

**THE COGNITIVE EFFECTS OF VERBAL REDUNDANCY  
AND ANIMATED CONCEPT MAPS ON LEARNING**

**By**

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## **Abstract**

This dissertation seeks to contribute to the literature on the selection and combination of media to facilitate learning. Principally, this research seeks to understand the effects of learning from four different media types concurrently presented with audio narration: (a) static text, (b) animated text, (c) static concept map, and (d) animated concept map. The inclusion of audio narration in multimedia materials introduces verbal redundancy, which is the concurrent presentation of verbatim spoken and printed words. Therefore, an additional goal of this work is to comprehensively review prior research on verbal redundancy.

A meta-analysis was conducted to review experimental studies that compared verbally redundant presentations with non-verbally redundant presentations. After an extensive search for studies meeting specified inclusion criteria, data was extracted from 48 independent verbal redundancy effect sizes obtained from 32 research reports with a total of 3,192 participants. Overall results indicated that students who learned from redundant multimedia presentations outperformed those who learned from non-redundant presentations but this effect was dependent on learners' prior knowledge, pacing of learning materials, and inclusion of animation or diagrams. Specifically, verbal redundancy benefited low prior knowledge learners exposed to system-paced learning materials provided there were no concurrently presented images. However, heterogeneity was found in most categories of analyses.

The effects on transfer, recall and comprehension of a learner-paced, concept map accompanied by redundant audio narration was investigated through a 2 X 2 factorial

experiment in which an animation factor (animation versus static) was crossed with a representation factor (concept map versus text). One hundred and forty participants were randomly assigned to study one of four learner-paced multimedia presentations (animated concept map, static concept map, animated text and static text). Both concept map groups outperformed both text groups on tests of free recall and transfer. The animated concept map group outperformed the static text group on a knowledge test ( $p < .05$ ). No statistically detectable differences were found with respect to subjective evaluation of the multimedia presentations. Further analyses with sequential regression showed that *time-on-task* positively predicted achievement on free recall, transfer and knowledge tests. Results are discussed in the context of various theoretical frameworks.

**Keywords:** Verbal Redundancy, Redundant Audio, Redundancy, Meta-Analysis, Animation, Concept Maps, Text, Multimedia, Cognitive Load.

## **Dedication**

I dedicate this thesis to:

God, Who endowed me with the knowledge, wisdom and understanding to successfully complete my doctorate degree,

My wife and children, who walked with me every step of the way; supported me with prayers and love and endured my times away from home while writing the dissertation,

To my parents, in-laws, brothers, sisters and all loved ones who prayed and desired to see me complete the program.

## Acknowledgements

I am happy to have come this far. Indeed, it has been a journey spanning four good years of being accompanied by brilliant people. Although I can now heave a sigh of relief and move on to another phase of my life, I would like to pause, reflect and thank all those without whose passion, vision, support, love, and prayers, I would not have made it this far.

I would like to extend my profound appreciation to my senior supervisor, Dr. John Nesbit, for his valuable support, guidance and exceptional scholarly ability to challenge the norms and think outside the box. I have benefited immensely from Dr. Nesbit's methodological acumen and for challenging me to attain high standards of academic excellence. The intellectual depth of the overall thesis was greatly enhanced by John's insistence on conceptual clarity with different constructs examined in this thesis. I also benefited from stimulating conversations we have had on contemporary issues and questions related to meta-analysis and multimedia learning. It's truly been a joy to work with you over the past couple of years. I will forever treasure our working relationships and use it as a model when I have an opportunity to mentor other students. Thank you!

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I wish to extend my thanks to my external examiner, Dr. Richard E. Mayer from the University of California, Santa Barbara. This dissertation would not have been possible without the empirical and theoretical background provided through the many studies authored by Dr. Mayer. I am thankful for the probing questions and insightful comments provided by Dr. Mayer and my internal/external examiner, Dr. Kevin O'Neill. Those comments have encouraged me to conceptualize this work beyond the limitations



of the dissertation. Thanks a lot. I would also like to thank Dr. Margaret MacDonald for chairing the defense and moderating the questions.

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To my dearest wife Tolu, and my children, Florence-Felicia and Josiah, I say a BIG thank you for praying for me, loving me, enduring my times away from home to complete this thesis, and always telling me ‘*yes you can*’. It would not have been possible without you standing with me during the rough patches on this journey. This is far from being a personal accomplishment – it is a collective one. Thank you my dear family.

To Mom and Dad, to my in-laws, and my brothers, sisters, and the entire family members, I say a BIG thank you for supporting me all the way. To my Pastor, his wife and all my Church family members, this is the product of your prayers and support over the years. It’s a pleasure to share this joy with you and thank God for answered prayers.

Most importantly, I would like to express my profound appreciation and thanks to God for providing me with all the resources needed to complete the program. I am grateful to God for the strength, help, the wisdom, knowledge and understanding He endowed me with – this work would never have been done without You, Lord.

I have found out in life that some people are great because they only do great things while others are greater because they not only do great things but love and support others to do great things. Unequivocally, all the people mentioned above and those not mentioned but have supported me down through the years belong to the later category. I have been moved and touched by your support throughout my program at SFU. You will always remain part of this success. Everyday I am thankful that my life has been enriched by getting to know you all. Thank you for being there for me and supporting my work.

Sir Winston Churchill once said: “Now this is not the end. It is not even the beginning of the end but it is, perhaps, the end of the beginning”. With this end of the beginning, I can look forward to brighter days ahead, knowing that God is “able to do exceeding abundantly above” all that I may ask or need in future.

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# Glossary

<b>Term</b>	<b>Meaning</b>
Animation	An appearance of motion that displays sequence of text or images one after the other.
Cognitive Load	An aggregate demand placed on working memory as a result of inherent task demand, poor instructional design or germane effortful processing.
Cognitive Theory of Multimedia Learning (CTML)	A cognitive theory resulting from the dual channel nature of working memory, the limited capacity of human's memory and active processing of learning materials.
Concept Maps	Concept maps are node-link diagrams that show concepts as nodes, and relationships among the concepts as labeled links. I use the term more broadly to refer to knowledge maps, topic maps, semantic networks and similar node-link diagrams.
Dual Coding Theory	A cognitive theory that posits two different memory representations for verbal and visual information and that connection between these representations afford easier retrieval of information and consequently enhances learning
Free Recall	A basic psychological paradigm that allows participants to recall the contents of a study session in any order.
Graphic Organizer	An advanced organizer used to spatially arrange words (or group of words) to represent the conceptual organization of text.
Learner-pacing (or self-pacing)	This refers to learning environments where learners exercise a degree of control over the pace of the presentation (e.g., pause, play, previous, next, etc).
Meta-Analysis	A research approach that applies statistical techniques to examine, standardize and combine the results of different empirical studies that investigate a set of related research hypotheses.
Multimedia	Presentations with words and pictures.

Redundancy	Concurrent (or sometimes non-concurrent) presentation of the same information in multiple modes and modalities.
Transfer	Another paradigm used to assess participants' ability to transfer learning in one context to another context.
Verbal Redundancy	The concurrent presentation of verbatim spoken and printed words. It is a subclass of redundancy.



# CHAPTER 1: OVERVIEW

The aims of this chapter are to (a) contextualize studies conducted for this dissertation within the extant literature on multimedia learning and verbal redundancy; (b) highlight the mixed results that have characterized studies of verbal redundancy and how the dissertation seeks to address the inconsistent results; (c) present the animated concept map as a knowledge representation medium, and (d) present a summary of findings.

## 1.1 Multimedia in education

Multimedia presentations display information in more than one medium. They may use text, static graphics, animations, interactive hypermedia, video, or audio in the form of sounds, music, and narration (Tannenbaum, 1998).

Extensive instructional research comparing the use of different media has been conducted over a period of about 50 years (Broadbent, 1956; Cuban, 1986; Kinchla, 1974; Lewandowski & Kobus, 1989; Martin, 1980; Mayer & Moreno, 2002; McLuhan, 1964; Miller, 1937; Moore, Burton, & Myers, 2004; Severin, 1967). The goal of comparative media research is to investigate if students learn more from one medium than another. Comparative analysis of instructional media resulted in a classic debate about whether media in and of itself influence learning (Clark, 1983, 1994, 2001; Kozma, 1991, 1994). More recent research on instructional media has principally explored the conditions under which various media may accentuate or attenuate learning, and

especially on the combined use of different media (Kalyuga, Chandler, & Sweller, 2004; Mayer, 2001, 2009; Mayer & Moreno, 2002b; Mayer, Hegarty, Mayer, & Campbell, 2005; Mayer & Johnson, 2008; Moreno & Mayer, 2002a).

This dissertation seeks to contribute to the literature on the selection and combination of media to facilitate learning. Principally, this research seeks to understand the effects of learning from four different media types concurrently presented with audio: (a) static text, (b) animated text, (c) static concept map, and (d) animated concept map. The inclusion of audio narration in multimedia materials introduces verbal redundancy, which is the concurrent presentation of verbatim spoken and printed words. Therefore, an additional goal of this work is to comprehensively review prior research on verbal redundancy. Thus, a meta-analysis was first conducted to investigate the cognitive effects of learning with verbally redundant multimedia materials under a variety of conditions.

## **1.2 Redundancy in Multimedia Presentations**

Advances in information technologies have resulted in considerable use of computer-based multimedia materials, ostensibly to improve teaching and learning (Mayer, 2001; Schnotz & Rasch, 2005; Zhu & Grabowski, 2006). Teachers and instructional designers can now use a number of multimedia tools to present instructional materials with a mixture of on-screen texts, narration, and animation. Increasingly, computer-based multimedia presentations include simultaneously presented spoken narration and written text (Kalyuga, Chandler, & Sweller, 2004).

The term *redundancy* has been frequently used by researchers to describe the simultaneous presentation of the same information in multiple modes and modalities

(Sweller, 2005a). Modes can be defined as the format in which learning materials are presented (e.g., words or pictures). On the other hand, modalities are often conceived of in terms of the information processing channel used to process the learning materials (e.g., visual or auditory). The use of multi-modal materials for learning is prevalent. Students listening to their instructors and simultaneously reading the instructors' slides, read-along books accompanied by audio tapes, and instructional television programs with closed captions are few examples of redundant presentations that deliver information concurrently using multiple modalities.

The general concept of redundancy has been explored in various disciplines, including communications, business, and education. Sweller (2005a) observed that the effects of redundancy have been “discovered, forgotten, and rediscovered many times over many decades” (p. 159). Examining past research on redundancy, Moreno and Mayer (2002a) concluded that “response times and memory are facilitated when redundant signal information is presented simultaneously in two sensory channels rather than in one” (p. 156). Earlier, Lewandowski and Kobus (1993) had found that, with two separate samples, participants who were presented with the same category words concurrently in auditory and visual modes recalled more words than participants who were presented with words in a single mode. Even much earlier, Miller's (1937) seminal work (as cited in Sweller, 2005a) had showed that presentation of redundant materials facilitated better reading and text comprehension than presentation of non-redundant materials.

Verbal redundancy is a subclass of redundant presentation in which verbatim spoken and printed words are presented concurrently (Koroghlanian & Klein, 2004;

Moreno & Mayer, 2002a). Although Moreno and Mayer observed that “bisensory redundant stimulus presentations are more efficiently processed by the human cognitive system” (2002a, p. 157), initial analyses of recall from verbally redundant texts have produced contradictory results. For example, Koroghlanian and Sullivan (2000) found that verbally redundant audio and text did not yield learning benefits when compared with text only presentation. Conversely, Kalyuga et al. (2004) found that, in two experiments, participants who were presented with non-concurrent text and audio recalled more information than those presented with concurrent text and audio. In a third experiment, they found that concurrent presentation of verbally redundant text and audio resulted in less recall than from audio alone. Researchers have acknowledged the opposing findings in the literature on verbal redundancy and the need for resolution (Moreno & Mayer, 2002a).

One of the goals of this work is to reconcile the contradictory outcomes in verbal redundancy research through a meta-analysis that addresses this broadly stated research question:

*What are the cognitive effects of learning with verbally redundant presentations under a wide variety of multimedia features, learning conditions, comparison treatments and outcome measures?*

### **1.3 Verbal Redundancy Meta-Analysis**

Meta-analysis is a research approach that applies statistical techniques to examine, standardize and combine the results of different empirical studies that investigate a set of related research hypotheses (Hedges & Olkin, 1985). Although research on verbal redundancy has been conducted for decades (Sweller, 2005a), there is no meta-analysis on the overall effect of verbal redundancy on learning as well as the effects of hypothesized moderating variables on learning from verbally redundant materials. Thus, researchers, teachers and instructional designers have limited understanding of the different conditions under which such materials enhance or inhibit learning, and thus have little empirical guidance toward a theory of how underlying processes are affected by verbal redundancy.

Researchers have hypothesized several factors that may account for inconsistencies in the research on verbal redundancy. These include: (a) the level of redundancy between the text and speech (Mayer & Johnson, 2008), individual differences of participants presented with verbally redundant materials (Atkinson et al., 2007), size of text segments that learners process continuously without a break and the required level of integration between the visual and verbal information (Kalyuga et al., 2004).

Synthesis of research on verbal redundancy may provide valuable information about the use of multimedia materials for learning, particularly about the conditions under which verbal redundancy may accentuate or attenuate learning. I conducted a meta-analysis to answer the research question on the effects of learning with verbally redundant presentations. The meta-analysis, reported in Chapter 3, reviewed experimental studies that compared verbally redundant presentations with non-verbally redundant

presentations. After an extensive search for studies meeting specified inclusion criteria, data was extracted from 48 independent verbal redundancy effect sizes obtained from 32 research reports with a total of 3,192 participants. Overall results indicated that students who learned from redundant multimedia presentations outperformed those who learned from non-redundant presentations but this effect was dependent on learners' prior knowledge, pacing of learning materials, and inclusion of animation or diagrams. Specifically, verbal redundancy benefited low prior knowledge learners exposed to system-paced learning materials provided there was no concurrently presented animation or images.

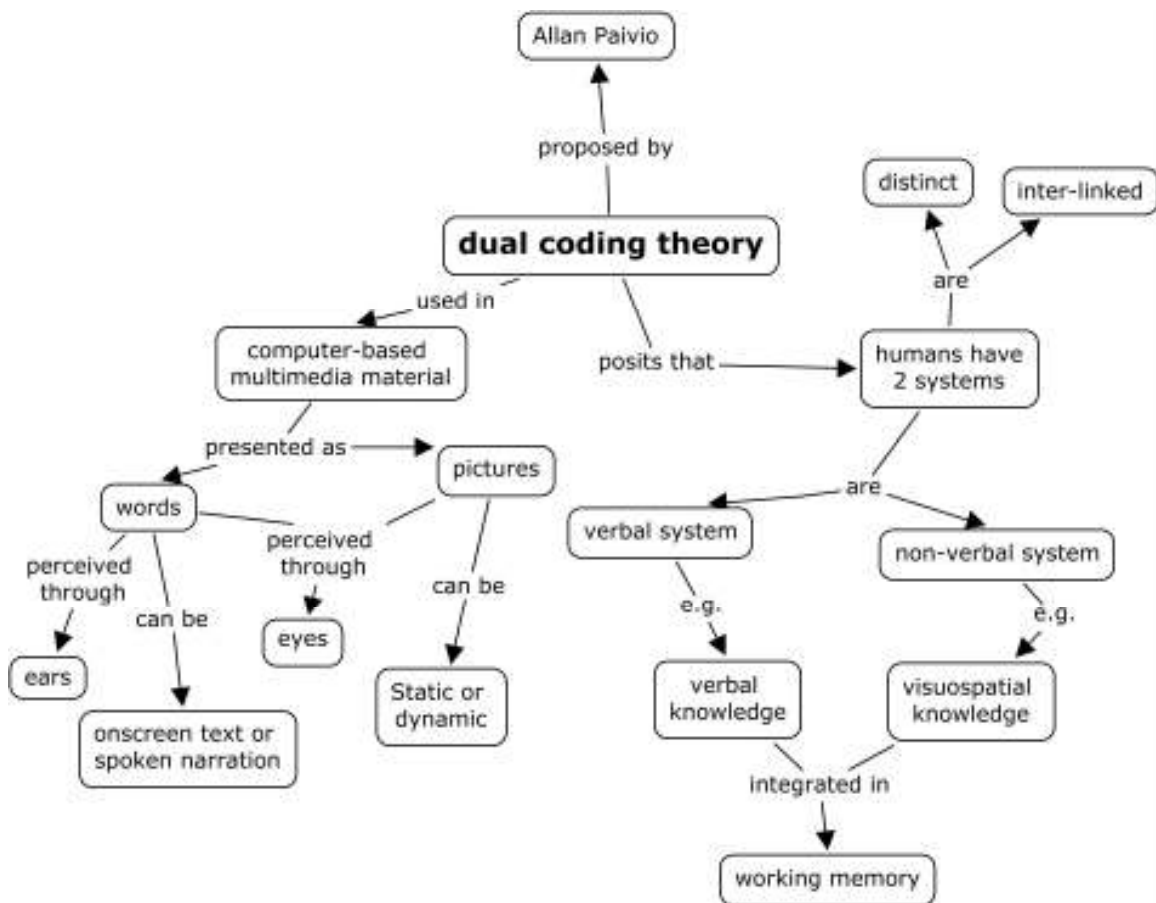
Instructional designers and educators may use these results to inform pedagogical practices in the delivery of multimedia learning materials. More importantly, results of this meta-analysis may help in interpreting an experiment on animated concept maps in which all visually presented information was accompanied by redundant audio narration.

## **1.4 Learning with Concept Maps**

Concept maps are node-link diagrams that show concepts as nodes, and relationships among the concepts as labeled links. Here I use the term concept maps to refer to knowledge maps, topic maps, semantic networks and similar node-link diagrams. Figure 1 shows an example of a concept map with directional and labeled links. Concept maps have been used for different activities including graphic organizers in lectures, as adjuncts to individual and group counseling, and as study materials in individual and collaborative learning (Cañas et al., 2003; Newbern, Dansereau, & Dees, 1997). More recently, researchers have investigated the use of computer-based concept maps for

learning (Cañas et al., 2003; Nesbit & Adesope, in press; Novak, 2002; Stull & Mayer, 2007). Research on the instructional use of concept maps has grown over the last three decades and has produced some consistent findings (Adesope & Nesbit, 2009; Holley & Dansereau, 1984; Nesbit & Adesope, 2006; O'Donnell, Dansereau & Hall, 2002). Generally, researchers have found that, under different instructional conditions, settings and experimental features, the use of concept maps produced increased retention and transfer of knowledge when compared with control conditions where students studied with text passages, outlines, lists or listened to lectures (Nesbit & Adesope, 2006).

**Figure 1** Example of a concept map showing information about dual coding theory



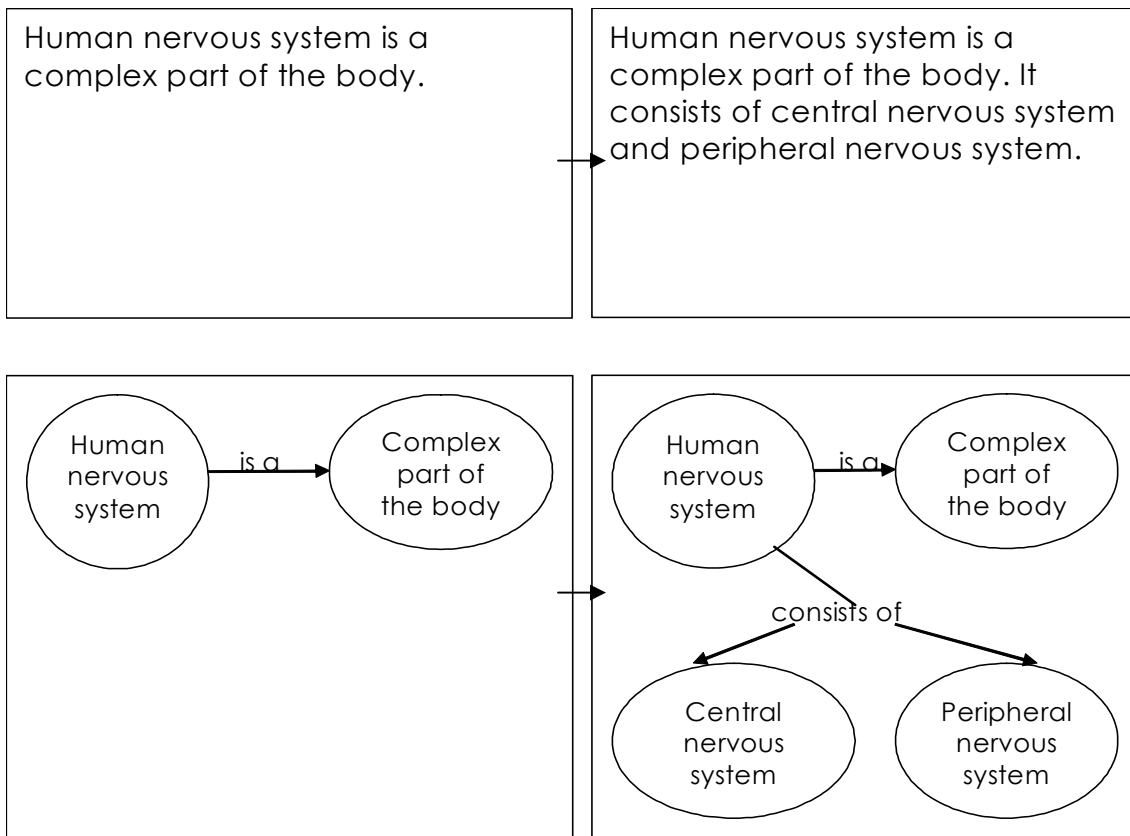
Unlike texts that have only one conventional processing order (left to right and top to bottom), static concept maps usually support many processing routes (Lambiotte et al., 1993). The indeterminacy of processing order in static concept maps has been recognized as a disadvantage. Blankenship and Dansereau (2000) coined the term map shock to describe the confusion learners experience when faced with the visual complexity of even moderately sized static concept maps. In a study that used eye tracking equipment to examine the order of initial processing of nodes in concept maps, Nesbit, Larios and Adesope (2007) observed varying patterns of map reading adopted by learners. When learners first approach a concept map of moderate complexity, they may find it difficult to process the entire map in a coherent order because maps are not linearly ordered like text. Learners may forget which nodes and links they previously visited, leading to incomplete or superfluous processing of the concept map. Researchers have hypothesized that map shock may produce a negative affective reaction that de-motivates engagement with the concept map consequently inhibiting learning (Dansereau, Dees, & Simpson, 1994). Animated concept maps have been proposed as viable alternatives to alleviating map shock and associated problems inherent in processing static concept maps (Blankenship & Dansereau, 2000; Nesbit & Adesope, in press).

An animated concept map is a knowledge representation medium that shows a node-link diagram changing over time. Animated concept maps may be implemented as a series of slides or frames ordered so that the first slide shows a blank map and the last slide shows a complete map. In animated concept maps, each slide presents all the nodes and links of the preceding slides and introduces a small number of new nodes and links.



Figure 2 shows an example of animated concept map and semantically equivalent animated text presentations. Such animated presentations may be used as a signaling technique showing learners what to attend to at any point in time during the presentation. This signaling technique reduces redundant and incomplete processing by guiding learners through the visual complexity of static concept maps.

**Figure 2** Example of an animated concept map and animated text presentations. The two upper slides show a transition in a text presentation while the two lower slides show a transition in a semantically equivalent animated concept map



Previous research by Blankenship and Dansereau (2000) investigated the effect of animated and static concept maps compared with animated and static texts on recall of ideas. In free recall of main ideas, they found a statistically detectable advantage for the

animated concept map group compared with the animated text ( $d = .71$ ) and the static map ( $d = .56$ ) groups. No differences were statistically detected in recall of detail ideas.

In Blankenship et al.'s study, multimedia presentations did not include audio narration and learners had no control over the pace of the animated presentations. A major goal of this dissertation is to examine the effect of learning from four different learner-paced media types concurrently presented with redundant audio. The experiment seeks to address this broadly stated research question:

*What are the cognitive effects of learning from redundant audio concurrently presented with learner-paced animated concept map, animated text, static concept map and static text?*

## **1.5 Experiment on an Animated Concept Map**

This dissertation extends previous research on concept maps by examining the effect of redundant audio on animated and static concept maps compared with animated and static text presentations. The effects on transfer, recall and comprehension of a learner-paced, concept map accompanied by audio narration was investigated through a 2 X 2 factorial experiment in which an animation factor (animation versus static) was crossed with a representation factor (concept map versus text).

One hundred and forty participants were randomly assigned to study one of four learner-paced multimedia presentations featuring semantically equivalent information about the organization and function of the human nervous system. The four presentations

were an animated concept map, a static concept map, an animated text, and a static text. To strengthen the equivalence of the information to which groups were exposed, all four presentations included an audio narration that replicated the content as the text and concept maps. The concept map groups outperformed the text groups on tests of free recall and transfer ( $p < .05$ ). In each of these tests, there was a statistically detectable main effect for representation. Neither the main effect for animation nor the representation X animation interaction was statistically detectable. The animated concept map group outperformed the static text group ( $p < .05$ ) on a knowledge test. No differences were statistically detected with respect to subjective evaluation of the multimedia presentations. Further analyses with sequential regression showed that *time-on-task* positively predicted achievement on free recall, transfer and knowledge tests.

The results suggest that in comparison with text, verbal information can be effectively communicated by concept maps accompanied by audio narrations. This study contributes further evidence supporting the learning effectiveness of concept maps.

## **1.6 Overview of the Chapters**

Chapter 2 is a review of the cognitive theories relevant to learning from multimedia redundancy, animation and concept maps. Relevant presentational features as well as individual difference measures that could potentially influence results of learning with verbally redundant materials are also presented.

Chapter 3 reports on a meta-analysis of verbal redundancy in multimedia learning environments. It presents the specific research questions addressed by the meta-analysis, and the method and results.

Chapter 4 reports on an experiment that compared the effects of animated and static concept maps and animated and static text, all presented with redundant audio narration. The chapter presents specific research questions addressed by the experiment, and the method and results. Chapter 5 presents a general discussion of the results of the two studies in the context of the theories presented in Chapter 2. The chapter concludes the dissertation with the theoretical and practical implications and limitations of the two studies investigated in this dissertation as well as how future research may address the limitations. In sum, my dissertation generates new knowledge about multimedia learning that has direct implications for the design of multimedia materials.

## **CHAPTER 2: THEORIES OF THE COGNITIVE EFFECTS OF MULTIMEDIA REDUNDANCY, ANIMATION AND CONCEPT MAPS**

The cognitive effects of the types of presentations investigated in this dissertation have been explained by theories of long-term memory, working memory, attention and the modal channels of which they are hypothetically comprised.

Fundamental theories, which describe human cognitive architecture, have been extended to form prescriptive theories that are intended to guide the design of instructional materials (Sweller, 2005b). Before synthesizing empirical studies on verbal redundancy and animated concept maps, I review existing literature guiding research on redundant multimedia presentations. Some of the theories make contradictory claims about the effects of learning with verbally redundant materials and animated concept maps concurrently presented with redundant audio.

### **2.1 Long-term Memory, Schema Acquisition, and Automation**

Long-term memory (LTM) is the repository for quasi-permanent knowledge, including information that is not currently being cognitively processed (Kirschner, 2002; Woolfolk, Winne, Perry, & Shapka, 2009). Many psychologists believe that humans are not conscious of the contents of long-term memory except when they are brought into and activated by working memory (Ericsson & Kintsch, 1995; Kirschner, 2002; Sweller, 2003). LTM houses aggregations of knowledge stored as schemas (Chi, Glaser, & Rees,

1982). Schemas are cognitive structures that classify information according to the manner in which such information will be used (Bobis, Sweller, & Cooper, 1993).

One powerful advantage of schemas is that they are capable of organizing large amounts of information and allow aggregated information to be retrieved for processing in working memory as a single unit. Researchers have claimed that human expertise depends on the organized knowledge that is stored in schemas, and less on the interaction of independent elements unconnected in LTM that is thought to characterize novice performance (van Merriënboer & Ayres, 2005). A repeated finding in the literature is that problem solving expertise in complex domains requires the acquisition and automation of several domain-specific schemas while solving problems. Schemas are capable of integrating information elements and are consequently automated after repeated practice and usage of the elements. In other words, after practicing repeatedly, specific categories of information may be processed with decreased conscious effort (Sweller, 2003). There is evidence that schema construction aids in the storage and organization of information elements in long-term memory so that elements stored as a single schema can be brought into the working memory, thus extending its capacity. Sweller and colleagues (Sweller, 2005b; van Merriënboer & Sweller, 2005) suggested that schema can perform a central executive function by coordinating information that needs to be processed in working memory. There is a vast body of literature suggesting that assigning a significant share of cognitive resources to activities that are not directly related to schema acquisition and automation may be deleterious to learning (Kalyuga, Chandler, & Sweller, 2004; Sweller, 2005a).

The theory of schema acquisition is relevant to research on instructional redundancy and animated concept map because presenting redundant information may either accentuate or attenuate learning depending on how such redundant materials are used for schema acquisition. It can be hypothesized that learning may be inhibited when learners are presented with verbatim spoken and written text, especially when such learners attempt to coordinate or link the two representations in working memory. This may require greater use of cognitive resources, thereby leaving fewer cognitive resources for processes that engender schema acquisition and automation. In other words, when redundant materials preclude schema automation, learning is inhibited. Conversely, one can hypothesize that learning may be facilitated if verbally redundant presentations are designed to promote schema acquisition and automation. For example, research has shown that presentations with sparsely redundant textual summaries (2-3 printed words per sentence) complementing audio narration increased retention of scientific materials because such sparsely redundant text “served to guide learner’s attention without priming extraneous processing” (Mayer & Johnson, 2008, p. 380).

Similarly, learning from concept maps may facilitate schema acquisition if they enhance verbal coding by co-locating concepts that have similar meanings and thereby signaling the macrostructure of information more effectively than prose. In concept maps, a concept is represented by a single node regardless of how many relationships it has with other concepts. In this way concept maps visually integrate propositions dealing with the same concept and allow related ideas to be assembled in the memory at a lower cognitive cost, a characteristic similar to how schemas arrange related structures in the memory.

Winn (1991) reviewed research suggesting diagrams that allow learners to visually chunk nearby objects lend efficiencies to semantic processing.

Generally, it appears that individual differences among learners, variations among multimedia materials, presentational features, and the nature of learner interaction with multimedia materials may all contribute to different patterns of schema acquisition and automation and consequent facilitation or inhibition of learning with verbally redundant materials.

## **2.2 Working Memory and Its Dual Processing System**

Working memory is the cognitive structure that is used to temporarily store and consciously process information (Sweller, van Merriënboer, & Pass, 1998). Two common attributes of working memory are its extremely limited capacity and duration when dealing with novel information (van Merriënboer & Sweller, 2005). While initially theorized as a unitary concept, current views postulate that working memory consists of dual channels or processors and is the hub of all conscious activities (Miyake & Shah, 1999; Sweller, van Merriënboer, & Pass, 1998).

Mayer's dual-processing model of multimedia learning has three fundamental assumptions: (a) working memory has separate systems for processing verbal and non-verbal information, both of which are partially independent. These are also called the auditory working memory and visual working memory respectively. This assumption is grounded on earlier work on dual coding theory (Paivio, 1986); (b) each of these two working memory systems is limited in its processing capacity (Chandler & Sweller, 1992; Mayer, 2001; Moreno & Mayer, 2002a; van Merriënboer & Sweller, 2005); and (c)



learning from both verbal and visual materials occurs when relevant information in each mode is selected, organized, and integrated across systems (Clark & Paivio, 1991; Paivio, 1986). Research on verbal redundancy has been explained using the dual processing model of working memory (Mayer, 2005a; Moreno & Mayer, 2002a).

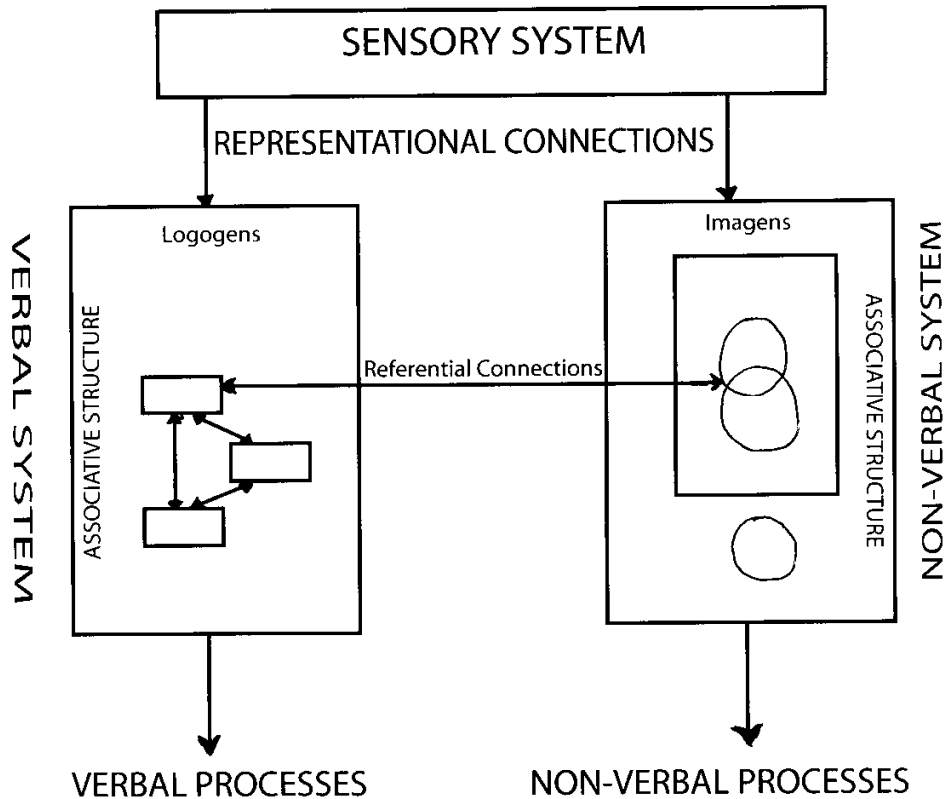
### **2.2.1 Dual Coding Theory**

Another important theory that can be used to offer explanation for the effect of learning with redundant multimedia materials is Paivio's dual coding theory (Paivio, 1986; 1991). As shown in Figure 3, Paivio's dual coding theory posits two different memory representations for verbal and visual information and that connection between these representations afford easier retrieval of information and consequently enhances learning.

Dual coding theory is relevant to research on concept maps because viewing or constructing concept maps, which consist of graphical and textual features, may support dual coding. If concept maps are partially processed by the visual channel of working memory, they may avoid overloading the verbal channel and consequently improve learning. In this case students who learn from concept maps may have an alternate retrieval path through the visual memory system that is not available to those who learn solely from text or speech. Dual coding theory has been used to explain enhanced knowledge retention and transfer results found in several multimedia and concept mapping studies (Mayer, 2001, 2005a; Moreno & Mayer, 1999b, 2002a; Nesbit & Adesope, in press). Empirical studies have shown that visual information helps to process and remember verbal information and vice versa (Mayer & Anderson, 1991).

Understanding concept maps may require translation between visual and verbal information and thus promote germane cognitive processing.

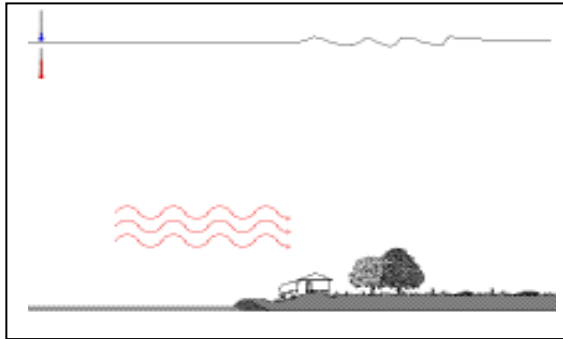
Figure 3 General model of dual coding theory



Although verbal redundancy may occur without any pictures included, some studies that investigated verbal redundancy in multimedia environments included presentation of pictures or animations with verbally redundant narration and printed text (Moreno & Mayer, 2002a). Figure 4 shows an example of such studies.

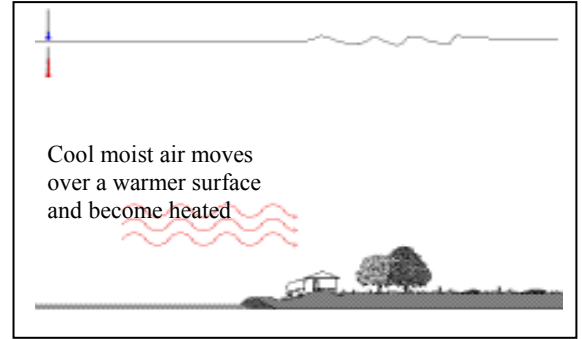
**Figure 4** Non-redundant (left panel) and redundant (right panel) examples of a slide on how lightning forms with narrated texts shown below the diagrams. Adapted with the kind permission of Mayer, R. E.

## Non-Redundant



Audio: “Cool moist air moves over a warmer surface and becomes heated.”

## Redundant



Audio: “Cool moist air moves over a warmer surface and becomes heated.”

With increasing use of pictures in addition to verbally redundant presentations, dual coding theory offers a theoretical understanding of how humans process multimedia (verbal and visual) information (Clark & Paivio, 1991; Paivio, 1986). Paivio theorized that a verbal memory system is used to store words and propositions presented verbally, including the verbal representations extracted from text. In contrast, a visual memory system is used to store visual information like pictures. Although these two systems are functionally and structurally independent, they interconnect and cooperate in the encoding and retrieval of information. The dual-processing theory of working memory posits that when learners cognitively process redundant presentations with animations or graphics, they represent the redundant text or audio in the verbal working memory and the corresponding animations or pictures in the visual working memory (Moreno & Mayer, 2002a). Since verbal and visual working memories are functionally distinct and

draw from different cognitive resources, concurrent verbal and visual processing can be efficiently performed such that learners can hold both representations in working memory concurrently and build referential connections between them (Baddeley, 1992; Clark & Paivio, 1991; Mayer & Moreno, 1998). Information that is misperceived in one modality is available through the other modality. Thus, the dual-processing model predicts greater learning, retention, and transfer from redundant information that uses both the verbal and visual channels than processing information from only the verbal or visual channel (Mayer, Heiser, & Lonn, 2001). On the other hand, when verbally redundant presentations including both text and audio narration are presented concurrently, they may overload the verbal channel, resulting in inhibited learning.

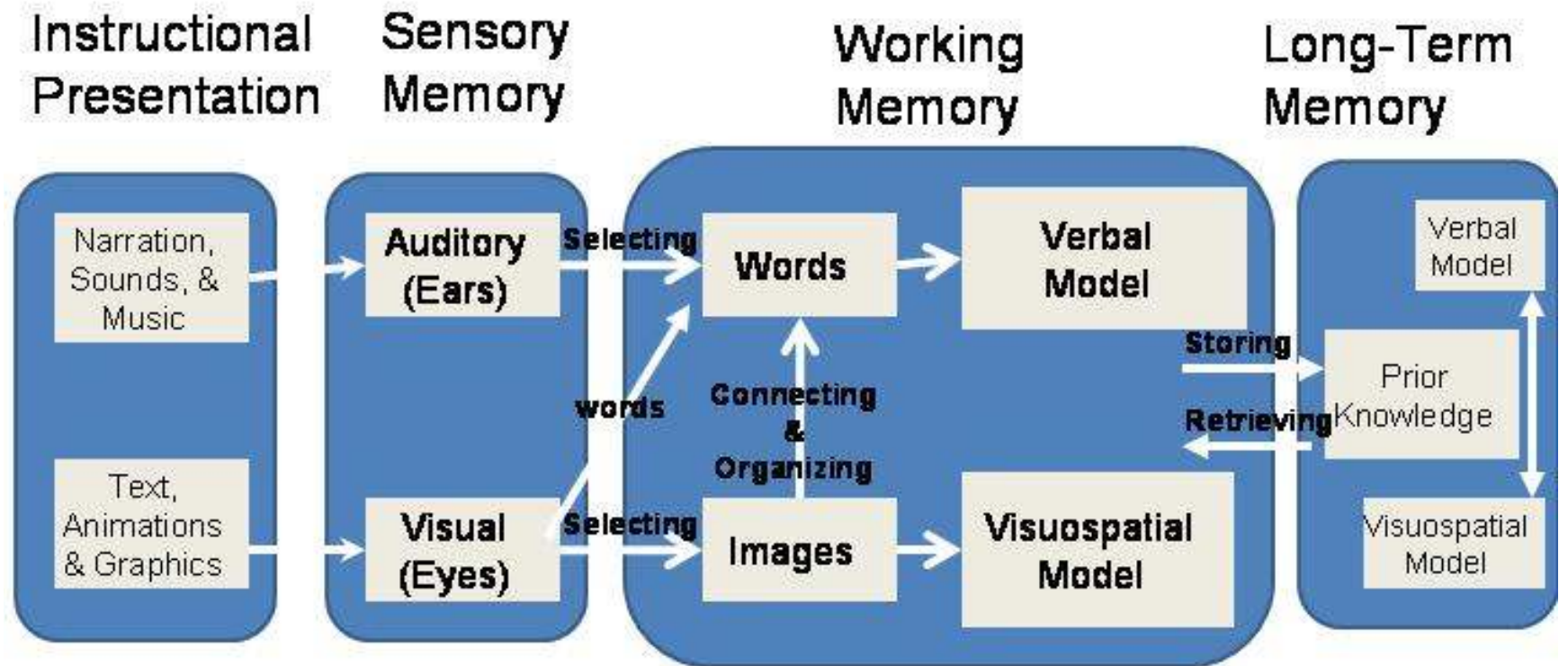
### **2.3 Cognitive Theory of Multimedia Learning**

Richard Mayer and his colleagues have presented a cognitive theory of multimedia learning (CTML) to guide the design of instructional multimedia materials (Mayer, 2001, 2005a; Mayer & Moreno, 2002, 2003). Schematically displayed in Figure 5, CTML is based on Paivio's (1986, 1991; Clark & Paivio, 1991; Sadowski & Paivio, 2001) dual-coding theory; Baddeley's (1986, 1992, 1998) model of working memory; Sweller's (Chandler & Sweller, 1991; Sweller, 1988, 1994; Sweller & Chandler, 1994) cognitive load theory; Mayer's active processing (Mayer, 2001; Wittrock, 1989) and the results of a series of empirical studies from an extensive multimedia research program at the University of California, Santa Barbara.

CTML is based on the following three fundamental assumptions:

1. Dual channels – that is the assumption that humans possess separate channels for processing visual pictorial information and auditory verbal information.
2. Limited capacity – that is the assumption that each channel is limited in the amount of novel information it can process actively at any given time.
3. Active processing – that is the assumption that for meaningful learning to occur, learners need to engage in effortful cognitive processes such as selecting relevant information, organizing the information, and integrating it with prior knowledge.

Figure 5 Schematic representation of Cognitive Theory of Multimedia Learning (CTML) adapted from Mayer (2009). Text initially perceived through the visual sensory memory but selected and processed through the verbal model of working memory



CTML posits that learners have a verbal information processing system and a visual information processing system and that these systems are potentially limited in the capacity of novel information they can process but active integration of information from both the verbal and visual systems can accentuate learning (Clark & Mayer, 2003; Mayer, 2001). Succinctly, Mayer (2005a) contends that in order to engender meaningful learning in a multimedia environment, learners need to use the two channels to engage in five cognitive processes: (1) select relevant words for further processing in verbal working memory; (2) select relevant graphics or animation to be processed in visual working memory; (3) organize the words selected into a verbal model; (4) organize the graphics selected into a pictorial or visuospatial model; and (5) integrate both the verbal and pictorial representations with each other as well as with prior knowledge for meaningful learning.

The empirical studies by Mayer used multimedia materials to present scientific cause-and-effect contents, such as how a bicycle pump works (Mayer & Anderson, 1991), how a braking system works (Mayer & Anderson, 1992), how lightning is formed (Mayer, Heiser & Lonn, 2001; Moreno & Mayer, 1999a, 2002a), and how the human respiratory system works (Mayer & Sims, 1994). More specifically, these empirical studies focus on the cognition underlying the presentation of animations, audio narration and on-screen text for scientific cause-and-effect purposes (Mayer et al., 2001; Mayer & Moreno, 2002). A cause-and-effect system is one in which a change in one part of the system causes a change in another part.

CTML is relevant to research on verbal redundancy. Indeed, CTML has been used to offer suggestions against adding on-screen text that may constitute redundant

information (Mayer, Heiser, & Lonn, 2001). First CTML predicts that learning will be inhibited when audio narration and on-screen text are presented concurrently because of the potential overload of the verbal working memory as both text and audio narration are processed through the verbal model of working memory. There is repeated evidence through CTML that when on-screen text and audio narration are presented concurrently, it may result in the verbal working memory being overloaded (Mayer, 2005b; Moreno, 2006). Conversely, CTML predicts enhanced learning with the addition of redundant on-screen text or audio narration to concurrently presented graphical or visuospatial information as learners can hold both pieces of information in working memory and build referential connections by representing the audio narration or text in the verbal working memory and the corresponding graphical information in the visual working memory.

Mayer's CTML is directly relevant to my research on animated concept maps because when learners study animated concept maps, they perceive the concept maps through the visual sensory memory and the audio narration through the auditory sensory memory. The limited capacity and duration of the working memory demands that learners select a few pieces of information from the sensory memory systems for further processing in the working memory. Whatever is selected from the narrated audio is then processed in the verbal model of the working memory and the concept map processed in the visuospatial model before the information is organized and integrated with learners' prior knowledge in the long-term memory. Thus the CTML predicts enhanced learning with animated or even static concept maps concurrently presented with audio narration.

Several instructional design principles, including the redundancy principle, have been derived from CTML (see Mayer, 2001 for a review). Although CTML has been



used as a theoretical basis to support these multimedia principles, I observe that most of the studies authored by Mayer and his associates reported (a) short presentation sessions as presentation time for many of the empirical studies earlier cited was less than 300 seconds; (b) multimedia presentations that were mostly system-paced, with learners not privileged to control the pace at which the materials were presented; (c) cause-and-effect materials on scientific systems were used and (d) process data were not collected during the presentation sessions to examine time-on-task and make reasonable inferences based on the degree of learners interaction with the multimedia presentations.

The concept map experiment conducted as part of this dissertation seeks to extend Mayer's studies on multimedia presentations. Specifically, I used learner-paced multimedia materials on human nervous system, consisting of animated and static concept maps compared with animated and static texts. The time spent by each participant interacting with the materials was also logged so as to investigate time-on-task and possible variance in times that participants from different experimental groups spent in studying the multimedia materials.

## **2.4 Cognitive Load Theory (CLT)**

Cognitive load is a multidimensional construct that refers to the amount of mental effort, usually associated with working memory, required to process a particular instructional element during learning (Ayres, 2006; Bobis, Sweller, & Cooper, 1993; Kirschner, 2005; Lee, Plass, & Homer, 2006; Paas, Renkl, & Sweller, 2003, 2004; Sweller, 1999; Sweller, van Merriënboer & Paas, 1998; van Merriënboer & Sweller, 2005). Cognitive load theory (CLT) assumes a working memory that is severely limited

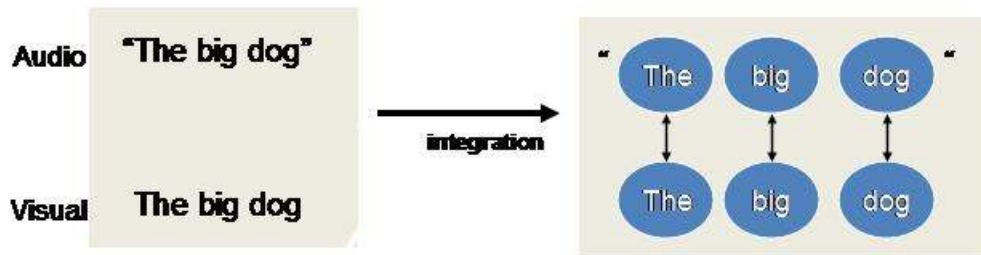
when dealing with novel information (Sweller, 2005b). Three independent sources of cognitive load have been identified in the literature. Cognitive load on working memory may be affected by the inherent nature of the learning task or materials for learning and the way the elements of the task interact (intrinsic cognitive load); the manner in which the learning materials are presented (extraneous cognitive load); and the amount of cognitive resources that learners devote to schema acquisition and automation (germane cognitive load). Researchers have claimed that cognitive load is additive in the sense that the total cognitive load is the addition of intrinsic, extraneous, and germane cognitive load (Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Since working memory capacity is limited, the overarching goal of instructional design is to reduce both the intrinsic and extraneous cognitive load while encouraging learners to devote mental resources to germane or effective processing of learning materials.

Sweller (2005a) noted that “redundant material interferes with rather than facilitates learning” (p. 159). Generally, cognitive load researchers have used the term *redundancy effect* to refer to situations where learning is hindered when redundant materials are included in presentations (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 1998; Sweller, 2005a). Although there are different instructional variations that may produce redundancy effect, many of them have been explained in terms of split-attention, a situation that arises when multimedia instructional materials require learners to split their attention among disparate sources of information and mentally integrate these multiple sources of information before meaningful learning can be attained. For example, learning is inhibited when an on-screen text is sequentially added to an already intelligible diagram because such texts redundantly describe with words what is already

represented with a diagram, requiring learners to integrate the sequential information (Chandler & Sweller, 1991; Moreno & Mayer, 2002a). Similarly, researchers have found that learning is inhibited when learners are presented with concurrent animation, narration, and on-screen text (Mayer et al., 1998; Moreno & Mayer, 1999a). Cognitive load theory suggests that, if the level of redundancy is high and semantic integration is required, concurrent presentation of spoken words and on-screen text may introduce extraneous cognitive load and result in reduced learning (Kalyuga et al., 2004; Nesbit & Adesope, in press).

Cognitive load theory predicts a deleterious effect of combining animated concept maps, speech and on-screen text. Because working memory is limited in its capacity, integrating across all these information sources may overwhelm the limited cognitive resources available for learning. Figure 6 shows an example of a redundant presentation where the words *'the big dog'* are presented both visually (as an on-screen text) and as audio narration. Learning is hindered when each of these words is integrated both visually and as audio narration. For example, when the audio narration of "*big*" is integrated with the word *big*, cognitive load researchers have claimed that such integration of information from two or more redundant sources needlessly "consumes cognitive resources that become unavailable for learners to process essential information" (Kalyuga et al., 2004, p. 568).

Figure 6 Presentation of redundant information



### 2.4.1 Modality Effect

A *modality effect* is the finding that learning is enhanced when verbal information accompanying an image is presented as audio rather than as on-screen text. (Sweller et al., 1998; Tindall-Ford et al., 1997). With the use of audio narration, a learner does not need to split visual attention between diagram and text. Earlier research has found that verbal and visuospatial information can be more efficiently integrated in working memory when the verbal information is presented as audio narration rather than text. Researchers have explained this with the superiority of dual mode processing over single mode processing (Baddeley, 1986; Hede, 1980; Mousavi, Low & Sweller, 1995; Paivio, 1991; Penney, 1989). More recently, researchers have also found that narration is superior than on-screen text if it is accompanied by other visuospatial information regardless of whether it is a diagram or animation (Gellevej et al., 2002; Ginns, 2005; Leahy et al., 2003; Sweller et al., 1998; Moreno & Mayer, 2002a). There is a separate literature on modality effect that has investigated the effects of bisensory stimulus presentations on short-term memory (Broadbent, 1956; Hede, 1980; Martin, 1980; Treisman & Davies, 1973). In a review, Penney's (1989) research on modality effects in

short-term memory found plentiful evidence of superior recall of items when words were presented in two modalities (visual and auditory), rather than in one modality. Succinctly, *modality effect* helps students learn more or learn with less effort because cognitive load is decreased as the processing of the multimedia presentation is spread over both the visual and auditory processing systems.

Although there is plentiful evidence in multimedia research showing the superiority of the modality effect, the result is limited to specific conditions. For example, researchers have found that learning performance with the modality effect may be negligible or possibly even reverse, when multimedia materials are segmented while being presented or when students view learner-paced presentations (Ginns, 2005; Mousavi et al. 2005; Mayer & Anderson, 1992; Tabbers, Martens, & Van Merriënboer, 2004).

Mousavi et al. (1995) investigated split-attention and modality effects by comparing three groups: simultaneous group use of diagram, printed text, and audio tape; visual visual group use of diagram and printed text; and visual-auditory group use of diagram and audio tape. The results demonstrated greater performance in mixed modality groups (simultaneous and visual-auditory) than the visual split-attention group (visual-visual), while no difference in performance was found between simultaneous and visual-auditory groups. In another experiment reported in their study, Mousavi et al. (1995) tested whether the advantage of modality effect exists if a diagram and an audio tape are presented sequentially. They paired visual-visual and visual-auditory information to compare the effects of simultaneous and sequential presentations. They found that sequential presentation of visual and auditory materials did not eliminate the benefit of

the modality effect. Mousavi et al. (1995) interpreted their results as ensuing from information segmentation because they used smaller information segments to explain geometry questions. They claimed that small information segments use fewer working memory resources for retaining information in sequential presentations; hence the modality effect in bimodal presentations is preserved.

These results were further substantiated in a recent meta-analysis of 43 independent studies on modality effect (Ginns, 2005). The meta-analysis found a strong modality effect under system-paced conditions. Specifically, when learners view system-paced slides, modality effect produced greater performance on transfer tests and lower perceived cognitive load. The meta-analysis did not detect any effect on measures of knowledge retention. Although the meta-analysis by Ginns (2005) did not examine possible moderating effects of using animated diagrams rather than static diagrams, there is evidence that strong modality effects are also obtained with animated materials (e.g., Mayer & Moreno, 1998; Moreno & Mayer, 1999a, 2002a)

In summary, it appears that the modality effect is greater when (a) multimedia materials are presented in small segments regardless of whether presentations were redundant or not (Mousavi et al., 1995); (b) system-paced multimedia materials are used rather than learner-paced materials (Tabbers et al., 2004).

In the experimental study on the effect of learning with concept maps presented in Chapter 4 of this dissertation, I used learner-paced animated and static concept maps with redundant audio narration. Although Ginns (2005) found that the modality effect may be negligible when students view learner-paced presentations (Ginns, 2005; Tabbers, Martens, & Van Merriënboer, 2004), I speculate that the modality effects found in most

system-paced studies could be attributed to the fact that some learners may not have had sufficient time to mentally integrate the two sources of information because participants in such studies had no control over the pace at which multimedia materials are presented. The modality and split-attention effects usually occur when multiple sources of information are unintelligible in isolation. An interesting perspective on modality effect is introduced with verbally redundant presentations. Since verbally redundant materials are intelligible in isolation, there is no firmly established empirical support on modality effect for presenting verbally redundant materials. Similarly, research on the modality effect does not provide empirical indications of the effect of presenting audio narration specifically with learner-paced, animated and static concept maps compared with animated and static text. My rationale for using redundant audio narration is that it may increase meaningful processing of map elements by guiding participants through the concept map with little or no extrinsic cognitive load incurred.

#### **2.4.2 Redundancy Effect in Cognitive Load Literature**

Cognitive load researchers have used the term '*redundancy effect*' to illustrate a decrease in learning produced by redundant materials (Kalyuga, Chandler & Sweller, 1998, 1999). Moreno and Mayer (2002a) observed two important empirical findings in studies that investigated redundancy effect. First, if textual information only repeats information in an intelligible diagram, such textual information is said to be redundant and hinders learning (Chandler & Sweller, 1991). In other words, if multiple sources of information that can be understood independently are presented concurrently in different

modes, extraneous cognitive load is invoked through such redundant presentation, consequently hindering learning (Sweller & Chandler, 1994).

Second, there is empirical evidence that instructional materials consisting of concurrent diagrams and auditory verbal information facilitate learning in comparison with those consisting of concurrent diagrams and on-screen text or concurrent diagrams and redundant auditory and visual information (Kalyuga et al., 1999; Moreno & Mayer, 2002a). This is a redundancy between visual and auditory verbal materials and has been explained in terms of split-attention resulting from addition of an unnecessary visual input to graphic materials that are already intelligible. According to Mayer (2009), “pictures and words compete for limited cognitive resources in the visual channel because both enter the learner’s information processing through the eyes” (p. 124). Thus, extraneous cognitive load is incurred as learners attempt to organize and integrate multimedia presentations including concurrently presented diagrams and texts. Such visually redundant presentations are deleterious to meaningful learning.

## **2.5 Individual Differences**

The effects of verbal redundancy may also depend on individual differences among the learners. Indeed, the individual differences principle of multimedia learning posits that low prior knowledge learners show stronger multimedia effects than high prior knowledge learners (Mayer & Gallini, 1990; Mayer, Steinhoff, Bower & Mars, 1995). For example, it is possible that a fluent reader who is familiar with the visual and auditory representations of the words in a passage may be able to integrate redundant text and speech more efficiently and thus experience less redundancy-generated cognitive



overload than poor readers. Conversely, where redundancy supports poor readers by helping them decode unfamiliar words, fluent readers may receive no benefit. By processing only the surface features of the stimuli when deeper cognitive integration is not activated, fluent readers may not benefit from learning with verbally redundant materials (Nesbit & Adesope, in press). Conversely, verbatim spoken and written words may benefit early readers since such readers may devote more cognitive resources to integrating visual and auditory representations in working memory.

There is also empirical evidence showing that low verbal ability students may derive learning benefits from verbally redundant presentations. For example, in a study of students of English as a Second Language (ESL) learning about the human circulatory system in a multimedia environment, Atkinson et al. (2007) found that verbally redundant on-screen text and audio narration improved ESL students' retention and conceptual understanding of the multimedia material compared to audio narration or on-screen text only. Atkinson et al.'s (2007) study further showed that students with low verbal ability benefited more from verbally redundant presentations. However, other research suggests that such findings may not apply to all ESL learners. For example, Diao and Sweller (2007) found that learning was hindered in older ESL students with many years of experience studying English language when the students were presented with concurrent written and spoken words. In other contexts, redundant materials may serve as additional options for those who are hard of hearing and for blind learners. Such materials have been endorsed as accessible for these types of learners as they significantly remove or minimize barriers to accessing information for learning (Adesope & Nesbit, 2005; Wald, 2008).

Research on the effect of learning with concept maps have also been explained in terms of individual differences among learners. Essentially, concept maps promote learning because they convey information using a simple and highly regular visual syntax built from shapes, lines, spaces, and minimal textual labels. Their minimal use of text and reduced syntactic complexity may make it easier for students, especially those with low verbal ability, to scan for, locate and process information (Plotnick, 1997). Indeed, there is plentiful evidence that concept maps communicate effectively because they are less wordy than typical instructional texts (Blankenship & Dansereau, 2000; O'Donnell, 1993; O'Donnell, Dansereau, & Hall, 2002). Compared with the typical language used in textbooks, the simpler node-link-node propositions used in concept maps impose lower extrinsic cognitive load on learners with lower reading ability or those studying in a second language.

Unlike texts that have only one conventional processing order (left to right and top to bottom), concept maps usually support many processing routes (Lambiotte et al., 1993). This flexibility may allow learners to choose a route that suits their prior knowledge, thus affording deeper cognitive processing and more meaningful learning. On the other hand, the indeterminacy of processing order in static concept maps may impose extraneous cognitive load thereby inhibiting learning.

## **2.6 Degree of Redundancy**

The degree of redundancy between the auditory and visual materials could determine the beneficial or inhibiting nature of learning with verbally redundant materials. There is some evidence that low-level redundancy between audio and textual

materials may guide essential processing and accentuate learning. For example, Mayer and Johnson (2008) found that, on a test of retention, students who were presented with low-level redundant materials with each slide consisting of two to three printed words that were identical to the words in the narration outperformed students presented with non-redundant materials.

Similarly, animated concept maps can be viewed as having low-level redundancy because of their minimal use of text and the capability to signal main ideas or concepts through animation. Thus, one can predict that animated concept maps may enhance learning because the low-level redundancy inherent in animated concept maps may improve signaling of important concepts thereby showing learners what to attend to at any point in time during the presentation. This signaling technique reduces redundant and incomplete processing by guiding learners through the visual complexity of static concept maps. In other multimedia studies, Mayer (2005) reported that the signaling technique yielded a median effect size of .60 across three studies (Harp & Mayer, 1998; Mautone & Mayer, 2001). Signaling technique may reduce extraneous cognitive load associated with processing static concept maps, and thereby free cognitive resources for operations that are germane to learning (Pollock, Chandler, & Sweller, 2002; Sweller, van Merriënboer, & Paas, 1998).

## **2.7 Applied Bimodal Stimulus Research with Redundant Signals Effect**

Historically, research on presentation of redundant bisensory stimulus has been explained using the redundant signals effect. Researchers have investigated the *redundant signals effect* to examine how people concurrently process sensory information through

multiple channels. Redundant signals effect is a phenomenon that predicts faster detection responses when the same signal is presented on two sensory channels simultaneously rather than when such signal is presented on either channel alone (Moreno & Mayer, 2002a).

Applied research aimed at finding ways to improve operational performance on bimodal tasks has been conducted with presentation of stimuli such as lights and tones, and sonar targets (Lewandowski & Kobus, 1989, 1993; Kinchla, 1974; Miller, 1982; Moreno & Mayer, 2002a). Generally, there is a great deal of evidence for the benefit of bimodal redundancy in job tasks or learning situations. For example, researchers have found improved detection and recognition of sonar signals in bimodal redundant condition (Lewandowski & Kobus, 1989; Kobus et al., 1986). Similarly, Halpern and Lantz (1974) demonstrated an improved rate of learning in bisensory redundant conditions with sea noise recordings.

There are at least two dominant models that researchers have proposed to explain the facilitation of reaction time in the redundant signals effect (Lewandowski & Kobus, 1993; Miller, 1982). The first model was based on the hypothesis that signals on different channels produce *separate activation*. This model was grounded on the “*race*” metaphor that Raab (1962) succinctly described as a race between the signals presented on two channels. Response to a redundant signal is produced by the winner of the race between two separate activation processes. Generally, responses to redundant bimodal targets are faster than responses to single unimodal targets.

Another dominant model provides an alternative explanation to the separate activation model. Miller (1982) proposed a *coactivation* model that independently allows

both components of a redundant signal to influence response time on a single trial. In the *coactivation* model, the redundant targets independently produce activations that are summed together before responses are made. In general, responses to redundant signals are faster in the *coactivation* model because two sources provide activation prior to making a decision and a response.

A very important conclusion in the theoretical, applied and memory literatures on the redundant signals effect is that response times and memory are enhanced in human performance when bimodal redundant stimuli are presented. Using this theoretical basis, it is hypothesized that bisensory redundant presentations and concept maps with audio narration will enhance learning than unisensory non-redundant presentations.

## **CHAPTER 3: VERBAL REDUNDANCY IN MULTIMEDIA LEARNING ENVIRONMENTS: A META-ANALYSIS**

This Chapter presents a meta-analysis of verbal redundancy in multimedia learning environments. It is comprised of three sections. First, the purpose and the research questions addressed by the meta-analysis are listed. Second, the methodological approaches of this meta-analysis, including criteria for the inclusion of research studies, are described. Finally, the results of the meta-analysis are presented and discussed relative to the theories presented in Chapter 2.

### **3.1 Purpose of the Meta-Analysis**

Verbally redundant presentations that allow learners to read words while hearing those words spoken by a recorded or synthesized voice have been used with learners of different verbal abilities. For example, early readers have been exposed to toys that help them read different words and passages while hearing those words and passages read to them by a recorded voice programmed into the toys. Many students with reading difficulties have also been introduced to read-along initiatives that are geared toward improving the reading skills of such learners as they read along while listening to audio recording of the materials being read. Furthermore, many attendees at conferences read presenters' slides while also hearing the presenters speak (Kalyuga, Chandler & Sweller, 2004). Presenting redundant information in both auditory and visual modalities is based on the assumption that concurrent presentation of narration and text with identical words

is beneficial for learning. However, research on verbal redundancy has produced mixed results.

Although some studies found positive effects of verbal redundancy (Atkinson et al., 2007; McNeill, 2004; Mousavi, Low & Sweller, 1995; Ritzhaupt, Gomes, & Barron, 2008), others have reported that learning with verbally redundant materials may attenuate performance on achievement-related tasks (Jamet & LeBohec, 2007; Kalyuga et al., 2004; Mayer et al., 2001). Mixed results have even been found within a few studies (Craig et al., 2002, 2004; Moreno & Mayer, 2002a) with positive effects occurring in some conditions and negative effects in others. These contradictory outcomes are not surprising considering that verbal redundancy research has been conducted with a wide variety of multimedia features, learning conditions, comparison treatments, and outcome measures. In the present study, a meta-analysis of verbal redundancy was conducted to reconcile these inconsistencies and estimate the specific effects of learning with verbally redundant multimedia materials under identified conditions.

## **3.2 Research Questions**

The meta-analysis addressed the following research questions.

1. What are the effects of learning with concurrent verbally redundant bisensory materials in comparison with unisensory and non-concurrent bisensory learning materials?
2. How do these effects vary when redundant materials are used for learning in different knowledge domains, settings, and educational levels?

3. How are the effects of learning with verbally redundant materials moderated by pacing, reading fluency, size of text segments, degree of redundancy between the audio and the text, and the presence or absence of images in the learning materials?
4. How do different levels of verbal ability and prior domain knowledge affect learning from verbally redundant presentations?
5. How are these effect sizes influenced by methodological features of the research?
6. What are the implications for practice and directions for future research in this area?

### **3.3 Method**

#### **3.3.1 Selection Criteria**

*A priori* description of eligibility criteria for inclusion and exclusion as well as a comprehensive search for studies are fundamental in high quality meta-analysis (Egger, Smith & Phillips, 1997). For this meta-analysis, a study was deemed eligible for inclusion if it:

- (a) investigated the effect of learning with verbally redundant materials within a multimedia environment comparing the effects of presenting non-redundant verbal information with redundant ones
- (b) reported measurable cognitive and motivational outcomes including recall, transfer, attitude and response times
- (c) reported sufficient data to allow for effect size calculations



- (e) randomly assigned participants to groups, or reported pretest or other prior data to control for preexisting differences between the groups
- (f) was publicly available either online or in library archives
- (g) was published or presented no later than December 2008.

When basic descriptive statistics were not included in a study, I used other statistics (e.g.,  $t$  and  $F$  statistics) but coded the reviewer's confidence in effect size calculation as medium. When descriptive statistics were provided, I used them to calculate the effect size and coded the confidence in effect size calculation as high. Studies with insufficient data for effect size calculations were excluded. For multiple reports of the same study (e.g. dissertation, conference proceedings and journal article), the version published as a journal article was coded but other versions were used to make the coding features more extensive and accurate.

### **3.3.2 Location and Selection of Studies**

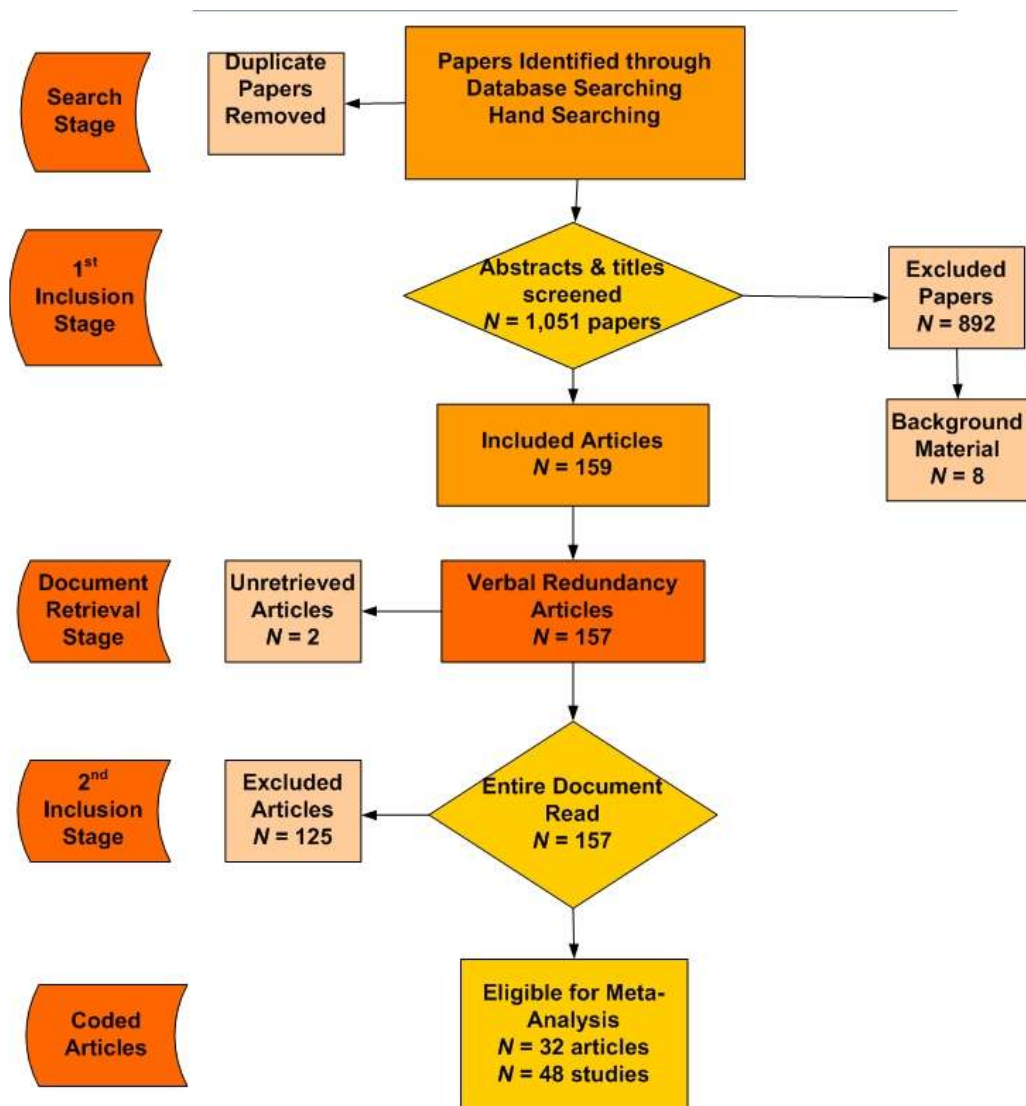
I used the query *redundan\** OR *bisensory stimul\** as keywords to conduct a comprehensive and systematic search on the following electronic databases: Digital Dissertations, ERIC, PsycARTICLES, PsycINFO, and Web of Science. I also searched the reference sections of a number of recent papers that investigated the effect of verbal redundancy on learning (e.g., Kalyuga, Chandler, & Sweller, 2004; Moreno & Mayer, 2002a; Mayer & Johnson, 2008). The search procedure returned a total of 1,051 articles.

There were two filtering phases to determine whether articles returned by the search should be included or excluded. In the first filtering phase, I read the abstract or online text of all articles found in the search to determine eligibility for further

examination. Full text copies were obtained for the 157 articles that passed the first filtering phase.

In the second filtering phase, I reviewed the 157 full-text copies by applying the selection criteria stated above. A total of 32 articles (with an overall sample size of 3,192 participants) met all inclusion criteria and were coded for meta-analysis. Figure 7 shows a detailed flowchart of procedures followed in the selection of studies.

**Figure 7** A flowchart showing how relevant studies were selected



Data from the 32 articles were extracted and entered into an extensive coding form. The coding variables were organized into 8 major categories: (a) study identification, (b) research questions, (c) sample information, (d) treatment and control conditions, (e) research design, (f) recruitment and consent, (g) dependent variables, and (j) results. In cases where a coded variable was not explicitly reported, I made reasonable inferences and noted that the coding was based on inference. Although this practice is somewhat subjective and less ideal than directly coding information reported in the articles, documentation of the inference provided a degree of control and allowed me to rate the methodological quality of the studies and evaluate the impact it had on the effect sizes. This practice has been recommended by researchers as one way of explaining the variability among studies included in a meta-analysis (Abrami & Bernard, 2009). Appendix A shows the coding book containing a description of all coding variables and categories.

The coding scheme allowed me to avoid inappropriately combining statistically dependent comparisons in calculating mean effect sizes. To generate a single distribution of statistically independent effect sizes, a mean effect size was obtained for each set of statistically dependent effect sizes by averaging over similar treatments, dependent measures and conditions. For example, Atkinson et al. (2007) compared an experimental group that studied using verbally redundant materials with two control groups that studied with either on-screen text or audio narration. A single independent effect size was obtained from this article by calculating a weighted average of the two different control groups.

### 3.3.3 Extraction of Effect Sizes

Effect size is a standardized metric obtained by finding the difference between the means of the experimental and comparison groups divided by the pooled standard deviation of the two groups. Cohen's  $d$ , a biased estimate of the standardized mean difference effect size was computed for each study using the formula:

$$d = \frac{\overline{X}_e - \overline{X}_c}{S_{Pooled}}, \quad (1)$$

where  $\overline{X}_e$  is the mean of the experimental group presented with verbally redundant materials,  $\overline{X}_c$  is the mean of the comparison group that learned with non-verbally redundant materials, and  $S_{Pooled}$  is the pooled standard deviation for both groups. In few cases where basic descriptive statistics were not provided (e.g., Mousavi, Low and Sweller, 1995), effect sizes were estimated from other statistics provided in the studies using conversion formulae (Glass, McGaw, & Smith, 1981).

Hedges (1981) observed that estimates of effect sizes may yield inflated effect sizes when samples are small. To correct for such bias in effect size estimation, especially with small sample sizes (Lipsey & Wilson, 2001), Cohen's  $d$  values were converted to Hedges'  $g$  unbiased estimate values (Hedges & Olkin, 1985) of the standardized mean difference effect size:

$$g = \left(1 - \frac{3}{4N - 9}\right)d, \quad (2)$$

where  $N$  is the sum of the number of participants in the experimental and control groups.

The inverse variance weight,  $w$ , was calculated for each effect size:

$$w = \frac{2n_e n_c (n_e + n_c)}{2(n_e + n_c)^2 + n_e n_c g^2}, \quad (3)$$

where  $n_e$  is the sample size of the experimental group and  $n_c$  is the sample size of the control group.

### 3.3.4 Data Analysis

In all analyses, guidelines and equations provided by Lipsey and Wilson (2001), Hedges and Olkin (1985), and Cooper and Hedges (1994) were followed. Data analyses were conducted using SPSS ver. 16 and Comprehensive Meta-Analysis™ 2.2.048 (Borenstein, Hedges, Higgins & Rothstein, 2008).

*Aggregating effect sizes.* Equation 4 was used to compute the weighted mean effect sizes so that the effect of a finding was proportionate with its sample size:

$$\overline{ES} = \frac{\sum (w_i ES_i)}{\sum w_i}, \quad (4)$$

where  $ES_i$  is Hedges' unbiased estimate ( $g$ ) of effect size  $i$  and  $w_i$  is the inverse variance weight coded for effect size  $ES_i$  (Lipsey & Wilson, 2001). The standard error of Hedges' unbiased estimate of the mean effect size, i.e. the square root of the sum of the inverse variance weights, was calculated using equation 5:

$$SE_{\overline{ES}} = \sqrt{\frac{1}{\sum w_i}}, \quad (5)$$

where  $SE_{\overline{ES}}$  is the standard error of Hedges' unbiased estimate of effect size mean, and

$w_i$  is the inverse variance weight coded for effect size  $i$  (Hedges & Olkin, 1985).

A 95% confidence interval was computed around each weighted mean effect size to determine statistical significance using equation 6 (Hedges & Olkin, 1985).

$$\begin{aligned}\overline{ES}_L &= \overline{ES} - 1.96(SE_{\overline{ES}}), \\ \overline{ES}_U &= \overline{ES} + 1.96(SE_{\overline{ES}}),\end{aligned}\tag{6}$$

where  $\overline{ES}_L$  and  $\overline{ES}_U$  are the lower and upper limits of the confidence intervals respectively,  $\overline{ES}$  is the mean effect size, 1.96 is the critical value for the  $z$ -distribution ( $\alpha = .05$ ), and  $SE_{\overline{ES}}$  is the standard error of the mean effect size. If the confidence interval did not include zero, the mean effect size was interpreted as indicating a statistically detectable result. The width of the confidence intervals also helped show the extent of variability among studies that were in the particular category under investigation. More specifically, the band around the weighted mean effect size for each category was much wider when there was a greater degree of variability in the results across the studies that made up a particular category being investigated.

A fundamental part of any meta-analysis is to determine if the various effect sizes that are averaged into a mean value all estimate the same population effect size. This assumption of homogeneity of variance was tested by the  $Q$  statistic:

$$Q = \sum w_i (ES_i - \overline{ES})^2.\tag{7}$$

When all findings share the same population value,  $Q$  has an approximate  $\chi^2$  distribution with  $k-1$  degrees of freedom, where  $k$  is the number of effect sizes or studies for a particular subset. When  $Q$  exceeded the critical value of the  $\chi^2$  distribution, (i.e.,  $p < .05$ ), the mean effect size was reported to be heterogeneous, meaning that there was more variability in the effect sizes than would be expected from sampling error, and thus

suggesting that each effect size obtained did not estimate a common population mean (Lipsey & Wilson, 2001). Succinctly, a statistically detectable  $Q$  test indicates heterogeneity among the studies that constitute the specific category under investigation.

Due to the extreme sensitivity of the  $Q$  statistic when used with large sample sizes, researchers have recommended that the  $I^2$  statistic be used to complement results of  $Q$  statistic to improve reporting standards and interpretation of homogeneity (Higgins & Thompson, 2002; Huedo-Medina, Sánchez-Meca, Marin-Martinez, & Botella, 2006).  $I^2$  represents the percentage of variability that results from heterogeneity rather than sampling error:

$$I^2 = \begin{cases} \frac{Q - (k - 1)}{Q} \times 100\% & \text{for } Q > (k - 1) \\ 0 & \text{for } Q \leq (k - 1) \end{cases}, \quad (8)$$

where  $Q$  is the heterogeneity statistic and  $k$  is the number of studies for the subset under consideration ( $df = k - 1$ ). Equation 8 shows that when the value of  $Q$  is less than or equal to the degrees of freedom associated with a subset,  $I^2$  is assigned a value of zero.

Similarly, negative values of  $I^2$  are assigned a value of zero such that  $I^2$  lies between 0% and 100%. A value of 0% indicates no observed heterogeneity, and larger values show increasing heterogeneity. Higgins and Thompson (2002, p. 1553) also recommended the following expressions of  $I^2$  to interpret its magnitude: percentages of around 25% ( $I^2 = 25$ ), 50% ( $I^2 = 50$ ), and 75% ( $I^2 = 75$ ) would mean low, medium, and high heterogeneity, respectively.

## **3.4 Results**

### **3.4.1 Attitudinal Outcomes and Cognitive Load Ratings**

Nine articles, listed in Table 1, investigated self-report of attitudinal outcomes and cognitive load ratings. In this table, the signs of effect sizes were reversed because low extrinsic or intrinsic cognitive load and low response times are usually associated with positive learning. Throughout this result section, positive effect sizes indicate an advantage for verbal redundancy while negative effect sizes indicate a disadvantage for verbally redundant learning materials. A decision was made not to obtain mean effect sizes for attitudinal and other self-reported outcomes because few studies that used such outcomes were identified. However, I observe that a majority of the studies produced negative effect sizes suggesting a deleterious effect or higher extrinsic cognitive load associated with verbally redundant presentations. On the other hand, few studies showed that presenting verbally redundant learning materials can potentially sustain learners' interest, motivation and consequently lead to more invested efforts. The remainder of the results section deals with studies reporting achievement-related outcomes.



**Table 1** Effect Sizes for Self-Reports of Attitudinal Outcomes and Cognitive Load Ratings

---

<b>Study, treatments, sample size and attitudinal outcome constructs</b>	<b><i>Effect size (g)</i></b>
<hr/>	
DeLeeuw and Mayer (2008), exp. 1, redundant speech and text versus speech, $N = 54$	
Effort rating (diagram included)	.345
Difficulty rating (diagram included)	.138
Response times as measure of learning	-.522
DeLeeuw and Mayer (2008), exp. 2, redundant speech and text versus speech, $N = 96$	
Effort rating (diagram included)	-.417
Difficulty rating (diagram included)	-.069
Response times as measure of learning	-.476
Diao and Sweller (2007), redundant speech and text versus text, $N = 57$	
Mental load (Sessions 1 and 2)	-.483
Diao, Chandler and Sweller (2007), redundant speech and text versus speech, $N = 159$	
Mental load	.249
Kalyuga, Chandler and Sweller (1999), redundant speech and text versus speech, $N = 35$	
Mental load (Experiment 1)	-.845

TABLE 1 (continued)

*Effect sizes for self-reports of attitudinal outcomes and cognitive load ratings*

---

<b>Study, treatments, sample size and attitudinal outcome constructs</b>	<b><i>Effect size (g)</i></b>
<hr/>	
Kalyuga, Chandler and Sweller (2000), redundant speech and text versus text, $N = 44$	
Mental load (Experiment 1)	.206
Kalyuga, Chandler and Sweller (2004), redundant speech and text versus speech, $N = 21$	
Mental load (Experiment 3)	-.422
Koroghlanian and Klein (2004), partial redundant speech and lean text vs. text, $N = 103$	
Interest, motivation, and amount of invested mental effort	.228
Moreno and Mayer (2002), redundant speech and text versus speech, $N = 42$	
Mental load	-.032
Rehaag and Szabo (1995), redundant speech and text versus text, $N = 82$	
Attitude towards learning Mathematics by computer	.069

---

### 3.4.2 Achievement-Related Outcomes

A total of 32 articles yielding 48 independent effect sizes involving 3,192 participants were analyzed on different study features and outcomes. Figure 8 shows the distribution of effect sizes. Note that the effect sizes are approximately normally distributed and the majority of effect sizes are clustered between -.50 and .75.

**Figure 8** Distribution of 48 independent effect sizes obtained from 32 articles (M = .160, SD = .638)

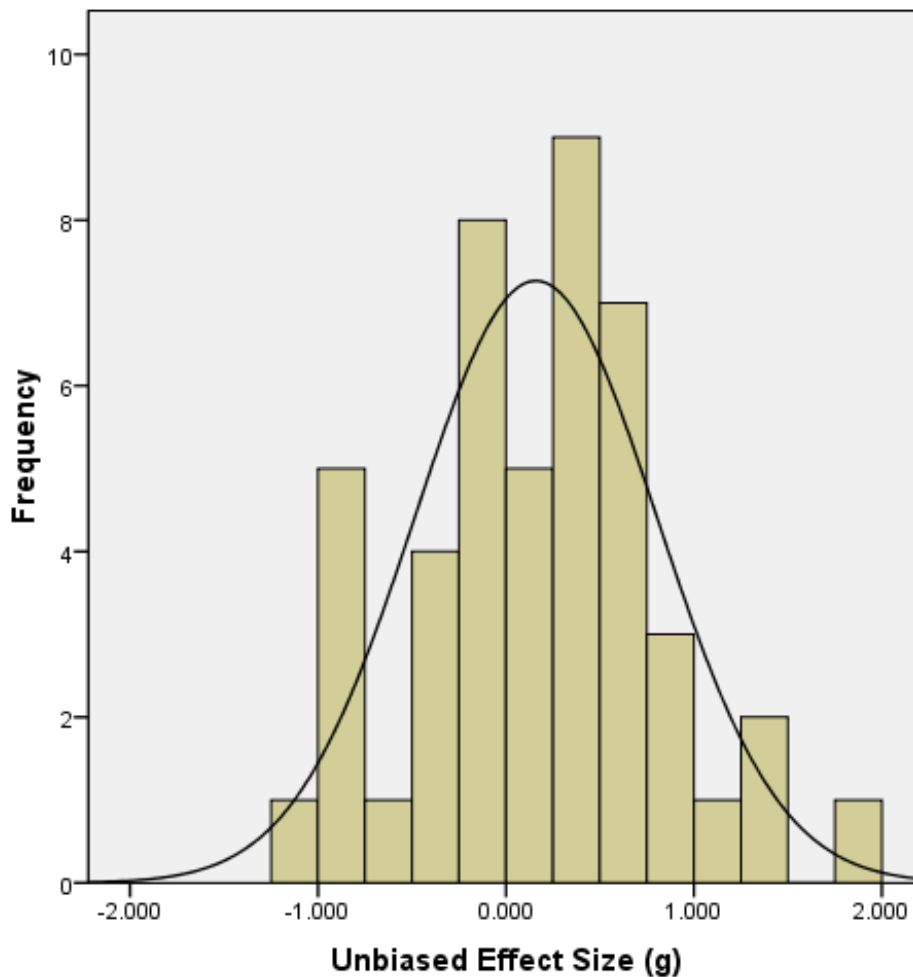


Table 2 shows a summary of the variables coded for each of the studies. This includes the study identification, domain of study, grade level of participants, total

number of participants involved in each study, comparison materials, pacing of materials, level of redundancy between the text and audio, whether images were included or not, and the associated unbiased effect size, Hedges'  $g$  of the outcome measures. In interpreting all effect sizes reported in this dissertation, I adopted Cohen's (1988) rule of thumb that an effect size  $d = 0.2$  could be regarded as "small", an effect size that is within the range  $.20 < d < .50$  could be regarded as "medium" or "moderate", and an effect size  $d = .8$  could be regarded as "large".

**Table 2 Characteristics of Studies Included in the Meta-Analysis and Associated Effect Sizes**

Study	Domain	Grade Range	<i>N</i>	Comparison material	Pacing of presentation	Level of redundancy	Images included?	Effect Size ( <i>g</i> )
Atkinson et al. (2007)	Biology	7	70	Audio+Text	Learner-paced	High	Yes	.475
Barron (1994)	Computer lit.	PS	101	Audio	Learner-paced	Mixed	Yes	-.119
Barron & Kysilka (1993)	Computer lit.	PS	60	Text	Learner-paced	Mixed	NR	.158
Chu (2006)	Computer lit.	PS	112	Audio	System-paced	High	Yes	-.149
Chu (2006)	Computer lit.	PS	112	Audio	System-paced	High	Yes	.248
Craig et al (2002), exp. 2	Meteorology	PS	71	Audio+Text	Learner-paced	High	Yes	-.227
Craig et al. (2004), exp.1	Computer lit.	PS	30	Audio	NR	High	Yes	.545
Craig et al. (2004), exp.1	Computer lit.	PS	30	Audio	NR	High	No	.292
Craig et al. (2004), exp.1	Computer lit.	PS	30	Audio	NR	High	Yes	-.292
Craig et al. (2004), exp.1	Computer lit.	PS	30	Audio	NR	High	No	.156
Diao et al. (2007)	Reading	PS	159	Audio	System-paced	High	No	.358
Diao & Sweller (2007)	Reading	PS	57	Text	System-paced	High	No	-.493
Jamet & LeBohec (2007)	Memory model	PS	90	Audio	System-paced	High	Yes	-.962
Kalyuga et al. (1999),exp. 1	Mechanical	PS	34	Audio+Text	Learner-paced	High	Yes	-.771

TABLE 2 (continued)

*Characteristics of studies included in the meta-analysis and associated effect sizes*

Study	Domain	Grade Range	<i>N</i>	Comparison material	Pacing of presentation	Level of redundancy	Images included?	Effect Size ( <i>g</i> )
Kalyuga et al. (2000), exp.1	Mechanical	PS	44	Text	Learner-paced	High	Yes	-.412
Kalyuga et al. (2004), exp.3	Mechanical	PS	21	Audio	System-paced	High	No	-1.094
Koroghlain et al. (2000)	Computer lit.	PS	134	Text	Learner-paced	High	Yes	-.099
Koroghlanian et al. (2004)	Biology	8-12	103	Text	Learner-paced	Low	Yes	-.149
Lai (2000)	Computer lit.	PS	126	Text	System-paced	High	Yes	-.050
Lai (2000)	Computer lit.	PS	127	Text	System-paced	High	Yes	.567
Leahy et al. (2003)	Meteorology	4-7	30	Text	System-paced	High	Yes	-.944
LeBohec & Jamet (2008)	Accounting	PS	123	Audio	System	Mixed	Yes	-.147
Linebarger (2001)	Reading lit.	K-3	76	Audio	System-paced	High	Yes	.317
Markham (1999)	Social Studies	PS	59	Audio	System-paced	High	Yes	.710
Markham (1999)	Biology	PS	59	Audio	System-paced	High	Yes	1.026
Mayer et al. (2001), exp. 1	Meteorology	PS	41	Text	System-paced	Low	Yes	-.696
Mayer et al. (2001), exp. 1	Meteorology	PS	37	Text	System-paced	Low	Yes	-.431

TABLE 2 (continued)

*Characteristics of studies included in the meta-analysis and associated effect sizes*

Study	Domain	Grade Range	N	Comparison material	Pacing of presentation	Level of redundancy	Images included?	Effect Size (g)
Mayer et al. (2001), exp. 2	Meteorology	PS	109	Text	System-paced	Mixed	Yes	-.884
Mayer et al. (2008), exp. 1	Meteorology	PS	90	Audio	System-paced	Low	Yes	.253
Mayer et al. (2008), exp. 2	Mechanical	PS	62	Audio	System-paced	Low	Yes	.300
McNeill (2004)	History	PS	56	Audio+Text	Learner-paced	High	No	.450
Montali et al. (1996)	Reading	8-9	18	Audio+Text	Learner-paced	High	No	.514
Montali et al. (1996)	Reading	8-9	18	Audio+Text	Learner-paced	High	No	.838
Moreno et al. (2002a),exp.1	Meteorology	PS	38	Audio	System-paced	High	No	.793
Moreno et al. (2002a),exp.1	Meteorology	PS	36	Audio	System-paced	High	Yes	.684
Moreno et al. (2002a),exp.2	Meteorology	PS	34	Audio	System-paced	High	Yes	-.849
Moreno et al. (2002a),exp.2	Meteorology	PS	35	Audio	System-paced	High	Yes	.352
Moreno et al. (2002a),exp.3	Meteorology	PS	35	Audio	System-paced	High	No	1.427
Moreno et al. (2002a),exp.3	Meteorology	PS	36	Audio	System-paced	High	No	1.271
Moreno et al. (2002b),exp.2	Botany	PS	42	Audio+Text	Learner-paced	High	Yes	.226

TABLE 2 (continued)

*Characteristics of studies included in the meta-analysis and associated effect sizes*

Study	Domain	Grade Range	<i>N</i>	Comparison material	Pacing of presentation	Level of redundancy	Images included?	Effect Size ( <i>g</i> )
Mousavi et al. (1995), exp.1	Geometry	8	30	Audio+Text	System-paced	High	Yes	.632
Mousavi et al. (1995), exp.2	Geometry	8	30	Audio+Text	System-paced	High	Yes	.545
Neuman et al. (1992)	Science	7-8	69	Captioned text	System-paced	High	No	.267
Olson & Wise (1992)	Reading lit.	2-6	90	Text	Learner-paced	Low	No	.754
Rehaag & Szabo (1995)	Mathematics	10	82	Text	Learner-paced	High	NR	-.010
Reitsma (1988)	Reading	1-2	37	Guided reading	System-paced	High	No	.245
Ritzhaupt et al. (2008)	Computer lit.	PS	183	Audio	System-paced	Low	NR	1.852
Severin (1967)	Nature	7	96	Text	System-paced	High	No	.224

*Note.* PS = postsecondary, *N* = number of subjects, NR = not reported, computer lit. = computer literacy, reading lit = reading literacy



To determine under what conditions verbal redundancy may enhance or inhibit learning, discussion of these results is organized thus: comparison treatments, presentation features, level of redundancy, segmentation, images and animation, media, participant characteristics, outcome constructs/test formats, methodological research features, publication bias, setting, domain and duration.

#### **3.4.2.1 Effects of Learning with Verbally Redundant Materials in Comparison with Non-Redundant Text or Speech (Audio)**

Tables of results presented henceforth include the number of participants ( $N$ ) in each category, the number of findings ( $k$ ), the weighted mean effect size ( $M$ ) and its standard error ( $SE$ ), the 95% confidence interval around the mean, the results of a test of homogeneity ( $Q$ ) with its associated degrees of freedom ( $df$ ) and the magnitude of heterogeneity ( $I^2$ ). Table 3 shows an overall analysis of the weighted means of all statistically independent effect sizes as well as the results of learning with verbally redundant speech and text compared with non-redundant materials, either presented as text or speech. Subsequent tables then show a more detailed description of study features or moderators that accounted for the variability in the overall findings. In all reported analyses, a positive weighted mean effect size ( $M$ ) means that students benefited more from redundant text and speech. Conversely, a negative effect size means that students benefited more from non-redundant text or speech.

Overall, Table 3 shows a small but statistically detectable effect of learning with verbally redundant speech and text. However, homogeneity was rejected for this overall effect, meaning that there is wide variability represented in the individual effect sizes that

constitute the overall result. Therefore, moderator analyses for study features and other moderators earlier described in the paper were investigated.

The effect of learning with verbally redundant speech and text in comparison with text only or speech only was analyzed. As reported in Table 3, there was variability in the magnitude of effect sizes across comparison treatments, ranging  $-.130$  to  $.335$ . The variability both within and between each of the subgroups is heterogeneous. However, significant heterogeneity allows further examination of study features that may be responsible for the variability in effect sizes.

Table 3 also shows that students did not benefit from learning with concurrent redundant text and speech when compared with text only presentations. Conversely, redundant speech and text accentuated student learning with statistically detectable benefits when compared with speech-only presentations. One-third of the studies meta-analyzed investigated learning with redundant materials in comparison with both text and speech. These were studies that typically had one experimental group studying with redundant speech and text compared with two control groups, one that studied with only text and the other group that studied with only audio narration. To maintain statistical independence, I combined the results of the two control groups and compared that with the result of the redundant experimental group, yielding a single effect size. I found a statistically detectable benefit for learning with redundant materials compared with learning from only text or speech. Although weighted mean effect sizes in most categories in Table 3 were statistically detectable, they were all heterogeneous indicating wide variability between studies that is greater than that expected from sampling error.

**Table 3** Weighted Mean Effect Sizes for Comparison Treatments

			Effect size ( <i>g</i> )		95% confidence interval		Homogeneity of effect size		
	<i>N</i>	<i>k</i>	<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
All	3,192	48	.174*	.037	.101	.247	273.865*	47	82.838
<u>Comparison Treatments</u>									
Text (on-screen) Only	1,003	16	-.130	.066	-.259	-.001	50.596*	15	69.206
Speech (audio) Only	1,380	16	.335*	.056	.226	.445	106.564*	15	85.869
Text or Audio	809	16	.280*	.075	.133	.428	84.707*	15	81.715
TOTAL WITHIN ( <i>Q<sub>w</sub></i> )							241.868*	45	81.395
TOTAL BETWEEN ( <i>Q<sub>B</sub></i> )							31.997*	2	93.749
TOTAL ( <i>Q<sub>T</sub></i> ) = <i>Q<sub>w</sub></i> + <i>Q<sub>B</sub></i>							273.865*	47	82.838

\*  $p < .05$

### 3.4.2.2 Presentation Features

Table 4 shows the weighted mean effect sizes for different features incorporated in the presentation of redundant materials for learning. First, I investigated the moderating effect of pacing of learning materials on the overall study on verbal redundancy. There is some evidence that pacing of multimedia materials may affect the way learners comprehend them (Kalyuga et al., 2004; Nesbit & Adesope, in press; Tversky, Morrison, & Bentrancourt, 2002). Studies were coded as system-paced if participants had no control over the pacing of the multimedia material. However, if participants were able to exercise a degree of control over the materials (e.g., pause, play, previous, next, etc.), then such studies were coded as learner-paced. Most of the studies were system-paced or delivered contents in such a way that participants did not have control over the pace at which the materials were presented. These system-paced studies yielded a statistically detectable effect in favor of verbally redundant speech and text presentation. Conversely, verbally-redundant learner-paced studies did not produce any statistically detectable benefits over non-redundant learner-paced studies. There seems to be a greater benefit in presenting verbally redundant speech and text when learners do not have control over the pacing of the materials. This could be because learners in system-paced conditions who misperceive information from one source may not have time to re-read or re-listen to the missed information. If the system-paced presentation uses both modalities then information in one modality can be recovered from the other modality. On the other hand, when learners have full control over the pace of the materials, they may not benefit from redundant presentations because they are able to navigate, pause,

rewind, or slow down the pace of the textual or narrated material for effective apprehension.

#### **3.4.2.3 Level of Redundancy**

In Table 4, level of redundancy was coded high when there was complete isomorphism or total correspondence between the narration and on-screen text; that is, when the on-screen text reproduced the entire narration word-for-word. Conversely, level of redundancy was coded low when summaries of narrated segments were used as on-screen text instead of complete isomorphism between the narrated and on-screen text.

Most of the studies were high in level of redundancy. In studies with high-level redundancy between text and speech, a small but statistically detectable benefit was detected in support of redundant presentation. Studies that exhibited a low-level redundancy produced a statistically detectable moderate effect, suggesting an advantage of presenting redundant materials over non-redundant ones. However, this effect was highly heterogeneous, therefore depicting wide variations between studies with low-level redundancy. A critical review showed mixed results within this category of low redundant studies. For example, in Mayer, Heiser, and Lonn (2001), non-redundant presentations benefited learners more than redundant ones. Conversely, Mayer and Johnson's (2008) studies produced medium to large effects in support of verbally redundant presentation. I observed that, apart from a passing statement that "on-screen text summaries" (Mayer et al., 2001, p. 191) were presented in the redundant information, there is no further information about the nature of these on-screen text summaries. On the other hand, Mayer and Johnson (2008) clearly reported that two-to-three word summaries were provided as on-screen text however long the narration may be. It appears that Mayer

et al.'s (2001) study used long summaries as on-screen texts. If so, this implies that the levels of speech-text redundancy within these two studies seem to be the reason for the contradictory results.

These results suggest that students learn better when summaries of on-screen texts are used with narrated materials (low-level redundancy) than when the on-screen text reproduces the entire information in the narrated material (high-level redundancy). In other words, if the level of verbal redundancy is high, concurrent speech and text may impose high extrinsic cognitive load thereby inhibiting learning.

#### **3.4.2.4 Segmentation of Learning Materials / Size of Text Segments**

Table 4 also shows the result of presenting segmented learning materials. Kalyuga et al. (2004) define segmentation as “the size of textual segment that learners process continuously without a break” (p. 579). I found a statistically detectable mean effect size favoring redundant presentation of non-segmented learning materials. There was no statistically detectable benefit of verbal redundancy with segmented materials. This result contradicts the perspective that learners are able to more easily integrate pieces of information together when the information is segmented, that is, segmentation seems to be a viable approach to reducing intrinsic cognitive load thereby accentuating learning. In order to resolve this contradiction, I reviewed studies that investigated redundancy with split attention engendered by inclusion of visual displays. Using cognitive load theory as its basis, researchers have found that learning is hindered when learners are required to split their attention between simultaneously presented text and already intelligible diagram, (Chandler & Sweller, 1991; Kalyuga, Chandler, & Sweller, 1999). More

recently, Moreno and Mayer (2002a) found that learners benefited from redundant presentations more than non-redundant ones when there was no competing presentation of concurrent visual diagrams. Kalyuga et al. (2004) observed that the size of textual segments that learners process without a break could explain the mixed findings in the literature with respect to segmentation and inclusion of diagrams. Thus, in this meta-analysis, studies that presented segmented materials with or without diagrams were reviewed to further investigate any design features that contributed to this contradiction. I found that when learning materials were segmented and did not include diagrams, a statistically detectable mean effect size favoring redundant speech and text was obtained. Conversely, segmented materials that included diagrams produced a negative effect of verbal redundancy. These further analyses showed strong support for the deleterious effect of split attention in multimedia learning environments.

#### **3.4.2.5 Images and Animation**

I analyzed the effect of verbal redundancy moderated by inclusion or exclusion of images and animation in the learning materials. Table 4 shows statistically detectable benefits of redundant learning materials with no images or animations. In contrast, when images or animations were included in the presentations, verbal redundancy did not accentuate learning. I also observed large statistically detectable mean effect sizes for studies that did not report whether images or animations were included in the presentation. The large effect size found with few studies that did not report whether animations or images were included in the verbally redundant presentations somewhat undermines the certainty of this result..

**Table 4 Weighted Mean Effect Sizes for Presentational Features**

	<i>N</i>	<i>k</i>	Effect size ( <i>g</i> )		95% confidence interval		Homogeneity of effect size		
			<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Pacing of Presentation</u>									
Learner-paced	923	14	.068	.069	-.067	.203	29.040*	13	55.235
System-paced	2,149	30	.220*	.045	.131	.309	233.427*	29	87.576
Not Reported	120	4	.173	.184	-.188	.533	2.711	3	.000
<u>Level of Redundancy</u>									
Low	606	7	.526*	.086	.357	.695	94.020*	6	93.618
High	2,193	37	.158*	.044	.071	.245	128.061*	36	71.888
Mixed low and high	393	4	-.281	.107	-.492	-.071	11.741*	3	74.448
<u>Materials Segmented while being Presented?</u>									
No	842	9	.411*	.073	.268	.554	95.885*	8	91.657
Yes	1,902	32	.084	.048	-.010	.178	126.980*	31	75.587
Not Reported	448	7	.127	.098	-.066	.319	31.448*	6	80.921
<u>Images Included in Material?</u>									
No	790	15	.380*	.075	.233	.526	40.679*	14	65.583
Yes	2,077	30	-.006	.046	-.095	.084	113.888*	29	74.536
Not Reported	325	3	.930*	.123	.688	1.171	53.265*	2	96.245
<u>Animation Included in Material?</u>									
No	1,804	28	.183*	.049	.087	.280	103.988*	27	74.035
Yes	1,123	18	-.032	.062	-.154	.089	62.577*	17	72.834
Not Reported	265	2	1.125*	.138	.855	1.396	43.336*	1	97.692



TABLE 4 (continued)

*Weighted mean effect sizes for presentation features*

			Effect size (g)		95% confidence interval		Homogeneity of effect size		
	<i>N</i>	<i>k</i>	<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Media Used</u>									
Computer	490	8	.637*	.099	.443	.831	95.119*	7	92.641
Video Projector	118	2	.862*	.195	.480	1.244	.655	1	.000
Captioned Television	145	2	.293	.167	-.035	.621	.023	1	.000
Mixed Media	2,439	36	.050	.042	-.032	.133	129.233*	35	72.917

\*  $p < .05$

#### **3.4.2.6 Type of Media used for Presentation**

Table 4 also shows the results associated with type of media used to present the learning materials. Most of the studies investigated used mixed media, such as computer and paper. The use of computers and video projector to deliver learning materials produced statistically detectable benefits in favor of redundant presentation. I observed that studies with video projector were mainly system-paced with no learner control over the pace of the materials. As explained earlier, with such a system-paced delivery, learners appear to benefit from redundant presentation of speech and text. The effect size distribution of using video projector was homogeneous although with very few studies. Studies that used captioned television and mixed media did not produce any statistically detectable benefits.

#### **3.4.2.7 Participant Characteristics**

Table 5 presents the results of three different participant characteristics that were investigated, namely educational level, reading fluency and prior domain knowledge. *Educational Level:* It was observed that most of the participants in the studies meta-analyzed were undergraduate university students. Although primary school students in grades K-3 benefited from redundant presentation, the effect ( $g = .293$ ) was not statistically detectable. This result could be attributed to the small number of studies ( $k = 2$ ) in this grade category. Similarly, the effect of verbal redundancy was not statistically detected for secondary (high) school students. However, statistically detectable benefits of presenting verbally redundant materials were found for intermediate students (grades 4-7), as well as post-secondary students attending universities. Both results from intermediate and postsecondary grade categories were highly heterogeneous.

**Table 5 Weighted Mean Effect Sizes for Participant Characteristics**

	<i>N</i>	<i>k</i>	Effect size ( <i>g</i> )		95% confidence interval		Homogeneity of effect size		
			<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Educational level</u>									
Primary (K to grade 3)	113	2	.293	.189	-.078	.664	.032	1	.000
Intermediate (grades 4 - 7)	355	5	.318*	.111	.100	.535	15.284*	4	73.829
Secondary (grades 8 - 12)	281	6	.130	.123	-.111	.370	7.555	5	33.815
Postsecondary	2,443	35	.152*	.043	.069	.236	243.265*	34	86.023
<u>Reading Fluency</u>									
Fluent L1	2,695	40	.122*	.040	.043	.201	237.412*	39	83.573
Early L1 or Non-fluent L1	163	4	.613*	.163	.292	.933	1.885	3	.000
L2	334	4	.378*	.115	.152	.604	17.328*	3	82.687
<u>Prior Domain Knowledge</u>									
Low	2,287	35	.187*	.044	.101	.273	252.881*	34	86.555
High	183	3	.088	.158	-.221	.398	4.745	2	57.847
Mixed	118	3	.175	.189	-.195	.544	2.780	2	28.049
Not Reported	604	7	.149	.084	-.016	.315	7.724	6	22.322

\*  $p < .05$

**Reading Fluency:** A few studies failed to directly report the reading fluency of participants, although I was able to code for it by inferring from the participants' description provided in such studies. Statistically detectable benefits in favor of redundant presentations were demonstrated for participants who were (a) able to read fluently in their first language (L1); (b) early or non-fluent readers in first language; and (c) second language (L2) learners. However, the effect size distributions for fluent L1 and L2 participants were highly heterogeneous, indicating that the variability among effect sizes was greater than that expected from sampling error. A much larger statistically detectable mean effect size was obtained for beginning first language learners (L1). These were learners who were learning to read in their first language. Interestingly, the effect size distribution for this category of beginning L1 learners was homogeneous, reflecting a more accurate result with lower variability among studies in that category. The results obtained with beginning L1 and L2 learners seem to uphold the hypothesis that these learners devote a large portion of their cognitive and attentional resources to word decoding, and consequently have less cognitive resources available for comprehension of reading materials than fluent readers who can decode words accurately with minimal use of their cognitive resources. I found, in short, that less fluent readers benefited from redundant speech as complements to text materials being read. It appears that verbally redundant materials may help less fluent readers to devote more resources to higher cognitive engagements and comprehension

**Prior Domain Knowledge:** Learners' domain knowledge was also investigated to determine the moderating effect of prior knowledge. Learners' prior domain knowledge

was coded based on information provided explicitly in the studies. It was observed that most of the studies involved learners with low prior domain knowledge. These learners appeared to benefit from verbally redundant presentations. A statistically detectable mean effect size was obtained for low prior knowledge learners, although heterogeneity was noticeably higher across studies with low prior knowledge participants. Conversely, statistically detectable benefits were not detected for studies with high prior knowledge learners although only a few studies ( $k=3$ ) were conducted with high prior knowledge learners.

#### **3.4.2.8 Setting, Knowledge Domain, and Duration**

Table 6 shows the results of presenting redundant speech and text under various conditions, including the setting where the research was conducted, knowledge domain, as well as duration of the entire study and treatment. When learning activities were reported as part of a formal course of study or were conducted entirely in a classroom under the supervision of an instructor, the setting for such studies was coded as “classroom”. In turn, when learning activities were not reported as part of a formal course of study or were conducted in a laboratory, the setting was coded as *laboratory*. Under domain knowledge, I categorized studies that examined the effect of verbal redundancy in mechanical systems and meteorology under physical sciences. Reading literacy was separated from computer literacy. Computer literacy studies examined the effect of using verbally redundant materials to learn different concepts about the computer, e.g. the central processing system and its use. Table 6 also presents an approximate median split

on duration of treatment as well as duration of study. Both treatment and study duration were reported in all but four studies.

Classroom and laboratory studies show statistically detectable mean effect sizes although the effect size distributions were statistically heterogeneous, meaning that the variability among studies in each category was greater than expected from sampling error.

The mean effect sizes for biological science, reading literacy, and computer literacy were statistically detectable showing greater benefit for redundant presentation but the studies were heterogeneous. Conversely, studies conducted in the physical sciences and humanities do not facilitate learning with redundant presentations.

A pattern showing higher mean effect sizes for longer treatment and study duration was observed. The mean effect size and confidence interval for treatments that were equal to or greater than one hour in length produced statistically detectable benefits in favor of learning with redundant materials, although this finding was limited by medium level heterogeneity. Similarly, studies that were conducted for over a week yielded a statistically detectable effect..

**Table 6 Weighted Mean Effect Sizes Under Various Conditions**

			Effect size (g)		95% confidence interval		Homogeneity of effect size		
	<i>N</i>	<i>k</i>	<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Setting</u>									
Classroom	1,324	19	.114*	.057	.002	.227	57.203*	18	68.533
Laboratory	1,868	29	.217*	.049	.121	.312	209.548*	28	86.638
<u>Domain</u>									
Biological Science	274	4	.293*	.126	.046	.541	12.345*	3	75.698
Physical Science (Mechanical systems & Meteorology)	753	16	-.093	.077	-.243	.058	85.700*	15	82.497
Mathematics	265	4	.055	.128	-.197	.307	4.876	3	38.470
Reading Literacy	455	7	.329*	.098	.138	.521	14.278*	6	57.977
Computer Literacy	1,075	12	.320*	.064	.196	.445	101.277*	11	89.139
Humanities	205	3	-.053	.151	-.350	.243	25.976*	2	92.301
Not Reported	165	2	.243	.161	-.073	.559	.018*	1	.000
<u>Treatment duration</u>									
Less than 1 hour	1,978	33	.056	.047	-.035	.147	144.422*	32	77.842
Greater than or equal to 1 hour	764	11	.187*	.076	.038	.336	24.067*	10	58.449
Not Reported	450	4	.740*	.104	.536	.943	64.034*	3	95.315
<u>Study duration</u>									
Less than or equal to 1 week	2,173	36	.049	.045	-.038	.137	148.562*	35	76.441
Greater than 1 week	646	8	.276*	.082	.115	.436	13.931	7	49.751
Not Reported	373	4	.818*	.116	.590	1.046	65.997*	3	95.454

\*  $p < .05$

#### **3.4.2.9 Outcome Variables and Test Formats**

Table 7 presents the result of different outcome variables as well as test formats. The outcome variables were categorized into three groups: retention, transfer, and mixed retention and transfer; and test formats into four: multiple choice or objective items, short answer items, mixed item types, and those not reported. A majority of the studies used mixed retention and transfer outcomes with various test formats. Mean effect sizes were statistically detectable for the retention only outcome and objective items, but both categories of results were heterogeneous. Studies that used mixed retention and transfer outcome constructs produced negative but non-statistically detectable effects with verbally redundant learning materials; that is, students learned a bit better with non-redundant materials in comparison with redundant speech and text. All the test formats produced learning gains with redundant materials, with the exception of the one study that used a short-answer format. However, a statistically detectable mean effect size was obtained for only the objective test format.



**Table 7 Weighted Mean Effect Sizes for Outcome Constructs and Test Formats**

			Effect size (g)		95% confidence interval		Homogeneity of effect size		
	<i>N</i>	<i>k</i>	<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Outcome Variables</u>									
Retention	1,392	18	.447*	.056	.337	.558	107.912*	17	84.246
Transfer	179	2	.035	.160	-.278	.348	2.957	1	66.188
Mixed retention & transfer	1,621	28	-.043	.052	-.145	.058	115.768*	27	76.677
<u>Test Formats</u>									
M/C Objective	1,069	14	.465*	.065	.338	.592	107.410*	13	87.897
Short answer	30	1	-.944						
Mixed item types	2,033	32	.043	.046	-.047	.134	124.572*	31	75.115
Not Reported	60	1	.158						

\*  $p < .05$ ; M/C – multiple choice

#### **3.4.2.10 Methodological Research Features**

Table 8 presents the result of the effect size variations related to varying methodological quality of the research studies reviewed. This includes our rating of confidence in effect size calculations, treatment fidelity of the studies examined, the reliability of measures that were used in the primary studies, whether incentive for participation was reported or not, and whether research was published in a journal or as a book chapter, presented at a conference, or as a dissertation. Mean effect sizes were statistically detectable when the confidence in calculating effect sizes from the meta-analyzed studies were rated as medium and high but the distributions of effect sizes were highly heterogeneous. A similar result was obtained with the treatment fidelity category.

When the reliability of measuring instruments was reported, I found a moderate and statistically detectable mean effect size favoring redundant speech and text. On the other hand, there was no effect of redundant presentation when reliability was not reported. A statistically detectable mean effect size was obtained only for studies published in journals, possibly because such peer-reviewed studies are usually characterized by higher quality, sound methodology, and a more rigorous scientific approach to a greater extent than many conference presentations and dissertations. The fewer number of studies presented at conferences or as dissertation reports may be responsible for the non-statistically detectable effects found in these two categories.

**Table 8 Weighted Mean Effect Sizes for Methodological Features and Document Type**

	<i>N</i>	<i>k</i>	Effect size ( <i>g</i> )		95% confidence interval		Homogeneity of effect size		
			<i>M</i>	<i>SE</i>	Lower	Upper	<i>Q</i>	<i>df</i>	<i>I</i> <sup>2</sup> (%)
<u>Confidence in effect size</u>									
Medium	548	5	.639*	.093	.456	.822	70.029*	4	94.288
High	2,644	43	.087*	.040	.008	.166	169.189*	42	75.176
<u>Treatment fidelity</u>									
Medium	628	7	.256*	.082	.096	.416	18.304*	6	67.220
High	2,564	41	.153*	.042	.071	.234	249.018*	40	83.937
<u>Reliability</u>									
Not Reported	1,790	32	-.014	.050	-.111	.083	126.181*	31	75.432
Reported	1,402	16	.411*	.056	.302	.521	109.957*	15	86.358
<u>Incentive for participation</u>									
Yes	1,028	16	.305*	.067	.174	.436	162.303*	15	90.758
Not Reported	2,164	32	.116*	.044	.029	.203	100.782*	31	69.240
<u>Document Type</u>									
Journal Publication / Book	2,760	43	.179*	.040	.100	.257	262.555*	42	84.003
Chapter									
Conference Paper	152	2	.195	.168	-.133	.524	2.039	1	50.956
Dissertation	280	3	.120	.122	-.118	.358	3.776	2	47.036

\*  $p < .05$

### 3.4.3 Publication Bias

There is an inherent bias against publishing non-statistically detectable results in peer-reviewed publications. Hence, journals are more likely to publish studies associated with statistically detectable mean effect sizes than conference proceedings and presentations. This could be as a result of more stringent reporting requirements for publishing in a journal than for conference proceedings. Thus, studies with non-statistically detectable findings are often either tucked away in file drawers or reported in the less accessible grey literature (Orwin, 1983; Rosenthal, 1979). This problem, referred to as the “*file-drawer problem*” becomes apparent in meta-analyses, where there is a tendency to include studies with positive outcomes and exclude unpublished and grey literature, thereby potentially skewing meta-analytical findings towards a positive mean effect size. This poses a threat to the validity of results obtained from meta-analyses. Since the identification of this potential bias for publication, researchers have developed different methods to examine the validity of results obtained from meta-analyses.

In the current work, two statistical tests were performed in Comprehensive Meta-Analysis™ software to assess potential for publication bias. First, a “Classic fail-safe  $N$ ” test was performed to determine the number of null effect studies needed to raise the  $p$  value associated with the average effect above an arbitrary alpha level (set at  $\alpha=.05$ ). This test revealed that 182 additional qualified studies will be required to invalidate the effect found in this meta-analysis. The second test, Orwin’s Fail-Safe  $N$  (equation 9) was used to estimate the number of file-drawer studies with null results required to nullify the effects found in this meta-analysis.

$$k_0 = k \left[ \frac{\overline{ES}_k}{\overline{ES}_c} - 1 \right], \tag{9}$$

where  $k_0$  is the number of effect sizes with a value of zero needed to reduce the mean effect size to  $\overline{ES}_c$ ,  $k$  is the number of studies involved in generating the mean effect size (48 studies),  $\overline{ES}_k$  is the overall weighted mean effect size (0.174), and  $\overline{ES}_c$  is the criterion effect size level (0.05).

Using a criterion effect size level of 0.05, the fail safe  $N$  was found to be 118 studies, meaning that 118 missing null studies would be needed to bring the current mean effect size found in this meta-analysis to 0.05. The results of these two statistical tests suggest that it is unlikely that publication bias poses a significant threat to the validity of findings reported in the current work.

### 3.5 Discussion

Although, overall, a statistically detectable learning benefit for verbal redundancy was found, the small size of this effect and its large heterogeneity render it theoretically and educationally meaningless. A meaningful interpretation of verbal redundancy effects can only be made with a consideration of moderating conditions such as pacing, level of redundancy, inclusion of images and animations, and reading fluency. For example, verbal redundancy was only effective under system-paced conditions. Also, I found that the effect of verbal redundancy was enhanced when short summaries of the narration were used as redundant texts, suggesting that multimedia presentations with short textual summaries of narration may help learners engage in essential cognitive processing that

facilitates learning. On the other hand, it appears that when verbatim texts are presented concurrently with other visual stimuli the advantages of redundancy are lost as learners struggle to hold the text and animation representations in visual working memory while integrating information from all the sources.

The effects of verbal redundancy were also moderated by individual differences related to the verbal ability or reading fluency of learners. It appears that verbal redundancy may benefit early readers and ESL learners [for example, grade 7 students in Atkinson et al.'s (2007) study]. It is perhaps not surprising that the greatest post-test performance enhancements from verbal redundancy were found for early or non-fluent readers. It appears that early readers may devote significant cognitive resources to linking visual and auditory representations in working memory. Such mental integration and expense of cognitive resources to germane processes might help explain the perceived benefit of verbal redundancy for early readers. However, there appears to be an expertise reversal effect associated with verbal redundancy for high verbal ability learners, whereby interventions that are beneficial for early readers and ESL students become ineffective and even deleterious for learners with high verbal ability learners. Similarly, fluent readers who are familiar with the visual and auditory representations of the words in a text passage may not invoke deeper cognitive integration of the two representations in working memory. By processing only the surface features of the stimuli, verbally redundant learning materials may not benefit fluent readers as much as they benefit naïve readers and ESL students (Nesbit & Adesope, in press). This is consistent with the work of Diao and Sweller (2007), who found that multimedia presentations in which spoken and written texts were presented concurrently inhibited learning for more experienced

readers of English language who have had six years of English language study in high school and were already studying in the University at the time the study was conducted.

Most of the studies meta-analyzed used system-paced learning materials. These system-paced studies produced a relatively small but statistically detectable effect in support of verbally redundant presentation while learner-paced studies did not show any benefits of verbally redundant over non-redundant presentations. Tversky, Morrison, and Betrancourt's (2002) apprehension principle may be useful in explaining these findings. According to these authors, multimedia learning resources "must be slow and clear enough for observers to perceive movements, changes, and their timing" (p. 258). They suggest that this can be accomplished by allowing learners to stop, start, pace, and review multimedia learning materials. When learners can exercise this degree of control over the pace at which multimedia materials are presented, they may not need identical speech and text to cognitively process the materials effectively, since they can review materials either presented as text or audio narration. Conversely, when learners are deprived of such control of the pace of learning materials, as in system-paced studies, the results show that learners may rely on both sources of redundant speech and text presentations to efficiently process the materials. In other words, when spoken words and text are presented concurrently without learners having control of the pace of the presentation, learners may more cognitively integrate these representations in working memory than when non-redundant text or audio is presented with the system having control of the pacing of the instructional materials.

Another important result that may influence instructional design of multimedia materials for learning is the inclusion of images and animation. The present meta-analysis

found that verbally redundant materials accentuated learning provided there were no concurrent presentations of visual stimuli such as animations or diagrams. Using the dual coding theory (Clark & Paivio, 1991; Paivio, 1986), this result suggests that learning is enhanced when materials are presented using auditory and visual stimuli (i.e. as audio narration and text). This is because as auditory working memory and visual working memory work independently, learners are capable of selecting and processing both pieces of information without suffering from extraneous cognitive load. On the other hand, the addition of concurrent text displays to an already intelligible diagram or animation may cause an overload of the visual working memory thereby inhibiting learning. In some cases, presentation of identical speech and text with inclusion of concurrent animation or diagram may cause split attention, a multimedia malady that is deleterious to learning (Ayres & Sweller, 2005; Mayer, 2001, Mayer & Moreno, 1998, 2002, 2003).

Consequently, if there is high redundancy between concurrent speech and text, and if semantic integration is required to hold both representations in memory, verbal redundancy may exert high extraneous cognitive load on working memory. Therefore, verbally redundant textual materials that require a high-level of integration of several sources of multimedia information may be deleterious to learning.



## **CHAPTER 4: AN EXPERIMENT ON ANIMATED CONCEPT MAPS**

This chapter presents a report of an experiment investigating the learning effects of animated and static concept maps compared with animated and static text concurrently presented with redundant audio narration. The chapter first presents an overview of research on learning with concept maps, and the research questions and hypotheses based on previous research on concept maps. The chapter then describes the sample, the multimedia materials, the dependent variables, research design, procedures through which data were collected and analyzed. Finally, the results of the study are presented and discussed in relation to previous empirical studies on concept maps.

### **4.1 Learning with Concept Maps**

There are at least three different ways that concept maps have been used in both individual and collaborative learning environments. First, learners may be required to construct concept maps to investigate their conceptual understanding of a domain (Novak, 2002; Okebukola, 1992). Second, learners may be asked to modify already constructed concept maps, so as to examine conceptual change in knowledge over a specified period of time (Chang, Sung & Chen, 2002; Novak, 2002). Third, learners may be required to study instructor- or researcher-generated concept maps (Bahr & Dansereau, 2005; O'Donnell, Dansereau, & Hall, 2002). A search on PsycINFO database conducted in August 2009 showed that over 500 peer-reviewed articles have discussed

the use of concept maps for different purposes. In a meta-analysis by Nesbit and Adesope (2006), we found that, under different instructional conditions, settings and experimental features, the use of concept maps produced increased retention and transfer of knowledge when compared with control conditions where students studied with text passages, outlines, lists or listened to lectures. The meta-analysis also found that studying with instructor- or researcher-generated concept maps when compared with text yielded an overall effect size  $d = .4$  standard deviations. Consistent with these learning effects, students often report positive attitudes toward learning with concept maps (Nesbit & Adesope, 2006), and there is evidence that using concept mapping as a learning strategy can lower anxiety and frustration while increasing motivation to engage in meaningful learning (Bahr & Dansereau, 2001; Czerniak & Haney, 1998; Okebukola & Jegede, 1988).

#### **4.2 Disadvantages of learning with static concept maps**

Despite the learning benefits, researchers have found inherent problems associated with processing static concept maps. The indeterminacy of processing order in static concept maps has been recognized as a disadvantage. Blankenship and Dansereau (2000) coined the term “map shock” to describe the confusion learners experience as a result of “bewilderment of not knowing where to start or how to penetrate the topography of the map” (Blankenship & Dansereau, 2000, p. 294). In another study that used eye tracking equipment to examine the order of initial processing of nodes in concept maps, Nesbit, Larios and Adesope (2007) observed varying patterns of map reading adopted by learners. When learners first approach a concept map of moderate complexity, they may

find it difficult to process the entire map in a coherent order because maps are not linearly ordered like text. Learners may forget which nodes and links they previously visited, leading to redundant, incomplete or superfluous processing of the concept map.

Researchers have hypothesized that map shock may produce a negative affective reaction that de-motivates engagement with the concept map consequently inhibiting learning (Dansereau, Dees, & Simpson, 1994).

### **4.3 Animated concept maps**

Researchers have hypothesized that animated concept maps may alleviate the problem of map shock inherent in processing static concept maps (Blankenship & Dansereau, 2000; Nesbit & Adesope, in press). As discussed earlier, animated concept maps may help reduce the redundant and incomplete processing associated with map shock by guiding learners through the visual complexity of static concept maps.

Many previous studies contrasting the cognitive benefits of learning with either static concept maps or text have been fraught with a major methodological flaw: the inability to control the processing order of concepts. While texts tend to be read conventionally from top to bottom and left to right, concept maps may be read using different processing routes (Nesbit, Larios & Adesope, 2007). The variability in processing order has limited researchers understanding of the contrasting cognitive processes underlying learning with these tools. Animated concept maps may be important in investigating the contrasting cognitive effects of learning with maps and text. Researchers can resolve the cognitive effects of maps and text and obtain a more precise comparison of the two information formats if animated concept maps are compared to

semantically equivalent “animated” text such that both treatments present information accumulating on a display.

In a previous research that used a 2 x 2 factorial experiment to investigate the effects of format (map versus text) and presentation mode (static versus animated), Blankenship and Dansereau (2000) examined recall of central ideas (macrostructure) and detail ideas (microstructure). In free recall of central ideas, they found a statistically detectable advantage for the animated concept map group compared with the animated text ( $d = .71$ ) and the static map ( $d = .56$ ) groups. Statistically detectable differences were not found in recall of detail ideas. The present experiment extends Blankenship and Dansereau’s (2000) study significantly. For example, in the present study, learners were allowed to control the pacing, pausing and reviewing of each animated slide. I also used well-structured concept maps in which semantically related nodes were placed in close proximity, and provided an audio narration of the text passage to all treatment groups. These presentational features were not included in Blankenship et al.’s study.

In another study, Nesbit and Adesope (in press) compared learning from animated concept maps and text by randomly assigning 133 undergraduates to study one of four multimedia materials that presented semantically equivalent information accompanied by identical audio narration. Two of the animations presented text; one with concurrent audio and another with delayed audio. Two of the animations presented concept maps; one in black and white and the other with nodes colored to represent semantic relatedness. The concept map groups outperformed the text groups on free recall ( $p < .05$ ). The black and white concept map group outperformed the text groups on a multiple choice knowledge test ( $p < .05$ ). No advantages were statistically detected for color

enhancements of the animated map. However, the cognitive effects of animated versus static concept maps were not investigated. Process data were not collected. In the current experiment, I examine the effects of learning with animated versus static concept maps and collected process data for further analyses relative to time on task.

#### **4.3.1 Issues with Animation**

When used to illustrate change in states, animation has only rarely been found to offer instructional advantage. In a review of animations that illustrate change in physical systems, Tversky, Morrison, and Betrancourt (2002) concluded that animated changes between states are often too transitory to be easily perceived and understood. They proposed an ‘apprehension principle’ of multimedia learning that allows learners to have complete control over the perception, pacing and navigation of animated instructional materials. In line with research on animation, especially Tversky et al.’s recommendation that animation should be clearly perceived, in designing the experimental study, I used learner-paced animated materials and included audio narration to supplement concept map animation so that learners’ attention may be directed to the meaning of the nodes and links that are introduced when they advance to a new slide. It is hypothesized that such cognitive integration of concept map and audio narration may introduce germane cognitive load and result in greater recall and comprehension. Prior research on modality effect in multimedia learning was also used as guidelines in choosing audio narration over text in the presentation of animated and static concept maps.

## 4.4 Research Questions & Hypotheses

The effectiveness of static concept maps is limited by the problem of map shock, a feeling of being overwhelmed with the scale and visual complexity of processing static maps. Researchers have proposed animated concept maps as a plausible alternative to static maps and as a viable approach to alleviating the problem of map shock. Indeed, animated maps may serve as an additional representational element for sustaining constructive, self-regulated learning. The effectiveness of animated concept maps can be enhanced by integrating interactive features. For example, software may allow the learner to click on a concept during a narrative to classify it as “well understood”, “not yet understood,” “controversial,” “needs further evidence” or some other task-appropriate category. I view the narrative sequence provided by animated concept maps as a form of scaffolding that may be extended or withdrawn as needed to support constructive learning. For example, an audio narration may be provided for a portion of the map, leaving the remainder of the map to be narrated by the learner. Before advancing to complex, interactive designs with animated concept maps, it is important to establish empirical evidence that animated concept maps can function effectively (or not) when presented in a simple, less interactive format. Hence, the present study asks eight research questions:

- (1) How much do animated concept maps benefit learning in comparison with static concept maps that are synchronized to an audio narration?
- (2) How much do animated texts benefit learning in comparison with static text presentations that are synchronized to an audio narration?

- (3) How much do animated concept maps benefit learning in comparison with animated text presentations synchronized to an audio narration?
- (4) How much do static concept maps benefit learning in comparison with static text presentations synchronized to an audio narration?
- (5) When compared with animated text displays, are animated concept maps effective for recalling central and detail ideas?
- (6) When compared with static text displays, are static concept maps effective for recalling central and detail ideas?
- (7) Do students perceive animated presentations as more useful for learning than static presentations?
- (8) In multimedia materials using concept maps and text concurrently presented with audio narration, is time-on-task a significant predictor of posttest scores?

On the basis of the literature, some predictions were made about the outcome of the present study that used a 2 X 2 factorial design to assess the effects of animation (animation versus static) and representation (concept map versus text) on the posttests:

- (1) The animated concept map group will outperform the animated text group on the posttests.
- (2) The static concept map group will outperform the static text group on the posttests.
- (3) The animated concept map group will outperform the static concept map group on the posttests.

- (4) The animated text group will perform similarly as the static text group on the posttests.
- (5) The benefits of animated and static concept maps over animated and static text presentations will be observed for both central and detail ideas.
- (6) Students will perceive animated presentations more useful for learning than static presentations.
- (7) Time-on-task will significantly predict posttest scores.

## 4.5 Participants and Research Design

The participants were 140 students recruited from different faculties and departments at a mid-sized Canadian university as shown in Table 9. Students who volunteered to participate in the experiment signed a consent form and were paid \$15 participation fee upon completing the session (see Appendices B, C, and D). The average age of the participants was 23.64 (SD = 6.98) years. Overall, there were 79 females (56.4%) and 61 males (43.6%). 34 participants were randomly assigned to the *staticText* group (67.6% females, 32.4% males), 37 in the *animatedText* group (64.9% females, 35.1%), 33 in the *staticMap* group (48.5% females, 51.5% males), and 36 in the *animatedMap* group (44.4% females, 55.6% males). Forty two participants (30%) indicated that they were native English speakers while 72 participants (51.4%) reported Chinese or Mandarin as their first language. 81.3% of the participants were undergraduate students while the rest were graduate students. As shown in Table 10, majority of the participants were Asians.



**Table 9 Participants' Faculties**

Academic faculty	Number of participants from faculty	Percentage
Applied Sciences	74	52.86
Arts and Social Sciences	28	20.00
Education	5	3.57
Science	12	8.57
Health Science	2	1.43
Business	10	7.14
Continuing Studies	9	6.43

Using a 2 X 2 factorial design, the study investigated the effects of representation (concept map versus text) and animation (animation versus static) on learning.

**Table 10 Ethnic Distribution of Participants**

Ethnic group	Number of participants	Percentage
African	5	3.57
Asian	107	76.43
Caucasian	22	15.71
Hispanic	2	1.43
Middle Easterner	3	2.14
Slavic	1	0.71

## 4.6 Multimedia Materials and Instrument

After random assignment to one of four treatment groups, each participant was presented with a 481-word multimedia presentation on the organization and function of

the human nervous system. Table 11 shows the structure of the presentations in each of the treatment groups. The audio narration was a recording of a human voice reading the passage. All the groups heard the same audio recording explaining the material but saw different Flash™ presentations. Prior research guided the format and style of the presentation of all four multimedia materials (Graesser, Hoffman & Clark, 1980; Hooper & Hannafin, 1986; Rieber, 1996; Tversky, Morrison & Betrancourt, 2002). For example, both text presentations were left justified because researchers have demonstrated that left justified texts are amenable to being read faster than full justified texts (Hooper & Hannafin, 1986). Font and other style characteristics were legible.

**Table 11 Structure of Materials**

Material	Properties	Audio	Synchronized with audio
<i>animatedMap</i>	Animated concept map	Yes	Yes
<i>staticMap</i>	Static concept map	Yes	No
<i>animatedText</i>	Animated text	Yes	Yes
<i>staticText</i>	Static text	Yes	No

The *animatedMap* group viewed an animated concept map synchronized with audio narration. Each slide of the animation presented one sentence of the narration and added the semantically corresponding nodes and links of the concept map to the display. The *staticMap* group viewed a static concept map with the audio narrated over the static map. The *animatedText* group saw an animated text display in which each sentence was presented as it was narrated, that is, the text presentation was synchronized with audio narration. The *staticText* group heard an audio narration played over a static text display

of the entire passage. For the *animatedMap* and *animatedText* animations, visual content remained on the screen while subsequent content was introduced. Each of these two animated materials presented 31 slides and allowed transitions between the slides to be controlled by clicking on a “next” button. Appendix H shows the number of words and sentences in the audio narration presented in each slide. Screen shots from the *staticMap* and *staticText* presentations are shown in Figures 9 and 10 respectively.

Figure 9 Screenshot of the animation viewed by the *staticMap* group

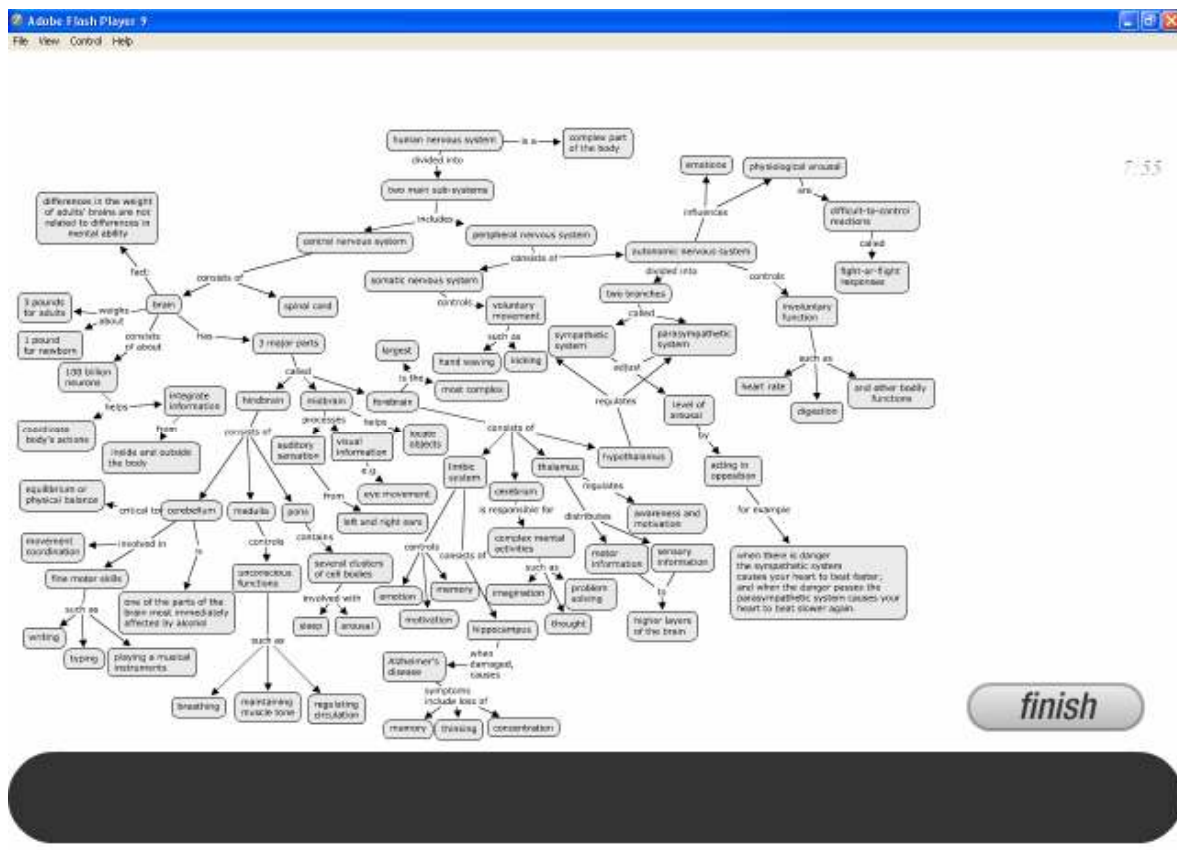
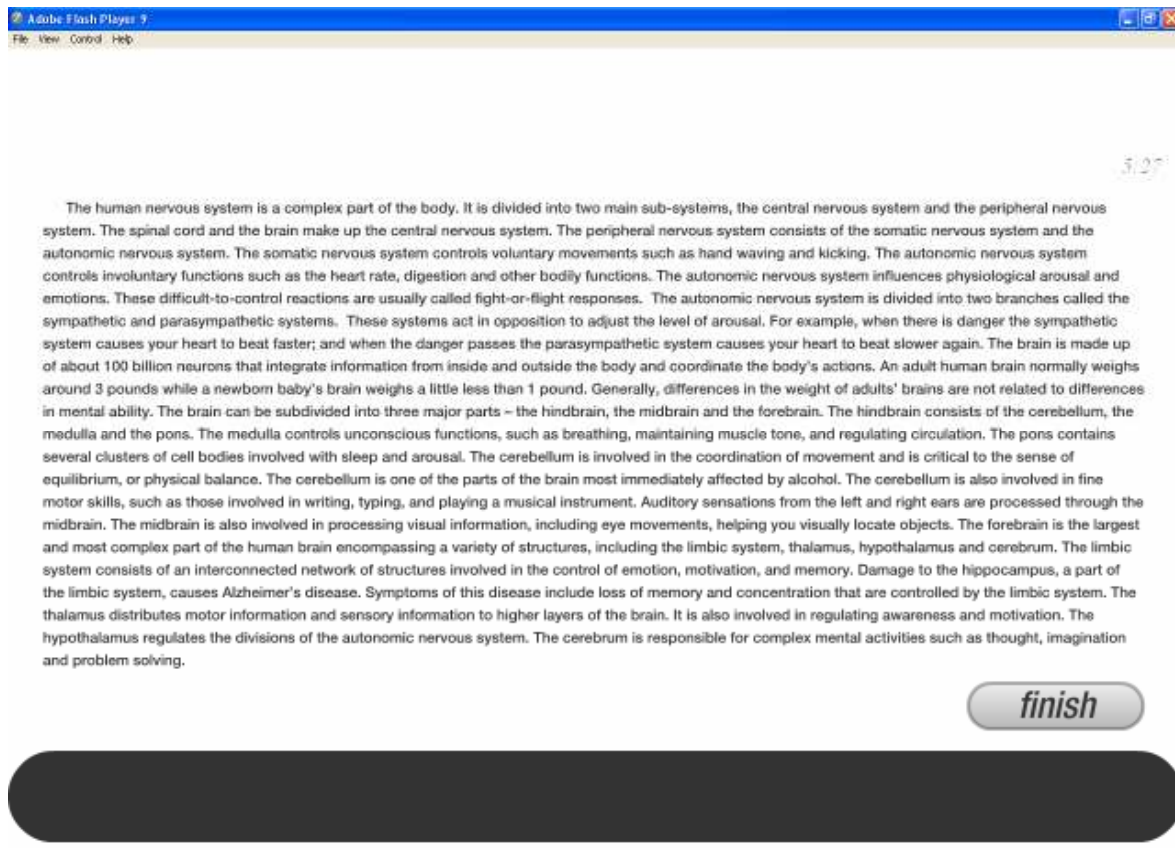


Figure 10 Screenshot of the animation viewed by the *staticText* group

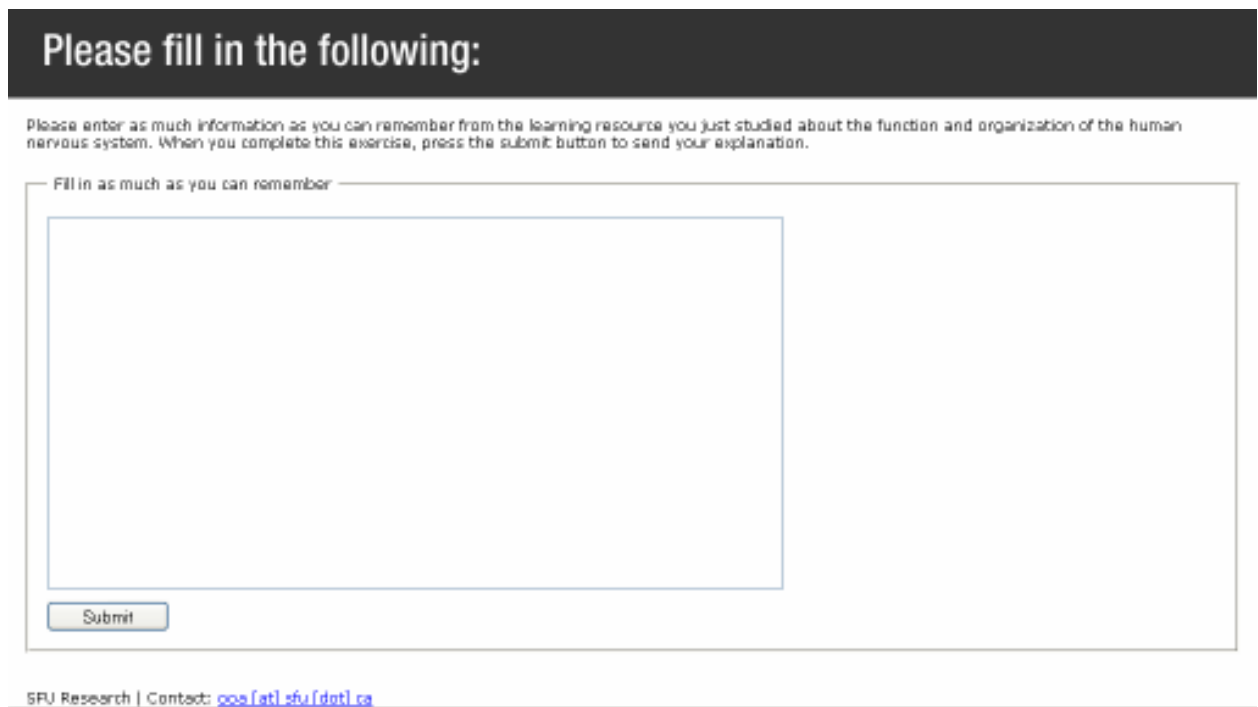


All multimedia materials were presented on Microsoft Windows XP personal computers equipped with 17-inch monitors and headphones. Times spent by each participant viewing each slide of the animated presentations were logged by the computer and used for further analyses. Overall time spent by each participant presented with static presentations were also logged and used for further analyses.

## 4.7 Dependent Measures

The dependent variables were the scores on the free recall, knowledge, and transfer tests. A free recall test was used to assess participants' memory of ideas in the passage. After presentation of the material, participants were instructed to write down all they could remember in the passage using a text field presented in an online web-based form, as shown in Figure 11. They were allowed 10 minutes to complete the recall task. None of the participants indicated a need for additional time.

Figure 11 Screenshot soliciting free recall responses



The screenshot shows a web-based form for free recall responses. At the top, a dark grey header contains the text "Please fill in the following:". Below this, a smaller text block reads: "Please enter as much information as you can remember from the learning resource you just studied about the function and organization of the human nervous system. When you complete this exercise, press the submit button to send your explanation." The main part of the form is a large, empty text input field with a light blue border. Above the input field, the text "Fill in as much as you can remember" is displayed. Below the input field, there is a "Submit" button. At the bottom of the page, a footer contains the text "SFU Research | Contact: [ccos@at1.sfu.ca](mailto:ccos@at1.sfu.ca)".

The transfer test (Appendix J) consisted of two questions that assessed participants' ability to not only understand the multimedia passage but also apply what

they had learned to novel situations. Participants were allowed 10 minutes to complete the transfer test. An example of the transfer question is presented below:

*At a treatment center for brain injuries, a patient was reported to have damaged only his forebrain. List 5 tasks the patient might **not** be able to do conveniently because of this injury and state what part of the forebrain is responsible for the inability to carry out your listed task.*

A 30-item multiple choice knowledge test (Appendix K) was designed to measure recall, understanding and application (Anderson & Krathwohl, 2001) of the human nervous system passage. Participants were allowed 17 minutes to complete the knowledge test. As in the other tests, none of the participants indicated a need for additional time with the knowledge test. The knowledge test consisted of 12 application items and 18 recall and understanding items. The recall and understanding items assessed recognition of concepts using terms that were the same or synonymous to those in the passage. Conversely, the application items presented scenarios and asked participants to make judgments. One of the application items in the knowledge test is the scenario presented below:

*While watching a suspenseful video late at night, Felicia hears a sudden crash in another room. She leaps out of your chair in fear, and then realizes that her dog has knocked over the water bowl again. Her fear reaction involved the activation of the \_\_\_\_\_ of the nervous system. Calming down involved the \_\_\_\_\_ of the nervous system.*

- a. *somatic branch; sympathetic division*

- b. *sympathetic division; parasympathetic division*
- c. *thalamus; hypothalamus*
- d. *parasympathetic division; sympathetic division*

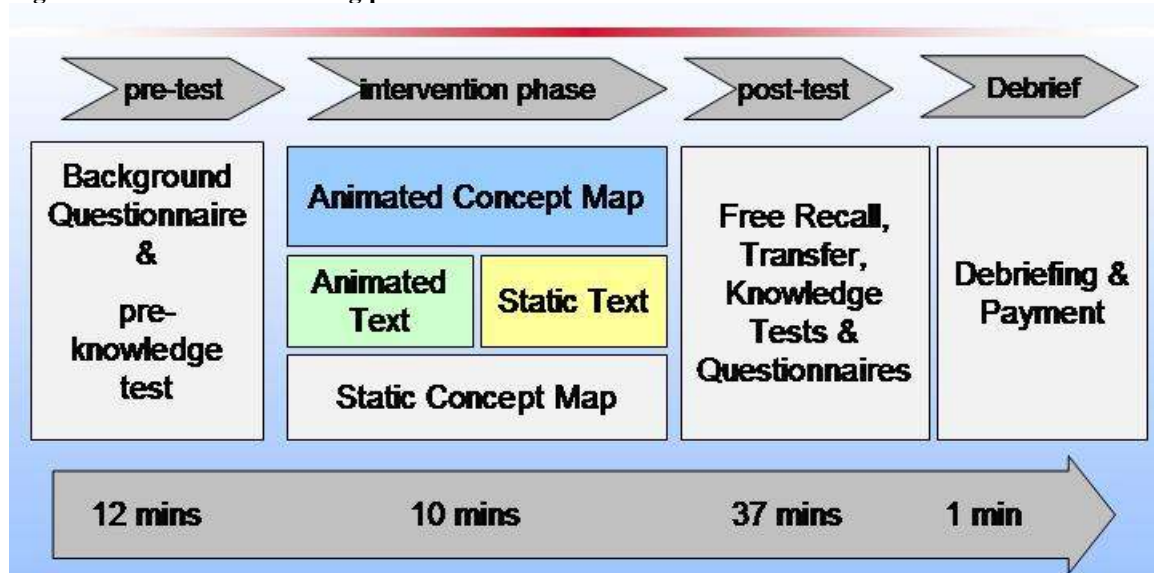
Participants were also asked to complete the scales for the subjective evaluation of the multimedia presentations (Appendix L) and to determine their levels of motivation, interest and perceived difficulty of the human nervous system material using a 7-point scale (1= not at all true and 7 = very true of me). Participants' responses on free recall, knowledge, transfer measures as well as subjective evaluation were collected and recorded electronically.

## **4.8 Procedure**

The experiment was conducted in a laboratory with participants seated in front of a computer monitor and wearing headphones. Each participant attended one session lasting approximately 60 minutes. Those who completed the session were paid \$15 participation fee. Prior to the beginning of each session, I emphasized the importance of studying very well within the time allotted. Participants were encouraged to study the material as if they were studying for an examination. They were told that after the presentation, they would be required to take some tests and that the top scorer on the test questions would receive an additional \$35 at the end of the study. Since a grade may motivate students in a typical classroom environment, participants in laboratory studies have tendency not to exert efforts at studying the materials, hence the rationale to pay the extra fee as an incentive.

Figure 12 presents the procedure and time assigned to each component. Within each session, participants were randomly assigned to study one of four multimedia presentations (*animatedMap*, *staticMap*, *animatedText*, or *staticText*). As shown in Appendix E, at the start of each session, written consent was required and obtained from each participant prior to administering the background information questionnaire, pretest studying activity, and posttest. The background information questionnaire (Appendix G) included questions about the participants' age, gender, ethnicity, and the degree to which they have used concept maps for studying. They were allowed 5 minutes to complete the background questionnaire.

Figure 12 Procedure showing phases within each session



For the pretest, the participants were allowed 6 minutes to list 10 parts of the human nervous system that they know and briefly describe the function of each part. After the pretest, the participants were informed that they would be given a passage to study and tested on their understanding of the materials at the end of the study session.



They were instructed to advance through the multimedia presentation on the organization and functions of the human nervous system within 8 minutes and review the last slide (which showed the complete concept map or text passage) for 2 minutes. A computer-controlled clock was displayed in the upper right corner of the screen so that participants could monitor the time left to study the material in minutes and seconds.

Upon completion of the multimedia presentation study session, participants answered the free recall question, the two transfer questions and the 30 multiple choice knowledge questions, and 10 subjective evaluation questions for measuring different scales (motivation, perceived ease of use, perceived usefulness and perceived difficulty of the materials). The background questionnaire, pretest, transfer, knowledge questions and the subjective evaluation scales were administered using *Web Questionnaire*, a tool developed as part of a large research project at the University of Victoria and Simon Fraser University (Adesope, Leacock, Nesbit, & Hadwin, 2006; Hadwin, Winne, Murphy, Walker, & Rather, 2005). Participants were provided with login and password information that allowed them to access the tool (see Appendices F and O). This online tool allowed participants to respond to the background questionnaire and answer the test questions. Participants' responses were saved into a database that was exported to SPSS for further analyses.

## **4.9 Results**

Prior to data analysis, all variables were examined for accuracy of data entry, outlying cases and normality of distributions through various SPSS programs including Frequencies and Descriptive Statistics as well as the normal probability plots (P-P plots).

No univariate or multivariate outliers were detected. Distributions were mostly normal and fell within acceptable levels of skewness and kurtosis (Tabachnick & Fidell, 2006). I eliminated the data for 5 participants who spent less than 2 minutes to study the materials because such participants were deemed not to have sufficiently studied the material under such a limited amount of time. Only the data for the remaining 135 participants were included in subsequent analyses.

#### **4.9.1 Pretest Scores**

The pretest was scored out of 20 points, a point for each part of the human nervous system listed and another point for proper description of the function of each listed part. ANOVA was used to determine that differences between treatment groups on the pretest were not statistically detectable ( $F_{3,131} = .87, p = .46$ ).

#### **4.9.3 Free Recall Scores (Central and Detail Ideas Combined)**

Responses from the free recall test were assessed with a conventional proposition scoring method (Nesbit & Adesope, in press; Rewey, Dansereau, Skaggs, Hall & Pitre, 1989). The original passage was analyzed into 72 propositional statements that were approximately equivalent in meaning to the original passage (see Appendix M). For example, the sentence “the autonomic nervous system is divided into two branches called the sympathetic and parasympathetic systems” was analyzed into three propositions: (1) the autonomic nervous system is divided into two branches, (2) the sympathetic nervous system is part of the autonomic nervous system, and (3) the parasympathetic system is part of the autonomic nervous system. A rater who was blind to the treatment conditions

assigned a score from 0 to 2 for each proposition recalled by the participants: 0 if the proposition was absent or completely inaccurate, 1 if partially present or partially accurate; and 2 if the proposition was entirely present and accurate. Each participant's free recall score was the sum of the proposition scores. Appendix N shows a sample free recall data.

To monitor reliability, another trained rater scored 51 randomly selected free recall responses. The Pearson product-moment correlation between the scores from the two raters was  $r = .94, p < .001$ , showing a very high inter-rater reliability for the free recall responses. Heterogeneity of variance among the treatment groups was not detected (Levene<sub>3,131</sub> = .48,  $p = .695$ ).

A 2 X 2 between-subjects multivariate analysis of variance (MANOVA) was conducted with free recall, transfer and knowledge scores as the dependent variables. There was a statistically detectable main effect for representation, ( $F_{1,131} = 33.08, p < .001$ ). Neither the main effect for animation, ( $F_{1,131} = 2.39, p = .125$ ), nor the representation X animation interaction, ( $F_{1,131} = .27, p = .605$ ) was statistically detectable. Univariate tests revealed a statistically detectable representation effect for free-recall, ( $F_{1,131} = 33.08, p < .001$ , partial  $\eta^2 = .202$ ; transfer, ( $F_{1,131} = 41.502, p < .001$ , partial  $\eta^2 = .241$ ); and knowledge test, ( $F_{1,131} = 7.90, p < .05$ , partial  $\eta^2 = .057$ ).

Table 12 shows the free recall means, standard deviation and sample size for each of the treatment groups. Analysis of variance detected an effect due to treatment ( $F_{3,131} = 11.78, p < .001$ ). The partial  $\eta^2$  was .21, indicating that 21% of free recall variance could be attributed to treatment. Bonferroni-adjusted multiple comparisons found differences for *animatedMap* vs. *animatedText* ( $d = .87, p < .001$ ), *animatedMap* vs. *staticText* ( $d =$

1.31,  $p = .002$ ), *staticMap* vs. *animatedText* ( $d = .70$ ,  $p = .019$ ), and *staticMap* vs. *staticText* ( $d = 1.13$ ,  $p < .001$ ). No differences were statistically detected for *animatedMap* vs. *staticMap* ( $d = .17$ ,  $p > .999$ ), and *animatedText* vs. *staticText* ( $d = .37$ ,  $p = .819$ ).

**Table 12 Free Recall Performance of the Four Treatment Groups**

Treatment	<i>M</i>	<i>SD</i>	<i>N</i>
<i>animatedMap</i>	43.63	18.55	32
<i>staticMap</i>	40.53	18.22	32
<i>animatedText</i>	27.86	17.90	37
<i>staticText</i>	21.65	15.06	34
Pooled	33.04	19.46	135

#### 4.9.4 Free Recall Scores (Central and Detail Ideas Separated)

I reanalyzed the free recall data to determine separate effects on recall of central and detail ideas. The inter-rater reliabilities for central ideas and detail ideas were, respectively,  $r = .93$  and  $r = .91$ . The correlation of recall scores for central and detail ideas was  $r = .65$  ( $p < .001$ ). Heterogeneity of variance, and departures from normality were not statistically detected.

The raw recall scores were converted into proportional scores. Table 13 shows the means and standard deviations for proportion of central ideas and detail ideas recalled in each of the treatment groups. An analysis of variance with idea type (central or detail) as a within-subject factor found that students recalled a greater proportion of central ideas

than detail ideas ( $F_{1,131} = 205.12, p < .001, \text{partial } \eta^2 = .61$ ). No interaction between treatment group and type of ideas recalled was detected ( $F_{3,131} = 1.539, p = .207, \text{partial } \eta^2 = .03$ ). Separate MANOVAs found treatment effects for central ideas ( $F_{3,131} = 6.73, p < .001, \text{partial } \eta^2 = .13$ ) and detail ideas ( $F_{3,131} = 12.94, p < .001, \text{partial } \eta^2 = .23$ ). For central idea recall, Bonferroni-adjusted multiple comparisons detected differences for *animatedMap* vs. *staticText* ( $d = 1.12, p < .001$ ), and *staticMap* vs. *staticText* ( $d = .79, p = .011$ ). For detail idea recall, Bonferroni-adjusted multiple comparisons detected differences for *animatedMap* vs. *staticText* ( $d = 1.21, p < .001$ ), *animatedMap* vs. *animatedText* ( $d = .96, p < .001$ ), *staticMap* vs. *staticText* ( $d = 1.18, p < .001$ ), and *staticMap* vs. *animatedText* ( $d = .93, p = .001$ ).

**Table 13** Proportion of Central and Detail Ideas Recalled by the Four Treatment Groups

<u>Treatment</u>	<u>Central Ideas</u>		<u>Detail Ideas</u>	
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>
<i>animatedMap</i>	.441	.171	.229	.128
<i>staticMap</i>	.392	.194	.223	.123
<i>animatedText</i>	.331	.203	.121	.097
<i>staticText</i>	.247	.174	.099	.084
Pooled	.350	.198	.165	.123

To more fully examine “focus” or “emphasis” on central ideas, an index variable was created for each participant using the ratio of proportion of central ideas divided by proportion of detail idea. The variable describes “focus” or “emphasis” on central ideas when the ratio  $> 1.0$ . Frequency results from SPSS showed that 91% of the participants

focused more on central ideas than detail ideas, thus confirming results from an analysis of variance that students recalled a greater proportion of central ideas than detail ideas.

#### 4.9.5 Transfer Scores

When answered correctly, participants received 10 points for each of the two transfer questions, making a total of 20 points for the transfer questions. For example, in the transfer question displayed earlier in this chapter, participants received 2 points for each correctly listed task that the patient might not be able to do conveniently because of injury to the forebrain and stated what part of the forebrain is responsible for the inability to carry out that listed task. If participants listed the five requested tasks in the question and the part of the forebrain responsible for each task, they received the 10 full points for this question.

To monitor reliability, another trained rater scored a sample of randomly selected transfer responses. The Pearson product-moment correlation between the scores from the two raters was  $r = .90$ ,  $p < .001$ , showing a very high inter-rater reliability for the transfer responses. Heterogeneity of variance among the treatment groups was not detected ( $\text{Levene}_{3,131} = 1.48$ ,  $p = .223$ ).

There was a statistically detectable main effect for representation, ( $F_{1,131} = 41.50$ ,  $p < .001$ ) and animation, ( $F_{1,131} = 4.52$ ,  $p = .035$ ) but the representation X animation interaction, ( $F_{1,131} = .54$ ,  $p = .463$ ) was not statistically detectable.

Table 14 shows the transfer means, standard deviation and sample size for each of the treatment groups. Analysis of variance detected an effect due to treatment ( $F_{3,131} =$

15.33,  $p < .001$ ). The partial  $\eta^2$  was .26, indicating that 26% of transfer variance could be attributed to treatment. Bonferroni-adjusted multiple comparisons found differences for *animatedMap* vs. *animatedText* ( $d = 1.05, p < .001$ ), *animatedMap* vs. *staticText* ( $d = 1.52, p = .002$ ), *staticMap* vs. *animatedText* ( $d = .73, p = .015$ ), and *staticMap* vs. *staticText* ( $d = 1.17, p < .001$ ). No differences were statistically detected for *animatedMap* vs. *staticMap* ( $d = .22, p > .999$ ), and *animatedText* vs. *staticText* ( $d = .55, p = .238$ ).

**Table 14** Transfer Performance of the Four Treatment Groups

Treatment	<i>M</i>	<i>SD</i>	<i>N</i>
<i>animatedMap</i>	12.25	4.53	32
<i>staticMap</i>	11.19	5.26	32
<i>animatedText</i>	7.89	3.81	37
<i>staticText</i>	5.71	4.09	34
Pooled	9.16	5.09	135

#### 4.9.6 Knowledge Scores

Each correctly answered question in the knowledge test attracted 1 point. Thus, participants can score a maximum of 30 points in this test. The internal consistency of the knowledge scores was  $\alpha = .79$ . This test showed acceptable levels of skewness and kurtosis, and passed the Levene test for homogeneity of variance, ( $\text{Levene}_{3,131} = .86, p = .463$ ). It was found that internal consistency could not be enhanced by deleting items. Separating the 12 application items from the 18 recall and understanding items produced two subscales with much lower internal consistencies ( $\alpha = .58$  for application items and

$\alpha=.69$  for recall and understanding items). Consequently, I decided to retain the full 30-item scale in further analyses of the knowledge scores.

Table 15 shows knowledge means, standard deviation and sample size for each of the treatment groups. Analysis of variance detected an effect due to treatment ( $F_{3,131} = 4.47, p = .005$ ). The partial  $\eta^2$  was .093, indicating that 9.3% of the variance in the knowledge scores could be attributed to treatment. On the six pair-wise multiple comparisons, the Bonferroni test found differences for *animatedMap* vs. *staticText* ( $d = .85, p = .002$ ). No differences were statistically detected for other pair-wise comparisons.

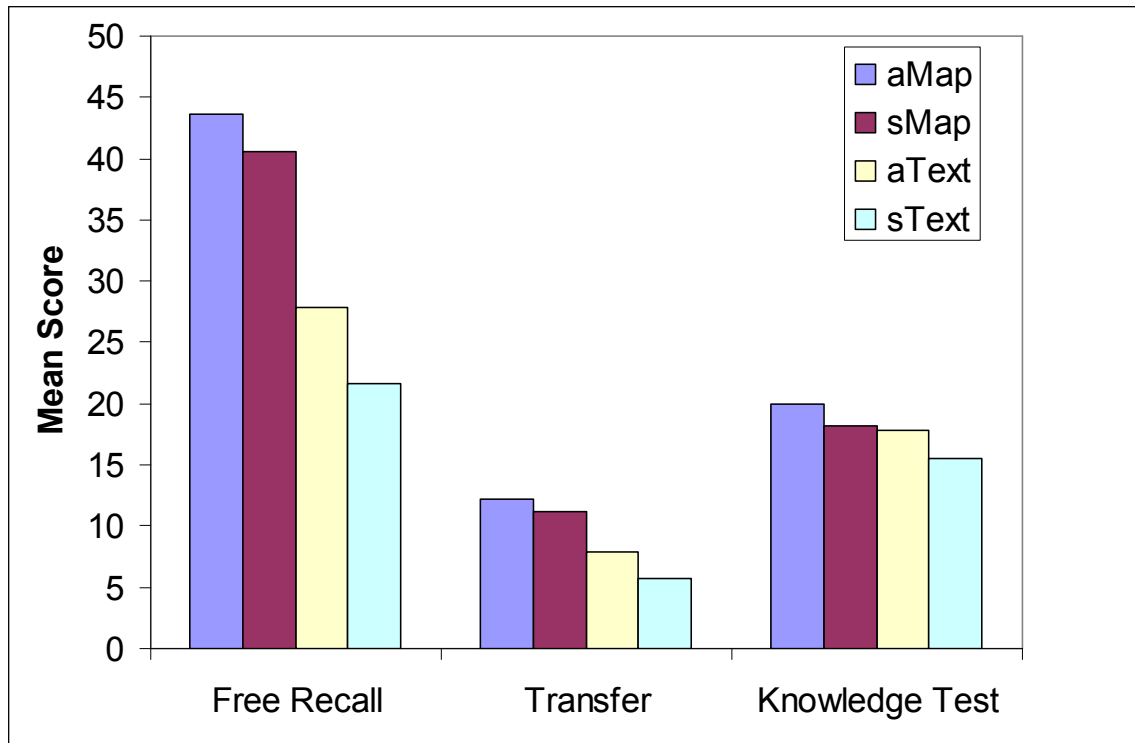
**Table 15 Knowledge Test Performance of the Four Treatment Groups**

Treatment	<i>M</i>	<i>SD</i>	<i>N</i>
<i>animatedMap</i>	19.97	5.38	32
<i>staticMap</i>	18.16	5.27	32
<i>animatedText</i>	17.78	4.23	37
<i>staticText</i>	15.50	5.12	34
Pooled	17.81	5.19	135

Figure 13 shows the mean score for each group on the free recall, transfer and knowledge tests.



Figure 13 Mean score for each group on the posttests



#### 4.9.7 Time-on-task

The time spent by each participant viewing the presentation was logged by the computer. This variable was referred to as *time-on-task*. Used as a dependent variable, *time-on-task* passed the Levene test for homogeneity of variance, ( $Levene_{3,131} = 1.00, p = .394$ ). Table 16 shows the means, standard deviation and sample size for each of the treatment groups. Analysis of variance did not detect an effect due to treatment ( $F_{3,131} = 2.37, p > .05$ ).

**Table 16 Time-on-task of the Four Treatment Groups (in seconds)**

Treatment	<i>M</i>	<i>SD</i>	<i>N</i>
<i>animatedMap</i>	467.94	92.25	32
<i>staticMap</i>	496.84	136.54	32
<i>animatedText</i>	469.03	121.96	37
<i>staticText</i>	420.15	121.14	34
Pooled	463.05	121.03	135

#### 4.9.8 Subjective evaluation of the multimedia presentations

The participants' subjective evaluation of the multimedia presentations comprised four scales: motivation, perceived ease of use, perceived usefulness and perceived difficulty of the materials. These scales were derived from research into technology acceptance (Davis, 1989) but for the present experiment, they were adapted relative to learning. The motivation scale referred to the participants' feeling of being motivated with the presentation (e.g., "I thought the material on the human nervous system was very interesting"). The perceived ease of use scale referred to the subjective ease of use of the presentation in terms of mental effort needed to learn the material (e.g., "I put a lot of effort into studying the material"). The perceived usefulness scale referred to the degree to which each participant believed that the presentation enhanced their learning (e.g., "The material was helpful in learning about the human nervous system"). The perceived difficulty of the material scale referred to the subjective evaluation of the difficulty of the material (e.g., "The material studied on the human nervous system was very difficult").

The full subjective evaluation questionnaire is presented in Appendix L.

Table 17 presents the mean scores and standard deviations for each of the treatment groups on the three scales. In each of the scales, Bonferroni-adjusted multiple comparisons did not find any statistically detectable differences on any of the six pairwise multiple comparisons, (Motivation,  $F_{3,131} = 2.32, p = .08$ ); (Perceived difficulty of the materials,  $F_{3,131} = 1.25, p = .30$ ); (Ease of use,  $F_{3,131} = 1.45, p = .23$ ); and (Perceived usefulness of the materials,  $F_{3,131} = 1.22, p = .30$ ).

**Table 17 Descriptive Statistics of Motivation, Perceived Ease of Use, Perceived Usefulness and Perceived Difficulty of the Materials Scales for the Four Treatment Groups**

<u>Treatment</u>	<u>Motivation</u>		<u>Perceived Ease of Use</u>		<u>Perceived Usefulness</u>		<u>Perceived Difficulty</u>		<u>Number of Participants</u> <i>N</i>
	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	<i>M</i>	<i>SD</i>	
<i>animatedMap</i>	5.55	.98	3.18	.91	5.38	1.32	4.16	1.20	32
<i>staticMap</i>	5.50	1.17	3.56	.79	5.45	1.50	3.79	1.52	32
<i>animatedText</i>	4.88	1.37	3.38	.87	4.89	1.34	4.14	1.23	37
<i>staticText</i>	5.06	1.46	3.22	.75	5.06	1.43	4.40	1.19	34
Pooled	5.23	1.29	3.33	.84	5.18	1.40	4.13	1.29	135

A correlation matrix of the variables investigated in this study is presented in Table 18. Positive correlations were statistically detected among free recall, transfer, knowledge and time-on-task.

**Table 18 Relationship Among the Pretests Scores, Free Recall Scores, Transfer Scores, Knowledge Scores and Time-on-task**

	1	2	3	4	5
1. Pretest	–				
2. Free recall	.26**	–			
3. Transfer	.28**	.63**	–		
4. Knowledge	.42**	.68**	.63**	–	
5. Time-on-task	.01	.40**	.21*	.29**	–

\*\*  $p < .01$ ; \*  $p < .05$

#### 4.9.9 Sequential Regression Analyses on Dependent Variables

Performance on the free recall, transfer and knowledge tests positively correlated with time on task. Hence, a decision was made to investigate further, the extent to which *time-on-task* will predict scores on the free recall, transfer and the knowledge tests.

Theoretically, *time-on-task* is one predictor of academic achievement (Louw, Muller, J., & Tredoux, 2008; Peterson, Swing, Stark, & Waas, 1984). Therefore, I hypothesized that *time-on-task* will result in better performance on free recall, transfer and knowledge tests.

Tables 19-21 present the sequential multiple regressions results. All analyses were conducted using SPSS REGRESSION but SPSS FREQUENCIES were used for

evaluation of assumptions. In sequential regression, predictor variables are entered into the regression equation according to some practical or theoretical rationale, such that the degree of relationship between the dependent variable and the predictors is examined at each step to see if prediction of dependent variable is enhanced after adjusting for variables entered in the previous step (Tabachnick & Fidell, 2006).

In Tables 19, 20 and 21, I present the sequential multiple regressions that used the variables (*representation*, *animation* and *time-on-task*) to predict the free recall, transfer and knowledge scores. In representation, the concept map groups (animated and static concept maps) were coded as +1 while the contrasting text groups (animated and static texts) were coded -1. In animation, groups who learned with animated presentations (animated map and animated text) were coded +1 while those who learned with static presentations (static map and static text) were coded -1. In Table 19, at step 1 with representation in the equation, the regression model predicting free recall scores was statistically detectable ( $p < .001$ ) and accounted for 19% of the variance in free recall scores. At step 2, with animation added to the model, only 2% of the additional variance in free recall score was explained, confirming that animation was not a statistically detectable predictor of free recall scores ( $p > .10$ ). At step 3, the interaction between representation and animation was added but was not a statistically detectable predictor of free recall scores ( $\beta = -.04, p = .61$ ). At step 4, with *time-on-task* added to the model, 11% of the additional variance in free recall was explained. Representation and *time-on-task* were statistically detectable predictors of free recall scores ( $p < .001$ ). This is a very important result because it shows that *time-on-task* contributed to higher performance on the free recall test, over and above the contribution made by representation.

**Table 19 Sequential Regression Table for Predicted Free Recall Scores**

Variable	$R^2$	Adjusted $R^2$	$\Delta R^2$	$F$	$B$	$SE B$	$\beta$	$t$
Step 1:	.19	.19	.19	32.42**				
Representation					8.60	1.51	.44	5.69**
Step 2:	.21	.20	.02	17.64**				
Representation					8.65	1.50	.45	5.76**
Animation					2.37	1.50	.12	1.58
Step 3:	.21	.20	.00	11.78**				
Representation					8.66	1.51	.45	5.75**
Animation					2.33	1.51	.12	1.55
Representation X Animation					-.78	1.51	-.04	-.52
Step 4:	.32	.30	.11	15.20**				
Representation					7.64	1.42	.39	5.37**
Animation					2.06	1.41	.11	1.46
Representation X Animation					.27	1.43	.01	.19
Time-on-task					.05	.01	.34	4.50**

\*\* $p < .001$

In Table 20, at step 1 with only representation in the equation, the regression model predicting transfer scores was statistically detectable ( $p < .001$ ) and accounted for 23% of the variance in transfer scores. At step 2, with animation added to the model, 3% of the additional variance in transfer score was explained. At step 3, the interaction between representation and animation was added but was not a statistically detectable predictor of transfer score ( $\beta = -.06, p = .46$ ). At step 4, with *time-on-task* added to the model, 2% of the additional variance in transfer was explained. Representation, animation, and *time-on-task* were statistically detectable predictors of transfer scores ( $p < .001, p < .05, \text{ and } p < .10$  respectively).



**Table 20 Sequential Regression Table for Predicted Transfer Scores**

Variable	$R^2$	Adjusted $R^2$	$\Delta R^2$	$F$	$B$	$SE B$	$\beta$	$t$
Step 1:	.23	.23	.23	39.79**				
Representation					2.44	.39	.48	6.31**
Step 2:	.26	.25	.03	22.81**				
Representation					2.45	.38	.48	6.44**
Animation					.83	.38	.16	2.17*
Step 3:	.26	.24	.00	15.33**				
Representation					2.46	.38	.48	6.44**
Animation					.81	.38	.16	2.13*
Representation X Animation					-.28	.38	-.06	-.74
Step 4:	.28	.25	.02	12.35**				
Representation					2.36	.38	.46	6.14**
Animation					.79	.38	.16	2.07*
Representation X Animation					-.18	.38	-.04	-.46
Time-on-task					.01	.00	.13	1.67~

\*\* $p < .001$ , \* $p < .05$ , ~ $p < .10$

In Table 21, at step 1 with representation in the equation, the regression model predicting knowledge scores was statistically detectable ( $p < .05$ ) and accounted for 5% of the variance in knowledge scores. At step 2, with animation added to the model, 4% of the additional variance in knowledge score was explained. At step 3, the interaction between representation and animation was added but was not a statistically detectable predictor of knowledge score ( $\beta = -.02, p = .79$ ). At step 4, with *time-on-task* added to the model, 6% of the additional variance in knowledge score was explained. Representation, animation and *time-on-task* were statistically detectable predictors of knowledge scores ( $p < .05$ ). This result shows that *time-on-task* contributed to higher performance on the knowledge test, over and above the contributions made by representation and animation.

**Table 21 Sequential Regression Table for Predicted Knowledge Scores**

Variable	$R^2$	Adjusted $R^2$	$\Delta R^2$	$F$	$B$	$SE B$	$\beta$	$t$
Step 1:	.05	.05	.05	7.38*				
Representation					1.19	.44	.20	2.72*
Step 2:	.09	.08	.04	6.71*				
Representation					1.21	.43	.23	2.82*
Animation					1.03	.43	.20	2.40*
Step 3:	.09	.07	.00	4.47*				
Representation					1.21	.43	.23	2.82*
Animation					1.02	.43	.20	2.38*
Representation X Animation					-.12	.43	-.02	-.27
Step 4:	.15	.13	.06	5.81**				
Representation					1.01	.42	.20	2.38*
Animation					.97	.42	.19	2.32*
Representation X Animation					.09	.42	.02	.21
Time-on-task					.01	.00	.25	3.00*

\*\* $p < .001$ , \* $p < .05$

## 4.10 Discussion

This study examined the effects of representation (concept map or text) and animation (animated or static) among university students studying the human nervous system in a computer-based learning environment. The results support the first and second hypotheses that concept maps are superior to text presentations as visual supplements to audio narration. Specifically, the animated concept map group outperformed the animated text group on the posttests (free recall and transfer tests). Similarly, the static concept map group outperformed the static text group on free recall and transfer posttests. The differences between groups' means on the posttests followed a similar pattern, showing higher means for the map groups and lower means for the text groups. However, on the knowledge test, only the difference between the animated map and static text presentations was statistically detected. On the recall, transfer and knowledge posttests, a pattern showing larger effect sizes for the animated concept map versus text presentations was observed suggesting that animated concept maps offer educationally significant learning benefits over and above that afforded by learning with text. Overall, these results are consistent with findings from past studies that show advantages of learning with concept maps relative to text (Blankenship & Dansereau, 2000; Hall, Dansereau, & Skaggs, 1992; Lambiotte & Dansereau, 1992; Nesbit & Adesope, 2006; in press; Newbern, Dansereau, & Patterson, 1997; O'Donnell, 1993; O'Donnell, Dansereau, & Hall, 2002; Rewey, Dansereau, & Peel, 1991).

Contrary to the third prediction, no statistically detectable difference was detected between the animated and static concept map groups. This is surprising because it was

anticipated that animation would sequentially focus learners' attention on small portions of the concept map thereby reducing the likelihood that any nodes or links are missed or redundantly revisited. I speculate that the absence of detectable differences between the animated and static concept maps may be due to the low complexity of the maps used in this study. It is possible that under conditions involving more complex concept maps with additional nodes and links, as demonstrated in Blankenship and Dansereau's (2000) study, the advantages of animation may be more apparent. Another plausible reason for the absence of detectable advantages for animated concept maps is that the audio narration and the animation may have a similar guiding effect. If this were the case, in this research design the audio narration common to all conditions would have eliminated the advantage of animating the concept map.

Consistent with the fourth prediction, there were no differences between animated and static text presentations on the posttests. The advantages associated with animation occurred only with concept maps and not with text. Typically, text offers a well-established processing route (i.e., left to right, and top to bottom) with ideas chunked in the form of paragraphs. These inherent characteristics of typical text may have limited the value of using animation to reduce incomplete processing and increase chunking (Blankenship & Dansereau, 2000).

Consistent with the fifth prediction, no interaction between idea type (central or detail) and treatment was detected, indicating that the benefits of learning with concept maps accrued in a similar fashion for both central and detail knowledge. Participants studying animated and static concept maps with concurrent audio recalled more central ideas and detail ideas than participants studying animated and static text presentations

with concurrent audio. I also found that participants recalled a greater proportion of central ideas than detail ideas. These results are consistent with previous findings that reported advantages of using concept maps to recall central and detail ideas better than text, and the affordance of concept maps to recall a greater proportion of central ideas than detail ideas (Blankenship & Dansereau, 2000; Lambiotte & Dansereau, 1992; Nesbit & Adesope, 2006; in press). It may be that the spatial structure of concept maps, especially when animated, can make the central ideas and their relationships more apparent than it would be with text presentations.

Contrary to the sixth prediction, no statistically detectable difference was detected between the groups on subjective evaluation of the multimedia presentations. Specifically, students did not perceive the animated concept map as more motivating or useful for learning than static concept map. This may be due to the novelty effect of concept mapping materials. Specifically, majority of participants in this study reported that concept maps (either animated or static) are new learning tool for them.

Consistent with the seventh prediction, time-on-task was a statistically detectable predictor of posttest scores. This result corroborates previous research showing that time-on-task was a good predictor of achievement (Berliner, 1990; Louw, Muller, J., & Tredoux, 2008; Stallings, 1980).

## **CHAPTER 5: GENERAL DISCUSSION AND CONCLUSION**

This chapter presents a general discussion of results of the verbal redundancy meta-analysis and animated concept map studies in light of prior research. The chapter is organized under four main sections. The first section discusses the theoretical contributions of the two studies reported in this dissertation by examining how concept maps with audio narration may be viewed as low-level redundant presentations. The second section discusses the practical implication of the studies to students and instructional designers. In the third section, limitations of the studies and opportunities for future research are discussed. The last section concludes with a discussion of how the studies advance previous research on verbal redundancy and concept map presentations for learning.

### **5.1 Theoretical Implications: Concept Maps with Audio Narration as Low-Level Redundancy**

In classic verbal redundancy studies, learners are presented with text and verbatim audio narration, that is, the text is a word-for-word representation of the audio narration (Mayer, 2005b, Moreno & Mayer, 2002a; Sweller, 2005). Such presentations are referred to as high-level redundancy. More recently, researchers have manipulated the level of verbal redundancy in multimedia presentations to investigate the effect of learning with varying degrees of redundant materials. For example, Le Bohec and Jamet (2008)

examined the use of the same multimedia slide show with three conditions: (a) full-text and totally redundant audio delivery, (b) partial-text (bulleted) with full-audio delivery, or (c) no text (graphics only) with full-audio delivery. They found that learners presented with partial (bulleted text with full audio) redundant materials outperformed those who learned with full-text and totally redundant audio.

In another study, Mayer and Johnson (2008) found that, across two experiments, students who learned with presentations that included short redundant phrases of 2-3 printed words that conveyed the main ideas in the narration outperformed students who learned with non-redundant materials that did not include on-screen text on a test of retention ( $d = .47$  and  $d = .70$ , respectively). These results predict that presentations with low-level redundant materials that use summary of narrated segments as text may potentially enhance learning more than high-level redundant presentations examined in many classical verbal redundancy studies. I henceforth refer to this prediction as the low-level redundancy hypothesis.

One plausible explanation why low-level redundant presentations might be beneficial for learning is that such presentations help students focus attention on relevant idea units by reducing the superfluous division of attention between the information sources (Le Bohec & Jamet, 2008). In other words, low-level redundant presentations enhance learning by signaling or directing learners' attention to relevant ideas in a passage. Researchers have observed that signaling is used "to guide the search for specific information and to simplify decisions the reader may have to make about which information is relevant" (Mautone & Mayer, 2000, p. 378).



Results of the two studies reported in this dissertation confirmed and extended the low-level redundancy hypothesis in multimedia learning. In the meta-analysis of verbal redundancy presented in Chapter 3, studies that exhibited low-level of redundancy produced a statistically detectable moderate-sized effect. Post hoc analyses showed that low-level redundancy studies produced statistically detectable higher effect sizes than high-level redundancy studies suggesting an advantage of learning with low-level redundant multimedia materials. Similar results were found in the concept map study reported in Chapter 4. Students who learned with computer-based animated or static concept maps with redundant audio narration (which can be classified as low-level redundant presentations) had higher posttest scores than students who learned with computer-based animated or static text presentations with audio narration (which can be classified as high-level redundant presentations). Classifying concept maps with audio narration as a form of redundancy significantly extends the low-level redundancy hypothesis and brings to bear another explanation of the findings of this dissertation. Conventionally, concept maps represent information with simple terms (consisting of few words or concepts in nodes) and visual cues that clearly reveal complex semantic relationships. Because of these inherent characteristics of concept maps, they can be classified as low-level redundant materials when presented with audio narration. It is possible that the visual differentiation of concepts in nodes signaled their importance, leading participants to focus more attention on the corresponding spoken words and thereby assist them to more meaningfully interpret the material.

Overall, the pattern of results found in the concept map study is consistent with the predictions of the cognitive theory of multimedia learning (Mayer, 2001, 2005a),

especially the notion that learning is facilitated when important concepts are signaled. The signaling technique minimizes redundant and incomplete processing of concept maps by guiding learners through the visual complexity of the maps. This helps students in (a) avoiding extraneous processing that may occur through needless revisiting of nodes, (b) managing essential processing by directing attention thereby encouraging learners to develop and express a rhetorical interpretation of the passage as it is being developed, and (c) fostering generative processing by organizing the material such that learners may be able to more easily relate it to prior knowledge.

## **5.2 Practical Implications**

Results of the studies reported in this dissertation have direct practical implications. Results of the verbal redundancy meta-analysis showed that students who learned from redundant multimedia presentations outperformed those who learned from non-redundant presentations but this effect depended on learners' prior knowledge, pacing of learning materials, and inclusion of animation or diagrams. Specifically, verbal redundancy benefited low prior knowledge learners exposed to system-paced learning materials provided there were no concurrently presented animations or images. Instructional designers may use these results to inform pedagogical practices in the delivery of verbally redundant multimedia learning materials.

The main contribution of the experimental study is to provide evidence that the learning advantages of animated concept maps over text found by Blankenship and Dansereau (2000) are upheld when the visual materials are supplemented by audio

narration and learners are able to control pacing of the animation. These results have practical implications for students, teachers and instructional designers who work with multimedia materials. On a practical level, these results suggest caution in the use of learner-paced concept maps with audio narration. The experiment did not examine the effects of learning with concept maps without audio narration and learning-pacing, thus I caution that the results do not constitute direct empirical support for the addition of these features to animated concept maps.

Although several computer-based software applications (e.g., *CMapTools*, *gStudy*, *Inspiration*, *MindMapper*) have been developed to allow students to dynamically manipulate concept maps and perform annotation, searching and other cognitive operations (Chang, Sung, & Chen, 2002; Lee et al., 2006; Perry & Winne, 2006; Wikipedia, 2009; Winne et al., 2006), none of these software applications provide learners with the capability to deploy animated concept maps as a form of narrative presentation. It is anticipated that the results of this study as well as those of Blankenship and Dansereau (2000) and Nesbit and Adesope (in press) may provide sufficient basis for instructional designers to explore the use of animated concept maps in multimedia learning resources.

Although many previous studies, including the present one, found no statistically detectable difference between animated and static presentations (ChanLin, 1998; Tversky et al., 2002), an important contribution of the present study is that it is the first to compare the use of animated and static concept maps with redundant audio narration for learning. Instructional designers, teachers and students should not interpret the result of this study to mean that animated concept maps are ineffective compared with static

concept maps. Indeed, I found some benefits, albeit not statistically detectable, of learning with animated concept maps compared with static concept maps.

The results of this study showed statistically detectable advantages of learning with concept maps over text. Nevertheless, instructional designers should consider appropriate ways of varying the presentation features used in this research to maximize the potential of animated concept maps. For example, it is possible that learners might first advance through the animated narrative and then review the concept map by focusing attention on concepts and relationships that were not fully understood. Also, in some cases, concept map elements may be semantically isomorphic to the narration, and in other cases they may summarize the narrative content. Instructional designers are encouraged to adapt this new animated concept map medium based on an understanding of how students learn from varying features of concept maps.

### **5.3 Limitations and Future Research Directions**

The meta-analysis of verbal redundancy has some limitations. While evidence was found for factors that appear to moderate the overall effect of presenting verbally redundant materials, there is a considerable need for further research to refine our understanding of these moderating effects. Especially, more studies are needed on the use of short summary phrases as on-screen text and to determine the broader, long term effects of such forms of low-level redundancy.

Furthermore, most of the studies reviewed involved participants with low prior knowledge. More research is needed to examine if an expertise reversal effect (Kalyuga,

2007) would be obtained when learners' level of expertise in the subject domain increases. Also, it was observed that there is limited research on the affective and motivational dimensions of verbal redundancy. Additional research that examines the affective and motivational effects of presenting learners with verbally redundant materials is needed.

Most of the studies on verbal redundancy were conducted with undergraduate students. There is a limited understanding of the learning effectiveness of redundant speech and text for students in K-12. More high quality studies on the usefulness of verbal redundancy with this group of learners are required. The brevity of instructional treatment was also noted, as many of the studies relied on treatment duration of under an hour. Investigations with longer instructional treatments as well as with students across educational levels and of different verbal abilities, especially early readers, would enhance the generalizability of a meta-analytical review such as this.

One viable area where verbally redundant materials may be especially useful is in the presentation of accessible materials for disabled learners, especially those who are visually impaired or have cognitive barriers that restrict their ability to read text on the screen. Such learners need assistive technology devices with text-to-speech functionality that reads the text on a screen out to the users. Studies with such learners are needed to investigate the effects of verbal redundancy. Finally, meta-analytical studies need to move beyond only the reporting of effect sizes to the practical and policy implications of the effect sizes derived. In corroborating Ginns' (2005) view, the field of multimedia learning would benefit from cost-benefit analyses (Cascio, 2000) of presenting graphics with verbally redundant audio narration and on-screen text compared with only graphics

and audio narration. This may determine at which point the “learning gains more than offset the extra resources” (p. 328), in time and money, that are required to create verbally redundant materials.

Similarly, interpretation of the results of the animated concept map experiment is subject to several important limitations. The study took place in a laboratory environment, involved university students, used short presentations, and employed an immediate test. The robustness of the effects should be examined in more authentic learning environments. Future studies are needed to determine whether the effects obtained in this experimental study will extend to a variety of content areas (e.g., procedural subject matter like how to ride a bike or other declarative subject matter like the human circulatory systems) and types of learners (i.e., other than university students). For example, animated concept maps may be particularly effective for students who possess little prior knowledge of the subject matter but have been considerably exposed to the use of concept maps (Nesbit & Adesope, in press).

Participants in this study were students with a variety of majors, suggesting that, to a certain extent; they were a representative sample of university students. Consistent with the research on the expertise reversal effect (Kalyuga, 2007; Kalyuga, Ayres, Chandler, & Sweller, 2003), which has found differential impact of learning materials depending on learner’s level of prior knowledge, I conjecture that learners with less prior knowledge may obtain greater benefit from concept maps. Future research should investigate the mediating role of learner’s level of prior knowledge on learning with animated and static concept maps.

The generalizability of this study is restricted by the brevity of the instructional treatment, which lasted only 10 minutes. It is possible that under more realistic conditions involving several sessions of greater length, learners would modify their strategies in some ways that may eliminate the type of differences observed among treatment groups. As the intervention in this experiment was brief, future work is needed to determine whether the findings would generalize to the long term use of concept maps as a form of digital multimedia.

This research compared on-screen concept maps with on-screen text. Thus, the results do not directly indicate that on-screen concept maps are more instructionally effective than printed text. Future research should contrast the cognitive effects of learning from on-screen concept maps and printed text.

What could have accounted for the unexpected finding of no statistically detectable differences between animated and static concept maps? I speculate that audio narration and animation may have a similar guiding effect and that the guidance offered by the narration masked the benefit from animation. To empirically test this conjecture, future research is needed that assesses whether the presence of audio narration moderates an animation effect. To further examine their viability as effective tools for communication and learning, researchers need to compare the effectiveness of animated and static concept maps under the condition where the maps have greater structural complexity.

Although animated and static concept maps were compared in this study, the research raises but does not fully address questions about the degree and type of cognitive load introduced by concurrent presentation of node-link images and semantically

equivalent audio narration. I hypothesize that the use of a static concept map with semantically equivalent audio narration can potentially introduce extraneous cognitive load. For example, when a static concept map is accompanied by audio narration, learners must search through the static concept map in order to establish a link between what they hear in the audio being narrated and what they see in the statically displayed map. There is repeated evidence in other multimedia contexts (Mayer, 2001; Mayer & Anderson, 1992; Mayer & Sims, 1994) that this searching process is facilitated if the two sources of information (audio narration and static map) are presented concurrently. But this concurrent presentation, also identified as temporal contiguity of the two sources (Mayer, 2001, 2009), may disappear with complex static concept maps because learners may not be able to sufficiently quickly establish a link between the audio narration and the complex static map. Conversely, presentations with animated concept maps that visually signal each proposition (node-link-node) referred to in the audio narration may facilitate cognitive processes involved in the selection of relevant information and allow a more efficient cognitive integration and processing of the sources. Although I hypothesize that concurrent presentation of animated concept maps and semantically equivalent audio narration may produce germane cognitive load resulting in enhanced learning, the inability to find statistically detectable differences between animated and static concept maps with audio narration somewhat undermines this prediction.

It appears that a fuller understanding of the cognitive effects of animated concept maps will follow from research that varies the type of cognitive load they induce by adjusting the informational properties of the auditory and visual information sources. Future research may also deploy eye-tracking methodologies (Korner, 2004; Morris,



1994; Pelz & Canosa, 2001; Rayner, 1998; Rudmann, McConkie & Zheng, 2003; Salvucci, 2000; Sereno & Rayner, 1992) to more carefully examine differential pattern of eye movements, fixations and saccades between students learning through static and animated concept maps with audio narration. Fixations refer to periods in which the eyes remain relatively still. Saccades are eye movements that occur between fixations (Rayner, 1998). These ocular behaviors can inform researchers about human attention, shifts in attention and the order of cognitive operations (Hegarty, 2006; Henderson, 2003). For example, there is research evidence showing that pupil dilation (Van Gerven, Paas, Van Merriënboer, & Schmidt, 2004), and fixation duration (Underwood, Jebbett, & Roberts, 2004) increase with increased processing demands (task difficulty), whereas the length of saccades decreases (Amadiou, van Gog, Paas, Tricot, & Marine (2009). Future research can gain substantially by merging eye tracking and trace methodologies (objective techniques) with self-report inventories (subjective techniques) for collecting data about extraneous cognitive load.

## **5.4 Conclusion**

Despite its limitations, this dissertation offers some advances over previous research on verbal redundancy and animated concept maps (Moreno & Mayer, 2002a; Blankenship & Dansereau, 2000). First, this is the only meta-analysis that investigates the different factors that moderate learning with verbally redundant presentations. Second, to the best of my knowledge, this is the first experimental study that logged participant interaction (operationally defined as time spent viewing each animated slide) with multimedia materials while learning with concept maps. Previous studies have either used

paper and pencil format or computers but did not capture any process data to more carefully examine whether and how participants interacted with the animated materials. Third, the concept map study measured learning by using transfer and retention outcomes, rather than retention (free recall) only outcome used in the Blankenship et al. (2000) paper. This allowed me to measure learning outcomes in terms of depth of understanding rather than simply through amount of information recalled. Fourth, the experiments involved self-paced instruction presented on a computer (i.e., multimedia flash presentations with audio narration) rather than paper-based material alone or system-paced instruction projected on a screen (Blankenship et al., 2000). This allowed me to determine whether the effects of learning with concept maps are robust across various presentation media.

In sum, this dissertation contributes significantly to the use of redundant multimedia materials for learning by bringing together research on concept maps, text, static versus dynamic media, audio narration and verbal redundancy. The results from this work can help instructional designers, teachers and students to more accurately evaluate the use of redundant multimedia materials for teaching and learning.

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*References marked with an asterisk indicate studies included in the meta-analysis.*

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## APPENDICES

### Appendix A. Coding Form

#### Section A: Reference Information

A.1 Name of the Reviewer	A.1.1 Details
A.2 Date of the Review	A.2.1 Details
A.3 Please enter details of the paper	A.3.1 Author[s] (last name, first name) A.3.2 Year of publication
A.4 Contrast description presentations to experimental and control groups	A.4.1 Details
A.5 Source	A.5.1 Journal A.5.2 Conference Proceedings A.5.3 Book Chapter A.5.4 Dissertation A.5.5 Other [please specify]
A.6 In what country was the study conducted?	A.6.1 USA A.6.2 Canada A.6.3 United Kingdom A.6.4 Australia / New Zealand A.6.5 China/Taiwan A.6.6 France/Netherlands A.6.7 Mixed groups

## Section B: Study Research Questions

<p><b>B.1 What is the theoretical/empirical basis for this study?</b>  <i>Please write in author's description if there is one. Elaborate if necessary, but indicated which aspects are reviewer's interpretation.</i></p>	<p>B.1.1 Explicitly stated (please specify)            B.1.2 Implicit (please specify)            B.1.3 Not stated/unclear (please specify)</p>
--	---

## Section C: Sample Information

<p><b>C.1 What was the total number of participants in the study (the actual sample)?</b></p>	<p>Please specify</p>
<p><b>C.2 What is the grade range of the participants?</b></p>	<p>C.2.1 Grades K-3  <i>(5-8 years old) – Primary</i>            C.2.2 Grades 4-8  <i>(9-13 years old) - Intermediate</i>            C.2.3 Grades 9-12  <i>(14-18 years old)-High School</i>            C.2.4 Post-secondary            (Undergraduate/Graduate/Technical)            C.2.5 Other (please specify)            C.2.6 Not Stated</p>
<p><b>C.3 What is the <b>prior domain knowledge</b> of the participants?</b></p>	<p>C.3.1 Low            C.3.2 High            C.3.3 Varied            C.3.4 Unknown</p>

<p>C.4 What is the <b>reading fluency</b> of the participants?</p>	<p>C.4.1 Fluent L1  C.4.2 Early L1  C.4.3 L2  C.4.4 Mixed</p>
--	---

**Section D: Conditions & Treatment**

<p>D.1 What is the setting of the study?</p>	<p>D.1.1 Classroom  D.1.2 Laboratory  D.1.3 Pull-out room  <i>(for instance, a resource room or another room within a school)</i>  D.1.4 Other  <i>Please specify</i></p>
<p>D.2 Media</p>	<p>D.2.1 Computer  D.2.2 Paper  D.2.3 Video Projector  D.2.4 Lecture  D.2.5 Mixed media  D.2.6 Not stated/Unclear (please specify)</p>
<p>D.3 Images  <i>(Did the source material include images?)</i></p>	<p>D.3.1 Yes  D.3.2 No  D.3.3 Not stated/Unclear (please specify)</p>
<p>D.4 Animation  <i>(Did the source material include animations?)</i></p>	<p>D.4.1 Yes  D.4.2 No  D.4.3 Not stated/Unclear (please specify)</p>
<p>D.5 Form of Audio</p>	<p>D.5.1 Recorded/Narrated Audio  D.5.2 Live audio (e.g., lecture)  D.5.3 Not stated/Unclear (please specify)</p>

<p><b>D.6 Participant Interaction</b>  <i>(Indicate how participants interacted while performing the task)</i></p>	<p>D.6.1 Individual  D.6.2 Group  D.6.3 Mixed (please specify)  D.6.4 Not stated/Unclear (please specify)</p>
<p><b>D.7 Content Domain</b></p>	<p>(please specify)</p>
<p><b>D.8 Pacing of information</b></p>	<p>D.8.1 Learner-paced  D.8.2 System-paced  D.8.3 Not stated/Unclear (please specify)</p>
<p><b>D.9 Level of Redundancy</b>  <i>(This is coded high when there is almost total correspondence between the narration and on-screen text, i.e. when the on-screen text reproduces the complete narration. It is coded low when summaries of narrated segments are used as on-screen text instead of complete isomorphism between the narration and on-screen text)</i></p>	<p>D.9.1 High  D.9.2 Low  D.9.3 Not stated/Unclear (please specify)</p>

## Section E: Research Design

<p>E.1 What is the design of the study</p>	<p>E.1.1 Randomly selected/assigned with treatment and control groups</p> <p>E.1.2 Non-randomized with treatment and control groups <i>How were the groups assigned/created?</i></p> <p>E.1.3 Other (please specify)</p>
<p>E.2 How do the groups differ?</p>	<p>E.2.1 Explicitly stated (please specify)</p> <p>E.2.2 Implicit (please specify)</p> <p>E.2.3 Not stated/unclear (please specify)</p>
<p>E.3 Duration of whole study <i>(Includes, pretest, training, treatment &amp; posttest)</i></p>	<p>(please specify)</p>
<p>E.4 Duration of treatment</p>	<p>(please specify)</p>
<p>E.5 Nature of control</p>	<p>(please specify)</p>
<p>E.6 Attrition: How many participants left before the end of the study? <i>If more than one group, please give numbers for each group.</i></p>	<p>(please specify)</p>
<p>E.7 Treatment fidelity <i>(e.g. extent to which groups were monitored for reliability of treatments)</i></p>	<p>E.7.1 Low (please specify)</p> <p>E.7.2 Medium (please specify)</p> <p>E.7.2 High (please specify)</p> <p>E.7.3 Not stated/unclear (please specify)</p>
<p>E.8 Control for prior differences</p>	<p>E.8.1 Random assignment (please specify)</p> <p>E.8.2 Matching of students (please specify)</p> <p>E.8.2 Covariates (please specify)</p> <p>E.8.3 Not stated/unclear (please specify)</p>
<p>E.9 Do the authors describe strategies used to control for bias from confounding variables and groups? <i>Please include information on: Were the groups similar at the start of the trial on factors like-</i></p>	<p>E.9.1 Age (please specify)</p> <p>E.9.2 Gender (please specify)</p> <p>E.9.3 Social class (please specify)</p> <p>E.9.4 Other (please specify)</p> <p>E.9.5 Not stated/Unclear</p>

## Section F: Recruitment and Consent

<p>F.1 Which methods are used to recruit people into the study ?  <i>e.g. letters of invitation, telephone contact, face-to-face contact.</i></p>	<p>F.1.1 Letter of invitation  F.1.2 Telephone contact  F.1.3 Other (please specify)  F.1.4 Not applicable (please specify)  F.1.5 Not stated/unclear (please specify)</p>
<p>F.2 Were any incentives provided to recruit people into the study?</p>	<p>F.2.1 Not applicable (please specify)  F.2.2 Explicitly stated (please specify)  F.2.3 Not stated/unclear (please specify)</p>
<p>F.3 Whose consent was sought?  <i>Please comment on the quality of consent if relevant</i></p>	<p>F.3.1 Participants  F.3.2 Parental consent  F.3.3 Other (please specify)  F.3.4 No consent was sought  F.3.5 Not stated / unclear (please specify)</p>

## Section G: Dependent Variable

<p>G.1 Type of Construct <i>(check all that apply)</i></p>	<p>G.1.1 Retention  G.1.2 Transfer  G.1.3 Mixed retention and transfer  G.1.4 Attitudinal (please specify)  G.1.5 Other (please specify)  G.1.6 Not stated / unclear (please specify)</p>
<p>G.2 Test format and information <i>(check all that apply)</i></p>	<p>G.2.1 Free recall  G.2.2 Objective items  G.2.3 Short-answer items  G.2.4 Various item types (please specify)  G.2.5 Other (please specify)  G.2.6 Not stated / unclear (please specify)</p>
<p>G.3 What measurement tool(s) is used?</p>	<p>G.3.1 Standardized test  <i>Please provide the name of the test if listed.</i>  G.3.2 Researcher developed test  <i>Please describe and give page number</i>  G.3.4 Other  <i>Please describe and give page number</i></p>
<p>G.4 Do the authors describe any ways they addressed the reliability of their data collection tools/methods?  <i>e.g. inter-rater reliability</i></p> <p><i>(Where more than one tool was employed, please provide details for each.)</i></p>	<p>G.4.1 Details</p>
<p>G.5 Do the authors describe any ways they have addressed the validity of their data collection tools/methods?  <i>e.g. mention previous validation of tools, published version of tools.</i></p> <p><i>(Where more than one tool was employed, please provide details for each.)</i></p>	<p>G.5.1 Details</p>

## Section H: Effect Size Computation and Conclusion

<p>H.1 What are the results of the study as reported by the author(s)?  <i>Please give details and refer to page numbers in the article, where necessary (e.g. for key tables).</i></p>	<table style="width: 100%; border-collapse: collapse;"> <thead> <tr> <th style="width: 50%;"></th> <th style="width: 25%; text-align: center;">Experimental group</th> <th style="width: 25%; text-align: center;">Control</th> </tr> </thead> <tbody> <tr> <td>group</td> <td></td> <td></td> </tr> <tr> <td>Means:</td> <td></td> <td></td> </tr> <tr> <td>SD:</td> <td></td> <td></td> </tr> <tr> <td>N:</td> <td></td> <td></td> </tr> <tr> <td>Biased effect size:</td> <td></td> <td></td> </tr> <tr> <td>Unbiased effect size:</td> <td></td> <td></td> </tr> <tr> <td>Pooled SD:</td> <td></td> <td></td> </tr> <tr> <td>Researcher's confidence in effect size: <b><i>Low, medium or High</i></b></td> <td></td> <td></td> </tr> <tr> <td>F, t statistic:</td> <td></td> <td></td> </tr> <tr> <td>Significance: <b><i>Yes, No, or Not specified</i></b></td> <td></td> <td></td> </tr> </tbody> </table>		Experimental group	Control	group			Means:			SD:			N:			Biased effect size:			Unbiased effect size:			Pooled SD:			Researcher's confidence in effect size: <b><i>Low, medium or High</i></b>			F, t statistic:			Significance: <b><i>Yes, No, or Not specified</i></b>		
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Unbiased effect size:																																		
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F, t statistic:																																		
Significance: <b><i>Yes, No, or Not specified</i></b>																																		
<p>H.2 Are there any shortcomings in the reporting of the data?  <i>Please list all implicit and explicit shortcomings of the study.</i></p>	<p>H.2.1 Yes (please specify)</p> <p>H.2.2 No</p>																																	
<p>H.3 What do the author(s) conclude about the findings of the study?  <i>Please give details and refer to page numbers in the study, where necessary.</i></p>	<p>H.3.1 Details</p>																																	
<p>H.4 General Remarks</p>	<p>H.4.1 Details</p>																																	



## **Appendix B. Advertisement**

### **Participate in a Study Strategy Research. Earn \$15, or \$50.**

Help to advance the field of learning! Upon arrival, you will be asked to complete a questionnaire and study a short passage.

After completing some test questions, you will be paid \$15 for your time. Top scorer on the test will be paid an additional \$35 at the end of the study.

Where: SFU labs (Both Surrey and Burnaby campuses)

When: Mondays through Saturdays (days and evenings)

Time: By appointment (book now for your preferred date and time)

Duration: ~ 1 hour

Interested? Contact Sola at [ooa@sfu.ca](mailto:ooa@sfu.ca) with your preferred dates and times.

## Appendix C. Ethics Approval



February 27, 2008

street address  
Simon Fraser University  
Multi-Tenant Facility  
Room 230, 8900 Nelson Way  
Burnaby, B.C. Canada  
V5A 4W9

Olusola Adesope  
Graduate Student  
Faculty of Education  
Simon Fraser University

mailing address  
8888 University Drive  
Multi-Tenant Facility  
Burnaby, B.C. Canada  
V4A 1S6

Dear Olusola:

**Re: The Effects of Redundant Audio Narration on Learning  
with Animated Concept Maps - Appl. #: 38708**

I am pleased to inform you that the above referenced Request for Ethical Approval of Research has been approved on behalf of the Research Ethics Board. This approval is in effect until the end date February 21, 2011, or only during the period in which you are a registered SFU student.

The Office of Research Ethics must be notified of any changes in the approved protocol. Request for amendments to the protocol may be requested by email to [dore@sfu.ca](mailto:dore@sfu.ca). In all correspondence relating to this application, please reference the application number shown on this letter and all email.

Your application has been categorized as "minimal risk" and approved by the Director, Office of Research Ethics, on behalf of the Research Ethics Board in accordance with University policy R20.01, <http://www.sfu.ca/policies/research/r20-01.htm>. The Board reviews and may amend decisions or subsequent amendments made independently by the Director, Chair or Deputy Chair at its regular monthly meetings.

.../2

The logo for Simon Fraser University (SFU), consisting of the letters "SFU" in white on a black rectangular background.

OFFICE OF  
RESEARCH ETHICS

Page 2

"Minimal risk" occurs when potential participants can reasonably be expected to regard the probability and magnitude of possible harms incurred by participating in the research to be no greater than those encountered by the participant in those aspects of his or her everyday life that relate to the research.

Please note that it is the responsibility of the researcher, or the responsibility of the Student Supervisor if the researcher is a graduate student or undergraduate student, to maintain written or other forms of documented consent for a period of 1 year after the research has been completed.

If there is an adverse event, the principal investigator must notify the Office of Research Ethics within five (5) days. An Adverse Events form is available electronically by contacting [dore@sfu.ca](mailto:dore@sfu.ca).

Please note that all correspondence with regards to this application will be sent to your SFU email address.

Best wishes for success in this research.

Sincerely,

## **Appendix D. Informed Consent Forms**

### **Informed Consent By Participants In a Research Study**

The University and those conducting this research study subscribe to the ethical conduct of research and to the protection at all times of the interests, comfort, and safety of participants. This research is being conducted under permission of the Simon Fraser Research Ethics Board. The chief concern of the Board is for the health, safety and psychological well-being of research participants.

Should you wish to obtain information about your rights as a participant in research, or about the responsibilities of researchers, or if you have any questions, concerns or complaints about the manner in which you were treated in this study, please contact the Director, Office of Research Ethics by email at [hweinber@sfu.ca](mailto:hweinber@sfu.ca) or phone at 778-782-6593.

Your signature on this form will signify that you have received a document which describes the procedures, whether there are possible risks, and benefits of this research study, that you have received an adequate opportunity to consider the information in the documents describing the study, and that you voluntarily agree to participate in the study.

---

Title: The Effects of Redundant Audio Narration on Learning with Animated Concept Maps

Investigator Name: Olusola Adesope

Investigator Department: Faculty of Education

---

Having been asked to participate in the research study named above, I certify that I have read the procedures specified in the Study Information Document describing the study. I understand the procedures to be used in this study and the personal risks to me in taking part in the study as described below:

Purpose and goals of this study:

This study is designed to investigate how students learn using concept maps compared with text and with animated material compared with static material.

What the participants will be required to do:

Participants in this study will be required to study a material on organization and functions of human nervous system. Participants are then required to recall and apply information gained from the material. Participation involves agreement to release these data for research purposes.

Risks to the participant, third parties or society:

There are no risks to participants or others

Benefits of study to the development of new knowledge:

This study will contribute to researchers' understanding of the cognitive processes underlying learning with different formats of concept maps and texts and also help teachers and instructional designers to prepare learning materials with concept maps in a way that will be beneficial for students' learning.

Statement of confidentiality: The data of this study will maintain confidentiality of your name and the contributions you have made to the extent allowed by the law.

The data released in this study will maintain confidentiality of your name and the contributions you have made to the extent allowed by the law. Data released to the researcher will be confidential and no information that could possibly identify the participant will be reported or released to others. To ensure confidentiality, usernames are used to identify participants and the kind of intervention (map or text) they received during the study. Also, information submitted by participants will be communicated over a secured website located at SFU-Burnaby. Website is:  
<http://www.learningkit.sfu.ca/site/pages/software/webq/index.html>

Interview of employees about their company or agency:

n/a

Inclusion of names of participants in reports of the study:

All identifying information including participants' names will NOT be used or included in reports of the study

Contact of participants at a future time or use of the data in other studies:

n/a

I understand that I may withdraw my participation at any time. I also understand that I may register any complaint with the Director of the Office of Research Ethics.

Dr. Hal Weinberg  
Director, Office of Research Ethics  
Office of Research Ethics  
Simon Fraser University  
8888 University Drive  
Multi-Tenant Facility  
Burnaby, B.C. V5A 1S6  
hal\_weinberg@sfu.ca

I may obtain copies of the results of this study, upon its completion by contacting:

Olusola Adesope Faculty of Education, Simon Fraser University, 8888 University Drive, Burnaby, BC, Canada, V5A 1S6. Email: ooa@sfu.ca.

I understand the risks and contributions of my participation in this study and agree to participate:

The participant and witness shall fill in this area. Please print legibly

Participant Last Name:	Participant First Name:
<input type="text"/>	<input type="text"/>
Participant Contact Information:	
<input type="text"/>	
Participant Signature (for adults):	Witness (if required by the Office of Research Ethics):
<input type="text"/>	<input type="text"/>
Date (use format MM/DD/YYYY)	Contact at a future time / use of data in other studies
<input type="text"/>	<input type="text"/>

## Appendix E. Guidelines for all Participants

There are 8 things to do in this study. Please follow the guidelines sequentially in order to successfully complete the research. As much as possible, please adhere to the maximum time allowed.

#	Task	Maximum Time Allowed (minutes)
1.	Sign consent form	1 minute
2.	Click on respond and fill in the “ <b>Background questionnaire</b> ” at <a href="http://142.58.195.208:8080/WQ/jsp/">http://142.58.195.208:8080/WQ/jsp/</a> using your assigned user id and password: cmap. <b>Please do not log out of this tool. When you finish this part, please click Submit.</b>	5 minutes
3.	Click on respond and answer the “ <b>Pretest</b> ” question. <b>When you finish this part, please click Submit.</b>	6 minutes
4.	Double-click on the folder “Study Strategies Research” on your desktop and click on the assigned file. Make sure you wear the headphone on this part of the study. You may adjust the volume appropriately	10 minutes
5.	Attempt the free recall test after listening to the presentation in 4. It is part of the file you listened to in 4	10 minutes
6.	Click on respond and attempt the “ <b>Transfer Test</b> ” also from the web questionnaire tool. <b>When you finish this part, please click Submit.</b>	10 minutes
7.	Click on respond and attempt the “ <b>Multiple Choice &amp; Ratings</b> ” from the web questionnaire tool that you used in 2, 3 & 6. <a href="http://142.58.195.208:8080/WQ/jsp/">http://142.58.195.208:8080/WQ/jsp/</a> . <b>When you finish this part, please click Submit.</b>	17 minutes
8.	Debriefing and Collection of participation fee	1 minute
	TOTAL TIME	60 minutes

## Appendix F. Screenshot of “web questionnaire logon page”



**W?**

**Web Questionnaire**

Welcome to Web Questionnaire, a tool for designing and distributing questionnaires.

Web Questionnaire allows the user to develop new questionnaires, manage multiple projects, quickly edit previously created questionnaires, and distribute them to respondents using a variety of methods. Responses are collected and available to the designer from one easy to manage location.

Login Name

Password

Login

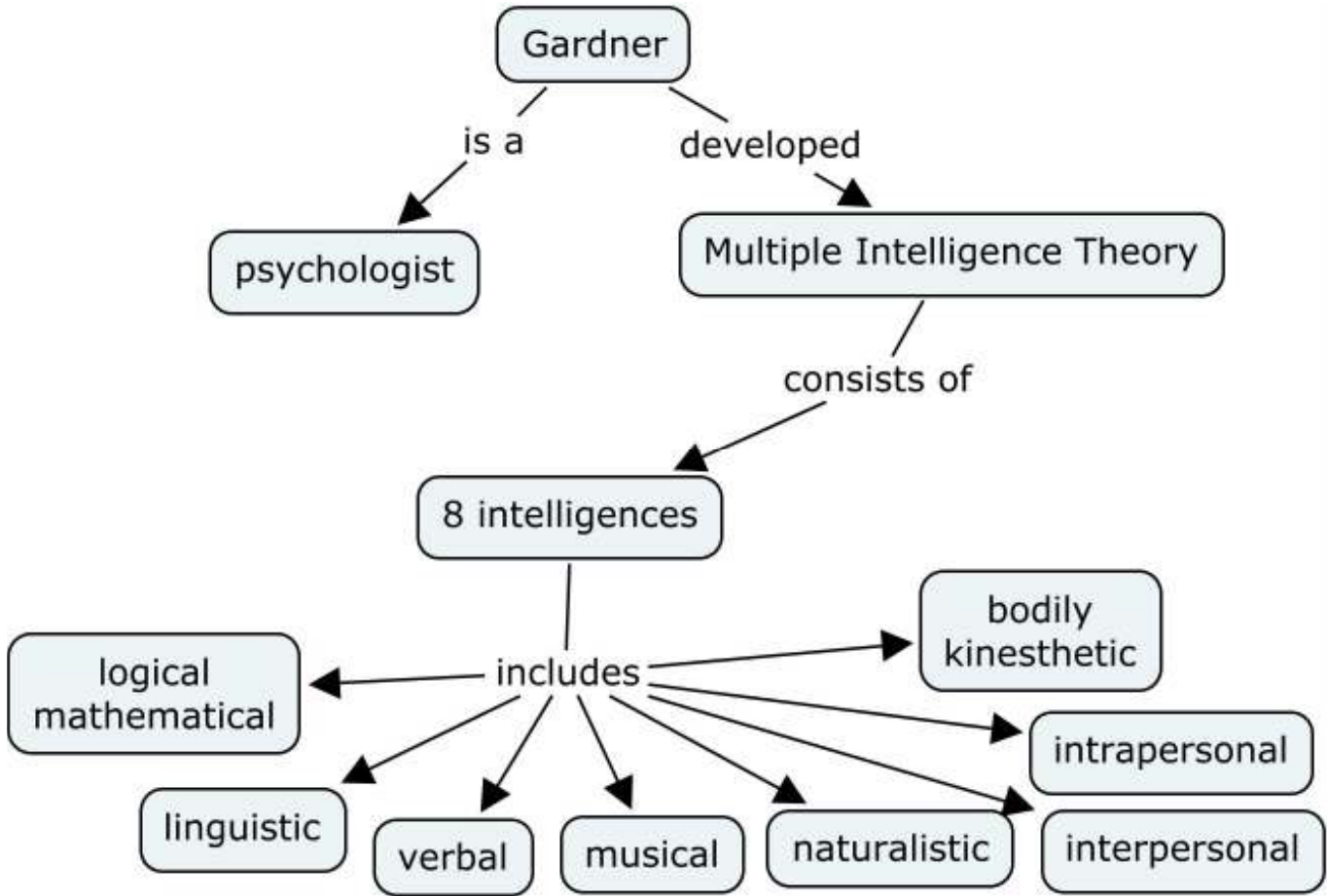
[Login Anonymously](#)





- 11) I \_\_\_\_\_ taken a psychology course before  
 a) have [state year(s) course was taken \_\_\_\_\_]  
 b) have not
- 12) I \_\_\_\_\_ studied the human nervous system before  
 a) have (circle whether in the **university** or **high school** or **both**)  
 b) have not

The picture below shows a sample concept map



Using the following scale, please circle the number that most closely describes your use of concept maps.

1 ----- 2 ----- 3 ----- 4 ----- 5  
 never      rarely      sometimes      often      almost always

- 13) I have previously seen a concept map

1 ----- 2 ----- 3 ----- 4 ----- 5  
 never      rarely      sometimes      often      almost always

14) I have constructed concept maps to study very often

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

15) I often use instructors' or textbooks' already constructed concept maps to study

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

16) I use concept maps to prepare for exams and quizzes

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

17) I use concept maps to help me understand what I read

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

18) I use concept maps as a review strategy to review lectures and notes

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

19) I use concept maps to take notes in class

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

20) I use concept maps to understand and solve problems

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
never rarely sometimes often almost always

21) My interest in learning about the human nervous system

1 - - - - - 2 - - - - - 3 - - - - - 4 - - - - - 5  
Low High

---

After the questionnaire, the pretest is administered

---

**Appendix H. Number of sentences, words, nodes and links introduced visually in each slide of the animations**

Slide	Text Animations (and Audio)		Concept Map Animations (and Audio)		
	Text Material	Words	Concept Map Proposition	New Nodes	New Links
1	The human nervous system is a complex part of the body.	11	The human nervous system is a complex part of the body.	2	1
2	It is divided into two main sub-systems, the central nervous system and the peripheral nervous system.	16	It is divided into two main sub-systems. Includes central nervous system. and peripheral nervous system (15 words)	3	3
3	The spinal cord and the brain make up the central nervous system.	12	Central nervous system consists of brain and spinal cord (9 words)	2	2
4	The peripheral nervous system consists of the somatic nervous system and the autonomic nervous system.	15	The peripheral nervous system consists of somatic nervous system and autonomic nervous system.	2	2
5	The somatic nervous system controls voluntary movements such as hand waving and kicking.	13	The somatic nervous system controls voluntary movements such as hand waving and kicking.	3	3
6	The autonomic nervous system controls involuntary functions such as the heart rate, digestion and other bodily functions.	17	The autonomic nervous system controls involuntary functions such as heart rate, digestion and other bodily functions.	4	4
7	The autonomic nervous system influences physiological arousal and emotions.	9	The autonomic nervous system influences physiological arousal and emotions.	2	2
8	These difficult-to-control reactions are usually called fight-or-flight responses.	8	Physiological arousal are difficult-to-control reactions called fight-	2	2

			or-flight responses.		
9	The autonomic nervous system is divided into two branches called the sympathetic and parasympathetic systems	15	The autonomic nervous system is divided into two branches called the sympathetic and parasympathetic systems	3	3
10	These systems act in opposition to adjust the level of arousal.	11	Sympathetic and parasympathetic systems adjust level of arousal by acting in opposition (12 words)	2	2
11	For example, when there is danger the sympathetic system causes your heart to beat faster; and when the danger passes the parasympathetic system causes your heart to beat slower again.	30	For example, when there is danger the sympathetic system causes your heart to beat faster; and when the danger passes the parasympathetic system causes your heart to beat slower again.	1	1
12	The brain is made up of about 100 billion neurons that integrate information from inside and outside the body and coordinate the body's actions.	24	Brain consists of about 100 billion neurons that helps integrate information from inside and outside the body and coordinate the body's actions.	3	3
13	An adult human brain normally weighs around 3 pounds while a newborn baby's brain weighs a little less than 1 pound.	21	Brain weighs about 3 pounds for adults and 1 pound for newborn	2	2
14	Generally, differences in the weight of adults' brains are not related to differences in mental ability.	16	Brain fact: differences in the weight of adults' brains are not related to differences in mental ability.	1	1
15	The brain can be subdivided into three major parts – the hindbrain, the midbrain and the forebrain.	16	Brain has three major parts called hindbrain, midbrain and forebrain.	4	4

16	The hindbrain consists of the cerebellum, the medulla and the pons.	11	The hindbrain consists of cerebellum, medulla and pons.	3	3
17	The medulla controls unconscious functions, such as breathing, maintaining muscle tone, and regulating circulation.	14	Medulla controls unconscious functions, such as breathing, maintaining muscle tone, and regulating circulation.	4	4
18	The pons contains several clusters of cell bodies involved with sleep and arousal.	13	Pons contains several clusters of cell bodies involved with sleep and arousal.	3	3
19	The cerebellum is involved in the coordination of movement and is critical to the sense of equilibrium, or physical balance.	20	Cerebellum is involved in movement coordination and is critical to equilibrium or physical balance.	2	2
20	The cerebellum is one of the parts of the brain most immediately affected by alcohol.	15	Cerebellum is one of the parts of the brain most immediately affected by alcohol.	1	1
21	The cerebellum is also involved in fine motor skills, such as those involved in writing, typing, and playing a musical instrument.	21	Cerebellum involved in fine motor skills, such as writing, typing, and playing a musical instrument.	4	4
22	Auditory sensations from the left and right ears are processed through the midbrain.	13	Midbrain processes auditory sensation from left and right ears and visual information	2	2
23	The midbrain is also involved in processing visual information, including eye movements, helping you visually locate objects.	17	Midbrain processes visual information, e.g., eye movement. Midbrain helps locate objects.	3	3
24	The forebrain is the largest and most complex part of the human brain encompassing a variety of structures, including the limbic system, thalamus, hypothalamus and cerebrum.	26	Forebrain is the largest and most complex. Forebrain consists of limbic system, thalamus, hypothalamus and cerebrum.	6	6
25	The limbic system consists of an interconnected network of structures involved in the	19	Limbic system controls emotion, motivation, and	3	3

	control of emotion, motivation, and memory.		memory.		
26	Damage to the hippocampus, a part of the limbic system, causes Alzheimer's disease.	13	Limbic system consists of hippocampus. When the hippocampus is damaged, it causes Alzheimer's disease.	2	2
27	Symptoms of this disease include loss of memory and concentration that are controlled by the limbic system.	17	Alzheimer's disease symptoms include loss of memory, thinking and concentration.	3	3
28	The thalamus distributes motor information and sensory information to higher layers of the brain.	14	Thalamus distributes motor information and sensory information to higher layers of the brain.	3	3
29	It is also involved in regulating awareness and motivation.	9	Thalamus regulates awareness and motivation	1	1
30	The hypothalamus regulates the divisions of the autonomic nervous system.	10	Hypothalamus regulates sympathetic and parasympathetic systems	0	2
31	The cerebrum is responsible for complex mental activities such as thought, imagination and problem solving.	15	Cerebrum is responsible for complex mental activities such as thought, imagination and problem solving.	4	4
	Total	481		80	81

## **Appendix I. Free Recall Test Question**

Please write down as much information as you can remember from the learning resource you just studied about the function and organization of the human nervous system.



## Appendix J. Transfer Test Questions

You have 5 minutes to attempt each question (i.e. 10 minutes for the 2 questions). When you finish, press the “Submit” button to send your explanations.

1. Generate one example (different from the example in the material you studied) to show how the divisions of the autonomic nervous system help maintain balance in the human nervous system by acting in opposition. In your example, please explain what could happen if one of the divisions malfunctions?
2. At a treatment center for brain injuries, a patient was reported to have damaged only his forebrain. List 5 tasks the patient might **not** be able to do conveniently because of this injury and state what part of the forebrain is responsible for the inability to carry out your listed task.

## Appendix K. Knowledge (Multiple Choice) Test Questions

Please choose the best answer

1) If Tim saw a snake and his heart started racing, it would be the result of \_\_\_\_\_ nervous system functioning.

- a. somatic
- b. central
- c. autonomic
- d. hypothalamus

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

2) Which part of the hindbrain is critical to equilibrium or physical balance?

- a. cerebellum
- b. medulla
- c. pons
- d. midbrain

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

3) The forebrain consists of the \_\_\_\_\_

- a. thalamus, hypothalamus, limbic system and medulla
- b. thalamus, hypothalamus, pons and cerebrum
- c. thalamus, hypothalamus, limbic system and cerebrum
- d. cerebellum, medulla and pons

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

4) Following an emergency at home, Victoria started to relax as a function of her \_\_\_\_\_ system.

- a. parasympathetic
- b. central
- c. sympathetic
- d. peripheral

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

5) Internal functions such as heartbeat, blood pressure, and digestion are controlled by the \_\_\_\_\_ nervous system.

- a. somatic
- b. central
- c. autonomic
- d. brain

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 6) Which part of the brain helps locate objects
- hindbrain
  - middlebrain
  - midbrain
  - forebrain
- How confident are you that your answer to this question is correct? \_\_\_\_\_ %
- 
- 7) Which part of the peripheral nervous system controls voluntary movement like hand waving?
- somatic nervous system
  - flight-or-flight response
  - limbic system
  - sympathetic nervous system
- How confident are you that your answer to this question is correct? \_\_\_\_\_ %
- 
- 8) While watching a suspenseful video late at night, Felicia hears a sudden crash in another room. She leaps out of her chair in fear, and then realizes that her dog has knocked over her water bowl again. Her fear reaction involved the activation of the \_\_\_\_\_ of the nervous system. Calming down involved the \_\_\_\_\_ of the nervous system.
- somatic branch; sympathetic division
  - sympathetic division; parasympathetic division
  - thalamus; hypothalamus
  - parasympathetic division; sympathetic division
- How confident are you that your answer to this question is correct? \_\_\_\_\_ %
- 
- 9) These two divisions adjust the level of arousal by acting in opposition
- thalamus and hypothalamus
  - central nervous system and peripheral nervous system
  - sympathetic and parasympathetic
  - thalamus and somatic nervous system
- How confident are you that your answer to this question is correct? \_\_\_\_\_ %
- 
- 10) Your hand pulls away from a hot surface, and you shake your hand few times to ease the pain. The pulling away was controlled by the \_\_\_\_\_ nervous system, while the shaking of your hand was controlled by the \_\_\_\_\_ nervous system.
- somatic; peripheral
  - somatic, autonomic
  - central; peripheral
  - sympathetic; parasympathetic
- How confident are you that your answer to this question is correct? \_\_\_\_\_ %

11) In the neuropsychologist's waiting room, you observe a man walks in an uncoordinated way. You notice that his movements are jerky and he frequently drops things. Most likely, he has damage to the \_\_\_\_\_.

- a. pons
- b. medulla
- c. cerebellum
- d. midbrain

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

12) The \_\_\_\_\_ processes auditory sensations from the left and right ears.

- a. forebrain
- b. midbrain
- c. hindbrain
- d. cerebrum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

13) The central nervous system consists of the \_\_\_\_\_.

- a. autonomic nervous system and spinal cord
- b. brain and somatic nervous system
- c. brain and autonomic nervous system
- d. brain and spinal cord

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

14) Alzheimer's disease results from damage to the \_\_\_\_\_.

- a. hippocampus
- b. thalamus
- c. hypothalamus
- d. cerebrum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

15) A structure in the forebrain through which sensory information is distributed to the cerebral cortex is the

- a. limbic system
- b. hypothalamus
- c. thalamus
- d. cerebrum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

16) Which part of the forebrain is responsible for solving complex mental activities like calculus problem?

- a. limbic system
- b. hypothalamus
- c. thalamus
- d. cerebrum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

17) Which part of the nervous system mobilizes the body's resources for emergencies?

- a. sympathetic division
- b. parasympathetic division
- c. central nervous system
- d. somatic nervous system

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

18) The \_\_\_\_\_ controls emotion, motivation and memory.

- a. reticular formation
- b. hindbrain
- c. limbic system
- d. forebrain

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

19) Which part of the forebrain regulates the sympathetic and parasympathetic divisions?

- a. limbic system
- b. hypothalamus
- c. thalamus
- d. cerebrum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

20) Victoria's brain weighs 2.5 pounds while Veronica's brain weighs 2.9 pounds. Which of the statement below is true about their mental abilities

- a. Victoria is more intelligent than Veronica
- b. Veronica is more intelligent than Victoria
- c. Both of them are equally intelligent
- d. None of the above

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

21) Difficult-to-control reactions are usually as a result of \_\_\_\_\_ arousal

- a. psychological
- b. physiological
- c. biological
- d. psycho-social

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 22) The limbic system consists of the \_\_\_\_\_.
- a. cerebellum
  - b. medulla
  - c. cerebrum
  - d. hippocampus

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 23) The hindbrain structure that controls unconscious functions such as breathing and circulation is
- a. pons
  - b. medulla
  - c. thalamus
  - d. cerebellum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 24) What part of the brain controls sleep and arousal?
- a. pons
  - b. sympathetic
  - c. parasympathetic
  - d. thalamus

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

For questions 25-30, identify which brain structure has primary function for each scenario.

- 25) Every time you come in contact with your best friend's dog, you begin sneezing and coughing.
- a. cerebellum
  - b. medulla
  - c. cerebrum
  - d. hypothalamus

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 26) Immediately following his twenty-first birthday celebration at a local sports bar, Felix had difficulty writing a note of 'thanks' to his friends.
- a. thalamus
  - b. medulla
  - c. cerebrum
  - d. cerebellum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

- 27) After playing tennis for two hours in the hot summer sun, Esther exhibits signs of increased body temperature (flushed and sweating) and elevated thirst.
- a. Spinal cord
  - b. pons
  - c. hypothalamus
  - e. somatic nervous system

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

28) Florence has consistently demonstrated her ability to exhibit fine motor skills such as writing and typing even though she is in grade 1.

- a. thalamus
- b. medulla
- c. hypothalamus
- d. cerebellum

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

29) In a laboratory, a researcher teaches a rat to run a simple maze perfectly to find a food reward. However, after surgery, the rat cannot remember how to solve the maze. Which part of the rat's brain was most likely removed?

- a. hypothalamus
- b. medulla
- c. olfactory bulb
- d. hippocampus

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

30) At a treatment center for the brain-injured, you observe a patient who frequently loses his thought and is unable to concentrate. When asked, the patient could not remember his home phone number or his address. He also reports other misperceptions about where parts of his body are. Most likely, the patient has damage to the \_\_\_\_\_.

- a. midbrain
- b. forebrain
- c. hindbrain
- d. autonomic nervous system

How confident are you that your answer to this question is correct? \_\_\_\_\_ %

## Appendix L. Subjective Evaluation Questionnaire

*Please rate on a 7 point scale your level of motivation, interest and perceived difficulty of the material you studied on the human nervous system.*

Q1. I thought the material on the human nervous system was very interesting.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7
not at all						very
true						true

Q2. The material did not hold my attention.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7
not at all						very
true						true

Q3. I put a lot of effort into studying the material.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7
not at all						very
true						true

Q4. I did not try very hard to do well on the tests given after studying the materials.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7
not at all						very
true						true

Q5. I did not put much energy into the tests.

<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>	<input type="checkbox"/>
1	2	3	4	5	6	7
not at all						very
true						true



- Q6. If I had a chance to use the program to study other material, I would be eager to do so.
- |                          |                          |                          |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |
| not at all               |                          |                          |                          |                          |                          | very                     |
| true                     |                          |                          |                          |                          |                          | true                     |
- Q7. The material was helpful in learning about the human nervous system.
- |                          |                          |                          |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |
| not at all               |                          |                          |                          |                          |                          | very                     |
| true                     |                          |                          |                          |                          |                          | true                     |
- Q8. The material studied on the human nervous system was very difficult.
- |                          |                          |                          |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |
| not at all               |                          |                          |                          |                          |                          | very                     |
| true                     |                          |                          |                          |                          |                          | true                     |
- Q9. Much effort is required to study the material.
- |                          |                          |                          |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |
| not at all               |                          |                          |                          |                          |                          | very                     |
| true                     |                          |                          |                          |                          |                          | true                     |
- Q10. I felt tense while doing the tests.
- |                          |                          |                          |                          |                          |                          |                          |
|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|
| <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> | <input type="checkbox"/> |
| 1                        | 2                        | 3                        | 4                        | 5                        | 6                        | 7                        |
| not at all               |                          |                          |                          |                          |                          | very                     |
| true                     |                          |                          |                          |                          |                          | true                     |

## Appendix M. Idea Units in the Human Nervous System Passage

Idea #	Idea Unit (Recall)
1	The human nervous system is a complex part of the body.
2	Human nervous system is divided into two main sub-systems
3	Human nervous system consists of the central nervous system.
4	Human nervous system consists of the peripheral nervous system.
5	Central nervous system consists of the brain
6	Central nervous system consists of the spinal cord
7	The peripheral nervous system consists of the somatic nervous system.
8	The peripheral nervous system consists of the autonomic nervous system.
9	The somatic nervous system controls voluntary movements such as hand waving
10	The somatic nervous system controls voluntary movements such as kicking.
11	The autonomic nervous system controls involuntary functions such as heart rate.
12	The autonomic nervous system controls involuntary functions such as digestion and other bodily functions.
13	The autonomic nervous system influences physiological arousal.
14	The autonomic nervous system influences emotions.
15	Physiological arousal are difficult-to-control reactions.
16	Difficult-to-control reactions are called fight-or-flight responses.
17	The autonomic nervous system is divided into two branches
18	The autonomic nervous system is divided into the sympathetic systems
19	The autonomic nervous system is divided into the parasympathetic systems
20	Sympathetic and parasympathetic systems adjust level of arousal by acting in opposition
21	For example, when there is danger the sympathetic system causes your heart to beat faster.

22	When the danger passes the parasympathetic system causes your heart to beat slower again.
23	Brain consists of about 100 billion neurons
24	These neurons help integrate information from inside and outside the body
25	These neurons help coordinate the body's actions.
26	Brain weighs about 3 pounds for adults
27	Brain weighs about 1 pound for newborn
28	Brain fact: differences in the weight of adults' brains are not related to differences in mental ability.
29	Brain has three major parts
30	Brain consists of hindbrain
31	Brain consists of midbrain
32	Brain consists of forebrain.
33	The hindbrain consists of cerebellum
34	The hindbrain consists of medulla
35	The hindbrain consists of pons.
36	Medulla controls unconscious functions, such as breathing.
37	Medulla controls unconscious functions, such as maintaining muscle tone
38	Medulla controls unconscious functions, such as regulating circulation.
39	Pons contains several clusters of cell bodies involved with sleep.
40	Pons contains several clusters of cell bodies involved with arousal.
41	Cerebellum is involved in movement coordination.
42	Cerebellum is critical to equilibrium or physical balance.
43	Cerebellum is one of the parts of the brain most immediately affected by alcohol.
44	Cerebellum is involved in fine motor skills, such as writing
45	Cerebellum is involved in fine motor skills, such as typing

46	Cerebellum is involved in fine motor skills, such as playing a musical instrument.
47	Midbrain processes auditory sensation from left and right ears
48	Midbrain processes visual information e.g., eye movement.
49	Midbrain helps locate objects.
50	Forebrain is the largest part of the brain.
51	Forebrain is the most complex part of the brain.
52	Forebrain consists of the limbic system
53	Forebrain consists of the thalamus
54	Forebrain consists of the hypothalamus.
55	Forebrain consists of the cerebrum.
56	Limbic system controls emotion
57	Limbic system controls motivation
58	Limbic system controls memory.
59	Limbic system consists of hippocampus.
60	When the hippocampus is damaged, it causes Alzheimer's disease.
61	Alzheimer's disease symptoms include loss of memory
62	Alzheimer's disease symptoms include loss of thinking
63	Alzheimer's disease symptoms include loss of concentration.
64	Thalamus distributes motor information to higher layers of the brain.
65	Thalamus distributes sensory information to higher layers of the brain.
66	Thalamus regulates awareness
67	Thalamus regulates motivation
68	Hypothalamus regulates the sympathetic systems
69	Hypothalamus regulates the parasympathetic systems
70	Cerebrum is responsible for complex mental activities such as thought.

---

71 Cerebrum is responsible for complex mental activities such as imagination.

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72 Cerebrum is responsible for complex mental activities such as problem solving.

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## Appendix N. Sample Free Recall Data

UserID	Free Recall Data
cmap100	<p>lumbic, thalumas, hypothalumas, cerebrum - forebrain - lumbic: memory, interconnection - hypoth***: damaged can cause memory problem, eg. Alzhamier patient - thalumas: sending motor motion to higher level of brain - hypothalumas: cerebrum - arosual auditorial, vision - midbrain - process auditorial and vision signals, control eye movement medulla, pons, cellebrum - hindbrain medula - pons - deep conscious: hear beat, breath cellebrum - motor skills: writing, typing etc central nerve system perpherial nerve system - somematic - automatic: controls fight to flight senses: breath, heart beat, musule - sympathetic: for critical, speed heart beat when in danger - parasympathetic: slow down the heart beat when danger pass, work opposite of sympathetic</p>
cmap009	<p>there are two parts of sensory actions, automatic actions, like heart beatriing, and voluntary actions, like moving your hand. a male adult's brain's brain weighs about 3 pounds, where as the baby's brain weighs 1 pound. the weight of the brain has no relation to smartness or activities performed by it. The brain is composed of three parts, the hindpart, the middlepart, and the front part. the hindpart has three segments, which deal with the heart beating, when danger comes for example, it makes the beats faster, whereas if danger passes, it becomes slow again. another part is related to sleep or arousel. the third part relates to feelin of balance and equilibrium. the middle part of the brain receives visual and audio information from the surrounding environement. it then analyze it and sends it to the other parts of the brain. the frontpart of the brain is the most complicated, it deals with alot of processes, and it has a part, which deals with alzhemers. if it is damaged, it causes memory loss.</p>
cmap010	<p>spinal cord and brian is the central nervous system. controls the kicking and waving parasypathmic - arise the heart rate go faster sypathemic - make the heart goes slower three parts of the brain - hindbrain, midbrain, and forebrain midbrain is mainly for hearing forebrain is the most complex brain, its deals with emotions, motivation, and memories. limbic system</p>
cmap012	<p>The Nervous system is split into two main parts. the central nervous system and the peripheral nervous system. the peripheral nervous system is split into to main parts which are the somantic and autonomic. the symantic deals with voluntary actions such as kicking and waving. the autonomic systems deals with involuntary movements such as blood regulation. there is the symantic and</p>

UserID	Free Recall Data
	<p>parasympathetic systems. they work together. for example, the sympathetic will speed up your heartbeat when you are in fear and the parasympathetic will slow it down. there is the brain. it has 100 billion neurons and in adults weighs about 3 pounds. and infants brain weighs around 1 pound. the brain is split up into 3 main parts. the hindbrain, the midbrain and the forebrain. the hindbrain has 3 main parts. the cerebellum, the medulla and the pons. the pons deals with sleep and arousal. the medulla deals with breathing and other similar functions. the cerebellum has to do with equilibrium. it is most effected by alcohol. it also has to do with fine motor skills like music. the midbrain has to do with auditory systems as well as some functions with the eye the forebrain consists of 4 parts, the cerebrum. the thalamus, the hypothalamus</p>
cmap013	<p>1. sympathetic higher heart rate 2. parasympathetic lower heart rate 3. cerebellum - balance affected by alcohol. used for playing instruments, typing 4. midbrain - auditory. also for sight 5. cerebrum - 6. pons 7. ? - used for sensing danger</p>
cmap024	<p>Brain has two part central system and peripheral system. the peripheral system has two parts itself: somic, and Autonomic, somic controls conscious activities like hand shaking and autonomic controls unconscious activities like heart beating. the autonomic part has two parts that work against each other, like in danger one part cause your heart to beat faster and the when the danger is removed the other part cause it to beat slower. the autonomic part also is related to the hard to control emotions. the brain has 100 billion cells. The brain of an adult weighs about 3 pound and the brain of baby weighs about 1 pound, but the difference in the weights is not related to the difference the mental abilities. the brain has 3 part: hindbrain, midbrain, forebrain. the hind brain has 3 parts. one controls the breathing and unconscious activities like that the other part is related to sleep. mid brain has a part that controls the body balance. and the forebrain has part that</p>
cmap033	<p>The human nervous system is mainly consist of two sub-systems: the central nervous system and peripheral nervous system. The brain and (...) are central system. The peripheral system consist of two systems. One system controls basic human biological functions such as heart rate. There are two opposite parts in this system. For example, if an emergency situation happens one part of it controls the heart to beat faster and when the emergency passes, the other part controls the heart to beat slower. The weight of the brain does not mean large difference in mental ability, like an adult and an infant. There are three parts in a brain, hindbrain, midbrain and forebrain. The</p>

UserID	Free Recall Data
	<p>hindbrain mainly controls the basic biological movements of human, like muscle. The midbrain is controlling human's visual perception and recognition of objects. The forebrain is the most complex part. It controls human's emotion and some upper level of mental activities.</p>
cmap041	<p>The nervous system is made of the somatic nervous system and the central nervous system. The central nervous system is composed of the spinal cord and the brain. The somatic nervous system is made of 2 subcategories: the autonomic nervous system and the voluntary. The autonomic consists of all the actions your body does involuntarily, and is further composed of the sympathetic and parasympathetic system which control bodily responses to stimulus, such as your heart beating faster when you are scared. The brain is generally 1 pound for adults, but brain weight is generally not linked with more intelligence. The brain is composed of the hindbrain, midbrain, and forebrain. the hindbrain is composed of the cerebellum, pons, and medulla. The pons controls things like dreams. The cerebellum controls things like motor movements and coordination, it is also the most susceptible to alcohol. The midbrain is in charge of functions such as auditory sensing. The forebrain is composed of the limbic system, cerebrum, and 2 more. The limbic system controls things like memory. While the cerebrum controls complex things like thinking and problem solving.</p>
cmap044	<p>the human nervous system is divided into 2 components 1. central 2. peripheral system -the central consists of the brain and spinal cord - the peripheral consists of 1.somatic and 2.autonomic systems 1. somatic controls voluntary actions such as waving and kicking 2. autonomic controls flight or fight responses which is divided into 1. sympathetic and 2. parasympathetic - sympathetic system will raise your heartbeat, make you sweat, nervous in uncomfortable/dangerous situations and the parasympathetic system will make your heart beat slow down and calm your mind/body after the danger passes - a baby's brain weighs on average 1 lb. a normal human brain normally weighs 3 lbs. - weight is not an indication of how smart one is/ if one is smarter than the other. - the human brain is made up of 3 parts. hind brain, mid brain and fore brain - the hind brain consists of 1. medulla 2. lobes? 3. cerebellum 1. the medulla oblongata controls unconscious actions such as breathing 2. the lobes? controls 3. the cerebellum controls things such as how to play an instrument, writing, fine motor skills - the mid brain takes in visual information and auditory information and puts it into something that we can use - the fore brain is the largest and most complex part of the brain. it contains the limbic system, the cerebellum, hippocampus, - the cerebellum controls thought/emotion - if damage occurs in the hippocampus,</p>



alzheimers will occur

cmap082

The nervous system is an important part of the body. It is divided into two subsystems, the central nervous system and the peripheral nervous system. The peripheral nervous system is further divided into the somatic nervous system and the automatic nervous system. The automatic nervous system controls involuntary functions, while the somatic nervous system controls voluntary functions, such as hand-waving and kicking. The automatic nervous system's involuntary functions, such as digestion, breathing and other bodily functions, are natural, uncontrollable responses often called fight or flight responses. The automatic nervous system is also divided further, into the sympathetic and parasympathetic nervous system. These two systems work in opposition responding to adjustments in sensors. For example, when there is danger, the sympathetic nervous system works to increase your heart rate, but when the danger passes away, the parasympathetic system returns your body to normal and decreases your heart rate to a resting rate. The parasympathetic and sympathetic nervous system are controlled by chemicals released by the hypothalamus, a part of the brain's forebrain. Going back to the central nervous system, this system consists of the brain and spinal cord. The human brain of an adult typically weighs about 3 pounds, and a newborn baby's about 1 pound, however, difference in weight of adult brains is generally not an indicator of difference in mental ability. The brain consists of about 100 billion neurons that are responsible for integrating information from inside the body as well as outside. Physically, the brain is composed of the hindbrain, the midbrain and the forebrain. The hindbrain consists of the medulla, cerebellum and the pons. The medulla is responsible for body coordination, and is therefore the first part of the brain affected by alcohol. The cerebellum is the part of the hindbrain that regulates involuntary functions such as muscle retention. The pons... ? The midbrain is responsible for taking information from visual and auditory sensors. The visual information is taken from what comes into your eyes, whereas the auditory sensors take information from your left and right ears. The forebrain is the most important part of the brain, and it consists of multiple parts, the medulla oblongata, the hypothalamus and the cerebrum. The cerebrum is the part of the brain where memories are stored, and when damage is done to it, the resulting illness is Alzheimer's, whose symptoms involve decreased concentration, memory loss, and \_\_\_\_\_. The hypothalamus, as stated before, regulates the somatic and automatic nervous system of the peripheral nervous system. The medulla oblongata...?

cmap083

Nervous system 2 main parts: CNS AND PNS (Central and Peripheral) PNS consists of SNS AND ANS: (Somatic nervous system

and Automatic nervous system) SNS is voluntary movements such as eyes hands foot movement ANS is the actions we do not control (fight or flight arousal) CNS (brain and spine) PNS consist of sympathetic and parasympathetic for arousal response (Fight or flight) Brain has 100 mill neuron cell; adult brain 3 pounds child brain 1 pound Weight not correlated with intelligence Brain consists of hind mid and fore brain Hind brain (Cerebellum Medula and Pons) Cerebellum: body balance Medula: Auto things we do, such as breathing and heart rate) Pons: Sensory pods... (for sleep) Mid brain for visual and auditory sense : seeing and hearing and locating objects Fore brain for higher level thinking (Cerebrum) Hippo campus related to Alzheimer's disease (loss of memory, awkward movement) Cerebrum responsible for higher level thinking (imagination and higher level reasoning) Hypothalamus (Part of hind brain?) adjust the sympathetic and parasympathetic system There is a part of organ that controls emotions, memory, and motivation (Cerebellum?).

Human nervous system consists of two components, central nervous system and peripheral nervous system. Peripheral nervous system consists of somatic nervous system and autonomous nervous system. Somatic nervous systems control the voluntary movements line kicking, hand waiving etc where autonomous nervous system controls the involuntary movements like emotion and heartbeat. It also controls the body reactions before or after a fight or flight. Autonomous nervous system is classified into two parts, the sympathetic and the asympathetic nervous systems, which control( e.g. increase heartbeat before some climax event or decrease heart beat after climax event). These two are also influences by hypothalamous. The other part of CNS, brain contains about 100 billion neurons. The weight of brain is about 3lbs in adults and around 1 lb in infants. The weight of the brain does not correspond to one's mental abilities. The brain is divided into three parts the fore-brain, the middle-brain and the rare-brain among which the fore brain is the most complex. The rare brain is further divided into three parts -- the ceribellum, the medulla and the pons. Ceribellum is responsible for maintaining balance when we are standing, walking or running etc. It also controls the finer motor actions like writing etc and is the first part of brain to get affected by alcohol consumption. The medulla is responsible for muscle toning and the pons is responsible for arousal,sleep etc. The fore-brain is divided into four parts -- limbic,cerebrum, thalamus and hypothalamus. The limbic brain controls memory and similar operations. Damage to limbic brain causes Alzemier. The main symptoms of which are loss of memory and thinking ability. The cerebrum performs complex brain operations like thinking, imagination and problem solving. The hypothalamus controls some components of autonomous nervous

cmap086

system

cmap089

The human nervous system consists of the Central Nervous System & Peripheral Nervous System The peripheral nervous system is divided into 2 parts Somatic System & ..... The central nervous system consists of the brain and spinal cord The brain contains 100 Billion neurons We also have the Cerebellum Medulla and the Pons There is the forebrain, midbrain and hindbrain There is the cerebrum, thalamus, hypothalamus There is the hippocampus which when damaged causes Alzheimer's disease which leads to loss of memory, thinking and concentration There are the sympathetic and parasympathetic systems working in opposition to manage responses e.g. to danger in which the first causes the heartrate to increase and the second causes it to reduce once the danger has passes

cmap093

The nervous system is one of the complex systems in human. It can divide into central nervous system and peripheral nervous system. Central nervous system can divide into brain and spinal cord. The peripheral nervous system is something out of brain. In brain, it consists of forebrain, midbrain and hinbrain. Hinbrain is for thinking and movement. Midbrain is related to visual and audio function. Forebrain is more difficult becuae it has hypotheleus. It helps to regulate breathing system. The brain is also individed into voluntary and involuntary function. In voluntary function, it can control movement. In the involuntary funciton, it divided into sympathetic system and somatic system. This sympathetic system is also called fight and flight reaction because when we meet danger, we can get a quick reponse such as changing breathing and heart breathing to protect ourselves. The brain size cannot determine whether you are smart or not. The child size is about 1 and the adult size is about 3.

cmap094

The nerveous system consists of the central nervous system and the peripheral nervous system, which can be further divided into the automatic nervous system and which regulates involuntary functions such as breathing and digestion, which we cannot control. the peripheral nervous sytem also regulates functions which we are more conscious of. the non-automatic part of the peripheral nervous system controls voluntary movements in the body such as the movement of the hand. The brain( part of the central nervous system)is also part of the nervous system, with 100 million neurons, weighing one pound for babies and 3 pounds for adults. It interprets the informations that is picked up by the nerves. the central nevous sytem also has the mid brain the frontal and the cerebellum. the cerebellum regulates balance and is the section that is most affected when we become intoxicated. The mid brain regulates the visual and auditory functions in the body. This is where we see and hear. the frontal part of the central nervous system has the most activity with the hyppocampus, the thalamus,

cerebrum. The cerebrum is what controls critical thinking, imagination, problem solving, heavier intellectual tasks. the hypothalamus regulates involuntary automatic systems such as sleeping patterns, digestion and metabolism. It is also responsible for emotions. The thalamus regulates involuntary movements in the body as well such as the regulation of temperature. The hippocampus affects memory in the body and is the part that is most affected with the disease of Alzheimers.

cmap095

The human nervous system consists of the central nervous system and the peripheral nervous system. The brain and the spinal cord make up the central nervous system and the somatic and autonomic nervous systems make up the peripheral nervous system. The somatic nervous system is responsible for voluntary actions such as kicking, typing, and writing. The autonomic nervous system is responsible for involuntary actions such as digestion. The brain is split into three sections: the hindbrain, the midbrain, and the forebrain. The cerebellum, pons, and medulla make up the hindbrain. The cerebellum is responsible for balancing and is the first part of the brain that is affected by alcohol. The pons is responsible for sleep and the medulla is responsible for regulation of circulation and breathing. Sounds and sights are processed through the midbrain. In the forebrain, there is the cerebrum, thalamus, hypothalamus, and the limbic system. Damage to the limbic system results in Alzheimer's disease, as this area of the brain is responsible for memory. The thalamus is the brain's sensory switchboard and regulates what goes through the brain. It is also related to awareness and motivation. The cerebrum is responsible for our thoughts.

cmap098

the nerve system has two parts - central nerve system - make up of brain and spinal cord - peripheral nerve system - parasympathy(don't know if spelled correctly) is responsible for slow down the heartbeat and the sympathy is responsible for fasten up the heartbeat - there are about 1 billion of neuron in body to help functions of nerve system - an adult human's brain weighs about 3 pounds and the different of the weight doesn't affect the mental ability the brain is divided into three parts hindbrain, midbrain, and forebrain hindbrain is responsible for the unconscious action such as breathing midbrain is responsible for the processing what a human hears from left and right ears and some visual sensory forebrain is responsible for awareness and motivation

cmap099

Our brain has two major nervous system which are central nervous system and subcentral nervous system. there are also two major functions. first one is voluntarily nervous system which is in control of our body movements such as kicking and walking. Another one is unvoluntarily nervous system such as heart beating, and limbic system. Our brain also has another two functions which are said for

	<p>example to speed up our heart beating when facing danger and slow our heart beating down when danger is gone. The brain has 3 major parts which are call hinbrian, middle brain, and fonthead. Each part has its different functions. The hinbrain which is also the back part of our brain controls our muscle movements. the middlebrain controls our other function system such as smell, speak and listen. the fonthead which is the front part of our brain is a complicated system which controls lots of our body functions such as limbic system, unvoluntarily system</p>
Cmap102	<p>Parts to the nervous system: autonomic controls arousal, heartbeat, digestion and other bodily functions somatic controls hand waving --- ----- ----- in the autonomic system baby brain, less than 1 pound and human brain 3 pounds Alzheimer's disease caused by the damaged limbic mid part of the brain controls visual thinking brain split into 3 parts, the medusa, pons and the cerebellum pons is used for sleeping cerebellum controls balance, equilibrium (paraphrased) information from the ears goes in and notifies the cerebellum of balance</p>
Cmap103	<p>The human nervous system has two parts, central and peripheral. Peripheral controls motion movements such as kicking. Human brain weights about 3 pounds for adult and 1 pound for baby. The weight of the brain does not indicate one's mental ability. There are 100 neuron ...in the brain. The central nervous system controls things such as heart rate. If someone is nervous, sympa (I forgot how to spell) increases the heart rate whereas para (donno how to spell) decreases the heart rate. There are three parts to the brain, hindbrain, midbrain, forebrain (donno how to spell these). Hindbrain controls actions and movement. Midbrain controls parts such as hearing. Forebrain controls memory. Alzeimer (donno how to spell) disease is someone who lost memory, often happens to seniors.</p>
Cmap109	<p>It divided into two main sub-system, which are central human nervous system and peripheral nervous system. For the central nervous system, it controls the human movement or action, and also the brain. There is also a semectic nervous system, it controls hand-waving, typing, writing and etc. Furthermore, there is autonotic nervous system, it controls heart-beating. When you are in dangerous, that system control your heart beat faster than normal period. Also, those human nervous systems are all related to human's brain. Normally, adult's brain weight is around 3 pounds and baby is less than a pound. Brain is also break down into 3 types, such are the forebrain, hidbrain and midbrain. Each of them are control different human nervous system. Limbic system is alongs with forebrain which control human movement.</p>


Cmap125	<p>There are two main branches of our nervous system, one is called central nervous system and the other is peripheral nervous system. The central nervous system involves with our brain. Our brain consists of three parts, hindbrain, midbrain and forebrain. Within our hindbrain, there is a part call cerebellum, which is responsible for our physical balancing and equalilbirum as well as our movement coordination. This is usually the first area to be affected when too much alcohol is intake. There other parts of hindbrain are medulla and pons. Medulla is responsible for our unconsiuous actions, such as breathing and heart beating. Midbrain controls and corresponds with our sight and smell and sound. Forebrain is the most complex part of our brain. It controls our thoughts and emotions. An average weight of an adult brain is about 3 pounds compared to an average baby brain is approximately less than 1 pound. The weight of the brain does not affect the mental ability. Aside from the central nervous system, the peripheral nervous system acts as another branch of our whole nervous system. It has two branches, somatic and autonomic. Somatic controls every voluntary action and autonomic controls every involuntary action.</p>
Cmap128	<p>The nervous system has 2 parts: the central nervous system and the peripheral nervous system. The central nervous system includes the brain and the spinal cord. The peripheral nervous system includes the hindbrain, and other brain parts. The pheripheral nervous system has 2 parts: the somatic nervous system and the autonomic nervous system. The somatic nervous system deals with the critical thinking and other actions that include the involvement of the cerebrum - like hand waving and kicking. The autonomic nervous system deals with the internal functions of the human body such as respiration, heart rate and etc. Through the autonomic nervous system, there are 2 systems that involve in a flihg-or fight response. That is the sympathetic nervous system and the parasympathetic nervous system. THE sympathetic nervous system helps the body to become aroused and more aware of the surrounding environment - speeds up heart rate, and the parasympathetic system does exactly the opposite - slows down heart rate and maintains the person in a calm state. The autonomic nervous system includes the pons, the hypothalamus, the hippocampus and many other areas. There are 3 parts to the human brain: the front, middle and back of the brain. And the brain is also divided into 4 lobes</p>
Cmap131	<p>Nervous system consist of two major parts: the central nervous system and peripharial nervous system. The central nervous system includes the brain and spinal cord. Peripharial Nervous system includes the sympathetic and parasympathetic system. The brain and spinal cord regulate unconciuous movements such as breathing,</p>

	<p>regulating blood pressure, etc. Sympathetic and parasympathetic work in opposite of each other. Sympathetic stimulates the body when in an stituation such as running. It increase heart beat and breathing. On the other hand, parasympathetic calms the body down after the event has taken place. This is known as the fight-or-flight response. In the brain in consist of the medulla, pon, cerebellum and cerebrum. The medulla regulates unconcious activities such as breathing. Cerebellum is for balancing and movement. There is also the limbic system, hypothalamus, and thalamus. Limbic includes body movement. Hypothalamus is most affected by alcohol. A disease called Ayzemier weakens the control of conciousness.</p>
Cmap132	<p>The nervous system consists of the Central nervous system(CNS) and the peripheral nervous system (PNS). The CNS is composed of the brain and the spinal cord. The brain size is not a factor in a person's mental abilities, and is 3 pounds in an average adult, 1 pound in infants, in adults, the brain contains approx. 100 billion neurons. The spinal cord conducts impulses through nerves. The PNS consists of the somatic and autonomic system. The somatic is voluntary movements such as punching and kicking, while the autonomic system is involuntary, (essential for it's fight or flight functions) and is essential in regulating the chemical balance in the body eg speeding up heart rate, breathing, etc. The autonomic nercous system contains the sympathetic and the parasympathetic systems, sympathetic is responsible for eg. speeding up a bodily function such as heart rate for a critical time such as when an organism is threatened, and the parasympthetic system is responsible for slowing down, eg the heart rate. The brain is divided into the hindbrain, mid brain, and the front. the hindbrain include the cerebellum (responsible for muscular balance and coordination) , pons, and medula, ( used for emotions, memories, etc) and is also involved with Alzheimers disease. The midbrain is responsible for intaking and interpreting sensory information from the auditory system, and the front brain is for higher level mental processes such as, imagination, resoning, beliefs and so on.</p>
Cmap138	<p>Nervous system made up of two main parts: brain, spinal cord two systems: somatic/autonomic - somatic dealing with voluntary actions - autonomic dealing with involuntary actions (breathing, heart rate, etc) - autonomic has two systems, sympathetic, parasympathetic. two systems work on balancing each other out, sympathetic increases, parasympathetic decreases. (eg. heart rate) brain controls most functions of body, adult brain can be 3 pounds, baby brain less than 1 pound - 3 different parts of brain: hind brain, mid brain, forebrain hindbrain 3 parts: pons, cerebellum, medulla - pons - cerebellum: deals with balance and motor functions (alcohol affects this part first)</p>

	<p>- medulla: deals with automatic actions, eg. breathing midbrain controls auditory functions, and seeing/reading forebrain largest and most important part - hypothalamus - limbic system: controls emotions, memories, etc (Alzheimers(sp) disease comes from damaged limbic system) - thalamus</p>
Cmap139	<p>The human nervous system is catagorised by two main parts. The central nervous system and the secondary nervous system. The central nervous system includes the brain and the spinal cord. The secondary nervous system includes the sensory system. The autonomous are the fuctions that can't be easily controlled, like digestion and heartrate. The brain is seperated by three parts, the hindbrain, midbrain, and the forebrain. The hindbrain contains the medula, pons, and cellebellum. The medula controls the heartrate, balance. The pons controls the arousal. The cellebellum controls the motor functions. Cellebellum is easily effected by alcahol. The midbrain controls the audio senses from the right and left ears. The forebrain controls the emotion, memory, and thought. Alzimers affects this part of the brain</p>
Cmap142	<p>The Human Nervous system (NS) consists of two main parts-2. The Central-2 and peripheral NS-2. The Central NS consists of the Brain-2 and Spinal Cord-2. The brain is divided into three parts-2. The hind-2, middle-1, and fore part-2. The hind part has the Cerebrum, Medular-2 and "pron". The cerebrum consists of the parts that is involuntary (like heart beat, digestion) and vuluntary systems (like movement of the eyes)</p>



## Appendix O. Screenshot of “Web Questionnaire Multiple-Choice Page”

 SECTION → **1** **2**

**TITLE: Multiple Choice & Ratings**

*Please choose the best answer and indicate your level of confidence in the choice you made using a scale from 0 to 100.*

**0 = Not at all confident because I took a wild guess**


**100 = I am very confident that I am right.**

**Q1.** If Tim saw a snake and his heart started racing, it would be the result of \_\_\_\_\_ nervous system functioning.

- somatic
- central
- autonomic
- hypothalamus

**Q2.** How confident are you that your answer to this question is correct?

0  100

Not at all confident  Very confident

**Q3.** Which part of the hindbrain is critical to equilibrium or physical balance?

- cerebellum
- medulla
- pons
- midbrain