THESIS

# COGNITIVE AGING AND COMPUTER-BASED INSTRUCTION: THE ROLE OF COHERENCE LEVEL AND ADVANCED ORGANIZERS

Submitted by

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ABSTRACT

COGNITIVE AGING AND COMPUTER-BASED INSTRUCTION: THE ROLE OF COHERENCE LEVEL AND ADVANCED ORGANIZERS

The purpose of this study was to examine the effect of two instructional design principles, instructional coherence and advanced organizers, on the learning outcomes of older and younger adults in a computer-based training context. Instructional coherence refers to the notion that people learn more deeply when information not directly relevant to the learning goal is removed from instruction. Advanced organizers are introductory organizing frameworks for the intended training content (e.g., outlines). Participants (49 younger adults and 52 older adults) completed a computer-based training program and were randomly assigned to a condition in which information was coherent or incoherent and to a condition in which learning material was preceded by an advanced organizer or not preceded by an advanced organizer. Results indicated that 1) overall, older adults performed worse on learning outcome measures compared to younger adults, 2) instructional coherence significantly improved the learning performance of both older and younger adults, and 3) advanced organizers improved the performance of older adults but did not affect the performance of younger adults in transfer tasks. Based on the results, it is recommended that future researchers explore age-specific instructional formats in order to optimize the performance of older adults in computer-based training contexts.

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# CHAPTER 1

# INTRODUCTION

Technology-based training is becoming increasingly prevalent in organizational settings (Bell & Kozlowski, 2002; Paradise, 2008) and, as research indicates, it is being delivered to a rapidly aging workforce. It is expected that by 2015, workers age 55 and older will comprise approximately one fifth of the American workforce (U.S. General Accounting Office, 2001). In the European Union, it is projected that, within the next 15 years, the percentage of workers over age 50 will increase by almost 25% ("Turning boomers into boomerangs," 2006). With this demographic trend, there is a burgeoning need to understand how to design computer-based instruction for older individuals. Considering that aging is associated with distinct cognitive changes, such as decreases in working memory function and cognitive speed, a question arises of whether we need to develop age-specific training principles or whether we can simply use general, age-independent principles when designing instruction for older learners. The aim of this study is to address this question.

This study comes on the heels of a recent theoretical article by Van Gerven, Paas, and Tabbers (2006), who proposed that there is no need for "age-specific" computer-based instructional formats. The authors suggested that general (age-independent) research-based instructional principles should be beneficial to all age groups, and what's more, these principles should be significantly *more* beneficial to older people than younger people. They argued this because older people: 1) have more room for improvement –not only do they have more difficulty with computer skill acquisition (Elias, Elias, Robbins, & Gage, 1987), but they also experience more deficits in cognitive functioning (e.g. Salthouse, 1996; Norman, Kemper, Kynette, 1992; Kim, Hasher, & Zacks, 2007); and 2) need more support in learning environments (e.g., Craik, 1986). These age-independent principles are derived from cognitive load theory (CLT; Sweller, van Merriënboer, & Paas, 1998) and the cognitive theory of multimedia learning (CTML; Mayer, 2005a; 2005b; 2005c). CLT is the basis of instructional principles designed to accommodate individuals' limited-capacity cognitive architecture and CTML is the basis of instructional principles specifically applicable to multimedia environments.

To date, only a few of the instructional principles of CLT and CMLT have been tested on older adults and these studies have produced mixed results. Some studies have found a main effect of CLT principles on learning outcomes (e.g., Van Gerven, Paas, Van Merriënboer, & Schmidt, 2006), while other studies have reported an interaction between age and design principle such that older adults benefited more from CLT principles than younger adults (e.g., Paas, Camp, & Rikers, 2001; Van Gerven, Paas, Van Merriënboer, & Schmidt, 2002). Instructional coherence, a principle derived from CTML, however, has yet to be tested on older and younger individuals. Instructional coherence refers to the notion that people learn more effectively when extraneous information (i.e., information not directly relevant to the learning goal) is removed from instruction (Mayer, 2005a).

In the present study, I examine the effect of instructional coherence on learning outcomes. It is expected that, compared to younger learners, older learners will benefit significantly more from coherent instruction. Second, I examine the effect of advanced organizers (AOs) on learning outcomes. Advance organizers are introductory organizing frameworks for the intended training content (Mayer, 1979). It is expected that, compared to younger individuals, older individuals will benefit significantly more from advanced organizers.

In the following sections, I delineate age-related cognitive deficits and then demonstrate how instructional coherence, a principle derived from the cognitive theory of multimedia learning, and advanced organizers specifically address the cognitive deficits of older individuals.

*Aging and specific deficits in cognitive functioning*

Research indicates that healthy aging is accompanied by several deficits in cognitive functioning, deficits researchers theorize stem from a decline in prefrontal cortex function (Perfect, 1997; West, 1996). It should be noted that aging is a complex and multifaceted process and that there is a distinction between chronological age and functional age. Chronological age is simply a proxy for a series of cognitive, physical, and psychological changes that occur over time in individuals. Previous studies, however, have indicated that age-related effects are apparent by the age of 65 (e.g. Kim et al., 2007). Unless otherwise specified, “older learners” will refer to those individuals over 65 with diminished cognitive capacities consistent with those defined below.

First, aging is associated with reduced cognitive speed (e.g., Salthouse, 1996). Research shows, for example, that older adults are considerably slower than younger adults in tasks that require participants to use a code table to determine the digit associated with a presented digit and in tasks that measure the rate at which participants can compare two letter strings and determine if they are identical or not (Salthouse, 1992; 1993). Studies also indicate that the reaction time of older adults is approximately 1.4 to 2 times slower than the reaction time of younger adults (Cerella, 1990). This slowing phenomenon has been demonstrated across a wide range of cognitive exercises and is well-accepted in the cognitive aging literature. Overall, Salthouse (1985) found a median correlation of .45 between age and measures of task speed.

Salthouse (1996) further proposed that reduced cognitive speed explains other age-related cognitive declines, such as the diminution of working memory capacity. Specifically, Salthouse showed that this slowing contributes to a reduction in synchronization of processing such that when individuals perform a series of mental operations, products of earlier mental processing decay or are displaced by the time later processing completes. As a result, the products of earlier mental processes are no longer available in working memory and cannot form associations with products of later mental processing.

Secondly, as noted, aging is related to a reduction in the processing capacity of working memory, particularly after the age of 75 (Norman et al., 1992). Working memory is a storage system within humans' cognitive architecture that temporarily maintains and processes incoming information before it can be transferred to a virtually unlimited long term storage system.

Thirdly, aging is associated with differences in fundamental attentional processes. Research shows that as people age, their attention span broadens and they have a decreased ability to inhibit irrelevant information, making them more susceptible to distraction (Hasher, Zacks, & May, 1999; Kim et al., 2007). May (1999), for example, found that in a Remote Associations Task, in which participants are asked to find the link between three weakly associated words, the presence of distractors was disproportionately detrimental to older adults' performance. Further, Connelly, Hasher, and Zacks (1991) found that, compared with younger adults, older adults were disproportionately slowed when reading material had distracters interspersed (in different type font), particularly when the distracters were meaningful and related to the focal reading.

Fourth, aging is associated with a reduced ability to coordinate and integrate different sources of information (Mayr & Kliegl, 1993; Mayr, Kliegl, & Krampe, 1996). These deficiencies in coordinating and integrating information contribute to the well-established "complexity effect." That is, the greater the task complexity, the greater the performance gap between younger and older adults (Oberauer & Kliegl, 2001). Along these lines, Naveh-Benjamin (2000) found that older adults have particular difficulty forging and retrieving connections between units of memory and therefore, their memories are less cohesive than the memories of younger adults.

In sum, research shows that aging is associated with four categories of cognitive decrements: reduced cognitive speed, reduced working memory capacity, reduced ability to inhibit irrelevant information, and reduced ability to coordinate and integrate different sources of information. In order for instructional design principles to be effective for older learners, they must address these cognitive deficits.

What follows is a discussion of cognitive load theory as well as the cognitive theory of multimedia learning and its derived instructional principle: the coherence effect. I predict that the coherence principle will be particularly effective for older individuals because the purported advantages of this principle specifically target age-related declines. Next, I will introduce research related to advanced organizers. I expect that, because AOs map onto age-related declines, they will be particularly effective for older learners.

*Cognitive load theory*

Cognitive load theory is the basis of a number of instructional principles that are designed to be consistent with how people learn. Cognitive load is defined as "the load imposed on working memory by information being presented" (Sweller, 2005, p.28). The central assumption underlying cognitive load theory is that humans have a cognitive architecture of limited capacity and care must be taken to ensure that it is not overloaded during learning. Specifically, cognitive load theory is based on the notion that humans have a limited working memory (WM), which restricts the rate of at which information can be processed. WM is essentially a limited-capacity storage system, with distinct channels for visual and verbal information, that holds and manipulates pieces of information (Paas, Renkl, & Sweller, 2003; Paas, Tuovinen, Tabbers, & Van Gerven, 2003). Although individuals have a limited WM store that deals with novel information and that should not be overloaded, they also have a virtually unlimited long term memory store containing rich knowledge structures which have the potential to reduce the load on WM by combining multiple knowledge elements into *one* singular structure. Automated knowledge schemas, which reside in long term memory and are developed after considerable practice, are particularly important in terms of reducing working memory load because they are activated without effortful processing (Van Merrïenboer & Sweller, 2005).

According to cognitive load theory, there are three types of load that can be imposed on a learner's cognitive system: intrinsic load, germane load, and extraneous load. *Intrinsic load* refers to the complexity inherent in the task itself. Intrinsic load is a product of the interactivity of instructional elements relative to the expertise of the learner. For example, a highly complex task may overwhelm the cognitive system of a novice, but not impose much load on the cognitive system of an expert who has prior knowledge available and can unify many interacting elements into one element. *Germane load* refers to a type of cognitive demand that, while not inherent to the task, aids the learner in more deeply processing and comprehending the material through schema formation and automation. Examples of germane load include asking learners to apply their problem-solving strategy to a different context or asking learners to provide examples of an important concept conveyed in instruction. The third type of load, *extraneous load,* refers to load that is not relevant to the instructional purpose. Extraneous load may include illustrations, background music, or additional text that divert attention away from the learning goal. This type of load is a result of poor instructional design and is deleterious to learning because it adds load but doesn't help learning. (Paas et al., 2003). Extraneous load needs to be minimized because cognitive load is cumulative in theory. Accordingly, if the intrinsic load is high, extraneous load must remain low so as not to overload the learner's cognitive system. This model of the human cognitive architecture and cognitive load has been used as a theoretical basis for reducing extraneous load in instruction.

*Cognitive Theory of Multimedia Learning*

Mayer's CTML is heavily influenced by CLT, but places learning in the context of multimedia instruction. Multimedia instruction refers to the presentation of words and pictures as a means of supporting learning (Mayer, 2005b). CTML, then, explains how people use words and pictures to construct mental models and accordingly, places emphasis on the attentional components of learning. This theory is based on three assumptions: 1) dual-processing (learners have two separate, independent channels for processing visual and verbal information), 2) limited processing capacity (WM can manage a limited amount of information during multimedia instruction), and 3) generative processing (learning is a three-step process that involves a) attending to relevant information, b) mentally organizing the selected information into coherent mental models, and c) integrating these mental models with existing knowledge) (Mayer, 2005c).

CTML has spawned ten principles for multimedia design. Examples of these principles are the split attention principle (learning is enhanced in multimedia environments where words are presented auditorily rather than visually as on-screen text), the segmentation principle (multimedia learning is enhanced when learners can control the amount of time spent on each section of instruction), the signaling principle (learning is enhanced when important words are highlighted rather than not), and the spatial contiguity principle (learning is enhanced when text is printed near rather than far from corresponding parts of a picture) (Mayer, 2005a). The focus of my research is on the principle of instructional coherence.

*The Coherence Effect*

The coherence effect refers to the notion that people learn more deeply when extraneous material is removed from instruction (Mayer, 2005a). This is because extraneous material takes up working memory capacity and thereby leaves less room for the selection, organization, and integration of core material. Because older adults have reduced cognitive speed, reduced processing capacity of WM, particular difficulty screening out irrelevant information, and a reduced ability to coordinate different sources of information, it is expected that older adults, in particular, will benefit from reduced extraneous load in instruction.

In this experiment, extraneous load will be imposed through seductive details. Seductive details are highly interesting and appealing pieces of information that are only tangentially related to the important points within the text (Garner, Gillingham, & White, 1989). They may be presented in the form of additional text, pictures, sound, or video (Thalheimer, 2004). Previous research examining the effect of seductive details on learning outcomes has produced mixed results. Many studies have found that seductive details interfere with the recollection of main idea units (e.g., Garner et al., 1989, Harp & Mayer, 1997; Harp & Maslich, 2005), though some studies have reported no interference effects (e.g., Schraw, 1998). Thalheimer, however, showed that across 24 studies comparing seductive detail and control conditions, the inclusion of seductive details tended to undermine learning.

Several researchers have proposed that seductive details are detrimental to learning because they impose an extraneous load on the learner and reduce valuable working memory capacity (Moreno & Mayer, 2000; Mayer, 2001). In this study, the absence of seductive details will correspond to low extraneous load and in turn, will be consistent with the coherence effect.

*Hypothesis 1: There will be a main effect of coherence on learning outcomes. Compared with those in the high extraneous load condition, those in the low extraneous load condition will have significantly higher learning outcomes.*

Furthermore, because the coherence effect accommodates age-related cognitive deficits such as reduced processing speed, reduced working memory capacity, a reduced ability to inhibit irrelevant information, and a reduced ability to coordinate and integrate different sources of information, it is expected that older adults will benefit significantly more from the coherence effect than younger adults.

*Hypothesis 2: The coherence effect will be moderated by age such that older individuals will show greater deficits in learning under high load than will younger participants.*

That is, coherence will be significantly more beneficial to older participants compared to younger participants.

*Advanced organizers*

Another instructional tool expected to be particularly effective for older adults is an advanced organizer. By outlining the main points of subsequent information, an AO not only focuses the learner's attention on the important aspects of the material, but also provides a foundation for the integration and meaningful processing of complex material (Preiss & Gayle, 2006, Mayer, 1979). In this sense, an AO provides the "cognitive hook" on which new information can rest and facilitates the structuring of new information in memory (Mayer & Bromage, 1980). Essentially, AOs are intended to help learners select, organize, and integrate information with an existing knowledge structure (Mayer, 1979). Examples of AOs include outlines and concept maps, as well as graphic organizers such as tree diagrams or matrices (Preiss & Gayle, 2006; Willerman & Mac Harg, 1991).

While research pertaining to the effectiveness of AOs has been mixed, meta-analyses indicate AOs play a small but significant role in facilitating learning (e.g., Luiten, Ames, & Ackerson, 1980; Mayer, 1979; Stone, 1983). Mayer (1979) proposed that AOs promote meaningful learning when they allow learners to pass through the following three stages of encoding: reception (information is received in WM), availability (prior to learning, the contextual knowledge conveyed by the AO is well-integrated and accessible in long term memory), and activation (the contextual knowledge from long term memory is actively used in WM to integrate new information and is then transferred back to long term memory). Mayer therefore posited that AOs could be effective if they provide a meaningful context, if the user has little background knowledge on the topic, and if the user is encouraged to pay attention to and actively use the AO during learning. In this experiment, I will ensure that the AO is presented under these conditions. Accordingly, it is proposed:

*Hypothesis 3: There will be a main effect of advanced organizers on learning outcomes. Compared to those in the control condition, those in the advanced* *organizer condition will have higher learning outcomes.*

Additionally, older learners are expected to benefit more from AOs, compared to younger learners, because AOs support learning processes compromised by age-related deficits, e.g., older adults are less able to coordinate and integrate different pieces of information (Mayr & Kliegl, 1993). There is also evidence that older learners initiate organizing processes less spontaneously than do younger learners and benefit from the facilitation of organizational processing (Hulicka & Grossman, 1967; Sauzéon, Claverie, & N'Kaoua, 2006; Witte, Freund, & Sebby, 1990). In fact, Meyer and Rice (1981) posited that older adults are not as attentive to the underlying structure of text. It is expected that AOs, by providing a framework for structuring information in memory, will benefit older adults significantly more than younger adults.

Not only should AOs help learners mentally organize material, but theoretically, they should also lessen learners' cognitive load. AOs allow learners to develop and integrate knowledge structures into long term memory in advance, so that during the learning process, WM is relieved of cognitive load. Since older adults have diminished working memory capacity, they may benefit significantly more from AOs compared to young adults.

To date, the sparse amount of research comparing the impact of AOs on older and younger adults has produced mixed results. For example, Thompson, Diefenderfer, and Doll (1986) found that, while AOs improved recognition performance for subjects of limited verbal ability, no one age group benefited more than the other. Thompson, Holzman, and Doll (1985), however, found that when older adults were presented with AOs, they benefited disproportionately compared to younger adults in terms of recognition performance. In terms of recall, however, AOs were disproportionately beneficial to younger subjects. Charness, Shumann, and Boritz (1992) found no benefits of AOs for older people while Thompson (1997) found that AOs diminished the performance gap between older and younger adults on a recognition test. Thompson (1997) further proposed that one of the limitations of previous research may be that participants aren't explicitly told about the importance of AOs and therefore, don't pay careful attention to them when presented. Thompson (1997) demonstrated that when both age groups were given orienting instructions—that is, they were told about the importance of AOs and told to pay close attention to them—older subjects benefited significantly more compared to younger subjects.

Based on Thompson's (1997) research, it is expected that when AOs become a prominent part of the instructional design and participants are informed of their importance, performance differences between older and younger learners will be significantly reduced. In this study, learners will be presented with an AO at the beginning of instruction in the form of a story map and they will be instructed to carefully study this organizing framework because it will facilitate learning. Participants will also be asked to perform a cognitive task based on the information presented through the AO. This task is intended to help participants mentally organize and integrate the AO into long term memory before reading the main instructional material.

*Hypothesis 4: The effect of advanced organizers on learning outcomes will be* *moderated by age such that older learners will benefit significantly more from AOs than younger learners.*

In addition to investigating how AOs interact with learner age to influence learning outcomes, it would be interesting to look into the three-way interaction among age, AO, and level of extraneous load. In a low extraneous load condition, where the primary purpose of the AO is to provide an organizing framework for the to-be-learned material and to facilitate the integration of new information with existing knowledge, it is expected that older adults will benefit more because they require more facilitation of organizational processing and because their memories tend to be less cohesive. In the high extraneous load condition, however, where the ability to screen out irrelevant information also becomes critical to learning, it is expected that younger adults will benefit more. With older adults, because they have particular difficulty inhibiting irrelevant information, it is expected that they will receive more extraneous information in WM and as a result, not be able to organize and integrate new information as effectively with the contextual knowledge structure in long term memory. To my knowledge, no other study has investigated AOs' effect on learning under high and low extraneous load conditions. Nonetheless, I propose:

*Hypothesis 5: There will be an interaction due to age and extraneous load such that:*

*a) In the low extraneous load condition, older adults will benefit from advanced organizers significantly more than younger adults.*

*b) In the high extraneous load condition, younger adults will benefit from advanced organizers significantly more than older adults.*

# CHAPTER 2

# METHOD

## *Participants*

The sample consisted of 52 older adults who were 65 years old and above ($M_{age}$ = 75.1; *SD* = 8.8) and 49 younger adults who were between the ages of 18 and 30 years old ($M_{age}$ = 21.7; *SD* = 3.1). Older adults were recruited from retirement homes, senior activity centers, and volunteer organizations in the Fort Collins area. Additionally, several older adults were recruited from a database of seniors who had previously participated in research at Colorado State University. Younger adults were recruited from undergraduate and graduate psychology classes at Colorado State University. A snowball recruitment method was also used such that after completing the experiment, subjects recommended younger and/or older friends or family members to participate. All subjects but four were entered into a raffle for a chance to win a $30 gift certificate to their choice of three stores. The exceptions were four introductory students who received experimental credit and were not allowed to receive monetary rewards as an incentive. Five older subjects were eliminated from the analyses – one subject was eliminated because he looked at his notes during the exam portion and the other four subjects were eliminated because they talked to each other during the exam and left the study room before the experiment had finished. Additionally, three subjects were identified as outliers based on extreme learning outcome scores and were subsequently dropped from the analysis. Demographic information about the final sample ($n$ = 93) is included in Table 1.

*Design*

This experiment used a 2 (young, old) X 2 (low coherence, high coherence) X 2 (no advanced organizer, advanced organizer) between-subjects design. Potential control variables were measured: verbal ability, computer experience, computer anxiety, physical and mental health, and prior knowledge related to the test material.

*Training Content and Independent Variables*

*Computer-Based Instruction.* Subjects were asked to read text on the causes of lightning formation. This text was adapted from Harp and Mayer's (1998) seductive detail material and was used more recently by Lehman, Schraw, McCrudden, and Hartley (2006). The text was presented in a Word document. Participants were presented with text with high extraneous load (in the form of seductive details) or with low extraneous load (few or no seductive details). Examples of seductive details that were interspersed throughout the presentation include, *"Swimmers in particular are sitting ducks for lightning because water is an excellent conductor of its electrical discharge,"* and *"Stepped leaders can strike a metal airplane, but rarely do any damage because airplane nosecones are built with lightning rods, which diffuse the lightning so it passes through the plane without harming it."* Additionally, an advanced organizer was presented to the learners prior to the main learning material or it was not presented at all. In this experiment, the AO was a story map depicting the major steps of lightning formation (See Appendix B).

Age. Participants between the ages of 18 and 30 were categorized as younger adults while participants above the age of 65 were categorized as older adults. Certainly, chronological age is simply a proxy for a series of physical, cognitive, and psychological changes that occur in individuals over the lifespan. For example, two individuals of the same chronological age may differ significantly with respect to their cognitive functioning; however, research suggests that age-associated deficits are evident by the age of 65 (e.g., Kim et al., 2007; Sauzéon et al., 2006). Additionally, in the cognitive aging literature, individuals between the ages of 18 and 30 are commonly classified as young adults (e.g., Kim et al., 2007; Connelly, et al., 1991).

*Measures*

The following measures were used either to screen participants or considered as potential covariates.

*Short Blessed Test.* The Short Blessed Test, modified and validated by Katzman, Brown, Fuld, Peck, Schecter, and Schimmel (1983), consists of six items and assesses participants' orientation, concentration, and memory. This test served as a screening device for all older adults who had been recruited from the database. This test was used exclusively on this segment of the older adult sample because many of the individuals in this database had cognitive impairments. A score between 0 and 4 indicated normal cognition, a score between 5 and 9 indicated questionable impairment, and a score of 10 or more indicated impairment consistent with dementia.  All ten participants who participated in the screening passed with a score of zero or one.

*Verbal Ability.* A 20-item vocabulary test taken from Salthouse (1993) was used to assess participants' verbal ability. For this multiple-choice test, participants were asked to choose the correct synonym and antonym of particular words.

*Computer Understanding and Experience.* The Computer Understanding and Experience (CUE) scale created by Potosky and Bobko (1998) was used to assess computer experience. The CUE is comprised of a technical factor and a general competence factor. Because the technical factor was not as relevant to this study's computer task (e.g., "I know how to write computer programs, "I know how to install software on a personal computer"), only the general competence factor was used (six items; α = .92). Example items from this factor include, "I am computer literate," and "I am good at using computers."

*Computer Anxiety.* A modified version of the Computer Anxiety Rating Scale validated by Heinssen, Glass, and Knight (1987) was used to assess computer anxiety. This is a 19-item questionnaire in which participants were asked to indicate the extent to which they agree with statements such as, "I have avoided computers because they are unfamiliar and somewhat intimidating to me," and "I feel apprehensive about using computers." Three items were removed from the scale, however, because they were quite dated. Cronbach's alpha for a scale score based on the remaining 16 items was .87.

*Physical and Mental Health.* A shortened version of the SF-36 health survey was used to assess the mental and physical health of participants (α = .84). This version is based on 12 items from the SF-36 scale. Example items include, "Does your current health status limit you from climbing several flights of stairs?" and " How much of the time during the past 4 weeks have you felt calm and peaceful?" (Ware, Kosinski, Turner-Bowker, & Gandek, 2002).

*Prior Knowledge.* Before beginning the web-based presentation, participants were asked to indicate, on a scale of 1-5 (1 indicating no prior knowledge and 5 indicating expertise), their understanding of how air temperature and the movement of electrically charged particles contribute to lightning formation. Prior research has shown that for similar purposes, self-items of prior knowledge correlate highly with scores on content tests (Towler, Kraiger, Sitzmann, Van Overberghe, Cruz, Ronen, & Stewart, 2008).

*Cognitive Load.* As an estimate of cognitive load, participants rated their level of mental effort. After five minutes of reading the main text, participants were interrupted by a 1-item questionnaire based on Paas' (1992) measure. Specifically, learners were asked to indicate on a scale of 1 (very, very low mental effort) to 9 (very, very high mental effort), how much effort they were investing in learning the material.

*Self-Efficacy.* After five minutes of reading the main text, participants were interrupted with a single item based on Lee and Bobko's (1994) measure to assess their self-efficacy for understanding the instructional material. Participants were asked to indicate, on a scale of 1(no confidence at all) to 5 (extremely confident), their degree of confidence in their ability to understand the material well.

The following measures were used to assess learning outcomes.

*Recall.* Participants were given a recall test and asked to provide an explanation of what causes lightning. That is, participants generated responses themselves rather than recognized the correct response from a list of possible responses. Their essays were scored based on Mayer and Moreno's (1998) protocol for an identical question. Specifically, a point was awarded for each of sixteen possible key idea units. For example, points were given for ideas such as the following: (a) air rises, (b) air forms a cloud, and (c) a cloud's top freezes. To test for interrater reliability, two raters scored the first 50% of essays, continually checking to ensure agreement. The intraclass correlation coefficient between the two was .98. The remaining responses were split up between the two raters for scoring.

*Knowledge Organization.* As an indication of participants' knowledge organization, participants were asked to list out the causal sequence of events that occur during lightning formation. The scoring scheme was based on the notion that knowledge is organized to the extent that steps are sequenced in the correct order. Thus, compared to the recall scoring in which participants were awarded points simply for the presence of particular idea units, for knowledge organization, participants were also penalized when steps were placed in the wrong order. Specifically, 0.5 points were subtracted from participants' score each time a step was placed in the wrong order. For the first 50% of responses, the intraclass correlation coefficient between raters was .97. The remaining 50% of responses were split up between the two raters.

*Transfer.* Transfer, in this study, refers to learners' ability to generate creative solutions to applied questions about the instructional material. The test consisted of two open-ended questions: "What does air temperature have to do with lightning?" and "Suppose you see clouds in the sky but no lightning. Why not?" These questions were borrowed from Mayer, Heiser, and Lonn's (2001) transfer test about lightning formation. Participants' responses were scored according to Mayer et al. (2001) protocol by counting the number of acceptable solutions to each of the two questions. For example, an acceptable solution to the first transfer question was that cool air causes moisture in the cloud to condense, and an acceptable solution to the second transfer question was that the clouds were not at freezing level. The intraclass correlation between rater 1 and rater 2 for the first 50% of responses was acceptable (.83 for the first transfer question and .94 for the second transfer question). The remaining 50% of responses were split up between the two raters. A total transfer score was calculated by adding together the scores from the two transfer questions.

*Procedure*

*Pilot Test.* Before the experiment, a pilot test was conducted on ten participants (four younger adults and six older adults). The purpose of this pilot test was 1) to ensure that participants clearly understood the experiment instructions and test questions, 2) to determine how much time participants should be allotted for different portions of the experiment, and 3) to check the strength of the advanced organizer manipulation.

*Manipulation Check.* To determine whether or not participants were paying attention to and processing information conveyed through the AO, participants were given the following prompt and questions during the piloting stage: "An introductory organizer was presented to you at the beginning of this session. What was the topic of the introductory story map and what kind of task were you asked to complete related to this story map?" The correct responses to these two questions were: 1) the process of lightning formation and 2) an organizing task, respectively. Regardless of how participants worded their responses, they were awarded one point for each correct answer. Of the ten participants who were assigned to an AO condition in the pilot study, nine participants answered both of the manipulation check questions correctly. These results supported the strength of the advanced organizer manipulation.

*Main Experiment.* Upon entering the lab, young and old participants were randomly assigned to one of four conditions (low text coherence and no advanced organizer, high text coherence and no advanced organizer, low text coherence and advanced organizer, high text coherence and advanced organizer). Participants were first asked to provide demographic information and to complete several scales assessing their computer experience, computer anxiety, self-rated health, and knowledge of lightning formation. They also filled out assessments of their verbal ability.

Next, participants were informed that they would receive information about the process of lightning formation and then take a test on what they learned. Before the presentation of the main text, those in the advanced organizer condition were given four minutes to study a story map of the to-be-presented material in Microsoft PowerPoint. They were instructed to pay careful attention to this story map because it was crucial to the learning process. They then completed an organizing task based on the causal sequence presented in the AO. After they completed this task, they were asked to look back and assess their performance. The purpose of this organizing task was to help participants mentally organize and integrate the AO information into long-term memory. Participants in the control condition were not presented with an advanced organizer and moved directly into the main to-be-learned material. All participants were given 15 minutes to read the main learning material about lightning formation in Microsoft Word. As participants studied the text, they were given the opportunity to take notes, but their notes were taken away before test.

Following the computer-based instruction, participants completed learning outcome measures. First, they were given six minutes to complete a recall task in which they were asked to describe the process of lightning formation. Participants were then given four minutes to complete the test of knowledge organization. Finally, participants were given four minutes to complete each of the two transfer test questions. For each of these learning measures, however, if participants requested more time, they were given as much extra time as they needed. There was a concern that older adults might be slower at writing their responses compared to younger adults; therefore, this extra time was granted to allow all participants to fully communicate all that they had learned. The entire experiment took approximately an hour.

# CHAPTER 3

# RESULTS

Correlations between all study variables are presented in Table 2. This correlation table shows that recall, knowledge organization, and transfer scores were moderately to highly correlated (correlations ranged from .35 to .66). The strengths of these correlations suggested that the learning outcomes were distinct but related constructs, a finding that aligns with Kraiger, Ford, and Salas (1993) who argued that learning is multidimensional (i.e., different learning outcomes are differentially affected by training conditions). Because the learning outcomes were distinct but intercorrelated, a multivariate analysis of variance (MANOVA) was conducted with age, coherence level, and advanced organizer condition as the independent variables and recall, knowledge organization, and transfer performance as the dependent variables. Overall, the potential covariates (e.g., verbal ability, computer usage and experience, self-rated health) had low correlations with the learning outcome measures, and adding them to them to the MANOVA did not improve results. Therefore, I used a MANOVA for the primary analyses.

Tables 3, 4, and 5 show the cell means and standard deviations across each of the dependent variables (recall, knowledge organization, and transfer). First, results of the MANOVA revealed that there was a multivariate effect of age on learning outcomes such that older adults tended to perform worse than younger adults, ($\lambda = 0.88$, $F(3, 83) = 3.66$,

$\eta_p^2$ = .12, $p$ = .02). Univariate between-subjects tests indicated that age significantly predicted recall performance ($p$ =.00; $\eta_p^2$ = .11) and knowledge organization performance ($p$ = .01; $\eta_p^2$ = .08), but age did not predict transfer performance ($p$ = .25; $\eta_p^2$ = .02). This result was expected given that older adults tend to experience cognitive declines and therefore, may not perform as well on some learning measures compared to younger adults.

Next, the main effects of the instructional design manipulations (coherence effect and advanced organizers) on learning were examined. Results indicated that there was a significant multivariate effect of coherence level on learning outcomes. Compared with those in the low text coherence condition (i.e., high extraneous load condition), those in the high text coherence condition (i.e., low extraneous load condition) had significantly higher learning outcomes ($\lambda = 0.91$, $F(3, 83) = 2.66$, $\eta_p^2$ = .09, $p$ = .05) (Hypothesis 1 was supported). At the univariate level, coherence was significantly related to recall performance ($p$ = .01; $\eta_p^2$ = .08), marginally related to knowledge organization performance ($p$ = .07; $\eta_p^2$ = .04), and unrelated to transfer performance ($p$ = .73; $\eta_p^2$ = .00). Theoretically, instructional coherence interferes with learning because it takes up working memory capacity and leaves less room for the processing of core material. Thus, I tested whether cognitive load mediated the relationship between instructional coherence and learning outcomes using Baron and Kenny’s (1986) method. Results revealed that instructional coherence significantly predicted recall performance ($B$ = -1.33, $p$ = .01, $R^2$ = .06). However, instructional coherence did not predict cognitive load ($B$ = .04, $p$ = .88, $R^2$ = .00). Thus, the mediation hypothesis was not supported. The multivariate effect for advanced organizers was not significant ($\lambda = 0.94$, $F(3, 83) = 1.67$, $\eta_p^2 = .06$, $p = .18$) (Hypothesis 3 was not supported).

The interaction hypotheses were then examined. First, it was expected that the effect of coherence level on learning outcomes would be moderated by age such that older learners would benefit significantly more from instructional coherence than younger learners (Hypothesis 2). Results indicated that there was not a significant interaction between age and coherence level. That is, the positive relationship between coherence level and learning did not depend on age ($\lambda = 0.98$, $F(3, 83) = .71$, $\eta_p^2 = .03$, $p = .55$) (Hypothesis 2 was not supported). Additionally, it was expected that the effect of AOs on learning outcomes would be moderated by age such that older learners would benefit significantly more from advanced organizers than younger learners (Hypothesis 4). Results indicated that, indeed, there was a significant multivariate interaction between age and advanced organizers in predicting learning outcomes ($\lambda = 0.90$, $F(3, 83) = 3.12$, $\eta_p^2 = .10$, $p = .03$). Univariate between-subjects tests revealed that age and AOs did not interact to influence recall performance ($p$ =.70; $\eta_p^2 = .00$) or knowledge organization performance ($p = .71$; $\eta_p^2 = .00$), but they did interact to influence transfer performance ($p = .01$; $\eta_p^2 = .08$). Follow-up univariate post hoc comparisons between groups were conducted using a Bonferroni t-test and results showed that, in terms of transfer performance, older adults benefited significantly from advanced organizers ($p = .01$) while younger adults did not benefit from advanced organizers ($p$ =1.0) (Hypothesis 4 was supported).

Figures 1-3 depict the main findings of this study. Overall, analyses revealed 1) a main effect of age on learning outcomes (older adults tended to perform worse than younger adults on recall and knowledge organization), 2) a main effect of instructional coherence on learning outcomes (participants who received highly coherent text tended to perform better on recall and knowledge organization) and 3) an interaction between age and advanced organizers in predicting transfer performance. Specifically, results indicated that older adults benefited significantly from advanced organizers in terms of their transfer performance, while younger adults did not benefit significantly from advanced organizers. This finding suggests that older and younger adults do learn in different ways and, contrary to recommendations by some researchers, perhaps training designers should consider implementing age-specific instruction.

# CHAPTER 4

# DISCUSSION

The goal of this study was to investigate the effects of two instructional design principles (instructional coherence and AOs) on the learning outcomes of older and younger adults in a computer-based training context. I hypothesized that these instructional manipulations would have positive main effects on learning outcomes. Furthermore, I hypothesized that, because these instructional manipulations map onto and accommodate age-related cognitive declines, that they would be significantly more beneficial for older adults (compared to younger adults) in terms of improving their learning performance.

Results indicated that older adults performed worse than younger adults on recall and knowledge organization measures. Given that older adults tend to demonstrate various cognitive declines (e.g., Salthouse, 1996; Norman et al., 1992) and the fact that the training material was complex, it was expected that they would perform worse on learning measures compared to younger adults. This finding of an age-related training performance decrement is consistent with previous research suggesting that older adults learn less rapidly and exhibit less mastery of training material (e.g., Elias et al., 1987; Kubeck, Delp, Haslett, & McDaniel, 1996). For example, Kubeck et al. (1996) conducted a meta-analysis of 32 studies examining the relationship between age and job-related training outcomes across a variety of occupations. Training tasks such as job-skills training, computer skills training, and lab simulations of work tasks were included in the study. Their results indicated that, overall, older adults took longer to complete training programs and learned less in training compared to younger adults.

Second, analyses showed that instructional coherence positively affected recall and knowledge organization performance. This finding is also in line with the literature such that removing interesting but irrelevant details from learning material is associated with improved training performance (e.g., Mayer et al., 2001; Moreno & Mayer, 2000). Specifically, it has been proposed that irrelevant details are detrimental to learning because they take up working memory capacity and leave less room for the selection, organization, and integration of core learning material (Mayer, 2005a; Mayer, personal communication). Prior to this study, however, researchers had not tested the potential moderating effect of age on the relationship between instructional coherence and learning outcomes. In this experiment, no support was found for age as a moderator. That is, coherence was beneficial for both younger and older adults to a similar extent.

Third, analyses revealed that the effect of AOs on transfer performance was dependent upon learners' age. Specifically, AOs significantly improved the transfer performance of older adults but did not affect the transfer performance of younger adults. This finding is crucial because it suggests that, contrary to the propositions of researchers such as Van Gerven et al. (2006) and Fisk, Rogers, Charness, Czaja, and Sharit (2004), the same instructional principles may not hold for older and younger learners.

Why might AOs improve transfer performance for older adults but not younger adults? In some ways, the transfer measure used in this study assessed the deepest level of understanding because, in order to come up with the acceptable solutions, learners were required to understand the underlying conceptual structure of the learning material, rather than simply repeat units of information or sequence events in the correct order. For example, to understand why there might be cloud in the sky but no lightning, learners needed to hold the sequence of lightning formation in consciousness and compare this schema to different scenarios where there might be a cloud in the sky but no lightning. By providing a framework for the to-be-learned material, AOs facilitate this necessary structuring of information in memory, combining multiple knowledge elements into one singular structure, and freeing up working memory capacity so learners can perform the complex mental operations required of applied problems. Because older adults experience cognitive deficits such as the diminution of working memory capacity and a reduced ability to coordinate and integrate different pieces of information in memory, AOs might be helpful primarily for older adults. Furthermore, it could be that the facilitative effect of AOs is most evident in learning outcome measures that assess deeper levels of understanding.

*Limitations and Future Directions*

This experiment is limited in terms of the participant sample, the training materials, and the learning outcome measures used. First, I while I did recruit most older adults from places such as senior centers, volunteer organizations, and independent living facilities, where members could be assumed to be active and self-sufficient, I did not screen all of the older participants for cognitive impairments. Future research should conduct cognitive screenings on older participants to ensure that they are normally functioning and thus, that their results can be generalized to the older worker population. Other generalizability concerns include the fact that younger participants consisted mostly of undergraduates and, though 44.9% of them were employed, a greater number of young adults could have been recruited from the working population. Similarly, the older adults who participated in this study were, for the most part, retired. In order to increase confidence in the external validity of their findings, future researchers should focus on both older and younger adults who are employed.

Second, in terms of the design of the computer-based training program itself, the interface was rather simplistic in that information was presented in only one mode—visually. Specifically, learners were given text to read on the computer and, in the advanced organizer condition, a story map of the learning content. Future researchers could investigate the effects of instructional design principles using more technologically advanced multimedia presentations that involve multiple modes of information delivery such as computer animation and narration. As the coherence principle is derived from the cognitive theory of multimedia learning, it could be the case that in more complex multimedia environments, the facilitative effect of coherence becomes more pronounced and older adults benefit more than younger adults from this instructional principle.

Third, results revealed that seductive details were detrimental to learning (supporting the importance of instructional coherence), but the experiment did not allow me to identify whether the deleterious effect of extraneous load was due to the addition of seductive details or simply the addition of more text (c.f., Goetz & Sadoski, 1995).

Specifically, those in the low coherence condition were presented with learning material that had 188 more words compared to those in the high coherence condition. Future researchers might control for length across the two conditions by inserting more intrinsic or germane load into the experimental condition and then determine whether or not the coherence effect remains.

Furthermore, most of the participants had little prior knowledge of the training topic – how air temperature and the movement of electrically charged particles contribute to lightning formation. Certainly, organizations have adopted an increasingly flexible structure such that workers are making more lateral movements and need to be trained on topics of which they have little prior knowledge, but future researchers might consider focusing on training topics with which learners have experience. Prior research has demonstrated that learners' level of task experience can moderate the effectiveness of training design manipulations (e.g., Kraiger & Jerden, 2007). In terms of the instructional design principles presented in this study, it could be that when learners have experience with a training topic, the effects of instructional coherence or advanced organizers on learning outcomes diminish. Specifically, rather than relying heavily on learning aids, learners may draw on their own expertise to help them process and make sense of the learning material.

The learning outcome measures were another limitation of this study. For example, the knowledge organization scoring scheme was constructed based on the causal sequence presented in the text. Future studies should consider use of a research-based methodology for assessing knowledge organization (e.g., Pathfinder; Goldsmith &

Kraiger, 1997). Furthermore, future researchers might consider a knowledge organization scoring scheme that is based on the *importance* of information rather than the sequential order of information. In this study, each unit of recalled information was given equal weight. Perhaps future studies could have experts rate the centrality of different units of information and determine the extent to which older and younger adults recalled important information.

Additionally, it should be noted that the way the transfer questions were written introduces a potential confound in terms of interpreting results. Analyses revealed that, with the transfer questions, older adults benefited significantly from advanced organizers while younger adults did not benefit significantly from advanced organizers. However, transfer was assessed using a cued recall task while recall and knowledge organization were assessed using free recall. Cued recall tasks are distinct from free recall tasks in that learners are given a hint, or a cue, which helps them to generate units of information that were presented in the learning phase. In this case, the transfer questions cued learners to aspects of the learning material that related to air temperature and clouds. As older adults require more support in learning environments (Craik, 1986), this begs the question: was it the advanced organizer or the support embedded in the question that aided the older adults? Future researchers should ensure that all learning outcome measures provide equivalent amounts of support in order to enhance their comparability.

Another limitation of this study is that learning was assessed using only three of many potential learning measures. Although the recall, knowledge organization, and transfer measures each assessed unique and important aspects of learning, future researchers could examine the effect of these instructional principles on different learning outcomes such as metacognition or retention. Schmidt and Bjork (1992) argued that acquiring knowledge and skills during training is important, but retention is also important and sometimes differs from observed learning during training. Learners, immediately following training, may demonstrate certain knowledge but fail to retain that knowledge in the long term or they may demonstrate new knowledge later on that wasn't evident at the time of training. By testing the relationship between age, instructional principles and different learning outcomes, researchers can gain a more sophisticated understanding of how to design computer-based instruction depending on the age of the learner and the learning outcome of interest.

*Practical and Theoretical Implications*

This study has important practical and theoretical implications. One of the most substantial contributions of this study was the finding that, in the transfer task, older adults benefited from AOs while younger adults did not, as this finding provides evidence that we need to consider implementing age-specific principles to the design of training. As the purpose of most organizational training programs is to enable trainees to apply their knowledge and skills to novel workplace problems, the fact that this interaction effect emerged in the transfer task is practically significant. In particular, these results suggest that, as a critical component of training needs assessment, training designers should administer surveys to determine the age composition of trainees. If trainees are predominately younger adults, it might not be necessary to incorporate advanced organizers into the training program. On the other hand, if trainees are predominately older adults, it might be worthwhile to invest time in the development of an advanced organizer because this instructional tool has been shown to improve transfer performance for this age group.

These results may have broader implications for our cumulative knowledge about training effectiveness. Historically, the majority of training studies have been conducted using younger adult samples. For example, in a meta-analysis of 96 studies comparing web-based and classroom style instruction (Sitzmann, Kraiger, Stewart, & Wisher, 2006), 67% of studies were conducted on college students and the mean age across participants was 24. However, based on the findings of this experiment, we should be cautious about generalizing these results beyond the young adult population. Furthermore, we should pursue more research with older learners to determine which instructional principles facilitate learning and which instructional principles hinder learning for this age group. For example, Noe and Colquitt (2002) proposed that training programs are more effective when learners are given the opportunity to interact with one another. This principle, however, might not generalize across age groups because it does not specifically accommodate any age-related cognitive deficits. In fact, interaction among trainees may actually introduce a distraction that *hinders* learning for older adults (older adults are more distractible than younger adults). Thus, future research would benefit from exploring age-specific instructional formats in order to optimize the performance of older adults in computer-based training contexts.

Finally, this experiment bolsters the propositions of Kraiger et al. (1993) that learning is multidimensional and provides evidence that researchers should take into consideration how the training design is linked to specific learning outcomes in order to fully capture the effects of instructional design manipulations. Consider the effect sizes I found for training interventions. Arthur, Bennett, Edens, and Bell (2003) conducted a meta-analysis of training studies and found that, compared to the control condition, computer based training had a mean effect size of 0.40 on reaction, learning, behavioral, and results criteria. Sitzmann et al. (2006) reported a mean effect size of .15 in all studies comparing web-based to classroom instruction. In this study, in which I simply compared different types of computer-based training programs, the effect size of instructional coherence on learning outcomes was even larger. Specifically, the effect size of instructional coherence on recall and knowledge organization was 0.59 and 0.41, respectively. While the larger effect size produced by instructional coherence in this study may be explained by a stronger manipulation, it could also be attributed, in part, to the fact that the learning outcome measures were carefully selected to address unique and important aspects of learning *related to the intervention*. Thus, these results highlight the value of choosing learning outcomes carefully based on their importance and the purported advantages of the instructional design principles. By doing so, researchers can detect learning when it occurs and get a clearer understanding of the effectiveness of various training design principles.

In summary, this study generated three main findings. First, older adults tended to perform worse than younger adults in computer-based training. Second, instructional coherence significantly improved the performance of both older and younger adults. Third, age interacted with AOs to influence transfer performance. Specifically, AOs improved the performance of older adults but did not affect the performance of younger adults in transfer tasks. The two main effects are consistent with previous findings which indicate that aging is associated with training performance decrements and that instructional coherence is important for learning. The interaction result demonstrates that AOs may differentially affect older and younger adults' training performance. Broadly, this result suggests that learners' age is an important factor to consider in training design because older and younger adults may require different instructional formats depending on the learning outcome of interest. Further research should be conducted to determine which instructional design principles are helpful for which age group, under what circumstances, and why.

References


Arthur, W., Bennett, W., Edens, P. S., & Bell, S. T. (2003). Effectiveness of training in organizations: A meta-analysis of design and evaluation features. *Journal of Applied Psychology, 88,* 234-245.

Bell, B. S., & Kozlowski, S. W. J. (2002). Adaptive guidance: Enhancing self-regulation, knowledge, and performance in technology-based training. *Personnel Psychology, 55*, 267-306.

Cerella J. (1990). Aging and information-processing rate. In J. E. Birren, & K. W. Schaie, (Eds.), *Handbook of the psychology of aging* (3rd edition, pp. 201–221). San Diego: Academic.

Charness, N., Shumann, C., & Boritz, G. M. (1992). Training older adults in word processing: Effects of age, training technique, and computer anxiety. *International Journal of Technology and Aging, 5,* 79-106.

Craik, F. I. M. (1986). A functional account of age differences in memory. In F. Klix, & H. Hagendorf, (Eds.), *Human memory and cognitive capabilities, mechanisms and performance* (*Part A*) (pp. 409–422). Amsterdam: North-Holland.

Elias, P. K., Elias, M. F., Robbins, M. A., & Gage, P. (1987). Acquisition of word processing skills by younger, middle-age, and older adults. *Psychology and Aging, 2*, 340-348.

Fisk, A.D., Rogers, W.A., Charness, N., Czaja, S.J., & Sharit, J. (2004). *Designing for older adults: Principles and creative human factors approaches*. Boca Raton, FL: CRC.

Garner, R., Gillingham, M.G., & White, S. (1989). Effects of "seductive details" on macroprocessing and microprocessing in adults and children. *Cognition and Instruction, 6,* 41-57.

Goetz, E. T., & Sadoski, M. (1995). Commentary: The perils of seduction: Distracting details or incomprehensible abstractions? *Reading Research Quarterly, 30*, 500-511

Goldsmith, T., & Kraiger, K. (1997). Applications of structural knowledge assessment to training evaluation. In J.K. Ford and Associates (Eds.), *Improving training effectiveness in work organizations* (pp. 73-96). New Jersey: Erlbaum.

Hasher, L., Zacks, R. T., & May, C. P. (1999). Inhibitory control, circadian arousal, and age. In D. Gopher & A. Koriat (Eds.), *Attention and performance XVII: Cognitive regulation of performance: Interaction of theory and application. Attention and performance* (pp. 653–675). Cambridge, MA: MIT Press.

Harp, S., & Maslich, A. (2005). The consequences of including seductive details during lecture. *Teaching of Psychology*, 32, 100-103.

Harp, S. F., & Mayer, R. E. (1997). The role of interest in learning from scientific text and illustrations: On the distinction between emotional and cognitive interest. *Journal of Educational Psychology, 89,* 92-102.

Heinssen, Jr., R., Glass, C, & Knight, L. (1987). Assessing computer anxiety: Development and validation of the computer anxiety rating scale. *Computers in Human Behavior*, *3*, 49-59.

Hulicka, I., & Grossman, J. (1967). Age group comparisons of the use of mediators in paired-associate learning. *Journal of Gerontology, 22,* 46-51.

Katzman, R., Brown T., Fuld, P., Peck, A., Schechter, R., & Schimmel, H. (1983). Validation of a short orientation-memory concentration test of cognitive impairment. *American Journal of Psychiatry, 140*, 734-739.

Kim, S., Hasher, L., & Zacks, R. T. (2007). Aging and a benefit of distractibility. *Psychonomic Bulletin & Review*, *14,* 301-305.

Kraiger, K., Ford, J. K.., & Salas, E. (1993). Application of cognitive, skill-based, and affective theories of learning outcomes to new methods of training evaluation. *Journal of Applied Psychology, 78,* 311-328.

Kraiger, K., & Jerden, E. (2007). A new look at learner control: Meta-analytic results and directions for future research. In S. M. Fiore & E. Salas (Eds.), *Where is the learning in distance learning? Towards a science of distributed learning and training* (pp. 65 – 90). Washington, DC: American Psychological Association.

Kubeck, J. E., Delp, N. D., Haslett, T. K., & McDaniel, M. A. (1996). Does job-related training performance decline with age? *Psychology and Aging, 11,* 92-107.

Lee, C., & Bobko, P. (1994). Self-efficacy beliefs: Comparison of five measures. *Journal of Applied Psychology, 79,* 364-369.

Lehman, S., Schraw, G., McCrudden, M. T., & Hartley, K. (2006). Processing and recall of seductive details in scientific text. *Contemporary Educational Psychology, 32,* 569-587.

Lord, F. M. (1977). A broad-range tailored test of verbal ability. *Applied Psychological Measurement, 1,* 95-100.

Luiten, J., Ames, W., & Ackerson, G. (1980). A meta-analysis of the effects of advanced organizers on learning and retention. *American Educational Research Journal, 17,* 211-218.

Mayer, R. E. (1979). Twenty years of research on advance organizers: Assimilation theory is still the best predictor of results. *Instructional Science, 8,* 133-167.

Mayer, R.E. (2001). *Multimedia learning*. Cambridge, UK: Cambridge University Press.

Mayer, R. E. (2005a). *The Cambridge handbook of multimedia learning*. Cambridge: Cambridge University Press.

Mayer, R. E. (2005b). Introduction to multimedia learning. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 1-16). Cambridge: Cambridge University Press.

Mayer, R. E. (2005c). Cognitive theory of multimedia learning. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 31-48). Cambridge: Cambridge University Press.

Mayer, R., & Bromage, B. (1980). Different recall protocols for technical texts due to advance organizers. *Journal of Educational Psychology, 72*, 209-225.

Mayer, R.E., Heiser, J., & Lonn, S. (2001). Cognitive constraints on multimedia learning: When presenting more material results in less understanding. *Journal of Educational Psychology, 93,* 187-198.

Mayr, U., & Kliegl, R. (1993). Sequential and coordinative complexity: Age-based processing limitations in figural transformations. *Journal of Experimental Psychology: Learning, Memory, and Cognition*, *19*, 1297–1320.

Mayr, U., Kliegl, R., & Krampe, R.T. (1996). Sequential and coordinative processing dynamics in figural transformations across the life span. *Cognition*, *59*, 61–90.

Meyer, B.J. & Rice, G. (1981). Information recalled from prose by young, middle, and old age readers. *Experimental Aging Research, 7,* 253-268.

Moreno, R., & Mayer, R. E. (2000). A coherence effect in multimedia learning: The case for minimizing irrelevant sounds in the design of multimedia instructional messages. *Journal of Educational Psychology, 92*, 117-125.

Naveh-Benjamin, M. (2000). Adult age differences in memory performance: Tests of an associative deficit hypothesis. *Journal of Experimental Psychology: Learning, Memory, and Cognition, 26*, 1170-1187.

Noe, R. A., & Colquitt, J. A. (2002). Planning for training impact: Principles of training effectiveness. In K. Kraiger (Ed.) *Creating, implementing, and managing effective training and development* (pp. 53-79). Mahwah, NJ: Jossey-Bass.

Norman, S., Kemper, S., & Kynette, D. (1992). Adults' reading comprehension: Effects of syntactic complexity and working memory. *Journal of Gerontology, 47,* 258-265.

Oberauer, K., & Kliegl, R. (2001). Beyond resources: Formal models of complexity effects and age differences in working memory. *European Journal of Cognitive Psychology*, *13*, 187–215.

Paas, F. (1992). Training strategies for attaining transfer of problem-solving skill in statistics: A cognitive-load approach. *Journal of Educational Psychology*, *84*, 429-434.

Paas, F., Camp, G., & Rikers, R. (2001). Instructional compensation for age-related cognitive declines: Effects of goal specificity in maze learning. *Journal of Educational Psychology*, *93*, 181–186.

Paas, F., Renkl, A., & Sweller, J. (2003). Cognitive load theory and instructional design: Recent developments. *Educational Psychologist, 38*, 1-4.

Paas, F., Tuovinen, J. E., Tabbers, H., & Van Gerven, P. W. M. (2003). Cognitive load measurement as a means to advance cognitive load theory. *Educational Psychologist, 38*, 63-71.

Paas, F., Van Gerven, P.W.M., & Tabbers, H.K. (2005). The cognitive aging principle in multimedia learning. In Mayer, R.E. (Ed.), *Cambridge handbook of multimedia learning* (pp. 339–351). New York: Cambridge University Press.

Paradise, A. (2008). *State of the industry report.* Washington, D.C.: ASTD.

Perfect, T. (1997). Memory aging as frontal lobe dysfunction. In M. A. Conway (Ed.), *Cognitive models of memory* (pp. 315-339). Cambridge, MA: MIT Press.

Potosky, D., & Bobko, P. (1998). The computer understanding and experience scale: A self-report measure of computer experience. *Computers in Human Behavior, 14,* 337-348.

Preiss, R.W., & Gayle, B.M. (2006). A meta-analysis of the educational benefits of employing advanced organizers. *Classroom communication and instructional processes: Advances through meta-analysis,* 329-344.

Salthouse, T. A. (1985). Speed of behavior and its implications for cognition. In J. E. Birren &K. W. Schaie (Eds.), *Handbook of the psychology of aging (2nd* ed., pp. 400-426). New York: Van Nostrand Reinhold.

Salthouse, T. A. (1993). Speed and knowledge as determinants of adult age differences in verbal tasks. *Journal of Gerontology: Psychological Sciences, 48,* 29-36.

Salthouse, T.A. (1996). The processing-speed theory of adult age differences in cognition. *Psychological Review*, *103*, 403–428.

Sauzéon, H., Claverie, B., & N'Kaoua, B. (2006). Age differences in the organization and acquisition-forgetting processes in a multi-free-recall task. *Current Psychology Letters, 1,* 18.

Schraw, G. (1998). Processing and recall differences among seductive details. *Journal of Educational Psychology, 90*, 3-12.

Schmidt, R. A., & Bjork, R, A. (1992). New conceptualizations of practice: Common principles in three paradigms suggest new concepts for training. *Psychological Science, 3,* 207-217.

Sitzmann, T., Kraiger, K., Stewart, D., & Wisher, R. (2006). The comparative effectiveness of web-based and classroom instruction: A meta-analysis. *Personnel Psychology, 59*, 623-664.

Stone, C. (1983). A meta-analysis of advance organizer studies. *Journal of Experimental Education, 51,* 194-199.

Sweller, J. (2005). Implications of cognitive load theory for multimedia learning. In R. Mayer (Ed.), *The Cambridge handbook of multimedia learning* (pp. 19-30). Cambridge: Cambridge University Press.

Sweller, J., Van Merrïenboer, J.J.G., & Paas, F. (1998). Cognitive architecture and instructional design. *Educational Psychology Review*, *10*, 251–296.

Thalheimer, W. (2004, April). Bells, whistles, neon, and purple prose: When interesting words, sounds, and visuals hurt learning and performance—a review of the seductive-augmentation research. Retrieved February 27, 2007 from http://www.work-learning.com/seductive_augmentations.htm.

Thompson, D. N. (1997). Practice effects of advance organization with older adult subjects. *Educational Gerontology, 23,* 207-212.

Thompson, D. N., Diefenderfer, K., & Doll, L. S. (1986, April). *The use of advance organizers with older adults of limited verbal ability.* Paper presented at the annual meeting of the American Educational Research Association, San Francisco.

Thompson, D. N., Holzman, T., & Doll, L. (1985, April). *Using advance organizers to improve reading comprehension with older adults.* Paper presented at the annual meeting of the American Educational Research Association, Chicago.

Towler, A., Kraiger, K., Sitzmann, T., Van Overberghe, C., Cruz, J., Ronen, E., & Stewart, D. (2008). The seductive details effect in technology-delivered instruction. *Performance Improvement Quarterly, 21(2)*, 1-23.

"Turning boomers into boomerangs." (2006, February 16). *Economist, 378,* 65–67.

U.S. General Accounting Office. (2001). *Older workers: Demographic trends pose challenges for employers and workers.* Washington, DC: Author.

Van Gerven, P. W. M., Paas, F., & Tabbers, H. K. (2006). Cognitive aging and computer-based instructional design: Where do we go from here? *Educational Psychology Review, 18,* 141-157.

Van Gerven, P. W. M., Paas, F., Merriënboer, J. J. G., & Schmidt, H. G. (2006). Modality and variability as factors in training the elderly. *Applied Cognitive Psychology*, *20*, 311–320.

Van Merriënboer, J. J. G., & Sweller, J. (2005). Cognitive load theory and complex learning: Recent developments and future directions. *Educational Psychology Review*, *17*, 147–177.

Ware, J.E. Jr., Kosinski, M., Turner-Bowker, D. M., Gandek, B. (2002). *How to score version 2 of the SF-12 health survey*. Lincoln, RI: QualityMetric Incorporated.

West, R. L. (1996). An application of prefrontal cortex function theory to cognitive aging. *Psychological Bulletin, 120,* 272-292.

Willerman, M., & Mac Hag, R.A. (1991). The concept map as an advanced organizer. *Journal of Research in Science Teaching, 28,* 705-712.

Witte, K.L., Freund, J.S., & Sebby, R.A. (1990). Age differences in free recall and subjective organization. *Psychology and Aging*, 5, 307-309.

Table 1

*Demographic information for study sample*

| | Younger Adults ($n$ = 47) | Older Adults ($n$ = 46) |
|---|---|---|
| *Gender* | | |
| Men | 36.2% | 52.2% |
| Women | 61.7% | 45.7% |
| *Education* | | |
| Did not complete High School | 2.1% | 2.2% |
| High School Degree | 80.9% | 15.2% |
| Bachelor's Degree | 14.9% | 45.7% |
| Master's Degree | | 19.6% |
| Ph.D. | | 17.4% |
| *Employment Status* | | |
| Employed | 44.7% | 4.3% |
| Unemployed | 51.1% | 10.9% |
| Retired | | 82.6% |
| *Assisted Living* | | |
| Living in an assisted living facility | 0.0% | 4.3% |

Table 2

*Descriptive statistics and intercorrelations among study variables*

| **Variable** | **M** | **SD** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | **8** |
|---|---|---|---|---|---|---|---|---|---|---|
| Computer Anxiety | 2.10 | .55 | – | -.60** | -.38** | -.27* | .10 | -.27** | -.21 | -.16 |
| Computer Usage and Experience | 4.32 | .83 | | – | .31** | .08 | -.12 | .35** | .27* | .14 |
| Self-Rated Health | 3.91 | .50 | | | – | -.14 | -.02 | .27* | .20 | .30** |
| Prior Knowledge | 2.42 | .95 | | | | – | .12 | -.03 | .00 | -.09 |
| Verbal Ability | 12.77 | 5.14 | | | | | – | .16 | .08 | .14 |
| Recall Performance | 5.21 | 2.83 | | | | | | – | .66** | .42** |
| Knowledge Organization Performance | 4.46 | 2.59 | | | | | | | – | .35** |
| Transfer Performance | 1.21 | .92 | | | | | | | | – |

*Note.* ** $p < .01$*, $p < .05$

Table 3

*Cell means and standard deviations for dependent variable, recall.*

| | Mean | SD | n |
|---|---|---|---|
| *Young Learner* | | | |
| No AO, Coherent | 6.33 | 3.45 | 12 |
| No AO, Incoherent | 4.75 | 2.05 | 12 |
| AO, Coherent | 6.00 | 2.37 | 11 |
| AO, Incoherent | 6.17 | 2.52 | 12 |
| *Older Learner* | | | |
| No AO, Coherent | 4.91 | 2.02 | 11 |
| No AO, Incoherent | 2.50 | 2.07 | 10 |
| AO, Coherent | 5.50 | 2.47 | 12 |
| AO, Incoherent | 3.77 | 2.28 | 13 |

Table 4

*Cell means and standard deviations for dependent variable, knowledge organization.*

| | Mean | SD | n |
|---|---|---|---|
| *Young Learner* | | | |
| No AO, Coherent | 4.38 | 2.84 | 12 |
| No AO, Incoherent | 4.71 | 2.55 | 12 |
| AO, Coherent | 6.14 | 2.40 | 11 |
| AO, Incoherent | 5.04 | 2.40 | 12 |
| *Older Learner* | | | |
| No AO, Coherent | 4.36 | 2.15 | 11 |
| No AO, Incoherent | 2.30 | 2.00 | 10 |
| AO, Coherent | 4.46 | 2.85 | 12 |
| AO, Incoherent | 3.35 | 2.41 | 13 |

Table 5

*Cell means and standard deviations for dependent variable, transfer.*

| | Mean | SD | n |
|---|---|---|---|
| *Young Learner* | | | |
| No AO, Coherent | 1.42 | 0.79 | 12 |
| No AO, Incoherent | 1.17 | 0.58 | 12 |
| AO, Coherent | 1.09 | 1.22 | 11 |
| AO, Incoherent | 1.25 | 0.97 | 12 |
| *Older Learner* | | | |
| No AO, Coherent | 0.64 | 0.67 | 11 |
| No AO, Incoherent | 0.60 | 0.70 | 10 |
| AO, Coherent | 1.50 | 0.80 | 12 |
| AO, Incoherent | 1.38 | 0.77 | 13 |

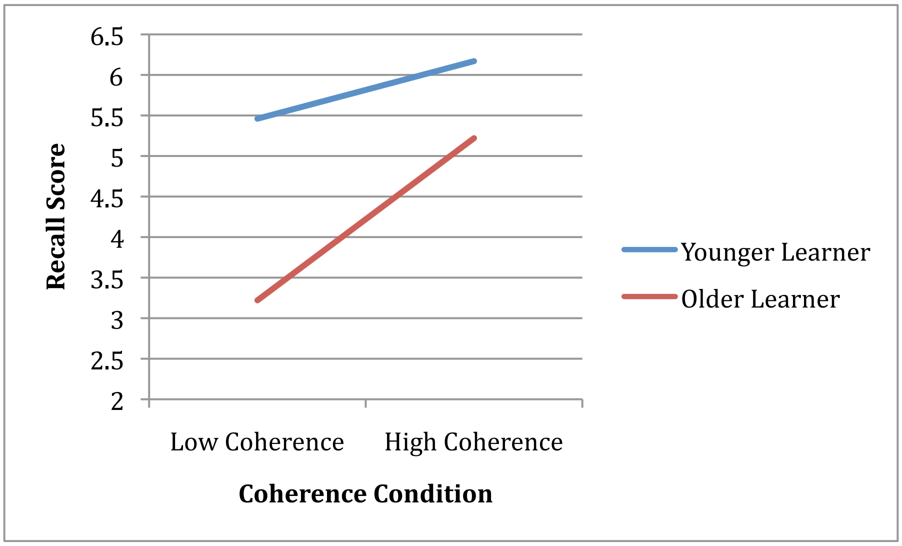

Figure 1

*Main effect of age and instructional coherence on recall*

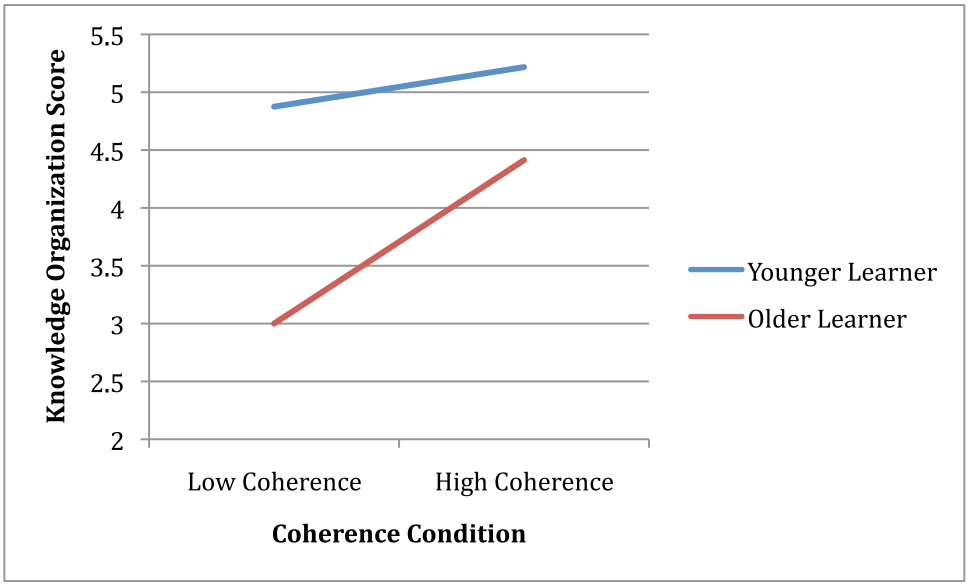


Figure 2
*Main effect of age and instructional coherence on knowledge organization*

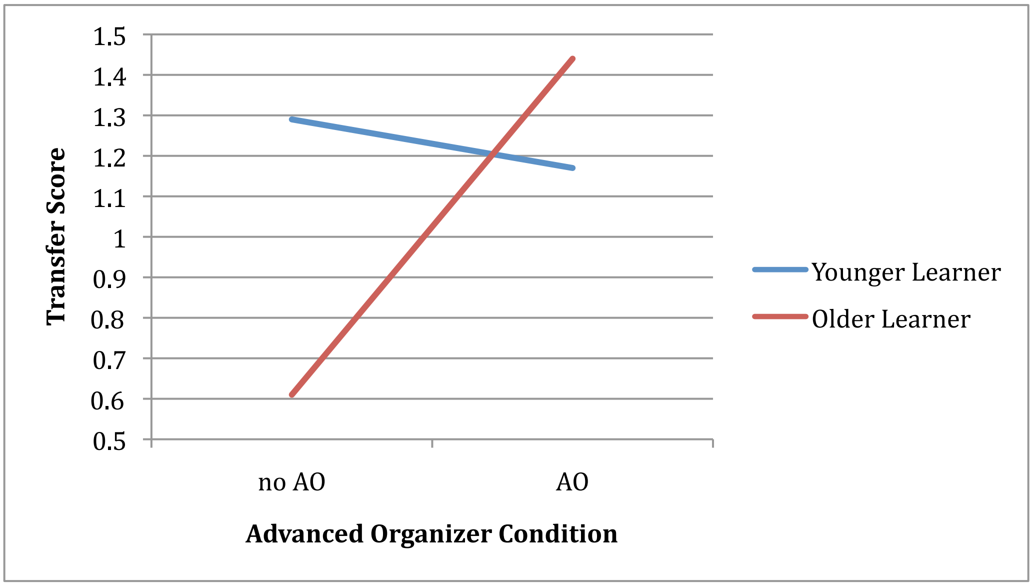


Figure 3

*Interaction between age and advanced organizer in predicting transfer*

## Appendix A

## The Process of Lightning Formation

Lightning can be defined as the discharge of electricity resulting from the difference in electrical charges between the cloud and the ground. Understanding how lightning is formed is important because approximately 150 Americans are killed by lightning every year. *Swimmers in particular are sitting ducks for lightning because water is an excellent conductor of its electrical discharge*.

The electrical differences between cloud and ground begin when warm, moist air near the earth's surface becomes heated and rises rapidly, producing an updraft. You may have experienced these updrafts on airplanes. *Flying through clouds with updrafts can cause the plane ride to be bumpy.* As the air in these updrafts cools in the cold upper atmosphere, moisture from the updraft condenses into water droplets and forms a cloud. The cloud's top extends high into the atmosphere. At this altitude, the air temperature is well below freezing, so the water droplets become tiny ice crystals.

Within the cloud, the water droplets and ice crystals gradually become too large to be suspended by the updrafts rising from the earth's warm surface. As the ice crystals within the cloud begin to fall, they drag some of the air from the cloud downward, producing downdrafts. These downdrafts meet the updrafts from the surface within the cloud. These rising and falling air currents within the cloud may cause hailstones to form because the water droplets are carried back up to the cold upper atmosphere. As we will see shortly, these hailstones play an important role in the formation of lightning. Eventually, the downdrafts overcome the updrafts and descend to the earth, where they spread out in all directions, producing the gusts of cool wind people feel just before the start of the rain. When lightning strikes the ground, the heat from the lightning melts the sand, forming fulgurites. *Fulgurites are glassy, root-like tubes shaped by the electricity's path.* Fulgurites help scientists understand how lightning spreads and acts against resistance from the soil.

Inside the cloud, it is the movement of the updrafts and the downdrafts that cause electrical charges to build, although scientists do not fully understand how it occurs. Most believe that the charge results from the collision of rising water droplets and tiny ice crystals in the updraft with hailstones in the downdraft. This movement causes static electricity to develop with the negatively charged particles falling to the bottom of the cloud, while most of the positively charged particles rise to the top.

The negatively charged particles at the bottom of the cloud provide the power for the first downward stroke of a cloud-to-ground lightning flash, which is started by a "stepped leader." Many scientists believe that this first stroke is triggered by a spark between the areas of positive and negative charges within the cloud. *In trying to understand these* *processes, sometimes scientists launch tiny rockets into overhead clouds to create lightning.* Once triggered, the stepped leader moves downward in a series of steps, each of which is about 50 yards long, and lasts for about 1 millionth of a second. It pauses between steps for about 50 millionths of a second. *Stepped leaders can strike a metal airplane, but rarely do any damage because airplane nosecones are built with lightning rods, which diffuse the lightning so it passes through the plane without harming it.* As the stepped leader nears the ground, positively charged upward-moving leaders travel up from such objects as trees and buildings, to meet the negative charges. Usually, the upward moving leader from the tallest object is the first to meet the downward moving stepped leader and complete a path between the cloud and earth. The two leaders generally meet about 165 feet above the ground. Negatively charged particles then rush from the cloud to the ground along the path created by the leaders. This type of lightning is not very bright and usually has many branches.

Understanding that lightning often strikes the tallest object in the area can help reduce the number of lightning injuries. People in flat, open areas are at greater risk of being struck. *Golfers are prime targets of lightning strikes because they tend to stand in open grassy fields, or to huddle under trees. These lightning strikes can be very dangerous. For example, eye witnesses in Burtonsville, Maryland, watched as a bolt of lightning tore a hole in the helmet of a high school football player during practice. The bolt burned his jersey, and blew his shoes off. More than a year later, the young man still won't talk about his near death experience.*

The "return stroke" is the electrical current that returns to the cloud. As mentioned previously, when the negatively charged stepped leader nears the earth, it induces an opposite charge, so that when the two leaders connect the cloud to the ground, positively charged particles from the ground rush upward along the same path. This upward motion of the current is the "return stroke," and it reaches the cloud in about 70 millionths of a second. It produces the bright light that people notice in a flash of lightning, but the current moves so quickly that its upward motion cannot be perceived. The lightning flash usually consists of an electrical potential of hundreds of millions of volts. The powerful electrical charge of the return stroke causes air along the lightning channel to be heated briefly to a very high temperature. Such intense heating causes the air to expand explosively, producing a sound wave we call thunder.

Understanding the process of lightning is important to both scientists and the public. Scientists need to know how lightning is created. People in general need to understand how lightning behaves, where it strikes, and how to avoid risk. *This knowledge can help to protect the 10,000 Americans who are injured by lightning each year.*

Appendix B

Advanced Organizer

**Lightning Formation: air temperature, movement and buildup of electrically charged particles**