COGNITIVE LOAD THEORY'S COHERENCE PRINCIPLE: THEORY MEETS REALITY

By Julie M. Arts

For learning to occur, the individual must make sense of the presented material by attending to relevant information, mentally reorganizing it, and connecting it with existing knowledge. A great deal of this process occurs in working memory. However, working memory is extremely limited.

With the learning process in mind, the challenge is evident. The learner must actively process new material within the limits of working memory. Cognitive load theorists determine how to best design instruction with this limitation in mind. Cognitive load theory suggests that instruction imposes three different types of cognitive load, and because the total mental capacity is limited, it is important to balance all three forms. When a lesson is high in one type of cognitive load, there is very little capacity remaining for the other forms.

To create instruction that meets these goals, cognitive load theorists have developed several universal principles that are proven to result in efficient instructional environments by accommodating the limits and exploiting the strengths of working memory. This paper looks closely at the coherence principle. Based on the coherence principle, instruction should not include extraneous material (i.e., learning material that is not directly related to the lesson's objectives). Extraneous materials can provide interest, expand on key ideas, or provide technical background. Regardless of the purpose, extraneous material imposes undue cognitive load on the learner. Therefore, learning material should not be included unless it is essential to the learning goals.

Knowing that theories often conflict with real-world constraints or expectations, this paper looks for ways that instruction can foster learning with these cognitive principles in mind even when they cannot be leveraged in their full sense.

The instructional designer may attempt to minimize extraneous material. However, the intent is moot if the client (for whom the instruction is created) does not share the same intent. So while extraneous material should be ruthlessly weeded out, the instructional designer needs a backup plan. The purpose of this paper is to develop a method by which the framework behind the cognitive load theory and its principles can be leveraged to reduce the effects of extraneous material. While the cognitive load theory and its principles pertain to both paper and electronic learning materials, the backup plan developed in this paper requires the use of electronic learning formats.

COGNITIVE LOAD THEORY'S COHERENCE PRINCIPLE:
THEORY MEETS REALITY

by

Julie M. Arts

A Thesis Submitted
In Partial Fulfillment of the Requirements
For the Degree of

Master of Arts-English

at

The University of Wisconsin Oshkosh
Oshkosh WI 54901-8621

December 2009

COMMITTEE APPROVAL

_______________ Advisor

Dec. 18, 2009 Date Approved

_______________ MEMBER

12/18/09 Date Approved

_______________ Member

12/18/09 Date Approved

PROVOST
AND VICE CHANCELLOR

____

1/12/2010
Date Approved

FORMAT APPROVAL

____

11/10/2009
Date Approved

TABLE OF CONTENTS

Page

CHAPTER 1 — INTRODUCTION 1

CHAPTER 2 — LITERATURE REVIEW 7

Introduction 7
Process of Learning 8
Cognitive Load Theory 13
Summary 29

CHAPTER 3 — COHERENCE AND SIGNALING: AN IN-DEPTH REVIEW 30

Coherence Principle 30
Background Music and Sounds 32
Graphics 34
Words 36
Seductive Details Effect 38
Heavy Load and the Impact of Coherence 41
Interest Versus Extraneous 42
Signaling 43
Media 49
Summary 53

CHAPTER 4 — REAL-LIFE PROBLEMS AND POTENTIAL COMPROMISES 54

Intentions of the Client 54
Alleviating the Effects of Extraneous Material 55
Seductive Details Effect 61
Increased Interest 63
First Solution 64
Online Learning Environments 66
Node 67
Linear Text 67
Hypertext 68
Increased Cognitive Load 68
Link Labels 71
Link Previews 73
Second Solution 78
Summary 82

TABLE OF CONTENTS (Continued)

Page

CHAPTER 5 — CONCLUSIONS 85

APPENDIX A 89

Screenshot of Rollover Link Preview 89

WORKS CITED 91

CHAPTER 1

INTRODUCTION

Over the years learning psychologists have studied, researched, and theorized the ways in which the mind works. They have created numerous theories to explain the factors that affect learning and the ways that these factors relate to the learner. Instructional designers—people who design instruction with the intent of maximizing the effectiveness and efficiency of learning—should embrace these findings when determining the strategy and design elements that will best suit the learner's needs.

As learning theorists have discovered, the learning process is complex. The learner is an active participant who must engage in cognitive processing. Therefore, as Driscoll maintains, the learner must attend to relevant information, mentally organize it into a coherent structure, and integrate it with his or her existing knowledge (137). With the learning process in mind, the challenge is evident. The learner must actively process new material within the limits of working memory. To promote learning, then, it is important for the instructional designer to understand the learning process, its constraints and limitations, and the best ways to encourage successful learning. The intent of this paper is to look specifically at one very well known theory and then evaluate the theory's weaknesses. From there, the paper's focus is to determine the best ways to leverage the theory's principles and develop compromises when the coherence principle falls short in practice. While the cognitive load theory and its principles pertain to both paper and electronic learning materials, the solution developed in this paper requires the use of electronic learning formats.

The role of working memory is essential to the learning process. For learning to occur, new information must pass from working memory to long-term memory. The learner actively processes incoming information in the working memory. During this processing, the learner uses his or her working memory to hold and manipulate information while organizing it into a coherent structure and integrating it with what he or she already knows (Driscoll 74). Working memory is extremely limited; it can hold very little information for a short time (Clark, Nguyen, and Sweller 29-30). After the information is encoded, it moves to long-term memory, and the duration and capacity limitations associated with working memory disappear. The long-term memory stores knowledge in a permanent form (Driscoll 89).

Cognitive load, stated simply, refers to the load inflicted on working memory during learning; it is the amount of mental resource that is required to learn a given task (Clark and Mayer 39). Cognitive load theory is based on knowledge of how the human mind works. Cognitive load theorists determine how to best design instruction based on cognitive structures that make up the way humans learn, think, and solve problems. The theory suggests that instruction imposes different types of cognitive load. According to Sweller, the founder of the cognitive load theory, some forms of cognitive load are useful while others waste mental resources (Clark, Nguyen, and Sweller 9). The three main types of cognitive load are intrinsic load, germane load, and extraneous load.

Intrinsic load is imposed by the complexity of the information. This type of load, therefore, is mainly determined by the instructional goals themselves and cannot be directly reduced. Instructional designers, however, can manage intrinsic load by breaking down complex material into smaller segments and then sequencing the material so that prerequisite information supports more complex information. Germane load uses mental capacity in ways that contribute to learning. Mental load of this type is beneficial because it leads to a better learning outcome. The processing associated with this type of load is aimed at a more meaningful understanding of the core information and occurs largely when the learner organizes the material and integrates it with his or her existing knowledge. According to Clark and Mayer, this processing results from the learner’s motivation to make sense of the information (37). This type of load is important because it is relevant to learning and can be used, for example, to help the learner apply the learned principles in various settings. Extraneous load is the mental work that is irrelevant to the learning goal. Because this type of load does not support the instructional objectives, it wastes limited mental resources. Extraneous load occurs when instruction is poorly designed and, for this reason, instructional designers can alter this type of cognitive load the most easily (Clark, Nguyen, and Sweller 12). To reduce extraneous load, for example, instructional designers can remove information that is not essential to the learning objectives. By doing this, instructional designers ensure that learners use their mental resources to focus on the relevant material.

Because the learner’s total mental capacity is limited, it is important to balance all three forms of cognitive load in order to maximize learning efficiency. When a lesson is high in one type of cognitive load, there is very little capacity remaining for the other forms. The aims of cognitive load theory are to alleviate extraneous load, maximize germane load, and manage intrinsic load. When instruction is designed to meet these aims, the learning material is more efficient, which enables the learner to learn the intended skills more easily and quickly.

To create instruction that meets these goals, cognitive theorists have developed several universal principles that are proven to result in efficient instruction by accommodating the limits and exploiting the strengths of the working memory. When developed based on the cognitive load theory, learning materials put limited mental resources to work in ways that are proven to minimize wasted mental resources while maximizing learning. Based on this ideal, this paper investigates the effects that various cognitive load principles have on instruction and looks at the principles and their individual implications.

After looking closely at learning theories, cognitive science, and instructional design, the best methods for applying the theories in practice become clear. However, when examining the ways that these methods can improve instruction, it becomes evident that sometimes cognitive load principles fall short in the real world. Put differently, when instructional designers attempt to apply various cognitive load principles to instruction, there are shortcomings. In certain situations, the theories conflict with real-world constraints or expectations. This paper uncovers the shortcomings and then explores the possibility for compromise in one particular situation. In other words, the intent of this paper is to investigate the ways that instruction can foster learning with these cognitive principles in mind even when one such principle cannot be leveraged in its full sense.

One of the principles of the cognitive load theory, the coherence principle, indicates that extraneous material should be eliminated from learning materials. Based on this principle and the supporting research, the instructional designer knows that learning is promoted when the information is narrowed to include only that which is relevant to the instructional objectives. While the instruction could include additional background information or other interesting related information, the instruction should contain only the information that is essential to learning. However, in the real world, this ideal may not be realized.

Even though the instructional designer may work hard to minimize extraneous material, the intent is moot if the client (for whom the instruction is created) does not share the same intent. Because the typical client has very little knowledge about the best ways to design instruction, the client may not understand the intentions of the instructional designer. Even when the designer makes a case for coherence, then, the client may not agree.

If, despite the instructional designer’s advice, the client is convinced that the extraneous material should be included in the lesson, the designer should look for ways to alleviate the load imposed by the extraneous material. The instructional designer can look for ways to creatively design the lesson while adhering to the client’s demands and while still attempting to factor in the cognitive load theory and its principles. When designing the instruction, then, how can the instructional designer incorporate extraneous material while minimizing its negative effects?

CHAPTER 2

LITERATURE REVIEW

Introduction

To understand the manner in which cognitive load theories often fall short in practice, it is first necessary to understand the basics about the cognitive load theory and the way in which the human mind works. This chapter first considers the process of learning, including the events necessary for learning to occur, and then looks more specifically at the cognitive load theory and its principles.

Theorists have described three major metaphors of learning during the past one hundred years. In one view, which is sometimes referred to as “response-strengthening,” the learner is passive. The recipient receives rewards and punishments from the instructor; punishments weaken certain responses while rewards strengthen others. Although this view is the foundation for some instruction even today, most experts believe that it is not complete because it does not explain meaningful learning. The next learning metaphor, the information-acquisition view, also considers the learner to be passive. In this view, however, the learner receives information—rather than punishments and rewards—from the instructor. While this view is widely accepted among experts, its major flaw is that it considers the learner to be an empty vessel into which the instructor pours information. The knowledge construction metaphor, on the other hand, views the learner as an active participant who must engage in cognitive processing. The learner must attend to relevant information, mentally organize it into a coherent structure, and integrate it with his or her existing knowledge.

With the knowledge construction view in mind, the challenge is evident. The learner must actively process new material within the limits of working memory. To promote learning, then, it is important for the instructional designer to understand the learning process, its constraints and limitations, and the best ways to encourage successful learning. The learning process, human cognitive architecture, cognitive load theory, and the principles associated with cognitive load theory are described in this literature review.

Process of Learning

Learning occurs when the individual makes sense of the presented material by attending to relevant information, mentally reorganizing it, and connecting it with existing knowledge. Cognitive theorists propose that learning is an internal process that involves higher order mental activities such as memory, perception, thinking, and concept formation (Driscoll 137).

As part of the learning process, information must progress from sensory register to working memory and finally to long-term memory. The sensory register stage of information processing is associated with the senses and is extremely brief. Sensory memory functions to hold information just long enough for the information to be processed further (Driscoll 74). The learner's attention to the information is therefore crucial during the progression from sensory memory to working memory.

After a sensory impression has registered, the information passes into working memory. Working memory is extremely limited; it can hold very little information for a short time. For this reason, working memory is sometimes referred to as “short-term memory” (Gredler 154). Encoding, which refers to the process of moving incoming information from short-term memory to long-term memory, must occur during this time in order for the information to reach long-term memory (Driscoll 89).

When information moves to long-term memory, the duration and capacity limitations associated with working memory disappear. The long-term memory stores knowledge in a permanent form. At this point experts are unaware of limits in long-term memory. Hence, most experts believe that information cannot be lost once the learner stores it in long-term memory (Driscoll 75). If the learner struggles to remember the information, it was either never encoded in the first place or the information is irretrievable (Driscoll 102). In the case of the latter, the individual may suffer from retroactive interference. If, for example, the learner stored a phone number in his or her long-term memory, the number is still there. However, the individual cannot retrieve the number as a result of the other phone numbers that he or she has since learned.

Dual Channels

Cognitive theorists believe that the working memory is divided into two separate channels. One channel is for processing visual material while the other is for processing auditory material. The auditory channel processes information that enters through the ears; the visual channel processes information received through the eyes. While only a small amount of information can be processed in each channel at one time, this means that the individual processes visual and verbal material through separate channels (Clark and Mayer 36; Clark, Nguyen, and Sweller 33, 48). This is an important point about working memory because it affects the amount of information that can be processed at one time.

The Role of Working Memory

The role of working memory is essential to the cognitive process. Working memory is linked to consciousness; the ideas that are in an individual's consciousness are the ideas currently in working memory (Driscoll 75). The learner actively processes incoming information in working memory. Incoming information includes new information as well as existing knowledge that is retrieved from long-term memory. During this processing, the learner uses his or her working memory to hold and manipulate information while organizing it into a coherent structure and integrating it with what he or she already knows.

Both the capacity and the duration of working memory are limited. Individuals can hold material in working memory for a very short time. Individuals may be able to hold material for a maximum of 20-30 seconds. According to Sweller, however, the working memory starts losing information within the first two to three seconds. By the 20-30 second range, then, nearly everything is lost (Clark, Nguyen, and Sweller 29-30). It is for this reason that an individual must repeat a phone number to remember it; he or she must refresh the working memory in order to hold the number for more than a few seconds (Gagné, Wager, Golas, and Keller 7).

Individuals can hold roughly seven elements of information in working memory. However, these elements are not limited in size, complexity, or sophistication (Gredler 245). For example, an individual may struggle to manage seven single words in a foreign language. However, the same individual may easily manage seven sentences in his or her own language. The unknown words are meaningless to the learner. The sentences, however, are meaningful and therefore require less working capacity. When referring to these seven elements of information, it is important to note that individuals can *hold* seven pieces of information. They can repeat these seven pieces; however, they cannot process all seven of them at one time. When it comes to processing information (e.g., combining, contrasting, and dealing with it), which is the primary purpose of working memory, working memory can handle no more than two to four elements of information at a time (Clark, Nguyen, and Sweller 29).

Schema

Schema is a hypothetical mental structure that is part of an individual's mind. This structure represents generic concepts that are stored in the individual's memory. Schemata contain slots or placeholders for new information to be stored and are created through experiences with people, objects, and events in the world. When individuals encounter repeated situations and events, they begin to generalize their experiences to develop an abstracted, generic set of expectations pertaining to the situation, event, or concept (Driscoll 126). The concept of the restaurant, for example, becomes familiar to individuals so that they know what to expect when in a restaurant. Schemata are useful because they help the individual put stories and new information into context. If an individual hears a story that involves a friend eating at a restaurant, the story does not need certain generic details about the restaurant to make sense. For example, details about being seated, placing an order with the server, and leaving a tip for the server can be excluded. The individual's schema for restaurant allows the individual to fill in these missing details (Gagné, Wager, Golas, and Keller 118).

Transfer

Because the learner is not an empty vessel, he possesses existing knowledge, which must be accessed during learning. New knowledge is not simply added to long-term memory in a cumulative way (Driscoll 137). In fact, learning occurs as a result of the interaction between new information that the learner acquires and the specifically relevant knowledge that the learner already possesses. Therefore, the learner must relate incoming information to concepts and ideas already in memory.

To facilitate this process, the learner must bring new knowledge structures into long-term memory in a way that allows the structures to be easily retrieved. Practice exercises and worked examples stimulate the integration of new knowledge into prior knowledge. For example, a practice assignment could ask the learner to review new software features and describe ways that their current clients might take advantage of this software. This assignment requires active processing of the software features in a way that links the features with prior knowledge about their clients. In contrast, a practice exercise that simply asks the learner to recall facts about the new software would not promote transfer. Transfer is important because it enables the learner to access the information when it is called upon (Gredler 206).

Cognitive Load Theory

Cognitive load theory is based on knowledge of how the human mind works. Cognitive load theorists determine how to best design instruction based on cognitive structures that make up the way humans learn, think, and solve problems. The theory suggests that instruction imposes three different types of cognitive load.

Cognitive load, stated simply, refers to the load inflicted on working memory during learning. It is the amount of mental resource in working memory that is required to learn a given task (Clark and Mayer 39). As mentioned in the previous chapter, some forms of cognitive load are useful while others waste mental resources. The three main types of cognitive load are intrinsic load, germane load, and extraneous load, which are explained more thoroughly here.

Intrinsic load is imposed by the complexity of the information. This type of load, therefore, is mainly determined by the instructional goals themselves. The level of intrinsic load is determined based on the material’s element interactivity. If the learning material consists of many elements that interact, the material is high in element interactivity. Due to the interaction of these elements, the learner must consider all the elements at one time. In other words, several knowledge elements must be accomplished in a coordinated fashion. Learning material that is low in element interactivity, on the other hand, allows the learner to handle one element at a time. This is because the material is accomplished in a serial fashion. Learning material that is low in element interactivity imposes a low level of intrinsic load while learning material that is high in element interactivity imposes a high level of intrinsic load (Clark, Nguyen, and Sweller 9-10, 48). Learning vocabulary in a foreign language, for example, is low in element interactivity whereas constructing sentences in that same foreign language is high in element interactivity because the learner must consider the meaning of several words in addition to the grammar and syntax rules (Clark, Nguyen, and Sweller 10). Because intrinsic cognitive load is determined by the knowledge and skills associated with the instructional objectives, the intrinsic load of the instructional content cannot be directly reduced. Instructional designers, however, can manage intrinsic load by breaking the lesson into manageable segments, for example.

Germane load uses mental capacity in ways that contribute to learning. Mental load of this type is beneficial because it leads to a better learning outcome. Germane load can help to build mental models as they pertain to instructional goals (Clark, Nguyen, and Sweller 11). The processing associated with this type of load is aimed at a more meaningful understanding of the core information and occurs largely when the learner organizes the material and integrates it with his or her existing knowledge. This processing results from the learner’s motivation to make sense of the information (Clark and Mayer 37).

Extraneous load is the mental work that is irrelevant to the learning goal. Because this type of load does not support the instructional objective, it wastes limited mental resources. Extraneous load occurs when instruction is poorly designed and, for this reason, is the most easily altered type of cognitive load (Clark, Nguyen, and Sweller 12).

Because the total mental capacity is limited, it is important to balance all three forms of cognitive load in order to maximize learning efficiency. When a lesson is high in one type of cognitive load, there is very little capacity remaining for the other forms. The aim of cognitive load theory is to alleviate extraneous load, maximize germane load, and manage intrinsic load. When instruction is designed to meet this aim, the learning material is more efficient, which enables the learner to learn the intended skills more easily and quickly.

To create instruction that meets these goals, cognitive theorists have developed several universal principles that are proven to result in efficient instructional environments by accommodating the limits and exploiting the strengths of working memory. When developed based on the cognitive load theory, learning environments put limited mental resources to work in ways that are proven to minimize wasted mental resources while maximizing learning.

Multimedia Principle

Cognitive theorists agree that some information is better portrayed verbally while other information is better portrayed visually. Spatial material (e.g., angles in geometry lessons, screens in software instructions, and diagrams in assembly instructions) does not lend itself to verbal form. The learner's ability to process spatial material is significantly higher when instructional designers use graphics instead of words because graphics explicitly illustrate representations of spatial tasks (Clark, Nguyen, and Sweller 50-53). The opposite is true for certain abstract concepts (e.g, truth, beauty, and justice). These concepts do not lend themselves to visual form. When portraying concepts such as these, instructional designers should use words instead of graphics. Therefore, some material is strongly suited for one form of presentation, and instructional designers should use the most suitable form. By presenting material in the appropriate form, the instructional designer greatly reduces cognitive load.

As a result, some material is best suited for a combination of visual and verbal form. For example, a geometry lesson that contains an angle and text explaining that abc = xyz is suited for a combination approach because the angle (e.g., spatial material) is best suited for visual form while its explanation is best suited for verbal form (Clark, Nguyen, and Sweller 61).

The multimedia principle, then, explains that people learn more deeply from verbal and visual than from verbal alone. Verbal representation (i.e., words) can include printed text or spoken text while visual representation (i.e., graphics) can include static illustrations (e.g., drawings, charts, graphs, maps, photos) and dynamic graphics (e.g., animation, video). The term “multimedia presentation” refers to any presentation that contains both words and graphics.

By pairing verbal and visual material, the instructional designer encourages the learner to make connections between the verbal and visual depictions, and the learner is more likely to understand new material when he or she engages in this form of active learning. In contrast, instruction that presents words alone does not encourage deep learning, and the learner may not connect the words with other knowledge (Clark and Mayer 57). To improve an instructional message that uses words alone, the instructional designer should convert the message into a multimedia presentation.

It is important to realize the productive nature of various types of visual representations. Not all types of graphics promote learning. Instructional designers should avoid graphics that decorate the page or represent a single object. Instead, graphics should help the learner to understand the material, organize the material, describe a quantitative relationship, or describe changes over time. Instructional designers should use these types of graphics as appropriate to the subject. Learning is facilitated when these types of graphics and text work together to present a unified instructional message (Clark and Mayer 58).

While multimedia lessons encourage active processing, it is important to look at how they affect learners with different levels of knowledge. The multimedia principle is more important with the novice learner (i.e., a learner who is new to the subject). While the novice learner benefits from the combined use of text and illustration, the more experienced learner (i.e., a learner who possesses existing knowledge pertaining to the subject) can create his or her own mental images while reading the text. Therefore, graphics can be redundant for the experienced learner. In some ways, the use of graphics may even pose a negative effect on the experienced learner (Clark and Mayer 69). Therefore, instructional designers must first understand their audience in order to fully utilize the advantages of the multimedia principle. The novice learner requires additional support, thus, multimedia instruction is appropriate. For experienced learners, however, it is appropriate to base instruction more heavily or even entirely in text.

Knowing the benefits that graphics can bring to instruction, it is now important to look at the differences between static illustrations and animations. At first glance, animations may appear to be the best choice for learning. They are an active medium and can portray changes and movement. Static illustrations, on the other hand, may seem second best because they are a passive medium and cannot portray changes and movement with the same level of detail. However, research reveals that static illustrations are generally the most effective for learning.

Static illustrations, though passive, allow for active processing when paired with text because the learner must mentally animate the changes from one frame to the next. In addition, the learner is able to control the order and pace of his or her processing. Conversely, animations and narration foster passive learning because the learner does not mentally animate or control the pace and order of the portrayal. In addition, animation may overload the learner's working memory. Because the images are extremely detailed and so brief that the learner must hold the images in his memory, animation can actually discourage effective learning. A series of static frames, on the other hand, does not impose additional cognitive load because the learner can review a previous frame at any time (Clark and Mayer 70). It is important to note here, however, that animations are not always inferior to static illustrations. Some content, such as the portrayal of a motor skill, may be particularly suited for animation or video. Instructional designers should choose static illustrations and text unless there is a compelling rationale for animation and narration (Clark and Mayer 72).

Contiguity Principle

As cognitive theorists establish the benefits of using graphics in addition to words, they also examine the organization of these sources. In one study on eye movement, researchers found that successful learners read a portion of the text, then searched the diagram for the object being described in the text, then read the next portion of the text, and then again searched the diagram for the object being described (Clark and Mayer 92).

Based on these findings and many others like these, researchers developed the contiguity principle. This principle explains that people learn more deeply when corresponding printed words and graphics are placed close to one another (Clark and Mayer 80). While growing evidence supports this principle, it remains evident that instructional designers do not always follow this principle. e-Lessons often include long scrolling pages that do not allow the learner to view the image and the text at the same time. Sometimes, they present narration before or after the graphics being described, and in other cases, instructional designers number objects in a graphic and then include a legend at the bottom of the screen to indicate the name associated with each object. Each of these situations results in a physical separation of the text and the graphic. While some designers may not realize the effects this separation has on learning, others believe that separate displays allow the learner to experience the information in two different ways (first in a visual manner and second in a textual manner or vice versa). Whatever the reason, instructional designers must consider the proven benefits that result from portraying a unified structure of text and graphics.

Placing corresponding words and pictures far apart from each other creates split attention, which forces the learner to mentally coordinate the multiple sources of information. When information is not presented in a unified manner, the learner must use his or her scarce cognitive resources to search graphics and connect the words to their corresponding images (Ayres and Sweller 135). Instruction should therefore integrate text and graphics in order to reduce the imposed cognitive load.

The contiguity principle also applies with spoken words and corresponding graphics. Similar to written text, the instructional designer should present narration and images at the same time. One common violation occurs when instruction presents one link to start a video and another link to begin the audio. Instructional designers again break the contiguity principle when they provide a continuous unit that includes a narrated introduction followed by animation or video. Some instructional designers believe that this allows the learner to choose his or her preferred method. Other instructional designers think it is beneficial to allow the learner to first hear the information and then view it (or vice versa) since it provides two options for exposure to the information. The problem is that, when a lesson separates corresponding words and graphics, the learner experiences a heavier load on working memory—leaving less capacity for deep learning. After listening to the narration, the learner needs to hold the relevant words in his working memory and then match up each segment with the corresponding segment of the animation. Because the learner is already holding a great deal of information in his working memory, the learner may not be able to engage in other cognitive processes that are necessary for deep learning (Clark and Mayer 87).

Modality Principle

The modality principle proposes that people learn more deeply from multimedia lessons when graphics are explained by audio narration rather than onscreen text.

Onscreen text and images compete for the same limited attention in the visual channel. The learner must simultaneously process graphics and printed words. When the learner's eyes attend to the printed text, they cannot fully attend to the graphics (Clark, Nguyen, and Sweller 61-62).

According to the modality principle, instructional designers can reduce the load on the visual channel by presenting verbal explanations as speech. By doing so, verbal material enters the cognitive system through the ears and is processed in the auditory channel. At the same time, graphics enter the cognitive system through the eyes and are processed in the visual channel, and the learner can process the pictures and words without overloading either channel. In other words, presenting words as speech offloads some weight from the visual channel and moves it to the auditory channel, thereby, increasing the learning efficiency. Balancing the load between the channels effectively increases the learner's working memory (Clark, Nguyen, and Sweller 61-62).

The modality principle applies when the e-lesson simultaneously presents graphics and their verbal explanations. It particularly applies when the information is complex or presented at a rapid continuous pace. If the learner is familiar with the material or if he has control over the speed of the material, the modality principle becomes less important. Moreover, the modality principle does not apply when words are presented without concurrent images (Clark and Mayer 112-13).

Redundancy Principle

Redundancy occurs whenever instruction presents the same material in two different forms. The redundancy principle explains that people learn more deeply from multimedia lessons when graphics are explained by audio narration alone, rather than by audio narration and onscreen text. When creating multimedia lessons that contain graphics and narration, instructional designers sometimes include printed words. According to the redundancy principle, however, e-lessons with narrated graphics should not contain redundant onscreen text. The learner cannot devote adequate attention to printed words and graphics because he or she can only look at one at a time (Clark and Mayer 121). Therefore, while the learner focuses on the printed words, he or she devotes less attention to the accompanying graphics. In addition, learners often devote unnecessary time and effort to comparing and reconciling onscreen text with the narration (Mayer 189). This requires cognitive processing that is extraneous to learning the content.

There is a common belief that some people have visual learning styles, while others have auditory learning styles. According to this belief, words should always be presented in both spoken and printed form so that learners can choose the presentation format that best matches their learning preference. However, this unproven belief contradicts what is known about cognitive processing. Adding redundant onscreen text to a multimedia presentation may overload the learner’s visual channel (Clark and Mayer 121).

The redundancy principle also explains that people learn more deeply from multimedia lessons when graphics and text are not repetitive. This aspect of the principle is also counterintuitive to many designers. For example, some instructional designers include the material in textual form and then follow it with a visual representation of the same material because they believe that individuals have different learning styles.

However, when material is complete and understandable in isolation, it is redundant to then follow it with another version of the same material (Clark, Nguyen, and Sweller 69). By including redundant material, the instruction forces the learner to process both versions of the information and thereby causes the learner to waste mental resources processing both sets of information, coordinating them, and determining the relation between them.

Coherence Principle

According to the coherence principle, people learn more deeply when distracting stories, graphics, sounds, and extraneous words are eliminated. This principle has an extreme impact on learning. Instructional designers should therefore remove anything that is not essential to learning. In spite of this principle, instructional designers often stray from conciseness in an effort to foster learner motivation. Some designers embellish lessons in an attempt to add entertaining or motivating elements (e.g., dramatic stories, pictures, or background music) (Clark and Mayer 136-38).

As empirical evidence shows, interesting but unnecessary material can harm the learning process because the learner actively tries to understand all presented material. Extraneous material then interferes with the sense-making process by wasting the learner’s limited cognitive resources. Extraneous materials are especially troublesome in situations when the learner may experience a heavy cognitive load (Clark and Mayer 143-45). For example, the learner may experience a heavy cognitive load when the subject is unfamiliar to the learner, when the material is presented at a rapid rate, or when the rate is not in the learner’s control.

Some instructional designers believe in the arousal theory, which states that the learner becomes more aroused when entertaining and interesting effects are embedded in the learning material. According to this theory, the learner works harder to learn the material as a result of the arousal. Because working memory is limited, however, entertaining and interesting effects can overload and disrupt the cognitive system (Clark and Mayer 148). Distraction occurs when the learner's limited attention is guided away from the relevant material and toward irrelevant material; disruption occurs when extraneous graphics prevent the learner from building appropriate links among pieces of relevant material because pieces of irrelevant material are in the way; seduction occurs when extraneous graphics prime inappropriate existing knowledge, which is then used to organize the incoming material (Clark and Mayer 142).

To some instructional designers it may seem beneficial, or at least harmless, to add cute short stories and interesting pieces of trivia that loosely relate to the lesson material. However, the coherence principle applies to words as well as audio and graphics. Additional words may provide interest, expand on key ideas of a lesson, or add technical details beyond the lesson's objectives. Whatever their purpose, instructional designers should avoid using extraneous words. Extraneous words distract, disrupt, and seduce just as extraneous graphics do (Clark and Mayer 149-50). The simplest lesson for instructional designers is that less is more. When designing instruction, every word should directly contribute to the instructional objectives.

Segmenting and Pretraining Principles

The segmenting principle explains that people learn more deeply when content is broken into small chunks. It also proposes that people learn more deeply when they can control the rate at which they access the chunks. This principle is especially valuable with complex material (i.e., material with a high intrinsic load) (Clark and Mayer 189).

While instructional designers cannot simplify the material itself, they can present the information in ways that make it easier for the learner to manage its intrinsic load. One way to do this is to break the lesson into manageable segments. The learner can better manage the complexity of the material when he or she receives the material in parts that present one, two, or three steps at a time. A novice learner requires time to consolidate the new information. When instruction continuously presents interrelated concepts, the learner's cognitive system is overloaded because too much essential processing (i.e., mental processing that is inherent to the material's complexity) is necessary (Clark and Mayer 189-90). Instructional designers can alleviate this problem by allowing the learner time to process each part.

A related technique, the pretraining principle, can also be useful in complex lessons. When the learner is expected to hold information while processing it, his or her working memory can be overloaded (Clark and Mayer 191). When attempting to multiply 3-digit numbers in their heads, for example, people often experience this overload. It is a struggle to remember the numbers while multiplying at the same time (Gagné, Wager, Golas, and Keller 8). Therefore, as explained by the pretraining principle, people learn more deeply when lessons present key concepts prior to presenting the processes or procedures related to those concepts. When key concepts are essential to a complex procedure or process, instructional designers should segment and present the concepts up front.

Before the leaner watches a video about the human digestive system, for example, he or she should become familiar with certain parts of the body and what those parts do for the digestive system. By reducing the amount of essential processing that is required during the presentation, pretraining helps the novice learner to manage the processing of complex material. Because the learner understands the relevant terms, he or she can dedicate cognitive processing to forming a mental model of how the elements relate to each other in the causal chain. Therefore, pretraining helps to manage the learner’s essential processing by shifting some of the necessary processing to the pretraining portion of the lesson (Clark and Mayer 193).

Signaling

Instructional designers should also alert the learner to the schematic structures of a text. Just as schemata apply to information and events, they also apply and help the learner with textual organization. Therefore, the learner becomes accustomed to certain aspects of texts, and instructional designers should develop materials to fit the standard arrangement. This allows the leaner to leverage textual schemata and reduce the cognitive load that is involved in reading new material. Instructional designers can help the learner by encouraging him or her to read titles and headings. In addition, certain signals can help focus the learner’s expectations. Additive conjunctions (e.g., as, also, likewise) signal a comparison or contrast; causal conjunctions (e.g., consequently, as a result) signal cause and effect structures. To actively process incoming information, the learner must attend to relevant information and engage in the appropriate mental processing (Gredler 207).

This technique is called “signaling.” Signaling includes using headings, bold, italics, underlining, capital letters, larger font, color, white space, arrows, and related techniques to draw the learner’s attention to specific information. A signal shows the learner what information is relevant (Mayer 185). Thus, one goal of instruction is to direct the learner’s attention to crucial material in order to avoid overloading the working memory.

Expertise Reversal Principle

When a learner has prior experience in a particular domain, he or she is considered an expert learner or a high-knowledge learner. Conversely, when a learner lacks prior knowledge in the domain, he or she is a novice learner.

The expert learner retrieves prior knowledge during the learning process; the expert learner leverages relevant schemata to process information and guide his or her learning process. Because schemata allow the individual to absorb information and fill in missing details, they reduce the cognitive load that is imposed on the learner. The concerns regarding the learner’s cognitive load, then, are less important when the learner has prior knowledge in the given domain. The more knowledge and skills stored in long-term memory, the greater the virtual capacity of working memory as a result of larger, more complex schemata (Clark, Nguyen, and Sweller 31).

As a result of schemata, then, the instructional methods that are helpful to the novice learner may either have no effect or, in some cases, decrease learning in the expert learner. This is known as the expertise reversal effect. While the novice learner lacks relevant schemata and cannot guide his or her learning process, the expert learner can engage in complex tasks and can process much larger amounts of information than the novice learner can process. For example, a chess board includes about 24 information elements for a novice player while it includes only eight or nine for the expert player. This is because the expert player views the chess board in terms of play patterns that involve clusters of several pieces. Each cluster translates into a schema. The chess board of twenty-four pieces, then, contains approximately eight or nine schemata for the chess expert (Clark, Nguyen, and Sweller 31).

The novice learner greatly benefits from learning environments that compensate for the lack of relevant schemata in the long-term memory. The expert learner, on the other hand, can simultaneously process several information elements because they are incorporated into a relevant schema, which is then treated as a single element in working memory (Clark, Nguyen, and Sweller 250). As the learner gains expertise, his or her new schemata compensate for limited working memory capacity. Thus, as the learner's expertise changes, the instructional methods must change as well.

Because the instructional methods that serve as schema replacements for the novice learner are not needed by the expert learner, they consequently are redundant. As explained by the redundancy principle, redundant information burdens the learner's working memory with unnecessary data and consequently depresses learning (Low and

Sweller 154). The cognitive load principles primarily apply to the novice learner; therefore, the effects of these principles must be reevaluated when designing instruction for the expert learner.

Summary

The above literature review reveals the manner in which cognitive load theory serves as a framework for instructional design. As instructional designers attempt to apply these principles, however, flaws are revealed. There are situations in which the cognitive load principles conflict with real-world constraints or expectations. The intent of this paper, consequently, is to look more closely at one such principle and its flaws. In addition, the intent of this paper is to explore the possibility for compromise when the aforementioned principle does not meet real-world expectations.

CHAPTER 3

COHERENCE AND SIGNALING: AN IN-DEPTH REVIEW

Coherence Principle

Before we discuss the struggles associated with the coherence principle, it is necessary to fully understand it and the techniques commonly used in an attempt to alleviate the cognitive load associated with extraneous material. When theory meets practice and the instructional designer must explain to a client that extraneous material can damage learning, the instructional designer must fully understand the principle and its attributes. Thus, the content in this chapter provides the detail needed to fully understand the impact that extraneous material can have on learning.

It is fairly common to hear instructional designers debating over whether to keep certain information in a lesson. During a typical debate like this, at least one person will argue that it cannot hurt to include the additional information. As cognitive scientists have discovered, however, unnecessary information can deter learning. According to the coherence principle, in fact, instructional designers should eliminate information that does not directly relate to the learning goal.

The coherence principle states that people learn more deeply when extraneous material is excluded from the learning material. The basic premise behind the coherence principle is that less is more. Meaningful learning requires a great deal of effort as the learner engages in cognitive processing, and instructional designers should aid learners by minimizing the required effort. For meaningful learning to occur, three kinds of cognitive processing must take place: selection, organization, and integration (Mautone and Mayer 377). Instructional materials should therefore guide the learner's cognitive processing so that the learner selects the relevant information, logically organizes the information, and integrates the new information with his or her prior knowledge. When instruction includes extraneous material, the learner engages in these cognitive processes in an effort to learn the extraneous material and wastes his or her resources as a result. In other words, it is helpful for instructional designers to remove extraneous material and thereby eliminate extraneous processing. This enables the learner to maximize the cognitive capacity available to him or her as the learner focuses solely on essential processing.

According to the coherence principle, instructional designers should keep their lessons simple and uncluttered. Instruction should contain material that is essential to the lesson objectives and nothing more (Mayer 191). While this principle is easy to understand and apply, it provokes much debate as instructional designers struggle to motivate learners. It is common practice for designers to include extra words, graphics, and sounds in the interest of motivation. The commonly believed idea behind this behavior is that the lesson must entertain the learner in order to capture his or her attention. Cute short stories and interesting pieces of trivia, background music, and entertaining video clips may seem like great ways to embellish a lesson, but all these items contribute to extraneous cognitive load (i.e., mental work that is irrelevant to the learning goal). When instruction imposes extraneous load, the learner has fewer resources available for cognitive processing. As a result, the addition of unnecessary material can harm the learning process (Clark and Mayer 134). Instructional designers should provide lessons with the perfect amount of content to meet the lesson's objectives. Each word, sound, and illustration should help the learner to construct the desired schemata (i.e., cognitive frameworks that help organize ideas) (Clark, Nguyen, and Sweller 113).

As a word of caution, the coherence principle does not indicate that lessons should be boring. While there is a great deal of support to defend the idea that extraneous material causes an unjustifiable increase in the learner's cognitive load, there is also ample evidence that learner interest in the material can increase learning. Thus, instructional designers should seek to stimulate interest in the learner without damaging learning by adding extraneous material. Additional research is needed to determine ways to add interest without causing an undue increase in cognitive load. The intent of this paper is focused on the coherence principle, and as such, the matter of entertainment is not of concern here.

Background Music and Sounds

Critics of the coherence principle question the level of harm that background music and other sounds can cause when added to multimedia lessons. These critics are often proponents of the arousal theory, which proposes that entertaining and interesting embedded effects arouse learners on an emotional level (Clark and Mayer 138). The idea is that learners will work harder to learn the material because of this emotional arousal. According to the arousal theory, people learn more from multimedia presentations when they contain interesting sounds and music. However, as the cognitive theory of multimedia learning indicates, background sounds and music can add to the learner's cognitive load given that the learner attends to the background sounds and music. When background audio occupies cognitive resources, there is less working memory capacity remaining for processing material that is essential to the lesson's goals (Clark and Mayer 138).

Extraneous sounds negatively impact learning more than most people realize. In a study by Kenz and Hugge, they compared learning from a seven-page text in a quiet learning environment to learning from the same text in an environment with background music. The recall of ideas contained in the text was significantly better among the readers from the silent reading group indicating that extraneous sounds negatively impact the learner's ability (Clark and Mayer 139).

Additional research also supports the idea that environments free from background audio foster learning. Moreno and Mayer compared learning from multimedia lessons with and without extraneous audio. One lesson, the base version, contained narrated animation to explain lightning formations. The other lesson contained additional audio, which entailed either instrumental music, related environmental sounds, or both music and environmental sounds. The additional audio did not obscure the narration. The learners in this study answered questions following the lesson. The questions required learners to apply their understanding of the content. The base version supported efficient learning, whereas versions with additional background audio resulted in poorer test results (Clark, Nguyen, and Sweller 119).

Graphics

While agreeing that it is logical to avoid using extraneous audio, some instructional designers may still feel compelled to enhance lessons by interspersing interesting video clips and other graphics. Anchored in the arousal theory, it is commonly believed that graphics can enhance the interest of a multimedia lesson. As a result, instructional designers sometimes include graphics to evoke an emotional response in the learner. This, according to the arousal theory, should increase the learner's level of cognitive engagement (Clark and Mayer 142). By increasing the learner's engagement level, the arousal theory predicts that better learning will occur as a result. As the cognitive theory of multimedia learning points out; however, extraneous graphics can depress learning just as extraneous audio can.

According to the cognitive load theory, the learner actively seeks to understand all presented material, not knowing what information is extraneous. The learner wastes mental resources each time he or she processes extraneous material whether it is audio or graphical. When the learner successfully creates a coherent mental representation of extraneous material, the learner may experience enjoyment. However, creating a coherent mental representation of extraneous material can interfere with the sense-making process of the essential material because the learner's cognitive capacity is limited.

Level of Detail

In addition to removing extraneous graphics, instructional designers must consider the level of detail contained within the essential graphics themselves. The coherence principle suggests that instructional designers should include essential details and nothing more. Consequently, illustrations should not provide more detail than necessary. Instruction should not include graphics that are embellished to look realistic unless the realistic portrayal is necessary for the lesson objectives. In some cases, simple line drawings can be more effective than detailed color drawings, photos, or even animations (Clark and Mayer 145).

In a study by Butcher, students studied a lesson on the human heart and answered subsequent test questions to determine their understanding of how the heart works. In one version, the lesson contained text and simple illustrations. The other version contained text and detailed illustrations. Students who learned from the simple version performed better than students who learned from the detailed version. Students who studied the simple version made multiple conclusions based on the integration of the text and illustrations, which indicates an attempt to understand how the heart works. In comparison, students who learned from the detailed version made fewer conclusions based on the integration of the text and illustrations. The suggestion here is that the simple version can promote mental processing. By providing simple illustrations rather than detailed, learners mentally fill in the visual gaps in order to understand the full meaning of the diagram (Clark and Mayer 145).

This is not to say that including details is a bad choice; it is merely a word of caution. Sometimes details are necessary to convey the material. None-the-less, instructional designers should use less when sufficient.

Words

Knowing that extraneous audio and graphics negatively affect learning, instructional designers must also question the impact that unnecessary words can play on learning. To some instructional designers it may seem beneficial, or least harmless, to add cute short stories and interesting pieces of trivia that loosely relate to the lesson material. However, the coherence principle applies with words as well as audio and graphics. Additional words come in three types. The first type provides interest; they are directly related to the topic at hand but are not relevant to the instructional objectives. The second type expands on key ideas of a lesson, and the third type adds technical details beyond the lesson's goal. Whatever their purpose, instructional designers should avoid using extraneous words. Extraneous words can distract, disrupt, and seduce just as extraneous audio and graphics can. When designing lessons, every word should directly contribute to the instructional objectives. It is important to explain only the essential information and to simplify material when clarification is necessary:

> One must deliberately not explain everything, only what must be explained…. Perhaps most important, when there is a problem one must not automatically *add* functions or build additional training modules; one must consider *removing* the function or documentation material associated with the problem. (Clark, Nguyen, and Sweller 110)

In an effort to promote interest, instructional designers may be tempted to include entertaining or interesting stories that are related to the topic at hand in a general way. For instance, in a lesson about the lightning formation process, stories about lightning may entice instructional designers. Nevertheless, while a story about a boy being struck by lightning may pique the learner's interest, the story contributes nothing to the primary instructional goal (Harp and Mayer 415).

To spice up a lesson by expanding on the key ideas, instructional designers sometimes add trivia or interesting facts. It is tempting to add this type of extraneous material because it is related to the topic and it is useful information. In addition, because the information is not technical in nature, instructional designers often fail to see that the extra words can deter learning. Instructional designers expand on key ideas to provide unnecessary background information with the idea that it helps learners to understand foundational concepts. They also provide information beyond the immediate need because it is nice-to-know information. In this case, the instructional designer believes that the learner may find the additional information useful even though it is not necessary to the learning objectives.

Extraneous technical information, on the other hand, is somewhat less likely to excite instructional designers. Because of the technical nature, instructional designers are more likely to realize that extraneous technical information can be damaging to learning. Subject-matter experts, however, fail to see the complex nature of the material (because, well, frankly they are the experts on the material). Thus, they often persuade instructional designers to include considerable amounts of technical information that go beyond the needs of the lesson.

In an experiment comparing different summary texts, each student received the same illustrations and one of the three summary versions describing the illustrations.

Each of the three versions of the summary text contained a different number of words: 50 words, 100 words, or 550 words. Not surprisingly, the leanest version led to the most learning. The students received the same amount of time to review their designated version of the summary. According to Clark, Nguyen, and Sweller, however, it is very likely that the lean version would require less study time than the verbose version if the students had received as much time as needed to fully understand the material (Clark, Nguyen, and Sweller 113). Thus, concise writing contributes to less study time and better learning.

Seductive Details Effect

Harp and Mayer use the term "seductive details" to refer to highly interesting and entertaining information that is "only tangentially related" to the subject but is extraneous to the lesson objectives (Harp and Mayer 414). Based on empirical research, the addition of seductive details leads to poorer learning, which is referred to as the "seductive details effect." Seductive details can interfere with learning in three ways: distraction, disruption, and diversion.

Distraction Hypothesis

The distraction hypothesis theorizes that seductive details draw the learner's limited attention away from relevant material and toward irrelevant material. The irrelevant information therefore entices the learner's attention away from important information. For instance, learners may remember an interesting story about a boy being struck by lightning instead of remembering the key steps in lightning formation. A possible explanation for the distraction hypothesis is that seductive details require little attention and are easy to understand. With this explanation in mind, it seems that the organization of the lesson itself may be the answer to averting distraction. If instructional designers organize their lessons to guide learners toward the structurally important concepts by highlighting them, they should in fact minimize the effects of the seductive details. Instructional designers can guide learners by simply pointing out the key information. By telling learners which information is important, the instruction compels the learner to apply weight to the core concepts instead of equally processing extraneous and essential information. Learners who are directed to fundamental ideas should be less susceptible to seductive details than those learners who are not guided (Harp and Mayer 415).

Disruption Hypothesis

Seductive details disrupt learning by interrupting it. They prevent learners from connecting ideas because irrelevant material is in the way. For learners to form coherent mental models of the events that lead to lightning formation, for example, they must understand the correlation between the steps in the causal chain of events. When seductive details appear between related steps or ideas in a lesson, learners do not perceive the steps as connected. Instead, learners consider each step as an individual event rather than a causal chain that includes each interrelated, dependent step. Learners fail to note the relationships among the steps because the seductive details break the chain (Harp and Mayer 415). According to the disruption hypothesis, instructional designers can help learners to organize the main ideas of a lesson and thereby reduce the effects of seductive details. Instructional designers should design lessons with organizational signals such as numbering sequential steps. By numbering each of the main steps in a chain of events, learners should be able to connect the steps and understand the relationships among them.

Diversion Hypothesis

The diversion hypothesis explains that seductive details divert the learner by causing him or her to prime inappropriate existing knowledge. Because it is necessary to integrate newly learned material with prior knowledge, it is crucial for learners to prepare the appropriate prior knowledge before integrating the newly learned material. Seductive details, however, cause the learner to interpret the material by organizing it around the seductive details instead of the lesson’s main ideas. Seductive details activate inappropriate prior knowledge as the organizing schema for the lesson. In a lesson about lightning formation, for example, the learner reads about a death that was caused by lightning. The learner is misled by the seductive details and relates the passage “to prior knowledge about ‘what lightning causes’ rather than ‘what causes lightning’” (Harp and Mayer 415). As a result, the learner may determine that the lightning formation material is supportive rather than essential to the lesson’s objectives. Additionally, the learner incorrectly makes sense of the lesson in terms of the seductive details.

Based on the diversion hypothesis, instruction that presents irrelevant information at the beginning of a lesson is extremely harmful. When irrelevant information comes before the lesson’s essential material, learners activate inappropriate existing knowledge, which is then used to organize incoming content. Instruction that begins with seductive details is likely to negatively affect learning. On the other hand, seductive details that are interspersed throughout the lesson are less harmful, and seductive details that come at the end of a lesson are less harmful even still. When seductive details are provided after the crucial material, the irrelevant material should have no effect on the learner's expectations of the passage content (Harp and Mayer 415).

Heavy Load and the Impact of Coherence

Extraneous material is more harmful when learners are likely to experience an already heavy load. Learners are likely to experience heavy cognitive load when the material itself is unfamiliar to the learner or extremely complex or when the material is presented at a rapid or uncontrollable pace.

Instructional designers should show extreme caution with extraneous material when preparing lessons for novice learners (Clark and Mayer 136). Sanchez and Wiley found that extraneous illustrations depressed learning especially for low-ability learners. These learners are more susceptible to the cognitive processing demands that are inflicted by extraneous material. In an eye-tracking study, high-working-memory students (i.e., students with more working memory than the average individual) spent much less time looking at irrelevant graphics than the low-ability learners. These results indicate that extraneous illustrations can be more distracting for low-ability learners (Clark and Mayer 145). A great deal of research examines the novice learner (i.e., the learner who lacks prior knowledge in the lesson domain). However, the expertise reversal effect and the research backing it suggest that expert learners (i.e., the learner with prior knowledge in the lesson domain) may not benefit from the same instructional design techniques from which novice learners benefit. While empirical research indicates that novice learners are harmed by extraneous material, it is unclear whether extraneous material has the same effect on the expert learner (Clark and Mayer 151). None-the-less, good instructional design—which includes the absence of extraneous materials—is crucial for novice learners.

Instructional designers should be especially careful not to include extraneous material when creating dynamic lessons. When a lesson is presented dynamically (i.e., without learner control), it requires the learner to immediately process the material. A narrated animation (that is designed without learner control) and a classroom lecture provide lesson material in a dynamic delivery format that determines the rate of the presentation. Therefore, these examples demand extra cognitive support. Static lessons, on the other hand, allow the learner to proceed at his or her own pace and also to return to any part of the lesson as needed (Clark, Nguyen, and Sweller 78). Examples of static lessons include workbooks and e-lesson in which the pace is controlled by the learner.

Interest Versus Extraneous

The coherence principle does not declare that all interesting material must be cut from lessons; it does not indicate that lessons must be boring. Interesting material is not harmful in all situations. Interesting audio, graphics, and words can be useful to learning; they are harmful only “to the extent that they can interfere with the learner’s attempts to make sense of the presented material” (Clark and Mayer 141). For this reason, instructional designers should not include audio that is added for entertainment, graphics that are added to decorate the page, or words that are added to provide more background information even though it is not essential to the lesson.

Although it is important to avoid extraneous material, evidence shows that learning is improved when the learner is interested in the material. The objective for the instructional designer, then, is to promote interest without distracting the learner from the lesson's goals by adding extraneous material. To increase interest in learning materials, instructional designers should look for ways to create interest while supporting the lesson's objectives instead of overloading the learner's cognitive resources.

Signaling

Selection, organization, and integration must take place for meaningful learning to occur. Therefore, it is crucial for learners to select, or pay attention to, the relevant aspects of a lesson. It is crucial that the learner then logically organizes the novel information and also integrates the information with appropriate existing knowledge. For meaningful learning to occur in a lesson on airplane lift, for example, learners must focus on the three main links in the causal chain (selection); they must recognize that the first link is causally related to the second link, which is causally related to the third link (organization); and then they must relate the concept of pressure to the number of units per area (integration) (Mautone and Mayer 377-78).

As previously noted, signaling text is one technique that can improve learning. By steering the learner's focus toward the lesson's essential material, instructional designers enable the learner to ignore extraneous material and devote his or her cognitive resources solely to essential processing. While extraneous material is more harmful when learners are likely to experience a heavy load, signaling is more beneficial in these same situations. Signaling is more important when lessons are long and complex or when the lesson is geared for novice learners. Research shows that signals are not effective with simple lessons because these lessons do not require cognitive support. The learner's cognitive resources readily process the simple, unsignaled lesson without difficulty. Conversely, research shows that signaling is quite effective with complex lessons. Complex lessons (i.e., lessons that are high in element interactivity) impose a heavy demand on the learner's cognitive resources and thus the learner can benefit from signaling (or any form of cognitive support) (Clark, Nguyen, and Sweller 79). Signaling reduces the cognitive load for novice learners, but it does not have the same strong impact on expert learners. Even the complex lessons referred to above may seem simple to the expert learner and therefore signaling may be unnecessary for him or her (Clark, Nguyen, and Sweller 79).

Guiding Selection

Signaling can help learners to discriminate the relevant from the irrelevant. Signaling facilitates the selection process by telling the learner where to focus his or her attention. Italics, bolding, underlining, capital letters, font size, and font color—which are known as typographical signals—draw the learner's attention to individual words. Typographical signals "make the words, and the concepts they describe, visually distinguishable from other text. This not only labels the concept as important, but it also makes it more memorable" (Mautone and Mayer 378). Paragraph headings alert learners to a new topic. Headings and titles declare the main concept of the lesson or paragraph, thus creating a theoretical framework to guide the leaner in his or her quest for relevant topics. In lessons with narration, the narrator can draw attention to key words or sections with vocal emphasis. Complex graphics can contain arrows, circles, lines, white space, and color to draw attention to critical areas of the graphic. Function and relevance indicators (e.g., in summary, it is important to note) point to key information that is important to remember.

A study by Loman and Mayer shows that, for the most part, recall among readers of signaled text is different from recall among readers of nonsignaled text. The amount recalled did not significantly vary between the two groups; however, nonsignaled readers recalled much less relevant information. Loman and Mayer found that:

> Participants in the nonsignaled group tended to exhibit recall patterns that resemble those of rote learning, namely increased recall of information from the beginning and end of the text (Loman & Mayer, 1983). Therefore, signaling increased recall of relevant (i.e., signaled) idea units and decreased recall of irrelevant (i.e., nonsignaled) idea units. (Mautone and Mayer 378)

Signals guided the readers and simplified their decision making as they sought out relevant information.

Guiding Organization

Signals can guide learners to organize the lesson material. They can help learners visualize and understand the organizational structure of the material by making clear connections between topics, ideas, and occurrences. Without signals, learners would be forced to discover these connections on their own (Mautone and Mayer 378).

When transitioning between topics in a lesson, the learner may try to integrate the new topic with previously related topics or he or she may treat the new topic as independent of the previous topics. It is crucial that the learner makes the right decision about the connections between the topics. If the learner fails, he or she will probably also fail to understand the overall topic structure. Headings are useful in guiding the learner's organization because they guide the learner to process the shift in topic. At that point, the learner acknowledges the shift and then pulls up an appropriate schema. Headings also point to the main concepts of the lesson and reveal the global organization of it. Enumeration signals (e.g., first, second, finally) cue the learner to the overall organization of the lesson or lesson section. These signals reveal the topic structure by creating distinct sections (Mautone and Mayer 378). Additionally, enumeration signals can be useful when a lesson includes a chain of events or a series of steps.

As previously noted, other signals (e.g., additive conjunctions) draw connections among various concepts by clearly pointing out the relationships among the concepts. It is especially important for instructional designers to draw these connections for novice learners who may not see the relationship among the concepts (Mautone and Mayer 378-79). Instructional designers use signal phrases to explicitly state the significance of the subsequent words (Clark, Nguyen, and Sweller 79). For example, in the lightning formation lesson, the instruction may say “The following four conditions must be met for lightning to form.”

Another type of signal, the topical overviews, let learners know what to look for in the next section. For example, a lesson on lightning formation could contain a topical overview that states “In the next section we are going to consider the role of positively charged particles.” Topical overviews are preview statements that enable the learner to focus his or her attention on the essential elements within the section. They also emphasize major topics and cue the learner to the general organization of the text. According to Mautone and Mayer, topic overviews are extremely important with complex or poorly organized text. Overviews should help by providing learners with a more coherent topic structure. Summaries are similar in function as they guide learners to select the main ideas and consolidate the material (Mautone and Mayer 378).

Another way to help learners visualize the organization of a lesson is with graphic organizers. Instructional designers provide graphic organizers at the beginning of a lesson to direct learner attention; a graphic organizer is a graphic representation of the lesson that enables learners to “preview the relationships among the content.” By including graphic organizers, instructional designers help learners to build a mental model (Clark, Nguyen, and Sweller 116). Graphic organizers are often used in the form of a flow chart that represents the cause and effect relationships of the text’s main ideas. Instructional designers can also include one or two sentences immediately preceding the main content to help learners create a mental model. The organizer tells learners what to look for within the lesson. In a lesson on airplane lift, Clark, Nguyen, and Sweller provided the following organizer:

> To understand how lift works, you need to focus on differences between the top and bottom of an airplane's wing. First, how the top of the wing is shaped differently than the bottom; second, how quickly *air flows* across the top surface, compared to across the bottom surface; and third, how the *air pressure* on top of the wing compares to that on the bottom of the wing. (Clark, Nguyen, and Sweller 79)

Previous tests by Lorch and Lorch examined the effects of organizational signals on recall. These tests showed that participants in the signaled group recalled more topics than did the nonsignaled group. Perhaps more importantly, participants in the signaled group recalled the information in an order that was similar to the lesson's order (Mautone and Mayer 379).

Guiding Integration

Signaling indirectly aids learners with the integration process. By helping learners to select relevant information and accurately organize it, signaling reduces the cognitive load imposed on the learner and thereby frees up more cognitive resources for the integration process. To assess the value of signaling in terms of the integration process, researchers examine the learner's ability to use the new information in solving transfer problems. Transfer problems are different from the problems taught during the lesson and as a result require the learner to apply the newly learned concepts. The learner cannot solve a transfer problem by remembering a statement from the lesson; instead, the learner must have an integrated knowledge of the material and then use that knowledge to solve the problem (Mautone and Mayer 379). Transfer tests reveal how well the learner can apply the learned information to solve new problems.

A study comparing a signaled and nonsignaled text showed that participants in the signaled group recalled more relevant (i.e., signaled) ideas and that the signaled group produced more high-quality answers to related transfer problems. In this study, therefore, signaling helped learners to build a more meaningful representation of the scientific model (Mautone and Mayer 379).

Media

Signaling has the same effect on cognitive resources with text, speech, and narrated animation. Instructional principles that apply in one medium often pertain to another; according to Mautone and Mayer "good pedagogy can flourish across media" (386).

Text

Mautone and Mayer compared learning from a signaled text to learning from a nonsignaled text. The purpose of the study was to determine whether signaling text would improve learning of a scientific explanation. Students read the text (either the signaled or nonsignaled), wrote an explanation of how airplanes achieve lift (to test retention), and then answered five transfer questions (to test transfer). The study shows that students in the signaled group recalled slightly more than students in the nonsignaled group. The difference in retention was not significant; however, transfer results are a more accurate measure of learner understanding. As expected, the signaled group produced around 54% more acceptable solutions in the transfer test than the nonsignaled group did (Mautone and Mayer 384).

Speech

In the same study, Mautone and Mayer examined whether signaling has the same effect on speech as it has on text. They applied the typical form of research on signaling (the same methods as used in the previous experiment) to investigate the effects of signaling on narration. The narration contained the same words and signals as the text in the previous experiment. The signaled version consisted of the narrator reading headings, bolded text, and italicized text more slowly, with a deeper intonation, and followed by a pause. Students listened to the lesson, wrote a description of how airplanes achieve lift, and then answered five transfer problems. The signaled speech group recalled 37% more of the seven core ideas than did the nonsignaled speech group. In terms of transfer, the signaled group produced 48% more useful answers on the transfer test than did the nonsignaled group. Overall, these results indicate that signaling in spoken text has a positive effect on retention and transfer (Mautone and Mayer 384).

After considering the results, it is important to question the results of the signaled speech in comparison to the results of the signaled text. Signaling speech significantly improved recall results, but signaling text did not affect recall results in the same way. Mautone and Mayer suggest that printed text may be—by virtue—somewhat signaled. The layout of a text, with its paragraph structure, naturally holds some signaling qualities. Speech may be less structured in its pure state, making it more receptive to signaling

(Mautone and Mayer 387). It is also likely that speech is more taxing on the learner's cognitive load. Learners read at their own pace, pause to reflect on the material, and return to previously read sections at their own discretion. On the other hand, listeners have no control over the pace of the spoken text. The information is transient so there is little time for processing and no time for returning to previous sections. Because added demand on working memory increases the need for signals, it makes sense that speech benefits more from signaling than text does (Mautone and Mayer 387)

Graphics

Mautone and Mayer conducted yet another experiment on signaling; this time they set out to determine whether signaling a narrated animation would improve the learner's understanding of a scientific explanation. As in the previous experiment on narration, there were two versions of the narration, one signaled and one nonsignaled. The signaled narration contained the same signaling techniques as in the previous experiment. In addition, the animation was either signaled or nonsignaled. To signal the animation, Mautone and Mayer included colored arrows to draw attention to important aspects of the illustration and colors to convey the organization and the connections between components. They also used summary icons to exemplify the overall structure of the presentation.

Students viewed the narrated lesson, wrote a description of how airplanes achieve lift, and then answered five transfer problems. Mautone and Mayer first compared the students who received both kinds of signaling (i.e., signaled narration and signaled animation) to the students who received neither kind of signaling (i.e., nonsignaled narration and nonsignaled animation). When asked to recall how airplanes achieve lift, students in the double-signaled group did not recall significantly more core ideas than the nonsignaled group. Next, Mautone and Mayer analyzed all four groups. The analysis revealed that signaled narration did not lead to significantly more core ideas in retention tests. Likewise, the analysis showed that signaled animation did not lead to significantly more core ideas.

Looking at transfer results for all four groups, Mautone and Mayer conducted similar analyses. First, they compared the double-signaled group to the nonsignaled group and found that students in the double-signaled group generated 54% more acceptable solutions on the transfer test than students in the nonsignaled group did (Mautone and Mayer 386). Students who received signaled narration produced significantly more acceptable answers on the transfer test. However, students in the signaled animation group generated a similar amount of acceptable answers on the transfer test when compared to students in the nonsignaled animation group. These findings are consistent with the signaling principle overall. The weak results pertaining to signaled animation suggest three possibilities. The first is that the signals were "not strong enough to be effective" (Mautone and Mayer 386). The second possibility is that the animation itself did not require signaling because it was not complex in nature. And third, these results may suggest that learners are "more skilled at taking processing cues from text than from pictures" (Mautone and Mayer 387).

Summary

Meaningful learning requires effort from the learner. To encourage learning, then, the instructional designer should reduce the amount of effort needed on behalf of the learner. As explained in this chapter, extraneous material requires additional effort from the learner. This effort does not improve learning; in fact, it can damage learning because the learner uses precious cognitive resources to process material that is not essential to learning objectives. Extraneous material can serve several purposes. It can provide interest, expand on key ideas or provide technical background. Regardless of the purpose, extraneous material can damage learning. Thus, whatever the intent, instructional designers should not include material that is not specifically relevant to the learning goals.

According to the coherence principle, then, instruction should be as concise as possible. It should not contain audio, graphics, or words unless they are directly relevant to the lesson’s objectives. Based on the signaling principle, instruction should include signals to highlight the essential concepts of the lesson. In addition, the instructional designer should consider the learner’s prior knowledge given that well-designed instruction is particularly valuable to novice learners.

CHAPTER 4

REAL-LIFE PROBLEMS AND POTENTIAL COMPROMISES

Intentions of the Client

With empirical research backing the coherence effect, it is clear that the instructional designer should evaluate every sound, graphic, and word included in multimedia lessons. Every item should directly benefit the lesson objectives. And while the principle does not go so far as to say that everything should be dull, it clearly indicates that interesting material should not be added purely for the sake of interest. In spite of this, it is necessary to consider whether any options exist when, for one reason or another, extraneous material cannot be completely avoided.

The instructional designer may work hard to minimize extraneous material. However, the intent is moot if the client (for whom the instruction is created) does not share the same intent. Because the typical client has very little knowledge about instructional design—and especially the cognitive load theory—the client may not be eager or readily adept to understand the intentions of the instructional designer. Even when the instructional designer makes a case for coherence, then, the client may not agree. For example, in a lesson about lightning formation in which the learner is expected to know what causes lightning to form, the client may want to provide stories about people and things being struck by lightning. While the stories are loosely related to the subject matter, they are not essential to the learning objectives. In this case, the instructional designer explains that the stories may decrease learning, but the client insists that the stories should be included because they will pique the learner's interest.

When the client rejects the advice of the instructional designer, the instructional designer can look for ways to alleviate the load imposed by extraneous material. The instructional designer can look for ways to creatively design the lesson while adhering to the client's demands and while still attempting to factor in the cognitive load theory and its principles. So while extraneous material should be ruthlessly weeded out so that the core of the essential material is salient to the learner, the instructional designer needs a backup plan. In other words, the instructional designer would benefit from knowing how to design a lesson when the client insists that extraneous material remain in the lesson. When including extraneous material, is there a way to use the cognitive load theory and its principles to at least reduce the effects of the extraneous material?

Alleviating the Effects of Extraneous Material

As discussed in the previous chapter, instructional designers can improve learning by showing the learner what is important and how it is organized. Various forms of signaling help with this by guiding the learner's attention to the important concepts and then helping the learner to organize these concepts. Signaling is thought to reduce the cognitive load imposed by extraneous material because it helps the learner to ignore the extraneous material and devote resources to the essential concepts.

Based on previous findings, signaling can improve learning. Loman and Mayer found that nonsignaled text led readers to recall less relevant information and more irrelevant information (when compared to readers of signaled text). Lorch and Lorch found that organizational signals led to improved recall performance, and Mautone and Mayer found that signaled text led to improved recall of relevant information and improved transfer performance (Mautone and Mayer 379). Although these findings show great promise for signaling, the true extent to which signals work still remains a question. The studies mentioned here do not consider extraneous material or seductive details. These studies examine only the effectiveness of signaling key ideas and organization.

In looking for ways to reduce the effects of extraneous material, it is necessary to consider the extent to which signaling is effective. Empirical evidence supports the idea that signaling improves learning. Here it is necessary to consider whether the positive effects of signaling are strong enough to negate the negative effects associated with extraneous material. Thus, research is needed to determine whether it is effective *enough* to reduce the cognitive load imposed by extraneous material.

In addition, consideration of other potential solutions is necessary to determine whether the cognitive load imposed by extraneous material can be reduced. In an attempt to present extraneous material in a way that inflicts the least amount of extraneous load, it is important to look at both the causes of the additional cognitive load and the potential methods for reducing it. Understanding the reasons why extraneous material may be damaging to learning is important because it can lead to better solutions. Thus, it is important to consider the causes of increased cognitive load in order to determine the best possible methods for reducing the amount of increased load.

Harp and Mayer conducted a four-part study in which they evaluated the distraction, disruption, and diversion theories and also considered various remedies to them. In each experiment, Harp and Mayer determined whether the seductive details effect was evident and then attempted to reduce the effect. Students read one of four versions of a scientific passage and took a retention test followed by a transfer test.

Typographical Signaling

Based on the distraction theory, the seductive details effect occurs because the learner selects interesting, irrelevant material rather than essential material. Including typographical signals in a lesson should increase learner recall, then, as the typographical signals should influence the learner to select the important information over the seductive details. Thus, typographical signals should reduce the seductive details effect in terms of recall. In an experiment by Harp and Mayer, however, typographical signals did not result in the recall of more important ideas. This finding is inconsistent with the idea that highlighting important information should help learners to select and recall important material even when seductive details are present.

Objectives

Substantial research shows that learning objectives can help learners to attend to essential material. In the same study by Harp and Mayer, the second experiment used learning objectives in an effort to guide learner selection. Prior to reading the lesson, some students received instructions indicating that they should look for the steps involved in the formation of lightning. They were also informed that they would be expected to explain the causes of lightning. The other students received no additional instructions.

The distraction hypothesis predicts that seductive details deter learning by distracting the learner's selection processes away from important material. If the distraction hypothesis is accurate, a learning objective could help to reduce the seductive details effect on recall by helping the learner to select the important information. Contrary to predictions, learning objectives did not reduce the effects of seductive details on recall. Thus, this experiment does not support the distraction theory.

Based on the disruption hypothesis, which predicts that seductive details interrupt the coherence of an explanation, lesson objectives should help to reduce the seductive details effect on transfer. In this experiment, informing students to find the major steps that lead to lightning formation should help them in mentally organizing the important ideas, and in turn, help them to see the relations among the steps in the chain. Thus, students who receive instructions prior to reading should be able to overcome the disruption of the text and therefore perform better on the transfer test. However, providing learning objectives did not reduce the seductive details effect on transfer performance. Therefore, the findings from this experiment do not support the disruption theory.

Organizational Signals

According to the distraction hypothesis, learners attend to seductive details rather than the essential ideas of a lesson. If this is true, providing signals to highlight the steps in a causal chain should help the learner attend to the essential ideas. The distraction hypothesis predicts, then, that organizational signals should reduce the seductive details effect on recall. Harp and Mayer's third experiment examined this idea and found that inserting organizational signals in passages with seductive details did not help students to attend to the signaled ideas, which is inconsistent with the distraction hypothesis.

Based on the disruption hypothesis, which indicates that seductive details interrupt the coherence of an explanation, organizational signals should reduce the seductive details effect on transfer. For the learner to comprehend a causal system, he or she must realize the manner in which each step in the process is related to the other steps. When seductive details are present, the seductive details interrupt the explanation and make it difficult for the learner to understand the relationship between the steps in a causal system. Thus, organizational signals highlighting the steps in a causal chain should reduce the seductive details effect and help the learner to build the necessary connections. To test this idea, Harp and Mayer used organizational signals including preview sentences and number signals. The results in this experiment did not support the idea that organizational signals can help learners to overcome the seductive details effect on transfer; these findings are inconsistent with the disruption theory.

Placement of Seductive Details

To test the effects of placement, Harp and Mayer created three lessons containing seductive details: they placed the seductive details before the lesson in one version, interspersed the seductive details throughout the lesson in one version, and placed them after the lesson in another lesson.

Interruption of Explanation

The disruption hypothesis predicts that seductive details make it difficult for learners to organize essential ideas by interrupting the flow of an explanation. Therefore, seductive details should not interfere with learning if they do not disrupt the explanation. The coherence of the explanation is uninterrupted if the seductive details come before the passage rather than throughout the body of the text. In terms of problem solving, then, placing the seductive details before a passage should reduce the seductive details effect. However, when comparing students who read the seductive details before the passage with students who read the seductive details interspersed throughout the passage, students from both groups recalled a similar number of main ideas. The results of this experiment are inconsistent with the disruption theory as the seductive details disrupted the coherence of the passage even when they were placed before the passage.

Perspective

The knowledge that the learner gains from a passage largely depends on his or her perspective while reading. Seductive details, according to the diversion theory, are dangerous because they can alter the learner's perspective by activating inappropriate knowledge with which to integrate new information. If seductive details can activate inappropriate prior knowledge in the learner, the placement of the seductive details should alter their influence. By presenting the seductive details before a passage, the seductive details are very likely to serve as a prime and therefore intensify the seductive details effect on both recall and transfer.

While students who read the seductive details before the passage performed similarly to those who read the seductive details interspersed throughout the passage, students who read the seductive details after the passage recalled significantly more main ideas and generated significantly more transfer solutions than students in both of the other groups. In addition, students who read the seductive details after the passage performed as well on recall of main ideas as students who read the passage without seductive details. And, while students who read the passage with no seductive details generated more transfer solutions than students in all of the other groups, students who read the seductive details after the passage performed nearly as well as students in the base passage group in terms of transfer solutions. Taken together, the findings from this experiment are consistent with past research and indicate that providing a context before a passage can alter the learner's perception of the lesson's content.

Based on the diversion theory, which is supported here, learner performance in both recall and transfer will improve by simply moving the seductive details after the passage. Presenting the seductive details after the passage should eliminate inappropriate priming and enable the learner to process essential material before the seductive details can interfere. The end of a passage should not influence the learner's interpretation of the previously read passage; consequently, the seductive details should not cause the learner to prime inappropriate knowledge as the organizing schema for the lesson.

Seductive Details Effect

Harp and Mayer examined the seductive details effect and compared the three theories behind it as if those theories are mutually exclusive. Based on their findings, Harp and Mayer concluded that the diversion theory is correct while the distraction and disruption theories are not. Based on findings from other experts, it seems plausible, however, that the three theories of the seductive details effect may not be mutually exclusive.

Distraction Theory

The distraction theory states that seductive details seduce the learner's attention away from the essential concepts and then hold the learner's selective attention. Harp and Mayer suggest that helping the learner to focus on the essential concepts instead of the seductive details should reduce the seductive details effect. Thus, Harp and Mayer's experiments tried typographical signals, learning objectives, and organizational signals to help the learner focus on the essential concepts. Because the findings in these experiments did not reduce the seductive details effect, Harp and Mayer concluded that the distraction theory is incorrect. According to Johnston, however, these results are inconclusive because Harp and Mayer did not measure the learner's attention. In a related study, Johnston collected reading times as a measure of the learner's attention and showed that seductive details drew attention away from the essential ideas. Although these findings cast doubt on the accuracy of Harp and Mayer's study, the findings do not provide conclusive evidence about the validity of the distraction theory. Additional research could examine eye movement to determine more precisely where the learner's attention is focused (Johnston 57).

Disruption Theory

The disruption theory indicates that seductive details damage learning by obstructing the learner's ability to develop a coherent model. Harp and Mayer tested this idea by including learning objectives, including organizational signals, and separating seductive details from the passage by placing them before the passage. Because none of these manipulations reduced the seductive details effect, Harp and Mayer determined that the disruption theory is incorrect. Johnston's results again contradict Harp and Mayer's results. Johnston attempted to replicate Harp and Mayer's findings, but instead found results that are consistent with the disruption theory (Johnston 57).

Diversion Theory

The diversion theory explains that seductive details damage learning by causing the learner to prime inappropriate knowledge. Harp and Mayer show that placing the seductive details after the passage lessens the seductive details effect. Johnston's results reiterate these results, which support the diversion hypothesis (Johnston 59). A study by Mayer, Heiser, and Lonn also defends the diversion theory and shows that the seductive details effect occurs in large part because seductive details prime inappropriate knowledge (Mayer, Heiser, and Lonn 196). In a similar study by Rowland, Skinner, Davis-Richards, Saudargas, and Robinson, the results show again that placement of seductive details before a passage reduced learning when compared to both the students who read the passage with no seductive details and students who read the seductive details after the passage (Rowland, Skinner, Davis-Richards, Saudargas, and Robinson 83).

Increased Interest

Experts believe that extraneous material can damage learning; they also believe that seductive details can damage learning. To determine whether seductive details are more damaging to learning than low-interest extraneous details, experts look at the element of interest. Mayer, Griffith, Jurkowitz, and Rothman tested the impact of seductive details by presenting two multimedia lessons, one with high-interest details (i.e., seductive details) and one with low-interest details (i.e., non-seductive details). The intent was to determine whether seductive details are more damaging to learning than non-seductive details are. In other words, the study evaluated whether the impact of extraneous details is affected by their interestingness.

The lesson contained six steps that explained how a cold virus infects the human body. One version of the lesson contained six high-interest details (details about the role of viruses in sex or death), and the other version contained six low-interest details (facts and health tips about viruses). Recall performances were comparable between both the high-interest group and the low-interest group. However, the low-interest group performed better on transfer solutions than the high-interest group did (Mayer, Griffith, Jurkowitz, and Rothman 334).

Overall, this study shows that high-interest details and low-interest details are equally damaging to the learner's ability to focus on the main ideas. On the other hand, high-interest details, in comparison to low-interest details, are more damaging to the learner's ability to organize and integrate the main ideas of a lesson.

First Solution

After examining several theories and various studies, the solution to reducing the effects of extraneous material remains unsubstantiated. While some experts focus on understanding why seductive details are damaging or whether seductive details are more damaging than non-seductive details, most experts focus their attention on the overall negative impact of extraneous material and emphatically recommend that instructional designers avoid extraneous material.

Taken together, the findings presented in this chapter provide strong evidence about the seductive details effect and its causes. While the evidence pertaining to the distraction theory and the disruption theory is inconclusive, several studies defend the diversion theory. The fact that inconsistent results exist in regard to the distraction and disruption theories is not enough to definitively dismiss them as invalid. Thus, the potential solutions of signaling, objectives, and organizational signals should not be discarded. At this point, however, it is important to look for the strongest possible solution.

Not only is there substantial support for the diversion theory, but the solution to the theory (i.e., placement of the extraneous material) is also strong enough to reduce the effects on seductive details. Based on findings that increased interest can cause more damage to learning, it is clear that if a given solution works on seductive details, it is also strong enough to work on non-seductive details. With this in mind, perhaps the reason the distraction and disruption theories were found inconsistent by Harp and Mayer is because the solutions to the theories (i.e., typographical signals, learning objectives, and organizational signals) are not strong enough to reduce the seductive details effect. Thus, it seems that the solution to the diversion theory is the strongest.

If the instructional designer cannot convince the client to remove extraneous material, I suggest that the best solution to reducing the effects of extraneous material is to discourage inappropriate priming in the learner. To do this, the instructional designer should place all extraneous material at the end of the lesson. Placing extraneous materials after the lesson discourages inappropriate schema activations because the learner processes the essential concepts prior to coming across the extraneous material.

Even though the placement of extraneous materials may seem like an easy and simple solution when the client insists on including irrelevant information, the solution may not be as simple as it seems. If, for example, the client insists on including seductive details for the sake of entertainment value, it is likely that the client will refuse to place these details at the end of the lesson. If the client insists on including seductive details in an effort to entertain and keep the learners interested in the lesson, it is just as likely that the client will insist that the seductive details come early in the lesson. The concern now becomes about what the instructional designer can do to reduce the negative impacts of extraneous material if the client insists on including them and refuses to place them at the end of the lesson.

Online Learning Environments

While learners (and instructional designers alike) are well suited to the practices surrounding paper-based learning material, this is not always the case with online learning environments. Although this topic is not directly related to the “problem” at hand, it is necessary to consider the principles and concepts surrounding online learning environments in order to consider all options for the “solution.” This is necessary because the nature of online learning environments can provide more options than paper-based materials. In other words, while the research presented in this paper pertains to both electronic and paper-based learning materials, it is important to consider specific attributes of online learning environments to consider whether online learning environments can provide a solution that would not otherwise be possible with paper-based materials.

Node

Information appears on the computer screen one unit at a time. These units are referred to as nodes. “Nodes are usually brief, self-contained text segments that describe a particular idea” (Antonenko 2). Nodes are then connected, by links, to create the larger text or e-lesson.

Linear Text

Linear text is much like paper-based text. In a linear text, the learner makes sense of the text according to its arrangement. In such texts, there is a chronological order. The instructional designer determines the order in which the learner should learn the material. Linear text consist of nodes that are connected by Next and Back links. As a result, the possible reading orders are very limited and the learner is very likely to read the material in the sequence determined by the instructional designer (DeStefano and LeFevre 1618).

Hypertext

In contrast to linear text, hypertext is non-sequential and does not provide a linear path to follow. Learners have many choices and determine the sequence of reading on their own (DeStefano and LeFevre 1618). Each hypertext is a network of nodes and links.

Increased Cognitive Load

Instructional designers create relationships among nodes by creating a chronological order in a linear text. On the other hand, instructional designers create *potential* relationships among nodes by linking various nodes together in hypertext. In the case of linear text, the learner follows along from node to node and understands that the nodes are in a sequential order as presented by the instructional designer. In the case of hypertext, however, there is no inherent conceptual flow. Instructional designers cannot simply build on previous information because they cannot enforce the reading order (Baron, Tague-Sutcliffe, Kinnucan, and Carey 897). The learner is required to determine the sequence of nodes by selecting links. The learner therefore establishes the relationship by following links and analyzing relationships between nodes (Antonenko 2). After reading the node and establishing the relationship between it and the previous node, the learner must select another link to move on to the next node. The learner, based on his or her learning goals, must determine which node to access next (Antonenko 3). Thus, the learner must process information while planning further navigation (Zumbach and Mohraz 876).

Because the learner must analyze relationships among nodes and plan further navigation all while processing information, there is a concern among experts that hypertext may lead to increased cognitive load. Experts hypothesize that hypertext directly or indirectly influences cognitive load. The direct influence occurs during link selection as the learner chooses whether to follow a link. This decision requires additional cognitive resources when compared to linear texts. The indirect influence occurs when the learner follows a link to semantically unrelated or less related text and subsequently causes an interruption of the comprehension process that requires extra cognitive resources (Madrid, Van Oostendorp, and Puerta Melguizo 67). Because hypertext forces the learner to determine the order of the material, it inherently forces the learner to determine for himself or herself whether to search for additional information to fill in possible information gaps. When learners follow links or search for information to fill gaps, they may lose track of their location in the text. "Therefore, navigating in a hypertext can lead to disorientation, caused by the difficulty users encounter in keeping track of their position in the network and determining how to reach another location in the network" (Amadieu, Tricot, and Mariné 381).

In addition to the concerns about disruption and disorientation, experts suggest that hypertext can impose extraneous cognitive load due to split attention. As explained by the contiguity principle, split attention occurs when instructional elements occur separately from each other. When elements are placed apart, not in a unified manner, the learner must use his or her cognitive resources to integrate the elements. Therefore, each time the learner accesses a node, he or she experiences split attention. As a result, the learner experiences extraneous cognitive load as he or she attempts to connect to the two nodes.

If the assumption of increased cognitive load in hypertext is accurate, instructional designers should always present lessons in linear text formats. However, hypertext has positive aspects and as such has not been pushed aside. Hypertext's high level of learner control is seen as an advantage for learning. Leaner control is thought to increase interest and motivation in learners. Hypertext also allows for instruction that is adapted to the learner's goals and preferences (Gerjets, Scheiter, Opfermann, Hesse, and Eysink 360). In addition, some experts believe that the trade off for additional cognitive load is a good thing. Based on the cognitive load theory, it is clear that additional cognitive effort does not always deter learning. In hypertext learning, students must activate prior knowledge to decide which links to access. According to some experts, the cognitive load inflicted here is germane (i.e., the type of cognitive load that contributes to meaningful learning). Thus, the additional mental effort, in the case of hypertext, may lead to deeper learning (Zumbach and Mohraz 876).

At a minimum, hypertext requires decisions and causes interruptions in the learning material. Whether these features enrich the learning experience or simply cause unnecessary cognitive load—that remains under debate.

As a result of the ongoing questions surrounding hypertext versus linear text, experts continue to search for answers. While seeking answers about whether the non-linear nature of hypertext deters learning, experts also continue to search for ways to alleviate extraneous cognitive load that is associated with hypertext. I look here at the possible solutions for issues related to hyperlinks in the hopes that commonalities surface between the struggles with hypertext and the concerns surrounding extraneous material. My hope is that the research pertaining to hypertext and alleviating split attention—when examined with a different perspective in mind—can help inspire me to develop a solution for reducing the effects of extraneous material.

Link Labels

While searching for a way in which to reduce the cognitive load caused by hypertext, several experts have examined and suggested link labels. Link labels, through words or icons, can provide insight about the type of information to expect from the destination node. For example, a link label could indicate that the destination node contains information to be integrated with information in the original node. Or, the link label could let the learner know that the destination node explores a new topic. By reducing the cognitive load associated with links, it is possible that link labels lead to better learning (DeStefano and LeFevre 1629). While the research included here is concerned with reducing split attention, I look at the research with a different perspective in the hopes of finding a solution for alleviating the cognitive load associated with extraneous material.

Campbell and Maglio used icons to signify the connection between nodes by portraying a red, yellow, or green traffic light next to a link. Campbell and Maglio's results indicate that the presence of these icons improved navigation when students who used hypertext with link labels were compared with those who used hypertext without link labels (DeStefano and LeFevre 1630).

A study by Baron, Tague-Sutcliffe, Kinnucan, and Carey also suggests that link labels are helpful for navigation. This study compared navigation of three hypertexts. One version of the hypertext contained only organizational links (e.g., Next, Previous, Beginning of section). The second and third versions contained the same organizational links in addition to content-based links. However, only the third version contained link labels for the content-based links. In the version with link labels, a one-word description (e.g., definition or explanation) of the destination node was included in parentheses next to the linked text. This study measured search accuracy in a setting where time was limited and found that accuracy was highest in the labeled-link group (Baron, Tague-Sutcliffe, Kinnucan, and Carey 907), which suggests that link labels can improve navigation.

While there is a great deal of anecdotal support for link labels, there is very little experimental data to substantiate labels and the idea that they can aid learner comprehension by lessening the imposed disruption of hypertext. With that in mind, there is even less data available to make and defend a reasonable argument about whether link labels could help to alleviate the load imposed by extraneous material.

Based on the findings (and anecdotal support) that link labels help learners with navigation, it is reasonable to argue that link labels can help to reduce the learner’s cognitive load and in turn enable deeper learning as more resources are available to the learner. Now knowing the pros and cons of link labels, it seems reasonable that link labels could help to reduce the load imposed by extraneous material if they can deter inappropriate priming in the learner. Link labels can tell the learner that the forthcoming information is extraneous and that he or she should not use the upcoming information to provide context for the basis of the lesson.

On the other hand, a link label does not explicitly tell the learner whether the destination node is extraneous or whether he or she should use the node’s information to provide context for the lesson. Instead, the link label merely provides a signal to help guide the learner’s expectations about the destination node. As such, it is necessary for link labels to be distinguishable and easily understood. At the same time, however, numerous types of links exist. While struggling with the balance of how many labels to provide, it is necessary to use caution when establishing the labels and their definitions. A lot needs to be said with very little (either an icon or a short description) so that the labels are comprehensible and intuitive. Otherwise, the occurrence of the labels themselves could cause increased cognitive load as learners try to decipher their meanings.

Link Previews

Because link labels offer many positive attributes, experts turn to a similar possibility. Experts examine link previews to determine whether they can reduce the cognitive load imposed by hypertext. Consistent with findings that link labels are helpful for navigation, similar studies suggest that link previews are helpful for learning. Link previews provide information about the destination node before the learner accesses the node. By viewing the preview, the learner can determine whether the destination node suits his or her needs. Previews can be presented with or without the link selection. When pop-up windows display previews, for example, the learner clicks the link in order to view the preview. On the other hand, rollover links display previews in a window when the learner places (or hovers) the cursor over the linked word or phrase.

Cress and Knabel tested the effects of previews in pop-up windows. Some previews contained a one-word title, while others contained brief summaries about the destination node, and others fell somewhere in the middle. In this study, they tested the effect of previews on searching and learning (Cress and Knabel 518) and found that link previews enhanced knowledge acquisition by providing coherence. Students in the link-preview group learned more than students in the group without link previews (Cress and Knabel 524-25). Cress and Knabel suggest that link previews help provide context for the upcoming material, which can help the learner to activate appropriate prior knowledge (518). Cress and Knabel also found that students in the link-preview group navigated backwards less often than students in the preview-free group (Cress and Knabel 522). This suggests that students in the link-preview group were better oriented in the reading.

In another study, Zhao, O' Shea, and Fung examined the possibility of using link previews and labels to promote learning from hypertext. In one version of the hypertext, link labels describe textual referential links by the relationship between the connected nodes (e.g., "is an example of" and "has contrast with"). In addition, information windows describe lexical links. In the case of lexical referential links, the link itself is a hotpoint. When the learner moves the cursor over the hotpoint, a window opened at the bottom of the screen to display one or two sentences about the destination node (357). The other version of the hypertext contained the link relationship labels (as in version one) for the textual referential links. However, link-type information was not provided for the lexical referential links. Before conducting the experiment, Zhao, O' Shea, and Fung predicted that labels and previews would reduce the learner's cognitive load by reducing the strain of decision making. They believe that labels and previews can help to make the decision about whether to follow a node easier. The results from this experiment show that labels that explicitly state the semantic relations between nodes had a positive influence on learning outcomes. In addition, similar findings indicate previews triggered by a hotpoint and shown at the bottom of the screen in an information window had a positive effect on learning outcomes when compared to students who used hypertext without previews.

Jonassen and Wang tested link previews in pop-up windows by comparing text recall after learners navigated one of three hypertexts. In one version, learners navigated from a semantic map. In the two other versions, learners navigated from a list of topics, either with or without link previews. In this study, the link previews described the relationship between the original node and the destination node (e.g., the destination node is an example of the original node). The results reveal that link previews did not affect recall performance (Jonassen and Wang 4).

In a related study, Antonenko examined the effect of link previews on learning. In particular, Antonenko looked at the effect of link previews on split attention and the extraneous cognitive load associated with it. Antonenko used rollover previews to introduce the content of the destination node. He hypothesized that link previews could reduce split attention by helping the learner to integrate information from various nodes. The link preview, in the form of a short summary of the destination node, acts as a transition to bridge the gap between nodes (Antonenko 28). Findings from this study revealed that link previews reduced brain activity associated with split attention; however, they did not affect learning (Antonenko 72). A possible reason for the lack of effect in learning could be explained by the complexity of the texts and the amount of redundant information in this study. The complexity and redundancy may have decreased the potential benefits of link previews by increasing extraneous load and decreasing germane load. Therefore, the benefits of previews may have been negated by the redundancy effect. Learners with developed metacognitive skills used link previews to review the information in the destination node while revisiting content in the original node (Antonenko 83-4).

Bétrancourt and Bisseret displayed word definitions and other added information about destination links in pop-up windows. In this study, the previews did not appear until the learner actively requested it by clicking the link. The study shows that pop-up windows enhanced searching without disturbing learning (Bétrancourt and Bisseret 270).

In a related study, Maes, van Geel, and Cozijn tested the usability (i.e., ease of use when employed) of rollover previews. The results show that previews led to an overall advantage in terms of efficiency and that decision making quickened with the use of previews. Based on these findings, it appears that previews are suited well to guide learners but not necessarily to improve learner recall or comprehension (Maes, van Geel, and Cozijn 277-78).

The link previews in a study by Schweiger contained a short summary of one or two sentences describing the destination node. In this study, link previews improved intentional link selection (i.e., link selection that led the learner to desired information) and reduced incidental selection (i.e., link selection that did not lead the learner to desired information) (Antonenko 29).

Madrid, Van Oostendorp, and Puerta Melguizo conducted a similar test to evaluate the usefulness of link previews. In particular, this study looked at link previews in terms of navigation support and the potential for enhanced learning and reduce cognitive load (Madrid, Van Oostendorp, and Puerta Melguizo 66). Through the use of link previews, this study attempts to make evident the relationships between nodes. This study also attempts to help the reader select a coherent reading order (Madrid, Van Oostendorp, and Puerta Melguizo 68). Results revealed that link previews helped learners to select a more coherent reading order. In addition learners using the hypertext with link previews learned more than students who received no navigational support (Madrid, Van Oostendorp, and Puerta Melguizo 71). Conversely, results showed that link previews did not lead to less cognitive load during link selection or reading (Madrid, Van Oostendorp, and Puerta Melguizo 69).

Looking at the various studies conducted in relation to hypertext, it is clear that link previews are a valuable resource. While more research is needed to fully understand the impact of link previews, there are some consistencies among the studies, which suggest that the benefits of link previews are real. Similar to the research on link labels, conclusive evidence supporting the benefits of link previews remains to be found. Even more so, evidence to prove the reasons that link previews work remain uncertain. While these studies, like those on link labels, focus on reducing split attention, I look at them with a different perspective in an effort to find a solution for reducing the effects of extraneous material. With that said, the findings thus far reveal several plausible explanations about link previews and their benefits. Considering these benefits and their possible explanations can again shed some light on potential methods for alleviating the effects of extraneous material and seductive details. Much like link labels, link previews can help the learner with expectations about the destination node. Unlike link labels, however, link previews can be explicit. Link previews can provide a summary of any length, and can even provide specific instructions to the learner. So while link labels can only *signal* the intent of the destination node, link previews can *explicitly state* the purpose of the destination node.

Second Solution

Returning to the underlying goal, the intent here is to recommend a method for handling extraneous material. If the instructional designer cannot convince the client to remove extraneous material, the best solution to reduce the effect of extraneous material is to place the extraneous material at the end of the lesson. While this may seem like a simple solution, the client may not agree to it. In this case, the concern becomes about how to reduce the effects of extraneous material when the client refuses to remove it and also refuses to place it at the end of the lesson.

Based on research pertaining to links and the cognitive load associated with it, it is clear that link previews enhance hypertexts in many ways. Because of the success rate of link previews in terms of providing navigational support and reducing split attention, it seems likely that link previews can prove to be useful in this situation as well. When it is necessary to include extraneous material at the beginning or in the middle of a lesson, I suggest using a link preview in the form of a rollover link. In the context of hypertext, summary previews can function as advance organizers. Advance organizers, which can simply be a short explanation that contains the central concept of a larger text, orient and prepare the learner for the upcoming text. The intent of advance organizers is to activate relevant schemas and thus enable the leaner to integrate new information more efficiently and effectively (Antonenko 27). In this case, the intent of the advance organizer is about not using the information in the destination node as a context for the lesson itself.

To use the link preview solution, the instructional designer must present the lesson in an electronic format with extraneous material contained in nodes separate from the main nodes of the lesson. Then, in the links to extraneous material, the instructional designer should use link previews to provide information about the destination node. The link preview can contain a brief summary about the destination node and an explanation that the destination node contains extraneous material that should not be used as an organizational schema for understanding the lesson.

For example, the client insists on including technical background information in a lesson about using Microsoft Excel even though it is not relevant to the lesson's goals. In this case, the link preview could read "This information is provided as a reference; it contains technical details." The preview could then continue with a brief summary of the destination node's content. Refer to Appendix 1 of this paper for a screenshot of the rollover preview as it would appear in this situation. In another example, the lesson objectives state that the learner is to learn what causes lightning. While stories about people and things being struck by lightning are irrelevant to the learning goal, the client insists on including these stories. In this lesson, the link preview could read "These stories are provided for entertainment value. While the stories are interesting and loosely related to the subject matter, the stories do not provide educational information." In a lesson about company policies, the client wants to explain how the policies came to be. Although the instructional designer explains that the information is not essential to the lesson's objectives, the client is adamant that the background information be included. In this case, the link preview could state "This information explains how the policies came to be. It is not necessary that you learn this information; it is here if you would like to know the background behind the policies."

Because the link previews are meant to alert the learner to extraneous material and potentially even deter the learner from accessing the node, rollovers are the best way to present link previews. Link previews are then visible when the learner hovers the cursor over the link. Using rollovers allows the learner to view the preview without any additional clicks. The learner can hover the cursor over the link, read the preview that appears in a window next to the cursor, and determine whether to access the link or return to the original node. When the learner makes his or her decision, he or she either moves the cursor off the pop-up window or clicks another link within the pop-up window, which will then open the destination node. The rollover technique is most appropriate because it requires very little additional effort on the learner's behalf. In addition, the rollover technique allows the preview to appear next to the cursor. This is beneficial because it does not cause any undue split attention, which can occur in the case of hotpoints that are used to display information windows at the bottom of the screen. The rollover technique also helps the learner to remain oriented in the text because he or she can view the link preview while remaining situated in the current node, which can be referred back to easily.

Although the research presented in this paper pertains to electronic and paper-based learning materials, the solution presented here turns specifically to the electronic format. While this may present difficulties as some clients may insist on paper learning materials, the use of an electronic format is necessary here. The nature of online learning environments allows the use of rollover previews; there is no equivalent match in paper-based formats.

Research is necessary to substantiate the idea of rollover link previews as a method for alleviating the cognitive load that is imposed by extraneous material. In addition, a few words of caution are necessary. It is important to remember that extraneous material is damaging to learning. Even if rollover link previews prove successful in reducing the load imposed by extraneous materials, this solution is not a license to include more extraneous material. Rollover previews can deter the learner from accessing nodes containing extraneous material. However, they do not eliminate the possibility. Thus, the cognitive load imposed by extraneous material would be largely dependent on the learner's decision about whether to access nodes containing extraneous material. "Link [previews] can only help to the degree that learners follow the suggestions" (Madrid, Van Oostendorp, Puerta Melguizo 72). Additionally, links cause additional cognitive load because the learner is forced to make a decision each time a link is present. For this reason, it is extremely important that the link preview provides explicit information. The learner should know whether he or she wants to access the link after reading the preview, which would then reduce the amount of additional load imposed by the use of links.

Although there is no simpler solution than avoiding extraneous material altogether, removal of extraneous material is not always an option. Even still, convincing the client to place the extraneous material at the end of a lesson may also prove to be a difficult task. Rollover link previews provide a reasonable method for including the extraneous material while still complying with the cognitive load theory as much as possible.

Summary

The aspirations of the instructional designer do not always become a reality. In theory, it is clear that instruction should be designed around good learning foundations. In practice, however, the instructional designer does not have full control. When theory meets practice, the designer works for a client who may disagree with the design of a lesson. The instructional designer may try to convince the client that extraneous material can be damaging to learning; the client may even agree that the coherence principle seems logical. However, agreeing that the coherence principle is logical does not mean that the client will agree to follow it. If the client intends to include certain materials in the lesson, he or she may not care if the designer is correct. Even more so, the client may not care if the lesson is less than a masterpiece in instruction.

Because strong evidence exists in support of the diversion theory, I suggest that the diversion theory deserves the spotlight in terms of finding a method to reduce the effects of extraneous material. By placing extraneous materials at the end of a lesson, the extraneous material cannot provoke inappropriate priming in the learner. This method has improved learning in several studies and therefore I suggest this as the best means to reducing the negative impact of extraneous material.

This solution, however, may fall short if the client refuses to hide the extraneous material at the end of the lesson. In this case, I suggest creating an e-lesson and providing extraneous material in nodes separate from the main nodes of the lesson. In the links to extraneous material, the instructional designer should use link previews in a rollover format to provide a brief description of the destination node. This approach is supported by the research of Cress and Knabel; Zhao, O’ Shea, and Fung; Jonassen and Wang; Antonenko; Bétrancourt and Bisseret; Maes, van Geel, and Cozijn; and Madrid, Van Oostendorp, and Puerta Melguizo as previously discussed. By providing information about the destination node, the link preview can deter the learner from using the extraneous material as a context for the lesson. While link previews cannot negate the effects of extraneous material, they should reduce the effects.

CHAPTER 5

CONCLUSIONS

To design great instructional materials, it is first necessary to understand the learning process. When instruction is designed with the learner in mind, the instruction can promote learning.

The process of learning is complicated; it requires the learner to attend to the relevant information, reorganize it, and connect it with prior knowledge. Information must move from the sensory register to working memory and then to long-term memory. During the sensory register phase, the learner must select and attend to the information. Next, the information passes to the working memory where the learner actively processes the information, and from there the information passes to long-term memory where it is stored in a permanent form.

Even though most of the learning process occurs in working memory, working memory is extremely limited. The learner uses working memory to hold and manipulate information while organizing it into a coherent structure and integrating it with what he or she already knows. Individuals can hold very little information in working memory for very little time. As a result the cognitive load, which refers to the load inflicted on working memory during learning, is extremely limited.

The cognitive load theory indicates that—because the total mental capacity is limited—it is important to balance all three forms of cognitive load. The goal of the theory is to alleviate extraneous load, maximize germane load, and manage intrinsic load.

Cognitive theorists have developed and proven the effectiveness of numerous principles that strive to balance cognitive load.

As with many of the other principles, the coherence principle strives to reduce the amount of *extraneous* load that is imposed on the learner. The coherence principle states that instruction should be as concise as possible. Material that does not directly pertain to the learning goals should be removed from the lesson. The coherence principle applies to sounds, graphics, and words. Thus, entertaining videos, environmental background noise, and even technical information should be removed from the lesson unless it directly relates to the lesson's objectives.

Because this principle cannot always be followed, the purpose of this paper is to determine ways to alleviate the cognitive load that is imposed by extraneous material. When the client insists that extraneous material be included in the lesson, the instructional designer has no choice. He or she can, with the cognitive load theory and its principles in mind, attempt to present the extraneous material in a way that inflicts the least amount of extraneous load. Extraneous material may be damaging for multiple reasons, but the diversion theory has the most support among these options. As a result, I focus my solution around the diversion theory and the belief that priming inappropriate knowledge in the learner is a major cause for the negative effects of extraneous material. Based on this belief, placing extraneous material at the end of a lesson should reduce the negative effect of extraneous material.

Knowing, again, that the client may not agree with the instructional designer, it is necessary to have an alternate plan. If the client insists on including extraneous material even though it means going against the instructional designer’s recommendations, the client may also insist that the extraneous material does not belong hidden at the end of the lesson. With the intent of directing the learner not to prime inappropriate knowledge, the solution is to alert the learner about the extraneous nature of the material with link previews. The lesson must be presented in an electronic form, and extraneous material must occur in nodes separate from nodes containing essential material. Then, the instructional designer can use link previews in the form of rollover links to alert the learner to the extraneous material. By alerting the learner, the instructional designer can direct the learner not to use the extraneous material as a context for the lesson. This approach is supported by the research by Harp and Mayer; Johnston; Garner et al.; Mayer, Heiser, and Lonn; and Rowland, Skinner, Davis-Richards, Saudargas, and Robinson as discussed in the previous chapter.

Additional research is needed to test and verify this solution. Even though rollovers require very little additional effort on the learner’s behalf, the use of rollovers could impose additional cognitive load, especially in novice learners or learners who are unfamiliar with online learning formats. In addition, because link previews require an electronic format, the extraneous load associated with certain types of online learning environments (e.g., hypertext) must also be considered when using link previews. So even if rollover link previews do not impose additional load, the format needed to use this solution may impose additional cognitive load.

The research and theories examined here, when taken together, shed light on the cognitive load theory of multimedia learning, the coherence principle, and the challenges that surface in the real world. While learning theories and instructional design principles are irreplaceable, they sometimes fall short in the real world. Regardless of the instructional designer's intent and knowledge about how the human mind works, the client's desires can often override the designer's suggestions.

APPENDIX A

Screenshot of Rollover Link Preview

Entering Dates

You can enter a date directly as a serial number (if you now it), but more often, you enter a date using any of several recognized date formats. Excel automatically converts your entry into the correspondin … uses for calculations), and it also applies the default da … plays as an actual date rather than as a cryptic ser…

> This information is provided as a reference; it contains technical details about how Excel uses the date serial number for calculations.

For example, if you need to ente… y enter the date by typing June 18, 2007 (or any of … Excel interprets your entry and stores the value 39251, the date serial number for that date. It also applies the default date format so that the cell contents may not appear exactly as you typed them.

When you activate a cell that contains a date, the Formula bar shows the cell contents formatted by using the default date format—which corresponds to your system's short date format. The Formula bar doesn't display the date's serial number. If you need to find out the serial number for a particular date, format the cell using a nondate number format.

WORKS CITED

Amadieu, Franck, André Tricot, and Claudette Mariné. "Prior Knowledge in Learning from a Non-Linear Electronic Document: Disorientation and Coherence of the Reading Sequences." *Computers in Human Behavior* 25 (2009): 381-88. *PsycINFO*. Web. 31 August 2009.

Antonenko, Pavlo, D. *The Effect of Leads on Cognitive Load and Learning in a Conceptually Rich Hypertext Environment.* Diss. Iowa State U, 2007. Ann Arbor: UMI, 2008. 3274900.

Ayres, Paul and John Sweller. "The Split-Attention Principle in Multimedia Learning." *The Cambridge Handbook of Multimedia Learning.* Ed. Richard E. Mayer. New York: Cambridge UP, 2005. 135-46.

Baron, Lisa, Jean Tague-Sutcliffe, Mark T. Kinnucan, and Tom Carey. "Labeled, Typed Links as Cues when Reading Hypertext Documents." *Journal of the American Society for Information Science* 47.12 (1996): 896-908. *ABI/INFORM Global*. Web. 20 October 2009.

Bétrancourt, Mireille and André Bisseret. "Integrating Textual and Pictorial Information Via Pop-Up Windows: An Experimental Study." *Behaviour & Information Technology* 17.5 (1998): 263-73. *PsycINFO.* Web. 21 October 2009.

Clark, Ruth and Richard E. Mayer. *e-Learning and the Science of Instruction: Proven Guidelines for Consumers and Designers of Multimedia Learning.* San Francisco, CA: Pfeiffer, 2008.

Clark, Ruth, Frank Nguyen, and John Sweller. *Efficiency in Learning: Evidence-Based Guidelines to Manage Cognitive Load.* San Francisco: Pfeiffer, 2006.

Cress, U. and O.B. Knabel. "Previews in Hypertexts: Effects on Navigation and Knowledge Acquisition." *Journal of Computer Assisted Learning* 19 (2003): 517-27. *Education Research Complete.* Web. 20 October 2009.

DeStefano, Diana and Jo-Anne LeFevre. "Cognitive Load in Hypertext Reading: A Review." *Computers in Human Behavior* 23 (2007): 1616-41. *ScienceDirect.* Web. 15 September 2009.

Driscoll, Marcy P. *Psychology of Learning for Instruction.* Boston, MA: Allyn and Bacon, 2004.

Gagné, Robert M., Walter W. Wager, Katherine C. Golas, and John M. Keller. *Principles of Instructional Design.* Belmont, CA: Wadsworth/Thomson Learning, 2005.

Gerjets, Peter, Katharina Scheiter, Maria Opfermann, Friedrich W. Hesse, and Tessa H.S. Eysink. "Learning with Hypermedia: The Influence of Representational Formats and Different Levels of Learner Control on Performance and Learning Behavior." *Computers in Human Behavior* 25 (2009): 360-70. *ScienceDirect.* Web. 7 May 2009.

Gredler, E. Margaret. *Learning and Instruction: Theory into Practice.* Upper Saddle River, NJ: Pearson Education, 2005.

Harp, Shannon and Richard E. Mayer. "How Seductive Details Do Their Damage: A Theory of Cognitive Interest in Science Learning." *Journal of Educational Psychology* 90.3 (1998): 414-34. *PsycINFO*. Web. 31 August 2009.

Johnston, Gregory Scott. *Effects of Seductive and Boring Details on Readers' Comprehension of Explanatory Texts.* Diss. U of Kentucky, 2002. Ann Arbor: UMI, 2002. 3064861.

Jonassen, David H. and Sherwood Wang. "Acquiring Structural Knowledge from Semantically Structured Hypertext." *Journal of Computer-Based Instruction* 20.1 (1993): 1-8. Print.

Low, Renae and John Sweller. "The Modality Principle in Multimedia Learning." *The Cambridge Handbook of Multimedia Learning.* Ed. Richard E. Mayer. New York: Cambridge UP, 2005. 147-67.

Madrid, R. Ignacio, Herre Van Oostendorp, and Mari Carmen Puerta Melguizo. "The Effects of the Number of Links and Navigation Support on Cognitive Load and Learning with Hypertext: The Mediating Role of Reading Order." *Computers in Human Behavior* 25 (2009): 66-75. *ScienceDirect.* Web. 15 September 2009.

Maes, Alfons, Arjan van Geel, and Reinier Cozijn. "Signposts on the Digital Highway: The Effect of Semantic and Pragmatic Hyperlink Previews." *Interacting with Computers* 18 (2006): 265-82. *ScienceDirect.* Web. 23 October 2009.

Mautone, Patricia D. and Richard E. Mayer. "Signaling as a Cognitive Guide in Multimedia Learning." *Journal of Educational Psychology* 93.2 (2001): 377-89. *PyscINFO*. Web. 31 August 2009.

Mayer, Richard E. “Principles for Reducing Extraneous Processing in Multimedia Learning: Coherence, Signaling, Redundancy, Spatial Contiguity, and Temporal Contiguity Principles.” *The Cambridge Handbook of Multimedia Learning*. Ed. Richard E. Mayer. New York: Cambridge University Press, 2005. 183-200.

Mayer, Richard E., Julie Heiser, and Steve Lonn. “Cognitive Constraints on Multimedia Learning: When Presenting More Material Results in Less Understanding.” *Journal of Educational Psychology* 93.1 (2001): 187-98. *PsycINFO*. Web. 28 September 2009.

Mayer, Richard E., Emily Griffith, Ilana T.N. Jurkowitz, and Daniel Rothman. “Increased Interestingness of Extraneous Details in a Multimedia Science Presentation Leads to Decreased Learning.” *Journal of Experimental Psychology: Applied* 14.4 (2008): 329-39. *PsycINFO*. Web. 31 August 2009.

Rowland, Emily, Christopher H. Skinner, Kai Davis-Richards, Richard Saudargas, and Daniel H. Robinson. “An Investigation of Placement and Type of Seductive Details: the Primacy Effect of Seductive Details on Text Recall.” *Research in the Schools* 15.2 (2008): 80-90. *Education Research Complete.* Web. 25 October 2009.

Zhao, Zhengmai, Tim O’ Shea, and Pat Fung. “The Effects of Visible Link-Types on Learning in the Hypertext Environment: An Empirical Study.” *Computers in the Schools.* 10 (1994): 353-68. Print.

Zumbach, Joerg and Maryam Mohraz. "Cognitive Load in Hypermedia Reading Comprehension: Influence of Text Type and Linearity." *Computers in Human Behavior* 24 (2008): 875-87. *ScienceDirect.* Web. 23 October 29.