APPLYING COGNITIVE LOAD THEORY TO THE DESIGN OF ONLINE LEARNING

Kate M. Erland Burkes, B.A., M.A.

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APPROVED:

Jeff M. Allen, Major Professor
Dale E. Yeatts, Minor Professor
Russell Elleven, Committee Member
Jerry Wircenski, Program Coordinator
Robin Henson, Chair of the Department of
    Technology and Cognition
M. Jean Keller, Dean of the College of
    Education
Sandra L. Terrell, Dean of the Robert B.
    Toulouse School of Graduate Studies

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The purpose of the study was to investigate the application of cognitive load theory to the design of online instruction. Students in three different courses (N = 146) were measured on both learning performance and perceptions of mental effort to see if there were any statistically significant differences.

The study utilized a quasi-experimental posttest-only control group design contrasting modified and unmodified instructional lessons. Both groups were given a posttest to measure knowledge gained from the lesson (cognitive domain of learning) and perceptions of mental effort involved.

Independent samples t-tests were used to compare the mean performance scores of the treatment groups (i.e. the sections using redesigned materials) versus the control groups for all three courses. Cohen's d was also computed to determine effect size. Mental effort scores were similarly compared for each group on the overall cognitive load score, for a total of six data points in the study.

Of the four hypotheses examined, three (H_1, H_2, H_4) found no statistically significant difference between the experimental and control groups. Negative significance was found between the experimental and control group on the effect of modality (H_3). On measures of cognitive load, no statistically significant differences were found.

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The successful completion of this research would not have been possible without support from my husband Dave and my children Laura, Corrie, Jonathan, and Sarah. I dedicate this dissertation to the memory of my parents, Milton C. and Elizabeth O. Erland, who believed in the value of education; and to my sister, Jean M. Brickey, who passed away during the completion of this work.

Sometimes our light goes out but is blown into a flame by another human being.

Each of us owes deepest thanks to those who have rekindled this light.

-- Albert Schweitzer

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CHAPTER 1

INTRODUCTION

This chapter explains the need to examine the application of cognitive load theory (CLT) to the instructional design of online courses and briefly discusses its use in education and training. Additionally, it provides a theoretical framework for cognitive load theory, the purpose of the study, the research hypotheses, and the limitations and delimitations which form the basis of this study.

Need for the Study

In recent years there has been an increased focus on the effectiveness and efficiency of instructional design strategies in education and training (Salas, Kosarzycki, Burke, Fiore, & Stone, 2002). Trends of "just-in-time" instructional strategies and rapid instructional design, as well as the use of computerized templates and shells, all highlight the focus of producing learning more proficiently, both in terms of the design of materials and the mastery of information by the learner.

Effectiveness is a concept fundamental to the design of instruction, which according to Rothwell and Kazanas (1998) represents a match between results achieved and those needed or desired. Such performance is understood as the achievement of measurable results, often stated as performance outcomes. Efficiency in learning, however, is a more complex concept. According to Paas and Van Merriënboer (1993), learning efficiency is a measure of the relationship between mental effort invested and performance output. In an applied sense, efficiency in instruction can

be understood to suggest that resources should be used to accomplish results in such a way as to maximize learning and minimize the amount of cognitive effort required.

This study fills a gap in current research (e.g., Clark, Nguyen, & Sweller, 2005; Morrison & Anglin, 2005) by documenting the application of theory to practice. Specifically, it tests three of the main effects of cognitive load theory in its application to online learning in a higher education setting. The intention of this study was to provide useful information for education and training personnel to better prepare them in applying research-based instructional design practices to the distance learning environment.

Instructional design is a critical component within the parameters of education and training. The role of the instructional designer has typically been to analyze and solve performance problems in a systematic manner and to implement various solutions so that people can be productive and knowledgeable. Instructional design has been described as the science of creating specifications to facilitate learning (Richey & Nelson, 1996) and the systematic process of translating principles of learning and instruction into plans for instructional materials and activities (Smith & Ragan, 1993). Ideally, effectiveness and efficiency can be achieved through the teaching methods, activities, and instructional materials designed to guide learning.

Recent years have seen a plethora of research related to instructional system design, particularly in the realm of cognitive learning theories and the use of educational technology (e.g., Clark et al., 2005; Morrison & Anglin, 2005; Paas, Renkl, & Sweller, 2004). However, it is debatable whether enough emphasis has been placed on the convergence of theory and practice. In theory, the instructional design models used in

online education should differ little from those applied to training and to other subject fields that emphasize improving practice (e.g., Morrison & Anglin, 2005; Salas et al., 2002; Tabbers, Martens, & van Merriënboer, 2004) so that good principles of instructional design remain static as applied to all types of learning. But as Clark et al. (2005) noted, "The training profession has been shaped by fad and folk wisdom more than by scientific evidence of what actually works" (p. 15). As in all aspects of instruction, a research-based approach should be applied to the design of online learning so that greater instructional efficiency and effectiveness will result.

As online education matures and becomes more ubiquitous, the issue of quality has come to the fore as a key question within distance learning (Clark et al., 2005). Quality as an outcome of instructional design seems especially difficult to produce at the intersection of technology and learning, since the normal classroom supports (i.e., the face-to-face explanation of materials and assignments) are pulled away, leaving the design itself to be the major mediator of learning (Morrison & Anglin, 2005). Educational researchers (e.g., Morrison & Anglin, 2005; Paas et al., 2004) have suggested that a need exists for more research in order to better understand how learning theory can be applied to "real-world" online instructional design situations, as well as for testing the tenets of cognitive learning theory.

Theoretical Framework

Within the trends of online learning, there has been an increased focus on the effectiveness and efficiency of instructional design strategies in education and training. Some of the most important advances have come from the field of cognitive science,

which deals with the mental processes of memory and learning. This section provides a review of the fundamentals of cognitive load theory, as well as a synthesis of its application to instructional design.

Cognitive load theory is an instructional model fashioned from the field of cognitive science research. It describes learning in terms of an information processing system made up of long-term memory, which stores knowledge and skills on a more-or-less permanent basis, and working memory, which performs the intellectual tasks associated with learning (Cooper, 1998). Information may only be stored in long-term memory after first being dealt with by working memory (Baddeley, 1992). Working memory is limited in both capacity and duration, and these limitations will, under some conditions, hinder learning (Mayer, Heiser, & Lonn, 2001). The fundamental principle of cognitive load theory is that the quality of instructional design will be greater if attention is paid to the role and limitations of working memory.

The total amount of mental activity imposed on working memory in an instance of time is known as cognitive load, which has been found to have three distinct parts (Sweller, 1994):

1. Intrinsic load includes the inherent complexity of the subject matter and reflects the level of difficulty of the material to be learned. For example, the mental calculation of 2 + 2 has lower intrinsic load than solving an advanced algebraic equation, due to a higher number of elements that must be handled simultaneously (element interactivity) in working memory.

2. Extraneous load is the load imposed by the elements of the instructional design itself. For example, an audiovisual presentation will usually have lower

extraneous load than a visual-only format, since the audio modality is also being used to convey information to the learner.

3. Germane load relates to the effort involved in processing and automating new information. Automation helps overcome working memory limitations and decreases cognitive load. For example, knowledge and skills that are used frequently, such as reading, may be accessed automatically without high levels of conscious effort even though the associated task may be complex.

While intrinsic load is integral to the subject matter, and therefore largely unchangeable, the instructional designer can manipulate extraneous load to increase learning efficiency and effectiveness (Clark et al., 2005).

Cognitive load theory highlights several practices that can be applied to training and performance improvement. The most fundamental of these include methodologies for reducing the effects of the extraneous cognitive load of instructional materials to ensure optimal leaning. These effects include split attention, redundancy, and modality.

Split-Attention Effect

Split-attention effect holds that the use of materials that require learners to split their attention between two sources of information causes a higher cognitive load on working memory and therefore impedes the learning process (Mayer & Moreno, 2003). Because physically distinct items must be considered separately, the learner is forced to integrate them mentally, a process that is cognitively demanding and usurps mental resources that could otherwise be allocated to the learning process (see Figure 1).
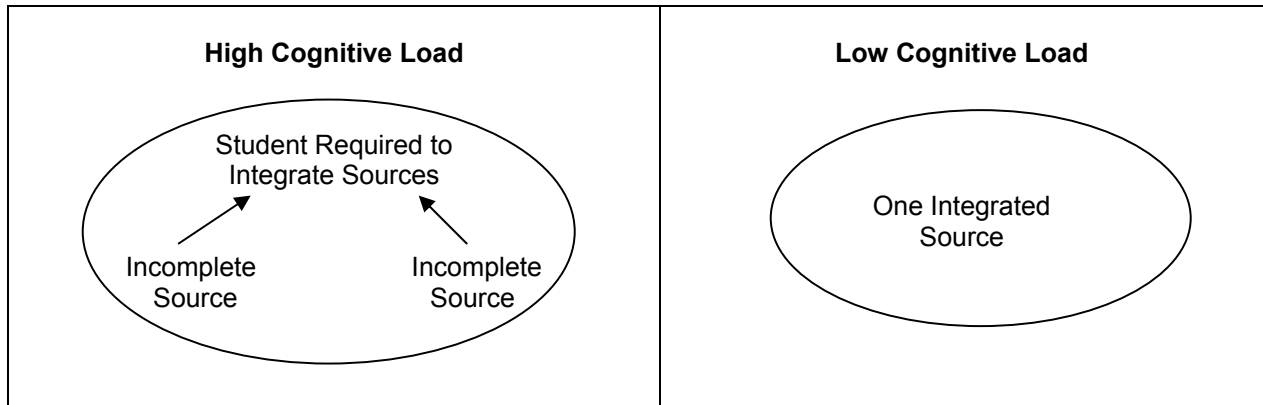
High Cognitive Load	Low Cognitive Load

Student Required to
Integrate Sources

Incomplete Source   Incomplete Source

One Integrated
Source

Figure 1. Split-attention effect.

Multiple sources of information will especially induce a split-attention effect if two
or more sources must be considered simultaneously. For example, this is likely to occur
in the cross-referencing of documents or even cross-referencing within a single
document. However, this effect can be diminished by more closely integrating textual
pieces, or text and diagrams, to eliminate the unnecessary load factor. For example, the
placement of text adjacent to an illustration produces less cognitive load for the learner,
since less effort is involved in the integration of pictures and text when they are placed
physically close to each other on the page or screen (Moreno & Mayer, 1999).

Redundancy Effect

In situations where one source of instruction, whether textual or graphic, provides
full intelligibility, then only one source of instruction should be used. Other sources,
which would be redundant, should be removed from the instructional materials. In these
contexts a single source of instruction returns higher levels of learning than multiple
resources, whether having an integrated format (for example, text integrated into a

graphic) or a dual format (both text and graphic presented in parallel) (Mayer et al., 2001).

Attending to multiple sources of instruction requires more mental resources than attending to a single source, resulting in a reduced portion of working memory available for the process of learning (see Figure 2).

High Cognitive Load	Low Cognitive Load
Complete Source Complete Source	Complete Source
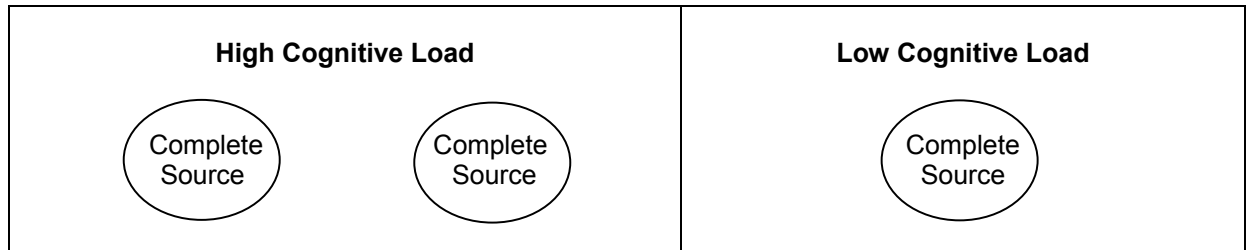
Figure 2. Redundancy effect.

Modality Effect

Several studies have concluded that learning is more efficient when multiple sensory pathways are used to present information (e.g., Leahy, Chandler, & Sweller, 2003; Moreno & Valdez, 2005). According to cognitive theory, the addition of audio narration to a visual presentation enhances understanding and related problem solving. For example, it is more effective to use spoken words (audio) to describe a graphic or visual component than to display a graphic with the same words in written form. The limited capacity of working memory is maximized by coordinated inputs into the visual and auditory subsystems rather than just the visual subsystem, as is the case when text alone is used to describe visuals (see Figure 3).

High Cognitive Load	Low Cognitive Load
Auditory input Only Visual Input Only	Auditory input + Visual Input
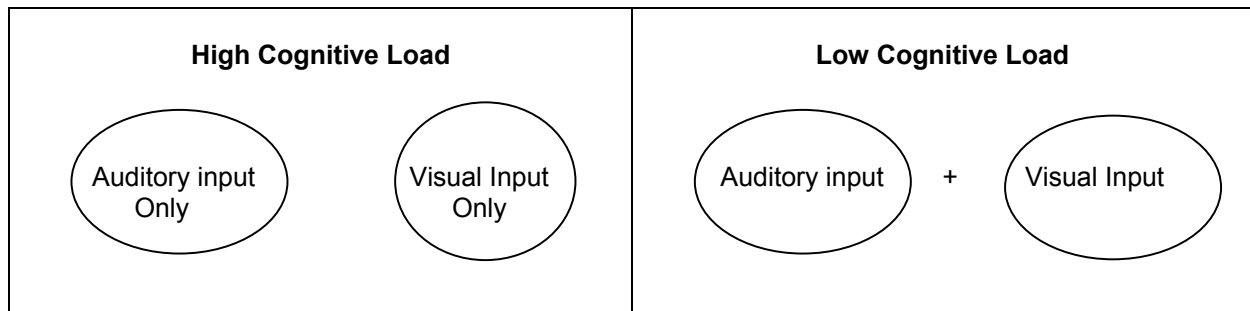
Figure 3. Modality effect.

Purpose of the Study

The purpose of the study was to investigate the application of cognitive load theory to the design of online instruction, specifically by redesigning aspects of three existing online courses to comply with the effects of split attention, redundancy, and modality. Students in three different courses (two class sections of each, treatment and control) were measured on both learning performance and on perceptions of mental effort to see whether there were any statistically significant differences.

Cognitive load theory has generally been applied to the instructional design of cognitively complex or technically challenging material (Morrison & Anglin, 2005). There is a lack of existing research on the application of cognitive load theory to "soft skills" performance development areas (such as leadership, personal development, etc.), as well as a gap in existing research on the cognitive load of online learning materials for these subjects. Given the trend to redesign existing human performance improvement courses into online versions, there is a need to determine whether the application of this theory is effective for these types of subjects in an online setting.

Research Hypotheses

H_1: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the split-attention effect of cognitive load theory (CLT) and those in the control group.

H_2: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the redundancy effect of CLT and those in the control group.

H_3: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the modality effect of CLT and those in the control group.

H_4: There is no statistically significant difference in cognitive load scores, as measured by the Paas Mental Effort scale, between students in the classes using redesigned materials and those in the control group.

Limitations

This study involved the redesign and comparison of existing online classes, and the scope of the study was limited to one online academic setting. The students varied in prior knowledge, skills, and attitudes and in their experience with online learning. Students also differed in level of education, life experience, motivation, and socioeconomic status. The number of students enrolled in each class section was also not equal. Neither entry-level skills, such as high school grade point averages, nor factors contributing to a student dropping a course (mortality rate) were examined.

Delimitations

The study was delimited to intact groups of students and operated under the assumption that the students surveyed could read and comprehend the measurement questions and answer them as honestly and accurately as possible.

Summary

This chapter explained the need to examine the application of cognitive load theory to the instructional design of online courses and briefly discussed its use in education and training. This chapter also provided a theoretical framework for CLT and presented the significance and purpose of the study. It also outlined the problem, the research hypotheses that form the basis of the study, and other important assumptions.

CHAPTER 2

LITERATURE REVIEW

This chapter provides an overview of the historical basis of cognition within instructional design, the tenets of human cognitive architecture, and a review of major findings from research done on split attention, redundancy, and modality effects. It also discusses research concerning the measurement of cognitive load and efficiency. This literature review does not address other cognitive factors that affect student performance (e.g., prior learning, expertise effect, motivation) or other factors that are outlined in the limitations and delimitations section of chapter 1.

Instructional Design and Cognition

The cognitive basis of instructional design has its roots in history. Early Greek philosophers identified cognition as one aspect of the mind, and thinkers such as Aristotle and St. Thomas Aquinas also recognized the importance of the cognitive basis of learning. But by the middle of the 19th century and into the early 20th century, with the advent of the ideas of behaviorism, the role of cognition played a less significant part in learning theory (Leigh, 1999).

In the middle of the 20th century, cognition again emerged as an important basis of instructional science. The Second World War presented a need for effective instructional design, as the rapid training of thousands of military personnel, and then returning soldiers, led to a heavy investment in training and instructional research (Raiser, 2001).

The 1950s were characterized by the formulation of new theoretical models of learning, including the work of B. F. Skinner, who codified the basic principles of programmed instruction, considered by many as the progenitor of contemporary instructional design (Leigh, 1999). In 1956 George Miller published "The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information." The idea of the brain as an information processing system presented a principle that is fundamental to cognitive load theory and instructional design: working memory can hold only five to nine chunks of information (seven plus or minus two) at a time.

Glaser (1962) synthesized the work of previous researchers and introduced the concept of "instructional design," linking systematic analysis to the design and development of instruction. Around the same time, Gagné (1962) defined several different levels of learning, including an explanation of cognitive learning strategies. Baddeley and Hitch (1974) later refined a model of working memory, merging the concept of cognitive limits with the instructional design process.

In 1988, John Sweller published "Cognitive Load During Problem Solving: Effects on Learning," followed by "Cognitive Load Theory and the Format of Instruction" (Chandler & Sweller, 1991). Cognitive load theory was used to shed light on the interactions between information and cognitive structures and the effect of these interactions on instructional design (Sweller, van Merriënboer, & Paas, 1998). Mayer (1997) later applied these ideas to the new field of multimedia learning.

Human Cognitive Architecture

Learning requires a change in the schematic structures of long-term memory, which is demonstrated by output that progresses from slow and difficult to smooth and effortless. This change in performance occurs because, as the learner becomes increasingly familiar with the material, the cognitive characteristics associated with the material are altered so that they can be handled more efficiently by working memory (Paas et al., 2004).

Performance improvement comes from the expansion of cognitive schemas and a high level of automation in the retrieval of information (Paas et al., 2004). Because cognitive load theory views the limitations of working memory to be the primary impediment to efficient and effective learning, reducing the total cognitive load in instruction increases the portion of working memory available to accomplish the learning process. This is normally achieved by engineering reduced levels of cognitive load through better instructional design (Clark et al., 2005).

The structure of human cognitive architecture, while not known precisely, can be perceived through the results of experimental research. Built on the early work of Miller (1956), who showed that short-term memory is limited in the number of elements it can contain simultaneously, Sweller's (1988) theory treats schemas, or combinations of learning elements, as the cognitive structures that make up an individual's knowledge base.

The Split-Attention Effect

Within the realm of cognitive load theory, several studies have documented split

attention as an important variable in instruction, showing that the close physical integration of instructional materials has a significant effect on both learning outcomes and measures of cognitive load.

Prior studies found that closely organized texts will reduce extraneous cognitive load because less effort is needed for the integration of related ideas and less effort needs to be given to searching for and maintaining related information in memory. Mayer (1997) and Mayer and Sims (1994) showed that learning was enhanced when pictorial and spoken materials were presented concurrently rather than sequentially. Learning enhancements were also demonstrated when printed text and pictures were physically integrated (Mayer, 1997; Moreno & Mayer, 2000) rather than spatially separated. Chandler and Sweller (1992) found much the same results when they investigated the influence of text organization on readers of research reports. Similarly, Schnotz (1993) found that readers performed memory tasks better when reading text with fewer topical switches and more textual integration.

In terms of the application of split attention to e-learning, Moreno and Mayer (1999) investigated the influence of spatial contiguity on the relative cognitive load level of learning materials and performance outcomes. Mayer and Chandler (2001) examined the temporal aspects of text presentation, in which the pace of text presentation (computer controlled or learner controlled) was in focus. McCrudden, Schraw, Hartley, and Kiewra (2004) investigated the organizational aspects of related sections of text, comparing a high-load versus a low-load format. In all these cases, it was found that a more closely integrated method of presentation resulted in lower measures of mental effort and increased learning transfer.

These findings provide support to the validity of the split-attention effect and extend the research to include subvariables that influence text processing in learning. Together, these studies have shown that, as text organization declines and related segments become less contiguous, learning decreases. These studies also demonstrated that removing the effects of split attention positively influenced cognitive load, and in each case, that an advantageous presentation format improved performance on learning tasks.

The Redundancy Effect

Redundancy describes the duplication of intact (complete) information within the design of instructional materials. Different forms of redundancy have been described in the literature:

1. Diagram/text redundancy: Chandler and Sweller (1991) showed that use of a self-explanatory diagram alone (without additional text) resulted in lower levels of cognitive load and increased transfer of learning. Craig, Gholson, and Driscoll (2002) replicated this study with the same results.

2. Mental/physical activity redundancy: Sweller and Chandler (1994) and Chandler and Sweller (1996) showed that reading text in a manual while physically using a computer was redundant and interfered with learning.

3. Auditory/visual redundancy: Kalyuga, Chandler, and Sweller (1999) showed that redundancy occurred when the same material was presented simultaneously in written and spoken form.

Mayer et al. (2001) extended the investigation of the redundancy effect by examining whether it can also occur in a multimedia environment. Using animation, narration, and text, they showed that adding redundant onscreen text to a multimedia explanation resulted in poorer student learning.

These studies show that establishing relationships between different sources of information may be difficult for learners dealing with multiple representations and that various forms of redundancy can interfere with learning and should be eliminated (Mayer, 2001; Sweller, 1999; Sweller et al., 1998).

The Modality Effect

Modality involves the presentation of instruction using more than one sensory path. Several studies have linked cognitive load effects to the components of working memory by examining the effects of presentation modality on working memory load (Goolkasian, 2000; Mayer & Moreno, 1998; Mousavi, Low, & Sweller, 1995).

A number of experiments have demonstrated that replacing written or onscreen text with spoken text improved the learning process in different ways: (a) lower mental effort during instruction and higher test scores (Chandler, & Sweller, 1996; Kalyuga et al., 1999, 2000; Tindall-Ford,); (b) less time on subsequent problem solving (Jeung, Chandler, & Sweller, 1997; Mousavi et al., 1995); and (c) improved scores on retention, transfer, and matching tests (Mayer & Moreno, 1998; Moreno & Mayer, 1999).

Mousavi et al. (1995) found that subjects performed better when presented with a dual modality, that is, visual diagram and auditory explanations. Mayer and Moreno (1998) concluded that when information is presented in different modalities, the subjects

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had more room in their cognitive systems to hold the information. Velayo and Quirk (2000) found that receiving visual-auditory information outperformed other mixed modalities. Tabbers et al. (2004) did a study of modality in a classroom setting, but in terms of learning efficiency, the results were somewhat mixed.

The Measurement of Cognitive Load

Establishing a reliable estimator of cognitive load is difficult because of its multidimensional character and the complex interrelationships between performance, mental load, and mental effort (Sweller et al.,1998). One early attempt to measure cognitive load was made by Sweller (1988) in his study on problem solving. Using an analytical approach, he developed a strategy using secondary task measurement to determine load. This secondary task technique has also been used in studies by Brünken, Plass, and Leutner (2003), Chandler and Sweller (1996), Marcus, Cooper,and Sweller (1996), and Van Gerven, Paas, van Merriënboer, and Schmidt (2002).

However, measurements limited to secondary task performance may not provide good estimates of cognitive load since a learner may compensate for increased task complexity (mental load) by increasing mental effort, thereby maintaining a constant level of performance. Measurements of mental effort are therefore necessary to index cognitive load. Paas (1992) was the first to demonstrate the use of a rating scale in the context of cognitive load theory. The scale's reliability and sensitivity (Paas, van Merriënboer, & Adam, 1994) and ease of use have made this scale, and variants of it, the most widespread measure of working memory load within CLT research. Other

researchers have demonstrated the scale's reliability, and convergent, construct, and discriminate validity (Gimino, 2000; Paas et al.,1994).

Several recent studies (Kalyuga, Chandler, Tuovinen & Sweller, 2001; Tabbers et al., 2004) used the Paas rating scale in the context of survey questions in which the participant indicated the experienced level of cognitive load. Although self-ratings may appear questionable, it has been demonstrated that people are quite capable of giving a numerical indication of their perceived mental burden (Gopher & Braune, 1984). Paas et al. (1994) showed that reliable measures could be obtained with unidimensional scales; that such scales are sensitive to relatively small differences in cognitive load; and that they are valid, reliable, and unintrusive.

Paas and van Merriënboer (1993) developed a computational approach to combine measures of mental effort with measures of primary task performance to compute the mental efficiency of instructional conditions. Since then, several studies have successfully applied this method or an alternative method combining learning effort and test performance (Clark et al., 2005).

Summary

This chapter has provided an overview of the historical basis of cognition within instructional design, as well as a review of major findings from research done on split attention, redundancy, and modality effects. It also discussed research concerning the measurement of cognitive load and efficiency.

CHAPTER 3

METHODOLOGY

The purpose of the study was to investigate the application of cognitive load theory (CLT) to the design of instruction, specifically by redesigning aspects of three existing online courses to comply with the effects of split attention, redundancy, and modality. This chapter discusses the design, population, sample, instructional materials, instrumentation, data collection, and analysis procedures.

Research Design

The study utilized a quasi-experimental design known as the posttest-only control group design. According to Gall, Borg, and Gall (1996), this design controls for history, maturation, testing, instrumentation, statistical regression, differential selection, and interaction of selection and maturation as sources for internal validity. In addition, the design controls for interaction of testing (experimental treatment) as a source of external validity.

Posttest-only control group design involves comparisons between an experimental group and a control group. The experimental groups in this study participated in a modified instructional lesson, and the control groups participated in a nonmodified instructional lesson. Both groups were given a posttest to measure knowledge gained from the lesson (cognitive domain of learning) and the mental effort involved.

Table 1 outlines the specific modifications made to each class:

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Table 1

Modifications Made to Each Class

Course / Module modified	Cognitive load effect tested & justification	Existing materials	*Modified materials*
ATTD 3010 Personal development / Module 2 -- Goal setting and time management	Split-Attention: replaced multiple sources of information with a single, integrated source of information; reduces extraneous load because there is no need to mentally integrate the information sources	Multiple layers of information on external Web site	Replaced with integrated activity on local Web site
ATTD 4070 Principles of Leadership / Module 5 – SLII Model	Redundancy: replaced multiple sources of information (that are self-contained) into one source of information; reduces extraneous load caused by unnecessary processing of redundant information	Multiple sources: - article - video	Replaced with SLII diagram and audio explanation
ATTD 4100 Introduction to Training and Development / Module 3 – Learning Theories	Modality: replaced a written source of information and another source of visual information with a spoken explanatory text and a visual source of information; reduces cognitive load because the multimodal presentation uses both the visual and auditory processor of working memory.	Printed copy of PowerPoint Slides	Replaced with narrated PowerPoint presentation

A pretest was not included because the study involves performance measures that might impact participation levels if the subjects show an initial lack of knowledge in the content of the lesson. This possibility was evidenced by Campbell and Stanley (1966), who stated that while the pretest is a concept deeply embedded in the thinking of research workers in education and psychology, it is not actually essential to a quasi-experimental design. Sprangers and Hoogstraten's (1989) work related to pretest sensitization and response-shift bias also showed that a pretest can lower internal validity by introducing a carryover effect when participants recall their responses made on the pretest.

Random selection and random assignment were both considered in this study to

ensure that the design met these requirements:

1. Random selection has been considered in the use of a cluster sampling procedure to ensure that each class in the defined population has an equal chance of being selected to take part in the study (Gall et al., 1996).

2. Random assignment was accomplished by computerized generation of random student numbers and assignment to class sections based on those numbers. Students were then manually moved from section to section within the university's enrollment system by departmental staff.

Population

The target population for this study was undergraduate students enrolled in online courses offered by the Applied Technology, Training and Development program (ATTD) in the department of the Technology and Cognition at the University of North Texas, Denton. Approximately 14 nonrestricted online courses were offered at the undergraduate level for the fall 2006 semester.

Sample

For purposes of this study, independent samples *t* tests with an alpha level of .05 were used, assuming a large effect size and a statistical power level of .80. A table of recommended sample sizes from Cohen (1988) suggested a sample of 26 for each comparison group:

Table 2

Excerpt from Table 2.4.1 by Cohen

α = .05	*d*	.60	.70	.80	1.00
Power					
.70		35	26	20	13
.75		40	29	23	15
.80		45	33	26	17
.85		51	38	29	19

Subjects were selected from the defined population by using a cluster sampling method. In this case, it was more feasible to select groups of individuals than to select individuals from a defined population (Gall et al.,1996). Six classes were involved in the study, consisting of two sections of Personal Development (ATTD 3010), Principles of Leadership, Empowerment and Team Building (ATTD 4070), and Introduction to Training and Development (ATTD 4100) offered by the program of Applied Technology, Training and Development in the College of Education at the University of North Texas. Based on estimates of previous enrollment, total sample size for the proposed study was estimated to be approximately 156 individuals (see Table 3).

Table 3

Sample Size per Comparison Group

Class	Experimental group η	Control group η
ATTD 3010	26	26
ATTD 4070	26	26
ATTD 4100	26	26

Instructional Materials

Three different online lessons were chosen for modification based on the suggested effects of cognitive load theory. Each lesson was chosen based on an evaluation of the status of existing lesson materials in terms of split-attention, redundancy, and modality. All classes were offered via WebCT Vista, a Web-based course delivery system provided by the University of North Texas.

Split Attention

In reviewing the lesson titled "Goal Setting and Time Management" in ATTD 3010, it was noted that multiple sources of information were used to convey the concepts of the lesson. Specifically, students were required to access an external Web site and follow multiple links through several steps to find pieces of required information. Students then had to return to the initial lesson page and integrate the external information into the required activities.

According to cognitive load theory, multiple sources of information should be replaced with a single, integrated source of information, which will reduce extraneous load because there is no need to mentally integrate the information sources. In the experimental version, the lesson was modified to include all the required information on pages internal to the module.

Two instructional items within the module were chosen for modification:

1. Reflection exercise: In the original (control) materials, students were required to access the Pearson/Prentice Hall companion textbook Web site (http://www.prenhall.com/success) and then access two subpages (Academic Skills and

Time Management). This exercise was modified to bring the information directly into the WebCT Vista module page so that students could complete the required assignment using the information provided without having to divert attention from the associated module materials.

2. Time management exercise: In the original (control) exercise, students were again required to access the Pearson/Prentice Hall companion textbook Web site, and copy a chart from the HTML page into a text document. In the modified (experimental) materials, students were directly provided with the required chart on the internal Vista page in order to reduce the effect of split attention by allowing the students to remain within the Vista system for the entire activity.

Redundancy

The redundancy effect was noted in a lesson on Situational Leadership in ATTD 4070. The existing module included an 11-page article for students to download, and a 15-minute commercially-produced video embedded into the lesson page. Upon examination, it was determined that several aspects of both materials overlapped in content: The video discussed concepts of leadership, leadership style, and the SL II model. The article also covered leadership styles and the SL II model.

The redundancy effect of cognitive load theory posits that multiple sources of information (that are self-contained) should be combined into one source of information, reducing the extraneous load caused by unnecessary processing of redundant information. The lesson was modified to combine the major content of the article and the video into one narrated diagram.

Modality

The modality effect was observed in a module on Learning Theories in ATTD 4100. The existing learning materials consisted of two sources of information: pages of printed PowerPoint slides and the course textbook.

In concert with the modality requirement to provide information through more than one sensory pathway, the written and visual information sources were replaced with a narrated PowerPoint presentation. This would reduce cognitive load because the multimodal presentation used both visual and auditory inputs into working memory.

Instrumentation

The method chosen for this study was survey research. As noted by Gall, Borg, and Gall (2003), studies involving surveys comprise a significant amount of the research done in the education field. Educational surveys are often used to assist in planning and decision making, as well as to evaluate the effectiveness of an implemented program. Questionnaires are an effective method for collecting information regarding sample characteristics, experiences, and opinions. The findings from survey questionnaires can then be generalized to the larger population that the sample represents (Gall et al., 1996).

Based on the work of Paas (1992) and existing content-based assessments, survey instruments were developed to collect student responses to a series of questions (items) based on the key constructs of the model. In this study, an online survey questionnaire was used to elicit data regarding student characteristics, mastery of content, and mental effort.

1. Demographic information was gathered concerning items integral to the comparison of groups: race, gender, and amount of previous online learning experience.

2. Content-based questions were developed for each course to test the learning outcomes of both the modified and unmodified modules (see Appendix A). The questions were structured as multiple-choice measures of content mastery based upon previously developed assessments. Several researchers (e.g., Chatterji, 2003; Dominowski, 2002; Popham, 2000) recommended this format as an objective measure of learning, with reliability in scoring being a prime factor. Multiple-choice instruments were also used for testing learning outcomes as a part of cognitive load measurement in other studies (e.g., Craig et al., 2002; Kalyuga et al., 1999).

3. An instrument using the rating scale developed by Paas (1992) was used to measure mental effort as an indicator of cognitive load (see Appendix B). Participants reported their invested mental effort after viewing the instructional materials. The scale's reliability (alpha > .8) and convergent, construct, and discriminate validity have been demonstrated (Gimino, 2000; Paas et al., 1994). Paas gave permission for use of the scale in this research study (see Appendix C).

Each content-based instrument was evaluated for content validity by a panel of experts. With input from faculty, 10 experts in the fields of adult education or training and development were identified to participate in this process. Draft materials were placed on a temporary Web site which each of the reviewers was asked to access to view the materials. Seven reviewers responded via a feedback form created for the site and by email. The reviewers indicated that each test was well aligned with the content

of the specified module. Formatting changes were made to the instruments according to recommendations made by the reviewers.

Data Collection Procedures

A posttest-only design was used in the study to assess student cognitive performance. Students enrolled in each section were requested to complete the survey during the course of their regular online instruction. Participation in the study was voluntary, and there was no extra credit for participation. Each student completed an instructional lesson and then accessed the research project via a link on the module assignment page. Participants were given notice of Informed Consent and indicated their agreement by clicking on a link that took them to the questionnaire. Participants clicked on radio buttons to indicate their responses, with submitted data being logged in a computerized database and emailed to the researcher. The entire survey process took less than 10 minutes.

The target lesson modules and surveys were available to the participants in accordance with the classes' regular lesson schedule. For each of the courses, the module content was accessed by the student without teacher input so that instructor variably was not a concern. The modules were made automatically available upon completion of the previous module, with a specific deadline given for assignment completion. In all cases, students were allowed at least 1 week in which to access the survey. Each section instructor was requested to also remind the students to complete the survey, which helped assure that the required sample size would be met.

Approval to conduct this study was received from the Institutional Review Board

(IRB) for the protection of Human Subjects in Research at the University of North Texas

(see Appendix D). Following the guidelines provided by the review board, a

computerized consent form was developed to provide each study participant with

information concerning study purpose, description, procedures, and confidentiality. This

form described the research subject's rights as well as time required to complete the

survey, risks associated with participation, and contact information for any questions or

concerns.

Data Analysis

In planning the study, it was anticipated that descriptive statistics would be

calculated to summarize and describe the data collected. A computerized survey form

was set up to measure categories representing demographic data, content knowledge,

and mental effort. Reponses to the content knowledge items were coded into the

computerized response form as a 1 (correct answer) or 0 (incorrect answer). Mental

effort was internally coded using the 9-point Paas scale, with 1 representing low effort

and 9, high effort. Responses from the surveys were stored in a computerized database

and transferred to SPSS 12.0 (Statistical Package for Social Sciences) for analysis.

Independent samples t tests were used to compare the mean performance

scores of the treatment groups (i.e., the sections using redesigned materials) versus the

control groups for all three courses. Independent samples t tests are widely used to

compare the means on a dependent variable for two independent groups. For small

sample sizes, the equal variances version of the test provides an exact test of the

equality of the two population means. The validity of the test demands that the samples be drawn from normally distributed populations with equal (population) standard deviations.

Cohen's *d* was also computed to determine effect size. *d* is defined as the difference between two means divided by the pooled standard deviation for those means ($d = M_1 - M_2 / \sigma_{pooled}$). Effect size is a measure of the strength of the relationship between two variables. In scientific experiments, it is often useful to know not only whether an experiment has a statistically significant effect, but also the size of any observed effects. In practical situations, effect sizes are helpful for making decisions about the need to make changes in materials, programs, and other outcomes.

Mental effort scores were similarly compared for each group on the overall cognitive load score, for a total of six data points in the study (see Table 4).

Table 4

Analysis by Group

Hypothesis	Independent	Dependent	Analysis	Effect size
H_1: Split-Attention	Group A Group B	Number of items correct	Independent samples *t*-test	Cohen's *D*
H_2: Redundancy	Group A Group B	Number of items correct	Independent samples *t*-test	Cohen's *D*
H_3: Modality	Group A Group B	Number of items correct	Independent samples *t*-test	Cohen's *D*
H_4: Cognitive Load -- 3010	Group A Group B	Scale score	Independent samples *t*-test	Cohen's *D*
H_4: Cognitive Load -- 4070	Group A Group B	Scale score	Independent samples *t*-test	Cohen's *D*
H_4: Cognitive Load -- 4100	Group A Group B	Scale score	Independent samples *t*-test	Cohen's *D*

Summary

This chapter discussed the design, population sample, instrumentation, data collection, and analysis procedures.   Chapter 4 presents the results of data collection and analysis.

CHAPTER 4

FINDINGS

The purpose of the study was to investigate the application of cognitive load theory to the design of online instruction, specifically by redesigning aspects of three existing online courses to comply with the effects of split attention, redundancy, and modality. Students in three different courses (two class sections of each, treatment and control) were measured on both learning performance and on perceptions of mental effort to determine whether there were any statistically significant differences. This chapter presents the data collected and the findings based on those data, including sections on demographics, hypothesis analyses, and summary features.

Introduction

This study utilized a quasi-experimental design known as the posttest-only control group design and used a sample drawn from students enrolled in online classes at the University of North Texas during the fall semester of 2006. Two sections of three courses were divided into control (A) and treatment (B) groups to test the hypotheses based on performance and measures of mental effort. The total number of participants was 146 out of a possible 156 active in the courses, for a 94% participation rate. Table 5 provides a breakdown of potential and actual participants by class.

Data were gathered using the instruments specified in chapter 3, including surveys of demographic information (3 questions), content mastery (7 questions), and mental effort (3 questions). Content validity for the performance measure was obtained through expert review and revision of the instrument. An instrument using the rating

scale developed by Paas (1992) was used to measure mental effort as an indicator of cognitive load. The scale's reliability (alpha > .8) and convergent, construct, and discriminate validity had previously been demonstrated (Gimino, 2000; Paas et al., 1994).

Table 5

Potential and Actual Participation by Class

Class	Potential participants*		Actual participants	
	Section A	Section B	Section A	Section B
ATTD 3010	25	26	25	26
ATTD 4070	27	26	27	26
ATTD 4100	26	26	21	21
Total	78	78	73	73

*Potential participants do not include students listed on the class roster but who were "no shows," drops, or withdrawals from the class prior to the survey administration.

SPSS 12.0 statistical analysis software was used for all analyses. Data were entered from the computerized results generated from the online data survey. Results were cross-checked for accuracy and completeness with two sources: an HTML log file and results sent to the researcher's external email address. Both sources were judged to accurately reflect the input generated from student responses.

Demographics

A total of 146 students took part in the overall study, including 80 females and 66 males. Respondents indicated that 63% were White, 23% African American, 8% Hispanic, and 6% Other. These figures roughly approximate the total population of UNT undergraduate students, with the exception of African American students showing a

somewhat higher percentage in the sample group. A total of 16% indicated that this was

their first online course, with 9% having taken one previous online class, 7% having

taken two prior online courses, and 68% having taken three or more prior online

classes.

Hypothesis Analysis

Each of the study's four hypotheses was analyzed using independent samples t

tests to compare the mean performance scores and mental effort scores of the

treatment versus the control groups for all three courses. Cohen's d was also used to

measure effect size for each test.

H_1: There is no statistically significant difference in learning scores between students in
the class using materials redesigned accorded to the split-attention effect of cognitive
load theory (CLT) and those in the control group.

The research sample for this hypothesis consisted of two groups of ATTD 3010

(Personal Development) students, with a control group of 25 and an experimental group

of 26. The experimental group used lesson materials redesigned to remove the effect of

split attention, while the control group used materials previously designed without

consideration of this effect.

An independent samples t test was performed to determine whether there was a

statistically significant difference between the group utilizing the materials modified to

eliminate split attention and the group that did not. Table 6 reflects the analysis for a

95% confidence rating. The results indicate no statistically significant difference in

performance; thus the hypothesis fails to be rejected.

Cohen's *d* was determined to be the appropriate effect size measure to use in the context of a *t* test on means. Effect size is a measure of the strength of the relationship between two variables and indicates practical significance. For these data, the *d* was calculated to be .114, where 0.2 is generally indicative of a small effect, 0.5 a medium, and 0.8 a large effect size (Cohen, 1988).

Table 6

Split-Attention Effect

Dependent variable	Group	Mean	SD	t	df	p
Number Correct	Non-Modified Materials	5.20	1.443	.410	49	.684
	Modified Materials	5.04	1.371			

H_2: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the redundancy effect of CLT and those in the control group.

The sample for this test consisted of 27 (control) and 26 students (treatment) enrolled in ATTD 4070 (Principles of Leadership). An independent samples *t* test was performed to determine whether there was a statistically significant difference between the group utilizing the materials modified to eliminate the redundancy effect and the group that did not. Table 7 reflects the analysis for a 95% confidence rating. The results indicate no statistically significant difference in performance; thus, the hypothesis fails to be rejected. Cohen's *d* was calculated to be .120, which is is generally indicative of a small practical effect.

Table 7

Redundancy Effect

Dependent variable	Group	Mean	SD	t	df	p
Number Correct	Non-Modified Materials	4.93	1.269	.428	51	.670
	Modified Materials	4.77	1.394			

H$_3$: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the modality effect of CLT and those in the control group.

Two groups of ATTD 4100 (Introduction to Training and Development) students were compared on the effect of modality on the mastery of module content. Twenty-one students from each section participated, which reflected 80% of the 26 active students in each class.

An independent samples *t* test was conducted to determine whether there was a statistically significant difference between the group utilizing the materials modified to eliminate the modality effect and the group that did not. Table 8 reflects the analysis for a 95% confidence rating. In this case, there was a statistically significant difference in the performance measures between the two groups. Cohen's *d* was computed to be 1.746, which indicates a very large effect size.

Table 8

Modality Effect

Dependent variable	Group	Mean	SD	t	df	p
Number Correct	Non-Modified Materials	5.67	1.017	5.654	40	<.001*
	Modified Materials	3.43	1.502			

*t >1.96, p < .05, statistically significant.

H$_4$: There is no statistically significant difference in cognitive load scores, as measured by the Paas Mental Effort scale, between students in the classes using redesigned materials and those in the control groups.

Cognitive load was calculated using three questions about mental effort. Each question used the Paas Mental Effort Scale to measure perceptions of cognitive load:

1. On Question 1, participants were asked to rate the mental effort invested in studying the contents of the module.

2. On Question 2, students rated their perceptions of the difficulty of the content of the module.

3. On Question 3, participants were asked to rate the degree of difficulty in understanding the module.

In calculating an overall cognitive load score, the total scores for all three questions were compared between the treatment and control groups. Tables 9 shows that there was no statistically significant difference in the overall perception of cognitive load among those receiving the modified instructional lessons (Group B) for any of the three cognitive load effects being tested.

Table 9

Cognitive Load

Class	Group	Mean	SD	t	df	p
ATTD 3010	A	12.16	4.23	-.846	49	.402
	B	13.08	3.49			
ATTD 4070	A	15.63	4.13	1.03	51	.307
	B	14.42	4.38			
ATTD 4100	A	15.52	3.41	-.104	40	.918
	B	15.62	2.46			

Cohen's *d* was also computed for each of the effects being tested, with the practical effect being small: ATTD 3010: *d* = -0.237; ATTD 4070: *d* = 0.284; ATTD 4100: *d* = -0.034.

Summary

Chapter 4 addressed the data collected and the statistical tests performed, including a series of *t* tests and measures of effect size used to substantiate the hypotheses. Of the four hypotheses examined, three (H_1, H_2, H_4) found no statistically significant difference between the experimental and control groups. Chapter 5 provides a summary of the study, a discussion of the significance of the findings, and recommendations for future research.

CHAPTER 5

SUMMARY OF FINDINGS, CONCLUSIONS,

AND RECOMMENDATIONS

This chapter includes three sections: Summary of Findings, Conclusions, and Recommendations for Future Research. In the Summary of Findings, an overview of the study methodology and results are provided. The Conclusions section includes a discussion of the findings for each of the four hypotheses as well as inferences drawn from the results. The Recommendations section provides areas for further research.

Summary of Findings

The purpose of the study was to investigate the application of cognitive load theory to the design of online instruction, specifically by redesigning aspects of three existing online courses to comply with the effects of split attention, redundancy, and modality. Students in three different courses (two class sections of each, treatment and control) were measured on both learning performance and perceptions of mental effort to see whether there were any statistically significant differences.

The method chosen for this study was survey research, with an online survey questionnaire used to elicit data regarding student characteristics, mastery of content, and mental effort. The study utilized a quasi-experimental design known as the posttest-only control group design. The target population for this study was undergraduate students enrolled in online courses offered by the Applied Technology, Training and Development program (ATTD) in the department of the Technology and Cognition at the University of North Texas, Denton. Subjects were selected from the defined population

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by using a cluster sampling method. Six groups were involved in the study, with a total sample size of 146 individuals.

Independent samples *t* tests with an alpha level of .05 were used, assuming a large effect size and a statistical power level of .80. These tests were used to compare the mean performance scores of the treatment groups (i.e., the sections using redesigned materials) versus the control groups for all three courses. Cohen's *d* was also used to measure effect size. Overall cognitive load scores were similarly compared for each comparison group, for a total of six data points in the study. SPSS 12.0 statistical analysis software was used for all analyses.

In comparisons made on the effects of split-attention and redundancy, no statistically significant difference was found between the test groups. Significance was found between the experimental and control group on the effect of modality. On the three measures of cognitive load, no statistically significant differences were found.

Conclusions

H_1: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the split-attention effect of cognitive load theory (CLT) and those in the control group.

Prior to the study, I believed that eliminating the students' need to search through several noncontiguous sources of information would improve outcomes. However, the study found no statistically significant difference ($p = .684$, $p > .05$) between the groups. It could be concluded from this section of the study that, in this case, redesigning online learning to reduce split attention held no relationship to performance on outcome measures and yielded little practical basis ($d = .114$) upon which to reduce or eliminate

the use of split information sources. This appears to contradict the findings of previously studies on split attention.

However, several inferences can be made to explain this outcome. While Mayer and Sims (1994) showed that split attention was affected by the concurrent presentation of separate materials, they did not account for materials that were spatially separated by layers of Web pages. A theory of Web organization, information foraging theory (Chi, Pirolli, Chen, & Pitkow, 2001), describes user behavior in terms of the trade-off of the cost of the activity versus the value of the information. It may well be that the control group using the original unmodified materials in this study considered the information worth searching for, so that learning was not obstructed. It should also be noted that in the sample demographics, a high percentage of students (68%) had taken 3 or more online classes, which may indicate a sample group that is accustomed to searching for online course information despite any barriers imposed by the course design.

It could also be concluded that other individual factors may have played a role in the lack of significance in this comparison. Chen, Czerwinski, and Macrredie (2000) found that individual cognitive style, visual ability, and associative memory affect information seeking on the Web, and it may be that these factors would lessen the effect of split attention in certain individuals.

H_2: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the redundancy effect of CLT and those in the control group.

On the question of redundancy, this section of the study found no significant difference (p = .670, p>,05) in the performance of the group using the modified, less

redundant materials compared to the group using the original lesson materials. Cohen's *d* was also low (.120), suggesting that there was little practical benefit in the instructional redesign carried out in the lesson. This finding appears to run counter to previous studies on the effect of redundancy on student learning.

There could be several reasons for the lack of significance in the redesign of these materials, especially since the treatment lesson involved replacing a commercially produced video with an audio-narrated diagram.

1. Seuffert and Brünken (2004) showed that some students need the reinforcement provided by an overlap in instructional content. Redundancy gives the user the ability to relate to a product on more than one level, enhancing or possibly enabling the experience. Comprehension can be affected by redundancy, since there is more chance of the information being understood. Since the mean performance of Group B declined slightly, removing redundancy in the modified materials may have been counterproductive for some students.

2. Shrank (1998) and Naijar (1998) also found that video as a mode of instruction adds interest and motivation and increases the amount of time students spend engaged with the materials. Since the mean performance of Group B declined slightly, it could be argued that students using the modified materials (narrated diagram) were not as engaged as those viewing the original video.

Although previous studies have compared aspects of audio and visual redundancy, no previous study focused on instances in which redundancy was reduced by replacing a video with a narrated diagram. It is possible that addressing the issue of redundancy in this way reveals that other factors such as repetition, interest, and

motivation, and dynamic versus static representations play a larger role in outcome

performance than a simple redesign of lesson materials.

H$_3$: There is no statistically significant difference in learning scores between students in the class using materials redesigned accorded to the modality effect of CLT and those in the control group.

I was surprised to find a statistically significant negative outcome between the

treatment and control groups on the question of modality (p < .001). The group using

the PowerPoint slides with audio narration (M=3.43) performed more poorly than the

group using the slides alone (M=5.67). Cohen's d was computed to be 1.746, which

indicates a very large effect size. This finding would seem to run counter to the well-

established concept of using more that one sensory path (visual and auditory) in the

presentation of instruction (Goolkasian; 2000; Mayer & Moreno; 1998; Mousavi et

al.,1995).

However, studies cited by Clark et al. (2005) may hold a clue to this outcome, as

they cite contradictory studies in which audio alone was contrasted with text plus audio

in presenting lesson materials to students. In the first study (Moreno & Meyer, 2002) the

version with text and audio resulted in greater learning. The second study (Kalyuga et

al., 2004) showed that audio alone yielded better outcomes. Clark et al. attributed this

difference to the segmentation of the audio track, stating that "a long audio segment is

difficult to hold and process in working memory, and even more difficult to coordinate

with visuals" (p. 133). It could be that, in the redesign of the instructional materials, I

unknowingly made the PowerPoint material more difficult to process (with the addition of

the lengthy narrative track) and thus negatively affected the comprehension and performance output of the treatment group.

H$_4$: There is no statistically significant difference in cognitive load scores, as measured by the Paas Mental Effort scale, between students in the classes using redesigned materials and those in the control group.

In the comparisons made on overall cognitive load, no statistically significant difference was found between the treatment and control groups. Cohen's *d* figures were also small for each group, indicating limited practical effect.

Although running counter to previous research outcomes, rationale for these findings may be related to the question of the importance of cognitive load in instruction for "soft skills" areas. Although Clark et al. (2005, p. 7) stated that "because cognitive load theory addresses how to use fundamental tools of training—text, visuals, and audio—it applies to everything from technical content to soft skills as well as to all delivery platforms from print to e-learning," it remains true that cognitive load theory has generally been applied to the instructional design of cognitively complex or technically challenging material (Morrison & Anglin, 2005). Is it possible that the cognitive loads for the lesson topics in this study were already so low that design modifications were not going to make a significant mental performance difference? Research indicates that effective instructional methods for practicing simple tasks differ from effective methods for complex tasks (van Merriënboer & Sweller, 2005), and it may be that the topics addressed in the modules did not merit the investment in redesign to reduce cognitive load. Tabbers et al. (2004) also found mixed significance on modality, which lends some credence to this idea.

Level of prior knowledge and expertise in the topics covered could also have made a difference in the perceived mental effort involved in interacting with the content used in this study. Kalyuga, Chandler & Sweller (2000) recognized that outcomes of mental effort depend not only on the structure and design of the information source, but also on the expertise of the learner. In general, it has been found that past experiences, perceptions of the task, and characteristics of the media may each contribute to the preconceptions that learners bring to an instructional setting and may in turn influence the reporting of invested mental effort.

Recommendations for Future Research

While much research has been done in the area of cognitive load theory, each of the investigations done for this study concludes with one common factor— instructional design theory can de difficult to apply in a real-world setting because so much depends upon the student. According to Lowman (1995), all motivated students perform best in any course and emerge as changed for the better. However, few individual student characteristics (such as level of motivation) were taken into consideration in this study.

Although this study has examined several aspects of applying cognitive load theory to the design of online learning, many more questions remain.

1. How do students of different backgrounds experience cognitive load? The present study was conducted using ATTD students only. For the results to have greater generalizability to the field of distance education, other studies should be conducted using samples from different subject areas.

2. It would be beneficial for future studies to use a larger sample from a wider population of distance learners, such as those who attend one or two face-to-face (hybrid) classes or those who are novice distance learners.

3. Improvements in the direct measurement of cognitive load should also be sought. While the Paas scale has an established reliability in the field, other researchers (Brünken, Steinbacher, Plass, & Leutner, 2002) have also used dual-task methods to assess cognitive load in multimedia settings. It would be interesting to see whether this assessment method would provide greater sensitivity to performance in soft skills areas.

4. An experimental study should be undertaken to determine what contributed to the significance found for modality. It is possible that the interactivity of factors found in learning styles research could add additional insight to this finding.

Summary

This study provides a foundation for future research related to applying cognitive load theory to online learning. The study found that, in the scenario to which it was applied, modifications of instructional materials made little positive difference in measures of performance or cognitive load. However, the sample size of this study prevents strong generalizations from being made. This study needs to be repeated several times involving many types of online education before the generalizability of the findings can be established.

I feel that the relevance of these findings to the field of distance education is solid, but should be used with caution because the field of online learning is still

relatively new. Especially in the area of applying cognitive load theory to soft skills instruction, more research is needed to determine whether this study was a good comparison between cognitively complex and relatively simple instruction or whether this is an area in which the theory does not apply.

This study has attempted to provide useful information for education and training professionals to better prepare them in applying research-based instructional design practices to the distance learning environment. As distance learning in all its forms becomes more ubiquitous, the concepts of effectiveness and efficiency will increasingly come to the fore. All programs can benefit from a cognitive model that emphasizes those factors contributing to a successful adult learning experience. And as instructional materials will be increasingly required to accomplish verifiable results -- results that maximize learning and minimize the amount of cognitive effort required -- the gap between research and practice will be diminished.

APPENDIX A

CONTENT KNOWLEDGE QUESTIONS

Content Knowledge Questions – ATTD 3010

1. Why is it wise to periodically evaluate your values?
   A. So your values always reflect those of your family.
   B. Values shouldn't change, even under evaluation.
   C. New perspectives may alter what you consider important.
   D. To remind yourself what you believe is important.

2. The primary purpose of time management is
   A. to make sure you have no down time that interferes with studying.
   B. to build and manage your schedule so you can accomplish your goals.
   C. to make you conscious of time and how you use it.
   D. to make your schedule rather than your goals your central focus.

3. Procrastination can be caused by all of the following reasons except
   A. facing an overwhelming task.
   B. fear of limitations.
   C. critical thinking.
   D. perfectionism.

4. How is academic integrity related to values?
   A. Academic integrity is useful when setting educational goals.
   B. Most campuses require "value statements" from all new students in conjunction with their academic integrity policy.
   C. Academic integrity instills a degree of perfectionism among college students.
   D. Academic integrity is a commitment to fundamental values such as honesty, fairness, respect, and responsibility.

5. How can your time management and goal-setting abilities affect your stress level?
   A. Using those skills correctly will prevent you from procrastinating, which is the main cause of stress.
   B. When you effectively use time management and goal setting skills, you can reduce the pressure that produces stress.
   C. Keeping your stress level low will ensure high performance in the classroom.
   D. All of the above.

6. Alicia prefers to work on her class assignments in the evening just before going to bed, but she often falls to sleep before she finishes. How could she solve this problem?
   A. She could rearrange her schedule so that her study time was earlier when she has more energy.
   B. She could boost her energy level by eating right and making sure she's getting plenty of rest.
   C. Both of the above.
   D. None of the above.

7. In what way can stress be helpful?
   A. Moderate stress can provide you with the readiness to perform well in certain situations.
   B. Low stress promotes relaxation, which is helpful in dealing with high stress in other situations.
   C. High stress motivates you to get the job done right.
   D. Moderate stresses can boost your immune system, keeping you healthier.

Content Knowledge Questions – ATTD 4070

1. One of the major demands that Situational Leadership II makes on a leader is:
    A. Willingness
    B. Ability
    C. Flexibility
    D. Appreciation of subordinates

2. If a leader properly diagnoses the situation and determines that the "best" style to use is S2 (Coaching), but the performance level of the follower begins to deteriorate, the best style to use under the new circumstances would be:
    A. S3, Supporting
    B. S1, Directing
    C. S4, Delegating
    D. No other style would be acceptable.

3. The "development level" aspect of Situational Leadership II
    A. is only a minor aspect
    B. will take care of itself
    C. cannot be overemphasized
    D. is not of concern

4. How should Situational Leadership II be used?
    A. As a developmental tool
    B. As a way to determine the one best way to treat each individual
    C. As a way to help individuals and groups increase their development level
    D. Both the first and the third answer are correct.

5. The leadership style which incorporates below average amounts of directive behavior and above average amounts of supportive behavior is:
    A. S1, Directing
    B. S2, Coaching
    C. S3, Supporting
    D. S4, Delegating

6. The emphasis in Situational Leadership II is on:
    A. the situational variables
    B. the behavior of the leader based on the development level of follower
    C. directive behavior
    D. supportive behavior

7. If a leader's style uses high amounts of directive behavior, what amount of supportive behavior will the leader use?
    A. Low
    B. High
    C. Most of the time high
    D. Impossible to tell; the two are independent of one another

Content Knowledge Questions – ATTD 4070

1. Goals tend to be more motivating when they are:
    A. General rather than specific
    B. Not accompanied by feedback
    C. Seemingly impossible to achieve
    D. Set by the learning and the facilitator (trainer)

2. _____ theory is based on the notion that learning can result from observing others' behavior and storing it for potential use.
    A. Reinforcement
    B. Social learning
    C. Goal setting
    D. Expectancy

3. Which of the following is not a characteristic of learning as defined in the text?
    A. Learning is produced by experience.
    B. Learning is a temporary change.
    C. Learning can be a change in knowledge
    D. Learning can be a change in a skill

4. _____ emphasizes that people are motivated to perform or avoid certain behaviors because of past outcomes that have resulted from those behaviors.
    A. Reinforcement theory
    B. Social learning theory
    C. Goal setting theory
    D. Expectancy theory

5. Relating work-related interests to training, providing realistic activities, and providing for immediate application of the content are all examples of strategies used in _____
    A. Expectancy theory
    B. Adult learning theory
    C. Goal setting theory
    D. Reinforcement theory

6. A training objective should have which three parts?
    A. A performance outcome, a level of quality, and a statement of conditions.
    B. A goal, an objective, and a summary.
    C. Expectations, conditions, and a reinforcement plan.
    D. Social learning, Expectancy, and Goal Setting.

7. According to Need theories, if the basic needs of trainees are not met,
    A. it is unlikely they will enroll in the training class.
    B. they will be poor communicators.
    C. they will not master the required tasks.
    D. they are unlikely to be motivated to learn.

APPENDIX B

COGNITIVE LOAD MENTAL EFFORT QUESTIONNAIRE

Cognitive Load Mental Effort Questionnaire

1. In solving or studying the preceding lesson I invested:								
1 Very very low mental effort	2	3	4	5 Neither low nor high mental effort	6	7	8	9 Very very high mental effort

2. I experienced the foregoing instruction as:								
1 Not difficult	2	3	4	5 Averagely difficult	6	7	8	9 Very difficult

3. How easy or difficult was this instruction to understand?								
1 Very easy				5 Neither easy nor difficult				9 Very difficult

Rating Scale based on Paas (1992)

APPENDIX C

LETTER OF PERMISSION

-------- Original Message --------
Subject: RE: Question about Cognitive Load survey
From: "Paas, Fred"
Date: Mon, February 27, 2006 6:21 am
To: Kate Burkes

Dear Kate,

In recent articles in Educational Psychologist (2003) and Instructional Science (2004) several variations of the mental effort scale are described. The original 9-point scale, which I developed, is really simple. However, several independent studies have proven its reliability and validity (see a recent example in Gimino).

Sure you can use the scale if you refer to my work.

Hope this is helpful to you and of course I am interested to see any results regarding cognitive load measurement.

Good luck with your dissertation and best wishes,

Fred

APPENDIX D

IRB APPROVAL

UNT
UNIVERSITY OF
NORTH·TEXAS

DISCOVER THE POWER OF IDEAS
June 22, 2006

Kate Burkes
Department of Technology and Cognition
University of North Texas

RE: Human Subjects Application No. 06-213

Dear Ms. Burkes:

Your proposal titled "The Application of Cognitive Load Theory to Online Learning" has been approved by the Institutional Review Board as permitted under federal law and regulations governing the use of human subjects in research projects 45 CFR 46.101. **Federal policy 45 CFR 46.109(e) stipulates that IRB approval is for one year only, June 22, 2006 through June 21, 2007.**

Enclosed is the consent document with stamped IRB approval. Please copy and **use this form only** for your study subjects.

It is your responsibility according to U.S. Department of Health and Human Services regulations to submit annual and terminal progress reports to the IRB for this project. Please mark your calendar accordingly. The IRB must also review this project prior to any modifications.

Please contact Shelia Bourns, Research Compliance Administrator, ext. 3940 or Boyd Herndon, Director of Research Compliance, ext. 3941, if you wish to make such changes or need additional information.

Sincerely,

Scott Simpkins, Ph.D.
Chair
Institutional Review Board

SS:sb

University of North Texas Institutional Review Board

Informed Consent Notice

Before agreeing to participate in this research study, it is important that you read and understand the following explanation of the purpose and benefits of the study and how it will be conducted.

Title of Study: The Application of Cognitive Load Theory to Online Learning.

Principal Investigator: Kate M. Burkes, a graduate student in the University of North Texas (UNT) Department of Applied Technology, Training & Development.

Purpose of the Study: We hope to learn more about how to design instructional materials for online learning.

Study Procedures: You will be asked to complete an online questionnaire that will take less than 10 minutes of your time.

Foreseeable Risks: No foreseeable risks are involved in this study.

Benefits to the Subjects or Others: We expect the project to benefit you and other students by helping improve the quality of online courses.

Procedures for Maintaining Confidentiality of Research Records: You will not be asked for any information that will make your survey answers personally identifiable. The data gathered will be coded and maintained in a confidential database. The confidentiality of all data sources will be maintained in any publications or presentations regarding this study.

Questions about the Study

If you have any questions about the study, you may contact Kate M. Burkes at ▉▉▉▉▉▉▉, or Dr. Jeff Allen, Applied Technology, Training & Development program, at 940-565-2093.

Review for the Protection of Participants:

This research study has been reviewed and approved by the UNT Institutional Review Board (IRB). The UNT IRB can be contacted at (940) 565-3940 with any questions regarding the rights of research subjects.

Research Participants' Rights:

- The study has been explained to you and all of your questions have been answered. You have been told the possible benefits and the potential risks and/or discomforts of the study.
- You understand that you do not have to take part in this study, and your refusal to participate or your decision to withdraw will involve no penalty or loss of rights or benefits. The study personnel may choose to stop your participation at any time.
- You understand why the study is being conducted and how it will be performed.
- You understand your rights as a research participant and you voluntarily consent to participate in this study.
- You may print a copy of this form for your records.

By clicking on BEGIN SURVEY you indicate that you are at least 18 years of age, and that you have read all of the above and agree to participate in this study.

CLICK HERE TO <u>BEGIN SURVEY</u>

APPROVED BY THE UNT IRB
FROM: 6/22/06 TO 6/21/07

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