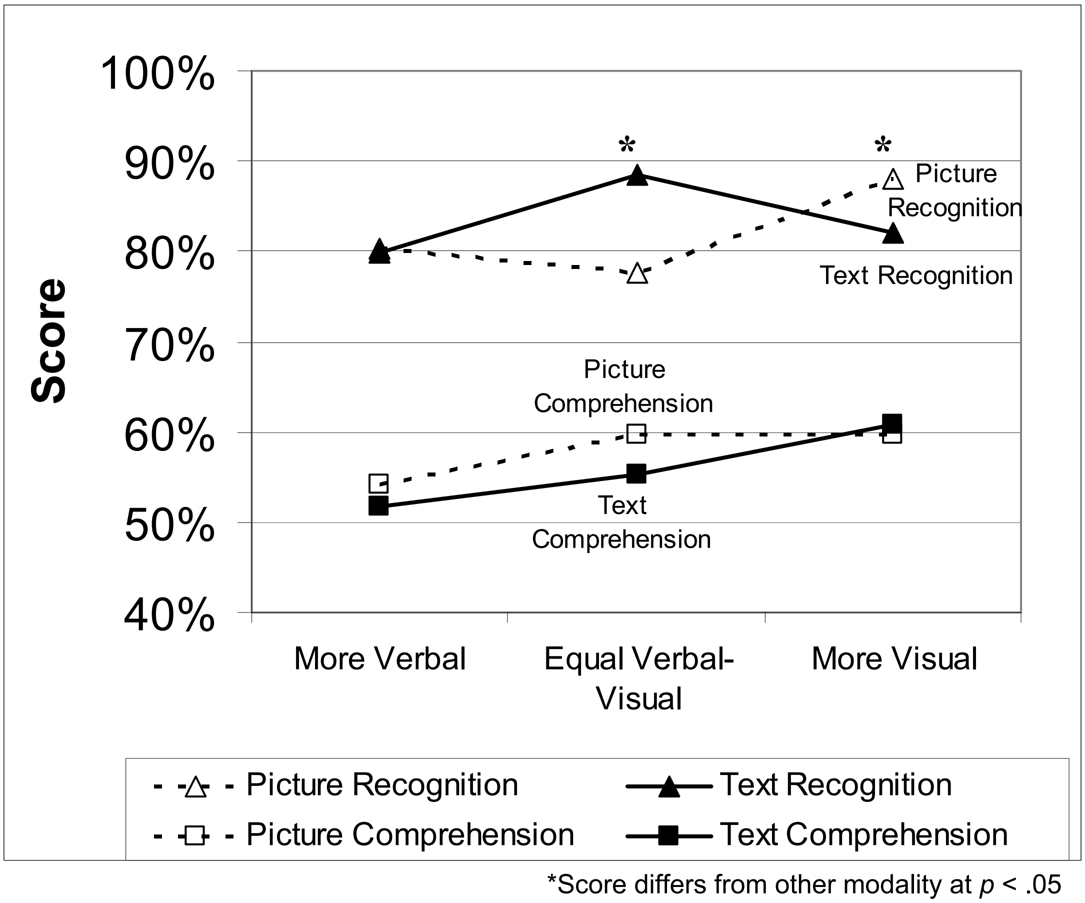

Figure 2. Impact of Visual-Verbal Learning Style on Test Scores.

For the recognition questions, there is a significant visual-verbal learning style x question modality interaction ($p = .004$). One way ANOVAs using Bonferroni's adjustment of significance ($.05/3 = .017$) showed that the students indicating a verbal preference scored equally well on picture and text recognition questions ($p = .902$).

Students indicating an equal preference for visual and verbal learning style scored higher on text recognition questions than picture recognition question (p = .015). Students indicating a stronger visual learning style scored higher on picture recognition questions than on text recognition questions (p = .004).

The effect of visual-verbal learning style was also assessed for the transfer problems. A general linear model univariate analysis was run to see if the difference in visual-verbal learning style had an impact on transfer scores. Visual-verbal learning style did not impact test scores for either the scenario transfer questions (p = .893), or the problem solving transfer questions (p = .538). Thus, even though visual-verbal learning style was unevenly distributed across study conditions, this variable did not impact transfer scores.

Because randomization did not evenly distribute visual-verbal learning style across study conditions, and because visual-verbal learning style was shown to interact with question modality and question type, visual-verbal learning style was included as a covariate in the recognition and comprehension analyses. Because visual-verbal learning style was shown to have no impact on the scenario or problem solving transfer questions, it was excluded from the transfer question analyses.

Section 1 Results: Recognition & Comprehension

The Model

The main model used to assess recognition and comprehension questions followed a split plot design and was run as a general linear model repeated measure in SPSS 16.0 for Windows. The repeated measures were the scores on picture recognition, text recognition, picture comprehension, and text comprehension questions. Question type (recognition or comprehension) and question modality (picture or text) were within-subjects variables. Study condition (picture or text) and study time (1, 2, or 4 minutes) were between-subjects variables. Test version (A&B or C&D) and visual-verbal learning style rating (1-7) were input as covariates. The Bonferroni adjustment was made for all post-hoc analyses.

Study Condition, Question Type, and Question Modality Results

As hypothesized (H1), there was a main effect of question type, with participants scoring higher on recognition questions than on comprehension questions (84.1% vs. 58.8%; p = .000).

There was no main effect of study condition across all questions and all times (p = .207). However, as predicted by the second hypothesis, there was a 2-way interaction of study condition x question type that demonstrated the picture superiority effect for recognition questions. Participants who studied pictures scored higher on recognition questions than those who studied text (87.0% picture study vs. 81.2% text study; p = .001). For comprehension questions, there was no difference between study conditions (58.3% picture study vs. 59.3% text study; p = .672).

Furthermore, there was a 3-way interaction between study condition, question type, and question modality (p = .000). As predicted by the first half of hypothesis 5, there was a modality interaction effect seen for recognition questions. Those who studied pictures scored higher on picture questions than those who studied text (95.5% for picture study vs. 75.3% for text study; p = .000) and those who studied text scored higher on text questions than those who studied pictures (86.9% for text study vs. 78.5% for picture study; p = .000). Another way to look at this is to consider the average scores for the same modality, whether picture study – picture questions or text study – text questions compared to if a modality transfer took place. For the same modality, participants averaged 91.2%, compared to 76.9% for those requiring a modality transfer. In other words, when participants answered questions in the same modality as their study materials, they scored nearly 15 percentage points higher than if a modality transfer occurred. This interaction is presented in the top half of Figure 3.

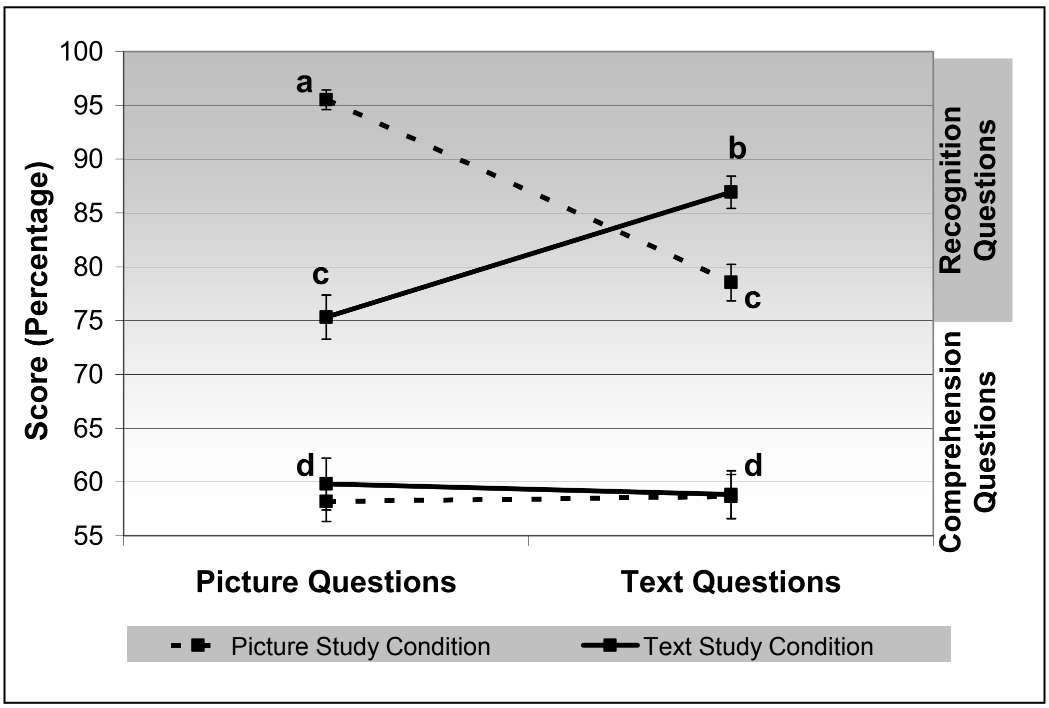

Figure 3. Interaction of study condition with question modality and question type (all study times combined). Points with different letters differ at $p < .001$.

Interestingly, neither the modality interaction effect nor the picture superiority effect was seen for comprehension questions. For comprehension questions, all scores were very close (58.2% picture study-picture test, 58.7% picture study-text test, 59.8% text study-picture test, 58.8% text study-text test). While those who studied text scored numerically higher than those who studied pictures regardless of question modality, this difference was not significant (p = .673). This goes against the expected hypothesis (H3) which predicted a significant difference between study conditions for comprehension questions. It also goes against the second half of hypothesis 5 which predicted a modality interaction effect for comprehension. These results are illustrated in the bottom half of Figure 3.

Impact of Study Time

As anticipated by hypothesis 6, there was a main effect of study time for recognition and comprehension, with overall test scores increasing as study time increased (p = .000). There was also a question type x study time interaction (p = .015) which is illustrated in Figure 4. Scores on recognition questions increased both from the 1- to 2-minute study times (p = .000) and from the 2- to 4-minute study times (p = .001). For comprehension questions, there were no differences in scores between 1- or 2-minute study times (p = 1.00), but there was a sudden increase in scores at the 4-minute study time (p = .002).

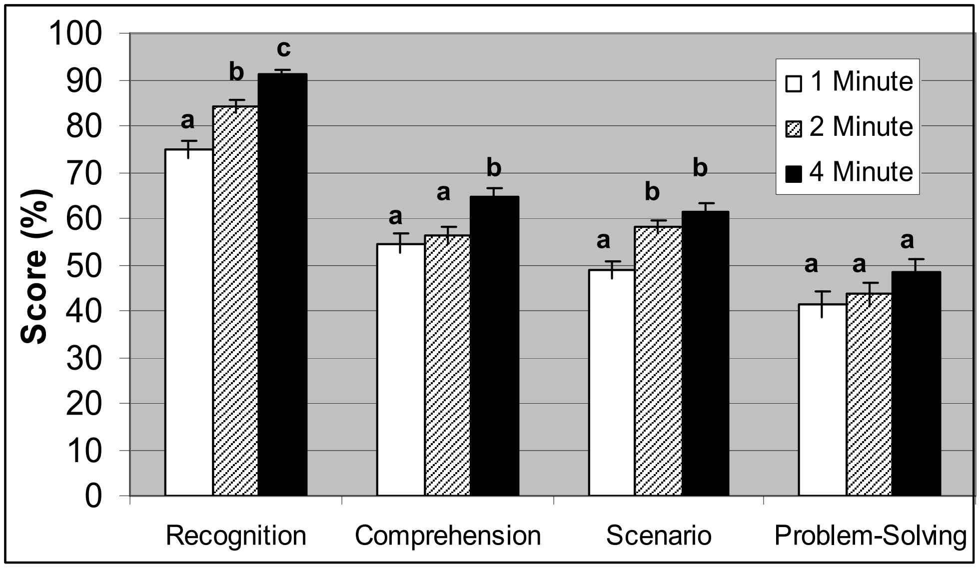

Figure 4. The effect of study time on test score by question type. Scores within question type with different letters differed at $p < .01$.

Histograms showed the comprehension scores were normally distributed at all three study times. Recognition scores were normally distributed at 1- and 2-minute study times, but might have experienced a slight ceiling effect at 4 minutes. However, since the recognition scores were shown to increase significantly from the 2- to 4-minute study time, it does not appear that this possible ceiling effect impacted the results. If anything, removal of the ceiling effect would make the score increase from the 2- to 4-minute study time even greater. Furthermore, when the analysis on study time was re-rerun excluding the 4-minute data, the question type x study time interaction remained ($p = .012$).

There was also a trend towards a study condition x study time interaction ($p = .066$). This trend was further elucidated when the repeated measures model was run at each time period, as described in the following sections.

Results by Study Time

Results at each study time are summarized in Table 5. The model used was the same as that used in the overall analysis except that study time was not included as an independent variable and only data for the specified study time was included. Specifically, recognition and comprehension questions were analyzed using the repeated measure general linear model with question type and question modality as the repeated measures and study condition as the independent variable. Test version (A&B vs. C&D) and visual-verbal learning style were included as covariates.

Table 5

Test Scores (%) ± SE at Each Study Time by Question Type and Modality

Question Type & Modality		1 Min Picture N=27	1 Min Text N = 30	2 Min Picture N = 38	2 Min Text N = 36	4 Min Picture N = 39	4 Min Text N = 36
Recognition	Picture Questions	92.59** ±1.85	63.33 ±4.18	95.18** ±1.88	76.85 ±2.99	97.86** ±0.90	83.80 ±2.78
	Text Questions	69.14 ±3.64	75.00 ±2.62	77.63 ±2.54	87.04* ±2.40	85.90 ±2.33	96.76** ±1.30
Comprehension	Picture Questions	58.02 ±3.92	52.78 ±4.73	57.02 ±2.86	58.33 ±4.17	59.40 ±3.05	67.13 ±3.35
	Text Questions	56.17 ±4.46	51.67 ±3.42	53.51 ±3.45	56.02 ±4.26	65.38 ±2.76	67.59 ±3.25
Transfer	Scenario Questions	46.15 ±2.62	51.79 ±2.48	56.88 ±2.30	59.40 ±2.36	58.19 ±2.05	64.74* ±2.13
	Problem Solving	39.26 ±4.38	43.33 ±4.15	41.58 ±3.38	45.56 ±3.47	51.28 ±3.57	45.56 ±3.72

Note. Within question type and modality, score is higher than the other study condition at

$*p < .05$ or $**p < .001$

At One Minute

At the 1-minute study time, a main effect of study condition emerged with the picture study condition scoring higher overall than the text study condition (69.3% vs.

60.4%; *p* = .016). This agrees with the first half of hypothesis 8, which predicted the picture study condition would outperform the text study condition at shorter study times.

There was no interaction between study condition and question type, suggesting that this overall picture superiority effect applies to both recognition and comprehension. However, a 3-way interaction of study condition x question type x question modality showed that this overall picture superiority effect was being driven primarily by the recognition picture questions.

For recognition picture questions, those who studied pictures scored higher than those who studied text ($p = .000$). For recognition text questions, there was no difference between those who studied pictures and those who studied text ($p = .190$). Likewise, for comprehension picture questions and comprehension text questions, there was no difference between those who studied pictures and those who studied text, although pictures were numerically higher (all at $p > .400$). As in the overall analysis, scores were higher on recognition questions than on comprehension questions ($p = .010$).

At Two Minutes

The overall picture superiority effect seen at the 1-minute study time disappeared at the 2-minute study time; there was no main effect of study condition ($p = .852$). As predicted by the second half of hypothesis 8, the picture study condition did not outperform the text study condition at this longer study time.

A 3-way interaction of study condition x question type x question modality ($p = .004$) demonstrated a modality interaction effect for recognition questions whereby scores were highest when the modality of the study condition matched the modality of the questions. For picture recognition questions, those who studied pictures scored higher than those who studied text (95.1% picture study vs. 76.8% text study, *p* = .000). For text recognition questions, those who studied text scored higher than those who studied pictures (87.0% text study vs. 77.7% picture study, *p* = .009).

This modality interaction effect disappeared for comprehension questions. For comprehension picture questions, there was no difference between those who studied pictures and those who studied text (57.0% picture study vs. 58.3% text study; *p* = .796). Likewise, for comprehension text questions, there was no difference between those who studied pictures and those who studied text (53.5% picture study vs. 56.0% text study; *p* = .647).

Interestingly, a study condition x question type interaction was seen (*p* = .016) suggesting those who studied pictures scored higher on recognition questions than those who studied text, while those who studied text scored higher on comprehension questions than those who studied pictures. This interaction replicates the finding for the overall analysis. However, the post-hocs on this interaction looked for study condition effects for recognition questions and for comprehension questions and both were non-significant (both at *p* > .100). Thus, while the interaction was significant, effects within each question type were not.

As expected, scores on recognition questions were higher than scores on comprehension questions (*p* = .000). This agrees with both the overall analysis and the results at the 1-minute study time.

At Four Minutes

As in the 2-minute study time, there was no main effect of study condition (p = .380). This confirms the results predicted by the second half of hypothesis 8, which stated that the picture study condition would not outperform the text study condition for the longer study times.

Like the results seen for the 2-minute study time, there was a 3-way interaction between study condition, question type, and question modality for the 4-minute study time (p = .000). This 3-way interaction again demonstrated a modality interaction effect for recognition questions. For recognition picture questions, those who studied pictures scored higher than those who studied text (97.8% picture study vs. 83.8% text study; p = .000). For recognition text questions, those who studied text scored higher than those who studied pictures (96.8% text study vs. 85.8% picture study; p = .000). Thus, the overall picture superiority effect for recognition seen at the 1-minute study time has been replaced by a modality interaction effect at the longer study times.

This modality interaction effect disappeared for comprehension questions. Although those who studied text scored numerically higher than those who studied pictures for both comprehension picture questions (67.2% text study condition vs. 59.3% picture study condition; p = .092) and comprehension text questions (67.7% text study vs. 65.3% picture study, p = .605) this difference was not significant.

Also similar to the 2-minute study time and the overall analysis, there was a study condition x question type interaction (p = .016). The picture study condition scored numerically higher on recognition questions than the text study condition (91.8% vs. 90.3%) while the text study condition scored numerically higher on comprehension questions than the picture study condition (67.3 vs. 62.3). These scores were similar, however, and the posthocs on the interaction were not significant (all at $p > .100$).

Again, scores were higher on recognition questions than on comprehension questions ($p = .000$). This replicates results seen overall as well as for the 1- and 2-minute study times.

Section 2 Results: Transfer

The Model

Because they were not part of the repeated measures design, transfer scores were analyzed separately from recognition and comprehension,. For each type of transfer task (scenario transfer and problem solving transfer) analysis was done using the general linear model univariate procedure with test score as the dependent variable and study condition (picture or text) and study time (1, 2, or 4 minutes) as the independent variables. No covariates were needed. The Bonferroni adjustment was made for all post-hoc analyses.

Transfer Questions Results

As predicted by the fourth hypothesis, there was a main effect of study condition for the scenario transfer questions ($p = .011$). Students who studied text scored higher than students who studied pictures (58.6% text study condition vs. 53.7% picture study condition). This difference was driven primarily by the test scores at the 4-minute study time (Figure 5). While the text study condition scored numerically higher than the picture study condition at each study time, this difference was greatest and statistically significant at the 4-minute study time (64.7% for text study condition vs. 58.2% for picture study condition; $p = .03$). There was no study condition by study time interaction ($p = .640$).

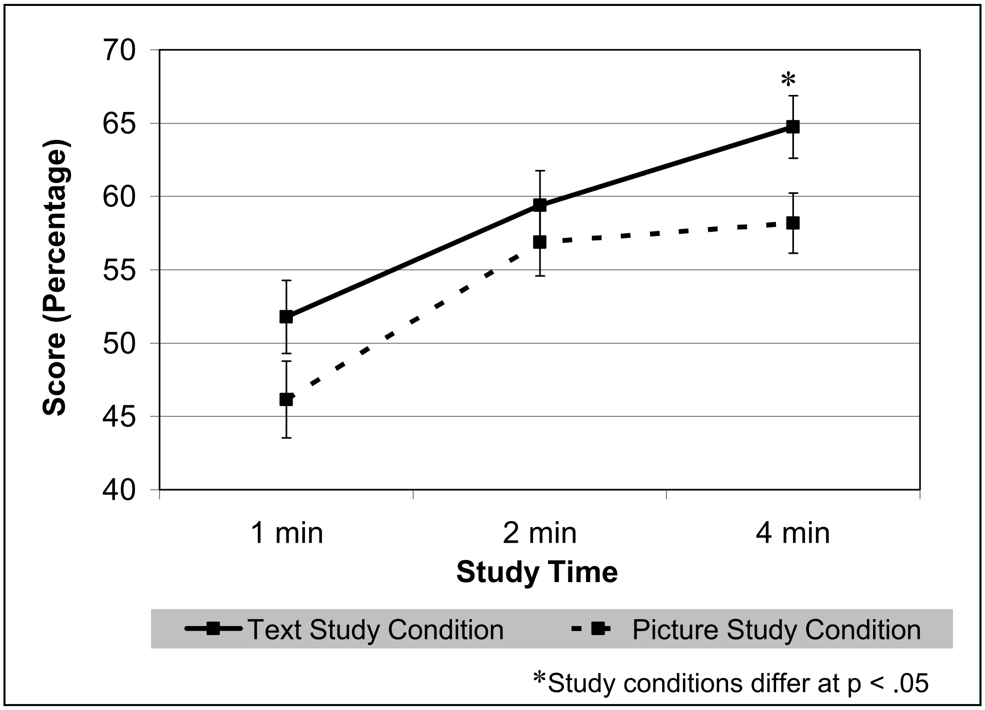

Figure 5. Scenario transfer scores across study times.

For the problem solving transfer questions, there was no difference in test scores between the picture study condition and text study condition (44.0% picture study vs. 44.8% text study; $p = .802$). These results are in contrast to the predictions made by the fourth hypothesis. Thus, hypothesis four was supported for the scenario transfer but not for the problem-solving transfer. Possible explanations for this are discussed in the next chapter.

Impact of Study Time

As predicted by hypothesis 7, there was a main effect of study time for the scenario transfer questions. As shown in Figure 4, scores increased from the 1- to 2-minute study times (49.0% vs. 58.1%; $p = .000$), but there was no further increase in score moving from the 2- to 4-minute study times (58.1% vs. 61.4%; $p = .407$). For the problem solving questions, there was no effect of study time ($p = .158$) and no study condition by study time interaction ($p = .310$). Possible reasons for this are explored in the next chapter. Thus, hypothesis 7 was supported for the scenario transfer task but not for the problem-solving transfer task.

To further understand the impact of study time, each transfer task was further analyzed using the general linear model univariate procedure using the data from each study time. Transfer score (scenario or problem solving) was the dependent variable and study condition was the independent variable. Results for each study time are shown in Table 5.

At One Minute

For the transfer questions, there was no difference between study conditions at the 1-minute study time. This was true for both the scenario transfer task ($p = .124$) and the problem solving transfer task ($p = .502$). Thus, hypothesis 9 was supported, which predicted that the picture advantage seen for recognition questions at the shorter study times would not be present for the transfer tasks.

At Two Minutes

As with the 1-minute study time, there was no difference between study conditions for the transfer tasks for the 2-minute study time. This was true for both the scenario transfer (p = .447) and the problem solving transfer (p = .675).

At Four Minutes

As in the overall analysis, the text study condition outperformed the picture study condition on the scenario transfer task (p = .030) for the 4-minute study time. There was no difference between conditions for the problem solving transfer task (p = .270) at four minutes.

Section 3 Results: Confidence Scores

The Model

Before analyzing participants' self-reported confidence in their answers, possible confounding effects of test version and demographic variables were assessed. Because most demographic variables were shown to be evenly distributed across treatments (see above section on tests and demographics), only the test versions and visual-verbal learning style were considered as possible covariates. A repeated measure general linear model was run with picture recognition confidence, text recognition confidence, picture comprehension confidence, and text comprehension confidence as the dependent repeated measures. Test version or ranking on the verbal-visual Likert scale were the independent variables.

Similar to the results seen using test scores as the dependent variable, test version was shown to have no main effect (p = .484), but to be part of a 3-way question type x question modality x test version interaction (p = .000). As a result, test version was included as a covariate in the confidence scores analysis. Visual-Verbal learning style had a trend towards a main effect (p = .074) and also had a 3-way question type x question modality x visual-verbal learning style interaction (p = .004). Thus, visual-verbal learning style was also included as a covariate in the confidence scores analysis.

Confidence Rating Results for Recognition and Comprehension

As predicted by hypothesis 10, participants indicated a greater confidence for recognition questions than for comprehension questions (4.0 vs. 3.5; p = .000).

Overall, there was a main effect of study time (p = .001) as well as a study time x question type interaction (p = .000). For recognition questions, confidence increased both from 1 to 2 minutes (3.5 vs. 4.1; p = .000) and from 2 to 4 minutes (4.1 vs. 4.4; p = .001). For comprehension questions, confidence increased from 1 to 2 minutes (3.2 vs. 3.6; p = .000) but not from 2 minutes to 4 minutes (3.6 vs. 3.7; p = .575).

There was also a main effect of study condition, with those studying pictures declaring a greater confidence in their answers than those studying text (p = .001). This was true for both recognition (p = .000) and comprehension (p = .02) questions.

A 3-way interaction between study condition, question type, and question modality also emerged. For picture recognition questions, those who studied pictures expressed more confidence than those who studied text (4.6 vs. 3.7; p = .000) while for text recognition questions, those who studied pictures and those who studied text expressed nearly identical confidence (3.95 vs. 3.98; p = .790). Similarly, for picture comprehension questions, those who studied pictures expressed more confidence than those who studied text (3.7 vs. 3.4; p = .005) while for text comprehension questions there was no difference in confidence between those who studied pictures and those who studied text (3.43 vs. 3.38; p = .653). Taken together, these numbers reflect a 2-way study condition x question modality interaction that was also seen, where those who studied pictures expressed greater confidence in picture questions than did those who studied text (4.2 vs. 3.5; p = .000). Alternatively, for text questions, there was no difference between those who studied pictures and those who studied text (3.71 vs. 3.69; p = .844). These results partially support hypothesis 11; a modality interaction effect was seen for pictures but not for text.

Confidence at the 1-Minute Study Time

At the 1-minute study time, the main effect of question type remained, with recognition questions being answered with higher confidence than comprehension questions (3.6 vs. 3.2; p = .011). There was also a main effect of study condition, with those who studied pictures indicating greater confidence across all questions than those who studied text (3.6 vs. 3.1; p = .003). This was true for both recognition questions (p = .000) and comprehension questions (p = .016)

A 3-way interaction between study condition, question type, and question modality was also present. For picture recognition questions, those who studied pictures expressed more confidence than those who studied text (4.4 vs. 3.1; p = .000) while for text recognition questions, those who studied pictures and those who studied text expressed similar confidence (3.5 vs. 3.3; p = .387). For picture comprehension questions, those who studied pictures numerically indicated more confidence than those who studied text (3.6 vs. 3.1; p = .017), but once the Bonferroni adjustment is made at .05/4 = .0125, this comparison is not significant. For text comprehension questions, there was no difference in confidence between those who studied pictures and those who studied text (3.2 vs. 3.0; p = .339). Taken together, these numbers reflect a 2-way modality by study condition interaction that was also seen, where those who studied pictures expressed greater confidence in picture questions than did those who studied text (4.0 vs. 3.1; p = .000). Alternatively, for text questions, there was no difference between those who studied pictures and those who studied text (3.4 vs. 3.3; p = .180).

Confidence at the 2-Minute Study Time

At the 2-minute study time, as in the 1- minute and overall analysis, there was a main effect of question type, with participants indicating greater confidence on recognition questions than on comprehension questions (4.1 vs. 3.6; p = .003). The main effect of study condition disappeared, with those studying pictures expressing similar confidence as those studying text (3.88 vs. 3.76; p = .546). However, there emerged a study condition x question type interaction (p = .023). Post hoc analysis indicated those who studied pictures expressed greater confidence on recognition questions than those who studied text (4.3 vs. 3.9; p = .015). There was no difference between study conditions for comprehension questions (3.6 vs. 3.5; p = .602).

There was also a study condition x question modality interaction (p = .000). For picture questions, those who studied pictures indicated greater confidence than those who studied text (4.2 vs. 3.6; $p = .000$) while for text questions there was no difference between study conditions (3.7 picture vs. 3.8 text; $p = .562$). These 2-way interactions are further elucidated by a 3-way interaction between study condition, question type, and question modality ($p = .002$). For picture recognition questions, those studying pictures indicated greater confidence than those studying text (4.6 vs. 3.7; $p = .000$). For text recognition questions, picture comprehension questions, and text comprehension questions, there was no difference between study conditions (all at $p > .1$). Thus, the study condition x question modality interaction and the study condition x question type interaction are being primarily driven by differences on picture recognition questions.

Confidence at the 4-Minute Study Time

At the 4-minute study time, question type was again significant, with participants indicating greater confidence for recognition questions than for comprehension questions (4.4 vs. 3.7; $p = .03$). Study condition was marginally statistically significant at $p = .051$; those studying pictures indicated greater confidence than those studying text (4.1 vs. 3.9). This was especially true for recognition questions (4.6 vs. 4.2; $p = .000$) and less so for comprehension questions (3.7 vs. 3.6;
$p = .322$). Those studying pictures also indicated greater confidence on picture questions than did those studying text (4.3 vs. 3.9; $p = .000$), while there was no difference between study conditions for text questions ($p = .385$).

Similar to the 2-minute study time, there was a 3-way interaction between study condition, question type, and question modality ($p = .000$). For picture recognition questions, those studying pictures indicated greater confidence than those studying text

(4.9 vs. 4.1; $p = .000$). There was no difference between study conditions for text recognition questions, picture comprehension questions, and text comprehension questions (all at $p > .1$). This again suggests that the study condition x question modality interaction and the study condition x question type interaction were being primarily driven by differences on picture recognition questions.

Confidence Rating Results for Scenario Transfer

A univariate analysis using the general linear model showed the demographic variable visual-verbal learning style had no impact on confidence scores for the scenario transfer questions ($p = .206$). Thus, this variable was excluded from the model. To assess if study condition had any impact on confidence for the scenario transfer question, a univariate analysis using the general linear model was run. Confidence score was the dependent variable, while study condition and time were input as fixed factors.

Confidence on the scenario transfer questions increased from the 1-minute study time to the 2-minute study time (3.4 to 3.8; $p = .018$). There was no change in confidence from the 2-minute study time to the 4-minute study time (3.8 to 3.9; $p = 1.0$). There was no difference in confidence between study conditions either overall (3.72 for picture study vs. 3.67 for text study; $p = .636$) or at each time period (all at $p > .6$)

Examination of Research Question Two

The second research question asked "For each level of learning, does the pattern of confidence ratings in each study condition follow the same pattern as the test scores?" A comparison of confidence ratings to actual scores provides some interesting findings.

Averaged across all study times, both the confidence ratings and actual test scores show an advantage for recognition questions compared to comprehension questions. Slight differences emerge, however, when the study conditions are considered. While test scores showed a picture advantage for recognition questions, confidence ratings showed a picture advantage for both recognition and comprehension.

Also, the modality interaction effect seen for recognition test scores, where those who studied pictures scored higher on picture recognition questions and those who studied text scored higher on text recognition questions, was only partially reflected by confidence ratings. For the confidence ratings, those who studied pictures expressed more confidence than those who studied text for the picture recognition questions, but there was no difference in confidence rating for the text recognition questions. Overall, then, those who studied pictures indicated greater confidence for recognition questions than what the actual test scores reflected.

Furthermore, at the level of comprehension, neither a picture superiority effect nor a modality interaction effect was indicated by actual test scores. However, participants' self-reported confidence indicated greater confidence for the picture study condition than for the text study condition. There was also a partial modality interaction effect seen in the confidence ratings; for picture comprehension questions, those who studied pictures expressed more confidence than those who studied text while for text comprehension questions there was no difference in confidence between those who studied pictures and those who studied text. This partial modality interaction effect was not seen in actual test scores.

At the level of transfer, there were also differences between the confidence rating and what actual test scores showed. The text study condition scored higher than the picture study condition for the scenario transfer task averaged across all study times and at the 4-minute study time. However, there was no difference in confidence between study conditions either overall or at any time period.

Taken together, these results suggest there are differences between the pattern of confidence ratings and the pattern of actual test scores at each level of learning. Further discussion is provided in the next chapter.

Confidence – Test Score Correlations

The pattern of results described above suggests difference between confidence ratings and actual test scores. To mathematically assess how well participants' self-reported confidence aligned with their actual test scores, correlations were run for both the picture study condition and the text study condition. Paired sample t-tests were used to identify differences between self-reported confidence scores and actual test scores. Results are summarized in Table 6.

Interestingly, those in the text study condition had significantly lower confidence in their text recognition responses than their actual test score ($p < .001$) while there was no difference between their confidence and test score for the picture recognition questions ($p = .165$). Likewise, participants in the picture study condition had a lower confidence in their picture recognition responses than their actual test score ($p = .023$) while there was no difference between their confidence and test score for text recognition question ($p = .756$). Both study conditions had significantly higher confidence than test scores for picture comprehension, text comprehension, and the transfer scenario (all at $p < .001$).

Table 6

Correlations Between Test Scores and Self-Reported Confidence (± SE) by Question Type

	Text Study Condition (N = 102)			Picture Study Condition (N = 104)		
Question Type	Mean Score	Mean Confidence	Correlation	Mean Score	Mean Confidence	Correlation
Picture Recognition	75.33 ±2.05	73.01 ±1.60	0.612**	95.51 ±0.92	92.51* ±1.27	0.322**
Text Recognition	86.93 ±1.50	79.64** ±1.69	0.655**	78.53 ±1.70	79.03 ±1.55	0.503**
Picture Comprehension	59.81 ±2.39	68.93** ±1.51	0.591**	58.17 ±1.84	74.78** ±1.42	0.103
Text Comprehension	58.82 ±2.22	67.76** ±1.38	0.400**	58.65 ±2.05	68.69** ±1.53	0.400**
Transfer Scenario	59.05 ±1.60	73.76* ±1.62	0.342**	54.59 ±1.20	74.90** ±1.21	0.218 *

*Note. Confidence differed from test score or correlation was significant at *p < .05; **p < .001*

In general, correlations were weaker for the picture study condition than for the text study condition. No correlation was found for participants in the picture study condition for picture comprehension questions ($p = .296$). Alternatively, positive correlations were found for every question type for participants in the text study condition. A one-tailed t-test comparing the correlations for the different questions showed that correlations for the text study condition were significantly higher than those in the picture study condition ($p = .03$). Thus, in response to the third research question, there is indeed a difference in correlation between confidence and actual test scores, with those in the text study condition having a stronger correlation between their confidence and actual test scores. Alternatively, those in the picture study condition indicated greater confidence in their answers than what their actual test scores warrant. Further discussion of these results is provided in the next chapter.

CHAPTER 5: DISCUSSION

One of the unique aspects of this study was the incorporation of several data layers within a single experimental design. This was made possible by the split-plot design that included both within-subject and between-subject variables. This design allowed for comparisons across study times, across learning levels, and across modality while accounting for related factors, such as learning style. The addition of the transfer tasks as a separate analysis expanded the study across three levels of learning. And, the self reported confidence of participants as they answered the different question types provides interesting insight into the differential processing of pictures and text.

The preceding chapter shared results from the many aspects of this study. Here, the placement of these results within existing literature is explored. Even considered separately, each individual result is interesting and could spawn its own follow-up studies (some ideas of which are provided here). However, it should be remembered from the introduction that the complexity of the design used was chosen for its ability to address a particular overarching question: As question complexity increases, does performance advantage switch from the picture study condition to the text study condition?

While the various facets of this study are important in their own right (e.g., the impact of learning style) and are included here for the interested reader, discussion will culminate by returning to this key question. The individual results of this study, when taken together, provide some interesting insight into the role of pictures vs. text in learning. Thus, the following sections provide a brief discussion of the various layers of the study – from the validation of materials through the use of self-reported confidence scores. Throughout this discussion, it should be remembered that these points lead to the final conclusion of the study: As question complexity increases, performance advantage does indeed switch from the picture study condition to the text study condition.

Material Validation

One of the most critical confounding factors to control when investigating visual vs. verbal learning is the task-specific informational equivalence of the visual and verbal materials used (e.g., Finnegan, 2006; Standing & Smith, 1975; Schnotz, 2002; Zillman et al., 1999). Failure to achieve this equivalency makes it difficult to assess whether differences seen are the result of the different modality or the result of different information provided to each treatment. Such an impact could undermine the results of the study; thus, this is not a topic to take lightly.

This study utilized a 3-pronged approach to material validation, including validation of the materials though a matching exercise, experimental control through the design of the materials, and statistical control through inclusion of necessary covariates. Results indicate task-specific informational equivalence was achieved.

According to Schnotz (2002), task-specific equivalence is achieved when individuals can use the information presented in picture or in text modality to answer the same questions. Previous picture and text research has typically controlled the equivalence of picture and text materials in one of two ways. Some studies had two independent observers view the pictures and create the equivalent text statements, evolving a consensus version if necessary (e.g., Standing & Smith, 1975). Others have used picture and text combinations already in existence, such as from encyclopedia entries (e.g., Mayer, 1997). Such previous research, however, has not reported empirical support for how their participants actually viewed the materials. The present study sought to provide empirical support for the information equivalence by having individuals match picture and text statements. This matching exercise, it was thought, would show whether participants were identifying the same information in the picture and in the text, since the similarities would have to be noticed before participants could make the appropriate match.

During the material validation phase of the study, participants drawn from the same pool as the main study correctly matched the equivalent pictures and text an average of 95% of the time, suggesting they recognized the same information whether it was presented in picture or text form. This supports the task-specific informational equivalence of the two modalities.

Experimental control was established by the creation of different test versions, which allowed the same question to be asked in both visual and verbal modality. The effectiveness of this control was demonstrated by the lack of a test version main effect. Further statistical control was achieved by including test version as a covariate in the models, which acted as an extra precaution against the question type x question modality x test interaction.

Taken together, these validations suggest that the study's results may be attributed to a modality impact rather than any differences in information that was presented. These results also suggest some important safeguards that may be used when designing this type of research: (1) use black and white as opposed to color images to prevent unequivocal cognitive load (Meyers-Levy & Peracchio, 1995); (2) choose images that minimize irrelevant details, since extraneous information has been shown to reduce learning (Mayer et al., 2001; Mayer et al., 1996); (3) highlight the saliency of image details with circles or arrows and use appropriate graphing techniques that minimize viewer confusion (Shah & Hoeffner, 2002); (4) identify the image first and then create the text. This allows for a more precise description of the image; (5) test materials with individuals draw from the same pool as the main study participants by having them match the informationally equivalent text and pictures; eliminate any pairs which participants frequently mis-match; (6) create different test versions so that the same question is asked in both picture and text form. This ensures that all the questions in one modality aren't "easier" to answer.

Impact of Learning Style

The impact of learning style was investigated to determine if learning style needed to be included as a covariate in the study's models. Since learning style was not a major variable under investigation in this study, the discussion here must be held within constraint of this fact. It is intended, however, that a discussion of the available learning style findings will allow the interested reader to utilize this information as a whiteboard for investigative ideas.

For recognition questions, students who indicated a preference for visual learning scored higher on picture recognition questions than on text recognition questions. It may be recalled that the learning style measure used in this study measures an individual's "cognitive style," or the way in which they process information (Mayer & Massa, 2003). It follows logically, then, that students with a visual cognitive style will process information visually and, thus, would have an easier time encoding visual material. This also agrees with previous work. A positive correlation has been shown between visual learning preference and recall of material that includes pictures (Chatterton, 2006).

It should be noted that some work has shown no difference in recall when students indicating high visual preference learn from text with photos versus plain text (Mendelson & Thorson, 2004). Direct comparisons with this study are difficult, however, because of differences in learning style measures. While the present study placed verbal and visual learning at opposite ends of the same continuum, Mendelson and Thorson (2004) did not – effectively creating nine categories of visual-verbal learning style compared to this study's three categories. More detailed analysis of learning style was outside the scope of this study.

Still, the implications of a learning style impact on memory merits some attention. The result that students indicating a visual learning style preference scored better on picture questions than on text questions suggests that the types of assessments used can impact results. In fact, these students scored more than five percentage points higher (88.0% vs. 82.1%) when the questions were in picture form rather than in text form. The existence of this scoring discrepancy becomes even more important when one considers that most students in the study (72%) indicated a visual preference. This proportion of visual learners suggests that any interaction between learning style and question modality will impact more than an occasional student. While care needs to be taken not to generalize this finding beyond the experimental population, this does agree with previous reports that suggest the majority of the population are visual learners (Barbe & Milone, 1980; Reiff, 1992; Silverman, 2002). Thus, whether an assessment is in visual or verbal modality could potentially impact a majority of test takers. Future research may wish to examine this possibility.

Taken together, the preceding discussion suggests the existence of a learning style x question modality interaction for recognition memory. For the present study, this conclusion resulted in the inclusion of learning style as a covariate so that the hypotheses put forth could be investigated without this confounding factor. However, the possibility of such an interaction warrants further research specifically investigating learning style and question modality.

An additional point of interest to the present study relates to the effect of learning style across learning levels. While an impact of learning style was seen for recognition questions as discussed above, there was no impact of learning style for comprehension or transfer questions. This agrees with work by Massa and Mayer (2006) that showed matching instructional materials to a verbal or visual learning style did not improve comprehension or problem solving transfer.

The waning of a learning style effect for deeper levels of learning is a point that deserves a more direct investigation. Whether or not learning style differentially affects different learning levels is an important question for education professionals and researchers alike. Both instructional and assessment materials may need to account for learning style for some types of learning but not others. Preliminary results from the present study suggest that when measuring recognition memory, simply changing the modality of the questions could increase or decrease a student's grade by half a letter grade or more. Or, an experimenter's research could be skewed by more than five percentage points. This is an effect that warrants further attention.

Impact of Learning Level

One of the main objectives of this research was to assess modality effects across three levels of learning: memory, comprehension, and transfer. Previous research has shown a picture superiority effect at the level of memory (Paivio & Csapo, 1973; Standing, 1973; Standing & Smith, 1975), but more inconclusive results at the levels of comprehension and transfer (e.g., Butcher, 2006; Mayer et al., 2006). Previous research generally lacks the direct attention to text-only and picture-only treatments needed to specifically compare text and pictures at deeper levels of learning, although such research is not completely absent (e.g., Mayer & Anderson, 1991). Instead, previous research tends to favor text and picture combinations assessed at one or two levels of learning (e.g., Mayer, 1997; Mayer & Sims, 1994). In contrast, the current research effectively demonstrated the impact of modality across three different levels of learning.

Averaged across all study times and all study questions, there was no main effect of study condition, but an important study condition x question type interaction emerged. For recognition questions, those who studied pictures scored higher than those who studied text, demonstrating the previously identified picture superiority effect (Paivio & Csapo, 1973; Standing, 1973; Standing and Smith, 1975). This result lends further support to the validity of the materials used. By receiving the expected result at the level of recognition, further confidence can be placed on the results obtained at the levels of comprehension and transfer, whose results have previously been less well documented.

In addition to the expected picture superiority effect, a modality interaction effect was also present for recognition questions. Those who studied pictures scored higher on picture questions and those who studied text scored higher on text questions. In other words, modality transfer – i.e., studying pictures and answering text questions or studying text and answering picture questions – suppressed scores. This agrees with previous research which also showed that participants score higher when the test item is in the same modality as the study item (Standing & Smith, 1975).

Score suppression during a modality transfer is also supported by transfer appropriate processing theory, which suggests that scores will be highest when conditions present at the time of study match the conditions present at the time of testing (Levin, 1989; Park & Gabrieli, 1995).

Interestingly, both the picture superiority effect and the modality interaction effect disappeared at the level of comprehension. A significant study condition x question type interaction suggests a shift from picture superiority towards text superiority. In fact, those who studied text scored numerically higher on comprehension questions than those who studied pictures. Although these numbers are not statistically significant, they do support a definite shift away from the picture superiority effect for comprehension questions. This shift away from a picture superiority effect is further elucidated with the analysis of the transfer questions. For the scenario transfer question, the text study condition scored higher than the picture study condition. Thus, as the levels of learning move from recognition memory to comprehension to transfer, the picture superiority effect weakens and a text superiority effect emerges.

One explanation for the shift from a picture superiority effect for recognition questions to a text superiority effect for deeper levels of learning may lie in the way visual and verbal information is stored. Visual information is perceived and stored as concrete imagens, particularly by high visualizers (Paivio, 1971). Visual memory storage may also be more stable than verbal memory (Hart & O'Shanick, 1993), so an exact depiction of the presented material could be maintained longer. When trying to remember an exact image, as was necessary for the recognition questions, such a precise mental representation is beneficial.

Alternatively, as one moves to deeper levels of learning, especially to the level of transfer where individuals are required to apply their learning to new situations, it becomes more important that the learner is able to manipulate the information and use it in new ways. For these tasks, flexibility in the mental representation becomes paramount. Such flexibility may favor verbal mental representations, which seem to be stored in a slightly more fluid fashion. Whereas visual representations depict one specific instance, verbal representations can include general concepts and whole classes of instances (Schnotz, 2002).

An additional explanation for the text superiority effect seen in transfer questions may lie in the need for both representational and referential connections to effectively solve transfer problems (Mayer & Sims, 1994). Representational connections are formed between the study material and the mental representation in the same modality as the study material. Referential connections are formed between the mental representation and other mental representations in the opposite modality. Because visual representations can be generated during verbal learning (e.g., Alesandrini, 1981; Mayer, 1997), participants in the text study condition may have been able to generate both verbal and visual representations more easily than those in the picture study condition. They could then establish the necessary referential connections that aid transfer. Alternatively, since visual representations generated from verbal information are weaker than visual representations generated from visual information (Paivio, 2007), and since only representational connections are necessary for memory (Mayer & Sims, 1994), the picture study condition would favor recognition memory. Indeed, this was seen in the picture superiority effect demonstrated for recognition.

Because all transfer questions were asked in text format, the possibility of a modality interaction effect impacting transfer results must be considered. However, there are a couple reasons why a modality interaction effect is likely not the only, or even primary, reason for the emergent text superiority effect. First is the study condition x question type interaction seen for the recognition and comprehension questions, where the text study condition scored numerically higher than the picture study condition on all comprehension questions. This suggests a trend towards a text superiority effect is already starting at the level of comprehension. The appearance of a text superiority effect at the level of transfer is a logical continuation of this trend.

Second, while there is a modality interaction effect for recognition questions, there is no modality interaction effect for comprehension questions. This is true both overall and at every study time (one minute, two minutes, and four minutes). Since transfer questions are hierarchically closer to comprehension than to recognition memory

(Bloom et al., 1956), there is no reason to believe a modality interaction effect would appear for transfer when it was not present for comprehension.

Still, the experimental design of this study cannot conclusively rule out the possibility of a modality interaction effect impacting the transfer results. In this case, the questions arise: what if the transfer results are due to a modality interaction effect? What if those who study text perform better on textual transfer tasks and those who study pictures perform better on pictorial transfer tasks?

If anything, the possibility of a modality interaction effect at the level of transfer has even greater implications for education professionals and researchers. In the presence of a modality interaction effect, the modality of instructional materials should match the modality of the assessments in order to maximize performance. However, this raises the question of how transfer learning should be defined. Is it enough if students score well in the same modality? Or is true transfer learning achieved only if a modality transfer is included as part of the transfer task?

Future research should further investigate the possible existence of a modality interaction effect at the level of transfer. Unfortunately, the difficulty of establishing an effective transfer problem that can be shown to be informationally equivalent in both picture and text modality should not be underestimated. Perhaps different treatments of an analogical transfer problem could use diagrams and text; students could draw or write their replies. Or, a problem within some kind of system could be shown both pictorially and in text. Students could draw or describe either an addition or an adaptation to the system that would solve the problem using some principle they had previously learned in either picture or text form. These are merely skeletons of transfer problems that would need to be developed, however. Clearly, whatever form these transfer problems would take, a great deal of creativity and experimental prowess will be needed.

Finally, the lack of results seen for the problem solving transfer questions must be addressed. These questions required participants to abstract key points from both their study materials and a new passage and then combine them in creative ways to answer the questions (e.g., Why might the Emerald Ash Borer cause more damage to the tree population in cities and towns than to the tree population in remote forests?).

Neither study condition nor study time impacted results on the problem solving transfer questions, and several explanations may exist for this. First, there may in fact be no modality advantage for pictures or text when trying to answer problem-solving questions. This would agree with a previous study which included comparable study conditions. In their study, Mayer and Anderson (1991) had students view animated pictures about working a bicycle pump, listen to narration, or both and then answer questions about making the pump more effective and troubleshooting problems with the pump. While the pictures plus narration group outperformed the others, there was no difference between the animation-only or narration-only groups (Mayer & Anderson, 1991). While this study used animation and narration rather than static pictures and text, the results were similar.

Second, the complexity of the problem-solving transfer questions used may have resulted in the lack of study condition and study time effects for the problem-solving transfer while the scenario transfer showed significant effects. Although both scenario transfer questions and problem solving transfer questions may be classified as content transfer questions, the learner skills needed to answer each type of question is different.

The scenario questions required participants to apply their learning to a real-life situation and determine if information presented to them was correct or not. Alternatively, the problem-solving questions required more analytical and creative skills; participants needed to abstract the key points from both their previous learning and the new passage and then combine them in creative ways to answer the questions. Such differences between questions suggest the possibility for differences to be seen between the scenario transfer questions and the problem solving transfer questions, as in fact was the case.

The idea that the problem solving questions required a different skill set is also supported by the fact that an increase in study time did not increase scores on the problem solving transfer questions. Problem solving questions may have been assessing individual students' problem solving abilities more than the actual learning of the material. In other words, if students weren't able to make the appropriate connection between what they learned and what the questions were asking, then their previous learning was useless to them. Research using analogical transfers, which requires a similar connection to be made between what was learned previously and what the current problem is asking, address this issue by assessing both spontaneous transfer and a post-hint transfer (Gick & Holyoak, 1983; Pedone, et al. 2001). Such an approach allows a distinction between those who are truly unable to answer the question and those who merely aren't considering their previous learning as a way to solve the problem.

The problem solving questions used in this study did include instructions to consider both the new passage and the information they saw previously. However, unlike analogical transfer problems that usually have a single schema transferred from the source to the target problem, the content problem-solving questions used here required identification and abstractions of several key facts out of dozens of competing facts.

For example, the radiation problem originated by Duncker (1945) is a common analogical transfer problem that encourages participants to pull from the source a convergence schema which is then applied to a new problem. Comparatively, in the present study, students had to extract and combine numerous facts. Just to answer the first question, students had to: (1) remember information about the migration of the Emerald Ash Borer, the spread of the Emerald Ash Borer by humans, and the tree demographics in Indiana cities and towns; (2) identify these as key facts from among the other information they remembered; (3) extract from the new text the percentage of ash trees in Indiana forests; and (4) appropriately combine this information to reach the conclusion.

Thus, the complexity of these problem solving questions may have produced the lack of study condition or study time effects. Future research may wish to use simpler problem solving transfer problems – perhaps having all the needed information in the original learning rather than requiring the abstraction of ideas from two sources. Future research may also wish to include analogical transfer problems rather than content transfer problems to see if different results are obtained.

Impact of Study Time

An examination of results at each study time also uncovered some interesting findings. At the shortest study time of one minute, an overall picture superiority effect was seen where those in the picture study condition scored higher than those in the text study condition. The presence of an overall picture superiority effect and the lack of a study condition x question type interaction is an interesting deviation from the overall results and the results seen at the 2- and 4- minute study times. This result suggests that pictures are processed faster, allowing those in the picture study condition to encode the information more effectively than those in the text study condition when given a restricted study time. This agrees with other findings that point to a quicker processing of pictures than text (Paivio, 1971; Pizlo et al., 1997; Weidenmann, 1989).

Analysis of the 3-way interaction of study condition x question type x question modality showed that the overall picture superiority effect at one minute is driven largely by the picture recognition questions. As discussed previously, this picture superiority effect for picture recognition questions was expected (Standing & Smith, 1975). However, at the 1-minute study time, the picture study condition also scored numerically higher than the text study condition for comprehension questions, preventing the modality interaction effect (study condition x question type interaction) seen overall and at the 2- and 4-minutes study times. Thus, when participants are given only enough time to quickly skim their study materials, pictures emerge as the overall winner.

The picture superiority effect for shorter study times agrees with two important facets of the picture processing literature. First, individuals who don't have the time to engage in systematic processing rely instead on more heuristic processing (Meyers-Levy & Malaviya, 1999). The "somewhat extensive processing" of heuristic processing has been noted as the opportune level of cognitive processing needed to maximize the impact of pictures on the viewer (Peracchio & Meyers-Levy, 2005, p.39). Thus, pictures can effectively convey information even when there is not time for extensive processing.

Second, the spatial processing of pictures allows for a quicker, more global intake of information than does the sequential processing of text (Paivio, 1971; Pizlo et al., 1997; Weidenmann, 1989). Unfortunately, while spatial processing excels in speed, it may be lacking in depth or flexibility. This becomes evident as study time increases to two or four minutes, where the overall picture superiority effect for recognition and comprehension questions disappeared. By the time the learning level of transfer was reached, text surpassed pictures as the superior learning modality, especially at the longer study times.

Similar to suggestions by others (e.g., Weidenmann, 1989), it appears that when individuals have enough time to process textual information, the sequential processing of text results in a deeper learning than the quicker processing achievable with pictures. However, when under a time constraint, individuals can extract information more quickly from pictures.

At the 2- and 4- minute study times, the picture superiority effect disappeared and was replaced by a modality interaction effect for recognition questions. Those who studied pictures scored higher on picture recognition questions and those who studied text scored higher on text recognition questions. This modality interaction effect for recognition questions was also seen when all study times were averaged, as was discussed in the previous section.

It is also worth noting that neither the picture superiority effect nor the modality interaction effect was present for comprehension questions at any study time (one minute, two minutes, or four minutes). This, too, was seen when all study times were averaged together, as was discussed in the previous section.

As study time increased, recognition scores improved, both from one to two minutes and from two to four minutes. Previous studies have demonstrated individuals' amazing capacity for memory, especially visual memory (Standing, 1973). Results of this study further support this premise. Participants seem to begin memorizing items almost immediately and continue for as long as time allows.

Alternatively, comprehension scores stayed the same between the one and two minute study times and didn't improve until the study time increased to four minutes. This suggests that this deeper level of learning requires a greater processing time before improvements are seen.

Scenario transfer scores improved from one to two minutes but then leveled off and no further improvement is made as study time increased beyond two minutes. This leveling off of transfer scores could be an indication that some of the skills necessary to perform accurate transfer are not enhanced by increased study time. As previously alluded to, a student's ability to transfer information is dependent upon several factors. While this includes an understanding of the study materials, it also includes the abstraction of the relevant facts and the correct application of those facts to the target questions (Bloom et al., 1956). While increasing study time improves comprehension, it does not necessarily improve transfer scores if the other necessary skills are not present.

Overall results of study time can therefore be summarized as follows. Recognition, comprehension, and transfer scores all increased as study time increased. However, recognition scores increased incrementally with study time, while study time exacted its greatest impact on comprehension between two and four minutes and on transfer between one and two minutes. At the shortest study time of one minute, pictures were a superior information source compared to text, but this superiority was lost as study time increased.

These findings may help explain results of other studies that included combinations of pictures and text. For example, it has been shown that when additional text is added to a visual presentation that already includes narration, retention and transfer scores are lower than when the additional text is not present (Mayer et al., 2001). However, if the extra text is limited to a couple key words placed in proximity to the relevant point in the picture, then recall scores improve (Mayer & Johnson, 2008). The authors refer to this as the “redundancy principle,” and suggest the splitting of the visual attention between the onscreen text and image produces a cognitive overload that is reduced when only a couple words rather than complete sentences are incorporated into the picture. The present study also suggests that because text is mentally encoded slower than images, participants would be unable to process both picture and text to the same extent they would be able to process the picture alone in the same amount of time. This would be particularly true if time was spent reading the text prior to engaging with the image.

Alternatively, the couple words incorporated into the picture would not require the same processing time as an entire sentence. The couple words would serve instead to enhance the saliency of the image, similar to the arrows or circles used in the present study, making key points more memorable. The key words would also serve the function Weidenmann (1989) described of engaging the viewer with the key points of the picture. Therefore, it would be expected that the key words incorporated into the picture would improve memory, as was found (Mayer & Johnson, 2008).

Implications of study time also extend into other venues. Whenever viewing time is short, pictures should be chosen over text to increase the amount of information received by the viewer, particularly for recognition memory. For text processing, it is important that adequate time is allowed. Experimentally, researchers need to consider how differential processing time could impact study results.

Participants' Confidence

One of the unique methods employed by this study was the collection of how confident participants were in their answers. This allowed for an alternative measure to gauge differences between study conditions. It also allowed for an interesting assessment of how well the participants' confidence matched their actual test scores.

As expected, participants expressed greater confidence for recognition questions than for comprehension questions, and this was true at each study time and averaged across all study times. This parallels the results seen for the actual test scores.

The effect of study time on confidence was also similar to the effect of study time on test scores, with the exception of comprehension questions. Confidence in answers increased both from one to two minutes and from two to four minutes for recognition questions. This parallels the results seen for test scores. For both comprehension and scenario transfer questions, confidence increased from one to two minutes but not from two to four minutes. While this paralleled the results seen for transfer test scores, it differed from confidence test scores. Actual test scores for comprehension increased from two to four minutes but not from one to two minutes. Thus, for comprehension, even though participants were more confident moving from the 1- to 2- minute study times, their test scores did not reflect this increased confidence.

Perhaps of greatest interest is the main effect seen for study condition, which suggests that the shift from greater confidence in pictures towards greater confidence in text lags behind the shift seen in actual test scores. Confidence on recognition questions was greater for the picture study condition than for the text study condition, which nicely parallels the test results. However, while confidence on comprehension questions remained higher for those who studied pictures than those who studied text, actual test scores did not vary between study conditions. Furthermore, while confidence on transfer scores showed no difference between study conditions, actual test scores showed a text superiority effect. Thus, while confidence scores showed a gradual waning away from a picture study condition preference as learning level deepens, this shift was slower than that seen on the actual test scores and did not culminate in the same preference for the text study condition by the third level of learning.

To graphically represent this shift, the confidence scores and test scores for the text study condition were subtracted from the confidence scores and test scores for the picture study condition and plotted in a bar graph. A positive difference indicates the picture study condition is higher than the text study condition, while a negative difference indicates the text study condition is higher than the picture study condition. Scores near zero suggest there is no difference between study conditions. Figure 6 shows how confidence scores lag behind actual test scores in the transition from a picture superiority effect to a text superiority effect.

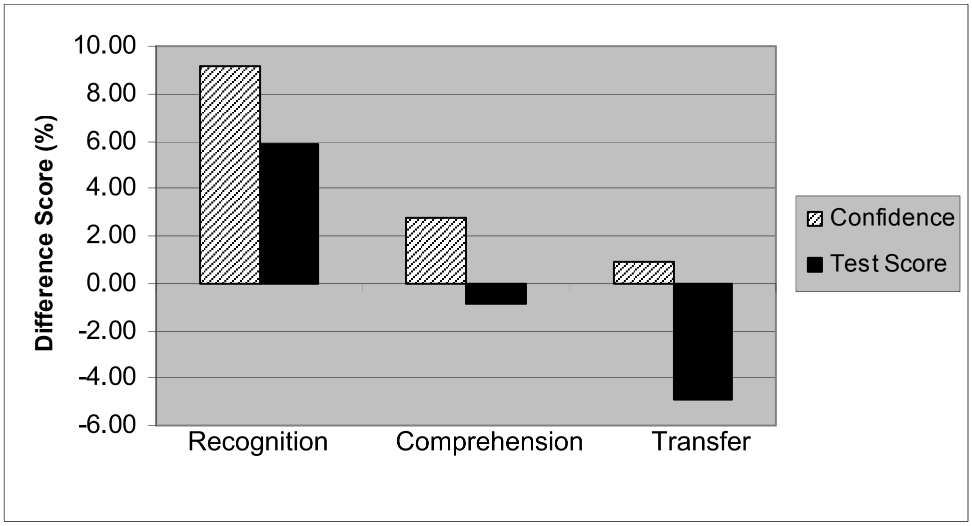

Figure 6. Difference scores of the picture study condition minus the text study condition showing how the confidence scores lag behind the actual test scores in shifting from a picture superiority effect (positive score) to a text superiority effect (negative score) as level of learning deepens.

This pattern supports the premise put forth by Weidenmann (1989) that learners tend to process pictures superficially and may think they understand the information better than they actually do. This may be particularly true when study time is reduced. The difference in patterns seen between confidence scores and test scores for the two study conditions was most prevalent at the shortest study time. At the 1-minute study time, confidence on both recognition and comprehension questions was higher for the picture study condition than the text study condition. At two and four minutes, the main effect is covered by a study condition x question type x question modality interaction. At first observation, this interaction appears to mirror the 3-way interaction seen for test scores. However, the confidence scores lack the strength of the modality interaction effect seen in the test scores. For test scores, those studying pictures score higher on picture recognition questions than those studying text while those studying text score higher on text recognition questions than those studying pictures. For confidence scores, those studying pictures indicate greater confidence on picture recognition questions than those studying text, but there is no difference between study conditions for text recognition questions. Thus, even the 3-way interaction for confidence scores at the 2- and 4- minute study times indicate a preference towards the picture study condition that is not reflected in actual test scores.

Both study conditions undervalued their ability to answer recognition questions that were presented in the same modality as their study condition. This is shown by the difference in test scores and confidence scores provided in the previous chapter (Table 6). For example, those who studied text had a confidence score of 79.64% and an actual score of 86.93% on text recognition questions. Likewise, those who studied pictures had a confidence score of 92.51% and an actual test score of 95.51% on picture recognition question. In both cases, the confidence score was significantly ($p < .05$) lower than the actual test score. Thus, participants were better able to recognize these same-modality questions than they thought they were. This may point to a subconscious ability to identify an exact representation that was previously seen even when participants are not consciously sure they are choosing the right answer.

Such subconscious mental activity is frequently evidenced in the advertising literature. Even when individuals are not conscious of the connection between what they are seeing and their actions, research suggests that this connection exists. For example, color has been shown to impact an individual's actions, from encouraging people to shop to making them eat faster (Barry, 1997). Likewise, taste tests have shown that package design can improve or detract from a product's taste, and simple alterations to product packaging – color, shape, graphics – can increase sales by 25%, or more (Barry, 1997; Gladwell, 2005). Clearly the possibility of a subconscious impact exists. It is not a large extrapolation to suggest that learners may likewise be able to more easily identify an exact representation than they think, because of a subconscious mental activity. Further research is needed to investigate this intriguing concept.

On the other hand, for recognition questions in the opposite modality of their study condition, all participants showed no difference between their confidence scores and their actual test scores (Table 6). Participants scored as well as they thought they would. This may be explained by the need for a modality transfer to occur in order for participants to recognize the correct answer. According to the definition of high-road transfer (Salomon and Perkins, 1989), this modality transfer would be an explicit and conscious act. Thus, participants would be more consciously aware of what they did and did not remember.

Both those who studied pictures and those who studied text exhibited greater confidence scores than actual test scores for comprehension and transfer questions (Table 6). In other words, participants were overconfident in their ability to answer comprehension and transfer questions. This may be a reflection of the movement from one level of learning to another. The relatively high recognition scores show that participants were able to remember the material, suggesting that appropriate mental representations of the study materials were made. However, despite the apparent existence of these representations, participants scored lower on comprehension questions. Apparently, the existence of a mental representation does not indicate an understanding of the representation or an ability to transfer the representation to new situations.

This inability to understand or transfer a mental representation supports previous transfer research which has shown that even if participants can answer questions about the source to demonstrate they remember it, they may not be able to apply it to solve the target problem (Beveridge & Parkins, 1987). In the present study when participants are providing a self-reported confidence, the fact that they could remember the material may have caused them to believe they had a deeper learning of the material than they actually did.

Overconfidence was especially a problem for those who studied pictures. In fact, for those who studied pictures, there was not even a correlation between their confidence scores and their actual test scores for picture comprehension questions, suggesting that questions they thought they were getting right they were not, and vice versa. Furthermore, a comparison between the text study condition and the picture study condition shows that correlations between actual test scores and participants' confidence in their answers was significantly greater for those who studied text than for those who studied pictures. In other words, those who studied text were better able to assess how well they would score. Those who studied pictures thought they would do better than they actually did.

This finding aligns with research that suggests people often think they have processed pictures deeper than they have. Weidenmann (1989) notes "the subjective ease of encoding [pictures] at a superficial level may lead the learner to the illusion of a full understanding" (p. 163). That is to say, while a visual representation of a picture can be made quickly, the existence of this representation does not guarantee a deeper learning of the material.

This premise of overconfidence in those who studied pictures also agrees with the finding that the picture superiority effect shifts towards a text superiority effect as learning level deepens. Those who studied pictures were able to remember more than those who studied text, resulting in the picture superiority effect seen for recognition questions. However, those who studied text processed their information at a deeper level, resulting in the shift towards a text superiority effect for deeper levels of learning. The relatively higher volume, lower-level learning for the picture study condition likely contributed to their overconfidence. Because they remembered a lot, they thought they understood a lot. This may have been especially true for the picture comprehension questions that saw no correlation between confidence and actual score. Having questions in the same modality as their study materials apparently compounded their false sense of learning.

Alternatively, the relatively lower volume, deeper-level learning for the text study condition resulted in a more accurate confidence level. Those in the text study condition apparently knew they didn't remember a lot (relative to those in the picture study condition) but what they did remember was better understood and more transferable than that which was remembered by those in the picture study condition.

Overall, results of the confidence score analysis suggest an intriguing over-confidence that is especially prevalent when learning from pictures. While all students seemed to think they understood and could transfer the material better than they actually could, this overconfidence was markedly greater for students in the picture study condition. This suggests that, particularly for pictures, additional instructional techniques may be needed to encourage deeper processing.

These results support findings from other who have likewise suggested that more explicit instruction on how to properly process visuals is needed (Peeck, 1993; Weidenmann, 1989). Since our educational system places a greater emphasis on textual reading and oral lectures than on visual learning (Paivio, 1971; Silverman, 2002), students may not be learning the skills they need to truly understand information presented in visual form. The results of the present study certainly support this premise.

Examination of the Primary Research Question

To summarize the various segments of this study, a return to the founding research question is warranted. As discussed in the previous sections, this study included in its analyses the effects of the materials used, learning style, learning level (including modality interactions), study time, and participant's self-reported confidence. After considering all of these factors, there is one question that remains the driving force behind this study: As question complexity increases, does performance advantage switch from the picture study condition to the text study condition?

Results of this study support the idea that performance advantage does switch from pictures to text as question complexity increased. A picture superiority effect was seen for recognition questions, especially at the 1-minute study time but also when all study times were averaged together. This effect disappeared for comprehension questions. At the level of transfer, a text superiority effect emerged, especially at the 4-

minute study time but also when all study times were averaged together. This shift was further supported through a 2-way study condition x question type interaction that showed the superiority of the picture study condition waned between recognition and comprehension questions. Analysis of the confidence scores also leads to this conclusion, with those in the picture study condition not able to understand or transfer the material as well as they thought they could.

The key finding of a shift from picture superiority to text superiority as learning becomes more complex suggests that picture and text modalities have differential strengths and weaknesses. This finding is even more remarkable if one ascribes to the hierarchy proposed by Bloom and his colleagues (Bloom et al., 1956), which would suggest there is a need to remember the material before it may be understood and transferred. If this is the case, then a greater proportion of what is remembered from text is transferable compared to the proportion for pictures. Those who studied pictures showed a significantly higher volume for recognition than those who studied text, and yet even with this higher volume of memory, those who studied pictures transferred less than those who studied text.

As discussed above in the section "Impact on Learning Level," the dual-coding of pictures and text may naturally benefit one type of learning over another. The better we understand the individual effects of these modalities, the better we will be able to apply them – alone or in combination – to the appropriate learning situation.

The present study suggests that pictures are not as effective as text for transfer tasks, despite the fact that recognition memory was higher for the picture study condition than for the text study condition. The information was encoded, participants could remember it, but they were not able to apply it. This suggests that an additional prompt is needed to extract the key information from pictures, a finding that supports the premise put forth by others (Peeck, 1993; Weidenmann, 1989).

The need for additional prompts to maximize picture processing also is instructive for explaining various other findings. For example, Pedone and colleagues (2001) found that static diagrams were not spontaneously noticed during an analogical transfer task, but if the static diagram included a textual statement of the key principle or if the diagram was animated, then spontaneous transfer improved. In fact, animated diagrams or diagrams plus a text principle have been shown to be even more effective at generating spontaneous and total transfer than verbal analogues of the same schema (Pedone et al., 2001; Gick & Holyoak, 1983). The present study would suggest the additional cues (animation or text principle) assist students in engaging with the key aspects of the image, allowing it to be processed at a deeper level.

Similarly, the stylistic properties of advertisement photos (e.g., the camera angle, artistic lighting, etc.) are noted by viewers only when appropriate advertisement copy is provided. For example, one study created advertisements for a watch using stylistic properties to indicate “power” or “dynamism” (Peracchio & Meyers-Levy, 2005). Viewers only noticed these qualities in the images when the corresponding advertisement copy was congruous with the stylistic properties (e.g., “Successful, confident, and admired. A powerful statement of who you are.” For the “power” ad. And “Spirited, spontaneous, and expressive. A provocative statement of who you are.” For the “dynamism” ad.). The text was needed for the viewers to process the key elements of the image.

The present study suggests that when pictures are to be processed beyond straight memorization, some cue needs to alert the viewer to the key message. This is exactly what these previous studies found.

Additionally, the present study offers some insight into findings that show combined picture and text study conditions outperform text-only study conditions (e.g., Carney & Levin, 2002; Mayer & Anderson, 1991; Mayer et al., 1996). While dual-coding theory (Paivio, 1971) offers insight into the simultaneous processing of pictures and text, and the work of Mayer and his colleagues continue to enhance the theory of multimedia learning (Mayer & Sims, 1994), the present study contributes a possible explanation of the underlying processing that makes picture and text combinations effective. The present study suggests that pictures are most effective for memory while text is most effective for transfer. It also suggests that picture processing should improve with appropriate cues for the viewer. Thus, when pictures and text are combined, text is acting as a cue to the viewer to engage with the image and process the key points. A striking example of this may be seen when shorter key words integrated into an image improved retention (Mayer & Johnson, 2008).

The interesting point in this particular study, though, is how the addition of the shorter key words within the image did not improve transfer over straight narration and diagrams (Mayer & Johnson, 2008). Again, one explanation may be found in the present study. Since text appears to be more effective for transfer while pictures appear to be more effective for memory, it would be expected that greater emphasis on pictures would improve retention while greater emphasis on text would improve transfer. It is possible that by using key words to draw attention to the image (Mayer & Johnson, 2008), greater cognitive resources were devoted to processing the image. This in turn resulted in greater retention but not greater transfer. An alternative to consider is that manipulations to enhance processing of the text rather than the image may result in improved transfer. Or, as shown for analogical transfer by Pedone and colleagues (2001), methods could be implemented to enhance the transferability of pictures, perhaps by cueing students to process pictures in more generalizable ways. Future research should investigate these possibilities..

Implications and Future Directions

As far as the researcher is aware, this is the first time a study has simultaneously assessed the impact of pictures and text across three levels of learning while including both modalities in the assessment instrument as well as in the study materials. The split plot design allowed each participant to be tested both within- and cross-modality at both recognition and comprehension. The addition of the transfer tasks expanded the study into the third level of learning. The inclusion of self-reported confidence was also a unique attribute of this study that yielded some interesting results. This design could be an important approach in future research since it allows for the investigation of multiple important comparisons within a single design. Future research may also wish to investigate additional uses for confidence scores, especially for multiple choice assessments. It may be possible to use confidence scores as a way to gauge guessing, ultimately allowing for more accurate assessments.

Out of this study come several important findings. The picture superiority effect was again replicated for recognition memory, showing that individuals do indeed remember pictures better than text. This is especially true for shorter study times. As study time increases, this picture superiority effect is replaced with a modality interaction effect where those studying pictures score higher on picture recognition questions than those studying text, while those studying text score higher on text recognition questions than those studying pictures. This modality interaction effect is an important consideration both for educational research and practice. When a modality transfer was needed, whether from pictures to text or text to pictures, scores were 15 percentage points lower than if no transfer was needed. Clearly, in assessments of memory, the modality used to test the learner's memory needs to be carefully considered. Experimental results could be skewed if the assessment modality doesn't match that of the study materials. And in practice, assessments may not be an accurate indication of the student's memory if their scores are being suppressed by modality transfer.

While the impact of modality appears to be strongest for the level of memory, further research is needed to confidently determine the impact for comprehension and transfer. This is especially true for the level of transfer, since modality interaction effects were not tested for transfer questions in this study.

The identification of a shift from a picture superiority effect for memory to a text superiority effect for deeper levels of learning also has important implications for both research and practice. The suggestion that one modality may be better for a particular level of learning is another step towards a deeper understanding of picture and text effects. The better the relative strengths and weaknesses of pictures and text are understood, the better they will be more precisely precribed – alone or in appropriate combinations – to augment a particular learning goal.

Indeed, combinations of pictures and text should also be tested at multiple levels of learning. However, the importance of basic research on each modality alone cannot be overemphasized. Only by studying each modality alone will it be possible to understand the contributions that each modality can make to learning. Studying each alone will allow a better understanding of the mental processing occurring for each and a better understanding of when adjustments could be made – for example, helping students process pictures more deeply or more abstractly – that would ultimately maximize the learning experience.

Underlying mechanisms that may explain this shift from a picture superiority effect to a text superiority effect are discussed above. These include (1) the possibility for text to elicit both a verbal and visual representation and necessary referential connection more easily than pictures; and (2) the possibility that the semantic nature of text lends it a generalizability that is advantageous in transfer situations. Future research needs to investigate these hypotheses.

In practice, the shift from a picture superiority effect to a text superiority effect suggests instructors need to be conscious of the learning level they are trying to achieve. In some instances this is rote memorization, while in others it is comprehension or transfer. Results of this study suggest the modality of the instructional materials can impact these learning levels differently. For memorization, instructors may wish to include visuals. For deeper levels of learning, text appears to be more beneficial.

In combination with the confidence score results, the fact that pictures were less helpful for deeper levels of learning also indicates a need for more explicit training or instruction in picture processing. Learners can remember an image better than they can remember text, but they cannot transfer it to new situations. Worse, learners seem to think they have learned visual material better than they actually have, so they don't even know that they don't know. The exciting aspect of this, however, is the potential. If learners could acquire the skill to process pictures in a way that enhances understanding or transferability without losing any of the memory advantage, then their overall learning would surpass that seen with text at every level. Future research should investigate how the findings of this study differ if students are given explicit instruction that allows them to process pictures in different ways.

Fundamentally, future research also needs to replicate the findings of this study. Although results here are grounded both experimentally and theoretically, they are still preliminary. Any time new territory is explored, it is critical that follow-up research confirms or denies the findings. To this end, it may be worth noting some adjustments to the present study that may be beneficial.

Although results of the material validation showed impressive functional equivalency – both on the matching test that was administered and by the lack of a main effect among test versions – there is always room for improvement. As discussed previously, the test x question type x question modality interaction suggests that participants scored higher on some questions than on others. Difficulty level of these questions could be better distributed so that a single test version doesn't have the easier questions all in one modality. Ultimately, a single test version with predictable reliability could be created.

Similarly, the present study used only one modality of transfer questions (text) which was analyzed separately from the recognition and comprehension questions. This approach helped minimize some of the complexity the design was taking on. Future research, however, needs to test for modality interaction effects at the level of transfer. Ideally, a repeated measure design could include both modalities and all three levels of learning so that comparisons could be made in a single statistical model. This would especially be achievable if the test versions are refined to a single version.

Finally, this research needs to be expanded to other populations. Additional topics should also be used to determine if results vary for different informational content. As further understanding is achieved, research can become more targeted to assess the many interesting questions that are raised.

Implications for Science Educators

In addition to the implications noted above, the practical applications of this study's results to science education are worth consideration. Perhaps the strongest implication for science educators is the presence of the modality interaction effect for memory. This effect suggests that when students study information in picture form, they will be better able to identify the picture than the equivalent text. The reverse is also true. When students study information in text form, they will be better able to identify the text than the equivalent picture.

As science educators, there are plenty of times when the educational objective is rote memorization. There are times students need to remember facts – whether those facts are presented in picture or text form. In these cases, the manner in which memory is measured needs to be carefully considered. In the present study, whenever a modality transfer was needed, whether from pictures to text or text to pictures, scores were 15 percentage points lower than if no transfer was needed. That's enough to bump a student from a low A to a C, just by changing the modality of the assessment instrument. Educators should carefully consider what information they want their students to remember. If the learning objective is visual in nature, then assessment instruments should also be visual; if the learning objective is textual, than assessment instruments should also be textural.

The present study also suggests several points to consider when designing instructional materials. When students only had enough time to quickly skim through the study materials, those who studied pictures scored higher – averaged across both recognition and comprehension questions – than those who studied text. This suggests that when study time is short, or when the attention of a learner may be limited, the ample use of informational pictures can be beneficial. This may be particularly true for learning outside of the classroom, such as in informational pamphlets, where the learner motivation is unknown.

While pictures were shown to be particularly powerful for shorter study times, they are not a panacea. Results of this study show that the superior learning of pictures tends to be constrained to the lower levels of learning such as memory and (for shorter study times) comprehension. If the educational goal is related more to transfer tasks, text becomes the more powerful modality. Thus, it is important that the educational goal is considered. When the goal is memory and/or if study time is limited, pictures should be used. When the goal is higher levels of learning, greater use of text and ample study time should be used.

Finally, educators may consider ways to improve picture learning. Despite the superiority of pictures for memory, students were not able to understand or transfer pictured information as well as textual information, particularly at longer study times. This suggests students require additional skills to extract the necessary information from pictures.

While the present study points to the need for additional research in this area, existing literature does offers some suggestions. Engaging students with an image by asking them questions that require them to notice features about the image has been shown to improve learning (Weidenmann, 1989). The use of contrasting cases – or two different pictures – may also cause students to notice key elements of the pictures and thus enhance their understanding of the pictured information (Bransford & McCarrell, 1974). The present study, in conjunction with previous literature (e.g., Mayer, 1997) also suggests that text can be used to improve picture learning. The points which the text emphasizes may increase the saliency of certain aspects of the picture. Text may also help students process the picture in a more focused or more abstract way, depending on the learning goal.

Text and pictures, alone or in combination, are already used in science education. However, as the relative strengths and weaknesses of these two modalities are uncovered, they become even more powerful instruments in the educator's toolbox. The strategic use of pictures and text in instructional materials and in learning assessments can directly impact the level of student learning that is achieved.

Conclusion

The main objective of this study was to expand the visual-verbal learning literature beyond the dominant text-centric paradigm. As far as the researcher is aware, this is the first time a study has directly compared pictures and text across three levels of learning using both picture and text assessment tools. This allowed for a more unrestricted investigation into the learning potential of these two modalities.

Results suggest a picture advantage for memory but a text advantage for transfer. Several hypotheses for the underlying mechanisms driving these differences have been presented here, but further research is needed to confirm these results and explore the underlying mechanisms. Further research is also needed to assess whether improvements to picture transferability is possible. The superiority of pictures for memory continues to remain steadfast; the possibility of expanding this potential into other levels of learning is enticing, but unknown. Continued investigation into the possibility of a modality interaction effect at deeper levels of learning, particularly transfer, is also needed.

Implications of this research provide both theoretical advances within the picture and text processing literature as well as practical applications for instructional design and learning assessment. It is hoped that future research will continue the line of inquiry begun here.

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APPENDICES

Appendix A: The Picture Study Condition

The materials used in the picture study condition follow. A couple pictures have been reduced in size in order to fit within the margin layout required for this dissertation, but the number of pages and the content of each page accurately represents the picture study condition materials.

P

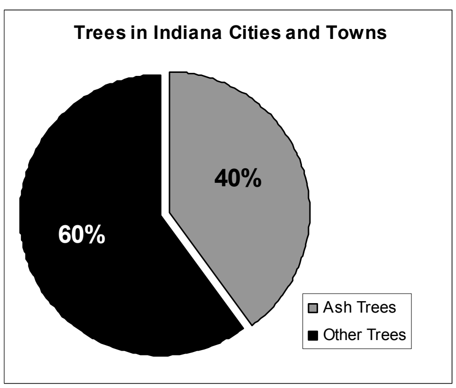
DO NOT turn the page until instructed to do so.

DO NOT write in or otherwise mark-up this packet.

What does the ash tree look like?

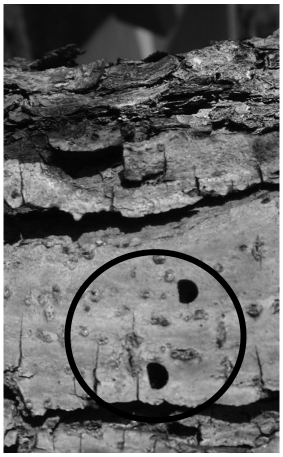


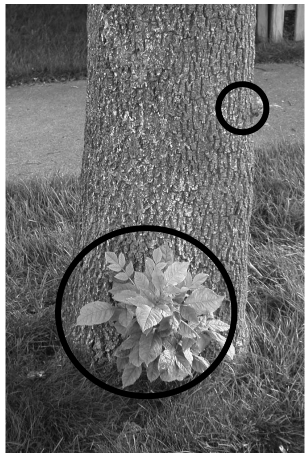

Why is the ash tree important?

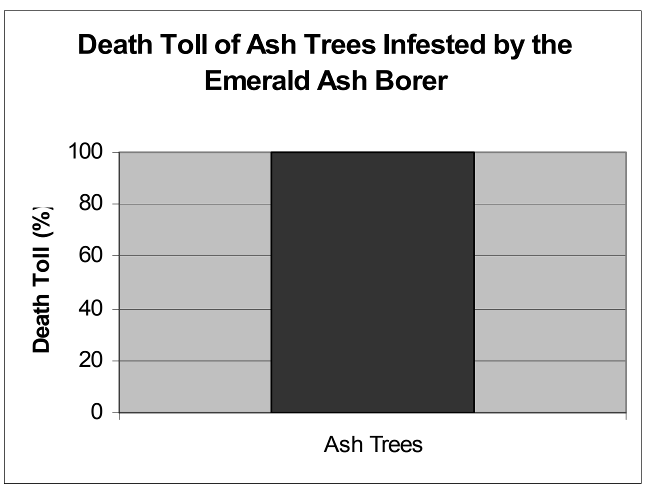




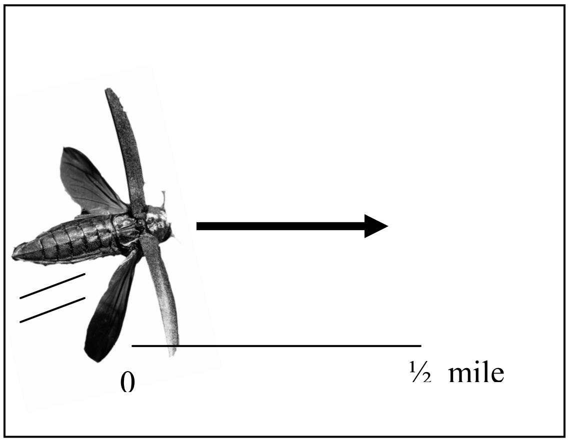
What are the signs of an affected ash tree?

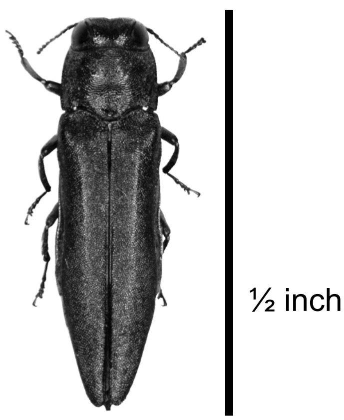


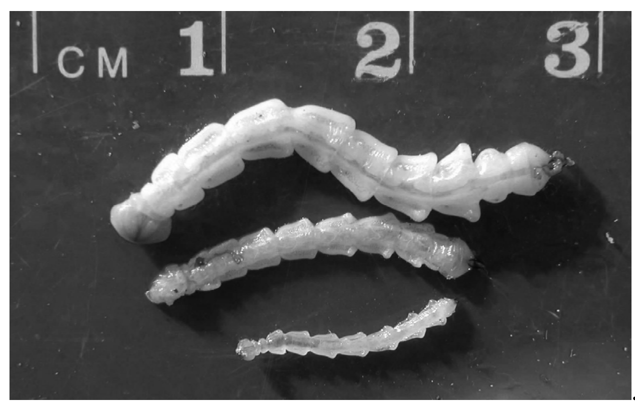




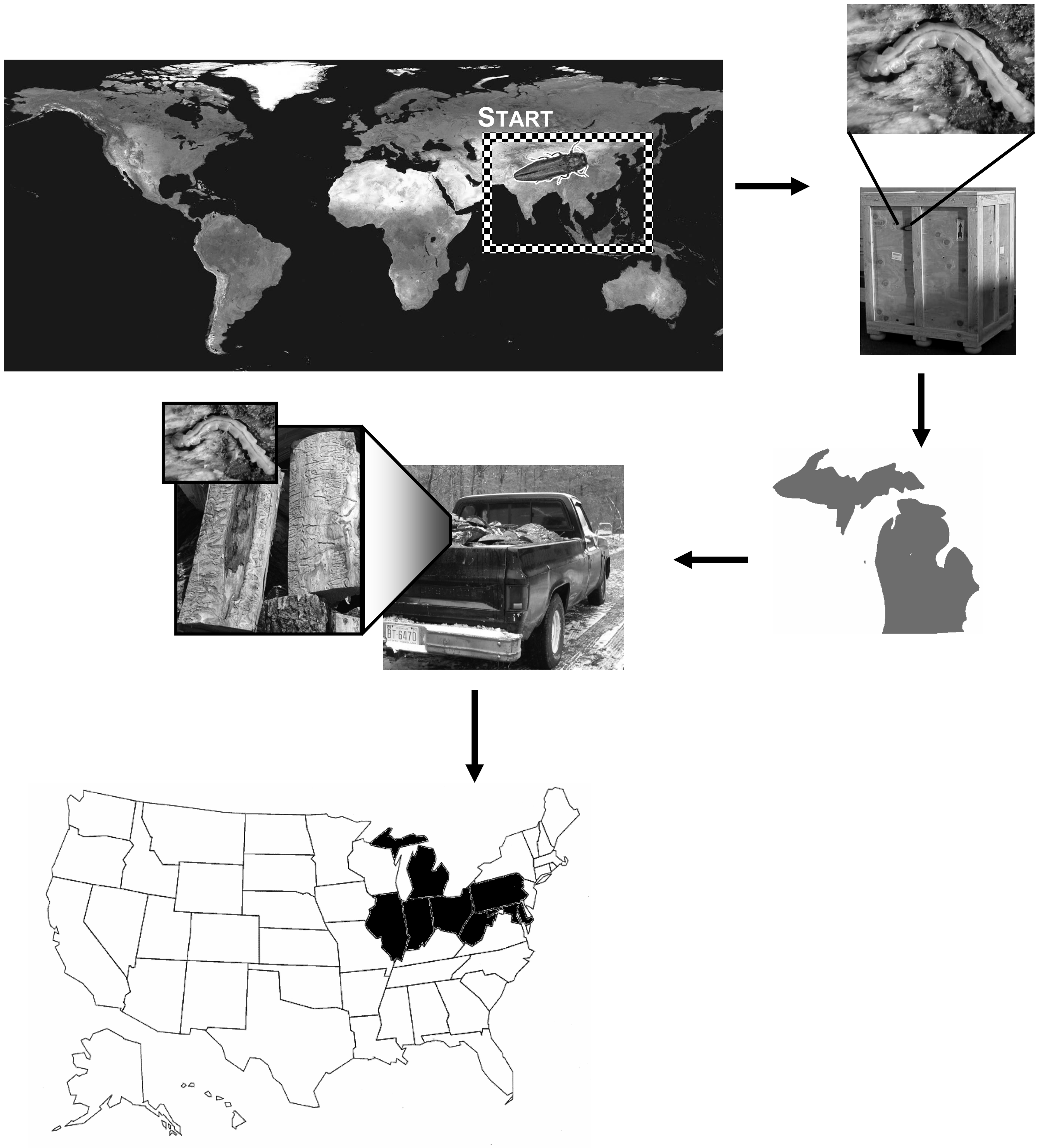
How do I identify the Emerald Ash Borer?







Where did the Emerald Ash Borer come from? How is it spreading?



Appendix B: List of Photo Citations

Below is a list of citations for images used in this study, including a thumbnail of the image, the photographer or company posting the image, the image number (when applicable) and the Web site URL.

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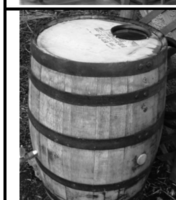	**Bruce Anderson** http://www.renewnorthfield.org/index.php?s=barrels
	**Steve Baldwin** http://www.brooklynparrots.com/2005_10_01_archive.html
	**Baseball Field Equipment** http://baseballfieldequipment.biz/tag/fastpitch-bats
	**Tommaso Branzanti** 0012012 www.forestryimages.com
	**David Cappaert** 5343091 www.forestryimages.com
	**David Cappaert** 9009086 www.forestryimages.com
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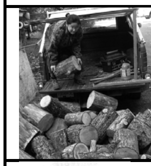	**Chief Ten Bears Blog** http://chief-ten-bears.blogspot.com/2006_11_01_archive.html
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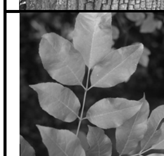
	**Steve Dewey** 1459160 www.forestryimages.com
	**Jodie Ellis, Purdue University** Personal Communication
	**Chris Evans** 2119053 www.forestryimages.com
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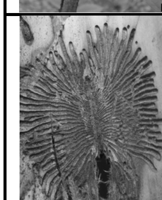	**Beat Forster** 1269044 www.forestryimages.com
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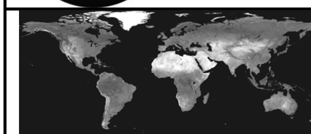
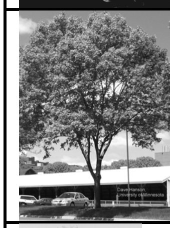
	**Geographic Guide** http://www.globe-images.com/world-image.htm
	**Dave Hanson, University of Minnesota** http://www.mntca.org/images/photos/resources/treeid/ dec_opp_ash_green/ph_ash_green_lrg_09.jpg
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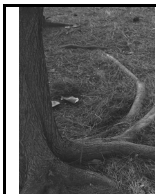	**Joseph LaForest** 5291050 www.forestryimages.com
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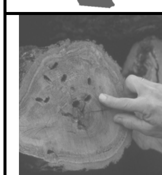	**Joseph O'Brien** 5031038 www.forestryimages.com
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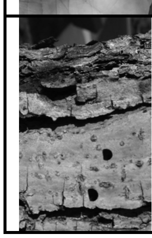	**Joseph O'Brien** 5038050 www.forestryimages.com

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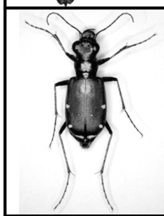	**Pennsylvania Department of Conservation and Natural Resources - Forestry Archive** 5017072 www.forestryimages.com
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	**James Solomon** 3056078 www.forestryimages.com

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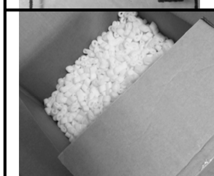	Unknown
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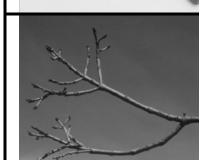
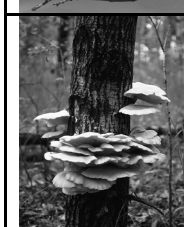
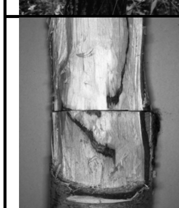
	**USDA Forest Service - Forest Health Protection - St. Paul Archive** 5037078 www.forestryimages.com
	**USDA Forest Service - North Central Research Station Archive** 1406225 www.forestryimages.com
	**E. Bradford Walker** 0907029 www.forestryimages.com
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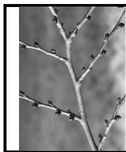
	**Paul Wray** 0008490 www.forestryimages.com
	**Paul Wray** 0008156 www.forestryimages.com
	**Paul Wray** 0008495 www.forestryimages.com
	**Paul Wray** 0008169 www.forestryimages.com
	**Paul Wray** 0008014 www.forestryimages.com

Appendix C: The Text Study Condition

The materials used in the text study condition follow. Text statements describe the corresponding pictures in the picture study condition, as described in the materials and methods.

T

DO NOT turn the page until instructed to do so.

DO NOT write in or otherwise mark-up this packet.

What does the ash tree look like?

A single leaf is made up of about seven little leaves with smooth edges, three pairs growing opposite each other on either side of the stem with one little leaf at the end of the stem.

Seeds are papery thin and hang from individual stems in clusters.

The branch has twigs that grow opposite each other.

The bark is rough, chunky, and diamond-shaped.

Why is the ash tree important?

40% of the trees in Indiana cities and towns are ash trees.

Baseball bats

Wooden chairs, tables and cabinets

Axe handles

What are the signs of an affected ash tree?

Small, D-shaped holes in the bark.

Leaves sprouting from the base of a tree and further up on the trunk.

A tree with no leaves on the top branches.

A piece of a log with the bark removed, revealing S-shaped patterns in the wood.

The death toll of ash trees infested by the Emerald Ash Borer is 100%.

How do I identify the Emerald Ash Borer?

A flying insect with four wings; it can fly ½ mile.

A rectangular insect with a square head, tapered hind end, six legs, and small antennae; it is about ½ inch long.

Larvae are cream colored with bell shaped segments; larvae range in size from 1 – 3 cm.

Where did the Emerald Ash Borer come from? How is it spreading?

The Emerald Ash Borer started in Asia.

Larvae were relocated in a wooden shipping box made from infested wood.

It entered Michigan.

Firewood was put into the back of a pickup truck. The firewood was infested with Emerald Ash Borer larvae.

The Emerald Ash Borer is now in Michigan, Illinois, Indiana, Ohio, Pennsylvania, Maryland, and West Virginia.

Appendix D: The Four Test Versions

The four test versions follow. Each test version had two sections that were handed out separately (e.g., A1 and A2). The cover sheet for each test was printed on a different color paper for ease of distribution during administration.

In tests A and C, the first section was recognition questions and the second section was comprehension and transfer questions. In tests B and D, the first section was comprehension questions and the second section was recognition and transfer questions. Transfer questions were always last. Questions that are in picture modality on tests A and B are in text modality on tests C and D. Questions that are in text modality on tests A and B are in picture modality on tests C and D. Further detail may be found in the materials and methods.

Please note: some photos were resized smaller here in order to accommodate the margin requirements for this dissertation. The number of pages, the questions per page, and the approximate layouts are accurate.

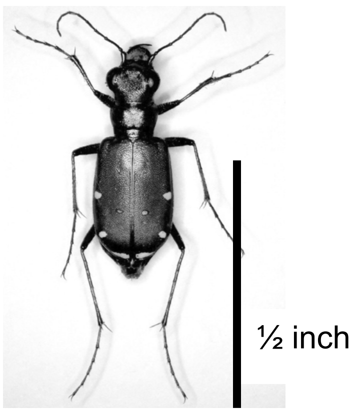
Please circle A1 next to SECTION 1 on your answer sheet.

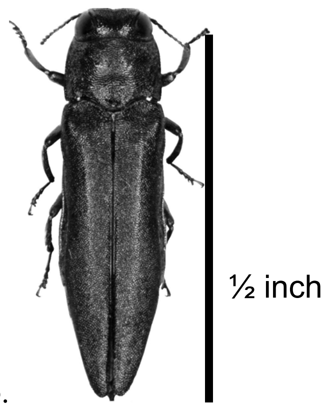
Once you have circled A1 on your answer sheet, you may turn the page and begin.

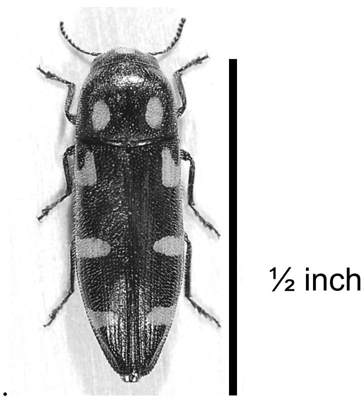
Think about the four pages of information you saw on the Emerald Ash Borer. In each of the following sets, choose the picture or phrase that best matches information you saw. Choose the one letter that looks <u>most familiar</u> to you, and mark this answer on your answer sheet under SECTION 1. After answering each set, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

1)

a. 

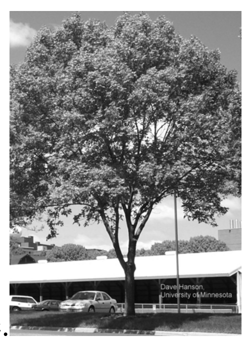
b. 

c. 

2)

a. 

b. 

c. 

3)

a. A piece of a log with the bark removed, revealing S-shaped patterns in the wood.

b. A piece of a log with the bark removed, revealing two jagged lines in the wood.

c. A piece of a log with the bark removed, revealing a deep groove down the center.

4)

a. Michigan forest acreage increased from 8000 to 28000 acres between 1935 and 2003.

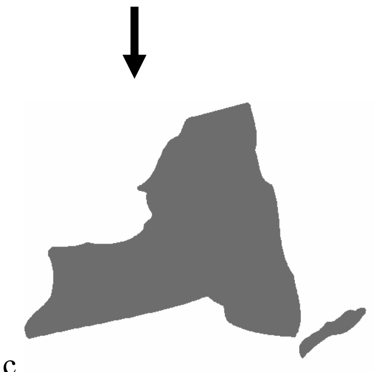
b. Northern hardwood forests increased from 8 million cubic feet to 12 million cubic feet between 1980 and 1993.

c. 40% of the trees in Indiana cities and towns are ash trees.

5)


a.


b.


c.

6)

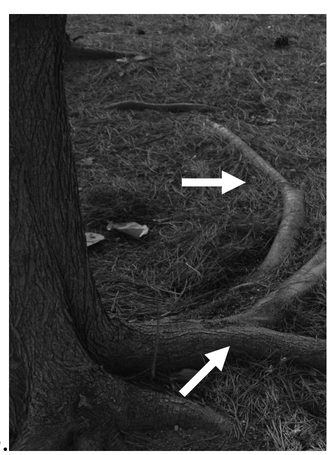
a. A swarm of flying insects; they are above pine trees.

b. A flying insect with four wings; it can fly ½ mile.

c. A bird with something in its beak; it is taking off in flight.

7)

a. 

b. 

c. 

8)

a. Larvae were relocated in a cardboard box filled with packing peanuts.

b. Larvae were relocated in a wooden shipping box made from infested wood.

c. Larvae were relocated in a barrel made from infested wood and metal.

9)

a. 

b. 

c. 

10)

a. The Emerald Ash Borer started in Africa.

b. The Emerald Ash Borer started in North America.

c. The Emerald Ash Borer started in Asia.

11)

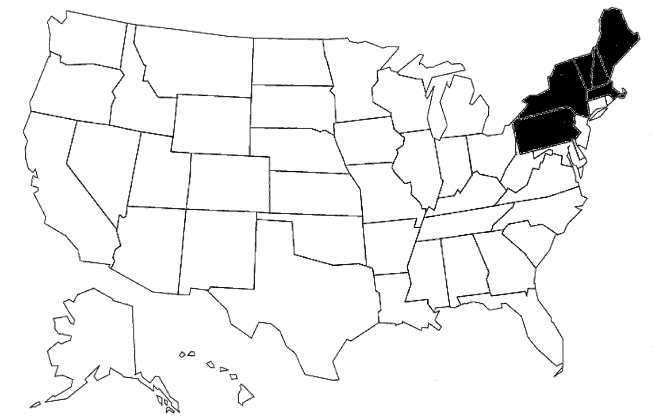
a. A man with a gas mask fills a tank in the back of a pickup truck.

b. Firewood was put into the back of a pickup truck.

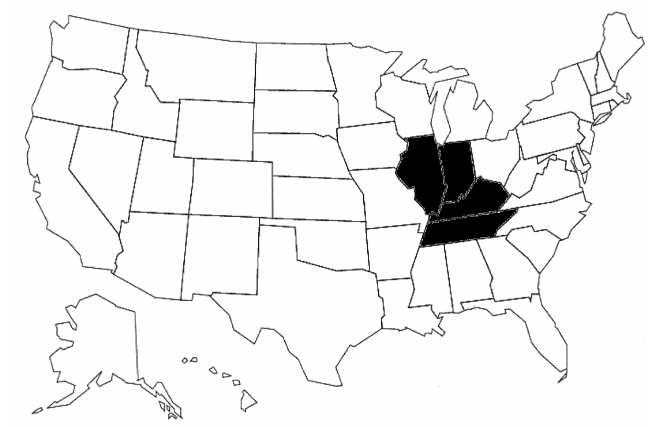
c. A man pushes a log into a woodchipper.

12)

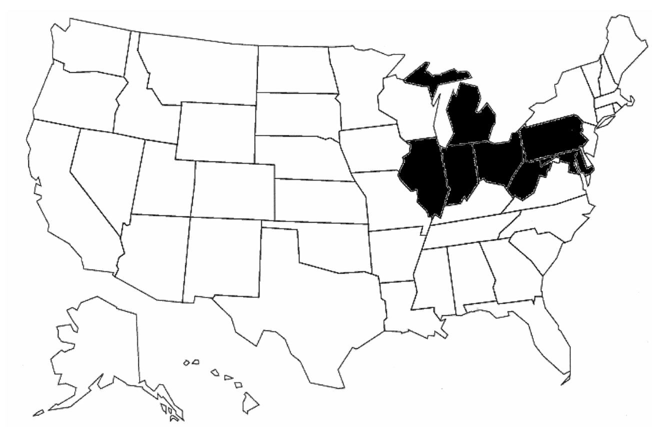
a.



b.



c.



Stop. Please raise your hand to receive SECTION 2.

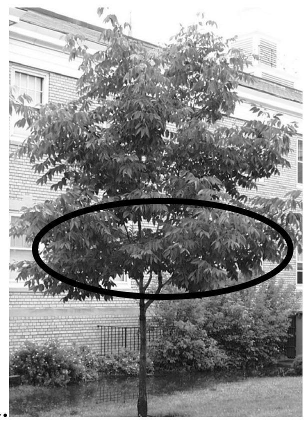
Please circle A2 next to SECTION 2 on your answer sheet.

Once you have circled A2 on your answer sheet, you may turn the page and begin.

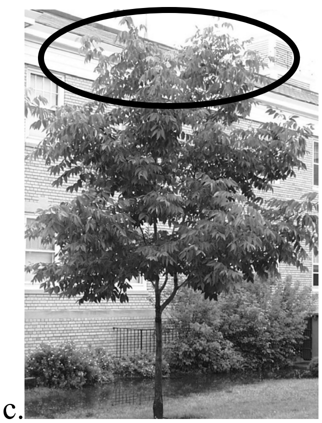
Consider the four pages of information you saw on the Emerald Ash Borer. Then, answer the following questions by choosing the one best answer from the three choices. Mark your answer on your answer sheet under SECTION 2. After you have answered each question, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

1) When a tree becomes damaged by the Emerald Ash Borer, what part of the tree loses its leaves FIRST?

a. 

b. 

c. 

2) Suppose the Emerald Ash Borer has been found in a city 10 miles from your house. If the Emerald Ash Borer moved ONLY by natural migration, how long would it take before the trees around your house were in danger?

a. Five years

b. Ten years

c. Twenty years

3) Which of the following is a common sign of the Emerald Ash Borer?

a. Grooves in wood that begin at a central point and move outward like a starburst.

b. Grooves in wood that begin at one end and move back and forth like a coil.

c. Grooves in wood that begin at one end and move straight through like a knife cut.

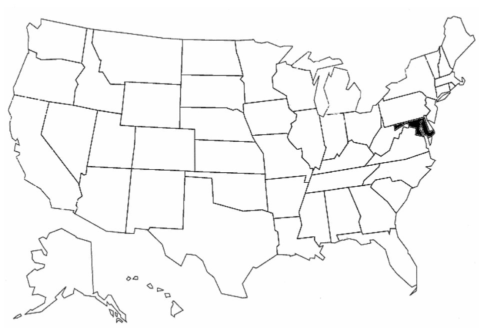
4) Which of the following are traits of the tree which the Emerald Ash Borer attacks?

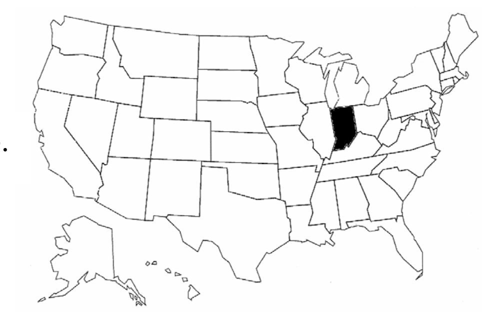
a.

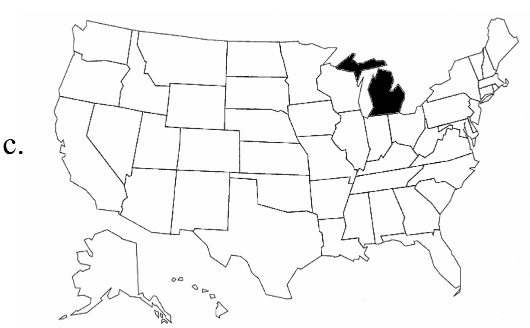
b.

c.

5) The Emerald Ash Borer was first found in the United States in what state?

a. 

b. 

c. 

6) A city in Indiana has 200 trees. How many of them are likely Ash trees?

a. Eighty

b. Forty

c. Twenty

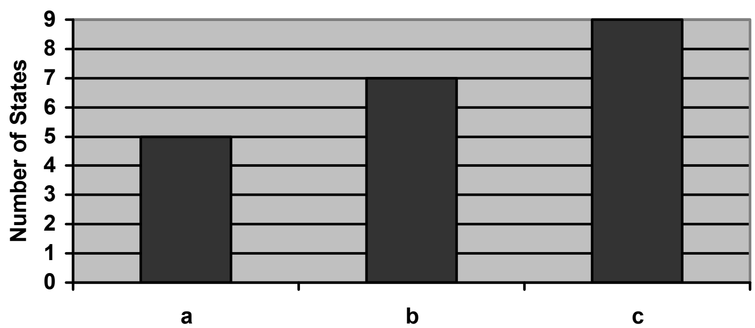
7) Which of the following best shows the way the Emerald Ash Borer **first** entered the United States?

a. Wooden pallets (platforms which help move large items).

b. Firewood was put into the back of a pickup truck.

c. Wooden chairs, tables, and cabinets.

8) The Emerald Ash Borer has now been found in how many states?



9) The Emerald Ash Borer's native region includes territory on which of the following continents?

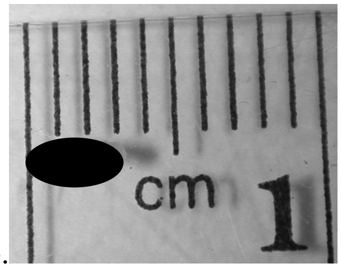
a. Asia

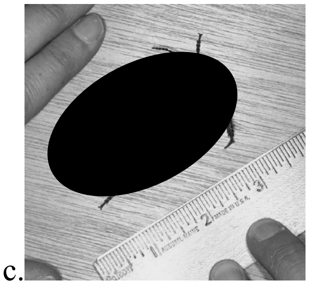
b. Africa

c. Australia

10) You are given three pictures of adult insects, except the insect has been blacked out so you can only see an oval silhouette. Using the context of the picture, which of the following is most likely the Emerald Ash Borer?

a. 

b. 

c. 

11) Suppose you had the option of stopping one of the following activities. Which one would most reduce the spread of the Emerald Ash Borer?

a. Men loading wooden furniture into a truck.

b. A lady putting firewood into a truck.

c. An adult Emerald Ash Borer flying away.

12) Which of the following best indicates damage resulting from the Emerald Ash Borer?

a. 

b. 

c. 

This is the end of SECTION 2. Please turn the page to begin SECTION 3.
Once you begin SECTION 3, please <u>do not return to a previous section</u>.

<u>SECTION 3A.</u> <u>Please do not look back at previous sections.</u>

A. Please read the following scenario. For each sentence numbered 1-13 in the scenario, decide whether what the expert said was correct or incorrect. Mark your answer next to the corresponding number in SECTION 3A of your answer sheet. Then, indicate how confident you are that *your* answer is correct.

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

[0]Suppose your friend recently bought a house and was approached by someone claiming to be an expert in Emerald Ash Borer identification. [1]The expert starts out by saying that it is important to keep an eye out for the Emerald Ash Borer, because once the Emerald Ash Borer has arrived, *all* of your friend's Ash trees will die! [2]This invasive insect, he says, first arrived in the United States when several adult Emerald Ash Borers were accidentally transported in wooden shipping boxes from Asia. [3]From there, natural migration has resulted in the Emerald Ash Borer's rapid spread to other states, including Indiana.

[4]He says you can identify the adult Emerald Ash Borer by the spots of color on its back. [5]Another feature, he says, is that the Emerald Ash Borer can fly.

[6]The expert begins his investigation and points to a tree with clusters of single, papery-thin seeds; he says this is an Ash Tree. [7]Ash trees, he says, also have compound leaves, or a single leaf that consists of several little leaves. [8]The expert says one sign of the Emerald Ash Borer is the fact that the tree is losing all of its lower leaves. [9]He says another sign is the fact that leaves are beginning to sprout out of the base of the trunk. [10]He also points to pointy, diamond-shaped holes in the bark and says that is a sure sign of the Emerald Ash Borer. [11]He kicks at the roots of the tree which are showing above ground, and says this is another common symptom. [12]Finally, he peels back a piece of bark to show black larvae tunneling in distinctive, curvy patterns, and says your friend needs no more proof than that. [13]The expert concludes that based on all this evidence, this tree is infested with the Emerald Ash Borer.

Once you have recorded your answers on the answer sheet, continue to SECTION 3B.

SECTION 3B. **Please do not look back at previous sections.**

B. Please read the following information. Considering this new information, as well as what you remember from the information you saw earlier, answer the questions on your answer sheet.

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

In Asia, Ash trees co-evolved with the Emerald Ash Borer and developed a unique protection system that allows them to survive an Emerald Ash Borer attack. The trees grow over and suffocate the larvae. If you inspect an Asian Ash tree that has been attacked by the Emerald Ash Borer, you may find a dead larva trapped inside, but you will not see the other internal and external signs you would see in a North American tree that has been attacked.

Ecologists don't know yet how the Emerald Ash Borer will affect America's forests. About 6% of forest trees are Ash. As low story trees, they shade the forest floor, and as water-loving trees they are frequently found along streams. If there were no Ash trees, the forest canopy could open up. Sunlight could reach the previously shady forest floor, altering the ecology and causing algae to grow in streams.

This is the end of SECTION 3. Please complete the SECTION 4 questions on your answer sheet and turn in everything when you are done.

Please circle B1 next to SECTION 1 on your answer sheet.

Once you have circled B1 on your answer sheet, you may turn the page and begin.

Consider the four pages of information you saw on the Emerald Ash Borer. Then, answer the following questions by choosing the one best answer from the three choices. Mark your answer on your answer sheet under SECTION 1. After you have answered each question, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

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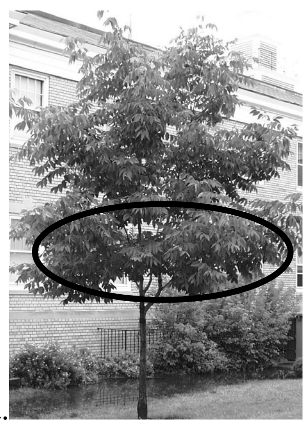
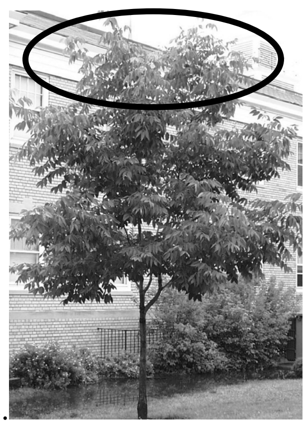
a. 

b. 

c. 

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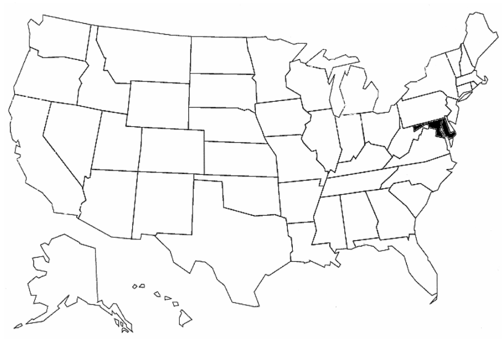
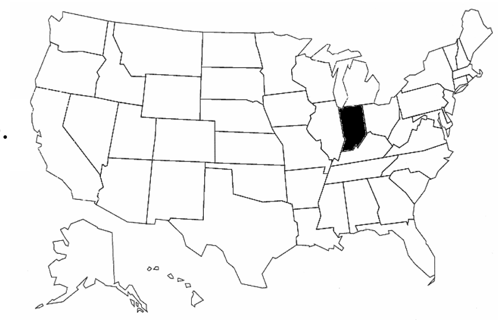
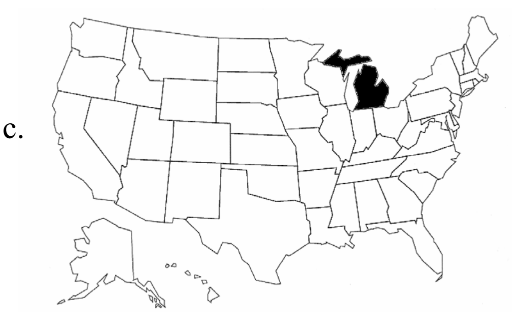
a. 

b. 

c. 

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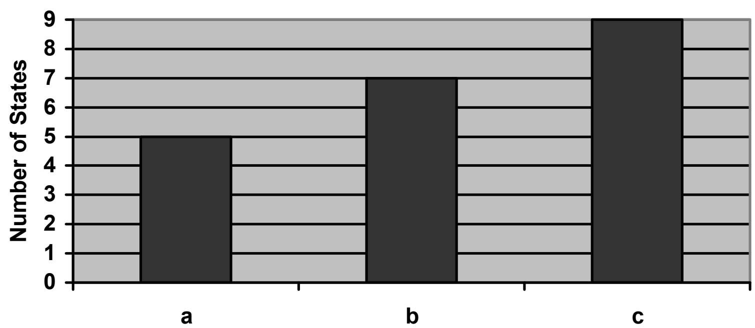

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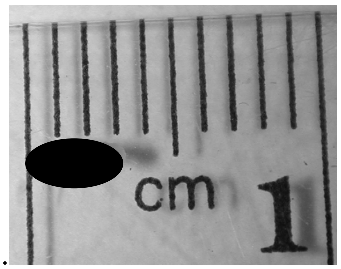
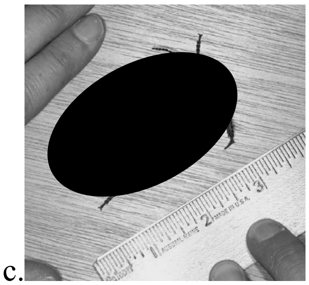
b. 

c. 

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a. Men loading wooden furniture into a truck.

b. A lady putting firewood into a truck.

c. An adult Emerald Ash Borer flying away.

12) Which of the following best indicates damage resulting from the Emerald Ash Borer?

a. 

b. 

c. 

Stop. Please raise your hand to receive SECTION 2.

Please circle B2 next to SECTION 2 on your answer sheet.

Once you have circled B2 on your answer sheet, you may turn the page and begin.

Think about the four pages of information you saw on the Emerald Ash Borer. In each of the following sets, choose the picture or phrase that best matches information you saw. Choose the one letter that looks <u>most familiar</u> to you, and mark this answer on your answer sheet under SECTION 2. After answering each set, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

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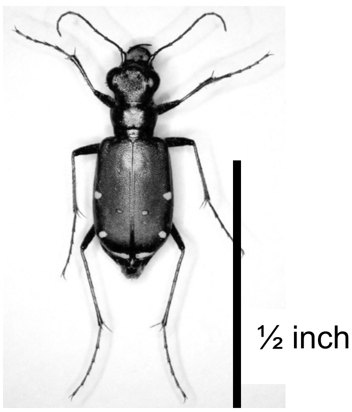
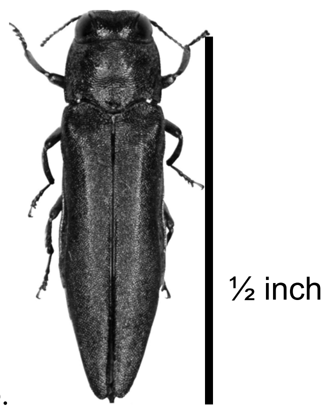
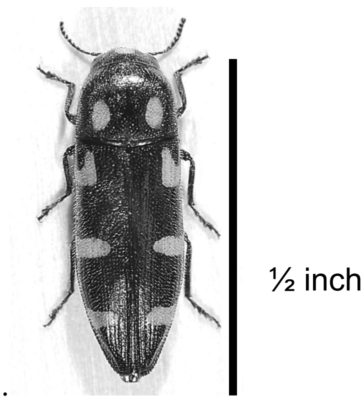
1)

a. 

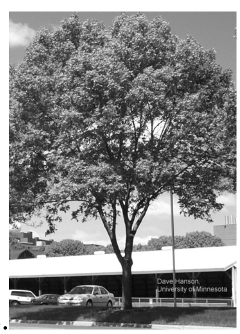
b. 

c. 

2)

a. 

b. 

c. 

3)

a. A piece of a log with the bark removed, revealing S-shaped patterns in the wood.

b. A piece of a log with the bark removed, revealing two jagged lines in the wood.

c. A piece of a log with the bark removed, revealing a deep groove down the center.

4)

a. Michigan forest acreage increased from 8000 to 28000 acres between 1935 and 2003.

b. Northern hardwood forests increased from 8 million cubic feet to 12 million cubic feet between 1980 and 1993.

c. 40% of the trees in Indiana cities and towns are ash trees.

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a.

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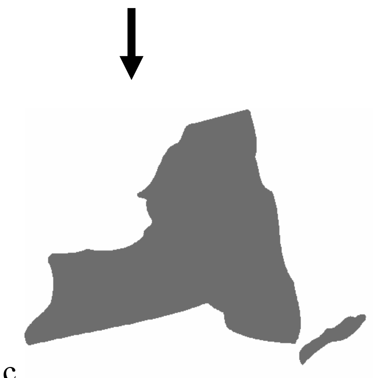


c.

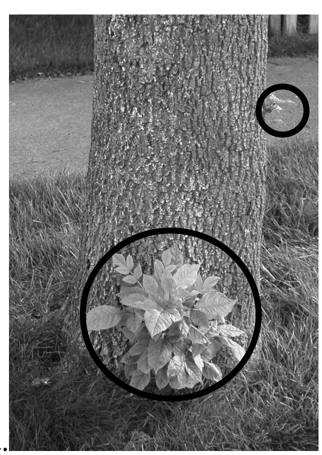
6)

a. A swarm of flying insects; they are above pine trees.

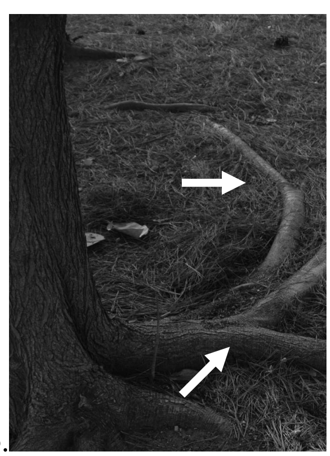
b. A flying insect with four wings; it can fly ½ mile.

c. A bird with something in its beak; it is taking off in flight.

7)



a.



b.

d.

8)

a. Larvae were relocated in a cardboard box filled with packing peanuts.

b. Larvae were relocated in a wooden shipping box made from infested wood.

c. Larvae were relocated in a barrel made from infested wood and metal.

9)

a. 

b. 

c. 

10)

a. The Emerald Ash Borer started in Africa.

b. The Emerald Ash Borer started in North America.

c. The Emerald Ash Borer started in Asia.

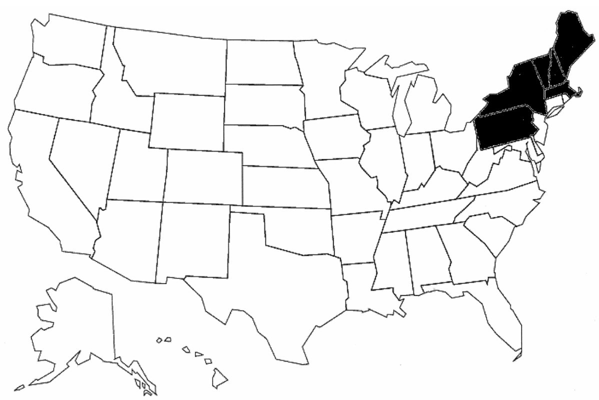
11)

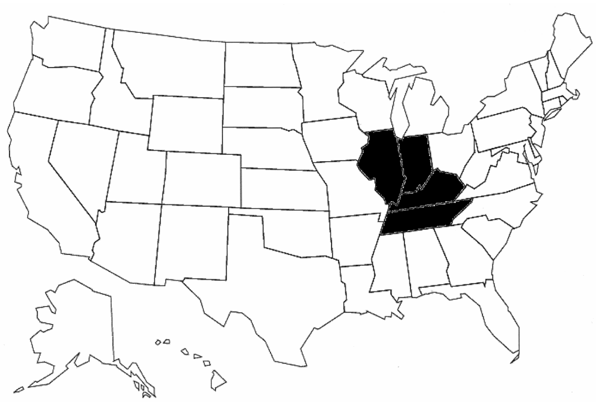
a. A man with a gas mask fills a tank in the back of a pickup truck.

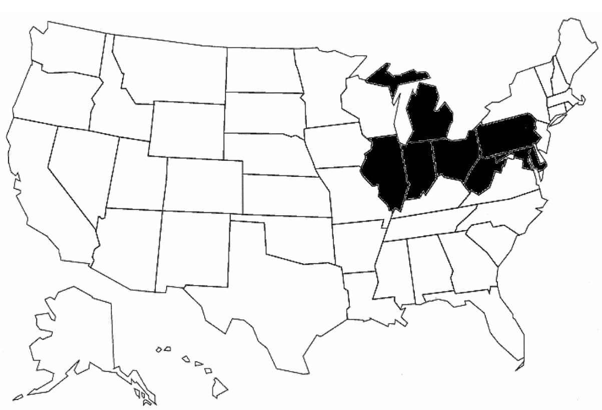
b. Firewood was put into the back of a pickup truck.

c. A man pushes a log into a woodchipper.

12)

a. 

b. 

c. 

This is the end of SECTION 2. Please turn the page to begin SECTION 3. Once you begin SECTION 3, please <u>do not return to a previous section</u>.

<u>SECTION 3A.</u> **<u>Please do not look back at previous sections.</u>**

A. Please read the following scenario. For each sentence numbered 1-13 in the scenario, decide whether what the expert said was correct or incorrect. Mark your answer next to the corresponding number in SECTION 3A of your answer sheet. Then, indicate how confident you are that *your* answer is correct.

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

[0]Suppose your friend recently bought a house and was approached by someone claiming to be an expert in Emerald Ash Borer identification. [1]The expert starts out by saying that it is important to keep an eye out for the Emerald Ash Borer, because once the Emerald Ash Borer has arrived, *all* of your friend's Ash trees will die! [2]This invasive insect, he says, first arrived in the United States when several adult Emerald Ash Borers were accidentally transported in wooden shipping boxes from Asia. [3]From there, natural migration has resulted in the Emerald Ash Borer's rapid spread to other states, including Indiana.

[4]He says you can identify the adult Emerald Ash Borer by the spots of color on its back. [5]Another feature, he says, is that the Emerald Ash Borer can fly.

[6]The expert begins his investigation and points to a tree with clusters of single, papery-thin seeds; he says this is an Ash Tree. [7]Ash trees, he says, also have compound leaves, or a single leaf that consists of several little leaves. [8]The expert says one sign of the Emerald Ash Borer is the fact that the tree is losing all of its lower leaves. [9]He says another sign is the fact that leaves are beginning to sprout out of the base of the trunk. [10]He also points to pointy, diamond-shaped holes in the bark and says that is a sure sign of the Emerald Ash Borer. [11]He kicks at the roots of the tree which are showing above ground, and says this is another common symptom. [12]Finally, he peels back a piece of bark to show black larvae tunneling in distinctive, curvy patterns, and says your friend needs no more proof than that. [13]The expert concludes that based on all this evidence, this tree is infested with the Emerald Ash Borer.

Once you have recorded your answers on the answer sheet, continue to SECTION 3B.

<u>SECTION 3B.</u> <u>Please do not look back at previous sections.</u>

B. Please read the following information. Considering this new information, as well as what you remember from the information you saw earlier, answer the questions on your answer sheet.

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

In Asia, Ash trees co-evolved with the Emerald Ash Borer and developed a unique protection system that allows them to survive an Emerald Ash Borer attack. The trees grow over and suffocate the larvae. If you inspect an Asian Ash tree that has been attacked by the Emerald Ash Borer, you may find a dead larva trapped inside, but you will not see the other internal and external signs you would see in a North American tree that has been attacked.

Ecologists don't know yet how the Emerald Ash Borer will affect America's forests. About 6% of forest trees are Ash. As low story trees, they shade the forest floor, and as water-loving trees they are frequently found along streams. If there were no Ash trees, the forest canopy could open up. Sunlight could reach the previously shady forest floor, altering the ecology and causing algae to grow in streams.

This is the end of SECTION 3. Please complete the SECTION 4 questions on your answer sheet and turn in everything when you are done.

Please circle C1 next to SECTION 1 on your answer sheet.

Once you have circled C1 on your answer sheet, you may turn the page and begin.

Think about the four pages of information you saw on the Emerald Ash Borer. In each of the following sets, choose the picture or phrase that best matches information you saw. Choose the one letter that looks <u>most familiar</u> to you, and mark this answer on your answer sheet under SECTION 1. After answering each set, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

1)

a. A segmented insect with a small head, rounded hind end, long legs, and small spots on its back; it is about ¾ inch long.

b. A rectangular insect with a square head, tapered hind end, six legs, and small antennae; it is about ½ inch long.

c. A rectangular insect with a round head, tapered hind end, six legs, and large spots on its back; it is about ½ inch long.

2)

a. A tree with no leaves on the top branches.

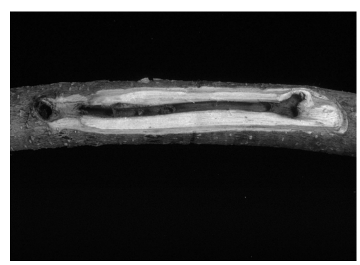
b. A tree with no leaves on any branches.

c. A tree with many leaves on its branches.

3)

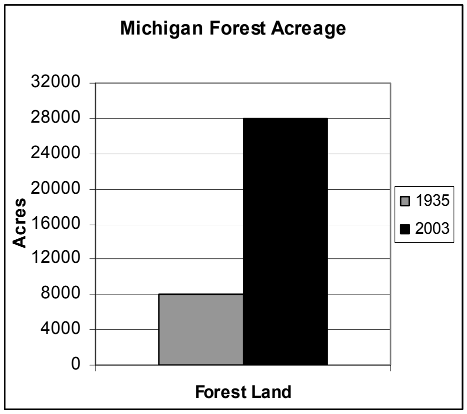
a. 

b. 

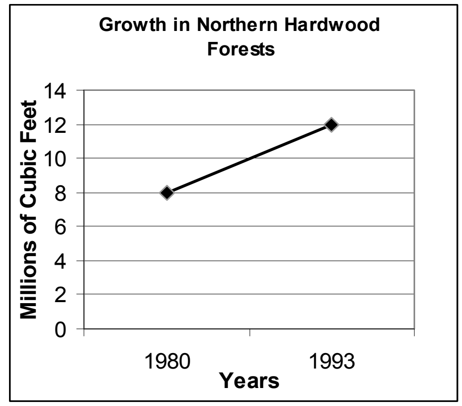
c. 

4)

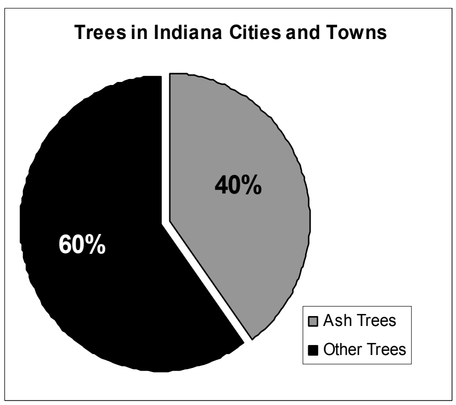
a.



b.



c.



5)

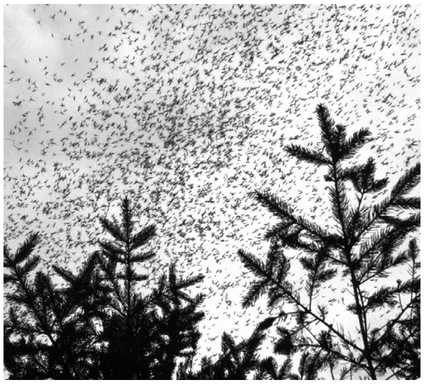
a. It entered California.

b. It entered Michigan.

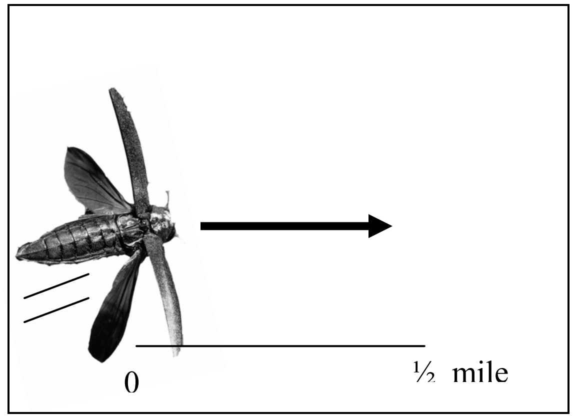
c. It entered New York.

6)

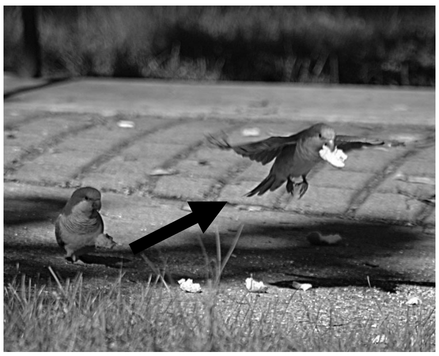
a.



b.



c.



7)

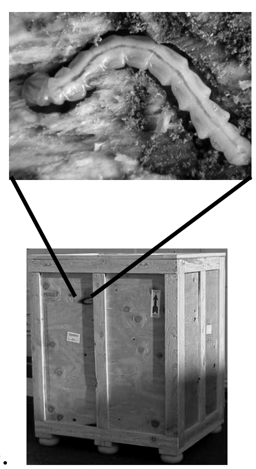
a. Leaves sprouting from the base of a tree and further up on the trunk.

b. Roots showing above ground surrounding the base of a tree.

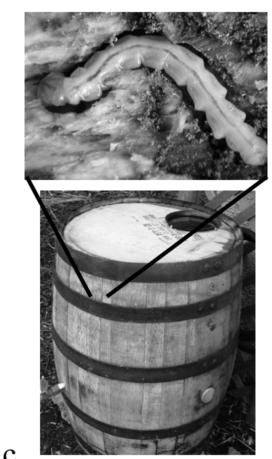
c. Mushrooms growing from a tree trunk midway up on the tree.

8)

a.



b.



c.

9)

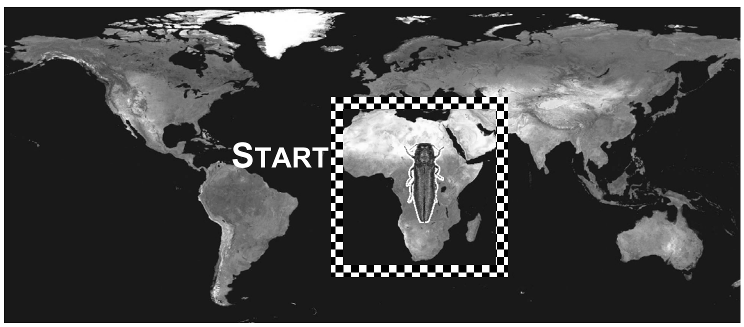
a. The branch has twigs and buds that do not grow opposite each other.

b. The branch has bark partially missing with sap dripping from the branch.

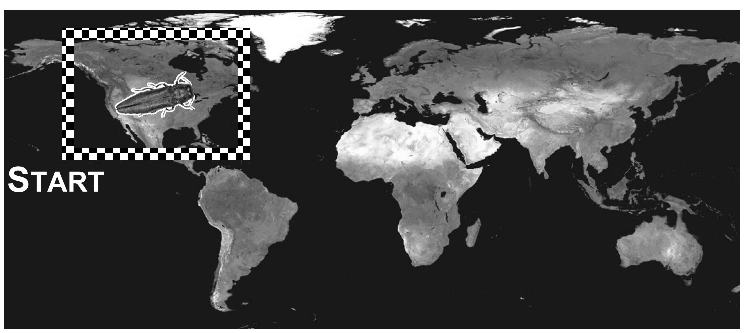
c. The branch has twigs that grow opposite each other.

10)

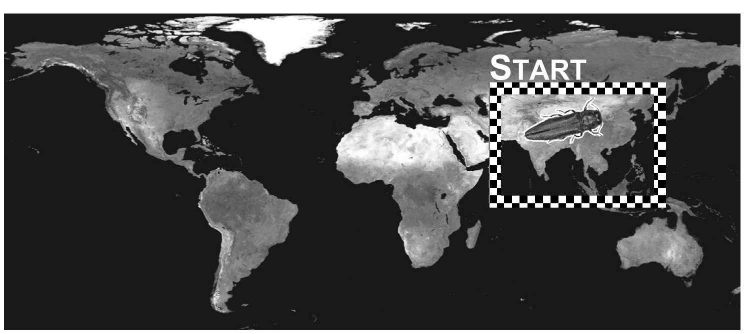
a.



b.



c.



11)

a. 

b. 

c. 

12)

a. The Emerald Ash Borer is now in Maine, New Hampshire, Vermont, New York, Massachusetts, and Pennsylvania.

b. The Emerald Ash Borer is now in Illinois, Indiana, Kentucky, and Tennessee.

c. The Emerald Ash Borer is now in Michigan, Illinois, Indiana, Ohio, Pennsylvania, Maryland, and West Virginia.

Stop. Please raise your hand to receive SECTION 2.

Please circle C2 next to SECTION 2 on your answer sheet.

Once you have circled C2 on your answer sheet, you may turn the page and begin.

Consider the four pages of information you saw on the Emerald Ash Borer. Then, answer the following questions by choosing the one best answer from the three choices. Mark your answer on your answer sheet under SECTION 2. After you have answered each question, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

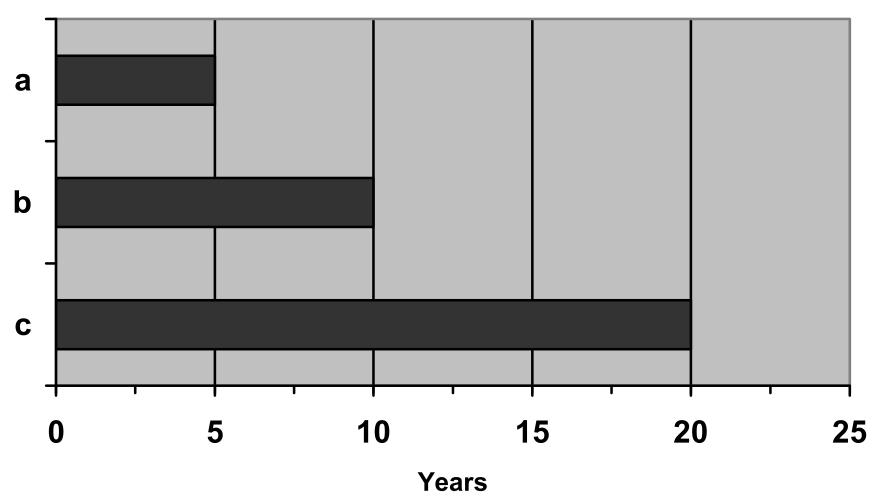
1) When a tree becomes damaged by the Emerald Ash Borer, what part of the tree loses its leaves FIRST?

   a. The bottom third of the tree.

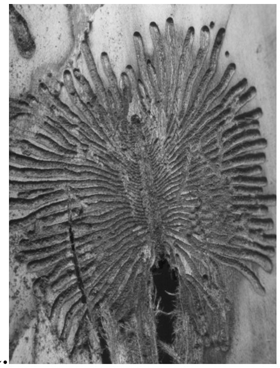
   b. The middle third of the tree.

   c. The top third of the tree.

2) Suppose the Emerald Ash Borer has been found in a city 10 miles from your house. If the Emerald Ash Borer moved ONLY by natural migration, how long would it take before the trees around your house were in danger?



3) Which of the following is a common sign of the Emerald Ash Borer?

a.  b.  c. 

4) Which of the following are traits of the tree which the Emerald Ash Borer attacks?

a. Branch with twigs growing in staggered pairs (not opposite each other); bark with a rough texture that is diamond shaped.

b. Little leaves with a serrated edge growing on the stem in staggered pairs (not opposite each other); papery thin seeds hanging in pairs.

c. Little leaves with a smooth edge growing on the stem in mirror-image pairs (opposite each other); branch with twigs growing in mirror-image pairs on either side of the branch.

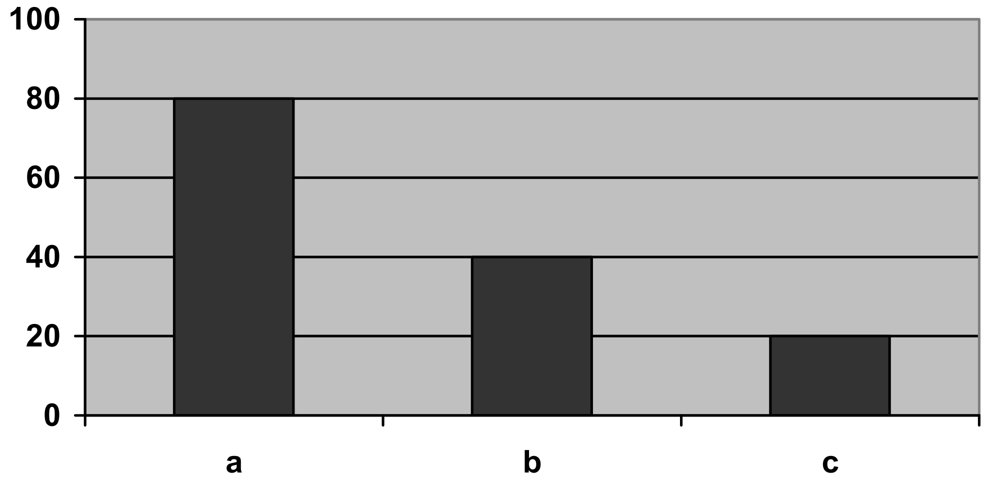
5) The Emerald Ash Borer was first found in the United States in what state?

a. Maryland

b. Indiana

c. Michigan

6) A city in Indiana has 200 trees. How many of them are likely Ash trees?



7) Which of the following best shows the way the Emerald Ash Borer **first** entered the United States?

a.  b.  c. 

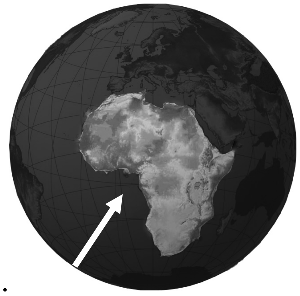
8) The Emerald Ash Borer has now been found in how many states?

a. Five

b. Seven

c. Nine

9) The Emerald Ash Borer’s native region includes territory on which of the following continents?


a.

b.

c.

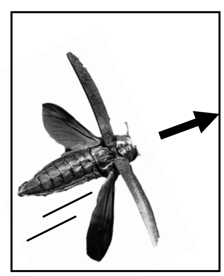
10) You are given three pictures of adult insects, except the insect has been blacked out so you can only see an oval silhouette. Using the context of the picture, which of the following is most likely the Emerald Ash Borer?

a. A picture of a penny. The length of the insect covers about 2/3 of the penny.

b. A picture of a metric ruler. The length of the insect covers about 3 mm.

c. A picture of an inch ruler. The length of the insect covers about 3 inches.

11) Suppose you had the option of stopping one of the following activities. Which one would most reduce the spread of the Emerald Ash Borer?

a. 
b. 
c. 

12) Which of the following best indicates damage resulting from the Emerald Ash Borer?

a. Small oval holes in the end of a log.

b. Leafy growth coming from a tree trunk.

c. Pale patches in the center of the leaves.

This is the end of SECTION 2. Please turn the page to begin SECTION 3. Once you begin SECTION 3, please <u>do not return to a previous section</u>.

<u>SECTION 3A.</u> <u>Please do not look back at previous sections.</u>

A. Please read the following scenario. For each sentence numbered 1-13 in the scenario, decide whether what the expert said was correct or incorrect. Mark your answer next to the corresponding number in SECTION 3A of your answer sheet. Then, indicate how confident you are that *your* answer is correct.

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

[0]Suppose your friend recently bought a house and was approached by someone claiming to be an expert in Emerald Ash Borer identification. [1]The expert starts out by saying that it is important to keep an eye out for the Emerald Ash Borer, because once the Emerald Ash Borer has arrived, *all* of your friend's Ash trees will die! [2]This invasive insect, he says, first arrived in the United States when several adult Emerald Ash Borers were accidentally transported in wooden shipping boxes from Asia. [3]From there, natural migration has resulted in the Emerald Ash Borer's rapid spread to other states, including Indiana.

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[6]The expert begins his investigation and points to a tree with clusters of single, papery-thin seeds; he says this is an Ash Tree. [7]Ash trees, he says, also have compound leaves, or a single leaf that consists of several little leaves. [8]The expert says one sign of the Emerald Ash Borer is the fact that the tree is losing all of its lower leaves. [9]He says another sign is the fact that leaves are beginning to sprout out of the base of the trunk. [10]He also points to pointy, diamond-shaped holes in the bark and says that is a sure sign of the Emerald Ash Borer. [11]He kicks at the roots of the tree which are showing above ground, and says this is another common symptom. [12]Finally, he peels back a piece of bark to show black larvae tunneling in distinctive, curvy patterns, and says your friend needs no more proof than that. [13]The expert concludes that based on all this evidence, this tree is infested with the Emerald Ash Borer.

Once you have recorded your answers on your answer sheet, continue to SECTION 3B.

<u>SECTION 3B.</u> <u>Please do not look back at previous sections.</u>

B. Please read the following information. Considering this new information, as well as what you remember from the information you saw earlier, answer the questions on your answer sheet.

Record all answers on the answer sheet. Please <u>do not</u> write in or otherwise mark-up this test.

In Asia, Ash trees co-evolved with the Emerald Ash Borer and developed a unique protection system that allows them to survive an Emerald Ash Borer attack. The trees grow over and suffocate the larvae. If you inspect an Asian Ash tree that has been attacked by the Emerald Ash Borer, you may find a dead larva trapped inside, but you will not see the other internal and external signs you would see in a North American tree that has been attacked.

Ecologists don't know yet how the Emerald Ash Borer will affect America's forests. About 6% of forest trees are Ash. As low story trees, they shade the forest floor, and as water-loving trees they are frequently found along streams. If there were no Ash trees, the forest canopy could open up. Sunlight could reach the previously shady forest floor, altering the ecology and causing algae to grow in streams.

This is the end of SECTION 3. Please complete the SECTION 4 questions on your answer sheet and turn in everything when you are done.

Please circle D1 next to SECTION 1 on your answer sheet.

Once you have circled D1 on your answer sheet, you may turn the page and begin.

Consider the four pages of information you saw on the Emerald Ash Borer. Then, answer the following questions by choosing the one best answer from the three choices. Mark your answer on your answer sheet under SECTION 1. After you have answered each question, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

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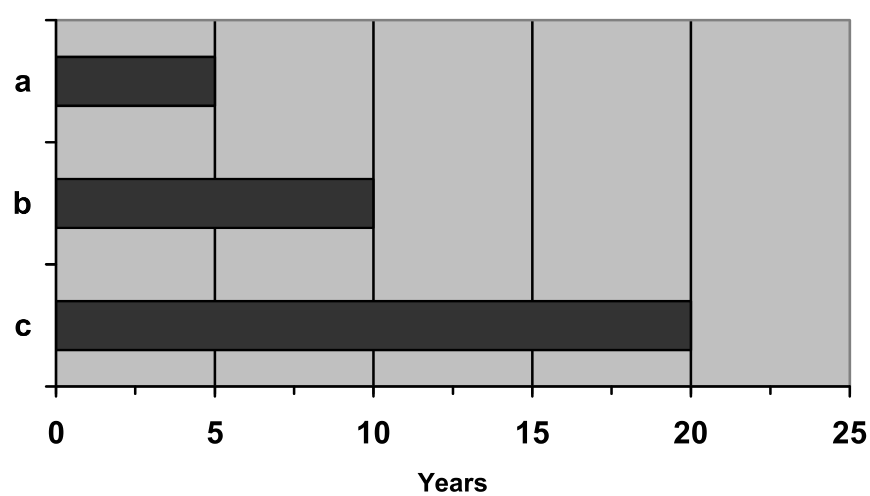
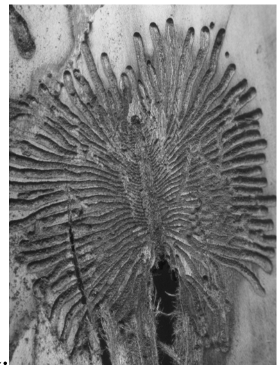
2) Suppose the Emerald Ash Borer has been found in a city 10 miles from your house. If the Emerald Ash Borer moved ONLY by natural migration, how long would it take before the trees around your house were in danger?



3) Which of the following is a common sign of the Emerald Ash Borer?

a.  b.  c. 

4) Which of the following are traits of the tree which the Emerald Ash Borer attacks?

a. Branch with twigs growing in staggered pairs (not opposite each other); bark with a rough texture that is diamond shaped.

b. Little leaves with a serrated edge growing on the stem in staggered pairs (not opposite each other); papery thin seeds hanging in pairs.

c. Little leaves with a smooth edge growing on the stem in mirror-image pairs (opposite each other); branch with twigs growing in mirror-image pairs on either side of the branch.

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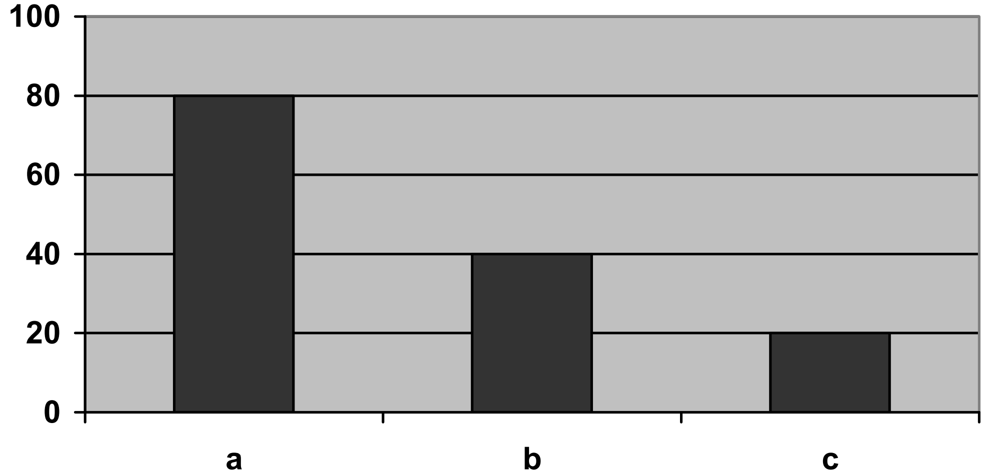


7) Which of the following best shows the way the Emerald Ash Borer **first** entered the United States?

a.  b.  c. 

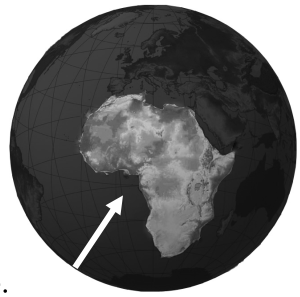
8) The Emerald Ash Borer has now been found in how many states?

a. Five

b. Seven

c. Nine

9) The Emerald Ash Borer's native region includes territory on which of the following continents?


a.

b.

c.

10) You are given three pictures of adult insects, except the insect has been blacked out so you can only see an oval silhouette. Using the context of the picture, which of the following is most likely the Emerald Ash Borer?

a. A picture of a penny. The length of the insect covers about 2/3 of the penny.

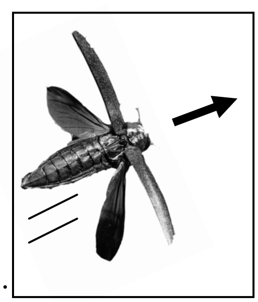
b. A picture of a metric ruler. The length of the insect covers about 3 mm.

c. A picture of an inch ruler. The length of the insect covers about 3 inches.

11) Suppose you had the option of stopping one of the following activities. Which one would most reduce the spread of the Emerald Ash Borer?

a.

b.

c.


12) Which of the following best indicates damage resulting from the Emerald Ash Borer?

a. Small oval holes in the end of a log.

b. Leafy growth coming from a tree trunk.

c. Pale patches in the center of the leaves.

Stop. Please raise your hand to receive SECTION 2.

Please circle D2 next to SECTION 2 on your answer sheet.

Once you have circled D2 on your answer sheet, you may turn the page and begin.

Think about the four pages of information you saw on the Emerald Ash Borer. In each of the following sets, choose the picture or phrase that best matches information you saw. Choose the one letter that looks __most familiar__ to you, and mark this answer on your answer sheet under SECTION 2. After answering each set, please mark on the scale of 1-5 how confident you are that your answer is correct (1=not at all confident; 5=very confident).

Record all answers on the answer sheet. Please __do not__ write in or otherwise mark-up this test.

1)

a. A segmented insect with a small head, rounded hind end, long legs, and small spots on its back; it is about ¾ inch long.

b. A rectangular insect with a square head, tapered hind end, six legs, and small antennae; it is about ½ inch long.

c. A rectangular insect with a round head, tapered hind end, six legs, and large spots on its back; it is about ½ inch long.

2)

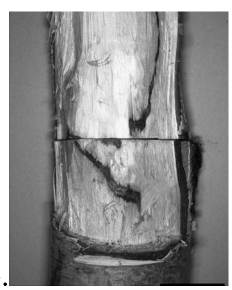
a. A tree with no leaves on the top branches.

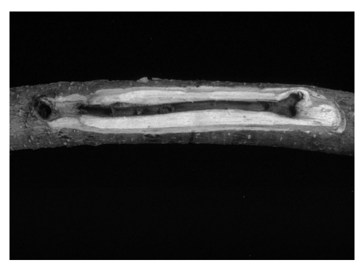
b. A tree with no leaves on any branches.

c. A tree with many leaves on its branches.

3)

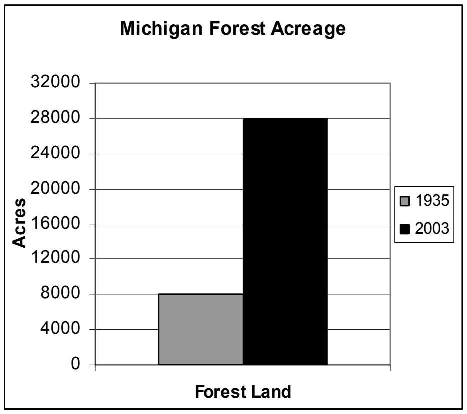
a. 

b. 

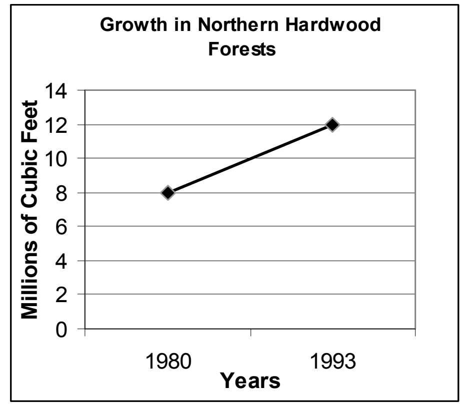
c. 

4)

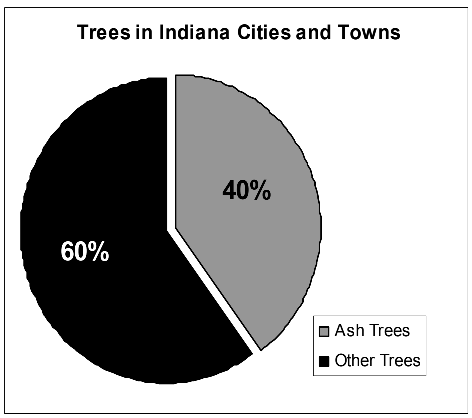
a.



b.



c.



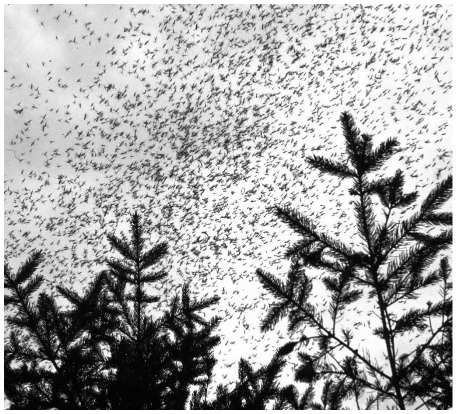
5)

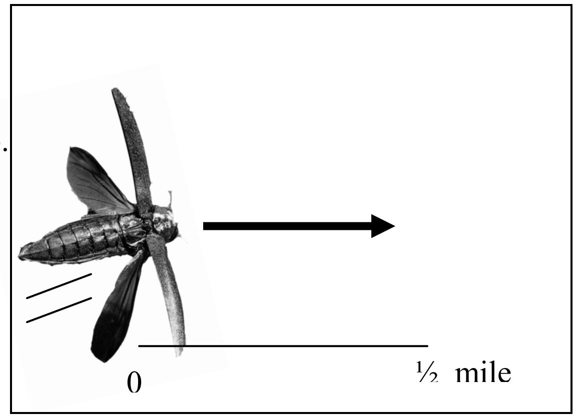
a. It entered California.

b. It entered Michigan.

c. It entered New York.

6)

a. 

b. 

c. 

7)

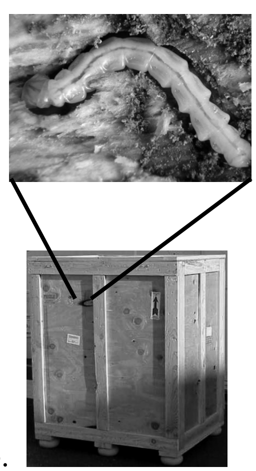
a. Leaves sprouting from the base of a tree and further up on the trunk.

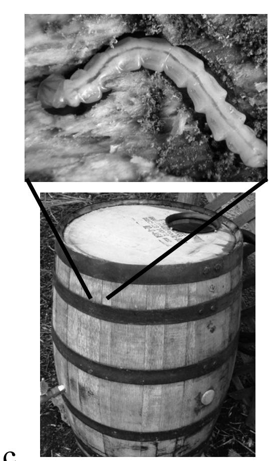
b. Roots showing above ground surrounding the base of a tree.

c. Mushrooms growing from a tree trunk midway up on the tree.

8)


a.


b.


c.

9)

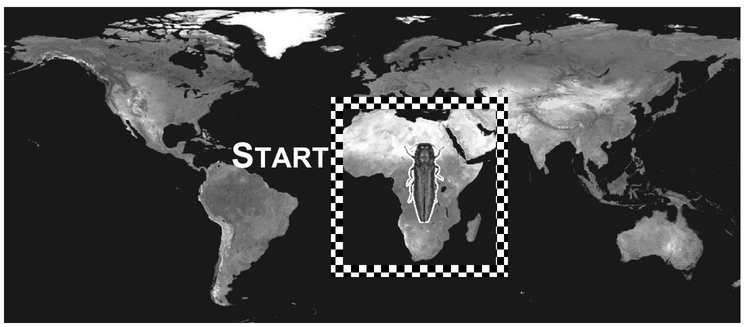
a. The branch has twigs and buds that do not grow opposite each other.

b. The branch has bark partially missing with sap dripping from the branch.

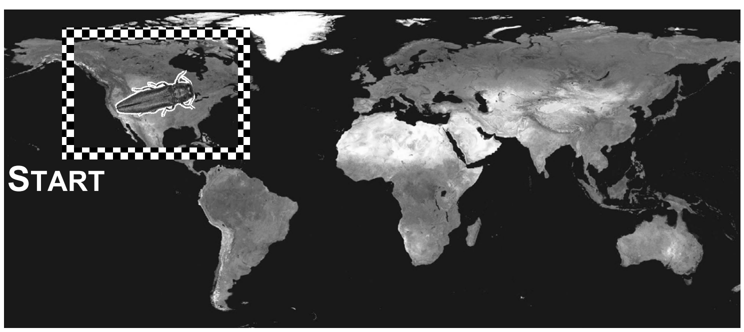
c. The branch has twigs that grow opposite each other.

10)

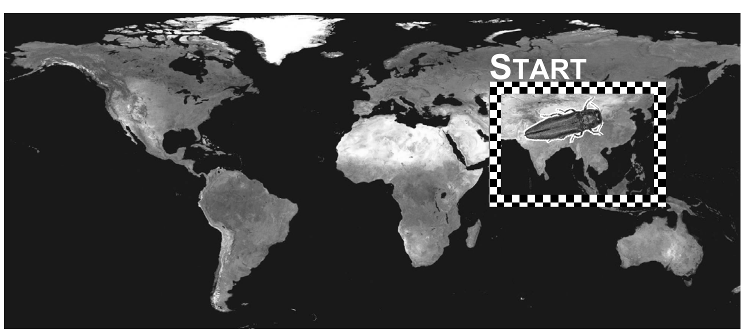
a.



b.



c.



11)

a. 

b. 

c. 

12)

a. The Emerald Ash Borer is now in Maine, New Hampshire, Vermont, New York, Massachusetts, and Pennsylvania.

b. The Emerald Ash Borer is now in Illinois, Indiana, Kentucky, and Tennessee.

c. The Emerald Ash Borer is now in Michigan, Illinois, Indiana, Ohio, Pennsylvania, Maryland, and West Virginia.

This is the end of SECTION 2. Please turn the page to begin SECTION 3. Once you begin SECTION 3, please do not return to a previous section.

SECTION 3A. **Please do not look back at previous sections.**

A. Please read the following scenario. For each sentence numbered 1-13 in the scenario, decide whether what the expert said was correct or incorrect. Mark your answer next to the corresponding number in SECTION 3A of your answer sheet. Then, indicate how confident you are that *your* answer is correct.

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

[0]Suppose your friend recently bought a house and was approached by someone claiming to be an expert in Emerald Ash Borer identification. [1]The expert starts out by saying that it is important to keep an eye out for the Emerald Ash Borer, because once the Emerald Ash Borer has arrived, *all* of your friend's Ash trees will die! [2]This invasive insect, he says, first arrived in the United States when several adult Emerald Ash Borers were accidentally transported in wooden shipping boxes from Asia. [3]From there, natural migration has resulted in the Emerald Ash Borer's rapid spread to other states, including Indiana.

[4]He says you can identify the adult Emerald Ash Borer by the spots of color on its back. [5]Another feature, he says, is that the Emerald Ash Borer can fly.

[6]The expert begins his investigation and points to a tree with clusters of single, papery-thin seeds; he says this is an Ash Tree. [7]Ash trees, he says, also have compound leaves, or a single leaf that consists of several little leaves. [8]The expert says one sign of the Emerald Ash Borer is the fact that the tree is losing all of its lower leaves. [9]He says another sign is the fact that leaves are beginning to sprout out of the base of the trunk. [10]He also points to pointy, diamond-shaped holes in the bark and says that is a sure sign of the Emerald Ash Borer. [11]He kicks at the roots of the tree which are showing above ground, and says this is another common symptom. [12]Finally, he peels back a piece of bark to show black larvae tunneling in distinctive, curvy patterns, and says your friend needs no more proof than that. [13]The expert concludes that based on all this evidence, this tree is infested with the Emerald Ash Borer.

Once you have recorded your answers on the answer sheet, continue to SECTION 3B.

SECTION 3B. Please do not look back at previous sections.

B. Please read the following information. Considering this new information, as well as what you remember from the information you saw earlier, answer the questions on your answer sheet.

Record all answers on the answer sheet. Please do not write in or otherwise mark-up this test.

In Asia, Ash trees co-evolved with the Emerald Ash Borer and developed a unique protection system that allows them to survive an Emerald Ash Borer attack. The trees grow over and suffocate the larvae. If you inspect an Asian Ash tree that has been attacked by the Emerald Ash Borer, you may find a dead larva trapped inside, but you will not see the other internal and external signs you would see in a North American tree that has been attacked.

Ecologists don't know yet how the Emerald Ash Borer will affect America's forests. About 6% of forest trees are Ash. As low story trees, they shade the forest floor, and as water-loving trees they are frequently found along streams. If there were no Ash trees, the forest canopy could open up. Sunlight could reach the previously shady forest floor, altering the ecology and causing algae to grow in streams.

This is the end of SECTION 3. Please complete the SECTION 4 questions on your answer sheet and turn in everything when you are done.

Appendix E: The Answer Sheet

A copy of the answer sheet follows. The answer sheet used by both study conditions was identical, except in the header for the picture study condition there was a P, and in the header for the text study condition there was a T.

SECTION 1.

Please circle the letter of your test booklet: A1 B1 C1 D1

Circle the correct answer. **Indicate how confident you are that your answer is correct.**

				Not at all Confident				Very Confident
1.	a	b	c	1	2	3	4	5
2.	a	b	c	1	2	3	4	5
3.	a	b	c	1	2	3	4	5
4.	a	b	c	1	2	3	4	5
5.	a	b	c	1	2	3	4	5
6.	a	b	c	1	2	3	4	5
7.	a	b	c	1	2	3	4	5
8.	a	b	c	1	2	3	4	5
9.	a	b	c	1	2	3	4	5
10.	a	b	c	1	2	3	4	5
11.	a	b	c	1	2	3	4	5
12.	a	b	c	1	2	3	4	5

Stop. Please raise your hand to receive the SECTION 2 test booklet.

Once you have received the SECTION 2 test booklet, you may turn the page and continue.

SECTION 2.

Please circle the letter of your test booklet: A2 B2 C2 D2

Circle the correct answer. **Indicate how confident you are that your answer is correct.**

				Not at all Confident				Very Confident
1.	a	b	c	1	2	3	4	5
2.	a	b	c	1	2	3	4	5
3.	a	b	c	1	2	3	4	5
4.	a	b	c	1	2	3	4	5
5.	a	b	c	1	2	3	4	5
6.	a	b	c	1	2	3	4	5
7.	a	b	c	1	2	3	4	5
8.	a	b	c	1	2	3	4	5
9.	a	b	c	1	2	3	4	5
10.	a	b	c	1	2	3	4	5
11.	a	b	c	1	2	3	4	5
12.	a	b	c	1	2	3	4	5

This is the end of SECTION 2. Please turn the page to begin SECTION 3. Once you begin SECTION 3, please <u>do not return to a previous section</u>.

SECTION 3A. Please do not look back at previous sections.

A. **For each sentence (numbered 1-13) from the scenario in SECTION 3A of your test booklet, circle whether what the expert said was correct or incorrect. Then, indicate how confident you are that *your* answer is correct.**

			Indicate how confident you are that your answer is correct. Not at all Confident				Very Confident
1.	Correct	Incorrect	1	2	3	4	5
2.	Correct	Incorrect	1	2	3	4	5
3.	Correct	Incorrect	1	2	3	4	5
4.	Correct	Incorrect	1	2	3	4	5
5.	Correct	Incorrect	1	2	3	4	5
6.	Correct	Incorrect	1	2	3	4	5
7.	Correct	Incorrect	1	2	3	4	5
8.	Correct	Incorrect	1	2	3	4	5
9.	Correct	Incorrect	1	2	3	4	5
10.	Correct	Incorrect	1	2	3	4	5
11.	Correct	Incorrect	1	2	3	4	5
12.	Correct	Incorrect	1	2	3	4	5
13.	Correct	Incorrect	1	2	3	4	5

Continue to SECTION 3B.

SECTION 3B. Please do not look back at previous sections.

B. Consider the new information you just read in SECTION 3B of your test booklet, as well as what you remember from the information you saw earlier. Please reason through the following questions and provide a short, written answer for each.

1. Why might the Emerald Ash Borer cause more damage to the tree population in cities and towns than to the tree population in remote forests?

2. When is the D-shaped hole created that is sometimes seen in the bark of affected Ash trees?

3. If you were a furniture maker specializing in fine Ash furniture, would you rather be located in Asia or North America? Why?

4. How specifically does the Emerald Ash Borer kill the tree?

5. You have seen Emerald Ash Borers in your backyard, and you know some of your trees are infected. Suppose you have a choice of two pesticides, one that kills larvae and one that kills the adults. Which would have the most immediate impact to save your trees?

This is the end of SECTION 3. Please turn the page to complete SECTION 4.

SECTION 4

How familiar were you with the material presented on the Emerald Ash Borer before today?

Not at all familiar					Very Familiar
	1	2	3	4	5

How interesting was the information about the Emerald Ash Borer?

Not at all interesting					Very interesting
	1	2	3	4	5

Which of the following statements best describes your experience answering the multiple choice test questions?

Picture questions were much easier than text questions	Picture questions were slightly easier than text questions	Picture and text questions were equally easy	Text questions were slightly easier than picture questions	Text questions were much easier than picture questions

In a learning situation sometimes information is presented verbally (e.g., with printed or spoken words) and sometimes information is presented visually (e.g., with labeled illustrations, graphs, or narrated animations). Please circle your learning preference:

Strongly more verbal than visual	Moderately more verbal than visual	Slightly more verbal than visual	Equally verbal and visual	Slightly more visual than verbal	Moderately more visual than verbal	Strongly more visual than verbal

Please comment on the information you saw about the Emerald Ash Borer and how easy it was to answer the questions after seeing this information:

I am (please circle): Male Female Age: ______

I am (please circle): Freshman Sophomore Junior Senior

Please list your home **country** ________________ **state** _________**county**__________

Is English your first language? (Please circle): Yes No

Stop. Please turn in your test booklet and this answer sheet and you are free to leave.

Appendix F: The Distracter Task

A copy of the distracter task follows. This task was printed on a single side of a single sheet of paper for the study. The larger margin requirements for this dissertation require the task to be shown here on two separate pages.

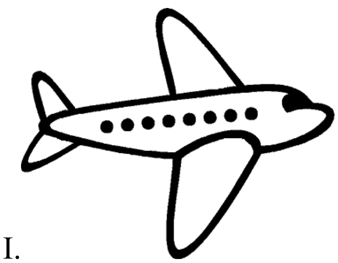
This task intentionally used ambiguous text and picture pairs to encourage participants to think about their matches. By using a task involving both pictures and text, both visual and verbal mental processes were needed, effectively preventing mental rehearsal of both modalities. Further details are available in the materials and methods chapter.

Match the following pictures and descriptions by writing the appropriate letter in the space provided. Use each description and each picture only once.

_____ Look waaay up there.
_____ Wow, is it really hot in here, or is it just me?
_____ Brrrr. It is cold.
_____ Let's go for a ride!
_____ There is no time to sit and talk.
_____ A lazy afternoon.
_____ So dainty and nice.
_____ Red and Blue.
_____ Around and around and around.
_____ What goes up, must come down.
_____ Faster than a speeding bullet (okay, maybe not.)
_____ Hurry up, we're going to be late!!

A. 
B. 
C. 

D. 
E. 
F. 

G. 
H. 
I. 

J. 
K. 
L. 

Appendix G: Experimental Protocol

The experiment described in this dissertation adhered to the following protocol, which was approved by the Purdue University Institutional Review Board, the party responsible for approving research conducted with human subjects (Protocol #0806007032).

Protocol

Participants had the option of attending one of several different time slots outside of class time for which they pre-registered using SurveyMonkey.com. The study was held in a classroom at Purdue University, West Lafayette. Answer sheets were not able to be traced to a particular individual. Neither the supervising instructor nor the teaching assistant had access to the answer sheets.

The random number generator in Microsoft Excel was used to assign pre-registered participants to a seat which indicated which study condition and test they would receive. They were asked to initial a sign-in sheet so they could receive extra credit for their participation.

The following information was presented orally:

Thank you for volunteering to participate in this research project! I should only use about 30-45 minutes of your time. Please note that participation is completely voluntary, and you may choose to end your participation at any time. However, your input is extremely important as we continue to study ways to improve educational materials. To participate, you will be asked to look at an information sheet and then answer questions about what you saw.

You will be given four pages of information on the Emerald Ash Borer. The Emerald Ash Borer is an invasive insect here in Indiana. It has the potential to cause widespread economic and environmental devastation and the Department of Natural Resources is asking all of us to help prevent its spread.

You will be given 1 minute [or 2 or 4 minutes] to review this information. There will be a 30 second [or one minute] warning when you have 30 seconds [one minute] left. Please study and try to understand the material the best you can. Later you will be asked questions about what you have studied. Please note that we are testing the effectiveness of the instructional materials and not your individual abilities.

Are there any questions? [Pause and address any questions.]

I will begin passing out the information. Please do not begin looking at it until I say to.

Participants then received either the picture information sheet (P) or the text information sheet (T).

Time was started and participants were told to begin reviewing the information. There was an announcement when there was 30 seconds or one minute left. Time was recorded with a stop watch. When time was up, the following was said:

Time is up. Please close your information sheet and pass it to the front of the room.

Once all the information sheets were collected, the following was said:

Now I am going to pass out a matching exercise. The instructions are at the top of the page. You will have 5 minutes to complete this exercise. Please don't begin until I tell you to.

The distracter task was then distributed, and participants were told to begin. At the end of 5 minutes, participants were told to pass the exercise to the front of the room and they were collected. Then, the following was said:

I will now begin distributing some questions about what you have just reviewed. There are FOUR sections with a few questions in each section. For sections 1 and 2, the questions are in a test booklet. You will mark your answer on an answer sheet. For sections 3 and 4, the questions are printed right on your answer sheet.

I will pass out the first section along with an answer sheet. The instructions for answering the questions are at the top of the page. Please mark your answers on the answer sheet under the heading SECTION 1. Make sure you circle your test letter on the answer sheet so I know what answer key to use for your test. Please write only on the answer sheet. Please do not write or otherwise markup the test questions.

Once you have completed SECTION 1, raise your hand and I will collect those questions and give you the questions for SECTION 2.

Once you have finished SECTION 2, please answer the questions in SECTION 3 and SECTION 4 on your answer sheet. You may then turn in your answer sheet and test booklet and you will be free to leave.

There is no time limit for answering the questions. Please do your best to answer the questions.

Are there any questions? [Pause and address any questions.]

Section 1 of the test was then distributed. As students finished section 1, those questions were collected and section 2 was distributed. Once students completed section 2 and the questions on the answer sheet (sections 3 and 4), their answer sheet and section 2 questions were collected. They were thanked for their time.

Appendix H: Material Validation Matching Test

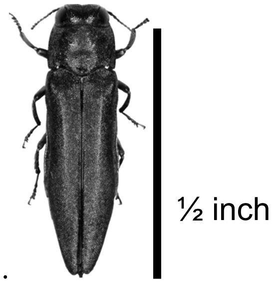
A copy of the matching test used during the material validation phase of the study is presented here. Due to margin requirements for this dissertation, many of the images shown here have been reduced slightly from the size used on the matching test. The overall layout, however, is shown here as it was on the actual test.

Image Packet

Images on the following pages are grouped into four sections.
Please match each of the following images with the appropriate statement on the matching sheet.

Begin Section 1.

1.


2.


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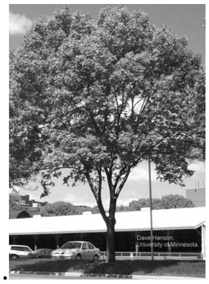
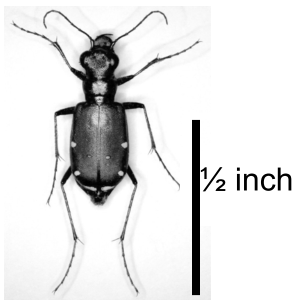
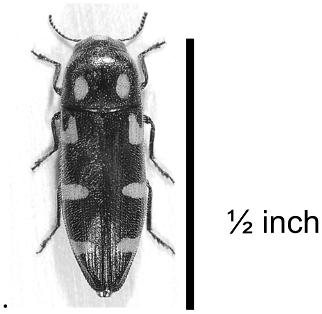


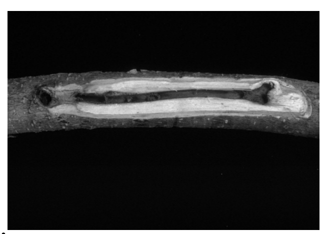
4.


5.


6.


7.


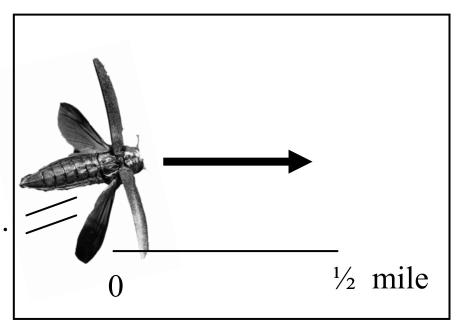
8.


9.


10.


11.


12.


13.


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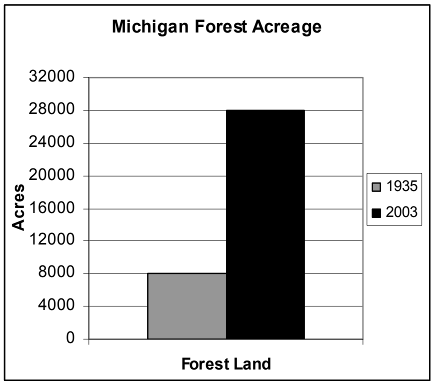
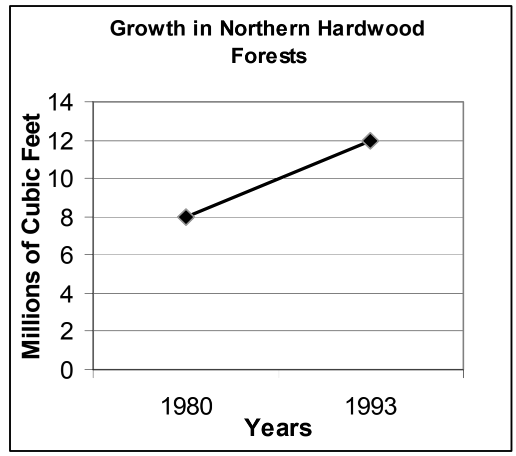
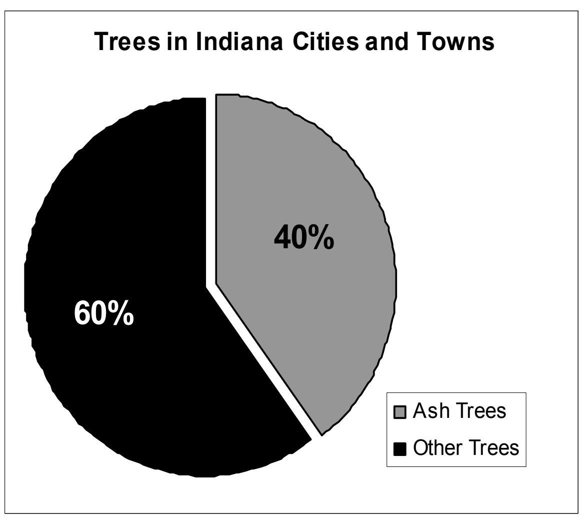
14. 

15. 

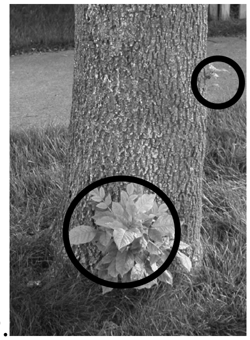
16. 

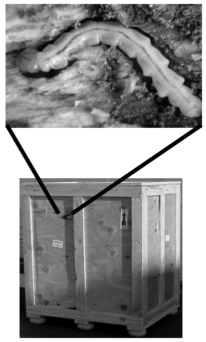
17. 

18. 

End Section 1.

Begin Section 2.

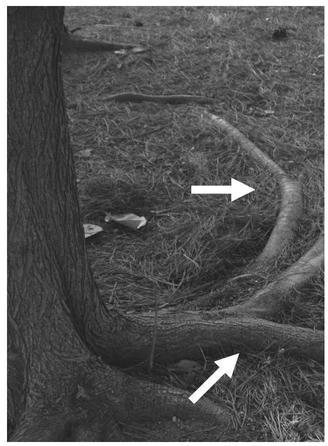
19. 

20. 

21. 

22. 

23. 

24. 

25. 

26. 

27. 

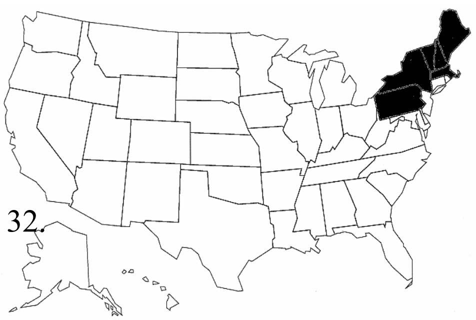
28. 

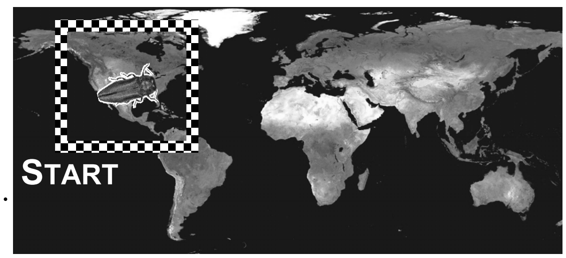
29. 

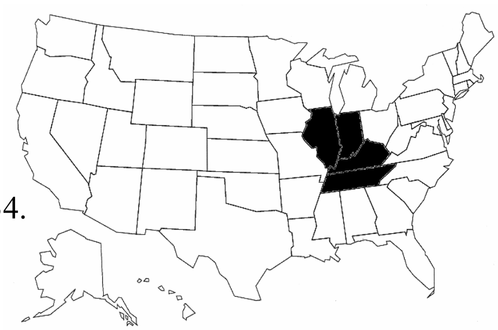
(Images continue on next page.)

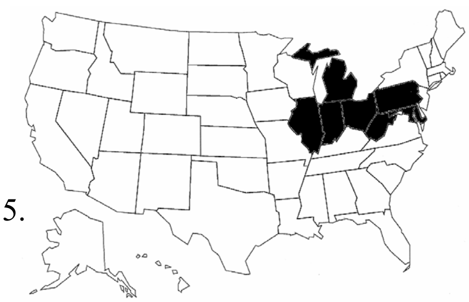
30. 

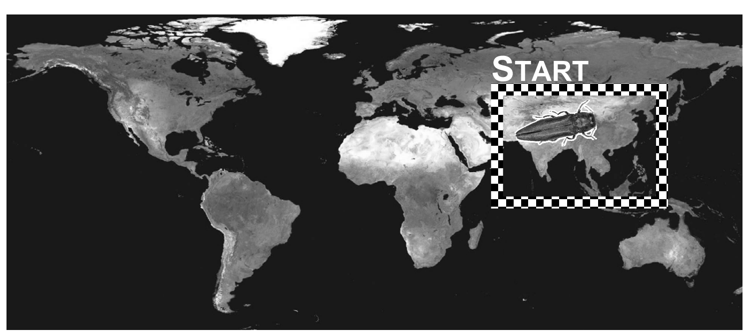
31. 

32. 

33. 

34. 

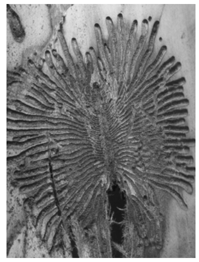
35. 

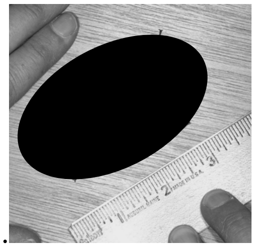
36. 

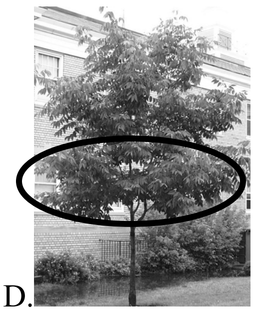
End Section 2.

Begin Section 3.

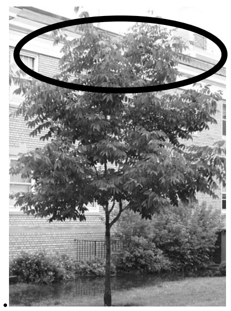
A. 

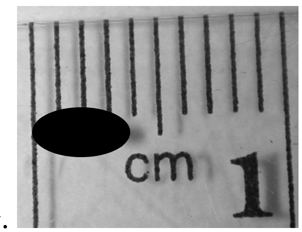
B. 

C. 

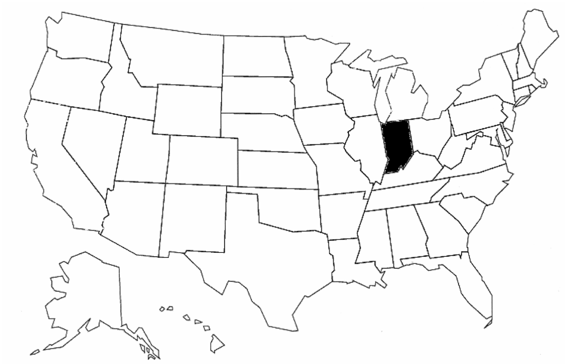
D. 

E. 

F. 

G. 

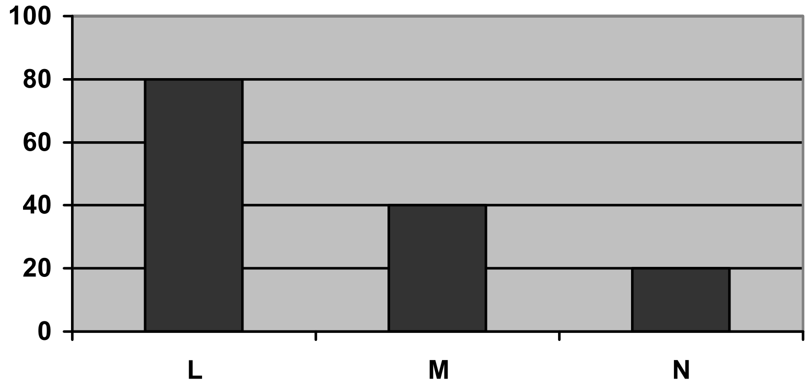
H. 

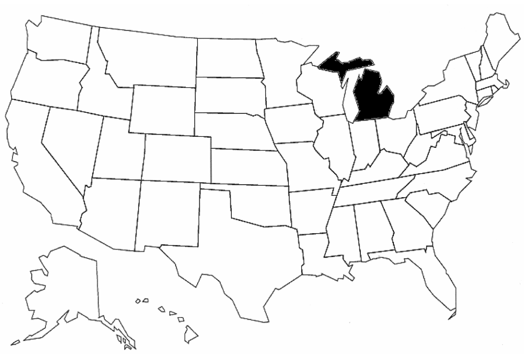
I. 

J. 

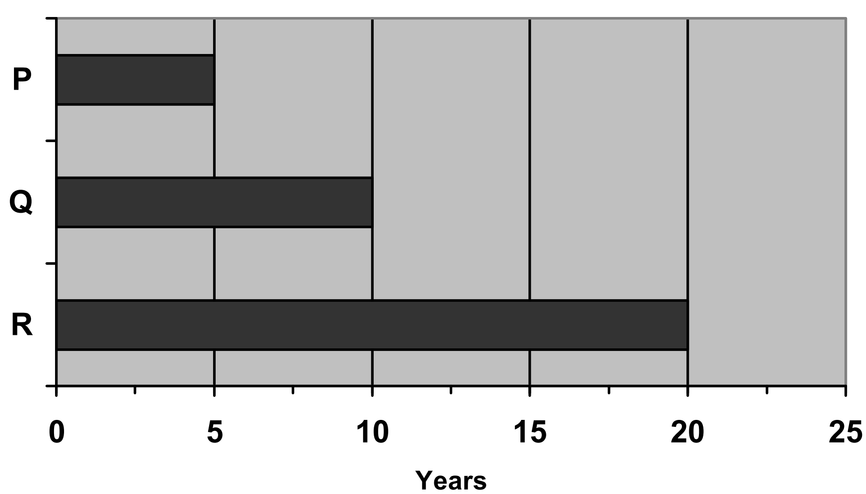
K. 

(Images continue on next page.)



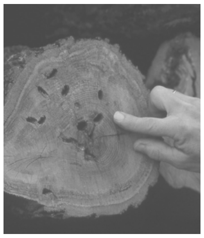
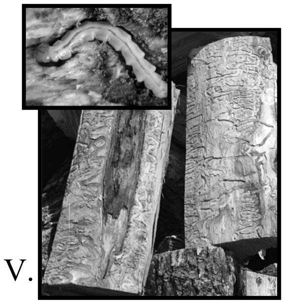


O.

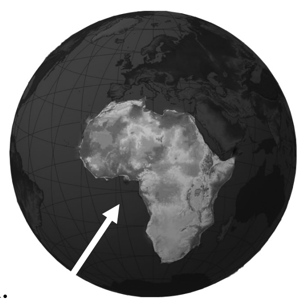


End Section 3.

Begin Section 4.

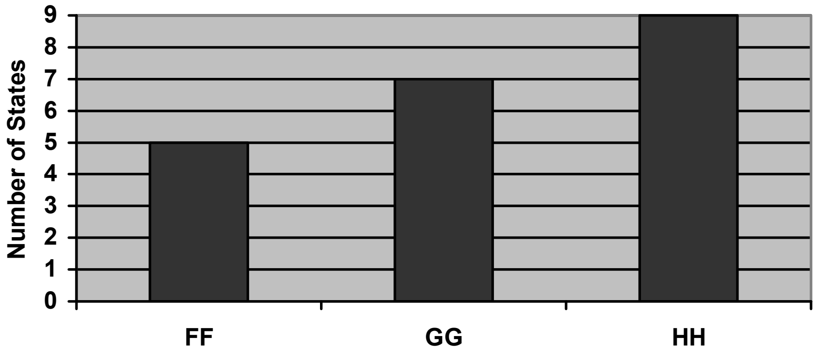
S.  T.  U.  V. 

W.  X.  Y. 

Z.  AA.  BB. 

CC.  DD.  EE. 

(Images continue on next page.)

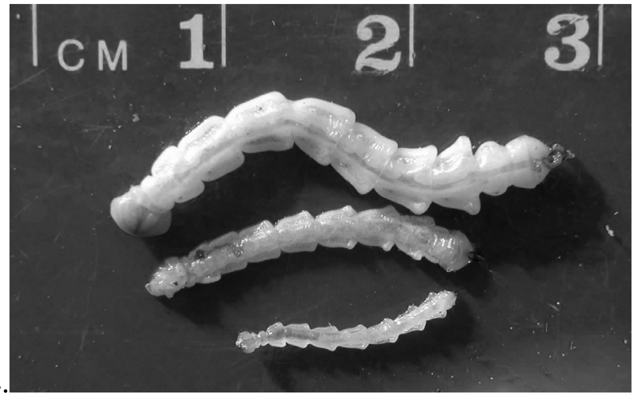


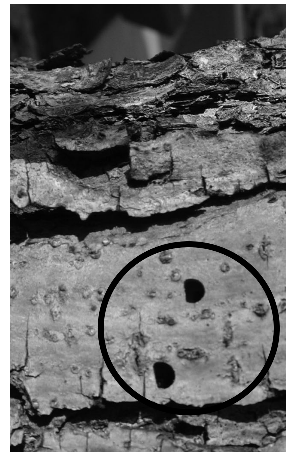
II.

JJ.

KK.

(Images continue on next page.)

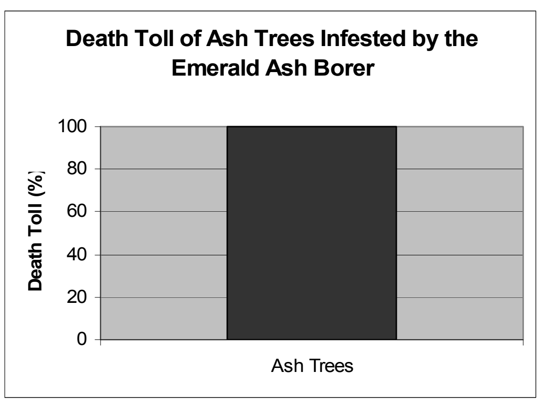
LL. 

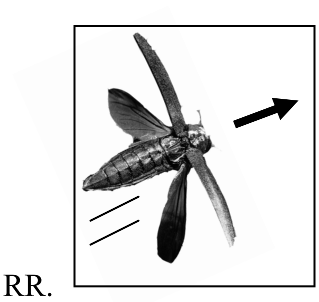
MM. 

NN. 

OO. 

PP. 

QQ. 

RR. 

End Section 4. **Please complete the Section 5 questions on the matching sheet.**

Matching Sheet

Section 1 Instructions:

On **pages 1 and 2 of your image packet** are a series of images **numbered 1-18**. Match each of the following statements with the one image it best describes. Write the corresponding number in the space provided next to the statement below. Use each statement and each image only once.

_____ It entered Michigan.

_____ A segmented insect with a small head, rounded hind end, long legs, and small spots on its back; it is about ¾ inch long.

_____ A tree with many leaves on its branches.

_____ Michigan forest acreage increased from 8000 to 28000 acres between 1935 and 2003.

_____ A tree with no leaves on the top branches.

_____ A flying insect with four wings; it can fly ½ mile.

_____ A piece of a log with the bark removed, revealing two jagged lines in the wood.

_____ A tree with no leaves on any branches.

_____ It entered New York.

_____ 40% of the trees in Indiana cities and towns are ash trees.

_____ A rectangular insect with a round head, tapered hind end, six legs, and large spots on its back; it is about ½ inch long.

_____ A piece of a log with the bark removed, revealing S-shaped patterns in the wood.

_____ A swarm of flying insects; they are above pine trees.

_____ Northern hardwood forests increased from 8 million cubic feet to 12 million cubic feet between 1980 and 1993.

_____ It entered California.

_____ A piece of a log with the bark removed, revealing a deep groove down the center.

_____ A bird with something in its beak; it is taking off in flight.

_____ A rectangular insect with a square head, tapered hind end, six legs, and small antennae; it is about ½ inch long.

End of Section 1. Continue to Section 2.

Section 2 Instructions:

On **pages 3 and 4 of your image packet** are a series of images numbered **19-36**. Match each of the following statements with the one image it best describes. Write the corresponding number in the space provided next to the statement below. Use each statement and each image only once.

_____ The branch has twigs that grow opposite each other.

_____ The Emerald Ash Borer started in Africa.

_____ The Emerald Ash Borer is now in Maine, New Hampshire, Vermont, New York, Massachusetts, and Pennsylvania.

_____ Leaves sprouting from the base of a tree and further up on the trunk.

_____ Larvae were relocated in a barrel made from infested wood and metal.

_____ The branch has bark partially missing with sap dripping from the branch.

_____ Mushrooms growing from a tree trunk midway up on the tree.

_____ A man with a gas mask fills a tank in the back of a pickup truck.

_____ The Emerald Ash Borer is now in Michigan, Illinois, Indiana, Ohio, Pennsylvania, Maryland, and West Virginia.

_____ Roots showing above ground surrounding the base of a tree.

_____ Larvae were relocated in a wooden shipping box made from infested wood.

_____ The branch has twigs and buds that do not grow opposite each other.

_____ The Emerald Ash Borer started in North America.

_____ Firewood was put into the back of a pickup truck.

_____ A man pushes a log into a woodchipper.

_____ The Emerald Ash Borer started in Asia.

_____ The Emerald Ash Borer is now in Illinois, Indiana, Kentucky, and Tennessee.

_____ Larvae were relocated in a cardboard box filled with packing peanuts.

End of Section 2. Continue to Section 3.

Section 3 Instructions:

On **pages 5 and 6 of your image packet** are a series of images lettered **A – R**. Match each of the following statements with the one image it best describes. Write the corresponding letter in the space provided next to the statement below. Use each statement and each image only once.

_____ A picture of a penny. The length of the insect covers about 2/3 of the penny.

_____ Grooves in wood that begin at one end and move straight through like a knife cut.

_____ Forty

_____ Michigan

_____ A picture of an inch ruler. The length of the insect covers about 3 inches.

_____ The middle third of the tree.

_____ Ten years

_____ A picture of a metric ruler. The length of the insect covers about 3 mm.

_____ Indiana

_____ Eighty

_____ Five years

_____ The top third of the tree.

_____ Grooves in wood that begin at one end and move back and forth like a coil.

_____ Grooves in wood that begin at a central point and move outward like a starburst.

_____ Maryland

_____ Twenty years

_____ Twenty

_____ The bottom third of the tree.

End of Section 3. Continue to Section 4.

Section 4 Instructions:

On **pages 7 through 9 of your image packet** are a series of images lettered **S-RR**. Match each of the following statements with the one image it best describes. Write the corresponding letter in the space provided next to the statement below. Use each statement and each image only once.

Please note this list continues on the next page.

_____ Seven

_____ Small, D-shaped holes in the bark.

_____ Seeds are papery thin and hang from individual stems in clusters.

_____ Wooden chairs, tables, and cabinets.

_____ The firewood was infested with Emerald Ash Borer larvae.

_____ Africa

_____ Little leaves with a smooth edge growing on the stem in mirror-image pairs (opposite each other); branch with twigs growing in mirror-image pairs on either side of the branch.

_____ The bark is rough, chunky, and diamond-shaped.

_____ Small oval holes in the end of a log.

_____ Baseball bats

_____ Pale patches in the center of the leaves.

_____ Wooden pallets (platforms which help move large items).

_____ Branch with twigs growing in staggered pairs (not opposite each other); bark with a rough texture that is diamond shaped.

_____ Five

_____ An adult Emerald Ash Borer flying away.

_____ The death toll of ash trees infested by the Emerald Ash Borer is 100%.

_____ Men loading wooden furniture into a truck.

_____ Australia

(List continues on next page.)

(Section 4 continued.)

_____ Little leaves with a serrated edge growing on the stem in staggered pairs (not opposite each other); papery thin seeds hanging in pairs.

_____ Asia

_____ Leafy growth coming from a tree trunk.

_____ Larvae are cream colored with bell shaped segments; larvae range in size from 1 – 3 cm.

_____ Axe handles

_____ A lady putting firewood into a truck.

_____ Nine

_____ A single leaf is made up of about seven little leaves with smooth edges, three pairs growing opposite each other on either side of the stem with one little leaf at the end of the stem.

End of Section 4. Continue to Section 5.

Section 5 Instructions:

Please complete the following:

Overall, how difficult was this matching test?

Very easy 1 2 3 4 5 Very difficult

Were there any images that were more difficult than others to match to a statement? If so, please list the number or letter of the image(s) here:

Age: ________

I am (please circle): Male Female

I am (please circle): Freshman Sophomore Junior Senior

Please list your home:

Country ___________________

State ______________________

County _____________________

Is English your first language? (Please circle): Yes No

How familiar are you with the Emerald Ash Borer?

Never heard of it 1 2 3 4 5 Very familiar

This is the end of the study. Please turn in your image packet and this matching sheet and you are free to go. Thanks for your help!!

VITA

VITA

JANET M. BEAGLE

Career Objective: To become a leader in agricultural education and communication, employing my science experiences and communication skills to promote understanding between agricultural researchers and lay audiences.

Education

PhD **Curriculum and Instruction (Agricultural Education)**
Purdue University, West Lafayette, IN
Expected Completion: December 2009
Cumulative GPA: 3.9
Dissertation: Pictures vs. Text: Modality Effects Across Three Levels of Learning and Study Time

M.S. **Animal Science (Swine Nutrition)**
Southern Illinois University, Carbondale, IL
Completed: August 2004
Cumulative GPA: 4.0
Thesis: The digestive fate of the *gdh*A transgene from transgenic corn diets fed to weanling swine.

B.S. **Large Animal Science**
English Minor
Delaware Valley College of Science and Agriculture
Doylestown, PA
Completed: May 2000
Cumulative GPA: 4.0

Experience

Purdue University Graduate School, Marketing & Communications Coodinator 2007-present

- Manage database of 30,000+ prospective graduate and professional students
- Conduct individual and group recruitment and database training for members of 70 graduate and professional programs
- Oversee all communication with prospective students, including the development and execution of a comprehensive communication plan and individual message content
- Maintain, track, and analyze data results including prospective, applicant, admit, and enrolled data from each recruitment initiative to determine the best allocation of resources
- Work with external vendors to design and develop persuasive Web and print communication pieces
- Recruit students at graduate school fairs and conferences
- Present formal presentations around the country to undergraduate classes and student groups on preparing for, applying to, and choosing a graduate school.

Purdue University Graduate School Recruitment Services, Graduate Assistant 2005-2007

- Assisted with oral and written communication with prospective graduate students
- Benchmarked peer institution recruitment activites
- Researched, designed, and developed new content for Purdue's website and marketing brochures

Purdue University Deparment of Animal Sciences, Research Assistant 2004-2005

- Drafted grant proposals, experimental designs, and progress reports
- Supervised metabolism trial analyzing nutrition of degermed, debranned corn in pigs
- Worked as part of a team implementing innovative solutions to reduce swine nutrient excretion
- Performed RNA/DNA extraction, purification and quantification to monitor gene expression
- Created trial specific protocols for PCR, RT-PCR, real-time PCR, and gel electrophoresis

Southern Illinois University, Research & Teaching Assistant
2002-2004

- Presented research results at national American Society of Animal Science meeting
- Conducted thesis research investigating the digesive fate of a patented transgenic corn
- Formulated and processed experimental diets and calculated nutrient analysis
- Performed total fecal and urine collections from swine, organ collections from swine and rats, and oocyte aspiration and enucleation from abattoir ovaries to assist with livestock nutrition and physiology studies within the department
- Responsible for the teaching, planning, grading, and tutoring of over 100 students in: Introduction to Animal Science, Livestock Feeds and Feeding, and Swine Management

Federation of Animal Science Societies
Office of Scientific Liaison (FASS-OSL) Student Intern
Summer 2003

- Single intern selected from a nationally competitive application process
- Researched and reported from Congressional hearings on animal agriculture
- Represented agricultural researchers and producers to leaders on Capitol Hill
- Authored novel "State of the Science" reports on biotechnology, biosecurity, and bioterrorism, published through FASS-OSL in print and on-line

AbstraKt Ranch Publishers, Owner
1994-present

- Developed business plan strategizing management, production, and marketing
- Wrote, edited, published and marketed booklet: *Surviving College: A collection of thoughts… and lack thereof* and *Bun Run News*, a newsletter on rabbits

Sturbridge Veterinary Hospital, Veterinary Receptionist
2000-2002

- Answered phones, fielded questions, scheduled appointments, checked patients in and out
- Recorded patient progress reports and balanced daily deposits against income records

Delaware Valley College Writing Center, Founding Tutor
1998-2000

- Developed and implemented start-up plan for the center
- Aided students with the writing process of all genres

Delaware Valley College Livestock Facility, Livestock Technician
1996-2000

- Vaccinated, dewormed, fed, and monitored calving of Angus and Polled Hereford herds
- Processed calves by taking birth weights, ear tagging, tattooing, and giving shots
- Mixed feed, monitored breeding dates, trimmed hooves of Dorset and Hampshire sheep
- Processed lambs by taking birth weights and ear tagging flock
- Assisted with farrow to finish Yorkshire hog operation detecting heat, pregnancy testing, processing piglets, giving shots, clipping needle teeth, taking birth weights, and ear notching

Delaware Valley College Presidential Diplomat
1998-2000

- Gave group and individual campus tours
- Furthered public relations with potential students

Guiding Eyes for the Blind, Whelping Kennel Technician
Summer 1999

- Attended whelping broods
- Fed, medicated, and exercised broods and newborn pups up to 7 weeks old
- Sanitized indoor and outdoor facility and helped with early socialization of puppies

Technical skills

Molecular biology: DNA extraction from tissue, white blood cells, plasma, digesta; RNA extraction from animal tissue. PCR, Real-time PCR, RT-PCR, gel electrophoresis; oocyte enucleation, oocyte aspiration from abattoir ovaries

Animal experience: general handling of swine, dairy, beef, sheep, horses, dogs, and rabbits; blood drawing; injections; artificial insemination in swine and cattle; surgical experience in swine and dogs; freezebranding cattle; tail docking lambs; castrating, needleteeth clipping piglets; stomach tubing lambs and piglets

Computer and database experience: Adobe Acrobat, Adobe InDesign, Adobe Photoshop, Apply Yourself (database), Microsoft Office Suite (including Word, Excel, Access), Powerpoint, SPSS, SAS, SunGuard Banner, Cognos

Certifications

Westfield State College
Sign Language Certification (Courses 1-3) 2001
Farm Credit Financial Partners, Inc.
Assistant Tax Specialist, September 2000
Select Sires Artificial Insemination Training School
Certificate of Completion, March 1998

Relevant Graduate Coursework

Education: Advanced Educational Psychology, Adult Education Principles, Philosophy of Education
Agriculture/Animal Science: Animal Biotechnology, Food Biotechnology, Monogastric Nutrition, Small Animal Welfare: Human-Animal Interaction
Communication: Agricultural Publishing, Foundations in Human Communication Inquiry, Media Communication & Public Health, Risk Communication

Memberships & Activities

American Psychological Association, Student Affiliate (2008-present)
American Marketing Association (2008-present)
Greater Lafayette Kennel Club (2005-present)
Member Director (2007-present)
Assistant Puppy Kindergarten Instructor (2007)
American Society of Animal Sciences (2003-2007)
Purdue University Graduate Student Government Senator (2004-2005)
SIUC Animal Science Food and Nutrition Department Chair Search Committee (2004)
Delta Tau Alpha Honor Society, President (1999-2000)
Delaware Valley College (DVC) Yearbook (1998-2000)
National and DVC Block and Bridle (1996-1997, 1998-2000)
American Rabbit Breeders Association (1992-2000)
Happpy Hoppers Rabbitry, Owner (1990-2000)
Guiding Eyes for the Blind, Volunteer Puppy Raiser (1995-1996)
Pioneer Valley Therapeutic Riding Association, Volunteer (1994-1996)

Honors & Awards

Purdue University Ross Fellowship Recipient (2004-2005)
Invited into Phi Kappa Phi National Honor Society (2004)
Southern Illinois University Carbondale Master's Fellow (2002-2003)
Summa Cum Laude, Top Day Student Delaware Valley College (Class of 2000)
Who's Who Among Students in American Colleges and Universities (2000)
Dean's List (1996-2000)
Livestock Publications Council Travel Scholarship Recipient (1998)
Girl Scout Gold Award (1996)
Second place American Rabbit Breeders Association (ARBA) National Rabbit Management Contest (1995)
Second place ARBA National Rabbit Achievement Contest (1995)

Publications

Beagle, J. (1997). *Surviving College: A collection of thoughts… and lack thereof*. Abstrakt Ranch, Monson, MA.

Beagle, J. (2003). The importance of bumper stickers. Federation of Animal Science Societies 2003 Student Intern Perspectives. Available: http://osl.fass.org/csf.asp?view=bumpstick.

Beagle, J. M. (2004). The digestive fate of the *gdh*A transgene from transgenic corn diets fed to weanling swine. Master’s Thesis. Southern Illinois University, Carbondale.

Beagle, J. M., G. A. Apgar, G. A. Jones, K. L., Griswold, K. E., Radcliffe, J. S., Qiu, X., et al. (2006). The digestive fate of *Escherichia coli* glutamate dehydrogenase deoxyribonucleic acid from transgenic corn in diets fed to weanling pigs. *Journal of Animal Science*, *84*, 597-607.

Hinson, R., Walsh, M., Yager, A., Sholly, D., Wilson, L., **Beagle, J**., et al. (2005). The effect of feeding low nutrient excretion diets with the addition of soybean hulls and non-sulfur trace minerals on growth performance and carcass characteristics in grow-finish pigs. *Journal of Animal Science, 83*(Suppl. 2), 83. (Abstr.)

Yager, A., Sholly, D. Wilson, L., **Beagle, J.**, Hinson, R., Saddoris, et al., (2005). Effects of increasing true ileal digestible amino acid to lysine ratios on grower pig performance. *Journal of Animal Science, 83*(Suppl. 1),161. (Abstr.)

Professional Presentations

Beagle, J. M. (2004, July). *The digestive fate of the gdhA transgene in corn diets fed to weanling swine.* Presented at the national joint meeting of the American Society of Animal Science, American Dairy Science Association, and Poultry Science Association, St. Louis, MO.

Beagle, J. M. (2009, March). *Pictures promote memory better than text: Is the reverse true for transfer?* Poster presented at the Purdue University Third Annual Graduate Student Educational Research Symposium, West Lafayette, IN.

Beagle, J. & Gabauer, C. (2009, April). *Setting the stage: Connecting admitted students to your institution.* Presented at the 22nd annual conference of the National Association of Graduate Admissions Professionals, New York, NY.

Beagle, J. M. & Sears, D. A. (2009, August). *Testing the Picture Superiority Effect at Three Levels of Learning and Study Time.* Poster presented at the 117th annual convention of the American Psychological Association, Toronto, Canada.

Beagle, J., & Werner, D. (2007, June). The value of an annual marketing communications plan – and how to evaluate it. Presented at the national Apply Yourself User Conference, Washington, D.C.