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The Activation and Long-Term Memory of Predictive Inferences: The Role of Working Memory Constraint and Text Elaboration

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THE FLORIDA STATE UNIVERSITY

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The Activation and Long-Term Memory of Predictive Inferences:
The Role of Working Memory Constraint and Text Elaboration

By

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ABSTRACT

The study was focused on the effects of working memory (WM) capacity and text elaboration on the processing and product of text comprehension. Deep text comprehension was assessed via the online activation and long-term memory of primary predictive inferences. Participants included 73 English-native-speaking university students. Based upon the top and bottom third of a tripartite split of the participants' Read Span (RSPAN; Engle, 2005) percentile scores, 22 low- and 25 high- working memory span readers were identified. A 2 (inferential vs. control target sentence) X 2 (low vs. high elaboration) X 2 (low- vs. high-span) mixed factorial design was conducted, with the former two variables as the within-subject external text factors, and the latter one as the between-subject inter-individual difference factor.

The reading materials were 24 narrative stories. In each story, the target sentence contained either the inference-evoking or control context for one primary predictive inference. The previous context of each story had either a low or high elaborative causal relation with the event described by the target sentence, thus eliciting either a low or high level of activation of a secondary inference.

It was first hypothesized that working memory capacity would be a major factor for the online activation of primary predictive inferences. The General Capacity Theory would be supported if high-span individuals have quicker naming times than low-span individuals. On the other hand, the Skilled Suppression Hypothesis would be supported if low-span individuals have quicker naming times. Second, it was hypothesized that there would be a significant interaction between the text elaboration and working memory. Third, once the activation of primary predictive inferences are generated, the readers could stably represent the inferential ideas into their long-term memory, no matter whether readers' working memory is low or high (i.e., no significant working memory effect on exact recall of the predictive inference). Finally, the contribution of the activation of the primary predictive inferences and working memory capacity to participants' coherence of text-recall was expected to be moderated by low and high text elaboration.

The results of the study pointed to two major conclusions. First, in the context of the reading passages in this study, working memory was related to the nature of the activation of primary predictive inferences. Specifically, the low-span poor readers had quicker naming times, which aligns with the enhancement mechanism proposed in the Skilled Suppression Hypothesis.

The enhancement mechanism refers to when readers are not engaged in deep text processing (i.e., making primary predictive inferences in this study) but accept the superficial meaning of text during reading. Whereas, the low-span good readers had slower naming times, which supports the General Capacity Theory in that they were affected by the text elaboration on the secondary inference and took more time to shift their attention from the secondary inferential concept to the primary concept. Second, working memory moderates the effects of text elaboration and primary predictive inferences activation on offline text memory differently among low- and high- span readers. The second conclusion extends the finding from the online activation to the offline text memory. If activation of primary predictive inferences occurs online, the readers would coherently recall the text if it contains less elaboration, but when text contains high elaboration, the readers with a larger working memory capacity would retain the mental model of text in a much more coherent manner.

These two conclusions demonstrate that generating predictive inferences is a form of deep text processing. This resource-demanding cognitive process requires less effort of high-span readers, but requires greater attentional effort of low-span readers. Engaging in this process, would help readers construct and integrate a coherent situational model of text in the long-term text memory. The implications of the study are discussed in relation to the suppression paradigm and the functions of deep text comprehension (i.e., generating elaboration inferences) and working memory engagement in text reconstruction (i.e., building a coherent situation model of the texts).

CHAPTER 1

INTRODUCTION

Learning is a by-product of deep comprehension. Deeper levels of comprehension are associated with “more elaborate, longer lasting, and stronger traces” of memory (Craik & Lockhart, 1972, p. 675). In the field of education, it is a well-acknowledged fact that college students rarely have deep comprehension of their required textbooks (Graesser, Person, & Hu, 2002). In addition, National Assessment of Adult Literacy (NAAL) data suggest that adults who read fluently may nonetheless struggle with certain tasks due to deficiencies in inferential skills (Institute of Education Sciences [IES], 2006). Simply put, the ability to generate inferences during reading, based upon the most relevant information either in the text itself or beyond text (i.e., reader’s prior knowledge), is one of the most important skills in reading comprehension (Singer, Audrusiak, Reisdort, & Black, 1992; Singer & Ritchot, 1996). Furthermore, being able to generate inferences spontaneously and integrate them into the long-term text memory is the cornerstone of deep comprehension, and the hallmark of skilled learning from text (Cain, Oakhill, Barnes, & Bryant, 2001; Chi, 2000; Graesser, Singer, & Trabasso, 1994).

Questions remain, however, about the circumstances under which the inference process occurs online (during reading) and whether or not these circumstances contribute to text comprehension offline (after reading). Research on factors that impact both the online deep text processing (in terms of making inferences) and offline text memory not only provides a theoretical contribution (Perfetti & Schmalhofer, 2003; Singer & Kintsch, 2001), but also contributes to the research agenda in reading instruction by informing our understanding about ways to achieve long-term improvement in learning from text comprehension (Snow, 2002).

In addition, cognition differs from one person to another with regards to the individual differences in cognitive capabilities. There is a growing trend to investigate the effects of internal and external individual differences on cognitive processes during reading comprehension (Daneman & Carpenter, 1980; Jenkins, Fuchs, van den Broek, Espin, & Deno, 2003; Just & Carpenter, 1992; Linderholm, Zhao, Cong, & Virtue, 2006; Rosen & Engle, 1997; 1998). Understanding this topic has both theoretical and practical importance. From a theoretical standpoint, the understanding of a specific reading task that allows individual components of the

reading process to be isolated and studied sheds light on the importance of those components to the reading process. For instance, investigating phonological, morphological and orthographic processing differences in children highlighted their importance in children learning to read words, learning to learn to read, and failing to learn to read (Wagner & Torgesen, 1987; Wagner, Piasta, & Torgesen, 2006).

From a practical standpoint, it is necessary to understand the cognitive process and product involved in reading. The findings from this line of research would inform instructional techniques and the design of reading materials, so that both instruction and materials may be adjusted to complement the characteristics of individual students in order to optimize their learning outcomes. For example, students with higher knowledge might be able to engage in a more active gap-filling deep processing when the text is less coherent, while students with lower knowledge might achieve equivalent comprehension if the text is more coherent (McNamara & Kintsch, 1996). Understanding how individuals differ in cognitive processes and products in reading comprehension may inform the individualization of instruction or materials for the purpose of optimizing learning.

The aim of this study was to investigate the effects of internal and external factors on the process and product of making inferences during reading (i.e., how the working memory capacity constraint accounts for the effects of text elaboration on comprehension among college readers). Specifically speaking, the predictive inference, a type of elaborative inference beyond the text, concerns the event which will causally unfold after the event currently being read (Graesser, Olde, & Klettke, 2002). Being engaged in making predictive inferences during text comprehension contributes to the mental representation and deep understanding of the text being read (Beenman, Bowan, & Gersbacher, 2000; Calvo, 2004; McKoon & Ratcliff, 1992). The saliency of particular predictive inferences, however, may interact with the reading context, which may be distractive to the activation of one primary predictive inference because it contains text elaboration on a secondary predictive inference (Byrne, Espino, & Santamaria, 1999)

The research paradigm employed in the current study originates from the finding that the abilities to adjust attention allocation priorities (Reynolds, 2000) and to suppress interferences from inappropriate information (Gernsbacher & Faust, 1995) are prerequisites for successful comprehension. In the methodology employed, the level of primary predictive

inference distraction was systematically varied by manipulating the text constraints in reading passages provided to participants. As making predictive inferences engages readers in controlled effortful processing to choose the context appropriate meaning that facilitates text processing (Schmalhofer, McDaniel & Keefe, 2002), working memory constraint is expected to be strongly related to this phenomenon of text processing (Calvo, 2001; Conway & Engle, 1996). Under the controlled-attention capacity view of General Capacity Theory (Engle & Kane, 2004), working memory is defined as a conscious control mechanism that resolves interference between activated action schema. Hence, it is theoretically plausible to explore how working memory capacity impacts the reading phenomenon of predictive inferences.

Since working memory may be important to long term retrieval (Radvansky & Copeland, 2006), it is also important to consider how readers appreciate inferential ambiguity online (i.e., quick naming time on the salient primary inference) and integrate contextually relevant and irrelevant concepts offline (i.e., coherent memory representation of the text). When predictive inferences are generated online, often times they are generated minimally or non-specifically (Duffy, 1986; McKoon & Ratcliff, 1986). Research shows that the predictive inference takes time to develop (Calvo, 2000). After being activated, if it is not supported by the subsequent text, it may decay rapidly (Keefe & McDaniel, 1993). Previous research has focused attention on manipulating the subsequent text to strengthen the saliency of the predictive inferences to be detected and retained into the long-term memory (Cook, Limber, & O'Brien, 2001; Klin, Murray, Levine, & Guzman, 1999). Researchers, however, still do not know how the previous context affects the online activation and long-term memory of the primary predictive inferences. While researchers have made progress in explaining how people process ambiguous words (Gernsbacher & Faust, 1991) and ambiguous syntactic structures (Pearlmutter & McDonald, 1995), we still know little about how readers process and store inferential ambiguity. Good readers have a tendency to hold multiple expectations of text without passive decay in their long term memory (Ericsson & Kintsch, 1995). Hence, exploring this phenomenon would also increase our understanding of attention-controlled skilled suppression on both online and offline inference-making mechanisms during text comprehension.

According to the Structure Building Framework (Gernsbacher, 1990), activated memory nodes transmit processing signals upon encountering ambiguous meanings. These processing signals either suppress or enhance the activation of other memory nodes. So, once

memory nodes are activated two mechanisms modulate their level of activation: suppression and enhancement. It may seem that skilled comprehenders should be able to more accurately select the context-appropriate information online (i.e., enhancement mechanism) and more efficiently suppress the related but irrelevant information that has already been activated by the previous context (i.e., skilled suppression). In fact, however, Skilled Suppression Hypothesis states that it is the suppression mechanism, rather than the enhancement mechanism, which underlies readers' success at comprehension (Gernsbacher & Faust, 1995). When the reading context becomes more ambiguous, skilled comprehenders employ the suppression mechanism. Consequently, it takes longer for them to process the ambiguous context than the less skilled comprehenders.

For instance, laboratory findings (Perfetti & Ruth, 1981), have already suggested that more skilled comprehenders are not more appreciative of predictable sentence contexts which means they were not employing the enhancement mechanism during reading. Reading the predictable context *The garbage men had loaded as much as they could onto the truck. They would have to drop off a load at the garbage **dump***, relative to the control context *Albert did not have the money he needed to buy the part to fix his car. Luckily, he found the part he wanted at the **dump***. Both skilled and less-skilled comprehenders read the word **dump** quicker from the predictable context than the control context, but less-skilled comprehenders process the word *dump* quicker than the more-skilled comprehenders in the predictable context.

Similarly, based upon studies on word ambiguity in text processing, the Skilled Suppression Hypothesis prescribes that the skilled comprehenders do not accept the contextually inappropriate information quicker than the less-skilled comprehenders (Gernsbacher & Faust, 1995). This means that when context becomes more ambiguous, alternative/multiple meanings are potentially activated. Skilled comprehenders should be able to suppress the related but irrelevant information, but good suppression takes time to happen. In contrast, less-skilled comprehenders would appreciate both the context appropriate and context inappropriate probes more quickly because they have not employed the suppression mechanism. Therefore, skilled comprehenders should accept the contextually inappropriate information more slowly than less-skilled comprehenders. On the discourse level, if the primary inference is supported by sufficient text constraints, the primary inference should be salient as a most appropriate causal consequence of the target event (McDaniel et al., 2001).

Thus, the reading task in the current study is designed such that participants detect one primary predictive inference during reading in the context where low elaboration of a secondary inference is provided in the preceding text. Alternatively, when high elaboration of a secondary inference is provided in the preceding text, the secondary inference might distract readers from the primary inference. It is assumed that the activation of the primary inferences should be impacted by the degree of elaboration on the secondary inferences.

The rationale for this study and its design are grounded by a previous study (Guan, Roehrig, & Williams, 2007). In the previous study, the general effects of distractor-elaboration (i.e., high elaboration of a secondary inference in the preceding text) on text comprehension among college students was investigated in terms of activating primary predictive inferences online (during reading) and remembering them offline (after reading). One key finding from the previous study was that college readers were capable of maintaining the primary predictive inferences in the long-term text memory once the inferences were activated online. This online activation was detected by a short naming latency of the primary predictive inference within 500ms. Text elaboration played a role in both the online activation and offline long-term recall of the implicit text (i.e., the primary predictive inference made by the reader). Specifically, the more elaboration there was in the text related to the secondary inference, the lower the level of activation of the primary predictive inference, but the higher the probability of the offline long-term recall of the primary inference.

Additional exploratory analyses conducted on the data collected for this previous study (Guan et al., 2007), however, indicated that when the effect of working memory constraint was partialled out, the effect of text elaboration on inference activation and offline memory disappeared. This indicates that it would be hard to generalize the findings of the previous study without considering the working memory differences among readers. Text elaboration is assumed to have different impacts on activation and long-term memory for individuals with high versus low working memory capacities. This current study, therefore, aimed to further investigate whether and how working memory constraint accounts for the effects of text elaboration on both inference activation online and long-term memory offline in the narrative reading context. It was generally hypothesized that both the cognitive skill (e.g., working memory capacity constraint) and the text stimulus (e.g., the amount of distractive elaboration on

the secondary inferences) would impact the level of primary inference activation and long-term memory.

The preliminary analyses examined the study variables to set up the basis for low- and high- working memory groups via two steps. The first step examined the criterion variable (i.e., naming times) to demonstrate that the findings in the previous study (Guan et al., 2007) were replicated in the current study so that the more in-depth exploration of the major study hypotheses could be conducted thereafter. The second step focused on pitting one working memory measures against the other measures to select the benchmark criterion for follow-up group comparison.

There are two major sets of study hypotheses. The first one centered on whether and how the text elaboration on the secondary inference affected online inference activation. It was presumed that RSPAN would be able to distinguish the high span readers from the low span readers in processing the ambiguous inferential concepts online. Thus, the naming latencies between low- and high- span readers would be different from each other (*Hypothesis 1*: there would be a significant main effect of working memory on naming times). To further explore the real picture on the naming times differences between the low and high span readers, the interaction between the text elaboration and working memory should reveal the fact that readers in different span groups are actually employing their working memory differently in processing the textual information in low and high elaboration context (i.e., *Hypothesis 2*: there would be a significant interaction between the text elaboration and working memory).

In the general hypothesis 1, two alternative hypotheses (*Hypothesis 1-a* and *1-b*) parallel what different theories have predicted. On the one side, *Hypothesis 1-a* predicted that high working memory span individuals would have quicker naming latencies on probe words than low working memory span individuals. According to the General Capacity Theory (Engle, Kane & Tuholski, 1999; Engle & Kane, 2004), high span individuals should be able to name the probe words representing the primary predictive inference quicker than low span individuals. The rationale is that high working memory span readers would engage in a conscious control mechanism in shifting their attention. When the text contains an ambiguous inferential context (i.e., high elaboration of a secondary inference), high working memory span individuals would be more efficient in figuring out the information most relevant to the primary inference in the

prior context and inhibiting the related but irrelevant information from the prior context. Thus, high span individuals, compared to low span individuals, would name the inferential probe words more quickly. If the General Capacity Theory holds across cognitive domains, this prediction should be tenable for inference-making process during reading comprehension.

On the other side, *Hypothesis 1-b* predicted that high working memory span individuals would have slower naming latencies on probe words than the low working memory span individuals. Reading researchers assume that the processing of predictive inferences is indicative of deep text processing because it is time consuming and resource-demanding (Beenman et al., 2000; Calvo, 2004; McKoon & Ratcliff, 1992). Research also suggests that predictive inferences take time to develop (Calvo & Castillo, 1998). As proposed by the Skilled Suppression Hypothesis, skilled comprehenders should more successfully employ the suppression mechanism. When multiple meanings occur online, they need time to suppress the related but irrelevant information. Therefore, when engaged in deep text processing, they would not process the text more quickly than the less skilled comprehenders (Gernsbacher & Faust, 1995). If the Skilled Suppression Hypothesis holds, it was expected that high span readers, despite their working memory advantage, would spend more time processing the inferential concept compared to low working memory span individuals.

The second sets of study hypotheses centered on whether and how the distractive text affected offline inference representation in long-term memory. *Hypothesis 3* predicted that working memory might not be a major factor for the offline recall of the inferential target concept (i.e., primary predictive inferences), but would be a major factor for the coherent representation of the text when the context becomes more ambiguous. To further explore the effect of working memory on the integration of the activated predictive inferences in the long-term memory, *Question 4* explored the extent to which working memory would be a factor that influences the long-term text representation in a coherently integrated manner, but this effect should be moderated by the text elaboration.

The design of the current study provided a way to explore how successful comprehenders implement their working memory capacity for the purpose of long-term text memory. This is an extension of the Skilled Suppression Hypothesis from the short-term memory perspective to the long-term perspective. While working memory capacity may not inhibit

interference, such as may be caused by distractions from competing inferences, it may contribute to better integration and comprehension of text at the situation model of text (Radvansky & Copeland, 2006). The situation model of text representation describes what the text is about but not the text itself. Indirect evidence has suggested that adult readers are capable of generating predictive inferences, and the generation of predictive inferences enhances the information retrieval on the situation model of text (Radvansky, Zwaan, Curiel, & Copeland, 2001). Thus, the findings from the current study contribute to long term retrieval literature with regards to how working memory functions according to text property changes in discourse processing.

In the current study, three circumstances that affect the online activation and long-term memory of primary predictive inferences were examined. These factors included working memory capacity (high vs. low span), the level of causal elaboration on the primary predictive inference, and the level of elaboration of a secondary predictive inference. A 2 (inferential vs. control target sentence) X 2 (high vs. low elaboration) X 2 (high vs. low span) mixed factorial design was conducted, with the former two variables as the within-subject factors, and the latter one as the between-subject factor. The hypotheses were tested using the methodology of word naming, which assessed the extent to which targeted concepts were automatically activated during reading without the problem of context checking inherent in other methods (e.g., lexical decision task, and question-answering). In the naming task, a single word representing the target inference was presented for naming following a delay of 500ms after the final sentence of each passage. A faster naming time in the inference condition relative to the control condition was an indication of activation. This paradigm produced reliable evidence of primary predictive inferences in previous research (Guan et al., 2007). Text memory was measured by the cued recall task, and working memory was measured via Reading Span task (RSPAN; Engle, 2005).

The reading materials comprised 24 narrative stories. In each story, the previous context provided an elaborative situation background from which either a strong or weak secondary causal relationship to the inferential target sentence could be established upon reading the target sentence. The target sentence contained either the inference-eliciting or a control sentence, which did not elicit the primary inference. The material design was grounded in theory and previous research. First of all, making predictive inferences as a form of deep text processing is resource-demanding in terms of online processing and offline storage (McKoon & Ratcliff, 1992; McDaniel et al., 2001). The materials containing text features eliciting this reading

phenomenon, therefore, were challenging enough to be able to discriminate the high from the low working memory capacity (WMC) individuals (Guan et al., 2007). For example, studies using similar materials suggested that low- and high-span individuals varied in their ability to make and integrate the ideas of predictive inferences into the overall text representation under different context constraints (Linderholm, 2002; McDaniel et al., 2001). Secondly, narrative text was selected because it prompted more familiar forms of causality than do expository text, thus evoking more predictive inferences (Einstein, McDaniel & Cote, 1990; Zwaan, 1994). The generic content of a variety of situations in the narratives minimized the demands for domain-specific background knowledge and mitigated the impact of individual life experiences.

The material design also created the conditions necessary to test the research hypotheses. Basically, the focused event presented by a target sentence at the end of each passage contained either an inducing or control context for a primary predictive inference. This manipulation varied the saliency of the online activation of the primary predictive inference. Meanwhile, the previous distractive context contained either a high or low amount of elaboration on a secondary predictive inference associated with the focused event presented by the target sentence. The manipulation first provided distraction to the activation of the primary predictive inference and also provoked the persistence of the implicit as well as the explicit text into the long-term text representation at the time of recall. Under varied causal elaboration constraints, the persistence of the offline memory varied (Guan et al., 2007).

The goals of this study were twofold. The first goal was to explore whether and how low- and high-working memory span readers differ in the tendency to activate primary predictive inferences under low and high levels of distractive elaboration conditions. Naming latencies on the probe word were used to detect the different patterns of online activation between two working memory groups. If differences existed, two competing theories prescribed two alternative hypotheses (see the first set of hypotheses described above). The second goal was to examine the extent to which the primary predictive inferences were integrated into readers' long-term memory representation. To this end, a surprise cued recall test was administered after the reading task (see the second set of hypotheses described above).

In Chapter 2, a theoretical framework is offered as the baseline within which the research findings were interpreted with respect to working memory capacity. Chapter 3 reviews previous

studies on working memory capacity (internal) and text property (external) factors related to inference activation and long-term text memory. Chapter 4 describes how the study was implemented, and Chapter 5 presents the data analytical strategies and concludes with the results. Finally, a general discussion of the findings and study implications are given in Chapter 6.

CHAPTER 2

THEORETICAL FRAMEWORK

Theories on both working memory and language-specific comprehension provided the overarching framework for this current study. Several theories that describe the processes and functions of working memory were reviewed, with one theory (i.e., the General Capacity Theory, (Engle, Cantor & Carullo, 1992) selected for the operationalization of working memory in this study. The general construct of cognitive processes prescribed by the General Capacity Theory, however, needed to be supplemented by a linguistic-specific comprehension framework. Because the General Capacity Theory was not exclusively developed to explain linguistic-specific cognitive processes, a more coherent guideline for investigating higher-order language processing under the distractive research paradigm might be suggested by the Skilled Suppression Hypothesis (SSH) (Gernsbacher, 1990). As reviewed below, the Skilled Suppression Hypothesis has been used to explain language comprehension under the biasing text context, which is grounded in the distractive research paradigm. Hence, SSH was proposed to strengthen the rationale for the current study.

Theories of Working Memory

The three most dominant theories of working memory are the Multi-Component Theory, General Capacity Theory, and Capacity Constrained Comprehension Theory. The Multi-Component Theory (Baddeley, 1986; 1998; 2000; 2003) defines the components and the basic functioning of working memory. The General Capacity Theory (Engle et al., 1992; Turner & Engle, 1989) and the Capacity Constrained Comprehension Theory (Just & Carpenter, 1992) focus on the relationship between working memory capacity and comprehension ability. This chapter introduces each working memory theory and discusses their pros and cons. Focusing on the debate over controlled attention (i.e., divided executive control) in the face of distraction in higher-order cognitive processing, this chapter finally establishes the General Capacity Theory as the theoretical baseline for working memory as operationalized in the current study.

Multi-Component of Working Memory Theory. The Multi-Component (MC) Theory of working memory (Baddeley, 1986) contradicts the traditional notions of unitary short-

term memory (Atkinson & Shiffrin, 1968). A series of experiments of the dual task method have suggested positive evidence supporting a multifaceted mechanism rather than unitary short-term memory mechanism. This multifaceted mechanism is what Baddeley defined as working memory. The dual task method requires participants to process information as well as hold digits in memory. When memory load reaches and goes beyond 6 digits, the performance of parallel processing (in activities such as reasoning, comprehension, and recall tasks) decreases. Based upon the evidence from the dual task method, Baddeley proposed the tripartite model of working memory, which includes two separate slave systems and a central executive system. The two slave systems are the phonological store and the visual-spatial sketchpad. These two systems are capable of recycling information into memory stores to keep them from fading away. Meanwhile, the central executive system actively shuttles information in and out of the former two stores and into other processing systems.

Most recently, Baddeley (2000) proposed a fourth subsystem, the episodic buffer. Figure 2.1 presents the latest model proposed by Baddeley (2003). The first slave system, the phonological or articulatory loop, comprises both the phonological store and an articulatory control process. The phonological store holds information in phonological form for one to two seconds after the verbal memory decays. The articulatory control process maintains decaying representations and subsequent verbal information by rehearsal, translates written language into phonological code, and sends the information to the verbal stores (Baddeley, 1998). The general function of the phonological loop is to provide temporary storage of unfamiliar phonological forms while more permanent memory representations are being constructed. The phonological loop component of working memory has a direct link to language acquisition, such as learning to read and acquiring vocabulary (Baddeley, Gathercole, & Papago, 1998).

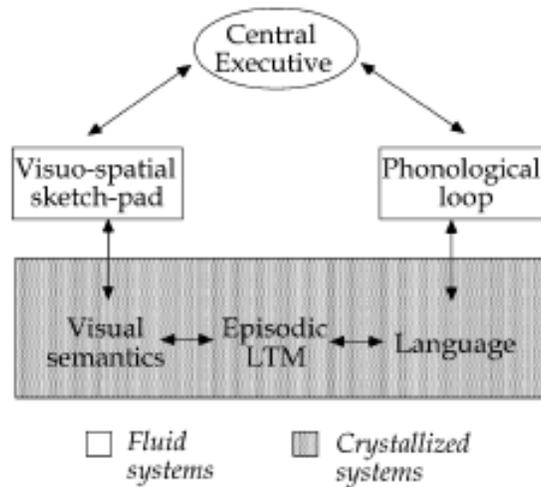


Figure 2.1. The three component model of working memory in which visual and verbal subsystems are controlled by an attentional executive. The shaded areas refer to crystallized, or long-term systems, which involve stored information which is capable of interacting with the working memory system (Baddeley, 2003).

The second slave system, the visual-spatial sketchpad, is responsible for the manipulation and temporary storage of visual and spatial information. Its subcomponents are analogous to those of the phonological loop: the storage component and a control process. The main function of this system is to store and process images and visual information of the objects (e.g., its location). To date, more is known about phonological processing by the phonological loop, than about visual coding in memory by the visual-spatial sketchpad (Baddeley, 1998). Both slave systems are dependent upon a third attentionally-limited control system, the central executive.

The central executive is responsible for the attentional control of working memory. It plays the role of selecting, initiating, and terminating processing routines. The central executive is responsible for attending to and switching attention from one cognitive process to another. For example, the central executive plans and operates the flow of information processing between the subcomponents of either slave system or between two slaves systems and long term memory. When the processing is completed, it also judges and evaluates the accuracy of the final representation of information and makes corrections if necessary.

The fourth subcomponent, the episodic buffer, has been newly added to the model (Baddeley, 2000). The episodic buffer comprises a limited capacity system that provides temporary storage of information held in multimodal code. The final product of episodic memory is a unitary representation built upon the binding information from the subcomponents of the slave systems and from long-term memory. This episodic buffer can even include information that is not processed from the two slave systems, such as sensory memory (Cowan, 2005). The addition of an episodic buffer greatly increases the scope of information that can be stored in the human information processing mechanism. Information from long-term memory helps to determine the form of the representation in the buffer stores. Meanwhile, conscious awareness is assumed to be the major model of retrieval from the buffer. Rather than isolating the subcomponents of the memory system, the episodic buffer provides a better basis for integrating information in terms of associated phenomenological experiences of remembering. This complex aspect of executive control is conscious monitoring, which plays a role in separating accurate recall from false memory (Baddeley).

The recent revision of this model highlights the role of central executive resources in strategic processing of information in the temporary stores (Baddeley, 2001). One interpretation of the model is that active processing of stimuli occurs in the episodic buffer to increase the amount that can be stored. For example, Baddeley (1996) suggested that the level of performance on the digit span task, which was argued to involve relatively little complex processing, would be determined primarily by storage rather than executive function. However, he also cautioned that maximal verbal memory span depended on both the phonological loop and central executive, with participants recruiting central executive resources as the digit load increased past capacity: “as the digit load increased, the demands made on the central executive will increase” (Baddeley, 1996, p. 11). An inference drawn from this statement is that maintaining high working memory loads requires input from strategic executive processes, such as chunking several digits together.

The multi-component theory provides a basic theoretical framework for understanding how higher level cognition is supported by the human working memory system. This symbolic structure of working memory, as the work space for human information processing, includes multiple subcomponents. Each subcomponent functions uniquely and interdependently in processing and learning. However, this model focused less attention to describe how working memory capacity functions regarding controlled, sustained attention in the face of interference.

Less attention does this model exert to explain the individual differences in working memory functioning. The following two theories, the General Capacity Theory (Engle et al., 1992) and Capacity Constrained Comprehension Theory (Just & Carpenter, 1992) attempt to fulfill these two unsolved questions.

General Capacity Theory of Working Memory. Engle and his colleagues (Engle et al., 1992; Turner & Engle, 1989) hold the idea that working memory capacity is a general, domain-free system that is independent of any one processing task. This General Capacity (GC) Theory of working memory proposes that the working memory system consists of storage processes, including long-term memory traces activated above the threshold and the processes required for achieving and maintaining that activation, as well as an executive attention component. This assertion has received support from a variety of experiments (Cantor, Engle, & Hamilton, 1991; Engle et al., 1992; La Pointe & Engle, 1990).

The span task has been regarded as an indicator of the generality of working memory capacity across a variety of processing capabilities, such as note-taking (Kiewra & Benton, 1988), bridge-playing (Clarkson-Smith & Hartley, 1990), computer-language learning (Shute, 1991), and novel reasoning (Kyllonen & Christal, 1990). A large amount of evidence supports the view that working memory span tests reflect a general cognitive construct (Engle, Tuholski, Laughli, & Conway, 1999).

In recent work, Engle called this a “controlled-attention capacity” (Engle, Kane et al., 1999; Engle & Kane, 2004). The controlled-attention view of working memory capacity (Engle, Kane et al., 1999; Engle & Kane, 2004) sets up the theoretical framework for GC theory. The controlled-attention capacity provides theoretical guidelines for how working memory plans, inhibits and abstracts information being processed. To explain how the mechanism works, an analogous model, the supervisory attentional system (SAS; Shallice & Burgess, 1993; Burgess & Shallice, 1996), is described here. SAS is hypothesized to be a conscious control mechanism that resolves interference between activated action schema. Shallice and his colleagues conducted a series of neuropsychological studies demonstrating three isolated functions of SAS: planning, inhibiting and abstraction.

In SAS, planning is defined as the capacity to analyze and elaborate possible solutions to a new problem. For example, the test of Tower of London (TOL) requires participants to move an initial arrangement of beads to match a goal arrangement presented by the experimenter. The patients with a frontal lobe lesion showed slower initiation and longer execution times than healthy participants. Inhibition requires suppressing a dominant response which has been initiated as an automatic response. For example, the last word of a sentence is missing, but participants are asked to complete the sentence with a word that does not make sense in the sentence context. The frontal patients were slower in inhibiting a dominant response (e.g., the automatic response of the missing word that fits in with the sentence context). Finally, abstraction refers to the ability to synthesize logical rules by performing cognitive integration based upon the relationships between items. For instance, in the Brixton test participants are shown a series of plates on which 10 circles are presented. The positions of the 10 circles on the plate change each time with a simple rule. The participants must figure out the rule and predict one of the filled positions of any of the 10 circles for each subsequent trial when the new plate is presented. The patients with frontal lobe damage gave responses with no rationale for the to-be-filled position of the circles on the plate. The SAS, thus, anticipates additional activation to a more appropriate action schema, inhibits the activation of the inappropriate scheme, and abstracts the patterns of schema activation by logical synthesizing and meaningful integration (Shallice & Burgess, 1993; Burgess & Shallice, 1996).

The controlled-attention capacity view of working memory received support from a variety of experiments using individuals scoring in the upper and lower quartiles of working memory Span measures. Studies on the Stroop task, antisaccade task, a dichotic-listening task, and an allocation of visual attention task have been used to explore the nature of this central executive and have supported the view that individual differences in working memory capacity are attention-constraint in nature. Kane and Engle (2000, 2003) tested low- and high- spans on the Stroop task, in which there is a conflict between the color of the word to be read and the word itself. The participants were required to report the color that the words were written in. The automatic processing of word reading interferes with color naming. The result showed that when there was conflict between word reading and color naming, high span individuals responded faster and more accurately than low span individuals. Kane, Bleckley, Conway, and Engle (2001) tested low- and high- span individuals in the antisaccade task, in which participants

presented a flashing visual and required to direct their attention to the opposite of the flash so as to identify a briefly presented item. The results indicated that high span individuals moved their eyes to the object faster and made fewer eye movement errors (looking towards the cue) than the low span individuals. In addition, Coway, Cowan, and Bunting (2001) tested low- and high-working memory span individuals in a dichotic listening task by presenting the participant's name in the unattended message. They found that low span individuals made more errors and reported hearing their names more than high span individuals.

Although the tasks in these varied experiments applied different modalities to instantiate the attentional control mechanism, the findings from the perspective of GC theory demonstrate a commonality among these tasks in that they all require the participant to resist, inhibit, or recover from salient or automatic influence from the environment. As to what is the essence of individual differences in their attention-controlled or resource-dependent capacity, "active goal maintenance," the core of working-memory capacity, is the major factor that "drives individual differences in the ability to block or inhibit distraction" (Kane & Engle, 2000, p. 336).

Although Engle and his colleagues (Engle et al., 1992) have attempted to fit reading comprehension within the framework of their GC theory, they have yet to explore in depth individual differences in the field of reading comprehension. To explore individual differences in complex reading domains, a linguistic approach of working memory was proposed by Just and Carpenter (1992). The next section reviewed Just and Carpenter's (1992) Capacity Constrained Comprehension (CCC) Theory. To some degree, CCC theory explains the individual differences between low- and high- span readers in the domain of reading comprehension.

Capacity Constrained Comprehension Theory. Daneman and Carpenter (1980) were the first to publish data examining individual differences specifically in verbal working memory. In contrast to the other general models of working memory (Baddeley, 1986; Engle et al., 1992), Just and Carpenter (1992) advocated a linguistic specific approach, such that linguistic working memory capacity directly constrains the operation of language comprehension processes, and that variation in the capacity of linguistic working memory is the primary source of individual differences in language comprehension. This task-specific Capacity Constrained Comprehension (CCC) Theory of verbal working memory basically assumes that capacity is the amount of activation available for both storage and processing. It is the limited activation currently

available that differentiates low- and high- span readers. If capacity is exceeded as a result of either inadequate capacity of the reader or the challenging demand of the task, the processing speed would slow down and the computation on the previous text comprehension would decay. In other words, this competition between slow computation in the current processing and lost computation from previous processing would occur among the low span readers because they only have a limited amount of activation available to them for both processing and storage. In contrast, the high span readers do not have this problem or at least are better at allocating their cognitive resources for knowledge activation during reading. As the reading task becomes more demanding, the capacity is more limited for both groups of readers, thus exacerbating the performance of online processing (Carpenter, Miyake, & Must, 1994; Just & Carpenter, 1992).

The task-specific CCC theory has been supported by many of the experiments focusing on the amount of capacity available in verbal working memory, with the Read Span task used to assess the efficiency with which information was processed. Daneman and Carpenter (1980) first developed the Read Span task to assess verbal working memory and to predict reading comprehension skill (Daneman & Carpenter). In this task, adult participants are presented with a series of sentences that they have to either simply read or which they have to read and verify as being true or false, with extra constraint that the last word at the end of each sentence has to be remembered. The scores for working memory span are based upon the maximum number of final words that an individual can recall in correct serial order under such constraints. Assessing the readers in this way, Just and Carpenter (1992) were able to support the hypothesis that comprehension is constrained by working memory capacity. Several capacity related constraint were identified, such as the time course of comprehending a complex syntactic embedding, the maintenance of two representations by the pragmatic cues during sentence processes, and the ability to track long-distance dependencies within and between sentences. The influence of pragmatic cues on sentence processing was elaborated in the following paragraphs to explain how individual differences in working memory constrain comprehension.

Just and Carpenter found that only high-span readers took advantage of pragmatic cues when comprehending reduced relative clauses. The pragmatic cues used in Just and Carpenter's (1992) study refer to the animacy of the head nouns, which signal the correct interpretation of the initial ambiguous portions of the sentences. For example, read the following two sentences:

1a) The evidence <that was> examined by the lawyer shocked the jury.

1b) The defendant <who was> examined by the lawyer shocked the jury.

Omitting the important syntactic cue “who was” from the *defendant* sentence 1b creates an ambiguity that is not present in the *evidence* sentence 1a. This is because after reading *the defendant examined*, readers tend naturally to continue the sentence with an object of *examine*, such as *the legal documents*. If the sentence is not followed by the legal document, but by the phrase *by the lawyer*, this would be unexpected to the reader and creates a garden-path effect. This effect requires extra time for readers to correct their wrong expectations of the sentence structure. This would not be the case in the *evidence* sentence because the inanimate noun *evidence* cannot be used as the subject of *examine*; readers tend to expect correctly that some animate pronoun should occur in the following text. Therefore, reading *the defendant* sentence should induce longer reading times than *the evidence* sentence. Interestingly, high span readers in fact reacted like this, but the low span readers did not.

Why did low span individuals read both sentences equally fast? Just and Carpenter (1992) explained that low span individuals do not have the capacity to take pragmatic cues presented by the previous context into the reading process. Even though the low span readers know how to use obvious pragmatic cues like *who*, they cannot take advantage of more subtle cues such as the animacy of the noun. Hence, they do not form expectations about the continuation of the sentence based upon the subtle cues. In contrast, high-span readers know and use such information in the comprehension process. This indicates that high-span readers are also high-skilled readers (Ericsson & Kintsch, 1995), who are capable of using their large span to hold potential expectations on the up-coming text event and conduct online processing while reading the proceeding text.

Nevertheless, deep processing or high working memory capacity is not always helpful and may even work against a skilled reader. For example, read the following two sentences:

2a) The experienced soldiers warned about the danger before the midnight raid.

2b) The experienced soldiers <who were> warned about the danger before the midnight raid were ready.

Omitting the syntactic cue *who was*, sentence 2a contains a simple structure <Subject + Verb + Object + Prepositional Phrase>. Low-span readers process through it without any difficulty. High-span readers, on the other hand, could form an expectation for a garden-path effect. For

instance, the sentence could be stumbled over by adding *were ready* at the very end like in sentence 2b. Indeed, this is exactly what was found by Just and Carpenter in a computer simulation of sentence processing using their program Capacity Constrained READER; high-span readers took 130ms longer to read *raid* than did mid- and low-span readers.

How did Just and Carpenter (1992) explain this result? Just and Carpenter attributed this result to short-term memory (STM). They claimed that both low- and high- span readers form two expectations, that the sentence might be normal and that it might contain a reduced relative clause. However, the low-span readers have insufficient memory capacity to retain both alternative expectations of the sentence in their STM. Thus, they drop the less likely parse (i.e., the reduced relative clause) before they reach the end of the sentence because it adds extra cognitive load for their memory. In contrast, high-span readers retain both parses to the end, which adds extra cognitive load and ensues with unnecessary processing difficulties. There might also be an alternative interpretation for this result. It is quite possible that the low-span readers never form the alternative expectation and hence have no difficulty with the garden-path effect.

Other researchers have found support for the conclusion that low span readers do not hold alternative expectations during reading. For example, Pearlmuter and McDonald (1995) investigated whether both the low- and high- span readers were sensitive to the probabilistic constraints in the sentence. They asked both groups of readers to do offline plausibility rating on the relative plausibility of half of the ambiguous sentences and collected the argument structure frequency data of the corresponding sentences from the corpus. There was a high correlation between the low- and high- span groups' offline plausibility rating. A step-wise regression was conducted with processing speed difference as the dependent variable, the offline plausibility rating and argument structure frequency were two independent variables. The results suggest that both the plausibility rating and the argument structure frequency accounted for all of the variance. This finding indicates that high span individuals were sensitive to the actual argument structure of the sentence that affected the relative plausibility of alternative interpretations of the ambiguity, but the low span readers', though they were sensitive to the probabilistic constraints offline, were not able to demonstrate their sensitivity online. This is consistent with Just and Carpenter's (1992) finding that only high-span readers were sensitive to probabilistic constraints

and spent longer on sentence processing, but low span readers ignored these constraints online, so they had quicker reading speeds than high-span readers.

Although Just and Carpenter provided some empirical evidence on how low- and high-span readers differ in comprehension. There are some criticisms of Just and Carpenter's (1992) CCC Theory and the Read Span task they used. First, they did not include other factors, such as increased interference in memory or slowed perceptual and cognitive processes, which could be the real sources of capacity in higher-order cognitive processes (MacDonald & Christiansen, 2002). Second, they intentionally ignored the knowledge-based explanation or the role of experience in individual differences in comprehension. They explicitly stated that the role of "knowledge-based explanations are less useful in accounting for the on-line processing profile of comprehension" (Carpenter et al., 1994, p. 1110) and thought that individual differences are "better explained in terms of total capacity than process efficiency" (Just & Carpenter, 1992, p. 145). Finally, Waters and Caplan (1996) have criticized Daneman and Carpenter's (1980) Read Span task, suggesting it should not be used as a measure of working memory for language comprehension. This Read Span measure is only a measure of storage, even though it requires both processing and storage. Just and Carpenter failed to provide any statistical data showing that the Read Span has statistically significant interactions between text difficulty and other external processing loads. Thus, this measure is not sufficient to explain individual differences in verbal working memory abilities. That is to say, a single measure of storage is an inadequate measure of the size of this working memory resource, since it does not reflect the tradeoff between processing and storage during the working memory task (Waters & Caplan, 1996).

Conclusions on Theories of Working Memory. Individual differences in working memory capacity have been a topic of considerable inquiry in the last decades. The three theories described above have a common goal in linking human beings' higher level cognition with the biological nature of the memory system. To achieve this goal, different theories have different characteristics and emphases. The Multi-Component Theory (Baddeley 1986, 2000, 2001) is the most classical one. It proposes a symbolic structure of working memory, which includes multiple subcomponents. The recent revision of the multi-component model depicts how the general working memory system has been conceptualized in current scientific research. Although this model is just a conceptual model, it pinpoints two pending questions: (1) whether increasing

working memory load has the ability to influence executive control of attention, and (2) what is the role of the episodic memory buffer in the information processing and product. The latter two theories reviewed help to fill this void.

The latter two theories (GC theory, Engle et al., 1992; Turner & Engle, 1989, and CCC theory, Just & Carpenter, 1992) focus on the positive relationship between working memory capacity and comprehension ability. Engle and his colleagues did a better job in capturing the general construct of working memory. Just and Carpenter attempted to establish a specific research paradigm to explore more in depth how verbal working memory differentiated low- and high- span individuals in the process of reading, but they no longer use their working memory measure. They have changed methodologies and now conduct brain imaging research to explore working memory differences (Baddeley, 2003). According to GC theory (Engle et al.), individual differences in working memory capacity arise from differences in both the ability to actively maintain information and the ability to retrieve task relevant information in the presence of irrelevant information. Based upon CCC theory (Just & Carpenter, 1992), individual differences in working memory are defined as how activation is allocated in working memory and how this allocation affects reading processes. Just and Carpenter focused much of their experiments on the amount of capacity available in working memory and the efficiency with which information is processed. Unfortunately, they did not devote much experimental effort to the retrieval structure after reading. Neither did they provide a measure to explore how external load interferes with target processing and storage. The measures developed by Engle and his colleagues, however, correlate well with measures of higher-order cognition because they provide an index of the general ability to retrieve information in the presence of competition (Conway et al., 2005).

Specifically, GC provides several guidelines for studies of working memory (Conway & Engle, 1996). First, the processing component has to be demanding enough that it forces participants to shift attention away from the storage component of the task and to engage in controlled effortful processing. Second, increasing the level of processing difficulty is the critical determinant of span. Third, the level of difficulty to switch attention should not have an effect on long term recall, although it would affect recall fluency.

In conclusion, it might be viable to use GC theory to account for performance in the proposed study, as it is designed based upon the distraction paradigm in the discourse-level (i.e.,

higher-order) text comprehension. It has been asserted that GC theory is generalizable to any higher-order cognitive processes (Engle, Tuholski et al., 1999). In addition, the working memory measure design under the GC framework specifically treats distraction as a major factor positively correlated with external working memory load. However, because GC theory was not originated for the sake of the explaining reading comprehension processes, it is worthwhile to supplement GC theory with the Skilled Suppression Hypothesis to develop a complete theoretical framework for this study.

Domain-General vs. Specific Views and Implementations of Working Memory

Working Memory. More than three decades have witnessed the development of the theoretical debates of Working Memory. Working memory refers to the ability to temporarily maintain information for use in ongoing mental operations (Baddely & Hitch, 1974). Since this introduction, this model has been exposed to several reconceptualizations. Some authors suggest that working memory has to be considered as a unitary system regulated by attentional resource (Engle, Kane et al., 1999), while other stress the modality specific nature of some of its processes (Miyake & Shah, 1999). It is well-accepted that the capacity of working memory is limited in nature and its limitations are due to different factors such as trace decay (Baddeley & Logie, 1999), susceptibility to interference (Engle, Kane et al., 1999), and processing speed rather than reasoning factors (Kyllonen & Christal, 1990).

The current trend in working memory research centers on the management of attentional resources as a distinctive feature of working memory functioning. This management system is usually considered at the point of conjunction between working memory and complex cognitive processes, such as a specific reading phenomenon (Daneman & Merikle, 1996; Conway et al., 2005). To complicate matters, the debate on domain-general vs. domain-specific views of working memory is taking place simultaneously with the current debates in various fields of psychology which address the same fundamental issue, i.e., to what extent are processes and resources that underlie higher cognition domain-general vs. domain-specific? Yet, the empirical research and theoretical arguments reviewed here are a long way from being conclusive.

The domain-general working memory theory assumes that the common attentional resource must be shared between maintenance and processing (Anderson, Reder & Lebiere, 1996; Engle, Kane et al., 1999). The contributors to this wing of thought suggest that domain-

general processes are essential, and that domain-specific processes cannot function without them. Rather than continuing to divide the mind's cognition into ever more specific domain, psychologists should look for greater integration and search for people's general cognitive skills to be viewed as an integral part of their lives (Roberts, 2007).

On the other hand, the alternative view, the domain-specific view of working memory, is based on the assumption that the processing task prevents the activation of the memory traces, which decay over time, or on the assumption that representation used for the processing task interferes with those to be memorized (Daneman & Merikle, 1996; Saito & Miyake, 2004). For example, Daneman and Merikle's (1996) meta-analysis study suggested that verbal storage tasks (word and letter spans) are better predictors of verbal comprehension (.28 and .40) than are math storage tasks (digit span; .14 and .30). This finding suggests that the domain of the storage component is relevant to the specific construct of working memory.

The model of Baddeley (2003) (see Figure 2.1) is largely silent about the domain-general vs. domain-specific debate. In an early version of the theory, the central executive took over maintenance functions to supplement the two domain-specific slave systems. In the current version, the central executive is only a device for monitoring and supervising task-related processes, but it is extended by a further storage system, the episodic buffer (Baddeley, 2000). To this end, the following three alternative explanations do not require the domain-general vs. domain specific debate in regards to the mechanisms of interference between two concurrent processes. First, when the dual-task uses representations from the same domain, the interference occurs because only the same slave system is involved. When the dual-task draws on separate domains (e.g., a verbal and spatial task, a mathematic and verbal task), this would permit parallel processes. Second, combining two tasks requires the central executive to coordinate them, and therefore dual-task costs increase when resources of the central executive are reduced (Oberauer & Gothe, 2006). Third, the critical functions do not involve the ancillary loop and sketchpad system, but are related to the central executive and are mainly content free (Baddeley, 2000). It is not clear, however, what the central executive does to coordinate the two tasks, and why this leads to dual-task costs in the first place, in particular when the tasks come from different domains.

To follow the current research trends in working memory theory and working memory capacity implementation, other researchers have taken sides to support either the domain-specific

or domain-general view of working memory. Specifically, literature on reading is divided on whether the sentence (e.g., listening) span measure taps individual differences in executive processing specific to the language realm (Daneman & Carpenter, 1980; Just & Carpenter, 1992; Miyake, Just & Carpenter, 1994), or reflects a domain-general system (Engle et al., 1992; Turner & Engle, 1989).

Daneman and Carpenter adopted the domain-specific view of working memory in the Comprehension Constraint Capacity theory (CCC theory). They assumed that there are limited resources that must be shared between the work and the memory during reading, between the processing and storage demands of the task in which comprehension occurs. Moreover, individuals differ in the ability to coordinate the processing and storage functions. In particular, individuals with inefficient processes have a functionally smaller temporary storage capacity because they must allocate more of the available resources to the processes themselves. Daneman and Carpenter (1980) argued that a functionally smaller storage capacity would lead to deficits in comprehension, particularly in the processes that integrate successively encountered words, phrases, and sentences into a coherent representation. Besides, they argued that if one is to measure this functional capacity, one needs a measure to assess the combined processing and storage resources of working memory rather than simply the storage resources, as on traditional span tests. Unfortunately, they have yet to make developments in assessing working memory in reading (i.e., read span task, see Daneman & Carpenter, 1980), as recently they have devoted much attention to employing the neuropsychological approach to studying working memory in language comprehension.

The General Capacity Theory of working memory by Engle and his colleagues provided evidence that the increase in attentional resources necessary to carry out typical working memory span tasks causes the disappearance of domain-specific differences. For example, structural equation modeling analysis demonstrates that all the working memory measures are loaded on a single general common factor (Engle, Tuholski et al., 1999; Conway et al., 2005). Regardless of the modality of the presentation model of the working memory materials (verbal span task, visual span task, operation span task, counting span task, etc.), working memory correlates well with fluid intelligence (Kane et al., 2004). In terms of the domain-general working memory view, the General Capacity model explicitly permits splitting the resources of the focus of attention among several elements, and also among several simultaneous processes, although this

comes at the cost of slowing down each process in general (Cowan, 1995, p.202-203). Furthermore, to carry out typical complex cognitive task requires the capability of dealing with proactive interference; proactive interference is the major source of competition for working memory resources (Conway et al., 2005; Engle, Kane et al., 1999). To reiterate, this domain-general approach will be used as underlying theoretical construct for the review of the working memory measure in the subsequent section and the interpretations of the results in the General Discussion section as well.

With the progresses in working memory theories, the working memory measures were developed and modified accordingly. Although research is not conclusive about whether the measure captures domain-specific or domain-general processing, the working hypothesis adopted by all working memory measures is that individuals differ in executive processing ability. These individual differences may manifest themselves across a broad array of processing measures. This view is founded on the notion that the sentence span measure is related to several measures other than reading. A comprehensive review of research on the measure indicates substantial correlations to low or non-language (non-reading) measures such as a solving arithmetic problems and reasoning problems, and remembering spatial locations of objects (Conway et al., 2005). The following section will review three working memory measures (i.e., listening span, operation span and reading span) in terms of their development, operationalization, empirical evidence of their relationship with reading comprehension, and standing in the literature.

Working Memory Measures. Working memory tasks (listening span, operation span, read span, etc.) were originally designed from the perspective of Baddeley and Hitch's (1974) theory of working memory, which stressed the functional importance of an immediate memory system that could briefly store a limited amount of information in the service of ongoing mental activity. These working memory measures were created to require not only information storage and rehearsal, but also the simultaneous processing of additional information. Such working memory span tasks interleave the presentation of to-be-remembered target stimuli, such as digits, letters or words, with the presentation of a demanding, secondary processing task, such as comprehending sentences, verifying equations, or enumerating an array of shapes. Three of the span tasks are reviewed here. They are Listening Span (LSPAN) (Daneman & Carpenter, 1980; Pickering & Gathercole, 2001), Operation Span (OSPAN) (Engle, 2005; Turner & Engle, 1989),

and Read Span (RSPAN) (Engle, 2005). Literature shows that they all hold predictive validity to reading comprehension.

Listening Span (LSPAN) was originally developed for use with adults (Daneman & Carpenter, 1980). The most recent version, which is still based upon Baddeley's theory, is an assessment of executive control functions (Gathercole, Lamont & Alloway, 2006). In the task the participants hear a series of short sentences and are asked to decide whether the sentences make sense by responding either "true" or "false". After hearing the first sentence in each trial, they must hold the final word of that sentence in mind while they listen to, and judge the veracity of, the next sentence, and so on. Adults find trials with more than three or four sentence challenging.

It has been established that LSPAN is one of the most important predictors of reading comprehension (Baddeley, Logie, Nimmon-Smith, & Brereton, 1985; Daneman & Carpenter, 1980; Jackson & McClelland, 1979) because it captures many of the processing requirements of sentence comprehension and consequently has an excellent probability of tapping the aspects of working memory that are important to comprehension. In regards to the debate over whether comprehension is limited by the capacity of a general working memory system or by one specialized for language processes, a legitimate concern about the listening span (LSPAN) task is that it is too much like comprehension itself. To this end, LSPAN stands as a domain-specific working memory measure in the literature.

OSPAN was developed by Turner and Engle (1989) for the purpose of predicting reading ability with a working memory span task that did not involve the reading of sentences. OSPAN requires participants to solve mathematical operations while trying to remember words. Turner and Engle (1989) first replaced the sentences in Daneman and Carpenter's (1980) task, but otherwise the task demands were unchanged. They then developed the current version of OSPAN by randomizing the presentation order rather than using the ascending order (items with fewer elements first) of the previous version. This modification prohibits participants from anticipating the number of the words, and as a result this task stimulates greater level of proactive interference. OSPAN requires mathematical computation as well as remembering words in arbitrary order. Therefore, it is a measure more of the domain-general capacity, rather than the content-specific (in this case, reading comprehension) capacity, aspect of working memory.

Engle, Tuholski et al. (1999) reported that the Operation Span task correlated .49 with Verbal SAT and .46 with Quantitative SAT scores. Meta-analysis also shows that OSPAN correlated .30 and .48 with different reading comprehension measures (e.g., Verbal SAT, Nelson Denney, or a specific test of the integration of successive ideas in a text, such as computing the antecedent referent for a pronoun) (Daneman & Merikle, 1996). The interpretation of this result is that OSPAN taps verbal processes to some extent. When one executes numerical computation (such as mental arithmetic), one typically operates on verbally coded numbers (Logie, Gilhooly, & Wynn, 1994). It seems that the math process plus storage measure (OSPAN) compares with the verbal process plus storage measures (LSPAN or RSPAN) in predicting comprehension. However, the substantial correlation between OSPAN and comprehension taps something else in working memory rather than a simple demonstration of the correlation between sentence comprehension and paragraph comprehension. The domain-general working memory view suggests that it is an individual's efficiency at executing a variety of symbolic manipulations and computations that is related to comprehension ability. The specific reading measure that Daneman and Merikle (1996) used is different from what was used in this current study. Therefore, the predictive power of OSPAN for the specific reading measure used in this study might not be exactly the same as what Daneman and Merikle (1996) found.

RSPAN was developed to further explore the issue of whether comprehension is limited by the capacity of a general working-memory system or by one specialized for language. In the RSPAN task, participants are required to comprehend unrelated sentences while trying to recall the single letter presented at the end of each sentence in the set. Similar to OSPAN, trials with varied numbers of sentences receive a randomized presentation order. Thus, the test involves the usual demands of sentence comprehension, from the lower level processes that encode the visual patterns of individual words and access their meanings, to the higher level processes that compute the semantic, syntactic, and referential relations among the successive words. The test also imposes the additional and simultaneous component of maintaining the unrelated letters in memory.

Several researchers have pitted RSPAN against nonverbal working memory measures (e.g., Baddeley et al., 1985; Shah & Miyake, 1996). RSPAN (the verbal process plus verbal storage measures) was predictive of comprehension ($r = .41$) (Engle, Carullo, & Collins, 1991; Engle, Nations & Cantor, 1990). In addition, in RSPAN task, the temporary storage of verbal

information (i.e., unrelated letters) could have been worse for poor readers who had to devote some of their limited working memory resources to compensate for inefficient reading processes. In alignment with Baddeley's view on interference mechanism (i.e., when the dual-task uses representations from the same domain, the interference occurs because the same slave system is involved), RSPAN should be regarded as the most appropriate working memory measure for the current study. If a key function of working memory is to deal with proactive interferences and if the domain-general approach is taken to explore the efficiency in complex cognitive processing (i.e., passage comprehension), RSPAN should have advantage over LSPAN and OSPAN in predicting the differences in the capacity of a working memory system that supports both storage and processing.

Skilled Suppression as the Prerequisite for Skilled Comprehension

Together the controlled-attention view of the General Capacity Theory and the Skilled-Suppression Hypothesis (Gernsbacher & Faust, 1995) provide a comprehensive framework for the study of the skilled comprehension. The Skilled Suppression Hypothesis (Gernsbacher & Faust) provides a specific language comprehension approach from the perspective of interference and suppression.

In the study of human cognition, the issues of interference and suppression play prominent roles in theories of learning and forgetting. The findings under the interference and suppression research paradigm sharpen our understanding of how the mind works, how it develops, and what goes wrong when it malfunctions. According to the Structure Building Framework (Gernsbacher, 1990), once stimuli are presented, memory nodes are activated. The activated nodes transmit the information to the other nodes. This transfer process either enhances or suppresses other nodes' activation. The process by which incoming stimuli activate memory representations is similar to this structure building framework. Thus, there are two mechanisms underlying the level of activation of memory: enhancement and suppression. Memory nodes are enhanced when the information represented by the nodes is necessary for ongoing processing, but the nodes are suppressed if the information is not necessary for ongoing processing.

The mechanisms of enhancement and suppression are crucial to skilled language processing. An efficient suppression mechanism is an important component of general comprehension skill. Often times, irrelevant or inappropriate information is automatically

activated. For example, to correctly understand a homophone (e.g., *rows*), readers must correctly suppress the homophone's alternate form (e.g., *rose*). This is because reading the letter string *rows* can activate the phonological sequence /roz/, which can activate the word *rose* (i.e., the word *rose* is pronounced the same as the phonologically similar word *rows*, but they differ in their semantic meaning) (van Orden, 1987).

Evidence of this suppression effect has been demonstrated in various language phenomena. An approach for investigating successful suppression is to compare the performance of more skilled and less skilled readers. The results of the experiments employing this approach demonstrate more-skilled comprehenders are more successful in suppressing inappropriate meaning, but they do not successfully enhance contextually appropriate meanings (Gernsbacher & Faust, 1995).

In one experiment about how quickly the participants activate the inappropriate meaning of the ambiguous word (Gernsbacher, Varner & Faust, 1990), the more time it took to reject the inappropriate meaning of the ambiguous word, the more activated that meaning of the word. For example, the word *ace* contains a meaning of the ambiguous word *spade* that was inappropriate to the context provided in 3a.

3a) He dug with the spade.

3b) He dug with the shovel.

The latencies of how long participants took to reject *ace* after reading sentences like 3a were compared to after reading sentences like 3b, in which the last word is unambiguous to *ace*. The findings suggest that immediately after the ambiguous word (e.g., *spade*) is read, contextually inappropriate meanings are activated. The results are the same for both more-skilled and less-skilled readers. However, the most interesting results occur after a 1-s delay. The inappropriate meanings were still highly activated among the less-skilled comprehenders, and as highly activated following the 1-s delay, as they were immediately after reading the ambiguous word (Gernsbacher et al., 1990). This was not the case among more-skilled comprehenders. This indicates that the less-skilled readers have difficulty rejecting the test words, which represented alternative meanings inappropriate to the context. On the contrary, the more-skilled readers are able to successfully suppress the inappropriate meanings. This is consistent with the skilled

suppression hypothesis in that skilled comprehenders are more successful in suppressing the inappropriate meanings of ambiguous words.

The Skilled Suppression Hypothesis, however, does not suggest that skilled suppression would lead to the enhancement of the contextually appropriate meaning during comprehension. For example, read the sentence *He dug with the spade* and read the ambiguous test word *ACE* or nonambiguous test word *SPADE*, should the more-skilled comprehenders be more efficient in rejecting the word *ace*? It seems that, the skilled comprehenders would appreciate the context of *digging* and reject the word *ace* more efficiently because this word is not related to the concept of *digging*. However, this is not the case. It is the less-skilled comprehenders rather than the more-skilled comprehenders who benefit more from the implication of the context. Less-skilled comprehenders seem to benefit more from the sentence context. For example, compare the predictable sentence context 4a to the control version 4b from Perfetti and Roth's (1981) study:

4a) The garbage men had loaded as much as they could onto the truck. They would have to drop off a load at the garbage dump.

4b) Albert didn't have the money he needed to buy the part to fix his car. Luckily, he found the part he wanted at the dump.

Participants in Perfetti and Roth's (1981) experiment were more efficiently processing the last word of the sentence *dump* in the predictable version 4a than the control version 4b. The less-skilled comprehenders benefited more than did more-skilled comprehenders by pronouncing the word *dump* more quickly in the predictable version than did the skilled comprehenders. Gernsbacher and Faust (1995) reevaluated the phenomenon by using sentence trials like examples 5a) and 5b). They used the word recognition task asking the participants to respond "yes" to verify that the test word did match the meaning of the sentence. For example, read sentence 5a containing an ambiguous word *spade*. The verb *dug with* is biased toward only one meaning of the ambiguous word *spade*. In the comparison condition, sentence 5b contains the verb "pick up", which is neutral to the word *spade*.

5a) He dug with the spade.

5b) He picked up the spade.

After reading one of these sentences, participants were presented with the word *garden*. This word is related to the meaning of the ambiguous word *spade* in the biasing context of digging in

5a. It was expected that, if readers could appreciate the biasing context in sentence 5a, they would accept the word *garden* faster relative to the neutral context in sentence 5b.

Perfetti and Roth's (1981) findings demonstrated that less-skilled comprehenders benefit even more from the biasing contexts than the skilled comprehenders. The less-skilled comprehenders accepted the word *garden* quicker under the biasing context. The interpretation of the findings was that more-skilled comprehenders did not actually appreciate the biasing context, so they did not benefit from the biasing context. In contrast, the less-skilled readers, paradoxically, responded quicker to the test word and benefited more from the biasing context. Therefore, less-skilled readers are not less efficient in activating contextually inappropriate information. On the other hand, more-skilled readers are not necessarily more successfully in enhancing contextually appropriate meanings. Gernsbacher and Faust (1995), thus, concluded that these results did not support the skilled-suppression hypothesis that more-skilled comprehenders are more efficient in suppression of inappropriate information.

This review leaves the Skilled Suppression Hypothesis open for discussion. Gernsbacher and her colleagues never extended their studies to test ambiguous inferential contexts, nor did they focus much attention on comprehension from the perspective of long-term text memory. Furthermore, in the seminal work on the skilled suppression mechanism, Gernsbacher and Faust (1991) pointed out that in order to further investigate suppression and enhancement mechanisms, it would be indispensable to include readers' effortful control in the theoretical framework. While this direction has theoretical implications, its practical implication lies in whether the skill is teachable. If the ability to suppress irrelevant information can be placed under readers' greater control, then this skill might be able attainable for everyone.

Thanks to the development of working memory theories, a new direction for research is whether individuals' greater control is manageable from both short-term and long-term memory perspectives. Exploring questions about cognitive processes by combining working memory theory with the skilled suppression framework provides the potential for unique contributions to our further understanding of skilled comprehension. True comprehension is not only activating prior knowledge but also building up new information, which is stored properly in the knowledge construct. Working memory is responsible for this active information processing, including the retrieving of information from long term memory and the storing of newly

generated information in long term memory. The proposed study would extend the skilled suppression hypothesis from the short-term memory perspective to the long-term perspective with regards to the issues of working memory.

Conclusions on Theoretical Framework

In conclusion, the Skilled Suppression Hypothesis proposes that all readers take time to appreciate contextually inappropriate meaning while they work to comprehend. That is, both the skilled and unskilled comprehenders automatically activate alternative/multiple meanings during reading. The ability to keep one primary meaning highly activated from memory beyond threshold is dependent upon the ability to suppress the other alternative meanings which are not appropriate for the context. The poor readers cannot suppress these alternate meanings, but employ the enhancement mechanism to process the alternate meanings. When the primary concept is distracted by alternative concepts, the poor readers accept the primary concept quickly, unaffected by the degree of distraction from alternative concepts. In contrast, the good readers would be able to suppress the alternative concepts and process the primary concept in a deep manner. This is the skilled suppression mechanism. Even though skilled suppression takes time to happen, it is expected that it helps to build information in a more structured manner (see Structure Building Framework, Gernsbacher, 1990).

In contrast, the General Capacity Theory claims that only the high span individuals have a capacity large enough to keep alternative/multiple meanings activated from memory, and inhibit one from the other in a more efficient way. While the low span individuals fail to do so due to capacity constraint. This is in contrast to what the Skilled Suppression Hypothesis predicts. However, previous research using the naming task though not in a distraction paradigm (Calvo, 2001; Linderholm, 2002) suggests that low span readers were unable to name the inferential probe word quicker due to the low capacity constraint. If this is still the case, along with the General Capacity Theory, it is expected that high span individuals would name the context appropriate inferential concept quicker than the low span individuals. If this expectation is not instantiated in this study, the General Capacity Theory may not be appropriate for application in the language comprehension literature, even though it claims to be general in cognitive domains.

Finally, these two theories propose different perspectives on whether and how individuals differ in holding alternative meanings in their minds. Both of these two perspectives are equally plausible as supported by evidence. A primary goal of the proposed study was to test both alternatives to see which could inform our understanding of a higher-order cognitive process – namely predictive inferences. The next section reviewed predictive inferences, their role in text comprehension during reading, and factors affecting the online activation and offline memory representation of predictive inferences during reading.

CHAPTER 3

LITERATURE REVIEW

Inferences in Reading

Making inferences is crucial during text comprehension. Making predictive inferences online is critical to deep text comprehension in terms of constructing a coherent situation model of text. Reading comprehension is achieved at multiple levels of text representation. They are surface level (the actual words and syntax that are used), textbased level (the propositional representation of textual constituents that are explicitly stated), and situation model (the events that are described by a text) (van Dijk & Kintsch, 1983). Making causal inferences is necessary for building situation models and successful text comprehension (Zwann & Radvansky, 1998). The online generation of causal inferences, integrating prior textual information with background and/or world knowledge, leads to the production of a coherent situation model. This implies that the generation of causal inferences may be indicative not only of the online construction of a situation model, but also of the achievement of a deeper comprehension of the text.

This chapter began by reviewing the roles of inferences in deep text comprehension and the unique features of predictive inferences for constructing a coherent situation model of text. Then, this chapter reviewed studies on both the internal (i.e., working memory capacity) and external (i.e., text elaboration) factors impacting the online activation and long-term memory of predictive inferences in text comprehension. In the course of this literature review, the gaps in this line of research were identified, with the research questions and hypotheses of the proposed study presented at the conclusion of this chapter.

Inference as Deep Comprehension during Reading

Encoding a text means comprehending it. However, there are many ways a text can be comprehended, ranging from a surface level (the actual words and syntax that are used), textbased level (the propositional representation of textual constituents that are explicitly stated), and situation model (the events that are described by a text) (van Dijk & Kintsch, 1983; Zwaan & Radvansky, 1998). Readers who engage in shallow text-processing focus primarily on understanding the meanings of individual words or text propositions. In contrast, readers who

engage in deep comprehension construct meaningful interconnections from the text-based information and integrate the text messages with knowledge-based information from long term memory (e.g., prior knowledge and personal experiences). Making inferences is the essential element in this constructive and integrative process (Kintsch, 1988, 1998). Thus, actively engaging in the inference-making process is critical for deep level of text comprehension (Beenman, Bowden, & Gernsbacher, 2000; Calvo, 2004; McKoon & Ratcliff, 1992).

Text comprehension involves generating two general classes of inferences: necessary and elaborative. The former, of which most are bridging inferences, is necessary for comprehension in general (e.g., pronoun resolution). Strong evidence reveals that the bridging inference integrates separate propositions within text in order to construct a coherent representation, and it is generally thought to be made during reading to maintain local coherence (McKoon & Ratcliff, 1986) and to establish causal relations (van den Broek, 1990) within text. Elaborative inferences, on the other hand, are not necessary for local text coherence but refine situation model construction. Research shows that elaborative inferences take time to develop (Calvo & Castillo, 1996, 1998; McDaniel et al., 2001), but has potential to be retained for later retrieval (Durgunoglu & Jehng, 1991; Guan et al., 2007; Klin, Guzman et al., 1999). The core purpose of making inferences is to make implicit connections explicit and facilitate “the active construction of a situation model, integrating text information with prior textual information and the readers’ prior knowledge”, which is considered a prerequisite for learning (Kintsch, 1994, p. 302).

Elaborative inferences are crucial for deep comprehension. In reviewing studies on children who have reading comprehension difficulties, Oakhill and Yuill (1996) claim that deficits in making inferences, understanding text structure, and comprehension monitoring are the three major roadblocks to successful comprehension. Pressley and Wharton-McDonald (1997) also did a similar review and argue that too much attention has been paid to the superficial level of text processing. Although they admit that it is necessary to increase the automaticity of word decoding in order to free the capacity for greater comprehension, they believe deep level text comprehension has been neglect and advocate for a strong emphasis on developing active readers. This call for developing active readers by emphasizing deep text comprehension coincides with the long-term agenda of comprehension instruction (Snow, 2002).

Making inferences, from the perspective of deep text comprehension, is important to learners in the following five ways. First, there is a claim that linguistic processes on superficial levels alone cannot account for less skilled readers' deficits in comprehension. Long, Oppy and Seely (1994) asked both skilled and less skilled post-secondary level students to read some sentences (e.g., *The townspeople were amazed to find that all the buildings had collapsed except the mint. Obviously, it had been built to withstand natural disasters*). Lexical decision latencies were used to measure readers' response time to context-appropriate homograph and topic-related inferences. The results suggested that both skilled and unskilled readers performed equally well on differentiating the context appropriate associate *money* from the context inappropriate control word *candy* of the homograph prime *mint*. Only skilled readers showed facilitation to the topic-related word (e.g., *earthquake*) relative to unrelated control words (e.g., *breath*). Long et al. (1994) argued that deficiencies in basic lexical level processing did not account for the failure to generate topic-related inferences, but only skilled readers generate knowledge-based inferences to elaborate their representation of the text.

Second, deep processing could help poor reader compensate their word-level processing. For example, slow decoders use higher-order processes to compensate for their lack of decoding skills (Kintsch, 1998); better top-down processors can use sentence context to speed up their word recognition (Stanovich, 1980). Without using higher-order processing, it takes the reader a longer time to form propositions (Bisanz, Das, Varnhagen & Henderson, 1992). Thus, deep processing compensates for a weakness in other components of the reading process.

Third, deep processing stresses the importance of establishing causal links in a text. The larger number of causal links connecting within text units, the better the text-based recall (Trabasso & van den Broek, 1985). For instance, Trabasso and van den Broek showed that among both adults and children, the recall of a text unit is a function of the number of causal links connecting it with other text units. If stories are analyzed according to text units that fall on the primary causal chains of states, events, and actions that make up the story versus dead-end units that are not located on this causal chain, units on the causal chain are recalled better than units off the chain.

Fourth, deep processing can increase working memory capacity. Tunmer (1989) asked adults to practice reading and attempting to understand long and/or complex sentence

constructions. The findings of the study were promising in that the efficiency of verbal working memory of the students increased. Richardson (1996) explained this phenomenon of the apparent memory span being increased by using strategy after practice. The adults, who were trained to understand long and/or complex sentences, improved their organization structure of sentence processing. In this way, the long and/or complex sentence constructions were organized as single chunks. By adding new items to these chunks, sentence processing is just as simple as with single-structured sentences. Finally, the efficiency in sentence processing increases because the processing of long/complex sentences becomes automatic.

Last but not least, overall deep processing combined with external regulation of learning (i.e., metacognitive strategies of learning for tests and other purposes) leads to the best learning outcomes. For example, Beishuizen, Stoutjesdijk, and van Putten (1994) compared the effects of deep-processing and surface processing on textbook learning outcomes, and found that deep-processing benefits students in terms of metacognitive support. That is, combining external regulation with deep processing outperforms any other combination between regulation and surface processing on text learning outcomes.

Predictive Inferences –Constructing a Coherent Situation Model of Text

Making predictive inferences is crucial for deep text comprehension and reading engagement in narrative text. Predictive inferences are a type of inference about likely upcoming events. Other researchers also have described them as causal consequence inferences or forward inferences (Graesser & Clark, 1985; van den Broek, 1990). In contrast to the bridging inference, the predictive inference is an important cognitive reading phenomenon in deep text processing. The generation of predictive inferences is a fundamental step for the creation of a situation model and is what needs to be retained in memory if an accurate situation model is to be useful at later retrieval (Radvansky et al., 2001).

Above all, when making predictive inferences, readers should connect what they have just read with background knowledge. Connecting explicit text events with background knowledge is the key step toward building situation models of text. Engaging in generating predictive inferences should enhance readers' strategic and active employment of knowledge (Fincher-Kiefer, 1993, 1996). By connecting text events with similar experiences of their own, the readers construct a strong but stable mental representation of the newly acquired information.

It then is easy for them to later retrieve the text information. The generation of predictive inferences also facilitates the processing of future text events (van den Broek, 1990). For example, if a reader anticipates an upcoming event and that event were confirmed, reading would proceed smoothly and predicted information would be easily integrated into the reader's situation model.

In addition, some predictive inferences are necessary in order to maintain coherence (Klin, Murray et al., 1999; Murray, Klin, & Myers, 1993). The following passage illustrates the role of predictive inferences for constructing a coherent understanding of text: *The angry waitress was totally fed up with all of the hassles of her job. When a rude customer criticized her, she lifted a plate of spaghetti above his head.* Readers cannot understand the reason why the waitress lifted the plate unless they predict that she will dump it on the customer's head. If readers do not make a prediction, coherence breaks down. On the other hand, predictive inferences, if made and matched up with the gist of the textual information, increase the number of interconnections between concepts in memory and provide additional retrieval routes (O'Brien, 1987). Thus, the positive product of generating predictive inference facilitates both the probability of recall and speed of retrieval of targeted concepts (Alba & Hasher, 1983).

Finally, making predictions while reading may help keep the mind actively focused on the author's meaning. This helps motivate the reader and stimulates a sense of purpose for reading. This active engagement is also the hallmark of desirable reading behavior. Good readers do not sit back and passively wait for meaning to come to them. As they read they grapple with and make meaning from text (Duffy, 2003). This mental activity happens in a flash and comes naturally to good readers. Struggling readers, however, often think that meaning would come to them; they do not understand the comprehension cycle and are inexperienced in constructing meaning from text through active reading.

Despite of its beneficial roles in reading, the predictive inference is cumbersome and takes time to develop. Previous research shows that bridging inferences take less than 500ms to develop after the inducing context (Magliano, Baggett, Johnson, & Graesser, 1993; Singer, Graesser & Trabasso, 1994). Thus, making bridging inferences, which is necessary for text comprehension, is automatic (Schmaholfer, McDaniel, & Keefe, 2002). Graesser and Bertus (1998) compared the construction of bridging inferences (e.g., causal antecedents of explicit

events in text) and forward inferences (e.g., causal consequences of implicit events beyond text) in scientific reading as functions of working memory span, general world knowledge, reasoning ability, and reading fluency. They used the reading time measure on the target sentences which either link to the previous context as the causal antecedent or induce what is happening next as the causal consequence of events. Across different groups of readers, the study found a stable and consistent finding that causal consequence inferences were more time-consuming to make than causal antecedent inferences. They explained that this was because the causal consequences were taxing on working memory. However, it is hard to infer the actual time course of inference development based upon reading time since the self-paced reading procedure used by reading time measures cannot tell us whether inferences are made during reading or after reading.

A good measure is important for the detection of the exact online status of inference activation. Naming time of probe words related to the inferences being induced is one of the most commonly used measures for this purpose (Keenen, Potts, Golding & Jennings, 1990; Potts, Keenen & Golding, 1988). It is hypothesized that if there is a shorter naming time on the inferential probe word after the inference inducing context relative to the control context, this demonstrates the online activation of the inference. The advantage of the naming task related to other tasks is that it is a pure measure of lexical access (i.e., the initial activation needed to start the articulation of the word but not processes it on a deeper level) and it is not affected by priming from intra-lexical association (i.e., the morphological or semantic relationship between words, such as derivational morphemes, synonyms, etc.).

The two major criteria used to evaluate whether a measure could be appropriately applied to detect the inference activation are (1) whether it is a pure measure of online lexical access, and (2) whether the lexical access is affected only by priming from text-level factor rather than intra-lexical association. The first criterion is to ensure the measure is used to detect online activation but not offline encoding, such as post-lexical access (i.e., the process of integrating or checking the representation of the word). The second criterion is to make sure if the inferences were drawn online, they were drawn based on the text (i.e., the causal relationship between sentences read) but not on the lexicon level (i.e., the relationship between other associated concepts not related to the text read). The naming task has advantages at both points. First, naming latencies reflect the time for both lexical access plus the time for onset of

articulation. The articulation, which is the post-access process, is rarely affected by the probe's relatedness to the text. That is, readers would not have time to process the probe word on the semantic level before they articulate that word via the grapheme-to-phoneme correspondence rule to complete the naming task. Thus, naming is regarded as a pure measure of lexical access (i.e., the processing stages beginning with the speakers' focusing on a target concept and ending with the initiation of articulation of that concept).

Second, when the word-based priming effect is well controlled in the naming task, the problem of intra-lexical associations (i.e., the morphological or semantic relationship between words, such as derivational morphemes, synonyms, etc.) should be eliminated. For example, if the target sentence contains the word *red*, word-based priming could be controlled to make sure the probe word is not *fire* or some other intra-lexically associated word (e.g., *blood*, *rose*, *read*, *led*, *garnet*, *color*, etc.). In this way, the only significant effect detected by naming latencies between the inference condition and the control condition is only caused by the text-level factor (i.e., the causal relationship between sentences) rather than the intra-lexical associations (Keenen et al., 1990; Potts et al., 1988). Despite some potential problems (Neely & Keefe, 1989; Norris, 1986), the naming task has been currently acknowledged as a good measure for use in detecting inferences. Researchers who use this naming measure have converging evidence that the activation of predictive inferences could be detected during reading (Estevez & Calvo, 2000; Guan et al., 2007; Harmon, 2005; Linderholm, 2002; Potts et al., 1988).

Due to variability in reading materials, characteristics of readers, and measures used to assess the activation of elaborative inferences, the time course of elaborative inferences vary from study to study. In general, the time range for the online status of predictive inferences is from 250ms to 1050ms if the context is sufficient enough for the generation of the primary predictive inference (Magliano et al., 1993; Millis & Graesser, 1994). Thus, it has been concluded that predictive inferences occur with delay (Calvo & Castillo, 1996, 1998; Fincher-Kiefer, 1995, 1996; Till, Mross, & Kintsch, 1988). Delayed occurrence indicates that the online computational speed is slow for the first time activation of the information from long-term memory. This is different from offline text representation, which is the reactivation of the information from long-term memory. In order to facilitate later meta-analysis on related topics, the reading materials selected for use in the proposed study have been used in previous

investigations (Guan et al., 2007; Harmon, 2005; Klin, Guzman et al., 1999; Perrachi & O'Brien, 2005).

Internal and External Factors on Inference Activation

Effect of Working Memory Constraint on Inference Activation

Regarding the role of working memory capacity constraints in inference-making processes, there is an argument supporting that working memory capacity constrains the development of elaborative inferences more than bridging inferences. The fact that predictive inferences develop with delay suggests that the online activation of predictive inferences is resource-demanding. If making predictive inferences engages readers in controlled effortful processing (Conway & Engle, 1996), working memory constraint is expected to be strongly related to this taxing comprehension process. The more activation that is available for the demands of processing and storage, the more likely it is that people would be able to make the inferences online.

Studies on the individual differences on the predictive inference began with the neuroscience study by St. George and his colleagues (St. George, Mannes, & Hoffman, 1997). They investigated the interaction between working memory and the generation of predictive (forward) and backward inferences. Participants were categorized into low- and high- span readers based upon the Read Span task (Daneman & Carpenter, 1980). The lower value on the N400 components of ERP would indicate that semantic priming and integration processing occurred in response to the explicitly stated inference concepts. Results showed both low- and high- span readers had low values on N400 in the bridging inferences condition, but only high span readers had low N400 values in the elaborative inferences. This suggested that the high span readers made both bridging and elaborative inferences during reading, whereas low span readers made only bridging inferences. This seminal work provides evidence that low span readers are unable to generate predictive inferences immediately online. However, as it has already been mentioned in the previous review, predictive inference takes time to develop. Given more lenient time constraint, the results might be different. Other researchers, hence, have attempted to reveal the interaction of the working memory constraint and different time delays of online inference activation.

Estevez and Calvo (2000) used the moving window technique, presenting the context one word at a time in a fixed-pace model. They varied the inter stimulus intervals (SOA at 50 vs 550 vs 1050ms) between the end of the predictable target sentence and the onset of an inferential target word representing the predictable event. The naming task was used to test whether there was facilitation in naming the inferential target word among both low- and high- span readers at any SOA level. The results showed there was facilitation in naming 1050ms after the inducing text for both low- and high- span readers, 500ms for only high span readers, but no such facilitation at 50ms for both groups. This result suggests that high working memory capacity accelerates the time course to compute the predictive inferences when the target sentence is predictable.

In a follow up of Estevez and Calvo's (2000) study, Linderholm (2002) varied the level of causal constraint of the text, providing high, moderate and low causal sufficiency. The self-paced reading technique was used, allowing individuals to read each sentence at their own pace. After reading one sentence on one screen, the readers moved to the next sentence on the next screen by themselves. A naming task was used to investigate the facilitation on the inferential probe target word at two time delays (250 and 500ms). Results showed that only for high span readers there was a naming facilitation when the context contained high causal sufficiency events at both time delays, but no such facilitation for low span readers in any of context condition at either time delay. This indicates that only high span readers were able to make predictive inferences, and then they were only able to do so if the context support was sufficient for inducing one inferential concept (e.g., *throwing the vase against the cement wall* elicits the inferential word "break").

The findings from Estevez and Calvo (2000) and Linderholm (2002) converge to suggest that the working memory capacity contributes to the computation of the predictive inferences if the context supports one predictive inference. Nevertheless, the findings from both studies are not conclusive about the role of working memory in predictive inferences in the normal reading situation. As Estevez and Calvo (2000) used the artificial procedure, the moving window technique, to determine the time course of inferences, the normal reading process has been truncated. The critical argument for the proposed study is that the reason why low-capacity participants failed to generate inferences during reading could have been caused by the fast speed of the presentation rate of the sentence. Low span readers did not have enough time to finish

reading the explicit text, not to mention develop a complete understanding of the explicit text, before they saw the probe word. Thus it is unfair to conclude that there was no naming facilitation in the inferential probe words only because the low span readers were unable to generate such inferences. In contrast, the high span readers in the study might have had enough time to complete reading before they saw the probe word, therefore their reading process was more complete than their low span cohorts, which made the naming facilitation possible.

The material design in Linderholm's (2002) study also was susceptible regarding the selection of the probe words, the limited sample size, and the way she defined the levels of causal sufficiency. The text materials were manipulated to create the levels of high, moderate and low causal sufficiency. Each text included one-sentence neutral background information, and one-sentence inducing event facilitating a predictable inferential probe word. The strength of causal sufficiency was determined by a pilot test from only 21 students. Each student gave a 7-point Likert scale on how likely the action depicted in the probe word would occur next in the text. Basically, every student read all 2-sentence texts in high, moderate and low versions, and gave ratings to the same probe word 3 times matched to each version of the text.

To begin with, the selection procedure of the probe words is not standard for the naming task experiment. In fact, based upon the inference literature on the standard of coherence (van den Broek, Risdén & Husebye-Hartmann, 1995), especially for the study of predictive inferences, it is the readers who set up the coherence standard of their own at the point of reading. The probe words were usually selected based upon the readers' responses to text, but not provided by the experimenter (Calvo, Castillo & Schmalhofer, 2006; Magliano, Trabasso & Graesser, 1999). The level of causal sufficiency (i.e., the probability of the likelihood of that upcoming event) should be matched up to the proportion of time the word has been mentioned by all the participants in the material validity checking procedure (Champion, 2004). In contrast, Linderholm (2002) provided the probe words for the readers and asked them to give cross-sectional comparison ratings of the same probe word in all three versions of the text. In the actual experiment, each reader only read one version of text in the high, moderate or low causal condition. It is suspected that the rating scores might have been affected by the comparison but not by the actual coherence standard established in reading one version of text.

Furthermore, even if the coherence standard set up by the experimenter matched up to the readers', the approach to defining the sufficiency of causal relation between the text and the

probe word is susceptible. Based upon the significant pair-wise comparisons of the mean rating scores ($M_{\text{high}} = 6.2$, $SD_{\text{high}} = 1.1$; $M_{\text{moderate}} = 4.4$, $SD_{\text{moderate}} = 1.6$; $M_{\text{low}} = 3.9$; $SD_{\text{low}} = 1.9$) between every two versions of text, the author claimed that the materials were valid in terms of high, moderate and low causal sufficiency. It is easily seen that the range of scores for three versions of text are overlapping somehow. It is even hard to tell how the author conducted the pair-wise comparisons (e.g., $t = -2.86$, $SEM = .16$, $p = .004$), but it is obvious that the t test results reported were given without properly adjusting the type I error rate.

Even worse, the limited sample size used in Linderholm's (2002) pilot study ($N = 21$) could be detrimental to the external validity of her study. This pilot study was conducted for the purpose of the validity checking of the materials to be used in the full study. The result on the levels of causal sufficiency based upon 21 people is hard to generalize. That is to say, a different sample from the population might provide different ratings. Hence, when another group of students participated in the actual experiment, it is likely that the high causal sufficient text might not have been regarded as causally sufficient enough to them. If this were the case, a lack of facilitation of naming among the low span readers in the high sufficiency condition might have been caused by problems with the material rather than their low span per se.

Consistent with this argument, in the second experiment, Linderholm (2002) used the contradictory paradigm, which provided the participants with more contexts to justify the possibility of the event. In this study, she found both low- and high- working memory capacity readers made predictive inferences in both high and moderate causal sufficiency texts. The levels of causal sufficiency based on her data in the final study did not match what her pilot rating data suggested. Even though she had the probe words rated in her pilot study, the probe word provided by the experimenter did not match up well with the inferential concepts. In the high causal sufficiency condition, it was possible that readers generated some specific primary inference other than the concept represented by the probe word. In future studies, selection of the most highly probable target probe word should be based upon the readers' response to the text. In addition, there is a lack of rationale for trying to detect the specific online activation of the inferences in the moderate and low causal sufficiency conditions, since failing to detect may not be due to failure in activation but to the fact that the generation of the predictive inferences was potentially multiple in number and minimal in nature (Fincher-Kiefer, 1995; McDaniel et al., 2001; McKoon & Ratcliff, 1992). As a result, in follow-up studies about working memory

constraint on online status of inferences, it is suggested to test the sufficiency of the text factor on the activation of the predictive inferences. Rather than manipulate the text in the level of causal sufficiency (e.g., high, moderate and low), instead it would be theoretically-grounded to manipulate the level of interference of the simultaneously competing inferential ideas.

Accordingly, the internal and external validity of the study can be improved given considerations to inference detection techniques, participant variability, and material manipulations. In this current study, hence, the self-paced reading paradigm was used, which allowed more natural reading. This study also recruited participants from a more heterogeneous college population. This guaranteed that the finding was more generalizable. Most importantly, the materials were selected with careful consideration of the competition between simultaneously generated inferences. The selected experimental texts have been academically recognized in the literature since 1999 and used by several researchers (Klin, Guzman et al., 1999; Harmon, 2005; Guan, 2006). In detail, the causal sufficiency of the inferential target sentence used in the reading materials of this study has been established by previous research with positive evidence that only one primary predictive inference was elicited (McKoon & Ratcliff, 1986), and further verified by eye-movement techniques, which were regarded as a more reliable way of capturing the online reading processes (Calvo, 2000, 2001). With regards to the stress on interference of one secondary inference to the simultaneously generated primary inferential concept, the material in this current study cautiously constrained the number of potential inferences to two concepts at most. This was achieved by manipulating the amount of text elaboration in the previous context on one explicitly stated causal consequence inference and the inference-inducing target sentence on one primary predictive inference. Depending on the amount of elaboration of the previous context, the saliency of the distracting feature of the one concept to the primary predictive inference varied. The next section focused on the effect of text elaboration on the inference activation in terms of the distractive elaboration.

Effect of Text Elaboration on the Activation of Bridging Inferences

The impact of elaboration on the inference activation has been demonstrated most extensively in the research on antecedent retrieval. The antecedent refers to a preceding event, condition, or cause, which could provide backgrounding information during reading. An example of antecedent retrieval is given as follows. A passage contains a description of the protagonist

(e.g., *Mary likes fantastic junk food* or *Mary likes health food*). This original description is regarded as the causal antecedent. A target sentence describes the protagonist performing an action that is either consistent or inconsistent in regards to the original description of the character (e.g., *Mary ordered a cheeseburger and fries*). Upon reading the target sentence, the reactivation of the original inconsistent description (e.g., *Mary likes health food*) causes the reading time to be slower relative to the reactivation of the consistent description. The reactivation of the original description in this example is called the causal antecedent retrieval.

In research on the influence of multiple antecedents on antecedent retrieval, the amount and distance of elaboration have become the focus of investigation. According to the memory-based view of text processing (Myers & O'Brien, 1998; O'Brien & Myers, 1999), elaboration influences antecedent retrieval because elaborating on a concept increases the number of retrieval routes to that antecedent, thus increasing the speed with which the antecedent would be reactivated. For instance, Rizzella and O'Brien (1996) examined whether readers accessed distant causal antecedents for consequent events when the text was locally coherent and a more recent causal antecedent was available. Participants read passages that contained two possible causal antecedents for a consequent event; one appeared early in the passage (e.g., *His father told him that if he was not more responsible, he would ground Billy for an entire month*), and the other appeared late (e.g., *Billy broke a small window*). The early causal antecedent was elaborated in half of the passages (e.g., giving examples of how Billy was irresponsible), and neither causal antecedent was elaborated in the remaining half. The last line of the passage provided a causal consequence (e.g., *Billy knew that once his father came home he would be in trouble*) for which there were two potential causal antecedents: being irresponsible and breaking the window. Probe words were selected to capture the basic idea of each early and late causal antecedent. Each passage was followed by a probe word to be named.

Rizzella and O'Brien (1996) found both early and late causal antecedents were backgrounded (i.e., providing the reader with background information) prior to reading the consequent event (e.g., *Billy was in trouble*). When neither causal antecedent had been elaborated, only the late causal antecedent was reactivated by the consequent event. However, when the early causal antecedent had been elaborated, only it was reactivated regardless of the recency effect of the sufficient causal antecedent provided by the late causal antecedent in the immediately preceding context. Thus, when the early antecedent was elaborated to a greater

extent than the late antecedent, the information was reactivated more quickly, even when the immediately preceding context offered a sufficient causal antecedent (Rizzella & O'Brien, 1996).

In addition to increasing the likelihood of activation of previous portions of the text, elaboration also influences the activation of the causal antecedent. In O'Brien and Albrecht's (1991) study, participants read passages containing either a low or high context in term of how much supporting description is given to the target concept. The low or high context supported one of two target antecedents (e.g., *skunk* or *cat*). In the high-context version (e.g., *a small black skunk/cat with a white stripe down its back*), the elaboration was highly supportive of one antecedent (e.g., *skunk*), but the target antecedent was either consistent with the context (e.g., *skunk*) or unrelated to the context (e.g., *cat*). In the low-context version (e.g., *a small black skunk/cat with a long furry tail*), the elaboration was equally supportive of either antecedent. The final line of the passage (e.g., *The attendant asked her what had run in front of her car*) prompted reactivation of the target antecedent (e.g., *skunk*). The results showed that the naming times for *skunk* were faster in the high context version, even when the unrelated concept (e.g., *cat*) was explicitly stated as the antecedent. This supports the view that elaboration would increase the success in retrieving the consistent causal antecedent.

Specifically speaking, when readers read a sentence like *a small black XX with a white stripe down its back*, no matter whether the XX turns out to be a skunk or a cat, this high context version activated the concept of "skunk" because activation spreads from concepts directly mentioned in the passage to semantically related concepts from the reader's general world knowledge that the black animal with *a white stripe down its back* is a "skunk". Although this word "skunk" was not explicitly stated in the text, the sum of the activation from concepts like *a black animal* and *a white strip down its back* to "skunk" was sufficient to raise the activation of "skunk" to a detectable level. Therefore, upon reading the final sentence, those concepts would become again reactivated and the concept "skunk" was inferred instead of the other antecedent "cat", even if *cat* has been explicitly stated in the text. In contrast, in the low context version, the amount of semantic information that is related to "skunk" was insufficient to raise the activation of the targeted concept "skunk" to a detectable level. Therefore, upon reading the target sentence the correct antecedent "cat" was reinstated rather than the target antecedent "skunk".

In conclusion, if factors such as text elaboration and the number of intervening causal elaborations can affect how quickly the backgrounded information is retrieved, they may also play a role in the activation of predictive inferences. As is introduced, the predictive inference is a type of causal consequence inference. Recently there has been a great trend in investigating the activation of predictive inferences in discourse comprehension. A clear understanding of the contextual factors on this topic has a practical importance in unraveling multiple levels of text representation (i.e., the surface level, the text-based level and situational level). For example, by using a computer simulation, Schmalholfer, McDaniel and Keefe (2002) proposed a unified model of bridging and predictive inferences and concluded that bridging inferences may well originate as predictive inferences and later be substantiated by a subsequent clause. Previous research has explored in depth the effects of text elaboration on bridging inferences, but fewer studies have been done on predictive inferences. Therefore, the focus of the research was to investigate the effect of text elaboration in the previous context on the activation and maintenance primary predictive inferences in long-term text memory, using a research paradigm similar to the one used with bridging inferences. Therefore, the following section extended the literature of the text elaboration on bridging inferences to predictive inferences.

Effect of Text Elaboration on the Activation of Predictive Inferences

Predictive inferences are activated when the text elaboration is highly supportive of the predictive concepts (Keefe & McDaniel, 1993; Murray et al., 1993). Murray et al. (1993) used an on-line naming time probe to investigate whether readers would be able to draw predictive inferences online under different text constraints. They presented passages that contained several text characteristics, which would increase the probability that predictive inferences would become activated. First, they controlled for the lexical associates of the target concepts, thus avoiding activation due to lexical priming. Second, the information relevant to the to-be-inferred event was salient at the time of test. The results of the experiment demonstrated that a concept from the targeted inference was activated, even when no lexical associates were presented in the passage. This study is consistent with previous findings in that the predictive inferences had become activated when the contextual support was sufficient (e.g., Calvo & Castillo, 1996; Keefe & McDaniel, 1993; McKoon & Ratcliff, 1986; Murray et al., 1993).

However, it is possible for the text elaboration to attenuate the activation of predictive inference. Peracchi and O'Brien's (2005) research findings demonstrated this phenomenon. In their study, readers read a passage describing Carol as short-tempered in the consistent condition, but a non-violent woman in the inconsistent condition. The backgrounding information introduced a situation in which Carol had an extremely rude customer yelling at her. The final line of the passage was either an inference-evoking sentence (e.g., *Carol lifted the plate of spaghetti above his head*) or a control sentence (e.g., *She lifted the spaghetti and walked away*). The naming time on the potential target concept (e.g., "dump") in the consistent condition was faster than in the control sentence condition, indicating that the predictive inference had been activated. However, naming times did not differ between the inconsistent and control sentence reading conditions.

Peracchi and O'Brien (2005) interpreted this finding based upon the resonance model, which maintains any information that shares semantic or contextual features with the information in working memory would be retrievable (Myers & O'Brien, 1998; O'Brien & Myers, 1999). More specifically, Carol lifting the spaghetti above the customer's head will activate all information related to the protagonist's characteristics, whether she was peaceful, violent or loved her kids (see Peracchi & O'Brien, 2005). Upon reading the inconsistent condition (e.g., *Carol was peaceful*), the information would mitigate against the activation from the immediately preceding context. Activation would thus be split between the activated information that Carol would never engage in a violent behavior and the activation on "dump" something onto the customer's head (i.e., the implicated potential action emanated from the inference-evoking sentence). This inconsistent reading condition would distract readers' attention from activating the potentially to-be-inferred action "dump", thus decreasing the likelihood its activation. However, this does not necessarily mean that the inference would receive no activation in the inconsistent condition.

Cook et al. (2001) manipulated similar text materials. A short backgrounding section was added after a context in which a predictive event has either a low or high likelihood of occurrence. This context was followed by a target sentence that either explicitly or implicitly referenced the predicted event. The hypothesis was that if the specific concept of a predictive inference is not instantiated in the long-term memory representation of the high-context implicit condition, then the reading time for the target sentence in the high-context implicit condition

should be longer than the high-context explicit condition. Sentence reading times on the target sentence were measured. Quicker reading time in the explicit high-context condition (high context) relative to the explicit low-context condition and implicit conditions (low context) indicated that the predictive inference was not instantiated in the long-term memory representation. Slower reading time in both implicit low and high context conditions relative to the explicit high-context condition could be explained by either the loss of activation of the predictive inference or the effect of the explicitly stated backgrounding information.

To test the effect of the surface feature on the availability of representation of the predictive inferences, the backgrounding information was removed and the surface feature of the explicitly-stated predicted event was more pronounced relative to the implicitly-stated inferential condition. Thus, reading times in the high-context implicit condition should remain significantly slower than either of the explicit conditions. Cook et al. (2001) actually detected no significant difference in reading time on the target sentence in the implicit high-context from either the explicit high-context or the explicit low-context condition when the specific concept of the predictive inferences was represented in text memory. This suggested that there was no reliable effect of surface feature. The slow reading times in the high-context implicit condition were due to a loss of activation of the predictive inferences. Once predictive inferences were activated, concepts representing predictive inferences decayed rapidly. The activation of the predictive inferences was associated with higher-order text processing rather than superficial semantic or contextual processing. This finding is in alignment with some other previous studies (e.g., Keefe & McDaniel, 1993; Murray et al., 1993).

To conclude, research on predictive inferences either only focuses on the online activation of the inference (e.g., Harmon, 2005; Linderholm, 2002; Peracchi & O'Brien, 2005) or provides indirect evidence (such as using a reading time measure) to infer whether the activated inferences were persistent in offline memory (e.g., Cook, et al., 2001; Klin, Murray et al., 1999). Thus, research on the linkage between on-line activation and offline memory for text has been limited by these methodological barriers (Perfetti & Schmalhofer, 2003; Singer & Kintsch, 2001). The next section first reviewed the related literature on the factors affecting this linkage.

From Inference Activation to Long-Term Text Memory

The previous section reviewed the studies that demonstrated how text elaboration and distracting information influence the speed of reactivation of concepts in memory. This section

focused on studies related to factors affecting how text representations of predictive inferences are created, stored and retrieved from long-term memory. The effects of both inter-individual differences (working memory capacity) and external stimulus (text elaboration) factors on the inference process were reviewed. The goal of the review was to better understand reading comprehension processes related to predictive inferences from online activation to long-term text memory. At the end of this chapter, the traditional approach to detect the linkage was established.

Effect of Text Elaboration on the Persistence of Predictive Inferences

There is a theoretical argument supporting the investigation of the continuum from inference activation to inference persistence in text representation. Previous studies concluded that predictive inferences are activated, but rapidly decay (e.g., Cook et al., 2001; Keefe & McDaniel, 1993). It is important to consider, however, whether we may use inference in later memory retrieval, since generating prediction increases the number of interconnections between concepts in memory and provides additional retrieval routes (O'Brien & Myers, 1985; 1987). Theoretically speaking, the positive product of generating predictive inferences facilitates both the probability of recall and speed of retrieval of targeted concepts. This is supported by the generation effect, which means a robust retention advantage found for materials that are self-generated compared to materials that are simply copied or read (McNamara & Healy, 1995). Here is a typical generation paradigm. Participants are shown related word pairs in either a reading or generation condition. In the reading condition, both words are displayed (e.g., short – tall), whereas in the generation condition, only the cue word and a portion of the target word are displayed (e.g., short – t_ _ _), and the participant generates the target word (i.e., tall). The participant's memory for the target word in the generation condition is significantly better than the reading condition (Healy & McNamara, 1996). If we could apply this generation effect in people's reading activity, the episodic memory generated during reading that is supported by the predictive inference may have beneficial effects on people's skill and knowledge acquisition.

There has been less agreement as to whether these inferences are instantiated into the memory representation of the text. In the previous section, supportive evidence was presented for the activation of predictive inferences given sufficient contextual support (e.g., Cook et al., 2001; Klin, Guzman et al., 1999; Klin, Murray et al., 1999; Linderholm, 2000; Murray et al., 1993),

and non-detectable activation of predictive inferences given insufficient textual support (i.e., inconsistent or distracting context; see Cook et al., 2001; Peracchi & O'Brien, 2005). Whether the same principle exists for the persistence of inferences into the long term text memory is unsettled. Some researchers demonstrated positive findings that predictive inferences are in fact encoded into text memory representation in the high-predictable inference-evoking condition (e.g., Klin, 1995; Klin, Guzman et al., 1999), while other researchers found that predictive inferences are not instantiated into text representation if the subsequent text does not support the inference (Cook et al., 2001; Fincher-Kiefer, 1996; Keefe & McDaniel, 1993; Whitney, Ritchie & Crane, 1992).

The group of researchers, who hold negative opinions on the persistence of predictive inferences in the long term text memory, used target sentence reading time as the measure for the representation of predictive inferences (e.g., Cook, et al., 2001; Klin, Murray, et al., 1999). Under the contradiction paradigm, the target sentence contradicted the potential inference. The non-availability of predictive inferences in text memory was concluded based upon the longer reading time in the contradictory target sentence than in the explicit control sentence (Cook et al., 2001). According to methodological reviews on both activation and memory measures (Guan et al., 2007; Keenan et al., 1990), any assumptions researchers make based on the reading time measure could be used to infer to the level of the activation of predictive inferences. Whether the reading time measure should be used as a memory measure has not been agreed upon by researchers. Since the key issue of the activation of predictive inferences has yet to be settled, it seems too early to infer from the longer reading time that predictive inferences are not represented in the long-term text memory. Despite this, research on the representation of predictive inferences in the long-term text memory still needs further investigation using a more reliable methodology, given the condition that the activation of predictive inferences has sufficient contextual support.

Klin and her colleagues have claimed positive evidence for the persistence of predictive inferences in the long-term text memory. Klin, Guzman et al. (1999) employed a contradiction paradigm to detect the inferential information that become available to readers when there is an additional consequence. Similar to previous studies, participants read passages with the high predictable context (e.g., *No longer able to control his anger, he threw a delicate porcelain vase against the wall*) or control context (e.g., *He then apologized for getting angry,*

and offered to clean her delicate porcelain vase to make up for it) in reference to a target concept (e.g., “break”). The inference-evoking sentence was highly predictive for the potential inference (e.g., “vase breaking”), but the control provided no reference for the potential inference. To make the to-be-inferred event (e.g., “vase breaking”) less salient, an elaboration (or introductory material) was added, which described an additional consequence of the event (e.g., Steven’s wife leaving him). After the contextual information was backgrounded by the text elaboration given from the introductory material, a target sentence was presented that contradicted the potential inference (e.g., *Steven picked up the vase and dusted it off*).

Klin, Guzman et al. (1999) found that reading times on the target sentence were slower in the high-predictable condition compared to the control condition, indicating that the inference had in fact been encoded into the working memory and retained in text representation. However, they did not use any memory measure to support this claim for the representation of predictive inferences in long-term text representation. To refer to what has been discussed in the methodological issues on the detection of predictive inferences, there are several potential problems in implementing reading time as the long-term text representation of the inferential concepts (Guan, 2006; Keenen et al., 1990). First, failing to reject the null hypothesis due to the lack of a difference in reading times between two versions of a sentence (inference-evoking or control) might not be caused by the fact that the participants fail to infer. Second, the lexical priming effect rather than the inferential activation would facilitate the detection of predictive inferences. Third, sentence reading time could not reveal exactly what inference has been drawn.

Elaborating on Klin, Guzman et al.’s (1999) study, Harmon (2005) studied the effect of low and high elaboration of the causal information on the activation of primary predictive inferences and found that there was evidence of activation of the primary predictive inferences when the amount of distracting information was decreased. She adapted Klin, Guzman et al.’s (1999) materials to the ones containing low and high distracting information (see Appendix A). In the high elaboration version, the amount of distracting elaboration was the same as the introductory material used by Klin, Guzman et al. (1999). In contrast, the low elaboration version contained less information that is relevant to the inference-evoking sentence. Therefore, less information from the portion of the passage could interfere with the potential primary predictive inferences. She used the probe word naming task to detect that the primary predictive inference was activated when there was low distracting information appearing before the inference-

evoking sentence. She concluded that the less elaboration on distracting information, the higher the likelihood for primary predictive inferences being activated. This aligns with a previous finding that increasing the amount of distracting material can result in interference (Corbett, 1984). However, the question left unresolved in Harmon's (2005) study is the effect on long-term text representation of the stories being read as a function of degree of distracting elaboration (low and high).

Another study extended the findings in Klin, Guzman et al.'s (1999) study, with specific focus on the persistence of the predictive inference in long term text memory. Klin, Murray et al. (1999) gave the participants a surprise recall task after they finished reading the high-predictability passages (e.g., *Brad wanted to buy a beautiful ruby ring, but he had been laid off from his job. ...Seeing no salespeople or customers around, he quietly made his way closer to the counter. Staring intensely at the ring...*). Participants explicitly recalled the inference event (i.e., made intrusions) significantly more often in the inference than in the control condition. Meanwhile, the difference in proportion recalled of the explicit text (excluding predictive inferences as the form of intrusion) did not differ between the two conditions (inference or control context). The results of a recall task suggested that the high-predictable forward inferences were encoded into the long-term text memory. However, Klin, Murray et al. (1999) did not manipulate the text in the way that Klin, Guzman et al. (1999) and Harmon (2005) did to test the effect of low and high elaboration of the causal information on the text representation of primary predictive inferences.

Guan et al. (2007) continued exploring the persistence of primary predictive inferences in the long term text memory by using Harmon's (2005) material. Stronger evidence was found in detecting the online activation of the primary predictive inferences in the low context condition, in which the secondary inference was elaborated less. Surprisingly, the cued recall data showed that the effect of text elaboration on the offline memory of the implicit text differed from its effect on the online activation. That is, the higher amount of elaboration there is in the text, the higher probability of the offline long-term recall of the implicit text, but the lower level of activation of the implicit text. This interesting finding suggested the differences in the online activation differed from the differences in the offline memory of the implicit text. Thus, the interaction between the human cognitive mechanism and text elaboration (i.e., working memory on text comprehension) is worthy of investigation. Before the details of the design of the

proposed study are covered, the next section briefly reviewed how working memory constraints may account for knowledge activation and representation in long term memory.

Effect of Working Memory Constraint in Text Comprehension

Working memory is defined as the part of permanent long term memory that is temporarily active above some critical threshold and can be recognized and manipulated by ongoing cognitive processes (Cantor & Engle, 1993). Within the information processing system, working memory is the arena where both processing and storage interact (Engle et al., 1992; Just & Carpenter, 1992). According to Engle (2002), working memory capacity is not directly about memory. Instead, it is about attention to maintain or suppress information. In alignment with the Construction-Integration model (Kintsch, 1988, 1998), this attention-driven working memory is crucial in text comprehension with regards to readers' ability to select relevant information and ignore irrelevant information in comprehension. Are there individual differences accounted by working memory constraint in the linkage between the online activation of the information and offline long term retrieval of the activated information from long term memory? So far, the integration of on-line activation of information during reading and memory for text has not been fully achieved (Kintsch, Patel & Ericsson, 1999; Perfetti & Schmalhofer, 2003; Singer & Kintsch, 2001; van den Broek et al., 2001). One of the research questions to be addressed in the proposed study is whether the information activated online exists in a readily stable and usable form in the long-term memory at time of recall.

Different levels of online activation may lead to different long-term representation. To begin with, it is necessary to reflect upon the effect of working memory capacity constraint on sentence processing and, further, to investigate the effects on long-term memory. Asking low- and high- working memory span participants to read sentences with pragmatic cues (see, Pearlmutter & McDonald, 1995), the high span readers were more sensitive to the pragmatic cues during reading and held alternative expectation of the sentences. Compared with low span readers, the high span readers spent longer time on sentence processing (Just & Carpenter, 1992). Do the low-span readers know about the probability of the sentence constraints (e.g., reduced relative clause in Just & Carpenter, 1992; or syntactic ambiguity in Pearlmutter & McDonald, 1995)? The answer should be yes. Both low- and high- span readers had the knowledge and awareness when appropriately questioned about these constraints, but the knowledge was not

used (e.g., automatically activated) when they were encoding the sentence in the actual comprehension process. In a word, the level of automatic activation of the knowledge representation from the long-term memory differed between the low- and high- span readers. This leads to the next question.

Does the activated knowledge from the long-term memory exist in a readily stable and usable form? This involves with the important feature of retrieval structures. Simply knowing something (i.e., being able to retrieve it under the optimal circumstances) is not sufficient for a retrieval structure. The low span readers could answer the question about the potential possibility of the reduced relative clauses, but they did not actually use it in sentence processing. This unstable but less practiced knowledge could not be automatically retrieved from long-term memory. The knowledge must be strong, stable, well-practiced, and automated (Kintsch et al., 1999), so as to be utilized for encoding purposes without additional resource demands. Therefore, the high span readers who have been accustomed with devoting additional resources to thinking processes are skilled in the automatic knowledge representation and mapping the activated knowledge onto their long-term memory retrieval structure in a quite stable and strong format. Even though it takes a longer time for the high-span individuals to process the information, the outcome represented by their memory retrieval structure would be more accurate and consolidate. In contrast, the unskilled, low-span individuals may have the declarative knowledge, but it is not in a readily usable form. The less stable form of memory structure contributes less to the overall construction of knowledge for later use.

Hypothetically, differences in available limited long-term text representations should occur between the low- and high- span readers. However, the earlier-conducted study (Guan, Roehrig & Smith, under review) failed to reveal this difference. ANOVA results based upon these 24 participants showed that there is no main effect of working memory on cued recall performance, but there was a significant main effect of text elaboration [$F(1, 33) = 9.275, p = .005$]. The post-hoc comparison revealed a statistically significant difference between the low- and high- spans in naming latency under low text elaboration condition [$F(1, 35) = 4.196, p = .024$] and a marginal significant difference in naming latency in high text elaboration condition [$F(1, 35) = 3.148, p = .056$]. None of the post hoc comparisons in long term text memory measured by the cued recall were significant. These results suggest that text elaboration might moderate the effect of working memory on the long-term text representation. Considering the

effects of both text elaboration and working memory constraint, the further study needs to treat long-term recall on a whole text level rather than an individual propositional level (i.e., the inferential concepts).

These unrevealed working memory capacity constraints on long-term memory might be caused by several reasons. One might be due to the lack of statistical power to detect the significance. The other reason might be due to the way the recall data was coded. In the previous study (Guan et al., 2007), due to time restriction and different research questions, the recall data was not coded based upon the meaningful units of each component of the sentence, but the upon gist of sentence. That is, if the participants recalled the general idea described from each sentence, they got credit for the whole sentence. Due to these reasons, the recall data were not as meaningful as expected. Therefore, new rubrics have been employed in the current study to code the recall data.

To assess the stability and accessibility of the activated long-term memory, working memory researchers have focused the role of working memory on the situation model construction. The working memory capacity is an essential element in unitizing the online processing to offline product in text comprehension. The working memory capacity influences the ability to generate a coherent representation of text. Cantor and Engle (1993) used fan-effect materials that varied in thematic relatedness to support the role of working memory capacity in forming mental models. The typical fan-effect materials contain simple sentences like *Bob read the menu*. By changing the predicate of the sentence into *Bob checked his wallet*, the size of the propositional networks developed from (S: Bob ((VP: Read) (NP: the menu))) to (S: Bob ((VP: Read) (NP: the menu)) + ((VP: Checked) NP: his wallet)). Anderson (1974) called this the propositional fan size. In this example, the fan size is two because there are two propositions. The fan effect refers to the longer reaction times and greater error rates associated the larger fan size than those associated with a smaller fan size. Cantor and Engle used such fan-effect materials varied in thematic relatedness. They used the oral recall task and the sentence verification task to assess the offline memory of the materials being read. It is assumed that the materials with high thematic relatedness induce the construction of integrated mental models. The results showed that the low spans produced positive fan effects independent of the relatedness of sentences, while the high span readers showed the negative fan effect. The results

indicate that the low spans failed to create the coherent mental models due to limited working memory capacity.

Cantor and Engle (1993) further speculated that there might be two potential reasons for them failing to do so. One possibility is that these readers processed each proposition separately, due to limited span, the total number of propositions which could be integrated into a coherent unit is limited. The other possibility is that the low span readers did try to integrate propositions together, but due to poor chunking, the size and complexity of the integrated propositions is limited. In other words, the low span readers' failure to develop and use mental models is either due to the limited number of proposition they could integrate together or the limited size and complexity of the situation model they could afford to integrate. It seems that both possibilities are plausible. Failing to consider either of them would lead to incomplete understanding how working memory contributes to the coherent situation model construction. This finding is consistent with the most recent research conclusion that the higher-order organization, such as the integration information into situation model and the management of interference, but not the suppression of the interference is controlled by working memory mechanism (Radvansky & Copeland, 2006).

Thanks to the coherent judgment criterion established by Golden and Vukulich (1989), it is possible to consider both possibilities related to the coherent situation model construction. According to this criterion, it might also be possible to explore the coherence of primary and secondary concepts of story memory under the distractive research paradigm. The five steps of text analysis prescribed by Golden and Vukulich consider the presence of the secondary concept, the presence of the primary concept, the gist of story, and the coherent manner at the global level between concepts (i.e., the information linking two concepts chronologically, and the coherent mechanism used to link the two concepts causally). The first two steps focus on the local coherence within each of the concept involved in the narrative story. It includes the event structure of each individual concept, such as the agent, attribute of the agent, state, time, and action. The next three steps focus on the global coherence. The gist of the story is the major theme mentioned. The chronicle is the information linking concepts over time. The causal relationship is what must be attained if the text is to be the most coherent.

To date, researchers have done little to link the text analytical approach to assess the offline text memory with the psycholinguistic approach to detect the online activation of

inferencing. According to the review of the relevant literature in Chapter 3, text elaboration and working memory play important roles in online processing and offline recall. Depending on the levels of distractive elaboration in the previous context, the saliency of the online primary predictive inferences determines whether the inferences could be detected online. Depending on the differences in working memory constraint among readers, the stability of the activated online activation determines whether the information could be recalled in an integrated manner in long term memory. To conclude, the current study attempted to apply a traditional measure—a cued recall task—to capture the detailed components of retrieval structures between both low- and high- span readers. Furthermore, coherence judgments were conducted to further explore how different online processes affect offline recall.

Research Questions & Hypotheses

Preliminary Research Questions

The preliminary research questions were focused on two issues. The first issue was to check whether or not the text manipulation worked. The second issue was to decide which working memory measure would be the most appropriate for establishing the basis for low- and high- span groups. It was expected that if the key function of working memory is to deal with proactive interferences and if the domain-general approach is taken to explore the efficiency in complex cognitive processing (i.e., passage comprehension), RSPAN should have advantages over LSPAN and OSPAN in predicting the differences in the capacity of a working memory system that supports both processing and storage during reading.

Research Questions 1& 2

Research Question 1 addressed the extent to which participants' naming times on the inference-testing probe words differed between low- and high-span working memory groups. It was expected that working memory capacity measured by the Reading Span task (RSPAN; Engle, 2005) would be a major factor impacting the online activation of the primary predictive inferences. Thus, it was hypothesized that there would be a simple main effect of working memory on the naming latencies. Two plausible alternative hypotheses (i.e., 1-a and 1-b) were tested in the proposed study: either high working memory individuals would have quicker naming latencies than low working memory individuals or vice versa. The result from Research Question 1 would be further explained by the answer to Research Question 2 about whether or

not text elaboration (low vs. high elaboration) affected participants' naming times on the inference-testing probe words within each of the low- and high-span working memory groups.

Hypothesis 1-a. According to the General Capacity Theory of working memory, the high span individuals would be more effective in shifting attention under the ambiguous context. It was hypothesized that high span individuals would name the inferential probe words quicker than the low span individuals. The rationale for this hypothesis is as follows. The General Capacity Theory proposes that controlled attention is an important aspect of working memory resulting in individual differences (Engle et al., 1999; Engle & Kane, 2004). It is assumed that high working memory span would engage readers in a conscious-control mechanism by shifting their attention in a controlled manner. Since RSPAN (Engle, 2005) has been regarded as an indicator of the general capacity across a variety of processing capabilities (Clarkson-Smith & Hartley, 1990; Kiewra & Benton, 1988; Kyllonen & Christal, 1990; Shute, 1991), it could also be used as an indicator of the higher-order language processing.

Specifically, in this study, the processing domain of interest is the generation of primary predictive inferences during reading. The high span individuals might be more able to shift their attention to be more appreciative to the ambiguous inferential context and make quicker naming responses to the inferential probe words. If this is the case, the result would be triangulated by a non-significant main effect of text elaboration on the naming latency among high span readers but a significant main effect of text elaboration on the naming latency among low span readers. Consistent with findings from previous study, high span individuals had quicker naming latencies compared to the low span individuals (Evestez & Calvo, 2000; Linderholm, 2002). Hence, the study results would be supportive to the General Capacity theory in the domain of higher-language processing.

Hypothesis 1-b. Alternatively, it was hypothesized that the low working memory individuals would have quicker naming latencies than the high working memory individuals. The rationale for this hypothesis is as follows. There is a great concern in reading research that the processing of predictive inferences is indicative of deep text processing because it is time-consuming and resource-demanding (Beenman et al., 2000; Calvo, 2004; Calvo & Castillo, 1998; McKoon & Ratcliff, 1992). The Skilled Suppression Hypothesis proposed that skilled comprehenders do NOT more successfully enhance contextually appropriate meanings (Gernsbacher & Faust, 1995). It is expected that high span readers, counterexplanatory to their

working memory advantage, spend longer time processing the inferential concept compared to the low working memory span individuals.

Hypothesis 2. It was hypothesized that there would be a significant interaction between Working Memory and Text Elaboration on naming latencies. Specifically, low-span readers, no matter whether they read low or high elaboration text, are actually not taking any effort in processing the ambiguous inferential context due to their low working memory capacity. Under the umbrella of the Skilled Suppression Hypothesis, the low span readers are actually enhancing but not suppressing context inappropriate information. In other words, the low span individuals are employing enhancement mechanism when text becomes difficult or ambiguous. On the contrary, high span individuals are paying efforts in suppressing context inappropriate information. If this were the case, the finding would be supported by previous research results in that the high span readers were more sensitive to the contextual effect during reading and held alternative expectations of the sentences (Pearlmutter & McDonald, 1995). Hence, this study results would be an extension of Skilled Suppression Hypothesis by adding working memory mechanism to the successful comprehension framework.

The goal of Research Question 1 and Research Question 2 was to investigate whether and how working memory and text elaboration were factors impacting the online activation of the primary predictive inferences. If it was suggested that the low- and high- span readers were performing differently in their online activation patterns, this result would imply that the ability to activate the primary predictive inferences was a matter of working memory. Therefore, researchers might be interested in training the readers to make this type of inference during reading. There might be many ways to achieve this goal. This was beyond the discussion of the current study. However, whether the low- and high- span individuals were making the primary predictive inferences online was not the end goal of comprehension or this study. Researchers were also interested in knowing, after the inferences have been activated online, how the low- and high- span readers complemented their working memory to construct and integrate the activated information into their long-term memory differently. Thus, it was necessary to further explore this topic by testing whether and how working memory functioned from the long-term memory perspective.

Research Questions 3 & 4

The second major set of research questions addressed in this study was focused on how the working memory constraint affected the integration of primary predictive inferences into the long-term memory and contributed to the coherent long-term text representation under the impact of the activating of primary predictive inferences. It was generally hypothesized that working memory contributes to the long-term text representation in a stable and coherently-integrated manner, but its impact on the specific portion of text (i.e., the activated primary predictive inference) should be moderated by the text elaboration. Hypothesis 3 was tested for Research Question 3 to investigate how working memory constraint affected the exact recall rates of the primary predictive inferences (i.e., Region 3 in the story). Research Question 4 explored the extent to which both activation of primary predictive inference and working memory contribute to the coherence of participants' text-recall.

Hypothesis 3. It was hypothesized there would be no simple main effect of working memory on the offline exact recall of the primary predictive inferences between the low- and high- span individuals. That is, working memory should NOT be a major factor impacting the offline memory recall of the specific portion of text (i.e., the primary predictive inference). This might be due to the distractive paradigm applied in this current study. The chance of failing to reject this null hypothesis (i.e., working memory should NOT be responsible for the offline memory recall of the primary predictive inference) was low. The previous study has already shown supporting evidence for this conclusion (Guan et al., 2007). Results in that study suggested the higher elaboration of the distractive text on the primary predictive inference activation online, the better recall of the generated inference offline. A significant main effect of the text elaboration on text recall of the inferential concepts may mask the strong effect of one independent variable (i.e., working memory) on the same outcome variable (i.e., recall performance). Hence, it was necessary to continue with the investigation on how the different working memory capacities affect the integration of the distractive text into readers' long-term memory between low and high text elaboration.

Research Question 4. In general, it was expected that within low and high elaboration context, the generating primary predictive inferences and working memory capacity would facilitate readers to integrate the distractive context into a more coherent text representation to different degrees. As working memory was conceptualized as the activation of the long-term

memory and a mechanism of higher-order integration and organization of the information under processing, working memory was expected to play a significant role for higher-order text-coherence. Therefore, the goal of Research Question 4 was to explore the extent to which Activation of primary predictive inferences and Working Memory (low- vs. high-span) affected the coherence of participants' text-recall.

CHAPTER 4

METHOD

Participants

Participants were 73 college students from two large state universities in the Southeastern US. They were recruited from different areas of study in order to generalize across a variety of college reading backgrounds. Their majors covered 28 academic programs from 11 fields of study (i.e., creative arts, performing arts, business administration, business marketing, communication, community services, computer science and math, engineering, humanities and languages, medical and health, and natural resources and environment). Thirty-seven were female and thirty-six were male, accounting for 51% and 49% of the total recruited participants respectively. Their ages ranged from 17 to 46 with a mean age of 25. The participants were 55.6% Caucasian, 22.2% African Americans, 8.3% Hispanic Americans, 4.2% American Indian, as well as 9.7% students who were Asian or belonged to other ethnic groups. First-year college students or freshmen accounted for 12.5% of the sample, sophomores 11.1%, juniors 20.8%, seniors 22.2%, and graduate students 33.3%. As a prerequisite for participation, English was the first language of all participants. Each individual received either \$10 cash or extra bonus course credits from their instructors for their participation in the 2-hour long experiment.

A power analysis to estimate sample size was performed based upon the study results in Guan et al. (2007). Using the formula for split-plot factorial design given by Cohen and Cohen (1983), assuming an alpha of .05 and a power value of .80, the estimated total number of participants should be at least 46. A sample size of 70 was set as a target for the following reasons. First, it was anticipated that it may be difficult to get a fairly even representation of numbers from across the spectrum of working memory scores. Second, all data collected may not be usable. For example, those scoring less than 85% of the comprehension questions correct in the online-reading session were to be excluded from final analyses.

Measures

Test of Sentence Reading Efficiency (TOSRE). TOSRE (Wagner, Torgesen, & Rashotte, in press) is a group or individually administered test that has been normed from Grade 1 to college level and is in the process of being published. The test was designed to be a measure of reading fluency and comprehension, and is a timed test (i.e., students are given 3 minutes to read as many short sentences as they can and answer “yes” or “no” to each sentence). In order to

do well on the test, the student needs to be able to quickly and accurately decode the words in each sentence (fluency) as well as comprehend what has been read in order to answer “yes” or “no” (comprehension). The score of the test is determined by the total number of correct answers they have finished within 3 minutes. No reliability or validity statistics have been published on this measure. In the analysis the variable measured by TOSRE was called reading efficiency (RE).

Listening Span Task (LSPAN). The Listening Span Task was used as the assessment of the executive control functioning in reading (Gathercole et al., 2006). LSPAN is an individually administered test, which takes about 20 minutes to complete. In LSPAN task, participants are required to hear and verify short sentences (processing) and then recall the final word of each sentence (storage). For example, participants hear a series of short sentences and assess the validity of each sentence by responding true or false on the keyboard. At the end of each trial, series of short sentences, they also have to recall all the final words of each sentence in the trial. The order of final words should follow the order the sentences were presented. The number of sentences in each trial increases from 2 to 6. The participants’ score is determined by calculating a percentage of the total number of words correctly recalled in serial order for each individual series. Responses were not counted as correct if the words were recalled in the incorrect order or if a word was skipped or omitted. Thus, a response was counted as correct only if the word was in the correct serial order and the word itself was correctly recalled. LSPAN has been demonstrated to have higher reliability than other span tasks (Water & Caplan, 1996); and its validity has been demonstrated by predicting reading comprehension and its high correlation with other working memory measures (Savage, Lavers & Pillary, 2007).

Operation Span Task (OSPAN). The OSPAN task (Engle, 2005) was developed as a math process plus storage measure (OSPAN) to be compared with the verbal process plus storage measures (LSPAN or RSPAN) in predicting comprehension (Conway et al., 2005). It takes about 15 minutes to complete this task. The task involves presenting several series of displays to the participant on a computer screen. The number of displays that compose a series of displays varies from two to five, and each display consists of a single mathematical equation and an answer, and after the equation, an unrelated word in capitals is also displayed. Each series length is presented three times and results in a net total of 12 series. The participant is required to evaluate the correctness of the given equation and to answer by responding either “yes” or “no”

(e.g., “ $(5 + 3)/2 = 4$; yes; DOG” or “ $(5 + 3)/2 = 2$; no; CLASS”). Following the yes/no response, the participant is then required to immediately say, and remember, the word that follows the equation. After the last display in a series is completed, the participant is given a blank response sheet and asked to write down all the words that she or he is able to remember for that series, in the same order in which they had appeared. Participants are evaluated on the correctness of their yes/no responses to the equation. Participants’ scores are determined by calculating a percentage of the total number of words correctly recalled in serial order for each individual series. Responses are not counted as correct if the words are recalled in the incorrect order or if a word was skipped or omitted. Thus, a response is counted as correct only if the word was in the correct serial order and the word itself is correctly recalled. The test-retest reliability is reported as .80 for OSPAN (Kane et al., 2004) and has been found to range from .70 to .81. Validity is demonstrated by correlations of .3 to .4 with reading comprehension measures and .4 to .6 with other working memory measures (Conway et al., 2005).

Read Span (RSPAN) RSPAN (Engle, 2005) was originally established by Turner and Engle (1989) and developed in the current version by Kane et al. (2004). This task is designed to force working memory storage in the face of processing (or distraction), in order to engage executive attention processes (Conway et al., 2005). It takes about 15 minutes to complete the task and involves reading a series of sentence-letter strings (e.g., *On warm sunny afternoons, I like to walk in the park. ? F*). Participants read each sentence aloud, and are asked to verify whether it makes sense by saying “yes” (makes sense) or “no” (does not make sense) immediately after they finished reading the sentence, and finally read the letter *F* aloud. At the end of the series, they write down the sequence of letters in exactly the same order they were read. Each series consists of two to five strings, and the order to string length is determined randomly. Individuals are tested on three series of each length (12 total). RSPAN scores (range: 0-42) consists of the total number of letters recalled on perfectly recalled trials. According to previous studies, the test-retest reliability ranges from .70 to .80 among adults (Conway et al., 2005; Kane et al., 2004), and it correlates with other working memory measures with a range of .4 to .6 (Conway et al., 2005).

Materials

Reading Passages. There were 24 experimental passages (see the sample text in Appendix A) and 6 filler passages. The experimental materials were borrowed from Harmon’s

(2005) dissertation materials, which was adapted from Klin, Guzman et al.'s (1999) study. In Klin, Guzman et al.'s (1999) study, there was no low distracting context condition. In Harmon's (2005) study, each passage contained either a high or low amount of distracting elaboration. In High Elaborating Distracter context, the distracting elaboration contained 4 sentences, the same as that in Klin, Guzman et al.'s (1999) study. In the Low Elaborating Distracter context, the amount of distracting elaboration was held constant at one sentence, made up of 22 words. The total number of sentences in both elaboration conditions (High Elaborating Distracter and Low Elaborating Distracter) was the same. The elaboration sections were followed by two-sentence backgrounding information, and then succeeded with either the control or the inference-evoking sentence. The filler passages were adapted from the Magliano et al. (1999) study. The key difference between the filler passages and the experimental passages lies in the probe words. In filler passages, the probe words were explicitly presented in the passage, whereas the probe words in the experimental passages conveyed the inferential concepts not explicitly stated in the text.

Probe Words. The experimental passage probe words represented the primary predictive inference that was evoked from each of the predictable inferential target sentences. These probe words have been assessed as the most likely inferential concepts (Linderholm, 2002; McKoon & Ratcliff, 1986); and their online activation has been successfully detected (Harmon, 2005; Klin, Guzman et al, 1999). The length of the probe words ranged from three to seven characters with a mean length of 4.92 characters. Since the Elaborating Distracter Type and Inference Type vary within each passage, the probe word was the same regardless of reading conditions. Therefore the naming time was not affected by the characteristics of the probe.

Four Reading Conditions. The four versions of each passage were as follows: high distracting context followed by inference-evoking sentence (High Elaborating Distracter Inference condition), high distracting context followed by control sentence (High Elaborating Distracter Control condition), low distracting context followed by inference-evoking sentence (Low Elaborating Distracter Inference condition), and low distracting context followed by control sentence (Low Elaborating Distracter Control condition). Twenty-four passages were divided into 4 sets. Each set contains 6 passages. These same 6 passages were manipulated in four different reading conditions in each individual reading list.

Four Reading Lists. There were four material reading lists. Each material reading list

contained an equal number (6) of passages from each of four material versions and six filler passages. A balanced Latin Square design (Kirk, 1995) ensured every 6 passages from one version were presented at different places and were followed by a different reading version only once in all four reading lists. The reading version as the condition effect was treated as a within-subject random factor and the list effect as a between-subject fixed factor. Two filler passages were presented in the same order between every two material versions in each list, but never shown at the end of the whole reading list (see Table 4.1).

Table 4.1
Design Chart for the Self-paced Reading Experiment

Passage Number	Presentation Order	List_1	List_2	List_3	List_4
1-6	1	HI	HC	LI	LC
Filler 1-2	2				
7-12	3	HC	LC	HI	LI
Filler 3-4	4				
13-18	5	LI	HI	LC	HC
Filler 5-6	6				
19-24	7	LC	LI	HC	HI

Note. HI = High Elaborating Distracter Infer, HC = High Elaborating Distracter Control, LI=Low Elaborating Distracter Infer, LC=Low Elaborating Distracter Control

Recall Task. The recall task involved asking the participants to type as much detailed information they could remember from the stories into a word processing document. Despite of the variation in the context of the materials in four different reading conditions, the first sentence or first two sentences of each passage was the same. The first sentence or the first two sentences from each of the 24 experimental passages were provided to the participants as recall cues in a word processing document. The order of the passages was exactly the same as they were presented to the participants during reading. The participants were required to type as much as detailed information they could remember from the stories. All participants were instructed that no penalty was given for the final score if they recalled something incorrectly.

Software/Apparatus

E-prime was used to present all the practice materials and test materials. This software is a comprehension suite of applications offering audited millisecond-timing precision (Schneider, Eschman & Zuccolotto, 2002). Fixed presentation of text was programmed first into the experiment, and then randomized presentation of text in each condition was set up containing an equal number of passages in each of the four conditions: High Elaborating Distracter Inference, High Elaborating Distracter Control, Low Elaborating Distracter Inference, and Low Elaborating Distracter Control.

The computer on which test materials were presented to participants was equipped with a Stimulus-Response (SR) box. There were three response keys designated on the response box. The “Line-Advance” key indicates moving the computer screen to the next page. “Yes” and “No” keys is used to answer simple Yes-No comprehension questions at the end of each passage. A microphone was linked to the response box to monitor the participants’ naming of the probe word and trigger the voice key to record the probe word naming time. Before the experiment, the participants were instructed and had practice in using the SR box and naming the probe word upon seeing it on the computer. In the actual experiment, when the word was named, the voice key was triggered, the probe word was erased from the screen, and the naming time for the word was recorded.

Task and Procedures

Following approval of this study by the Florida State University Institute Review Board (see the approval letter in Appendix B), participants from across campus were recruited by the researcher visiting classes in person and placing advertisements on campus bulletin-boards. When participants attended the experiment, they were randomly assigned to one of the four material reading lists. They began the study by filling out the Informed Consent Form (see Appendix C). Before the self-paced reading experiment, each participant was individually administered the TOSRE, OSPAN and LSPAN in a counterbalanced order. Each participant then was run individually in a session of online reading, which lasted approximately half an hour. All reading materials were presented on a monitor controlled by a computer. Before the actual experiment began, participants spent one practice session reading three practice passages to ensure that they were familiarized with and understand the procedure (see Appendix D for the instruction). If they were not feeling comfortable enough to begin the experiment, they were

given another practice session containing three different practice passages in order to become comfortable with the procedure in this experiment. In the actual experiment, participants took approximately 30-minutes to complete the self-paced reading.

During self-paced reading, sentences from each passage were presented on the computer screen one at a time. The participants pressed the button on the response box to read sentences from one screen to another. The last sentence from each passage (i.e., the target line of either inference-evoking or control sentence) was followed by a cue (i.e., ***), then a probe word (e.g., BREAK) flashed for 2 seconds on the computer screen. After the probe word, a simple comprehension question (e.g., Did Susan leave a big mess in the kitchen?) flashed for 2 seconds, and then a Y/N prompt was presented on the next screen. Participants were given the time they needed to make a “Yes” or “No” response to the comprehension question they had just seen. Feedback on the answer to each comprehension question was given at the end of each passage in order to ensure the participants read each passage carefully.

After self-paced reading, a 15-minute RSPAN task was assigned to every participant. Participants read each sentence aloud, and verified whether the sentence made sense immediately after they finished reading the sentence, and then named a letter after each sentence. After several trials of such reading, they were asked to write down the sequences of letters in exactly the same order they had named. Finally, each participant received a surprise cued recall task (see Appendix D for the instructions). In the current study, only the typing option was offered. At the end of the experiment, the participants filled out the demographic form (see Appendix E).

Scoring of the Recall

In the current study, the scoring rubric for the cued recall data was designed to capture the exact recall of the primary predictive inference as well as the coherence of the text recall. The exact recall refers to whether or not the participant could recall the exact primary predictive inference (i.e., the probe word) for each story. The coherence of the text recall consisted of five categories. The first two categories belonged to the local coherence, which referred to whether the participants could recall the inferential concepts (either the primary or the secondary inference) in a locally coherent text; the latter three categories belonged to the global coherence, which referred to the gist of story, the chronicle order of the story events, and the causal relations between the story events. The coherence judgment is introduced in the subsequent paragraph. All the text recall was blindly coded. One rater scored all the recall protocols, and a second rater

scored 12.5% of the protocols. The interrater reliabilities were conducted for each of 8 categories. Each pair of values on the eight coding categories for all participants' story recall was submitted to get the interclass correlation coefficients (ICC). The coefficient alphas range from .91 to .93 (see detailed results in Table 5.12). The disagreement on the coding was discussed and final agreed coding scores were used for subsequent analyses. Discrepancies between the two raters were resolved through discussion.

Coherence Judgment. The criteria for coherence judgment were based upon the criteria established by Golden and Vukelich (1989). The following five criteria were rated in each of the recalled texts:

- 1: Local coherence1: primary inferential concept (0, 1)
- 2: Local coherence2: secondary inferential concept (0, 1)
- 3: Global coherence: the gist of story (0, 1)
- 4: Global coherence: the chronicle order of story event (0, 1)
- 5: Global coherence: the causal relationship between the primary and the secondary inference (0, 1)

The primary inferential concepts referred to the primary predictive inferences which were supposed to be elicited by the target sentence. The secondary inferential concepts were tied closely to the gist of story. For each variable of local coherence (primary inferences and secondary inferences) and global coherence (gist, chronicle order of the story events, and causal relations between the story events), data were coded on a "0 - 1" scale (1= coherence, 0 = incoherence or no recall). To illustrate how the recall data were judged according to the established criteria, two recall examples from Sample Text 1 (see Appendix A) given by Participants A and B are provided below.

Participant A:

Steven abused Susan until she eventually had enough.
Susan told Steve that she would leave him if even a tiny violent event occurred in the house.
Susan left the kitchen a mess one day.
Steven got really angry.
He threw a small vase against the wall and broke it.
Susan saw the broken vase and left Steven.

Participant B:

Steven had a terrible temper.

Susan said that if one more act of violence was committed in the house, she would leave.

Steven got a new job at Sears.

Susan left the kitchen in a huge mess.

Based upon the original Sample Text 1 (see Appendix A), Participant A received “1” point for the local coherence for the primary inferential concept because this person recalled “He (Steven) threw a small vase against the wall and broke it”, but Participant B received “0” because he did not recall this concept. For the local coherence of the secondary inferences, both participants received “1” because they both recalled “she (Susan) would leave if ...”. Both participants received “1” for the gist of story because they both successfully captured the general picture of the story which was about family violence. Participant A received “1” for the chronicle order of story events and causal relations between the secondary and the primary inferential concepts because this participant could clearly represent the story events in the correct chronicle sequence and the last sentence of the recall, “Susan saw the broken vase and left Steven”, integrated the both inferential concepts coherently. In contrast, Participant B failed to meet the criteria for these two global levels of coherence.

One rater scored all the recall protocols, and a second rater scored the same 12.5% of the protocols. When coding the data, the coders were blind to the conditions to which the reading passages were assigned. The percentages of agreement of each pair of coding-results were calculated based upon whether the values were matched to each other. Discrepancies between the two raters were resolved through discussion. The final agreed coding scores were used for subsequent analyses.

CHAPTER FIVE

ANALYSES & RESULTS

The result section includes three sets of analyses: preliminary analyses, naming-time analyses, and recall analyses. The preliminary analyses were conducted to set up the foundation for the subsequent analyses. The preliminary analyses included (1) the manipulation check of the text materials by examining the effects of two within-subjects text-factors (i.e., low and high Elaboration; Inference-evoking and Inference-control) on naming times on the inferential probe words in order to ensure the current study replicated the results from previous studies (Harmon, 2005; Guan et al., 2007); and (2) the examination of the relationships among three working memory measures (i.e., LSPAN, OSPAN, and RSPAN), the test of sentence reading efficiency (i.e., TOSRE), and naming times on the inferential probe words in order to decide which working memory measure would be the most appropriate for conducting a tripartite split of the sample (i.e., high-span working memory group, moderate-span working memory group, and low-span working memory group).

The analyses on naming times focused on the first set of research questions, i.e., the extent to which participants' naming times on the inference-testing probe words differed between low- and high-span working memory groups (Question 1), and whether or not there was a significant interaction between Text Elaboration (low vs. high elaboration) and Working Memory (low vs. high span) on participants' naming times on the inference-testing probe words (Question 2).

The analyses on recall data focused on the second set of research questions, i.e., whether or not participants' recall of primary predictive inferences differed between the two working memory groups (low-span vs. high-span) (Question 3), and the extent to which Activation of primary predictive inferences (as calculated by the differences between the naming times on the probe words in the inference condition and the control condition) and Working Memory (low-span vs. high-span) affected the coherence of participants' text-recall (Question 4).

Preliminary Analyses

The preliminary analyses were conducted in two steps. First, the naming times on the inference-testing probe words in each of four reading conditions (i.e., Low Elaboration Inference, Low Elaboration Control, High Elaboration Inference, and High Elaboration Control)

were examined to demonstrate whether the results in this current study replicated the results from previous study (Guan et al., 2007). Second, to confirm that RSPAN was the appropriate working memory measure for the tripartite split of the sample, two relationships among variables were examined: (1) scores for the working memory measures (i.e., LSPAN, OSPAN, and RSPAN) and the reading efficiency measure (i.e., TOSRE), and (2) the naming times on the inference-testing probe words in the Low Elaboration Inference condition and the scores for the three working memory measures (i.e., LSPAN, OSPAN, and RSPAN) and the reading efficiency measure (i.e., TOSRE).

Manipulation Check and Replication

Manipulation checks were conducted to ensure that text manipulations (i.e., low and high Elaboration; Inference-evoking and Inference-control) worked in this study. The naming times on the inference-testing probe words in each of four reading conditions (i.e., Low Elaboration Inference-evoking, Low Elaboration Inference Control, High Elaboration Inference-evoking, and High Elaboration Inference Control) were examined. When participants give shorter naming times on the inference-testing probe words, after reading the target sentences than the control sentences, this implies that they have activated specific inferences represented by the inferential probe words during their sentence-reading (i.e., online inference activation). In this study, participants' naming times on inference-evoking probe words represented the extent to which the primary inferences were elicited by the target sentences.

Previous studies have shown that naming times on inference-evoking probe words in the Low Elaboration Inference-evoking condition (1) were the smallest among all four conditions (i.e., Low Elaboration Inference, Low Elaboration Control, High Elaboration Inference, and High Elaboration Control) (Harmon, 2005; Guan et al., 2007), and (2) should be smaller than 500ms (Calvo & Castillo, 1998). If these findings were replicated, then the research questions proposed in this current study would be justified.

The naming times among 70 out of 73 participants were submitted to a 2 (low vs. high elaboration) X 2 (inference vs. control) Repeated Measures ANOVA. Three participants' data were discarded from the final analyses because their accuracy rates for the comprehension questions were below 85%.

Participants' average naming times on the inference-testing probe words, standard deviations, and confidence intervals for the four reading conditions (i.e., Low Elaboration Inference-evoking, Low Elaboration Inference Control, High Elaboration Inference-evoking, and High Elaboration Inference Control) are presented in Table 5.1. To test whether participants' naming times were statistically shorter than 500ms, the 95% confidence intervals for the average naming times were consulted (see Table 5.1). Only the values within the confidence interval of the Low Elaboration Inference-evoking condition were smaller than 500ms. This indicated that almost all readers generated primary predictive inferences online in the Low Elaboration Inference-evoking condition.

Table 5.1
Means, Standard Deviations and Confidence Intervals of Naming Times in Milliseconds
(ms) (*n* = 70)

Elaboration Type	Inference Type					
	<u>Inference</u>			<u>Control</u>		
	<u>Mean</u>	<u>SD</u>	<u>Confidence Interval</u>	<u>Mean</u>	<u>SD</u>	<u>Confidence Interval</u>
<u>Low</u>	466.34	65.25	452.08--480.60	526.04	71.21	486.34--516.70
<u>High</u>	493.60	55.79	475.94--511.25	510.64	54.58	491.98--529.30

The bar chart (see Figure 5.1) shows participants' naming times in the four reading conditions (i.e., Low Elaboration Inference, Low Elaboration Control, High Elaboration Inference, and High Elaboration Control). The bar on the left-most of the chart represents the confidence interval of naming times for the Low Elaboration Inference condition. In this condition, the values within the confidence interval are no larger than 500ms. The 2 (low vs. high elaboration) X 2 (inference vs. control) Repeated Measures ANOVA demonstrated a significant main effect of Elaboration [$F(1, 69) = 11.84, p = .001$], a significant main effect of Inference [$F(1, 69) = 32.28, p < .001$], and a significant Elaboration by Inference interaction [$F(1, 69) = 5.55, p = .021$].

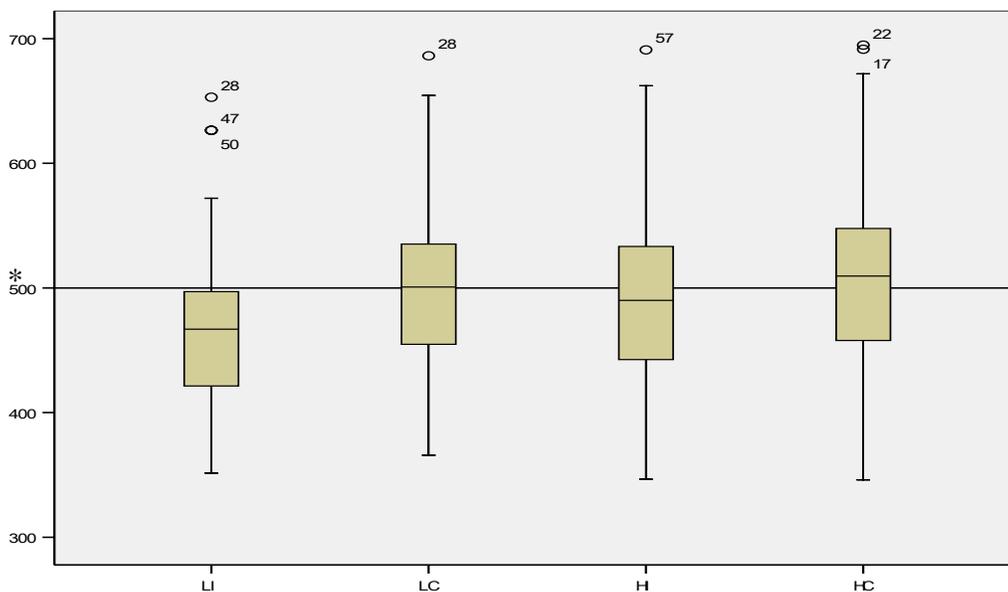


Figure 5.1 Naming Times in Four Reading Conditions

LI = Low Elaboration Inference; LC = Low Elaboration Control

HI = High Elaboration Inference, HC = High Elaboration Control

* The cut-off point for online activation time for predictive inferences is 500ms (Calvo, Meseguer, & Carreiras, 2001)

The estimated marginal means are presented in Figure 5.2. The blue line (at the bottom) represents the naming times on inference-testing probe words in the two control conditions (i.e., Low Elaboration Inference Control, and High Elaboration Inference Control). The green line (on the top) represents the naming times on inference-testing probe words in the two inference conditions (i.e., Low Elaboration Inference-evoking and High Elaboration Inference-evoking). Compared to the control conditions (i.e., Low Elaboration Inference Control, and High Elaboration Inference Control), the naming times were shorter in the inference conditions. When participants demonstrate shorter naming times on the inference-testing probe words in the inference-evoking condition, it implies that they have activated specific inferences represented by the probe words during their sentence-reading (i.e., online inference activation). Therefore, the target sentences manipulated in the inference-evoking conditions in this study successfully elicited primary predictive inferences online.

Additionally, as shown in Figure 5.2, the naming times were shorter in the two low elaboration conditions (i.e., Low Elaboration Inference-evoking and Low Elaboration Inference Control) than those in the high elaboration conditions (i.e., High Elaboration Inference-evoking and High Elaboration Inference Control). The lower degree of text elaboration on the secondary inference (i.e., the less distractive the information that participants received for activating the primary predictive inference online), the shorter their naming times on the inference-testing probe words of the primary predictive inferences. Therefore, the text elaboration was successfully operated in this study. The manipulation check and replicated evidence of naming times, thus, warranted the subsequent investigation.

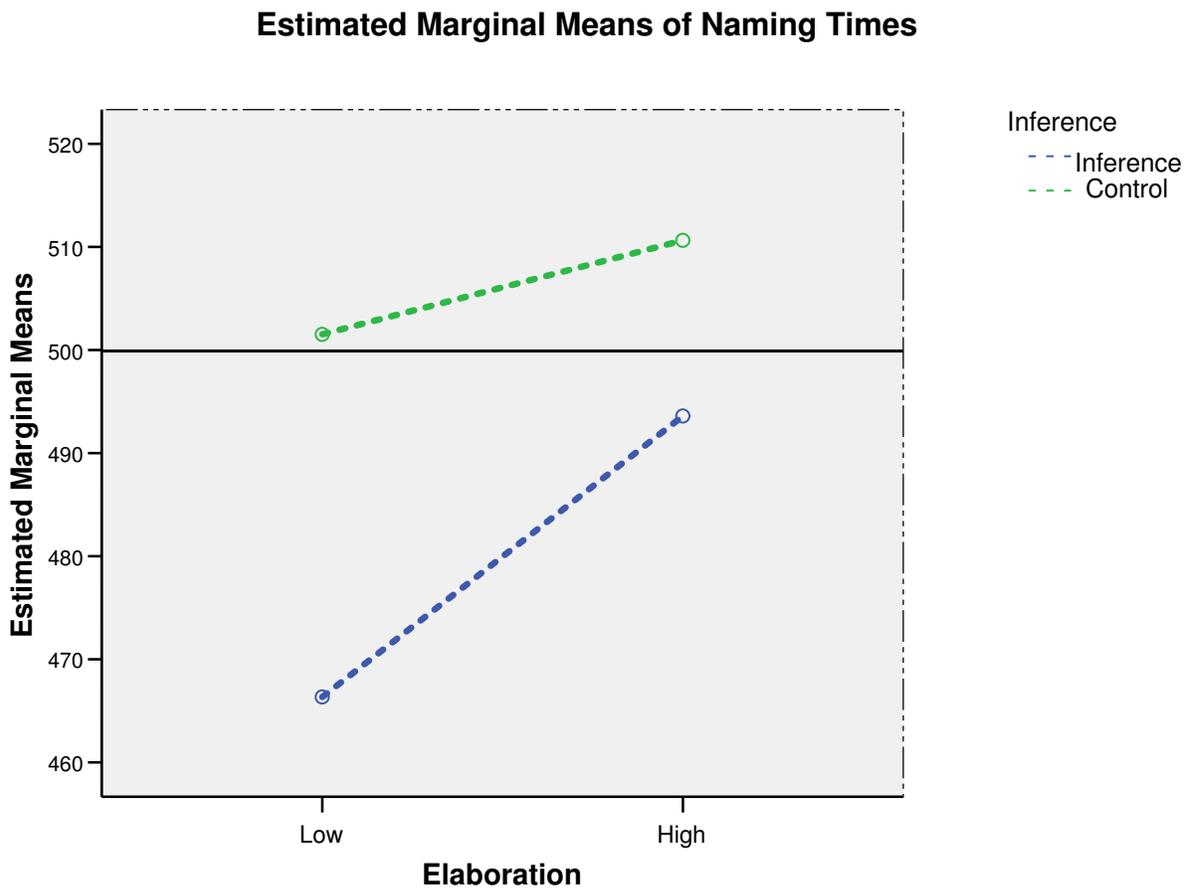


Figure 5.2 Estimated Marginal Means of Naming Times

Confirming RSPAN as a Appropriate Working Memory Measure

Data collection included three measures of working memory capacity: Listening-span (LSPAN), Operational-span (OSPAN), and Read-span (RSPAN) and one measure of reading efficiency, Test of Sentence Reading Efficiency (TOSRE). TOSRE was employed as an indicator of reading comprehension. The research design required that participants be grouped according to their working memory capacity; however, first, whether RSPAN should be used as the most appropriate working memory capacity measure the grouping variable had to be determined.

To decide which working memory measure would be the most appropriate for categorizing students in a tripartite split of the sample, two relationships among variables were examined: (1) relationships among LSPAN, OSPAN, RSPAN, and TOSRE scores, and (2) relationships between naming times in the Low Elaboration Inference and the scores for LSPAN, OSPAN, RSPAN, and TOSRE.

Relationships among LSPAN, OSPAN, RSPAN and TOSRE Scores. The means, standard deviations, and ranges of the scores for the three working memory measures (i.e., LSPAN, OSPAN and RSPAN) and the reading efficiency measure (i.e., TOSRE) are reported in Table 5.2.

Table 5.2
Means, Standard Deviations and Ranges for
LSPAN, OSPAN, RSPAN, and TOSRE Scores
(*n* = 73)

	Test	<i>M</i>	<i>SD</i>	Range
Working Memory	LSPAN (maximum = 100)	72.75	14.0	34-98
	OSPAN (maximum = 42)	31	5.8	17-42
	RSPAN (maximum = 42)	31.32	8.1	10-42
Reading Efficiency	TOSRE (maximum = 80)	38.96	10.5	20-67

Note. LSPAN=Listening Span, OSPAN=Operation Span, RSPAN=Read Span, TOSRE = Test of Sentence Reading Efficiency

Correlations among the scores for the three working memory measures (i.e., LSPAN, OSPAN and RSPAN) and a reading measure (i.e., TOSRE) are reported in Table 5.3. The three

working memory measures were positively correlated with each other. These correlations were in the expected direction, which indicates they all measured something in common. This result was consistent with the findings from recent studies (Conway et al., 2005; Sanchez & Wiley, 2006).

Table 5.3
Zero-order Correlations among Working Memory Measures and TOSRE
(n = 73)

Variable	LSPAN	OSPAN	RSPAN
1. Listening-span (LSPAN)	---		
2. Operation-span (OSPAN)	.37***	---	
3. Read-span (RSPAN)	.57***	.37***	---
4. Reading efficiency (TOSRE)	.42***	.23	.32**

Note. LSPAN = Listening Span, OSPAN = Operation Span, RSPAN = Read Span

** $p < .01$, *** $p < .001$ (2-tailed)

To examine the extent to which each of three working memory measures (i.e., LSPAN, OSPAN, and RSPAN) individually predicted and uniquely contributed to reading measured by TOSRE, bivariate correlation and semi-partial correlations were calculated between TOSRE scores and LSPAN, OSPAN, and RSPAN scores. The semi-partial correlations showed the unique correlation of the participants' Working Memory (LSPAN, OSPAN and RSPAN) scores and their Reading Efficiency (TORSE) scores, removing the over-lapping variance with the other Working Memory scores (e.g., the correlation between Reading Efficiency and LSPAN, removing the co-variance of OSPAN and RSPAN). Table 5.4 shows the results. The bivariate correlation results showed TOSRE scores were positively correlated with LSPAN s and RSPAN scores, but not correlated with OSPAN scores. These results indicated that LSPAN and RSPAN share common variance in predicting the reading efficiency assessed by TOSRE, while LSPAN and OSPAN did not share common variance in predicting the reading efficiency assessed by TOSRE.

Table 5.4
Bivariate and Semi-Partial Correlations between the Scores for
TOSRE and LSPAN, OSPAN and RSPAN (n = 73)

	Bivariate Correlation with TOSRE	Semi-partial Correlations with TORSE Controlling for Covariance of Remaining Memory-Span Measures
LSPAN	.42***	.29**
OSPAN	.23	.10
RSPAN	.32**	.06

Note. LSPAN = Listening Span, OSPAN = Operation Span, RSPAN = Read Span
 ** $p < .01$, *** $p < .001$ (2-tailed)

The semi-partial correlation results between LSPAN scores and TOSRE scores, controlling for OSPAN and RSPAN scores, was statistically significant, indicating that LSPAN is a domain-specific working memory measure of reading comprehension. However, the semi-partial correlation between the OSPAN scores and TOSRE scores, controlling for RSPAN and LSPAN scores, was not significant. Interestingly, although the bi-variate correlation between Read-span scores (RSPAN) and reading efficiency scores (TOSRE) was statistically significant ($r = .32, p < .01$), the semi-partial correlation for RSPAN scores and TOSRE scores, controlling for OSPAN and LSPAN scores, was not significant. The addition of neither RSPAN nor OSPAN to the prediction of TOSRE scores did not provide unique contributions to reading efficiency. This suggests RSPAN and OSPAN are measures for domain-general working memory.

Relationships between Naming Times and Working Memory Scores. As the replicated evidence on naming times indicated, all the participants in this current study generated primary predictive inference online in the Low Elaboration Inference condition. A question remains, however, regarding the extent to which participants' naming times (as an indication that participants activated the specific inferences represented by the probe words) were influenced by their working memory capacity and/or their reading efficiency.

In order to show the general tendency of the extent to which different working memory and reading measures predicted the naming times in this condition, the naming times measured

by milliseconds were submitted to the correlational analysis with LSPAN, OSPAN, RSPAN and TOSRE scores. Even though none of the relationships were significant, the direction of the relationships involved with RSPAN and TOSRE was opposite to the relationships involved with LSPAN and OSPAN. The trend analyses showed that the naming times were negatively predicted by the LSPAN scores ($r = -.14, ns$) and the OSPAN scores ($r = -.08, ns$), but were positively predicted by the RSPAN scores ($r = .11, ns$) and the TOSRE scores ($r = .05, ns$). These trend analyses demonstrated that the higher the RSPAN or TOSRE scores, the longer the naming times, while the higher the LSPAN and OSPAN scores, the shorter the naming times. At this point, however, the relationships between the working memory measures and the naming times were far from being conclusive. More power is needed to substantiate this statement.

Rationale for Confirming RSPAN for the Tripartite Split of the Sample. Based upon the results from the previous analyses, RSPAN was determined to be the most appropriate measure for the following reasons. Generally speaking, the results provided evidence regarding the discriminant validity of working memory measures in relation to reading efficiency as measured by TOSRE. LSPAN scores were strongly, uniquely related with reading efficiency scores (TOSRE) while the other working memory measures were not. The semi-partial correlations suggested that LSPAN is a domain-specific measure of reading comprehension, while RSPAN and OSPAN are domain-general measures of reading comprehension.

OSPAN should not be chosen as the criterion variable for the tripartite split of the sample because, though significantly correlated with RSPAN, OSPAN is not significantly correlated with reading efficiency (TOSRE). This means that even though the construct assessed by OSPAN might reflect domain-general Working Memory capacity, it does not reflect a common cognitive component skill in online processing efficiency during reading in this sample. LSPAN also should not be used as the criterion for the tripartite split of the sample because LSPAN scores predicted a significant unique amount of variance in TOSRE. This indicates that LSPAN and TOSRE might share some variance in predicting general comprehension for this sample. In contrast, while RSPAN scores were significantly positively correlated with the scores of reading efficiency (TOSRE), RSPAN did not make a significant unique contribution to the prediction of TOSRE. The task in RSPAN requires participants to meaningfully process a series of sentences and remember letters shown at the end of each sentence. In a sense, the RSPAN task

measures the working memory capacity involved *while* reading. This general cognitive component may be important during reading. To this end, RSPAN should be regarded as a domain-general Working Memory measure. Thus, taken together with the theoretical justification that RSPAN is a domain-general Working Memory measure which reflects one cognitive component skill in reading (Engle, 2005; Conway et al., 2005), RSPAN was justified as the most appropriate measure to use for the tripartite split of this sample.

Furthermore, RSPAN should have advantages over LSPAN and OSPAN in predicting the differences in the general capacity of a Working Memory system that deals with interference between two parallel mechanisms (i.e., both processing and storage), especially during reading. The current study design focused on the key function of readers' Working Memory as the capability of dealing with interferences during online reading processing. Therefore, the tripartite split of sample into different span groups was based upon the RSPAN scores.

Use RSPAN Scores as a Benchmark

To identify low- and high-span participants, all 73 participants were divided into three groups based upon the tripartite split of the participants' RSPAN percentile scores. Low-span readers ($n = 22$) were defined as the lowest scoring third (mean percentile score = 15.8; range = 1-29.5) on RSPAN, moderate-span readers ($n = 25$) were defined as the middle-scoring third (mean percentile score = 46.6; range = 33.56-63.70), and high-span readers ($n = 26$) were defined as the highest scoring third (mean percentile score = 82.9, range = 68.49-97.95).

To investigate if participants within this tripartite split of RSPAN scores would demonstrate a range of scores for reading efficiency, a tripartite split based on participants' percentile scores of reading efficiency (TOSRE) was also conducted. The split identified poor readers ($n = 30$) in the lowest scoring third (mean percentile score = 17.8, range 2-30.8) on reading efficiency (TOSRE), average readers ($n = 21$) in the middle-scoring third (mean percentile score = 53.4, range = 38.4-67.8), and good readers ($n=22$) in the highest scoring third (mean percentile score = 86.3, range = 74-100). Table 5.5 presents the number of participants based upon the tripartite split of the percentile scores of RSPAN and TOSRE among 73 participants.

Table 5.5
The Number of Participants in Working Memory Groups and Reading Levels Based upon the Tripartite Split of the Percentile Scores of RSPAN and TOSRE

		Working Memory Groups (RSPAN)			
		Low	Moderate	High	Total
Reading	Poor	14	4 (-1)	12	30
Levels	Average	5	10	6	21
(TOSRE)	Good	3	11(-1)	8 (-1)	22
Total		22	25	26	73

Note. The number (-1) represents there was one participant whose naming times was discarded from the subsequent sets of analyses because his/her accuracy rate for answering the online reading comprehension questions was below 85%.

One-way ANOVAs were conducted to test whether there were significant working memory span differences within each reading efficiency level (i.e., poor, average, and good) (see Table 5.6). The tripartite split based upon the percentile scores of RSPAN successfully distinguished high, moderate and low span readers within poor [$F(2, 29) = 70.87, p < .001$], average [$F(2, 20) = 45.26, p < .001$] and good [$F(2, 21) = 40.77, p < .001$] readers, respectively.

Table 5.6
One-Way Analysis of Variance of RSPAN Scores among Three Reading Levels Measured by TOSRE

Reading Level (TOSRE)	Working Memory Span (RSPAN)						
	Low ($n = 22$)		Moderate ($n = 25$)		High ($n = 26$)		<i>F</i>
	Mean	<i>SD</i>	Mean	<i>SD</i>	Mean	<i>SD</i>	
Poor ($n = 30$)	19.5	5.6	30.3	1.7	38.3	1.3	70.87***
Average ($n = 21$)	25.4	2.1	32.7	2.9	39.6	1.6	45.26***
Good ($n = 22$)	22.3	5.5	32.2	3.0	40.1	1.9	40.77***

Note. RSPAN = Read Span Task, TOSRE = Test of Sentence Reading Efficiency, *** $p < .001$ (2-tailed)

Conclusions of the Preliminary Analyses

The preliminary analyses pointed to three conclusions. First, the patterns of naming times in the four reading conditions replicated the findings from the previous study (Guan et al., 2007). In that study, the naming times in the Low Elaboration Inference Condition were statistically shorter than 500ms. This replication warranted the subsequent investigation of the proposed research questions based upon the previous study.

Second, the correlation among the study variables suggested that the working memory measures used in the current study tapped some common cognitive process or ability on the one hand, and revealed different aspects of working memory functioning on the other hand. Third, RSPAN was determined to be an appropriate benchmark to set a basis for low- and high-span group comparison. This decision was made because preliminary analyses supported that RSPAN is a measure of general Working Memory capacity, reflecting one cognitive component skill in reading. These findings from the preliminary analyses ensured that this current study followed the same trends of developmental inquiries established by the previous findings (Guan et al., 2007), thus validating further exploration into the two major research questions. Detailed interpretations of the findings from the preliminary analyses are discussed in the General Discussion chapter.

Analyses on Naming Times for Probe Words

The analyses on naming times were conducted to answer the first set of major research questions, i.e., the extent to which participants' naming times on the inference-testing probe words differed between low- and high-span working memory groups (Question 1), and whether or not text elaboration (low vs. high elaboration) affected participants' naming times on the inference-testing probe words within each of the low- and high-span working memory groups (Question 2). Two alternative hypotheses (Hypothesis 1-a and 1-b) were tested to answer Question 1 about how naming times would differ between low- and high-span individuals, and then hypothesis 2 about the simple Working Memory effects were tested to answer Question 2 about how working memory (low vs. high) moderated the effect of text elaboration on the naming times. The results on naming times were analyzed in the following four steps, and are presented below in the following order:

(1) Descriptive statistics were first examined to determine whether the general trends of planned comparison between low- and high- span groups were plausible. A 2 X 2 repeated measure ANOVA treating Working Memory as between subject factors was conducted to test the general hypothesis 1 (i.e., the simple main effect of Working Memory on naming times).

(2) To test the moderating effect of Reading Efficiency on naming times between low- and high- span groups, a two-way between-subject Multivariate Analysis of Variance (MANOVA) on naming times in the four reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, High Elaboration Control) was conducted. A 2 (Working Memory: low vs. high) X 3 (Reading Efficiency: poor, average, good) MANOVA revealed a significant Working Memory by Reading Efficiency interaction in three out of four reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, High Elaboration Control).

(3) To test the two alternative hypotheses (Hypothesis 1-a and Hypothesis 1-b), planned comparisons were tested via the simple effect of Working Memory on naming times in each of the three reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, High Elaboration Control). The analyses were done by examining the Working Memory effect on naming times across three levels of reading efficiency respectively. Hence, three MANOVAs were conducted, treating the naming times in each of the three reading conditions as dependent variables simultaneously.

(4) Finally, to test Hypothesis 2 about the effects of text elaboration on the inference activation were examined within low- and high- span group. For good readers, two plots of Elaboration by Inference interaction are presented in low- and high- span readers due to a small sub-sample size. For poor readers, a 2 (Elaboration Type) X 2 (Inference Type) X 2 (Working Memory: low vs. high span) mixed factor Repeated Measures ANCOVA with reading efficiency raw scores as a covariate was conducted. After a significant interaction effect between Working Memory and Elaboration was detected, the analysis was broken down to low- and high- span groups to test how Working Memory (low vs. high) moderated the effect of text Elaboration on naming times among poor readers (Baron & Kerry, 1986).

Outliers (those naming times exceeding 2.5 *SD* for a participant’s mean in a condition, and those times greater than 1,000 ms or less than 100ms) were discarded and constituted less than 4% of the data. No analyses were conducted on the item level (Raaijmakers, Schrijnemaker & Gremmen, 1999) because all the research questions were proposed on the subject-level. Also the within-subject design used in this study did not have enough passages allowing the item-level analysis to be conducted. The Naming times analyses were conducted based upon the aggregated mean of each participant’s naming times in 6 passages in the same reading conditions. For each participant, there were four aggregated means representing the naming times in the four reading conditions (i.e., Low Elaboration Inference, Low Elaboration Control, High Elaboration Inference, and High Elaboration Control).

Descriptive Statistics of Naming Times

The mean naming times for low- and high-span readers in the four reading conditions (i.e., High Elaboration Inference, High Elaboration Control, Low Elaboration Inference, and Low Elaboration Control) are displayed in Table 5.7. To simplify the matter, analyses for the proposed research questions focused only on the two extreme working memory groups (low vs. high).

Table 5.7
Mean Naming Times and Standard Deviations for Low, Moderate and High Span Readers

Reading Conditions	Low Span <i>n</i> = 22		High Span <i>n</i> = 25	
	Mean	<i>SD</i>	Mean	<i>SD</i>
LI	456.68	48.10	468.16	56.96
LC	479.31	61.53	511.04	60.52
HI	473.25	74.72	505.33	64.43
HC	481.04	61.15	527.84	81.45

Note. LI = Low Elaboration Inference, LC = Low Elaboration Control, HI = High Elaboration Inference, HC = Low Elaboration Control

Testing Alternative Hypotheses 1-a and 1-b

A 2 (Elaboration Type: low and high) X 2 (Inference Type: inference vs. control) X 2 (Working Memory: low and high) Repeated Measures ANCOVA was conducted, treating TOSRE raw scores as a covariate. The aggregated means of the participants' four naming times in four reading conditions were used as the dependent variable. The result suggested the simple main effect of working memory was marginal significant [$F(1, 44) = 3.641, p = .063$]. This supports the general hypothesis that naming times would differ between low and high-span readers. This provides evidence in the direction of support for Hypothesis 1-b (i.e., the low-span readers always had shorter naming times than the high-span readers, which is contradictory to the skilled suppression mechanism).

The subsequent post hoc analyses were conducted to further explore the effect of working memory within specific reading groups. This was done first within two steps as follow. First, a two-way between-subject Multivariate Analysis of Variance (MANOVA) on naming times in four reading conditions was conducted to display the moderating effect of Reading Efficiency on naming times between low- and high-span groups in three out of four reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, High Elaboration Control). Second, three one-way Multivariate Analysis of Variance (MANOVA) tests across three levels of reading efficiency were conducted, testing Hypothesis 1-a and Hypothesis 1-b, that is the alternative directions of the simple effect of Working Memory on the naming times in each of three reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, High Elaboration Control).

To examine the simple effects of Working Memory (low vs. high) across the levels of Reading Efficiency (poor, average, and good) on naming times, the moderating effect of Reading Efficiency was tested as indicated by a significant interaction between Working Memory and Reading Efficiency. A 2 X 3 between-subjects multivariate analysis of variance was performed on four dependent variables, i.e. the naming times in four reading conditions. Independent variables were Working Memory (low and high) and Reading Efficiency (poor, average, and good).

Testing Reading Efficiency as a Moderator Working Memory

SPSS MANOVA was used for the analyses with the sequential adjustment for nonorthogonality (Norusis, 2005). Order of entry of independent variables was Working Memory first, and then Reading Efficiency second. There were no missing cases. There were no univariate or multivariate within-cell outliers at $p < .001$. Results of evaluation matrices, linearity, and multicollinearity were satisfactory.

Table 5.8 shows the means and standard deviations of the naming times in the four reading conditions. There were no significant main effects of Working Memory or Reading Efficiency. The interactions between Working Memory and Reading Efficiency were significant in three out of four reading conditions, i.e., Low Elaboration Control condition [$F = 18.53, p < .001$], High Elaboration Inference condition [$F = 10.32, p = .003$], and High Elaboration Control condition [$F = 3.79, p = .05$].

Table 5.8
Effects of Reading Efficiency and
Working Memory by Reading Efficiency Interaction on Naming Times

Reading Condition	Working Memory	Reading Efficiency Levels						F-values	
		Poor <i>n</i> = 26		Average <i>n</i> = 11		Good <i>n</i> = 10		Reading Efficiency Levels (2,41)	Working Memory X Reading Efficiency (2,41)
		Mean	SD	Mean	SD	Mean	SD		
LI	Low	455	12.1	438	35.1	492	20.8	.16	2.17
	High	463	13	491	32.0	452	13.6		
LC	Low	462	13.4	472	34.4	570	20.8	.84	18.53***
	High	524	14.5	528	31.4	472	13.6		
HI	Low	467	17.2	447	35.0	543	26.6	.59	10.32**
	High	534	18.6	478	32.0	456	17.4		
HC	Low	467	19.6	509	32.3	495	31.2	.99	3.79*
	High	551	21.2	547	29.4	471	20.4		

Note. LI = Low Elaboration Inference, LC = Low Elaboration Control, HI = High Elaboration Inference, HC = High Elaboration Control
* $p < .05$, ** $p < .01$, *** $p < .001$ (2-tailed)

The significant interactions involved with Reading Efficiency suggested a moderating effect of Reading Efficiency. Hence, to examine the simple effect of Working Memory across the levels of Reading Efficiency, it was appropriate to break all observations down to three levels by Reading Efficiency (poor, average and good) (Baron & Kerry, 1986).

Three post-hoc exploratory analyses by using one-way Multivariate Analysis of Variance (MANOVA) tests were conducted within each of three level of Reading Efficiency. Each MANOVA test treated naming times in three reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, and High Elaboration Control) as dependent variables simultaneously, and Working Memory (low vs. high) as grouping variable.

Levene's test of equality of error variances was examined to test the assumptions of equality of covariance matrices. A greater than .05, non-significant statistic, indicated the covariance matrices were equal and the assumption was tenable. The results presented in Table 5.9 include the means, standard deviations, and omnibus test results of all planned comparisons across the poor, average and good readers. The statistical results from the Low Elaboration Inference were also presented as a reference to the other three reading conditions (i.e., Low Elaboration Control, High Elaboration Inference, and High Elaboration Control) in which the significant Working Memory by Elaboration were found in the previous step.

Testing Alternative Hypotheses across three Reading Levels. For the poor readers, participants whose working memory was low had shorter naming times than those participants whose working memory was high in the three reading conditions, i.e., Low Elaboration Control condition [$F(1, 25) = 10.0, p = .004$], High Elaboration Inference [$F(1, 25) = 6.97, p = .014$], and High Elaboration Control [$F(1, 25) = 8.27, p = .008$]. No planned comparisons among the average readers were significant. The good readers whose working memory was low had longer naming times than those participants whose working memory was high in two reading conditions, i.e., Low Elaboration Control [$F(1, 9) = 15.7, p = .04$], and High Elaboration Inference [$F(1, 9) = 7.5, p = .026$] respectively. Due to the restricted sample size, the results from good reading levels should be interpreted with caution.

Table 5.9
Effect of Working Memory on the Naming Times
among Poor, Average and Good Reading Levels

Reading Efficiency Levels		Working Memory Groups				MSE	F (1, 9)
		Low (n = 14)		High (n = 12)			
		Mean	SD	Mean	SD		
Poor	LI	455	12.1	463	13.0	2042.5	.19
	LC	462	13.4	524	14.5	2506.9	10.0**
	HI	467	17.2	534	18.6	4145.7	6.97*
	HC	467	19.6	551	21.2	5393.9	8.27**
		Low (n = 5)		High (n = 6)		MSE	F (1,10)
		Mean	SD	Mean	SD		
Average	LI	438	35.1	491	32.0	6157.3	1.26
	LC	472	34.4	528	31.4	5900.8	1.48
	HI	447	35.0	478	32.0	6135.2	1.43
	HC	509	32.3	547	29.4	5202.4	.76
		Low (n = 3)		High (n = 7)		MSE	F (1,25)
		Mean	SD	Mean	SD		
Good	LI	492	20.8	452	13.6	1294.1	2.67
	LC	570	20.8	472	13.6	1288.9	15.70**
	HI	543	26.6	456	17.4	2133.3	7.50*
	HC	495	31.2	471	20.4	2924.6	.41

Note. Good, Average and Poor = Three reading levels of the reading efficiency based on the tripartite split on the percentile scores of TOSRE

LI = Low Elaboration Inference, LC = Low Elaboration Control, HI = High Elaboration Inference, HC = High Elaboration Control

* $p < .05$; ** $p < .01$ (2-tailed)

Testing Hypothesis 2

To further explain the findings from the planned comparisons on naming times between the low- and high-span readers, the interaction effect between Text Elaboration and Working Memory was examined to further explore how low- and high-span readers' naming times were

affected differently by the text elaboration. A 2 (Elaboration Type: low vs. high) X 2 (Inference Type: inference vs. control) X 2 (Working Memory: low vs. high) on naming times was conducted, treating TOSRE raw scores as a covariate. The result suggested a significant Text Elaboration X Working Memory interaction [$F(1, 44) = 4.02, p = .05$]. This significant interaction effect supports the hypothesis 2 that the effect of Text Elaboration differed between low- and high-span readers.

Since the naming times patterns were different between the poor and good readers, the significant interaction between Text Elaboration and Working Memory was examined within poor and good reading groups respectively in the following post hoc analyses. Two 2 (Elaboration Type: high vs. low elaboration) X 2 (Inference Type: inference vs. control) X 2 (Working Memory: low vs. high) Repeated Measures ANCOVA was conducted within poor and good readers. These analyses treated the TOSRE raw score as a covariate.

Text Elaboration Effects among Good Readers. The analyses among good readers did not produce the proper Mauchly's test results, indicating that the homogeneity of variance assumption was not met. Due to the limited number of good readers (3 low-span participants and 7 high-span participants) for this analysis, only plots are presented to show the effect of text elaboration on the naming times in low- and high-span groups.

Figures 5.2a and 5.2b show the patterns of good readers' naming times between the low- and high-span individuals respectively. Low-span good readers ($RSPANGr = 1$) demonstrated quicker naming times in the inference condition than the control condition only when the text elaboration was low. Whereas high-span good readers ($RSPANGr = 3$) demonstrated quicker naming times in inference conditions than the control conditions no matter whether the text elaboration was low or high.

The results for good readers should be interpreted with caution due to the restricted subsample size. It seems, however, good readers have no problem generating primary predictive inferences online.

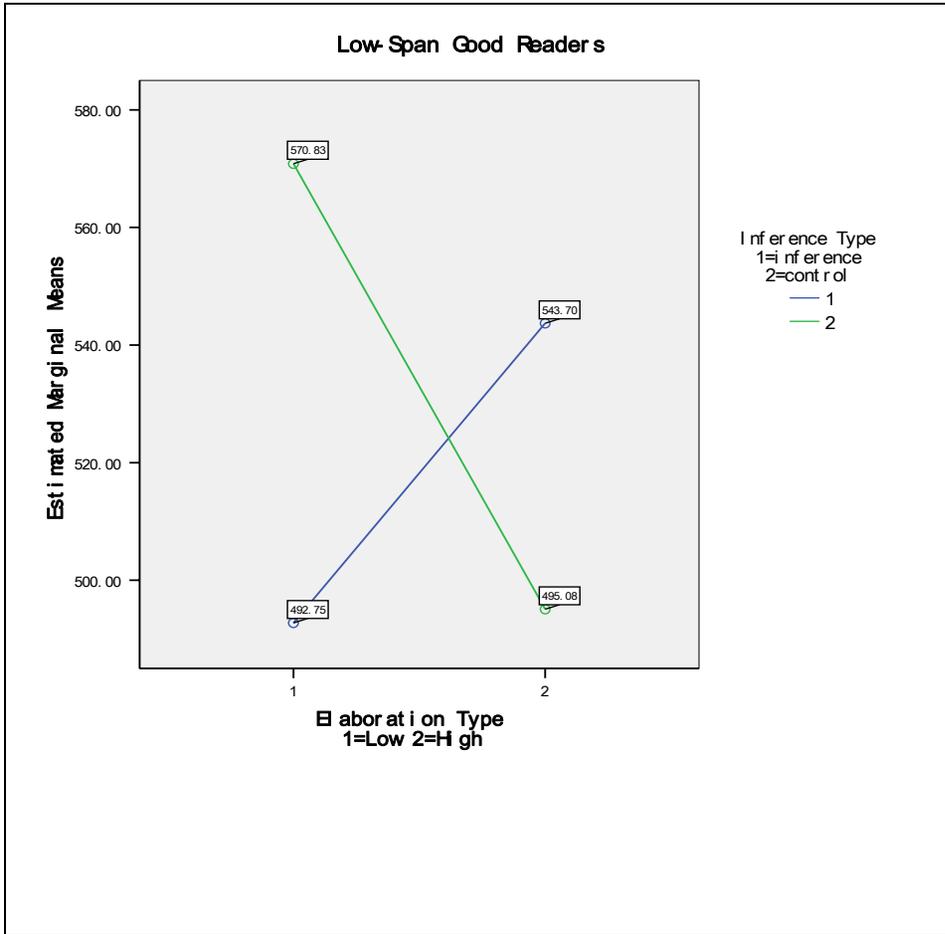


Figure 5.2-a

Elaboration X Inference Interaction for Low Span Good Readers

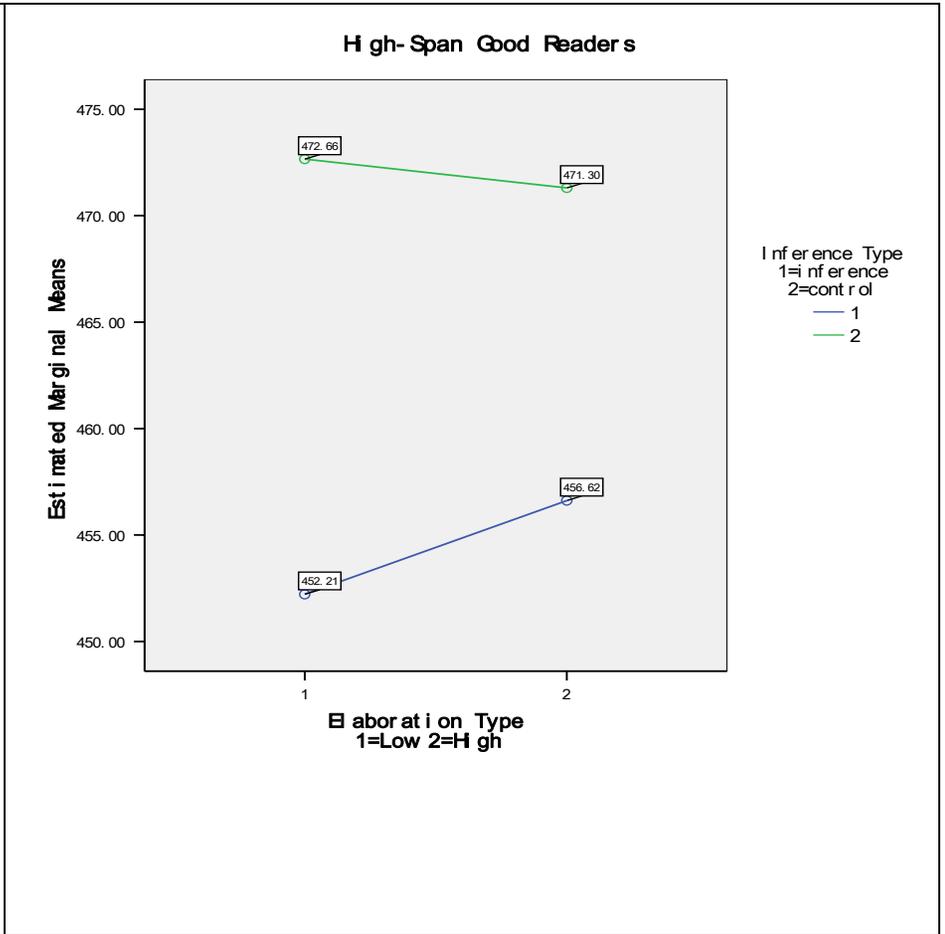


Figure 5.2-b

Elaboration X Inference Interaction for High Span Good Readers

Text Elaboration Effects among Poor Readers. For poor readers, Mauchly's test indicated that the assumptions of sphericity had not been violated for main effects and the interaction effects. There was a significant main effect of Elaboration [$F(1, 44) = 6.12, p = .017$] and a significant Elaboration X Working Memory interaction [$F(1, 44) = 4.08, p = .049$]. The between-subject effect of Working Memory reached marginal significance [$F(1, 44) = 3.59, p = .065$].

Finally, since there was a significant interaction of Elaboration by Working Memory, the effect of Elaboration was examined in the low- and high-span groups respectively to demonstrate the specific effect of Elaboration on the naming times in each span group (Baron & Kenny, 1986). Two 2 (high vs. low elaboration) X 2 (inference vs. control) Repeated Measures ANOVA analyses were conducted within the low- and high-span poor reader groups respectively. Table 5.10 displays the statistical results.

Table 5.10
Effects of Elaboration Type, Inference Type on the Naming Times
Within Low- and High-Span Poor Readers

Working Memory	Source	<i>df</i>	<i>MSE</i>	<i>F</i>
Low <i>n</i> =14	Elaboration	1,13	1372.8	.77
	Inference	1,13	501.9	.39
	Elaboration X Inference	1,13	525.6	.24
High <i>n</i> =12	Elaboration	1,11	2147.2	13.21**
	Inference	1,11	1879.8	9.76**
	Elaboration X Inference	1,11	5902.1	4.81*

* $p < .05$; ** $p < .01$ (2-tailed)

Among the low-span poor readers, neither main effects nor interaction effects were significant. In contrast, among high-span poor readers, there were significant main effects of Elaboration [$F = 13.21, p = .004$] and Inference [$F = 9.76, p = .010$], and a significant Elaboration by Inference interaction effect [$F = 4.81, p = .05$].

Figure 5.3 further illustrates the different patterns of naming times between low- and high-span poor readers. The low-span poor readers' naming times were almost all shorter than 500ms. The two right-most bars (i.e., the grey and purple bars) for the low-span readers suggest the naming times do not differ in the High Elaboration Inference condition and the High Elaboration Control condition, indicating that the text manipulation did not work among the low-span group of readers in the high elaboration conditions. In other words, the low-span readers rarely generated primary predictive inferences online in the high elaboration conditions. The test on the text elaboration effect would further explain this result.

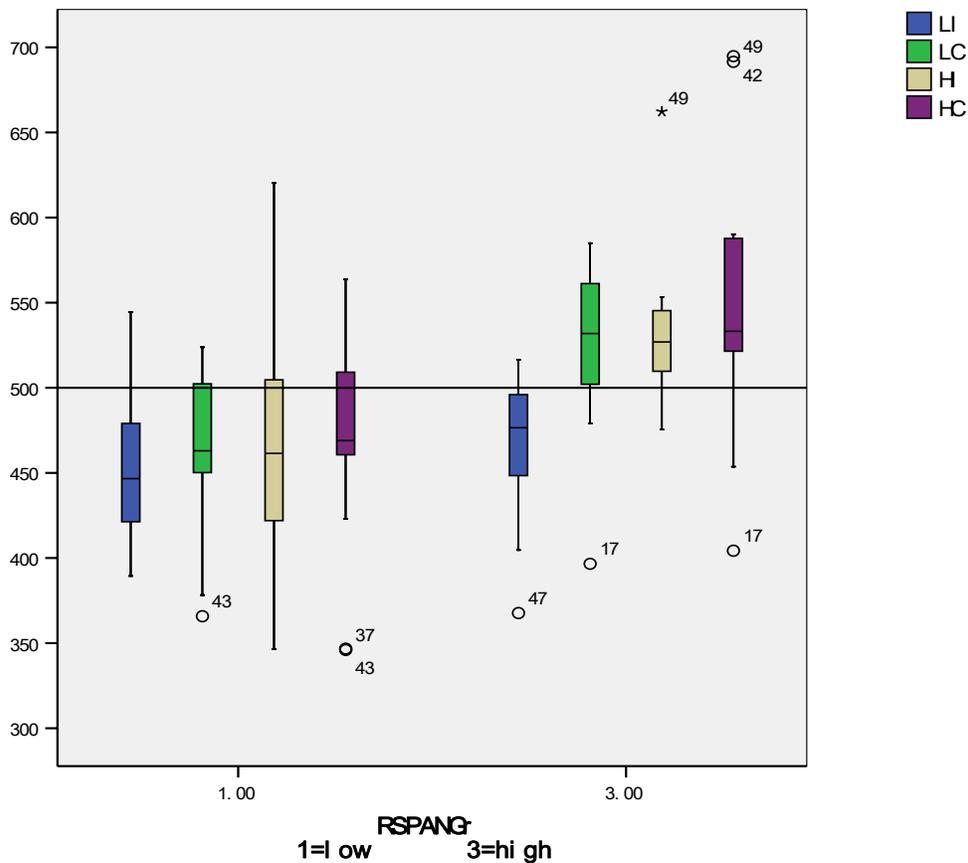


Figure 5.3

Naming Times in Milliseconds between Low-span and High-span Poor Readers

High-span poor readers' naming times were shorter in the inference conditions than the control conditions. Their naming times were shorter than 500ms in the Low Elaboration Inference condition, but ranged from 500ms to 550ms in the High Elaboration Inference condition. This 50ms additional processing time could be explained by the phenomenon of saccadic suppression.

During online reading, the movement of the eyes could stop any perception, i.e., stop sending visual information to the brain. This is called saccadic suppression. This phenomenon usually starts about 50ms before the next jump of the eye and lasts for at least 125ms. This means the readers in this study would not start sending the word to their brains at least in the first 75ms. Actually, in Calvo and Castillo's (1998) seminal paper, they found that the automatic activation of the predictive inferences could take as long as 550ms to happen online. Therefore, 550ms naming times to the inferential probe word should still be regarded as automatic. The high-span poor readers were able to generate primary predictive inferences in both low or high text elaboration in this study. The naming patterns of the high-span poor readers replicated the finding from the previous studies (Harmon, 2005; Guan et al., 2007).

Conclusions on the Naming Times

The analyses on the naming times point to three conclusions. First, the simple effects of Working Memory differ across the three levels of reading efficiency. For the poor readers, the lower the working memory capacity, the quicker the naming times. For the average readers, the naming times did not differ between the low- and high-span groups. For the good readers, the lower the working memory capacity, the slower the naming times. Due to the restricted sample size, however, the results on good readers' naming times should be interpreted with caution.

The low- and high-span poor readers demonstrated different effects of Text Elaboration on naming times. The low-span poor readers were actually not affected by the text elaboration, so their naming times were quicker than 500ms in both elaboration conditions. The high-span poor readers were affected by the text elaboration, but their naming times were always quicker in the inference conditions than the control conditions. This means, the low-span poor readers never generated the primary predictive inferences online, but the high-span poor readers were able to. This result is consistent with the prediction of the Skilled Suppression Hypothesis.

Third, for good readers, it seems that the high-span good reader generated primary predictive inferences online no matter whether the text elaboration was low or high. While the low-span good reader generated primary predictive inferences only when the text elaboration was low. Unfortunately, more data needs to be collected in a future study in order to verify this conclusion that text elaboration has no impact among high-span good readers, but does affect low-span good readers when they were engaged in generating predictive inferences. The interpretation on data collected among the good readers should be interpreted with caution. However, if this conclusion is accurate, it would support the proposition of the General Capacity Theory. Detailed interpretations of the findings from naming time data are discussed in the General Discussion chapter.

Analyses on the Recall of Predictive Inferences and Text Coherence

Participants' recall data were analyzed to explore the second set of research questions, i.e., the extent to which participants' Working Memory affected their exact recall of the primary predictive inferences (Question 3), and (2) the extent to which participants' Working Memory and Activation of primary predictive inferences affected their coherence of text-recall (Question 4). The results are presented in the following order:

- (1) Coding-schema of participants' recall data and the interrater reliabilities between coders,
- (2) Results of Multivariate Analysis of Variance (MANOVA) testing hypothesis 3 (i.e., Working Memory is not a major factor impacting the exact recall of primary predictive inferences), and
- (3) Results of post hoc hierarchical regression analyses exploring how participants' Working Memory and Activation of primary predictive inferences affected their coherence of text-recall in the low and high elaboration contexts.

Coding-schema and Interrater Reliabilities of the Recall Coding

The recall data from 22 low- and 25 high-span participants were qualitatively analyzed. There were originally 26 high-span participants, however; one person in the high-span group misunderstood the instructions for the cued recall task. Therefore, this participant's data were excluded from analysis.

Coding-schema. Each participant's text recall was coded based upon two coding schema. The first coding scheme was based on whether the participants could accurately recall the primary predictive inference for each story (1=accurate recall; 0=inaccurate or no recall). The score based upon the first coding scheme was used to answer Research Question 3: the extent to which the primary predictive inferences were accurately recalled. The second coding scheme involved rating the extent to which participants (1) coherently represented the local inferential concepts (i.e., primary and secondary inferences), (2) globally understood the story (i.e, the gist of the story), and (3) accurately recalled the global story-structures (i.e., chronicle order and causal relations). For each variable of local coherence (primary inferences and secondary inferences) and global coherence (gist, chronicle story, and causal relations), data were coded on a "0 - 1" scale (1= coherent, 0 = incoherent or no recall). The scores based upon the second coding scheme were used to answer Research Question 4: the extent to which Activation of primary predictive inferences and Working Memory affected the coherence of participants' text-recall.

Inter-rater reliability. In total, one category of coding was coded for Research Question 3 related to the exact recall of primary predictive inferences, and five categories were coded for Research Question 4: (1) local coherence of the primary predictive inferences, (2) local coherence of secondary inferences, (3) global coherence of gist, (4) global coherence of chronicle order, and (5) global coherence of causal relations. To ensure the reliability of coding, two coders (one of whom was the author) coded the same 1/8 of participants' recall data. When coding the data, the coders were blind to the conditions to which the reading passages were assigned. The percentages of agreement of each pair of coding-results were calculated based upon whether the values matched each other. The results are presented in Table 5.11. The inter-rater reliabilities for each coded variable were calculated, and then the remaining participants' recall data were coded by the author. To conduct data analyses, the coding values for each of the 6 stories within the same conditions were averaged. The six averaged values for each of the categories of coding (see Table 5.11) were used for analyses, treating subject as the unit of analysis.

Table 5.11
Inter-Rater Reliability for Coding of Accurate Recall and Text Coherence
(*n* = 216)

Research Questions	Coding Scheme	Category	Percentage of Agreement
Question 3	I. Exact Recall	Primary Predictive Inference	92.8%
	Local	1. Primary Inferential Concept	92.3%
Question 4	II. Text Coherence	2. Secondary Inferential Concept	96.2%
	Global	3. Gist	95.8%
		4. Chronicle	91.8%
		5. Causal Relations	96.9%

Testing Hypothesis 3

To test whether or not participants' Working Memory (low vs. high) was a major factor impacting their recall of primary predictive inferences, Multivariate Analysis of Variance (MANOVA) was conducted. Analyses investigated whether or not there was a Working Memory effect on the exact recall of participants' primary predictive inferences in all four reading conditions (i.e., Low Elaboration Inference, Low Elaboration Control, High Elaboration Inference, and High Elaboration Control). The means and standard deviations of recall rates of predictive inferences as well as *F*-values of planned comparisons between low- and high-span readers across four reading conditions are shown in Table 5.12.

In this analysis, the recall rates of predictive inferences in the four reading conditions were treated as dependent variables, and Working Memory (low vs. high) was treated as a fixed factor. As Table 5.12 shows, compared to high-span readers, low-span readers recalled higher proportions of the predictive inferences in the Low Elaboration Inference condition ($M=.47 > M=.31, F(1, 46) = 4.83, p = .033$) and in the High Elaboration Control condition ($M=.47 > M=.26, F(1, 46) = 10.33, p = .002$). Thus, the null hypothesis was partially accepted. The data from these two reading conditions (i.e., Low Elaboration Inference and High Elaboration Control) presented evidence to support rejecting the null hypotheses (i.e., Working Memory would not be a major factor impacting the offline recall of primary predictive inferences).

Table 5.12
The Means and Standard Deviations of Recall Rates of Primary Predictive Inferences and F-values of Planned Comparisons (across Four Reading Conditions)

Reading Condition	Low-span		High-span		<i>F</i>
	<i>n</i> = 25		<i>n</i> = 22		
	Mean	<i>SD</i>	Mean	<i>SD</i>	
LI	.47	.28	.31	.23	4.83*
LC	.28	.25	.28	.18	.01
HI	.41	.25	.47	.27	.48
HC	.47	.22	.26	.22	10.33**

* $p < .05$, ** $p < .001$ (2-tailed)

Exploring Question 4

Exploratory analyses were tested to answer Question 4 (i.e., the extent to which participants' Reading Efficiency, Activation of primary predictive inferences, and Working Memory affected the coherence of text-recall. The five outcome text-coherence variables included two levels of local coherence indicators (Local-Coherence of Primary Inferences, Local Coherence of Secondary Inferences) and three levels of global coherence indicators (Global Coherence-Gist, Global Coherence-Chronicle Order, Global Coherence-Causal Relations).

Activation of primary predictive inferences, as a new independent variable, was established first. This variable was determined for every participant by subtracting their mean naming times on the inference-testing probe words in the inference conditions from their mean naming times on the inference-testing probe words in the control conditions. For example, if on average, a student used 423ms milliseconds to name the inference-testing probe words in the inference-evoking condition and 503 milliseconds to name the inference-testing probe word in the inference control condition, then their difference score would be $503 - 423 = 80$. Because this number is positive, it suggests that participants recalled the inference-testing probe words shorter in the inference-evoking condition than they did in the inference control condition. The difference score was given a code of "1" if the difference score was positive or a "0" if the difference score was zero or negative. The positive difference scores suggested that predictive inferences were activated online as demonstrated by the faster naming times (Murray & Burke,

2003). Activation_1 refers to Activation of the primary predictive inferences in the low elaboration context, and Activation_2 to Activation of the primary predictive inferences in the high elaboration context.

Participants' data that were collected in only two reading conditions (i.e., Low Elaboration Inference and High Elaboration Inference) were used in the analyses because these two conditions were designed to elicit primary predictive inferences. Because text elaboration (low vs. high) was a within-subject factor, all the three predictors of interest were between-subject factors. If a MANOVA analysis were conducted, it would be a five-way mixed factor repeated measures analyses: 2 Elaboration (low vs. high) X 3 Reading Efficiency (poor, medium and good) X 2 Working Memory (low vs. high) X 2 Activation (Activated vs. Not Activated) X 5 Text-Coherence levels. Due to the lack of degrees of freedom and the difficulty of interpreting a five-way mixed factor repeated measures MANOVA, hierarchical regression analyses were conducted.

The predictor variables were Reading Efficiency (as defined by TOSRE scores), Working Memory Groups (low and high as defined by RSPAN scores), and Activation (i.e., Primary predictive inferences were activated or not activated) within the low and high elaboration contexts. To keep consistent with the naming-time analyses, Working Memory was dichotomously coded 1 for low-span working memory group and 2 for high-span working memory group. When conducting the analyses, participants' reading ability was control for. Therefore, Reading Efficiency was entered into hierarchical models first (block one). Reading Efficiency and Activation of Primary Predictive Inference s were entered into the second step of the model (block two), and then Reading Efficiency, Activation of Primary Predictive Inference, and Working Memory were entered last in the predictive model (block three). The Hierarchical Regression analyses investigated the changes in R^2 that occurred as each block was added to the regression equation. Hierarchical Regression analyses also allowed for the investigation of the unique contribution of the variables as well as the combined contribution of the variables as they were entered together as a block.

The means and standard deviations of Local coherence (i.e., primary inferences, secondary inference) and Global coherence (gist, chronicle order, and causal relations), organized by elaboration conditions (low vs. high), working memory (low vs. high) and Activation of primary predictive inferences (1, 0) are presented in Table 5.13.

Table 5.13
Means and Standard Deviations of Coherence Ratings
in Low and High Elaboration Reading Conditions,
Low- and High- Working Memory Groups
when Primary Predictive Inferences were Activated (Activation=1) and Not Activated (Activation=0)
(*n* = 47)

Elaboration	Working Memory	Activation	Local Coherence				Global Coherence					
			Primary	<i>SD</i>	Secondary	<i>SD</i>	Gist	<i>SD</i>	Chronicle	<i>SD</i>	Causal	<i>SD</i>
Low	Low-Span	0	.22	.22	.22	.23	.11	.09	.06	.09	.08	.07
		1	.51	.25	.63	.27	.48	.24	.22	.23	.19	.11
	High-Span	0	.44	.25	.28	.25	.18	.26	.05	.08	.01	.03
		1	.38	.22	.35	.19	.15	.37	.19	.18	.11	.17
High	Low-Span	0	.12	.13	.39	.26	.16	.15	.20	.13	.06	.09
		1	.52	.12	.67	.20	.49	.25	.26	.22	.10	.12
	High-Span	0	.42	.18	.56	.19	.42	.22	.37	.24	.17	.14
		1	.47	.30	.63	.22	.46	.27	.38	.34	.24	.27

Ten hierarchical regression analyses were conducted. First, using participants' data that were gathered within *the Low Elaboration context*, five hierarchical regressions were conducted to investigate the affects of participants' Reading Efficiency (as defined by TOSRE raw scores), Activation of primary predictive inferences, and Working Memory on the coherence of their recall: (1) Local-Coherence of Primary Inferences, (2) Local Coherence of Secondary Inferences, (3) Global Coherence-Gist, (4) Global Coherence-Chronicle Order, and (5) Global Coherence-Causal Relations. Then, using participants' data that were gathered within the *High Elaboration context*, another five regression analyses were repeated.

The results of the hierarchical regression analyses are described in the following four sections: (1) within the *Low Elaboration context*, the effects of the independent variables (Reading Efficiency, Activation, and Working Memory) on participants' *local coherence scores*, (2) within the *High Elaboration context*, the effects of the independent variables on participants' *local coherence scores*, (3) within the *Low Elaboration context*, the effects of the independent variables participants' *global coherence scores* and (4) within the *High Elaboration context*, the effects of the independent variables on participants' *global coherence scores*.

Predictions of Local Coherence in Low Elaboration Context. Table 5.14 shows the unique contributions of the three predictor variables (Reading Efficiency, Activation, and Working Memory Groups) on the two levels of local coherence (i.e., primary inference coherence, secondary inference coherence) within the low elaboration context. Two hierarchical regressions investigated the changes in R^2 that occurred as each independent variable was added to the regression equation for predicting participants' scores for (1) primary inference coherence, then (2) secondary inference coherence.

The purpose of the first step in the hierarchical regression analysis was to determine the contribution of students' Reading Efficiency (as defined by TOSRE raw scores) for predicting their recall coherence of the dependent variable (i.e., primary coherence or secondary coherence). The second step investigated the extent to which the activation of primary predictive inferences (activated or not activated) — both independently and in combination with their reading efficiency scores — significantly added to the prediction of the dependent variable (i.e., primary inference coherence or secondary inference coherence). The third step of the hierarchical regression analyses investigated the extent to which Working Memory Groups (low and high as defined by RSPAN raw scores) —both uniquely and in combination with the other

independent variables (i.e., Reading Efficiency and Activation) — significantly added to the prediction of the dependent variable (i.e., primary inference coherence or secondary inference coherence).

Regarding participants' abilities to coherently recall primary inferences in the Low Elaboration context none of the three predictor variables — uniquely or in combination — significantly predicted participants' primary inference recall scores. Regarding participants' abilities to coherently recall secondary inferences in the Low Elaboration context, the three predictor variables of Reading Efficiency, Activation, and Working Memory — both uniquely and in combination — significantly explained 40% of the total variance in participants' coherent representations of the secondary inference (see Table 5.14).

The lack of significant results for predicting participants' coherent representations of the primary inference in the Low Elaboration context seems to be inconsistent with the findings to answer Question 3. In Question 3, I replicated the effect of the self-generation hypothesis such that readers in the low working memory-span group correctly recalled inferential probe words more often in the Low Elaboration Inference-evoking context. However, remembering the inference-probe word (e.g., break) is a different task than coherently representing the inferential ideas (e.g., the vase broke after being thrown against the wall). The latter requires contextual support while the former does not. As previous research has suggested, predictive inferences, if not supported by subsequent text, are not integrated with individuals' online text-processing and therefore, the memory of the predictive inference decays rapidly (McDaniel, et al., 2001; McKoon & Ratcliff, 1986).

The significant results obtained for predicting participants' coherent representations for secondary inferences within the Low Elaboration context, suggested that, when readers process the sentence information more efficiently, they less coherently recall the secondary inference. This means the faster people read, the less attention they pay to the detailed background information. In addition, when online activation of a primary predictive inference occurs, readers' coherent representation of a secondary inference is enhanced. This means that evoking online activation of primary predictive inferences, along with even minimal elaboration, enhances participants' coherent mental model of the text message, and acts as a form of deep text-comprehension that facilitates readers' coherent text memory (Radvansky et al., 2001).

Table 5.14
Hierarchical Regression Analyses within Low Elaboration Context: Predicting Two Levels of
Local Coherence with Reading Efficiency, Working Memory, and Activation
(n = 47)

Levels	Step and Predictor Variables	R^2	ΔR	B	SEB	β	
Primary Inference	Step 1	RE	.01	.01	.00	.01	-.11
	Step 2	RE and Act1	.03	.02			
		RE			.00	.01	-.15
		Act1			.08	.09	.14
	Step 3	RE, Act1 and WM	.10	.07			
		RE			.00	.00	-.09
		Act1			.07	.09	.12
		WM			-.01	.01	-.27
	Step 1	RE	.07	.07	-.01	.01	-.26
	Step 2	RE and Act1	.28	.21***			
Secondary Inference		RE			-.01	.00	-.38**
		Act1			.30	.08	.47*
	Step 3	RE, Act1 and WM	.40	.12*			
		RE			-.01	.00	-.31*
		Act1			.28	.08	.45***
	WM			-.01	.00	-.36**	

Note. RE = Reading Efficiency, WM = Working Memory Group, Act = Activation,
 1= Low Elaboration Context

* $p < .05$, ** $p < .01$, *** $p < .001$ (2-tailed)

Interestingly, readers in low working memory group tended to remember the secondary inference within the text better than the readers in high working memory group if they employed predictive inferences as a form of reading strategy. This might occur because the high-span working memory readers may have already been accustomed to employing this deep text-processing strategy during reading and their reading goals are not simply to understand and remember the text on a surface level (such as the detailed secondary inference given in the text); they are achieving more through construction and integration during comprehension. It was

expected that the high-span working memory readers would perform even better on the higher-level text coherence analysis (i.e., global coherence of the gist, chronicle order, and causal relations of text). The hierarchical regression analyses predicting participants' global coherence in the Low and High Elaboration contexts test this expectation.

Predictions of Local Coherence in High Elaboration Context. Table 5.15 shows the unique contributions of three predictor variables (Reading Efficiency, Activation, and Working Memory groups) on the two levels of local coherence (i.e., primary inference coherence, secondary inference coherence) within the high elaboration context. Two hierarchical regressions investigated the change in R^2 that occurred as each independent variable was added to the regression equation for predicting participants' scores for (1) primary inference coherence, then (2) secondary inference coherence.

The purpose of the first step in the Hierarchical regression analysis was to determine the contribution of students' Reading Efficiency (as defined by TOSRE raw scores) for predicting their recall coherence of the dependent variable (i.e., primary inference coherence or secondary inference coherence). The second step investigated the extent to which the activation of primary predictive inferences (Activated or not Activated)—both independently and in combination with their reading efficiency scores — significantly added to the prediction of the dependent variable (i.e., primary coherence or secondary coherence). The third step of the hierarchical regression analyses investigated the extent to which the Working Memory groups (low and high as defined by RSPAN raw scores) — both uniquely and in combination with the other independent variables (i.e., Reading Efficiency and Activation) — significantly added to the prediction of the independent variable (i.e., primary inference coherence or secondary inference coherence).

In the High Elaboration Context, only Activation of the primary predictive inferences was a significant predictor contributing to 27% of the total variance for participants' coherent representations of the primary inference, and 15% of the total variance for participants' coherent representations of the secondary inference (see Table 5.15).

The results obtained for predicting participants' coherent representations for the primary inference, within the High Elaboration context, replicated my previous finding (Guan et al., 2007) that, when outcomes in reading are inconsistent with readers' predictive inferences, readers tend to retain predictive inferences better than when outcomes are consistent. This current finding also extends the previous research finding in that the predictive inferences

seemed to be better retained because the inconsistent outcome was coherently integrated. In other words, the mental model of the previous situation was updated coherently by interpreting the more information that was recently accepted as reading continued (Gueraud, Harmon & Peracchi, 2005).

Table 5.15
Hierarchical Regression Analyses within High Elaboration Context: Predicting Two Levels of Local Coherence with Reading Efficiency, Working Memory and Activation
(n = 47)

Levels	Step and Predictor Variables		R^2	ΔR	B	SEB	β	
Primary Inference	Step 1	RE	.00	.00				
		RE			-.01	.00	-.03	
	Step 2	RE and Act2	.22	.22***				
		RE			-.01	.00	-.03	
	Step 3	Act2			.23	.07	.47***	
		RE, Act2 and WM	.27	.05				
	Secondary Inference	Step 1	RE	.00	.00			
			RE			-.01	.00	-.05
		Step 2	RE and Act2	.14	.14**			
			RE			-.01	.00	-.05
Step 3	Act2			.17	.07	.37**		
	RE, Act2 and WM	.15	.01					
	RE			-.01	.00	-.06		
	Act2			.17	.07	.37**		
Step 3	WM			.01	.00	.07		

Note. RE = Reading Efficiency, WM = Working Memory Groups, Act = Activation, 2= High Elaboration Context

** $p < .01$, *** $p < .001$ (2-tailed)

The results obtained for predicting participants' coherent representations for the secondary inference, within the High Elaboration context, suggested that, when online activation of a primary predictive inference occurred, readers' coherent representation of a secondary inference was also enhanced. Even though this finding is similar to the finding in the Low Elaboration context, readers' coherent mental model of text could also be attributed to the high elaboration of the secondary inference. It was expected that activation of the primary predictive inference would act as a form of deep text comprehension that facilitates readers' coherent text memory (Radvansky et al., 2001). The results of the subsequent hierarchical regression analyses predicting participants' global coherence in the low and high Elaboration contexts supported this expectation.

Predictions of Global Coherence in Low Elaboration Context. Table 5.16 shows the unique contributions of the three predictor variables (i.e., Reading Efficiency, Activation, and Working Memory group) for predicting three levels of participants' global coherence (i.e., gist, chronicle order, and causal relations) within the Low Elaboration context. Three hierarchical regressions investigated the changes in R^2 that occurred as each independent variable was added to the regression equation for predicting participants' scores for remembering the (1) gist of story, then (2) chronicle order, and last (3) causal relations of story events.

The purpose of the first step in the hierarchical regression analysis was to determine within the Low Elaboration context the contribution of students' Reading Efficiency (as defined by TOSRE raw scores) for predicting their coherent recall of the dependent variable (i.e., gist, chronicle order, or causal relations). The second step investigated the extent to which the activation of primary predictive inferences (activated or not activated) — both independently and in combination with their reading efficiency scores — significantly added to the prediction of the dependent variable (i.e., gist, chronicle order, or causal relations). The third step of the hierarchical regression analyses investigated the extent to which Working Memory groups (low and high as defined by RSPAN raw scores) — both uniquely and in combination with the other independent variables (i.e., Reading Efficiency and Activation) — significantly added to the prediction of the dependent variable (i.e., gist, chronicle order, or causal relations).

Regarding participants' abilities to recall the gist of story, in the Low Elaboration context, both Activation of primary predictive inferences and Working Memory group — both uniquely and in combination — significantly predicted participants' recall scores for the gist of

story. Similar to the results obtained for predicting participants' coherent representations for secondary inference, within the Low Elaboration context, Activation of the primary predictive inferences was a positive predictor, while Working Memory was a negative predictor (see Table 5.16).

These results obtained suggested that evoking online activation of primary predictive inferences along with even minimal elaboration, enhances participants' coherent mental model of the text message, and acts as a form of deep text-comprehension that facilitates readers' global text memory in terms of gist. In addition, readers with low working memory tended to remember the gist of the story better than the readers with high working memory, suggesting that, although both groups' readers employed primary predictive inferences as a form of reading strategy, readers with low working memory capacity benefited more. However, this interesting finding might be due to the fact that the stories presented to the readers are quite simple; understanding the gist of the story does not require deep text-comprehension. High-span readers, who are accustomed to employing the deep text-processing strategy (i.e., making primary predictive inferences), do not aim to acquire the new information on a surface level. They are achieving higher levels of comprehension through construction and integration. Therefore, high-span readers are expected to perform even better on the higher-level text coherence analyses (i.e., chronicle order and causal relations of text). The subsequent hierarchical regression analyses predicting participants' global coherence on another two levels of coherence analysis (i.e., chronicle order and causal relations) would explore this expectation.

Regarding participants' abilities to recall the chronicle order of text events, in the Low Elaboration context, both Reading Efficiency and Activation of primary predictive inferences — both uniquely and in combination — significantly predicted participants' recall scores for the chronicle order of the story, accounting for 26% of the variance for recall scores for the chronicle orders of text events. Working Memory, however, was not a significant predictor for the chronicle order of the text events (see Table 5.16).

The results obtained for predicting participants' chronicle order of text events within the Low Elaboration context, suggested when readers process the sentence information more efficiently, they do not recall the text event with a better chronicle sequence. This means the faster people read, the less attention they pay to organize the information by chronicle order. Meanwhile, when readers generate primary predictive inferences online, the chronicle order of

their text recall is enhanced. This means evoking online activation of primary predictive inferences, in minimal elaboration context, enhances participants' recall with a better chronicle order. This further extends the effect of online activation of primary predictive inferences from the local coherence of text memory (i.e., the secondary inferences) and the gist of global text to a higher global level of text (i.e., the chronicle order of text events).

Regarding participants' abilities to recall the causal relations between the secondary and the primary inferences within the text, in the Low Elaboration context, only Activation of the primary predictive inference — both uniquely and in combination — significantly predicted participants' recall scores for causal relations between two inferences, accounting for 17% of the total variance (see Table 5.16). The results obtained for predicting participants' causal relations between the secondary and the primary inferences within text in the Low Elaboration context suggest evoking online activation of primary predictive inferences, in a minimal elaboration context, enhances participants' recall with clear causal relations within text. This further extends the effect of online activation of primary predictive inferences from the local coherence of text memory (i.e., secondary inferences) and the two levels of global coherence (i.e., gist of story, chronicle order of text events) to the highest global level of text (i.e., causal relations within text).

The results in the low-elaboration context presented the following four findings: (1) readers with higher reading efficiency scores, pay less attention to the chronicle order of the text event; (2) direct evidence was collected indicating generating primary predictive inferences is a fundamental step for the creation of a coherent situation model of text (Radvansky et al., 2001), by enhancing the recall of the gist of text, chronicle order of text events, and the causal relations between text events; (3) when text elaboration on a secondary inference is low, the low-span readers benefit more on remembering the surface text (i.e., gist of text), if they generated the primary predictive inferences; and (4) the working memory function, however, does not play a significant role in contributing to a more coherent representation of text. This might be due to the low elaboration context employed in this reading condition. The analyses on the high elaboration context is going to explore more on this issue on whether or not working memory contributed to the text recall in a more coherent manner in the High Elaboration context.

Table 5.16
Hierarchical Regression Analyses within Low Elaboration Context: Predicting Three Levels of Global Coherence with Reading Efficiency, Working Memory, and Activation
(n = 47)

Levels	<i>Step and Predictor Variables</i>		R^2	ΔR	B	SEB	β
Gist	Step 1	RE	.02	.00			
		RE			.01	.00	-.13
	Step 2	RE and Act1	.22	.20**			
		RE			-.01	.00	-.25
		Act1			.26	.08	.46**
	Step 3	RE, Act1 and WM	.29	.07*			
		RE			-.01	.00	-.19
		Act1			.25	.08	.44**
		WM			-.01	.00	-.27*
Chronicle	Step 1	RE	.05	.05			
		RE			-.01	.00	-.22
	Step 2	RE and Act1	.22	.17**			
		RE			-.01	.00	-.32*
		Act1			.17	.06	.43**
	Step 3	RE, Act1 and WM	.26	.04			
		RE			-.01	.00	-.28*
		Act1			.17	.06	.41**
		WM			-.01	.00	-.21
Causal Relations	Step 1	RE	.00	.00			
		RE			-.01	.01	-.07
	Step 2	RE and Act1	.13	.13*			
		RE			-.01	.01	-.16
		Act1			.12	.05	.36*
	Step 3	RE, Act1 and WM	.17	.04			
		RE			-.01	.01	-.12
		Act1			.11	.05	.35*
		WM			-.01	.01	-.21

Note. RE = Reading Efficiency, WM = Working Memory Group, Act = Activation, 1= Low Elaboration Context
 * $p < .05$, ** $p < .01$ (2-tailed)

Predictions of Global Coherence in High Elaboration Context. Table 5.17 shows the unique contributions of three predictor variables (i.e., Reading Efficiency, Working Memory, and Activation) for predicting participants' three levels of global coherence (i.e., gist, chronicle order, and causal relations) within the High Elaboration context. Three hierarchical regressions investigated the changes in R^2 that occurred as each independent variable was added to the regression equation for predicting participants' scores for (1) gist of story, then (2) chronicle order, and last (3) causal relations of story events.

The purpose of the first step in the hierarchical regression analysis was to determine, within the High Elaboration context the contribution of students' Reading Efficiency (as defined by TOSRE raw scores) for predicting their recall coherence of the dependent variable (i.e., gist, chronicle order, or causal relations) given the text elaboration on secondary inferences was high. The second step investigated the extent to which the activation of primary predictive inferences (activated or not activated) — both independently and in combination with their reading efficiency scores — significantly added to the prediction of the dependent variable (i.e., gist, chronicle order, or causal relations). The third step of the hierarchical regression analyses investigated the extent to which Working Memory group (low and high as defined by RSPAN raw scores) — both uniquely and in combination with the other independent variables (i.e., Reading Efficiency and Activation) — significantly added to the prediction of the dependent variable (i.e., gist, chronicle order, or causal relations).

Regarding participant's abilities to recall the gist of story in the High Elaboration context, Activation of the primary predictive inferences was the only significant predictor explaining the variance on the gist of global coherence, accounting for 13% of the total variance. While on the other two levels of global coherence (i.e., the chronicle and causal relations of text recall), Working Memory was the only significant predictor, ---uniquely and in combination -- adding 6% and 11% of the total variance for the recall scores of the chronicle order and the causal relations within text, respectively (see Table 5.17).

Table 5.17
Hierarchical Regression Analyses within High Elaboration Context: Predicting Three Levels of Global Coherence with Reading Efficiency, Working Memory, and Activation
(n = 47)

Levels	Step and Predictor Variables		R^2	ΔR	B	SEB	β
Gist	Step 1	RE	.00	.00			
		RE			.00	.00	.03
	Step 2	RE and Act2	.13	.13*			
		RE			.00	.00	.03
		Act2			.19	.07	.36*
	Step 3	RE, Act2 and WM	.16	.03			
		RE			.00	.00	.00
		Act2			.18	.07	.36*
		WM			.00	.00	.16
Chronicle	Step 1	RE	.00	.00			
		RE			.00	.00	-.01
	Step 2	RE and Act2	.01	.01			
		RE			.00	.00	-.01
		Act2			.04	.08	.07
	Step 3	RE, Act2 and WM	.07	.06			
		RE			.00	.00	-.06
		Act2			.04	.07	.07
		WM			.01	.00	.27*
Causal Relations	Step 1	RE	.01	.01			
		RE			.01	.01	.09
	Step 2	RE and Act2	.04	.03			
		RE			.01	.01	.09
		Act2			.06	.06	.16
	Step 3	RE, Act2 and WM	.14	.11*			
		RE			.01	.01	.03
		Act2			.06	.05	.17
		WM			.01	.01	.34*

Note. RE = Reading Efficiency, WM = Working Memory Group, Act = Activation, 2= High Elaboration Context

* $p < .05$ (2-tailed)

These results further present direct evidence that generating predictive inferences is a fundamental step for the creation of a coherent situation model of text (Radvansky et al., 2001). In addition, in the high-elaboration context, working memory played a significant role in facilitating a more coherent representation of text recall. Therefore, the result matches with the expectation that working memory would affect the text recall in a more coherent manner when the text elaboration on a secondary inference is high. The higher-order organization, such as integration by chronicle order and causal relations of long-term text memory, should be considered to be controlled by working memory mechanism (Cantor & Engle, 1993; Radvansky & Copeland, 2006).

The results of the third step from the ten hierarchical regression analyses are presented in Table 5.18. These results demonstrate that there are different contributions of activation of primary predictive inferences and working memory capacity to the participants' text coherence.

Table 5.18
Results Summary on the Step 3 of Hierarchical Regression Analyses
Predicting Text Coherence with
Reading Efficiency, Working Memory, and Activation
(n = 47)

Elaboration Context	Predictor Variables	Local Coherence		Global Coherence		
		Primary Inference	Secondary Inference	Gist	Chronicle	Causal
Low	RE	-.09	-.31*	-.19	-.28*	-.12
	Act1	.12	.45***	.44**	.41**	.35*
	WM	-.27	-.36**	-.27*	-.21	-.21
High	RE	-.08	-.06	.00	-.06	.03
	Act2	.47***	.37**	.36*	.07	.17
	WM	.24	.14	.16	.27*	.34*

Note. RE = Reading Efficiency, WM = Working Memory Group, Act = Activation, (-) indicates the regression weight is negative
 * $p < .05$, ** $p < .01$, and *** $p < .001$ (2-tailed)

Conclusions on the Recall Data

The recall data indicated two major findings. The first is that working memory capacity affected the offline recall of the primary predictive inferences in the Low Elaboration Inference and High Elaboration Control conditions. Consistent with Hypothesis 3, low-span readers did not perform worse on the recall of the primary predictive inferences. Unexpectedly, in the Low Elaboration Inferences and the High Elaboration Control conditions, they performed even better. This finding partially supports Hypothesis 3 (i.e., the low- and high-span participants' recall of the primary predictive inferences would not differ from each other). In two conditions (i.e., Low Elaboration Control and High Elaboration Inference), the low-span readers' recall on the primary predictive inferences did not differ from the high-span readers. In the other two conditions (i.e., Low Elaboration Inference and High Elaboration Control), the low-span readers' recall on the primary predictive inferences were even better than the high-span readers.

This finding replicates what was found in the previous study (Guan et al., 2007): (1) in the Low Elaboration Inference condition, the concepts of the primary predictive inferences were better integrated into the long-term text memory if they were self-generated (Self-generation Hypothesis), and (2) in the High Elaboration Control condition, the concepts of the primary predictive inferences were better retained if it was inconsistent with the previously highly elaborated context. In the Low Elaboration Control condition, there were no significant differences between the low- and high-span readers' recall on the primary predictive inference because few participants were generating the primary predictive inference. In the High Elaboration Inference condition, if the participants generated the inferences by themselves, they benefited from the self-generation hypothesis. If they did not generate the inferences by themselves, they remembered the primary predictive inferential words because they were inconsistent with the previously highly elaborated context (Guan et al., 2007). Therefore, in these two conditions (Low Elaboration Control and High Elaboration Inference), there was no difference between the low- and high-span readers' recall of the primary predictive inference.

The second finding further suggested how Activation of primary predictive inferences and Working Memory affected the coherence of the text recall. Direct evidence was collected to support that both Working Memory and Activation held unique contributions to the coherence of participants' text-recall at different degrees. When the text elaboration on the secondary inferences was low, the contributions of Activation were salient on all levels of explicit text

coherence, but not on the implicit text coherence (i.e., the primary predictive inference). When the text elaboration was high, Activation played a significant role in explaining the text coherence on two local levels and the gist of global coherence. Besides, Working Memory was a significant predictor in explaining the coherence representation on the chronicle and causal relations of the global coherence.

The results answered Research Question 4, in that generating primary predictive inferences facilitated coherent text representation. This is direct evidence validating the indirect the previous indirect evidence in that generating predictive inference is a fundamental step for the creation of a coherent situation model of text (Radvansky et al., 2001). In addition, Working Memory contributes to the higher levels of text coherence (i.e., the chronicle and causal relations within text) when the context becomes more distractive in nature. The higher-order organization skills, such as integrating by the chronicle order and causal relations seems to be controlled by the working memory mechanism (Cantor & Engle, 1993; Radvansky & Copeland, 2006).

CHAPTER SIX

GENERAL DISCUSSION

This section begins with snapshots of the study design as well as of the research questions and hypotheses. After interpreting the study results, two major contributions to the literature are highlighted. Finally, the implications of the preliminary working memory analyses, and the limitations and implications of the study are discussed.

Snapshots of the Study Design, Research Questions and Hypotheses

The focus of this study was to explore the extent to which working memory capacity is related to primary predictive inference activation and long-term text representation in narrative reading. The distraction paradigm employed in this study grounds theoretical conceptualization of working memory, i.e., dealing with the effects of proactive interference (i.e., difficulty people encounter when a new behavior is associated with a context related to previously existing behaviors, Kane & Engle, 2000). The inference-evoking target sentence in the material design of the current study was associated with the text elaboration which was presented early and elaborated a secondary inferential concept in low and high degree (text-characteristics 1: low vs. high text elaboration). Meanwhile the inference-evoking target sentence was supposed to elicit the activation of a salient primary inferential concept (text-characteristics 2: inference vs. control). The study design employed a 2 X 2 X 2 repeated measures mixed design with two text characteristics as two within-subject factors, and working memory (low vs. high-span) as a between-subject factor. The online primary predictive inference activation was measured by the naming times to the probe words after reading the inference-evoking target sentence versus control sentence. The long-term text representation was assessed by the accurate recall of the primary predictive inferences and the five levels of coherence of the participants' text-recall.

The major research questions were whether and how text elaboration affects the online activation of primary predictive inferences and in turn affects the offline text memory in different manners between low- and high-span readers. The first set of research questions included (Question 1) the extent to which the naming times differed between low- and high-span, and (Question 2) the extent to which text elaboration affected the low- and high-span participants' naming times. The second set of research questions included (Question 3) the extent to which working memory affected participants' recall of the primary predictive inferences, and (Question

4) the extent to which working memory and activation of primary predictive inferences affected the coherence of participants' text-recall in low and high elaboration context.

To answer Question 1, two alternative hypotheses (Hypothesis 1-a and 1-b) were proposed. Hypothesis 1-a predicted that if low-span readers were not engaged in deep-level processing (i.e., generating online primary predictive inferences), they would have quicker naming times on the probe word. Alternatively, *Hypothesis 1-b* predicted the opposite. Compared to the low-span readers, the high-span readers would have quicker naming times. The data from the whole sample did not support Hypothesis 1-b (which is contradictory to the proposition of the skilled suppression hypothesis). In addition, the post-hoc exploratory analyses within poor and good readers showed that *Hypothesis 1-a* was supported by the naming data among the poor readers, while *Hypothesis 1-b* was supported by the naming data among the good readers.

To answer Question 2, the interaction effect of text elaboration by working memory on the naming-time was tested. Among the poor readers, text elaboration affected the high-span readers' naming times but did not affect the low-span readers' naming times. Actually, the low-span readers could not make online primary predictive inferences in the high elaboration context. This finding aligns with enhancement mechanism (Gernsbacher & Faust, 1995). The expectation that there would be no text elaboration effect on the naming times among the low-span poor readers was supported. On the other hand, among the good readers, however, text elaboration affected the low-span readers' naming times, but did not affect the high-span readers' naming times. In fact, the high-span good readers almost always make online primary predictive inferences, while the low-span good readers usually could only make online primary predictive inferences in the low elaboration context but not in the high elaboration context. This finding aligns with Capacity-Constraint Hypothesis (Daneman & Carpenter, 1992; Engle et al., 1992). The expectation that with the text elaboration increases, the low-span readers' response time should decrease, was supported by the naming-time evidence shown by the low-span good readers.

To answer Research Question 3, Hypothesis 3 predicted that Working Memory should not be a major factor impacting the recall of primary predictive inferences. Results showed that Hypothesis 3 was supported only by the recall data in the Low Elaboration Control and High Elaboration Inference conditions. Research Question 4 further explored to what extent Working

Memory and Activation of primary predictive inferences affected the coherence of participants' text-recall. Direct evidence suggested that with the minimal text elaboration, Activation held unique contributions to the coherence of participants' text-recall. When text elaboration increased, Working Memory held unique contributions to the higher-order text-coherence (i.e., chronicle order and causal relations among text events) of participants' text-recall.

Two Major Contributions to the Literature

This study offers two important conclusions related to the extent to which the function of working memory differs in low and high text elaboration conditions under which (1) primary predictive inferences occur online and (2) the activated primary predictive inferences are constructed and integrated into a coherent situation model of text. This first conclusion is based upon the answers to Question 1 and 2. Low-span readers in both poor and good reading groups are not able to generate primary predictive inferences online in the high-elaboration context. The low-span readers in both reading groups, however, are affected by the text elaboration at different degrees. The low-span poor readers were not affected but the low-span good readers were affected by the text elaboration. The second conclusion extends the finding from the online activation to the offline text memory. If activation of primary predictive inference occurs online, the readers would coherently recall the text if it contains less elaboration, but when text contains high elaboration, the readers with a large working memory capacity who also generate the primary predictive inferences online would retain the mental model of text in a much more coherent manner. In other words, working memory capacity plays a significant role in recall when there is more distractive information: people with higher working memory capacity are better able to coherently organize the information that they process.

How Working Memory Accounts for Online Inference Activation

Firstly, working memory capacity is related to the nature of the activation of predictive inferences. Generally, the low-span readers fail to generate primary predictive inferences. The mechanism for nonactivation, however, between the low-span poor readers and low-span good readers may be different. The low-span poor readers quickly name the inference-testing probe words because they choose to enhance the process when text contains high elaboration (i.e., no effect of text elaboration for the low-span poor readers). Whereas, the low-span good readers slowly name the inference-testing probe words because they are trying to process the information; but the low-span poor readers fail to make inference because they have difficulty

inhibiting the information given in the high elaboration context (a significant effect of text elaboration on the low-span good readers).

This first major conclusion, on the extent to which working memory functions differently in low and high elaboration context between low- and high-span readers, lends support to both the General Capacity Theory (GCT) and the Skilled Suppression Hypothesis (SSH), such that different mechanisms function under different conditions. According to SSH, which predicts that the poor readers employed the enhancement mechanism, the low span individuals will have quicker naming times than the high span individuals (Hypothesis 1-b). This hypothesis was supported by the finding only among the poor readers in this study. As the degree of elaboration increases, poor readers, due to their short span and poor comprehension ability, would quickly accept the textual information into their current working memory. In contrast, the high-span poor readers would have the capacity to construct and integrate the newly activated information into their working memory as long as the text is not so difficult (e.g., the text contains less information/elaboration distracting readers from generating the specific local/secondary inference). The target sentences eliciting the primary predictive inferences were not difficult to understand, but the activating of the primary predictive inferences takes time to happen. Therefore, the high-span poor readers' naming times are longer than those of their low-span counterparts.

Alternatively, as GCT predicts the high span individuals are more capable of inhibiting the distractions., i.e., the high span individuals will have quicker naming times than the low span individuals (Hypothesis 1-a). This hypothesis was supported by the finding only among the good readers in this study. The secondary inference was directly (causally) tied to the final sentence of each text, while the primary predictive inference was supposed to be activated in readers' working memory if they worked to comprehend the entire text. As the degree of elaboration on the secondary inferences increases, it is harder for the low span to shift their attention from the secondary inference to the primary predictive inferences.

The result that high-span readers had quicker naming times than the low-span readers among the good readers echoes the findings from previous research on working memory capacity and inference activation (Calvo, 2000; Cook et al., 2001; Linderholm, 2002). The previous studies on the effect of working memory on predictive inferences, however, only focused on the causal sufficiency of the text property and concluded that only high span readers

consistently make predictive inferences if the context is sufficient (Calvo, 2000; Cook et al., 2001; Linderholm, 2002). The current study extends the accounts of working memory effect on primary predictive inferences activation into a distractive paradigm. Under this research paradigm, study revealed an interesting finding that low-span poor readers had quicker naming times than the high-span poor readers due to the fact that low-span participants were actually not affected by the distractive information. Actually, De Neys et al. (2003) has found similar results in that the low-span participants, due to their low working memory capacity, block the distractive information originally stored in their prior knowledge. This is consistent with another study finding that activating the most recent information (Recency Effect) at the current restricted capacity of working memory reflects an inhibitory mechanism that is blocking the impact of prior knowledge (Goel, Buchel, Frith & Dolan, 2003).

It seems that in this current study, when the low-span poor readers activated the primary predictive inferences (demonstrated by quicker naming times) in their working memory, they were inhibiting the other distant information. That is to say, accessing one piece of information (i.e., the primary predictive inferential concept) was easier and quicker than getting access to multiple pieces of information. It may be that the low-span poor readers took a lazy approach, naming the word as quickly as possible no matter whether the target sentence was inference-evoking or not. This could be a reason why their naming times were quicker than their high-span counterparts.

However, quicker naming times among low-span readers seem to be incongruent with findings from other investigators who have shown that poor readers experience difficulty with word naming due to poor quality lexical representation (Lemoine, Levy, & Hutchison, 1993). Especially among poor readers, they failed to activate topic-related inferences even when inference probes were presented in the context of a stimulus onset asynchrony (SOA; i.e., the relative timing of the onsets) condition of 1,000ms (Long et al., 1994). This discrepancy could be interpreted in terms of the Skilled Suppression Hypothesis, such that weak inference on the word-level activation could be due to the slow suppression of irrelevant associations among the skilled readers but the quick enhancement of appropriate associations among the unskilled readers (Gernsbacher, 1990; Gernsbacher & Faust, 1991). Moreover, similar findings have been reported from a word recognition task in a study on syntactic ambiguity (Pearlmutter & McDonald, 1995) and reading predictable sentences (Perfetti & Roth, 1981). Both studies

suggested evidence that poor reader had quicker word recognition speeds on the target concept because they were not actually processing the sentence at a deeper level.

The finding on different naming-time patterns between individuals has particular implications for researchers. It suggests that when collecting naming data, it is necessary to include individual difference variables (i.e., working memory capacity, reading skill) and text characteristic variables (i.e., the degree of elaboration in the prior text, the causal relations between the target sentence and the prior text, etc.). Otherwise, results might be misinterpreted.

How Working Memory Accounts for Text Memory after Deep Text Processing

At this point, generating predictive inferences is regarded as deep text processing (Beenman et al., 2000; Calvo, 2004; McKoon & Ratcliff, 1992). It might be difficult for readers with low working memory capacity to generate this type of primary predictive inference online. Once text properties (e.g., text elaboration of a secondary inference, and the inference feature of the target sentence in this current study) facilitate this form of deep text processing to occur online, readers' mental model of text memory would benefit after reading. The second conclusion addresses the extent to which the low- and high- text elaboration of secondary predictive inferences moderates the effects of online activation of primary predictive inferences and working memory on the offline text memory.

Under the low elaboration context, if the primary predictive inference occurs online, readers would coherently recall the explicit text at both the local level and global level, but they would not coherently recall the primary predictive inferences. Under the high elaboration context, i.e., when the context contains high elaboration on a secondary inference, if the primary predictive inference occurs online, readers would coherently recall the explicit and implicit text at a surface level (i.e., the local coherence of secondary inferences, the primary predictive inferences and the gist of story). Even though working memory does not contribute to the local coherence of participants' recall of secondary inferences, in order to achieve the mental model of text at higher levels of coherence (i.e., the chronicle and causal relations within text), a large working memory capacity is crucial.

The second major conclusion further substantiates that generating predictive inferences is a form of deep text processing. Reading in the high elaboration context, high-span readers comprehended the text by constructing the focused event at a deeper level and integrating different text events in a more coherent manner. High-span working memory individuals

probably understand the text very well and do not require extra background information to reiterate the gist of the information in the high elaboration context. They focus much more attention on the higher-order integration of text, such as the chronicle order of the text events and causal-relations between the text events. In addition, when the previous context contained high elaboration on a secondary inference, both low- and high-span working memory individuals did not differ in local coherence of offline recall on the secondary inference. According to the descriptive statistics presented in Table 5.13, both low- and high-span individuals recalled a high degree of local coherence of the secondary inferences, which were highly elaborated in the prior context. This very interesting offline recall pattern on the secondary inferences is different from the online processing pattern prescribed by the recency effect. The recency effect suggests that the most current information in working memory is better activated while the other earlier information in working memory is blocked. In contrast, it seems both the text property factor and the reader's online reading behavior factor may impact offline recall. High text elaboration strengthens readers' offline memory and activating predictive inferences contributes to a coherent text memory. Even though, low- and high-span individuals may complement their memory differently, their coherent memory on the elaborated secondary inferences did not differ.

Reading in the low elaboration context, high-span working memory individuals did not receive benefit from the elaboration (on the secondary inference) on their offline text coherence of the secondary inference (i.e., the gist of the text). There might be two possible interpretations. First, in accordance with the General Capacity theory, when high-span readers generated the primary predictive inferences from the local context, their attention to this activated information reached the activation threshold, thus inhibiting the distraction from the elaborated information from the prior text about the secondary inference. On the contrary, the low-span individuals were unable to inhibit the secondary information. In other words, the level of activation of the primary predictive inferences did not reach the threshold to inhibit the level of activation of the secondary inferences. Therefore, the low-span individuals outperformed the high-span individuals in remembering the secondary inference or the gist of the story. To instantiate this possible interpretation, more precise methods of activation detection should be applied. For example, the electroencephalography method of Event Related Potentials (EEG-ERP) could expose what happens in the human brain over the course of word identification within a discourse context.

Event-related potentials (ERPs) can provide evidence of whether the content word of a sentence across a boundary follows the default procedure of incremental, immediate processing (Pickering, 1999) or presents a special case of delayed processing. A recent study (Yang, Perfetti & Schmalhofer, 2007) has suggested that word-to-text integration in three reading conditions (i.e., referential-explicit, referential-paraphrased, and referential-implicit) happened at different time frames. The word-to-text integration in the referential-explicit condition occurred during the earliest time frame from 150ms to 250ms; the word-to-text integration in the referential-paraphrased condition occurred at 300ms; while the word-to-text integration in the referential-implicit reading condition took place from 300ms to 750ms (Yang, Perfetti & Schmalhofer, 2007). In my current study, the time frame of activation of the primary predictive inferences was close to Yang et al.'s (2007) referential-implicit condition, which could be described as a predictive inference condition. The secondary inferences used in the current study should be close to what Yang et al. (2007) defined as referential-explicit or referential-paraphrased conditions. If this analogy holds, it might be possible to use the same methodology to further replicate the fact that low-span individuals have less salient activation of the primary predictive inferences, while the high-span individuals could possibly have more salient activation of the primary predictive inferences. The implication of this research extension lies in not only exploring a complete picture of how the human brain is adaptable to different text stimuli at the higher-level of text integration, but also provide the neuro-scientific evidence for the language deficits for higher-level text comprehension from the perspective of working memory capacity.

Another interpretation for the potential reason why, in the low-elaboration text, the low-span individuals recalled more of the secondary inferences and the gist of story than the high-span individuals is because high-span readers descriptively recall more information extrapolated far beyond the text. For this current study, the extraneous information in the recall data were not coded. This might be another interesting future research study, to further explore the differences in the extraneous information intruding into low- and high-span readers' offline recall.

Very interestingly, reading in the low elaboration context and being engaged in deep text processing (i.e., generating inferences), no matter whether readers had low- or high-working memory capacity, they could construct and integrate text. While, reading in the high elaboration context, only the high working memory individuals could construct and integrate text on a higher level (i.e., the chronicle order of text and causal relations between text events). This strongly

suggests the extent to which text manipulation (i.e., the degree of text elaboration) differentially affects the low- and high-span readers coherent retention of text information after reading. It might be possible that the high-span individuals have already adapted their working memory mechanism to perform higher-level text integration. Hence, the high-elaboration context does not affect high-span readers, but helps low-span readers to coherently integrate different pieces of information.

Thus, future research also should address whether text manipulation in terms of text elaboration can have longitudinal impacts on a reader's working memory mechanism in processing elaborated information to achieve a coherent text memory. If working memory is really defined as the ability to deal with proactive interference, and low and high span individuals actually differ in this ability as suggested by this current study, researchers might be interested in providing training to test whether or not being able to prohibit the interference to a lesser extent could be trained. By increasing the degree of elaboration step by step, the low-span readers could hypothetically enhance their ability to perceive, organize, and construct information as they receive the information. In such conditions, it might be demonstrated that working memory is adaptable.

Finally, the successful activation of primary predictive inferences among the low-span readers would facilitate constructing memory at both the local and global levels of a coherent situation model of text. This linkage between online activation of predictive inferences and offline text memory is the first direct evidence of this, and it supports the previous indirect evidence that generating predictive inferences enhances information retrieval from situation models of texts (Radvansky, Zwaan, Curiel, & Copeland, 2001).

Why do the deep-processing and working memory engagement play significant roles in constructing a more stable long-term text memory? High span readers are accustomed to keeping items more efficiently active in their working memory. Low span readers, in order to achieve better comprehension, must keep items highly active beyond a certain threshold. If the information the low span readers encountered was difficult, it must be processed at a deeper level in order to reach its activation threshold (Gernsbacher, 1990; Reynolds, 1995). Since no level of superficial processing can achieve such knowledge activation, the level of superficial processing is not related to the quality of the offline memory representation. However, predictive inferences are a demanding cognitive process that requires a certain amount of cognitive resources (Calvo

& Estevez, 2000; Linderholm, 2002). People must achieve a basic understanding of text events before they are able to predict what will occur next. Most of the time low span readers, engaging in superficial processing, do not comprehend the text well enough to make predictive inferences. Once the low span readers are engaged in deep text-processing, the first step is for them to understand the overall text (i.e., the gist). Therefore, low-span readers' text memory on both local-level coherence of the primary and secondary inferences, as well as the overall gist level of global coherence, benefit from this deep form of text processing (i.e., generating inferences). In contrast, the high-span readers, who are used to engaging in deep text-processing, attempt to integrate the information in a much more coherent manner (i.e., chronicle order and causal relations). In a sense, this research finding is consistent with the conceptualization of the working memory mechanism in relation to memory retention. Working memory is the capacity for activating the information from long-term memory (Ruchkin, Grafman, Cameron, & Berndt, 2003) and reconstructing the information in a much more coherent way (Radvansky & Copeland, 2006).

Regardless of reading ability as defined by the sentence reading efficiency scores (i.e., TOSRE), reading ability does not facilitate offline text memory. Conversely, it negatively affects the offline memory—or at least the production during recall—of information specifically associated with the main idea of the story (i.e., the gist of the story and the secondary inference) when the text elaboration is low. This conclusion that reading ability has no impact on text memory of inferential concepts but does affect the activation of the inferences online seems logically inconsistent. Actually, this study is consistent with the previous study findings (Long et al., 1994; Murray & Singer, 2003). The previous findings concluded that offline text memory of the inferential or inferentially-related concepts occurred in the absence of evidence for activation. Regardless of whether or not the predictive inferences were activated online among the good readers, the evidence from the recall data is consistent with the notion that good readers are accustomed to engaging themselves in deep text processing. Meanwhile, the poor readers, regardless of low or high working memory capacity, benefit from generating predictive inferences. Therefore, it is possible that reading ability is not a significant predictor of offline text memory.

Implications of the Preliminary Analyses

The results from the preliminary analyses revealed relationships among the three working memory measures, LSPAN, OSPAN, RSPAN and a reading comprehension indicator, TOSRE. On the one hand, the three Working Memory measures (i.e., LSPAN, OSPAN and RSPAN) were positively correlated with each other. These results were consistent with findings from previous research related to these same measures (Conway et al., 2005). According to Conway et al., the correlations among the span tasks typically range from .40 to .60. This range of correlation was replicated in the current study. It suggests that these Working Memory measures are indeed tapping some common process.

On the other hand, the relationships of each of these Working Memory measures with the reading measure (i.e., TOSRE) indicate that different Working Memory measures reflect some different aspects of central executive functions of the Working Memory. LSPAN is a domain-specific measure of Working Memory, while RSPAN and OSPAN are domain-general measures of Working Memory. Specifically, LSPAN was the only significant predictor of reading comprehension among the three Working Memory variables (i.e., LSPAN, RSPAN and OSPAN). This aligns with the statement that LSPAN is a domain-specific Working Memory measure, which captures many of the processing requirements of reading comprehension. This domain-specific Working Memory measure also taps the aspects of Working Memory capacity that are important to reading comprehension (Baddeley et al., 1985; Daneman & Carpenter, 1980; Jackson & McClelland, 1979).

That RSPAN and OSPAN both measure the general capacity of the combination of storage and processing also was validated. They did not provide unique contributions to reading assessed by the test of sentence reading efficiency (i.e., TOSRE), an indicator of reading comprehension. OSPAN, as a domain-general Working Memory measure, captures mathematical ability, motivation, and word knowledge in a more general domain (Conway et al., 2005). RSPAN, a domain-general Working Memory measure as well, taps the general aspect of Working Memory capacity and verbal ability (Conway et al., 2005). The study results showed that OSPAN scores were not significantly correlated at the .05 level ($r = .23, ns$) with the scores of reading efficiency measure (i.e., TOSRE). This suggests that even though OSPAN purportedly measures the complex span, the OSPAN task does not have to involve sentence processing so as to predict reading comprehension (Turner & Engle, 1989). In this study, OSPAN failed to predict

the TOSRE scores, and hence was not chosen as a benchmark of general working memory capacity in reading.

In this study, even though RSPAN did not contribute to additional unexplained variance for the efficiency of sentence processing assessed by TOSRE, RSPAN captures the unique feature of the general working memory capacity which the reading indicator (e.g., TOSRE) could not capture. This unique feature of Working Memory is the capability of dealing with proactive interference. In fact, RSPAN task is originally designed to (1) assess how external load interferences with target processing and storage, (2) to explore the retrieval structure after reading, and (3) to correlate well with measures of higher-order cognition and provide an index of the general ability to retrieve information in the presence of competition (Conway et al., 2004). In this study, RSPAN positively correlated with the scores of reading comprehension indicator, TOSRE. Therefore, RSPAN was employed as benchmark of general working memory for reading.

In addition, the current trend analyses showed different predictive validities of the working memory measures to naming-time patterns. LSPAN and OSPAN might negatively predict the naming times, while RSPAN and TORSE might positively predict the naming times. The different predictive validities of the working memory measures to naming-time patterns implied a mediating model. For instance, the effect of Working Memory measured by RSPAN on naming times might be mediated by the mechanism represented by LSPAN or OSPAN (Woodworth, 1928). Future study is needed to elaborate more on this issue of interest.

Limitations & Implications of the Study

One thing that is unclear is whether the activation of the predictive inferences occurs before the construction of the situation model of a text, or whether once the situation model of a text has been established it is easier for the readers to get access to the event-related potential concepts. Future research should approach this issue by using more advanced technology to capture the sequence and saliency of information activation in the human brain. This can be done by using electroencephalography method of Event Related Potentials (EEG-ERP).

The study was not without limitations. First, the results of the extreme group comparisons should be interpreted and applied with caution. The relationship between working memory and naming times was not linear, with moderate-span individuals performing the best. More research is needed to understand the average readers. It is not possible to simply interpolate

average readers' performance based upon the patterns revealed from the low- and high-span readers from this study. It might be more interesting to further explore the research questions by taking the regression approach and treat the working memory as a continuous variable. Similarly, the regression approach was used to answer the research question about the relationship between working memory and participants' coherent text recall. The analyses were conducted by assuming there was a linearity relation between the working memory and the text coherence since only low- and high-span readers' data were used. Future research should also consider if there is a significant nonlinear relation.

Secondly, RSAPN was selected as the working memory benchmark for categorizing readers, as there is a strong theoretical rationale to do so because RSPAN is the only measure assessing working memory while reading. Despite the interesting findings from the study based upon this measure, it still might be interesting to explore results using different working memory measures. Since the data from the study have already shown that different working memory measures hold different relationships with participants' naming times, at least in current sample using the TOSRE as the test of reading ability. Using different working memory measures, the results of the current study may have been different. For example, future studies should also be conducted by splitting the sample based on different working memory measures to assess the spurious relationship between different working memory measures and online reading measures and offline recall measures. The study has already revealed the naming times had positive relationships with LSPAN and OSPAN scores, but negative relationships with RSPAN scores. Thus, the conclusions drawn in the current study about the role of working memory might have been different, and the implications of this should be considered in future research. Finally, the statistical evidence presented herein might indicate the artifact of some or all of these working memory measures in the study. Replication from repetitive data collections should be done to strengthen the findings from the study.

Research on inference generation has evolved through three generations. The first generation was led by Kintsch and Dijk (1978)'s pronouncement that no general theory of inference was in sight. In the second generation, from the mid 1980s to the mid 1990s, numerous attempts were made to describe inference activation under the balanced view that, on the one hand, inferences are necessary for text comprehension while, on the other hand, limited attentional or working memory resources constrain inference activation. Examples of models

developed in this generation include Current State Strategy (Fletcher & Bloom, 1988), the Causal Inference Maker (van den Broek, 1990), the Construction-Integration Model (Kintsch, 1988), Minimalist Theories (McKoon & Ratcliff, 1992), Constructionist Theories (e.g., Graesser, Singer, & Trabasso, 1994; Singer, Graesser, & Trabasso, 1994), and the Structure Building Framework (Gernsbacher, 1990). The third generation has yielded new insights as to the integration of the online and offline aspects of reading. The recent efforts by discourse psychologists seek to explain how readers construct “situation models”, i.e., mental models of what the text is about, and it is now established that inference generation is inextricably bound to the process of constructing situation models. The models developed in the third generation include the event indexing model (Zwaan, Langston, & Graesser, 1995), the resonance model (O’Brein, Raney, Albrecht, & Rayner, 1997), and the landscape model (van den Broek, Young, Tzeng, & Linderholm, 1999). To add one unique contribution to the third-generation of inference literature, the current study results demonstrated that working memory capacity was found to influence the capability of the online computation of inference-generation and the efficient online activation of predictive inferences strengthens coherent offline text memory. In addition, the working memory capacity contributes to a higher-order management of interference, not by suppressing the interference by integrating information into a coherent situation model of text.

The specific issues related with the generation of predictive inferences, inference-making and memory representation are intertwined with each other. This intertwinement between inferencing and memory was affected by many factors, such as processing skills at different levels (i.e., lexical access, semantic association, syntactic parsing, knowledge access, propositional integration, knowledge integration, and reasoning, etc.), inter-individual difference factors (i.e., story structure, text property, theme of topics, etc.), and intra-individual differences variables (i.e., working memory capacity, readers’ language background, reading skill, cognitive trait, age, personal traits, reading experiences, academic background, life experience, knowledge scope, and motivational factors, reading goals, readers’ interest, etc.), and explicit training factors. This current study addresses the relations among a couple of the abovementioned factors (utilizing strategies, enhancing the Inferencing awareness, etc.). As different types of inference and integration skills rely on different processing skills, inter- and intra- individual difference factors, an issue that clearly warrants further investigation in the study of comprehension development.

Furthermore, the two major conclusions of this study also provide two implications to the literature. First, the study offers a first look to pinpoint which types of individuals are likely to activate predictive inferences, and under which conditions the inferences are made online and represented offline. These findings may help expand our understanding of the mechanism and boundary conditions under which predictive inferences are activated and represented in memory. Second, the study focuses on the effects of cognitive factors (i.e., working memory, and engaging in making predictive inferences) on the processes and product of comprehension by controlling for readers' linguistic skill (i.e., reading efficiency). The implication of this study topic can offer insights into the nature of cognitive component skills in reading and may lead to progress in developing reading remediation strategies for online reading behavior and offline reading product.

For example, making predictions is difficult for some readers (e.g., Rosenshien & Meister, 1994). If this difficulty exists, readers' individual differences in reading abilities and working memory should be identified first before they receive strategy training. Thus, if low- and high-span working memory readers differ in their ability to prohibit the distractive information, especially, the proactive interference during text processing, trainers might be able to individualize interventions. For example, increasing the degree of elaboration on either the local or global textual information and providing explanatory instructions might be most appropriate for helping low-span individuals adapt their working memory to contextually-dense information. Along with the reading strategy-training, the goal of an effective reading program should not only be aimed at improving reading-speed and the ability to answer comprehension questions accurately, but also targeted at improving coherent text memory through organizational maps or argumentation maps in different genre of text. A good reading remediation practice module should be individualized to the aptitude of the individuals, adaptive to their capacity (verbal working memory capacity), apply the text-analytic approach, activate the employment of the reading strategies, and finally accelerate their reading skill (Duke & Pearson, 2002).

Finally, the painful fact that students rarely acquire a deep understanding of text they are supposed to learn is widely acknowledged in the field of education (Graesser et al., 2002). Inference is at the heart of comprehension process (Anderson & Pearson, 1984; Dole et al., 1991; Perfetti, 1997). Understanding text is constructing a coherent representation of the information in a text (Cain & Oakhill, 1999). When information that is not explicitly stated in the text is

activated, an inference is made (St. George, Mannes, & Hoffman, 1997). The process of inference-making is a key component of fluent reading, and as such, several aspects of the process are of interest, including the kinds of inferences readers make and the factors that determine whether and when inferences are made. Deeper comprehension is achieved when readers construct causes and motives that explain why events and actions occur. Deeper comprehension is achieved when readers infer the global message of the text, and the ability to draw inferences is the cornerstone of reading competence (Davoudi, 2005). However, in experimental and virtual reading situations, this level of text representation may be hard to achieve without the pragmatic context of the text, such as who wrote the text, why the text was written, and for what reason it was read. Questions which can seem simple are by no means simple for artificial intelligence researchers trying to replicate the brain's ability to process texts. As Johnson-Laird (1983) points out, "that is the nature of many problems about the mind; we are so familiar with the outcome of its operations, which are for the most part highly successful, that we fail to see the mystery" (p. x).

APPENDIX A

Sample Text 1

Skilled Suppression Hypothesis	The high span readers will NOT successfully enhance context appropriate meanings under the distractive elaboration context. It will take them longer time to name the word BREAK compared to the low span readers. As the degree of elaboration increases, the naming latencies among high span readers increase.		
Low Elaboration Control Condition (LEC)	Low Elaboration Inference Condition (LEI)	High Elaboration Control Condition (HEC)	High Elaboration Inference Condition (HEI)
<p>S1: (Cued) Steven and Susan had been married for twenty years.</p> <p><u>Region 1:</u> S2: After years of abuse, Susan told Steven she would leave him if there was even the mildest violent incident in the house. S3: In addition, Steven had just started a new job as the assistant manager of the accounting department at Sears. S4: It meant a lot of extra responsibilities, long hours, and more stress. S5: Steven and Susan were having a hard time adjusting their life to fit his schedule.</p> <p><u>Region 2:</u> S6: Today Susan had left a mess in the kitchen which had enraged Steven. S7: He felt himself losing it.</p> <p><Control Sentence> Working hard to control his anger, Steven apologized and offered to clean her delicate vase.</p>	<p>S1: (Cued) Steven and Susan had been married for twenty years.</p> <p><u>Region 1:</u> S2: After years of abuse, Susan told Steven she would leave him if there was even the mildest violent incident in the house. S3: In addition, Steven had just started a new job as the assistant manager of the accounting department at Sears. S4: It meant a lot of extra responsibilities, long hours, and more stress. S5: Steven and Susan were having a hard time adjusting their life to fit his schedule.</p> <p><u>Region 2:</u> S6: Today Susan had left a mess in the kitchen which had enraged Steven. S7: He felt himself losing it.</p> <p><Target Sentence> Unable to control his anger, Steven threw a delicate porcelain vase against the brick wall.</p>	<p>S1: (Cued) Steven and Susan had been married for twenty years.</p> <p><u>Region 1:</u> S2: After years of abuse, Susan had enough. S3: She joined a support group for battered women and told her husband, Steven, that she was going to leave him if there was even the mildest violent incident in the house. S4: Steven was taking her seriously. He had managed to control his temper for the past month. S5: He couldn't bear the thought of her leaving. He felt his life would be over if she left.</p> <p><u>Region 2:</u> S6: Today Susan had left a mess in the kitchen which had enraged Steve. S7: He felt himself losing it.</p> <p><Control Sentence> Working hard to control his anger, Steven apologized and offered to clean her delicate vase.</p>	<p>S1: (Cued) Steven and Susan had been married for twenty years.</p> <p><u>Region 1:</u> S2: After years of abuse, Susan had enough. S3: She joined a support group for battered women and told her husband, Steven, that she was going to leave him if there was even the mildest violent incident in the house. S4: Steven was taking her seriously. He had managed to control his temper for the past month. S5: He couldn't bear the thought of her leaving. He felt his life would be over if she left.</p> <p><u>Region 2:</u> S6: Today Susan had left a mess in the kitchen which had enraged Steve. S7: He felt himself losing it.</p> <p><Target Sentence> Unable to control his anger, Steven threw a delicate porcelain vase against the brick wall.</p>
Probe Word: Predictable <BREAK>			
Comprehension Questions: Did Susan leave a big mess in the kitchen? (Answer: Yes)			
<u>Inferential target word:</u> BREAK (Less Activation)	<u>Inferential target word:</u> BREAK (More Activation) <u>Secondary Inferential Concept:</u> LEAVE (Less Distraction)	<u>Inferential target word:</u> BREAK (Less Activation)	<u>Inferential target word:</u> BREAK (More Activation) <u>Secondary Inferential Concept:</u> LEAVE (More Distraction)
<p>*Low elaboration on the concept LEAVE in S2 only ONCE. *The control sentence is not predictable. It will NOT induce the target inferential concept BREAK * This LEC condition will produce slower naming latencies on BREAK than LEI condition.</p>	<p>* Low elaboration on the concept LEAVE in S2 only ONCE. * The target sentence will induce the target inferential concept BREAK. This concept was less distracted by the concept LEAVE. * This LEI condition will produce the quickest naming latencies on BREAK among these four conditions.</p>	<p>* High elaboration on the concept LEAVE in S3 and S5 THREE times. * The control sentence is not predictable. It will NOT induce the inferential concept BREAK. * This HEC condition will produce slower naming latencies on BREAK than HEI condition.</p>	<p>* High elaboration on concept LEAVE in S3 and S5 THREE times. * The target sentence will induce the target concept BREAK, but it will be more distracted by the concept LEAVE. * This HEI condition will produce the second quickest naming latencies, but slower than LEI condition.</p>
General Capacity Theory	The high span readers will be more effective in shifting attention under distractive elaboration context. They will name the word BREAK quicker than the low span readers.		

Sample Text 2

1	2	3	4
Low Elaboration Control Condition (LEC)	Low Elaboration Inference Condition (LEI)	High Elaboration Control Condition (HEC)	High Elaboration Inference Condition (HEI)
<p>S1: (Cued) Richard was starting a new job today repairing the roof of the old Federal Courthouse. <u>Region1:</u> S2: The courthouse was a 26-story building, so if anything were to drop from the roof, it would seriously injure a person. S3: The work should have been done years ago but the city had been short on money until now. S4: Richard had spent the last few days loading his truck with the supplies that he needed for the first week of work. <u>Region2:</u> S5: On the morning the new job was starting. S6: Richard carefully set up the scaffold making sure everything on it is intact.</p>	<p>S1: (Cued) Richard was starting a new job today repairing the roof of the old Federal Courthouse. <u>Region1:</u> S2: The courthouse was a 26-story building, so if anything were to drop from the roof, it would seriously injure a person. S3: The work should have been done years ago but the city had been short on money until now. S4: Richard had spent the last few days loading his truck with the supplies that he needed for the first week of work. <u>Region2:</u> S5: On the morning the new job was starting. S6: Richard carefully set up the scaffold making sure everything on it is intact.</p>	<p>S1: (Cued) Richard was starting a new job today repairing the roof of the old Federal Courthouse. <u>Region 1</u> S2: Few people wanted the job because the building was so tall. S3: It was also next to a very busy pedestrian walkway. S4: Dozens of people constantly filled the sidewalk far below. S5: It was a 26-story building so even the smallest falling object could be lethal. S6: If anything were to drop from the roof, it would seriously injure a person. <u>Region 2</u> S7: On the morning the new job was starting, S8: Richard carefully set up the scaffold making sure everything on it is intact.</p>	<p>S1: (Cued) Richard was starting a new job today repairing the roof of the old Federal Courthouse. <u>Region 1</u> S2: Few people wanted the job because the building was so tall. S3: It was also next to a very busy pedestrian walkway. S4: Dozens of people constantly filled the sidewalk far below. S5: It was a 26-story building so even the smallest falling object could be lethal. S6: If anything were to drop from the roof, it would seriously injure a person. <u>Region 2</u> S7: On the morning the new job was starting, S8: Richard carefully set up the scaffold making sure everything on it is intact.</p>
<Control Sentence> As he finished setting up he suddenly realized he forgot a bucket of paint downstairs.	<Target Sentence> As he set up the scaffold, he accidentally kicked over an open bucket of paint.	<Control Sentence> As he finished setting up he suddenly realized he forgot a bucket of paint downstairs.	<Target Sentence> As he set up the scaffold, he accidentally kicked over an open bucket of paint.
Probe Word: Predictable <SPILL>			
Comprehension Questions: Was Richard working on the U. N. Building? (Answer: No)			
<u>Inferential target word:</u> SPILL (Less Activation)	<u>Inferential target word:</u> SPILL (More Activation) <u>Secondary Inferential Concept:</u> INJURE (Less Distraction)	<u>Inferential target word:</u> SPILL (Less Activation)	<u>Inferential target word:</u> SPILL (More Activation) <u>Secondary Inferential Concept:</u> INJURE (More Distraction)
<p>*Low elaboration on the concept INJURE in S2 only ONCE. *Control sentence is not predictable. It will NOT induce the target inferential concept SPILL. * This LEC condition will produce slower naming latencies on SPILL than LEI condition.</p>	<p>* Low elaboration on the concept INJURE in S2 only ONCE. * Target sentence will induce the target inferential concept SPILL. This concept was less distracted by the concept INJURE. * This LEI condition will produce the quickest naming latencies on SPILL among four conditions.</p>	<p>* High elaboration on the concept INJURE in S5 and S6. * The control sentence is not predictable. It will NOT induce the inferential concept SPILL. * This HEC condition will produce slower naming latencies on SPILL than HEI condition.</p>	<p>* High elaboration on the concept INJURE in S5 and S6. * Target sentence will induce the target concept SPILL, but it will be more distracted by the concept INJURE. * This HEI condition will produce the second quickest naming latencies, but slower than LEI condition.</p>
General Capacity Theory	The high span readers will be more effective in shifting attention under distractive elaboration context. They will name the word SPILL quicker than the low span readers.		
Skilled Suppression Hypothesis	The high span readers will NOT successfully enhance context appropriate meanings under the distractive elaboration context. It will take them longer time to name the word SPILL compared to the low span readers. As the degree of elaboration increases, the naming latencies among high span readers increase.		

Sample Text 3

1	2	3	4
Low Elaboration Control Condition (LEC)	Low Elaboration Inference Condition (LEI)	High Elaboration Control Condition (HEC)	High Elaboration Inference Condition (HEI)
<p>S1: (cued) Bob was a pilot in the Air Force and was on a top-secret mission to destroy enemy military targets.</p> <p><u>Region1:</u> S2: On the last mission he had broken down sobbing after the attack and could do nothing to stop the sadness and tears. S3: Still, he was proud to be in the Air Force because all of the men in his family had served. S4: Bob enlisted after high school, just like his father and grandfather.</p> <p><u>Region2:</u> S5: Currently, Bob was nearing the enemy target. S6: He contacted the central command unit as he reached his destination.</p>	<p>S1: (cued) Bob was a pilot in the Air Force and was on a top-secret mission to destroy enemy military targets.</p> <p><u>Region1:</u> S2: On the last mission he had broken down sobbing after the attack and could do nothing to stop the sadness and tears. S3: Still, he was proud to be in the Air Force because all of the men in his family had served. S4: Bob enlisted after high school, just like his father and grandfather.</p> <p><u>Region2:</u> S5: Currently, Bob was nearing the enemy target. S6: He contacted the central command unit as he reached his destination.</p>	<p>S1: (cued) Bob had enlisted in the Air Force just after high school. Today, he was on a top-secret mission to destroy enemy military targets.</p> <p><u>Region1:</u> S2: Bob had only been on one other mission and it had been miserable. S3: He had been anxious the whole time. S4: Immediately after attacking the site he had broken down sobbing. S5: He couldn't bear to think about what he had done. The tears continued for an hour the attack.</p> <p><u>Region2:</u> S6: Currently, Bob was nearing the enemy target. S7: He contacted the central command unit as he reached his destination.</p>	<p>S1: (cued) Bob had enlisted in the Air Force just after high school. Today, he was on a top-secret mission to destroy enemy military targets.</p> <p><u>Region1:</u> S2: Bob had only been on one other mission and it had been miserable. S3: He had been anxious the whole time. S4: Immediately after attacking the site he had broken down sobbing. S5: He couldn't bear to think about what he had done. The tears continued for an hour the attack.</p> <p><u>Region2:</u> S6: Currently, Bob was nearing the enemy target. S7: He contacted the central command unit as he reached his destination.</p>
<Control Sentence> He checked a screen to make sure that all of the bombs were properly secured.	<Target Sentence> He pushed a flashing red button and two of the bombs fell from the plane aiming at the targeted destination.	<Control Sentence> He checked a screen to make sure that all of the bombs were properly secured.	<Target Sentence> He pushed a flashing red button and two of the bombs fell from the plane aiming at the targeted destination.
Probe Word: Predictable <EXPLODE>			
Comprehension Questions: Did Bob join the Air Force just after high school? (Answer: Yes)			
<u>Inferential target word:</u> EXPLODE (Less Activation)	<u>Inferential target word:</u> EXPLODE (More Activation) <u>Secondary Inferential Concept:</u> SOB (Less Distraction)	<u>Inferential target word:</u> EXPLODE (Less Activation)	<u>Inferential target word:</u> EXPLODE (More Activation) <u>Secondary Inferential Concept:</u> SOB (More Distraction)
<p>*Low elaboration on the concept SOB in S2 only ONCE. *Control sentence is not predictable. It will NOT induce the target inferential concept EXPLODE. * This LEC condition will produce slower naming latencies on EXPLODE than LEI condition.</p>	<p>* Low elaboration on the concept SOB in S2 only ONCE. * Target sentence will induce the target inferential concept SPILL. This concept was less distracted by the concept EXPLODE. * This LEI condition will produce the quickest naming latencies on EXPLODE among these four conditions.</p>	<p>* High elaboration on the concept SOB in S4 and S5. * The control sentence is not predictable. It will NOT induce the inferential concept EXPLODE. * This HEC condition will produce slower naming latencies on EXPLODE than HEI condition.</p>	<p>* High elaboration on the concept SOB in S4 and S5. * Target sentence will induce the target concept SPILL, but it will be more distracted by the concept EXPLODE. * This HEI condition will produce the second quickest naming latencies, but slower than LEI condition.</p>
General Capacity Theory	The high span readers will be more effective in shifting attention under distractive elaboration context. They will name the word EXPLODE quicker than the low span readers.		
Skilled Suppression Hypothesis	The high span readers will NOT successfully enhance context appropriate meanings under the distractive elaboration context. It will take them longer time to name the word EXPLODE compared to the low span readers. As the degree of elaboration increases, the naming latencies among high span readers increase.		

Sample Text 4

<p>General Capacity Theory 1</p>	<p>The high span readers will be more effective in shifting attention under distractive elaboration context. They will name the word RIP quicker than the low span readers. 2</p>	<p>3</p>	<p>4</p>
<p>Skilled Suppression Hypothesis Elaboration Control Condition (LEC)</p>	<p>The Low Elaboration Inference Condition (LEI) enhance</p>	<p>High Elaboration Control Condition (HEC) distractive</p>	<p>High Elaboration Inference Condition (HEI) higher</p>
<p>S1: (Cued) Bruce decided he needed to fix the roof on his house.</p>	<p>S1: (Cued) Bruce decided he needed to fix the roof on his house.</p>	<p>S1: (Cued) Bruce decided he needed to fix the roof on his house.</p>	<p>S1: (Cued) Bruce decided he needed to fix the roof on his house.</p>
<p><u>Region 1</u> S2: Because of all the mistakes and problems he had. Bruce vowed he would give up if one more thing went wrong. S3: His wife was inside making him some lunch. S4: She had decided to make him a ham and cheese sandwich and some chocolate chip cookies. S5: She also made a large pitcher of freshly squeezed lemonade. S6: She carefully set the food and lemonade on a tray and walked outside. <u>Region2:</u> S7: Meanwhile, Bruce was trying hard to be neat and meticulous.</p>	<p><u>Region 1</u> S2: Because of all the mistakes and problems he had. Bruce vowed he would give up if one more thing went wrong. S3: His wife was inside making him some lunch. S4: She had decided to make him a ham and cheese sandwich and some chocolate chip cookies. S5: She also made a large pitcher of freshly squeezed lemonade. S6: She carefully set the food and lemonade on a tray and walked outside. <u>Region2:</u> S7: Meanwhile, Bruce was trying hard to be neat and meticulous.</p>	<p><u>Region 1</u> S2: Although he wasn't much of a handyman, the guy at the store assured him it was an easy job and should only take a couple of hours. S3: However, it seemed like everything went wrong. S4: He had made many mistakes and his equipment kept falling to the ground. S5: Bruce was ready to give up. S6: He vowed that if even one more small thing went wrong he would be done. <u>Region2:</u> S7: He was trying to be neat and meticulous in his work.</p>	<p><u>Region 1</u> S2: Although he wasn't much of a handyman, the guy at the store assured him it was an easy job and should only take a couple of hours. S3: However, it seemed like everything went wrong. S4: He had made many mistakes and his equipment kept falling to the ground. S5: Bruce was ready to give up. S6: He vowed that if even one more small thing went wrong he would be done. <u>Region2:</u> S7: He was trying to be neat and meticulous in his work.</p>
<p><Control Sentence> He rolled up the sleeves of his shift, planning to do a good job fixing the roof to prevent any future leaks.</p>	<p><Target Sentence> However, while reaching for the hammer, his shirt snagged on the tooth of a nail.</p>	<p><Control Sentence> He rolled up the sleeves of his shift, planning to do a good job fixing the roof to prevent any future leaks.</p>	<p><Target Sentence> However, while reaching for the hammer, his shirt snagged on the tooth of a nail.</p>
<p>Probe Word: Predictable <RIP> Comprehension Questions: Was Bruce going to watch a baseball game? (Answer: No)</p>			
<p><u>Inferential target word:</u> RIP (Less Activation)</p>	<p><u>Inferential target word:</u> RIP (More Activation) <u>Secondary Inferential Concept:</u> GIVE UP (Less Distraction)</p>	<p><u>Inferential target word:</u> RIP (Less Activation)</p>	<p><u>Inferential target word:</u> RIP (More Activation) <u>Secondary Inferential Concept:</u> GIVE UP (More Distraction)</p>
<p>*Low elaboration on the concept GIVE UP/DONE in S2 only ONCE. *Control sentence is not predictable. It will NOT induce the target inferential concept RIP. * This LEC condition will produce slower naming latencies on RIP than LEI condition.</p>	<p>* Low elaboration on the concept GIVE UP/DONE in S2 only ONCE. * Target sentence will induce the target inferential concept RIP. This concept was less distracted by the concept GIVE UP/DONE. * This LEI condition will produce the quickest naming latencies on RIP among four conditions.</p>	<p>* High elaboration on the concept GIVE UP/DONE in S5 and S6. * The control sentence is not predictable. It will NOT induce the inferential concept RIP. * This HEC condition will produce slower naming latencies on RIP than HEI condition.</p>	<p>* High elaboration on the concept GIVE UP/DONE in S5 and S6. * Target sentence will induce the target concept RIP, but it will be more distracted by the concept GIVE UP/DONE. * This HEI condition will produce the 2nd quickest naming latencies, but slower than LEI condition.</p>

Sample Text 5

Skilled Suppression Hypothesis ¹	The high span readers will NOT successfully enhance context appropriate meanings under the distractive elaboration context. It will take them longer time to name the word SINK compared to the low span readers. As the degree of elaboration increases, the naming latencies among high span readers increase.		
Low Elaboration Control Condition (LEC)	Low Elaboration Inference Condition (LEI)	High Elaboration Control Condition (HEC)	High Elaboration Inference Condition (HEI)
<p>S1: (Cued) Roxy and Jason were on an Alaska cruise.</p> <p><u>Region 1:</u></p> <p>S2: Jason had been blackmailed by smugglers who threatened to kill his daughter if he didn't deliver some heroine to Anchorage by noon.</p> <p>S3: Incidentally, this was their first vacation together.</p> <p>S4: They married young, and neither one of them had much money. Roxy had become pregnant they year they married</p> <p>S5: It was a struggle to get by Jason worked three jobs while Roxy cared for the baby.</p> <p><u>Region 2</u></p> <p>S6: Today, they were sitting on the deck enjoying the views.</p> <p>S7: Suddenly, the ship rumbled and they heard a terrible sound.</p>	<p>S1: (Cued) Roxy and Jason were on an Alaska cruise.</p> <p><u>Region 1:</u></p> <p>S2: Jason had been blackmailed by smugglers who threatened to kill his daughter if he didn't deliver some heroine to Anchorage by noon.</p> <p>S3: Incidentally, this was their first vacation together.</p> <p>S4: They married young, and neither one of them had much money. Roxy had become pregnant they year they married.</p> <p>S5: It was a struggle to get by Jason worked three jobs while Roxy cared for the baby.</p> <p><u>Region 2</u></p> <p>S6: Today, they were sitting on the deck enjoying the views.</p> <p>S7: Suddenly, the ship rumbled and they heard a terrible sound.</p>	<p>S1: (Cued) Roxy and Jason were on an Alaska cruise.</p> <p><u>Region 1:</u></p> <p>S2: Roxy didn't know it, but Jason had been blackmailed by smugglers to deliver some heroin to Alaska.</p> <p>S3: They had threatened to murder his daughter if he didn't get the drugs delivered by noon today.</p> <p>S4: It was 9:30 AM and Jason was checking his watch. Jason prayed that the cruise would arrive on time so that his daughter would be safe.</p> <p>S5: The smugglers were so dangerous.</p> <p><u>Region 2:</u></p> <p>S6: They would dock in Anchorage in another two hours.</p> <p>S7: Suddenly, the ship rumbled and they heard a terrible sound.</p>	<p>S1: (Cued) Roxy and Jason were on an Alaska cruise.</p> <p><u>Region 1:</u></p> <p>S2: Roxy didn't know it, but Jason had been blackmailed by smugglers to deliver some heroin to Alaska.</p> <p>S3: They had threatened to murder his daughter if he didn't get the drugs delivered by noon today.</p> <p>S4: It was 9:30 AM and Jason was checking his watch. Jason prayed that the cruise would arrive on time so that his daughter would be safe.</p> <p>S5: The smugglers were so dangerous.</p> <p><u>Region 2:</u></p> <p>S6: They would dock in Anchorage in another two hours.</p> <p>S7: Suddenly, the ship rumbled and they heard a terrible sound.</p>
<Control Sentence>One of the waiters had dropped a huge tray of coffee mugs and breakfast dishes on the deck of the ship.	<Target Sentence>An announcement was made that the cruise ship had just run into a gigantic iceberg.	<Control Sentence>One of the waiters had dropped a huge tray of coffee mugs and breakfast dishes on the deck of the ship.	<Target Sentence>An announcement was made that the cruise ship had just run into a gigantic iceberg.
Probe Word: Predictable <SINK> Comprehension Questions: Were Roxy and Jason on a Caribbean cruise? (Answer: No)			
<u>Inferential target word:</u> SINK (Less Activation)	<u>Inferential target word:</u> SINK (More Activation) <u>Secondary Inferential Concept:</u> KILL (Less Distraction)	<u>Inferential target word:</u> SINK (Less Activation)	<u>Inferential target word:</u> SINK (More Activation) <u>Secondary Inferential Concept:</u> Murder (More Distraction)
<p>*Low elaboration on the concept KILL in S2 only ONCE.</p> <p>*Control sentence is not predictable. It will NOT induce the target inferential concept RIP.</p> <p>* This LEC condition will produce slower naming latencies on SINK than LEI condition.</p>	<p>* Low elaboration on the KILL in S2 only ONCE.</p> <p>* Target sentence will induce the target inferential concept SINK. This concept was less distracted by the concept KILL.</p> <p>* LEI condition will produce the quickest naming latencies on SINK among four conditions.</p>	<p>* High elaboration on the concept MURDER in S3, S4 and S5.</p> <p>* Control sentence is not predictable. It will NOT induce the inferential concept SINK.</p> <p>* HEC condition will produce slower naming latencies on SINK than HEI condition.</p>	<p>* High elaboration on the concept MURDER in S3, S4 and S5.</p> <p>* Target sentence will induce the target concept SINK, but it will be more distracted by the concept MURDER.</p> <p>*HEI condition will produce the 2nd quickest naming latencies, but slower than LEI condition.</p>
General Capacity Theory	The high span readers will be more effective in shifting attention under distractive elaboration context. They will name the word SINK quicker than the low span readers.		

APPENDIX B

LETTER OF APPROVAL FROM THE INSTITUTE REVIEW BOARD (IRB) (SCANNED)



Office of the Vice President For Research
Human Subjects Committee
Tallahassee, Florida 32306-2763
(850) 644-8673 · FAX (850) 644-4392

APPROVAL MEMORANDUM

Date: 12/14/2005

To:

Qun Guan
901 West Jefferson St. Apt. B23
Tallahassee, FL 32308

Dept.: **EDUCATIONAL PSYCHOLOGY AND LEARNING SYSTEMS**

From: **Thomas L. Jacobson, Chair**

A handwritten signature in black ink, appearing to read "Thomas L. Jacobson".

Re: **Use of Human Subjects in Research**
Assessing Metacomprehension: Monitoring Reading Behavior and Validating
Assessment Tool

The forms that you submitted to this office in regard to the use of human subjects in the proposal referenced above have been reviewed by the Secretary, the Chair, and two members of the Human Subjects Committee. Your project is determined to be Expedited per 45 CFR § 46.110(b) 9 and has been approved by an accelerated review process.

The Human Subjects Committee has not evaluated your proposal for scientific merit, except to weigh the risk to the human participants and the aspects of the proposal related to potential risk and benefit. This approval does not replace any departmental or other approvals, which may be required.

If the project has not been completed by **12/13/2006** you must request renewed approval for continuation of the project.

You are advised that any change in protocol in this project must be approved by resubmission of the project to the Committee for approval. Also, the principal investigator must promptly report, in writing, any unexpected problems causing risks to research subjects or others.

By copy of this memorandum, the chairman of your department and/or your major professor is reminded that he/she is responsible for being informed concerning research projects involving human subjects in the department, and should review protocols of such investigations as often as needed to insure that the project is being conducted in compliance with our institution and with DHHS regulations.

This institution has an Assurance on file with the Office for Protection from Research Risks. The Assurance Number is IRB00000446.

Cc: Alysia Roehrig
HSC No. 2005.1026

Qun Guan, Investigator

Assurance #IRB IRB00000446

Title of Study: Assessing Online and Offline Reading Behaviors

Requested IRB Addendum

In the current study design, the participants will take a working memory capacity task before they begin reading 32 short passages. Each passage will be 6 to 7 sentences long, and be presented on the computer screen. The participants will do naming-a-word task during reading and answer yes or no comprehension questions by pressing the button on the response box. The accuracy for the comprehension question will be presented as feedback to the participants at the end of each passage in order to ensure that the participants read passages carefully. After reading, the participants will be told to write down whatever they can remember for each story. They will choose to either type on the computer or write down on papers while they are recalling the story in the second part of the experiment.

**APPENDIX C
INFORMED CONSENT FORM**



227 N. Bronough Street, Suite 7250 • Tallahassee, Florida 32301 • 850.644.9352

Informed Consent Form

I freely and voluntarily and without element force or coercion, consent to be a participant in the research project entitled "Assessing Online and Offline Reading Behaviors".

This research is being conducted by Ms. Qun Guan at Department of Educational Psychology and Learning System. I understand the purpose of this research project is to better understand how individuals comprehend the text. There are two sessions in this experiment. Session 1 is about a memory task. Session 2 includes online reading session and offline written test. I will read several reading passages on the computer screen and give response by pressing the response button or speaking to the microphone. The topics of these reading passages are about generic everyday issues and of medium length. I won't expect any anxiety or discomfort during reading. I will also follow experimenter's instruction to provide corresponding response during or after reading. The speed and accuracy of my responses will be recorded by the computer. After reading I will be asked to have a written test, which is related to what I have read. There is no penalty for any mistakes I make during the whole process of experiment.

The total time commitment will be approximately 2 hours for Session 2. If I participate in the study, I will receive \$10 from the experimenter. All information obtained as a result of this project will be kept confidential, to the extent allowed by law. If I would like to participate, please read the following statement.

"I have read the preliminary description of the experiment and agree to participate. I understand that there are no anticipated risks. I understand that this consent may be withdrawn at any time without prejudice, penalty or loss of benefits to which I am otherwise entitled. I have been given the right to ask and have answered any inquiry concerning the study. Questions, if any, have been answered to my satisfaction."

I understand and if I want a copy of this form, I can ask the experimenter. I understand that I may contact Ms. Qun Guan for further information about this experiment at 645-2753, to receive answers to questions about this research or to receive answers to questions about my rights. If I have questions about the rights as a participant in this research or feel that I have been placed at risk, I know I can contact the Chair of the Human Subjects Committee, Instructional Review Board, through the office of the Vice President For Research, at 850-644-2002.

I have read and understand this consent form.

Signature

Date

APPENDIX D

INSTRUCTIONS for THE EXPERIMENT VIA E-PRIME AND CUED RECALL TASK

INSTRUCTIONS FOR SELF-PACED READING

[Screen One]

Welcome to the experiment!

In this experiment, you will read passages and answer questions.

Each passage begins with the word “READY”. When you are ready to read a passage, please press the spacebar, and then the whole passage will be presented on the following screens sentence by sentence.

Every time when you press the “SPACEBAR” on the button box, the current sentence you read will disappear and be replaced by a continuous sentence.

[Screen Two]

Read at a comfortable and normal pace.

Following the last line of each passage, a cue “XXX” will appear in the middle of the screen. The cue is then replaced by a word. You are required to name this word as quickly as possible.

Once you name the word, it will be erased from the screen.

[Screen Three]

At the end of each passage, a cue “QUESTION” will appear in the middle of the screen. The cue will be replaced by a comprehension question to which you will need to respond by pressing “Y” response key for YES or “N” response key for NO.

You will receive feedback for each comprehension question.

Now let us practice!

INSTRUCTIONS FOR CUED RECALL TASK

You are going to recall 24 out of 32 stories you’ve read.

The first sentence of each story is given to you.

Please try your best to recall the rest of the story as much as you can.

Every new idea you remember for each story begins with a new sentence.

Please use conjunction and time sequence adverbials to link the ideas you remember.

If you can remember the last word that you spoke to the microphone, please write it down first besides Last word ____.

and then link it to the whole content of the complete story you’ve read besides the line Link the last word to the complete content of the story.

Every sentence you’ve written must be a complete sentence.

There is no penalty for incorrect memory.

Thanks!

APPENDIX E

DEMOGRAPHIC FORM

Please provide some background information about yourself by filling out the following form.

1. SUBJECT ID: _____
2. Please enter your age in years: _____
3. Sex: (Select only one):
 - Male
 - Female
4. Race/Ethnicity: (Select only one)
 - American Indian/ Alaskan Native
 - African-American / Black
 - White
 - Hispanic/Latino
 - Other (please specify) _____
5. Years in School:
 - Community College _____ 1 _____ 2 _____ 3 _____ 4 _____ 5+
 - 4-year College _____ 1 _____ 2 _____ 3 _____ 4 _____ 5+
6. Language Background:
 - a. What is the first language spoken? _____
 - b. What is your second language? _____
7. Have you been diagnosed with any of the following:
 - a. language disabilities
 - b. ADHD (Attend-Deficit Hyperactive Disorder)

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BIOGRAPHICAL SKETCH

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