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Reading comprehension performance as a function of individual differences in working memory for texts of varying reading difficulty.

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READING COMPREHENSION PERFORMANCE AS A FUNCTION OF INDIVIDUAL DIFFERENCES IN WORKING MEMORY FOR TEXTS OF VARYING READING DIFFICULTY

A Dissertation Presented

By

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PREFACE

Overview of the Dissertation

This dissertation presents the rationale and relevant theoretical foundation for an experiment investigating reading comprehension performance as a function of individual differences in working memory. Although the construct of working memory is a critical feature in a commonly cited theory of reading comprehension (cf. Kintsch & van Dijk, 1978), there is no previous research which has investigated how reading comprehension performance varies as a function of individual differences in working memory. The general design of the experiment was that subjects read text of increasing reading difficulty level and responded to a reading comprehension task called the sentence verification technique (SVT) after reading the text. The subjects also responded to a test which presumably was sensitive to individual differences in working memory.

The experiment was based upon assumptions relating three areas of research: 1) working memory during reading comprehension, 2) the identification of semantic factors that account for differences in reading comprehension, and 3) the SVT as a valid method of measuring reading comprehension. The six chapters in this dissertation address these areas of research.

Chapter I presents research which suggests that working memory is a viable construct for identifying individual differences between readers. The chapter is divided into two sections presenting previous

research investigating reading performance as a function of individual differences in working memory, and research investigating cognitive capacity during reading. A third section discusses sources of individual differences in working memory that may affect reading comprehension.

Chapter II reviews research which has investigated semantic properties of text structure and their relation to reading comprehension. This chapter is divided into three sections. The first section addresses assumptions about memory structures and memory processes engaged during reading comprehension. The second section presents research which has identified text structure variables associated with passage difficulty. The third section suggests how individual differences in working memory may interact with semantic structures of text during reading.

The initial section of Chapter III reviews previous research which has used the SVT as a method of measuring reading comprehension. Chapters IV, V, and VI present an experiment which investigated whether reading comprehension performance as measured by the SVT varied as a function of individual differences in working memory when readers read text of increasing difficulty levels.

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Many other people have contributed greatly to this dissertation. Ronald K. Hambleton provided me with valuable knowledge and skills. Ron patiently emphasized the importance of psychometric theory and methodology for psychological research. Keith Rayner and Charles Clifton suggested alternative perspectives of reading comprehension from my own, helping me to recognize the rich complexity of language comprehension. I learned an appreciation for the wealth of information provided by statistical analysis from Arnold Well.

My greatest source of strength and courage came from my wife, Patrice Lynch. She supported me when I was discouraged and shared the joys of my progress. My son, Jesse, gave me hundreds of experiences enriching my life. Finally, I am truly thankful for the encouragement and support given to me by my mother, Jeannette Albersheim.

ABSTRACT

Reading Comprehension Performance as a Function of
Individual Differences in Working Memory for Texts of
Varying Reading Difficulty

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The construct of working memory is a critical feature in a commonly cited theory of reading comprehension (cf. Kintsch & van Dijk, 1978). The dissertation identified good and poor working memory fourth grade subjects with a probe recall test. The subjects read text of increasing reading difficulty level (easy, moderate and difficult) and responded to a reading comprehension task called the sentence verification technique (cf. Royer, 1984) after reading the text. The experiment investigated the reading comprehension performance of good and poor working memory readers and the relationship between text microstructure and reading comprehension performance.

Reading comprehension performance was significantly higher for good working memory readers compared to poor working memory readers at each level of text difficulty. Reading comprehension performance declined with an increase in text difficulty level, with a marginally significant working memory group X reading difficulty level interaction. There were no significant differences in reading time per passage between good and poor working memory readers.

The sentence verification technique provided reading comprehension

indices for each sentence for each passage. A Kintsch (1974) analysis of text microstructure of each passage sentence also identified text microstructure variables theoretically related to working memory. The combination of propositions from earlier text sentences and the number of propositions per clause were negatively correlated with reading comprehension performance of poor working memory readers. No combination of text structure variables was associated with reading comprehension performance of the good working memory readers. However, good working memory reading performance was negatively correlated with the number of propositions from earlier text sentences and the proportion of unfamiliar words per sentence. The dissertation provided strong evidence supporting the relationship between individual differences in working memory and reading comprehension performance. However, the association between working memory and reading comprehension may have been confounded with individual differences in other factors such as vocabulary or general language proficiency.

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CHAPTER I

INDIVIDUAL DIFFERENCES IN READING PERFORMANCE AS A FUNCTION OF WORKING MEMORY

The purpose of this chapter is to present research which suggests that working memory is a valid construct for identifying individual differences between readers. Working memory refers to active processing of stimuli by the short term memory (STM) system. Although research investigating working memory may use nonverbal stimuli, or lists of words (see Baddeley & Hitch, 1974; Waugh & Norman, 1965), the research which is most relevant to this dissertation investigated working memory of text. Research investigating working memory and reading comprehension is closely related to two contemporary research areas. Specifically, working memory is a central construct in the Kintsch and van Dijk (1978) theory of reading comprehension, and in research that argues that individual differences between good and poor readers are attributable to differences in working memory (cf. Perfetti & Lesgold 1977; 1979).

This chapter is divided into three sections. The first section presents two different methods of assessing immediate recall of words from a sentence as a means of determining proficiency in working memory. This research has shown that reading performance is related to individual differences in working memory performance, as indexed by the word recall measures. The second section reviews research which assessed cognitive capacity during reading. While this research may not be labeled working memory research in the literature, the design

of the experiments suggests working memory is a critical factor in variation in cognitive capacity. The third section presents several theoretical sources of individual differences in working memory which may affect reading comprehension.

Researchers have investigated the role of working memory during reading in two ways. The first approach requires the reader to report words immediately after reading a text. The words are presumably generated from memorial representations of words in the STM system. This method suggests that variation in the correct recall of target words is an index of individual differences in working memory. The second approach assesses cognitive capacity during reading. Variation in cognitive capacity may be an alternative way to indicate individual differences in working memory. The research which is presented below is subdivided into these two approaches.

Immediate Recall of Words from STM

Both Daneman and Carpenter (1980) and Perfetti and Goldman (1976) have assessed working memory by having subjects recall words from a text which was read immediately before the recall task. However, Daneman and Carpenter (1980) and Perfetti and Goldman (1976) used different recall tasks. Daneman and Carpenter (1980) investigated the recall of final words from sentences as an index of working memory span, but Perfetti and Goldman (1976) investigated working memory with a probe recall task. A review of these two studies illustrates that differences in reading comprehension are associated with individual differences in working memory.

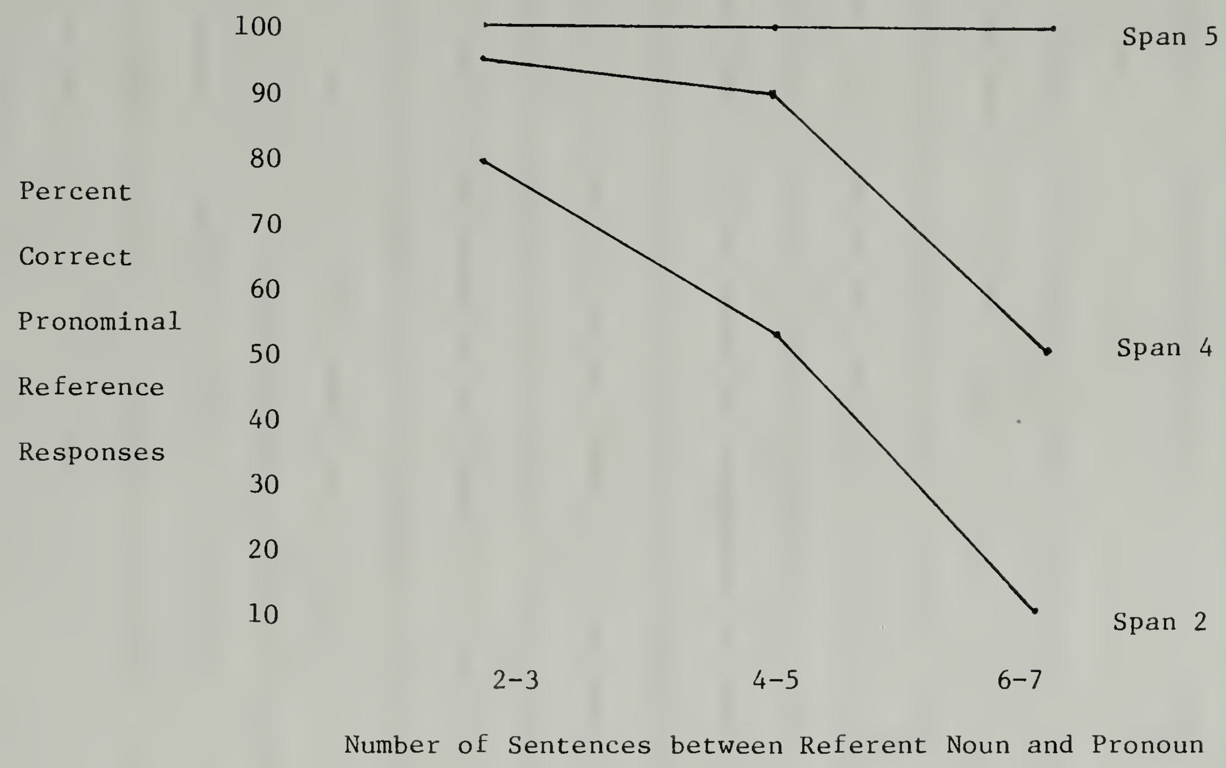
Working memory as memory span

Daneman and Carpenter (1980) found that college age readers performance on a working memory span test was highly associated with several measures of reading performance. They assessed working memory span by having subjects read sets of sentences aloud, and recall the final word of each sentence after reading one set. The sentences within and between sets were unrelated to each other. Set sizes varied from 2 to 5 sentences. If subjects correctly recalled the final words of the 2 sentence sets, they were presented with the 3 sentence set. The task continued by increasing the set size until subjects failed to recall at least one of the final words from a target sentence. The index of working memory was the maximum number of sentences in the set from which subjects correctly recalled all the final words of the sentences.

Daneman and Carpenter (1980) had the same subjects read 12 narrative passages (approximately 140 words in length) and respond to open ended questions assessing factual content and pronominal reference. Factual content questions asked one fact per passage. Pronominal reference questions asked the subjects to supply the noun reference associated with a pronoun in the last sentence of each passage. The 12 passages varied in the number of sentences intervening between the referent noun and the pronoun (the range was 2 to 7 intervening sentences). As shown in Figure 1, Daneman and Carpenter (1980) found the proportion of correct pronominal reference responses varied according to the working memory span and the number of sentences between the referent noun and the pronoun. Subjects with working

Figure 1

The Percentage of Correct Pronominal Responses as a Function of Working Memory Span and the Number of Sentences between the Referent Noun and the Pronoun (reported in Daneman & Carpenter, 1980).


Percent
Correct
Pronominal
Reference
Responses
100
90
80
70
60
50
40
30
20
10
Span 5
Span 4
Span 2
2-3
4-5
6-7
Number of Sentences between Referent Noun and Pronoun

memory spans less than 5 had poorer performance as a function of the number of intervening sentences. Daneman and Carpenter (1980) found that working memory span was highly correlated with the proportion of correct pronoun reference responses (r = .90). Working memory span was also significantly correlated with the proportion of correct responses to factual questions (r = .79) and verbal SAT scores (r = .59).

Daneman and Carpenter (1980) demonstrated a method of measuring working memory which was highly associated with responses to factual and pronominal reference questions. However, there are three weaknesses in the method and the type of questions Daneman and Carpenter (1980) used to assess reading comprehension. First, the working memory task utilized unrelated sentences and sentences which differed from the passages used in the study. The processing demands of STM may vary considerably between unrelated sentences and sentences in a text which is semantically coherent. Several studies have demonstrated that reading comprehension performance is significantly lower if sentences are scrambled within paragraphs rather than in their normal order (see Royer, Lynch, Hambleton, & Bulgarelli, in press; Perfetti & Lesgold, 1977). A second weakness of the working memory span task used by Daneman and Carpenter (1980) is that readers' recall of final words of sentences may not be an accurate assessment of working memory while processing the other words of the sentence. Since most of the meaning of a sentence is derived from words prior to the final word, research needs to establish the relationship between recall of final words and recall of previous words in the sentence. As described in Chapter II,

the meaning of text is theoretically represented by linguistic units called propositions. Research by Kintsch, Kozminsky, Streby, McKoon, and Keenan (1975) suggests the proportion of correctly recalled propositions from a sentence is related to the importance of the propositions rather than their serial position. The third weakness with the Daneman and Carpenter (1980) study is that the pronominal reference questions they used to assess reading comprehension may be more sensitive to proficiency in recall of exact words than recall of the meaning of the text. Several studies have presented evidence that reading is essentially the process of extracting the meaning from the surface structure of text rather than recording the surface structure itself (see Sachs, 1967, 1974; Bransford & Franks, 1971). Therefore, the assessment of reading comprehension utilizing factual and pronominal reference test questions needs further validation to support the argument that recall of final words is highly correlated with reading comprehension.

These weaknesses encourage the search for an alternative method of measuring working memory which may be a more valid means of assessing the processing activities of STM during reading.

Working memory as probed recall performance

The other research assessing working memory with an immediate recall task was conducted by Perfetti and Goldman (1976). Perfetti and Goldman (1976) used a probe memory task to assess the working memory of readers. The probe memory task required that subjects listen to a text and recall the word which immediately followed a probe word

in the text.

The subjects in the Perfetti and Goldman (1976) research were third and fifth grade good and poor readers who were matched on their IQ performance. The selection of good and poor readers was based upon performance on the Metropolitan Achievement Test. The subjects participated in two experiments. In the first experiment, Perfetti and Goldman (1976) used the probe memory task to assess recall of digits. They found no difference in the proportion of correct recall of target digits between good and poor readers at either grade level.

In contrast to the first experiment, the second experiment found evidence of individual differences between good and poor readers' working memory. In the second experiment, subjects listened to two passages of approximately 600 words. Twelve test sentences that varied in clause and sentence structure were distributed within each passage. As shown in Table 1, the test sentences differed in order of clause types (Main, Subordinate versus Subordinate, Main) and in whether the clauses were part of the same sentence or were in different sentences. All of the target sentences contained the same propositions. The probe words were either the first word of the main clause or the first word of the subordinate clause.

Subjects listened to portions of the text, were given the probe words, and then recalled the target words. Perfetti and Goldman (1976) found that the proportion of correctly recalled target words was significantly different between grade levels, reading comprehension levels, and probe structure. Probe structure refers to the position of the probe relative to a clause or sentence boundary prior to the

TABLE 1

Examples of Perfetti and Goldman's (1976)
Text Sentences Used in the Probe Memory Task

Main, Subordinate Sentences

It had been a beautiful day for rowing, Nick began to have trouble, when a thick fog came in from the sea. (Probe).

Subordinate, Main Sentences

It had been a beautiful day for rowing. When a thick fog came in from the sea, Nick began to have trouble. (Probe)

Clause, Subordinate, Main Clause in New Sentence

It had been a beautiful day for rowing, when a thick fog came in from the sea. Nick began to have trouble. (Probe)

Note. For each type, probe is underlined.

point of recall. Far probes had intervening sentences or clauses, while near probes were from immediate clauses. Recall was significantly higher for near probes compared to far probes for both good and poor readers. This result complemented the research of Jarvella (1971) which suggested clause and sentence boundaries provide structural units which cue the STM system to identify the appropriate string of propositions to be retained in a STM buffer.

Although Perfetti and Goldman (1976) did not find a statistically significant reading comprehension level by probe structure interaction, their data did suggest that poorer readers were less able to recall target words from far probes compared to good reader recall from far probes. Poor readers also supplied many fewer paraphrases of target words from far probes compared to the number of paraphrases supplied by good readers responding to far probes. These two results provide modest support for the suggestion that poor readers are less proficient in maintaining propositions in a STM buffer while reading.

Whereas the Daneman and Carpenter (1980) task assessed recall of final words, the probe recall task may be used to assess recall of any target words. This allows research to investigate whether certain types of words are recalled more frequently than other words. For example, one could investigate whether probe task performance was improved when recalling target words which represent superordinate propositions compared to recalling target words representing subordinate propositions.

Perfetti and Goldman (1978) and Daneman and Carpenter (1980) found evidence that proficiency in recalling words immediately after

reading or listening to a text was associated with reading performance. The second approach for assessing individual differences in working memory requires the subjects to respond to a task which presumably is sensitive to cognitive capacity during reading.

Assessing Cognitive Capacity as an Index of Working Memory

Several experiments conducted by Britton and his colleagues (Britton, Piha, Davis, & Wehausen, 1978; Britton, Westbrook, & Holdredge, 1978; Britton, Glynn, Meyer, & Penland, 1982) have required subjects to respond to a secondary task while performing the primary task of reading or listening to text. The secondary task is usually responding to a "click" by pressing a telegraph key or removing one's hands from a telegraph key. The mean reaction time to respond to the clicks is the index of cognitive capacity.

According to Britton, Piha, Davis, and Wehausen (1978), the cognitive capacity technique is based upon four assumptions: 1) the central processing system has limited capacity, 2) the primary and secondary tasks utilize the same central processing system, 3) the more capacity devoted to the primary task, the less is available to the secondary task, and 4) reductions in reaction time to the secondary task reflect a smaller amount of cognitive capacity available for performing the secondary task.

Based upon these four assumptions, Britton, Westbrook, and Holdredge (1978) found evidence that more cognitive capacity is required to read difficult text compared to the cognitive capacity

required to read easy text. In this experiment, college students read 10 easy passages and 10 difficult passages, responding to a mean of 3 clicks per passage. The easy and difficult passages were selected from a larger set of 36 passages which were 140 words in length and varied from primary school texts to difficult college texts. Each passage was evaluated for reading difficulty level by the cloze technique (see Miller & Coleman, 1967; Aquino, 1969). The easy and difficult passage sets were selected from the opposite ends of the distribution of cloze test scores.

Britton, Westbrook, and Holdredge (1978) found that the mean reaction time to respond to the secondary task was slower for easy passages compared to more difficult passages. This result is counterintuitive since it appears less cognitive capacity is being used for difficult passages compared to easy passages. Britton et al. (1978) also cited evidence discounting the following alternative explanations for the unexpected results: the passages differed in interest level, semantic arousal, or recall of passage topics.

Having examined these alternative explanations, Britton et al. (1978) investigated whether total cognitive capacity varied for easy or difficult passages. The index of total cognitive capacity was mean total reading time for easy or difficult passages multiplied by mean secondary task reaction time for easy or difficult passages. The index of total cognitive capacity was significantly greater for difficult passages compared to easy passages. Therefore, Britton et al. (1978) suggested that reading more difficult passages does require more cognitive capacity than reading less difficult passages.

Britton et al. (1978) contend that the unusual pattern of results with the secondary task reaction time data may have been due to STM processing breakdowns with difficult passages. They argued that when breakdowns occur, there is enough cognitive capacity in STM to respond faster to the secondary task. However, easy passages would presumably have fewer breakdowns during reading and STM capacity would be consistently filled. Given these conditions, reaction time to the secondary task may be faster for difficult passages compared to the reaction time to easy passages.

Britton, Glynn, Meyer, and Penland (1982) extended the previous work of Britton, Westbrook, and Holdredge (1978) by investigating the use of cognitive capacity during reading by varying the surface structure of text while holding the meaning of the text constant. Britton et al. (1982) conducted three experiments assessing response time to the cognitive capacity task. The subjects were college students in each experiment.

In their first experiment, subjects read either a standard english version of two technical passages or a basic english version of the two passages. Basic english is a collection of common words which may be used for general paraphrases of less frequent words (see Ogden, 1968; 1970). For example, the standard english sentence "The animals, if small, are minced whole, or if sufficiently large are dissected and the separate organs minced" is rewritten in basic english as "Where size makes it possible, organs are taken out of the animals and cut up separately into small pieces, but smaller animals are cut up as they are." Britton et al. (1982) found that mean reaction time to

the clicks was faster to basic english text compared to mean reaction time to standard english text.

In the second experiment, subjects read one of four types of passages. All of the passages had the same propositional base. Two versions of the passages consisted of either common or uncommon words. Two other versions of the passage were written with either simple or complex syntax. Britton et al. (1982) found significantly faster mean reaction times to the secondary task for the simple syntax version compared to the complex syntax version. There was no significant difference in reaction time due to the common or uncommon word manipulation.

In their third experiment, Britton et al. (1982) investigated cognitive capacity during reading as a function of signaling. Signal words are non content words in text which direct the reader's attention to the structure of the passage (see Meyer, 1975). Table 2 presents a sample of a with-signal version of text and a without-signal version of text from Britton et al. (1982). The underlined words in Table 2 are the signal words. Britton et al. (1982) reported that reaction time to respond to the secondary task during reading of the without-signal text.

The three experiments by Britton et al. (1982) suggest that several alterations of text structure may affect the processing load of the STM system, thereby affecting the amount of cognitive capacity available for processing information in working memory. Working memory is affected by common or uncommon vocabulary, simple or complex syntax, and variation in signal words that direct the reader's atten-

TABLE 2

Text from Britton et al. (1982) Illustrating
With-Signal and Without-Signal Text

With-Signal Version

Breader reactors produce more nuclear fuel than they consume. In addition, these reactors would operate without addiing noxious combustion products to the air. It is in light of these considerations that the U.S. Atomic Energy Commission, the nuclear industry and the electric utilities have mounted a large scale effort to develop the technology where it will be possible to have a breeder reactor generating electrical power on a commerical scale by 1984. Many scientists ...

Without-Signal Version

Breeder reactors produce more nuclear fuel than they consume. These reactors would operate without adding noxious combustion products to the air. The U.S. Atomic Energy Commission, the nuclear industry and the electrical utilities have mounted a large scale effort to develop the technology where it will be possible to have a breeder reactor generating electrical power on a commercial scale by 1984. Many scientists ...

Note. Signal words are underlined.

tion to the structure of text.

The cognitive capacity task has one major advantage in assessing working memory compared to the memory span task or the probe recall task. The cognitive capacity task assesses STM capacity during continuous reading, and is not dependent upon retrieval processes. However, the unexpected results in Britton, Westbrook, and Holdredge (1978), where mean reaction time to the secondary task was greater for easy passages compared to the more difficult passages, is reason for careful evaluation of the technique. If more rapid response rates are indicative of both STM breakdowns and an abundance of cognitive capacity during proficient working memory operations, it may be difficult to confidently interpret results. Research may need to use other dependent variables to cross validate the secondary task data. For example, research could investigate the proportion of correctly recalled text on the same text used for the secondary response task. An assessment of the proportion of correctly recalled "click" words might indicate whether the task was related to memory storage as well as cognitive capacity.

The research presented earlier in this chapter indicated that proficiency in working memory was associated with proficient reading comprehension. Individual differences in reading comprehension were related to memory span (Daneman & Carpenter, 1980), and probe recall performance (Perfetti & Goldman, 1976). Britton et al. (1978, 1982) presented evidence that alterations in text structure affect cognitive capacity during reading. These studies demonstrate that working memory is a viable construct to investigate in assessing individual

differences in reading comprehension. The following section describes a theoretical account of how differences in working memory affect reading comprehension.

The Role of Working Memory in Reading Comprehension

Perfetti and Lesgold (1977) emphasized the role of STM in reading comprehension. Their interpretation of STM processing is synonymous with the interpretation of working memory discussed in this dissertation. They contend the role of working memory in reading comprehension is to maintain memorial representations of as many words as possible, to interconnect the representations, and to relate the representations to long term memory. Perfetti and Lesgold (1977) described three sources of individual differences in working memory which would theoretically affect reading comprehension: proficiency in maintaining propositions in working memory, the rate of accessing the lexicon, and accuracy in representing the meaning of text in STM.

Although Perfetti and Lesgold (1977) did not discuss factors affecting the maintenance of propositions in working memory, proficiency in working memory may be affected by two factors. First, proficiency may vary with the size of text units maintained in working memory. As Perfetti and Lesgold (1977) noted, propositions derived from text must be interconnected to construct a coherent representation. The most inefficient unit would be maintaining single propositions in working memory. Even if single propositions were maintained for a considerable length of time, the lack of interconnections with other propositions derived from the text would prevent the construction

of a coherent representation of text meaning. If readers maintained more than one proposition in working memory, the effectiveness in constructing a coherent meaning would depend upon the number of propositions in the text. Both poor and good working memory readers may maintain a coherent unit of text if they read short sentences which contained few propositions. However, with longer sentences, proficiency in maintaining propositions may require retaining an appropriate set of propositions which are representative of the text meaning. The second factor which may affect proficiency in maintaining propositions in working memory is the amount of time propositions reside together in the STM buffer. There may be a set amount of time propositions must be processed together to generate interconnections with other propositions. In summary, failure to maintain an appropriate unit of text or failure to maintain propositions for a sufficient amount of time would result in an incomplete understanding of the text. Assumptions related to constructing interconnections between propositions are presented in Chapter II, as part of the discussion of the Kintsch and van Dijk (1978) theory of reading comprehension.

The second suggested source of individual differences in working memory is variation in verbal encoding speed. Verbal encoding speed is the amount of time required to access the lexicon. Perfetti and Lesgold (1977) contend readers with slow lexical access rates would have comprehension difficulties when reading lengthy sentences. Comprehension difficulty may arise if propositions derived from words early in the sentence decay prior to lexical access of words later in the sentence.

While there has been no clear demonstration that poor working memory readers are slower in lexical access rates than good working memory readers, there is some evidence that poor readers are slower in monitoring phonemes compared to good readers. Perfetti and Lesgold (1977) described an unpublished study (by Perfetti, Hogaboam, and Harned) in which 10 year old skilled and unskilled readers performed a phoneme monitoring task. The subjects detected a /b/ or /d/ in words from lists which varied in length. Mean detection time to identify phonemes was faster for skilled readers compared to mean detection time for the unskilled readers. The difference in mean detection time between skilled and unskilled readers increased when the target phoneme was from one of the last words of a long list of words. Perfetti and Lesgold (1977) cite the detection time difference as modest evidence of individual differences in lexical access rates between good and poor reading subjects.

The third source of individual differences in working memory affecting reading comprehension is general language proficiency. General language proficiency refers to the ability to generate an appropriate interpretation of text. Two sources which may affect the interpretation of text in working memory are knowledge of vocabulary and world knowledge. Readers with limited language experience (or limited skills) may be less able to generate accurate representations of text. They may not know the meaning of certain words or misinterpret the meaning of the words. There is considerable evidence that world knowledge affects reading comprehension performance (see Rumelhart, 1977; Royer & Cunningham, 1981; Bransford & Franks, 1971).

The role of world knowledge in working memory may be providing a knowledge structure or schema permitting inferencing. As Kintsch and van Dijk (1978) suggest, certain text may require that inferential propositions be generated from LTM. These propositions provide coherence that is not available without world knowledge. Chapter II describes processing assumptions related to inferencing in greater detail.

Whether individual differences in reading comprehension are related to variation in maintaining propositions in working memory, verbal encoding speed, or general language proficiency, researchers may attribute (or imply) the differences to variation in STM capacity. As Chi (1976) has noted, differences on cognitive tasks which presumably measure STM capacity have been interpreted in two ways. The first interpretation of STM capacity suggests individual differences are due to the size or number of "slots" available to store memorial stimuli. The slot concept has been used in developmental research to describe differences between children and adults on STM tasks (see Case, 1974; Mclaughlin, 1963; Pascual-Leone, 1970). The second interpretation of STM capacity suggests that individual differences are due to efficiency in functional processing. This interpretation accounts for individual differences on tasks assessing STM by identifying cognitive processes which would presumably influence the operation of the STM system. Chi (1976) reviewed research which had attributed performance differences on many tasks assessing STM processes to variation in "slot" capacity. Chi (1976) argued that individual differences may be found due to variation in familiarity with stimuli,

proficiency in grouping, speed of encoding, and retrieval from LTM. Familiarity with stimuli, proficiency in grouping and retrieval from LTM are similar to the sources of individual differences mentioned above.

Individual differences in working memory affecting reading comprehension are presumably related to the development of STM processing. Since Chi (1976) has presented extensive evidence that children do not differ from adults in absolute STM capacity, it is reasonable to assume the sources of individual differences in working memory are processing operations rather than structural limitations. The processing demands upon working memory which are most relevant to this dissertation relate to processing the semantic structure of text. The next chapter discusses text structure effects related to working memory during reading comprehension.

CHAPTER II

SEMANTIC TEXT STRUCTURE VARIABLES WHICH MAY ACCOUNT FOR DIFFERENCES BETWEEN READERS VARYING IN WORKING MEMORY

This chapter reviews research literature which has investigated semantic properties of text structure and their relation to reading comprehension performance. The chapter serves two purposes. The first purpose is to review research analyzing the theory of reading comprehension and text structure developed by Kintsch (1974) and Kintsch and van Dijk (1978). The first two sections of this chapter address this purpose. The first section focuses upon assumptions about memory structures and memory processes engaged during reading comprehension. The second section presents research which has identified text structure variables associated with passage difficulty. The second purpose of this chapter is to relate Kintsch's theory of reading comprehension difficulty to the argument in Chapter I that working memory deficits inhibit reading comprehension performance. The third section of this chapter describes how individual differences in working memory may interact with semantic structures of text during reading, leading to differences in reading comprehension performance between good and poor working memory readers.

Assumptions about Memory Structures and Memory Processes during Reading Comprehension

Since working memory has been described as the active processing of stimuli by the STM system, this section presents an overview of a hypothetical relationship between memory structures and processes and

the structure of text. Critical assumptions are identified which are commonly made regarding text structures and processing of that structure during reading comprehension.

One basic assumption is that reading comprehension is directed by the goal of "getting the meaning" or the semantic message of the text. Part of this process of deriving the meaning of text is generating a coherent memorial representation of the semantic message of the text. Kintsch (1974) refers to the memorial representation of text as the text base. Since researchers investigating reading comprehension cannot directly examine the reader's memory code of a text, researchers have developed formal systems of text structure which theoretically represent the text base.

There are several different formal systems for identifying text structure (see Kintsch, 1974; Meyer, 1975; Crothers, 1972). The differences between the systems of identifying text structure stem from alternative theoretical perspectives as well as differences in the purpose of conducting research. For example, research investigating the nature of inferencing in reading comprehension (see Fredricksen, 1979) utilized Fredricksen's (1972) system of identifying inference types to differentiate text structure. Meyer (1975, 1982) utilized her system of identifying the logical structure of content in order to assess the relationship between the level of importance of text ideas and recall of text. Kintsch (1974; Kintsch & van Dijk, 1978) developed a system for representing the semantic structure of text in order to investigate a theory of reading comprehension. Kintsch's (1974) system of identifying the semantic structure of text, as well

as the Kintsch and van Dijk (1978) theory of reading comprehension provides the most appropriate system for identifying semantic structure and cognitive processes associated with working memory. Kintsch and van Dijk (1978) present the only theory of reading comprehension which identifies both text structure features associated with reading comprehension and the processing of text structure by the STM system. Therefore, this chapter reviews the Kintsch (1974) system of describing text and the Kintsch and van Dijk (1978) theory of reading comprehension. The purpose of this review is to clarify basic assumptions relating text structure, memory structure and memory processes.

Semantic structure of text

Kintsch and van Dijk (1978) suggest that readers comprehend text at a microstructure and macrostructure level. The microstructure level of text consists of the basic details of the text. The details of text are derived from words within sentences or semantic relationships between a few sentences.

The macrostructure level of text structure represents the overall gist of a passage. According to van Dijk (1977) the processing of macrostructure is affected by the structure of knowledge in long term memory. The reader utilizes schematic knowledge structures to generate the gist of passages rather than recall details of sentences. While knowledge structures may affect the STM system during reading comprehension, the effect of macrostructure may be more closely related to cognitive processes and structures of long term memory. Therefore, the focus of this chapter deals with the Kintsch and van Dijk (1978)

assumptions about macrostructure and the processing of microstructure of text rather than on the processing of text macrostructure.

Propositions are often considered the basic units of comprehension at the microstructure level. Kintsch (1974) has developed an explicit system of deriving propositions from text. The system, described in considerable detail by Turner and Green (1977), is based upon the principles of case grammar developed by Fillmore (1968). The specific grammar of propositions is less relevant to this chapter than the concept that propositions are elementary idea units representing the meaning of text. Table 3 presents several propositions which were illustrated in Turner and Green (1977). The first term in each proposition is considered a predicate, and other terms are considered arguments. The importance of the distinction between predicates and arguments is that the Kintsch (1974) system of analysing text structure assumes semantic coherence of a text is related to argument overlap or connections between arguments. Furthermore, Kintsch and van Dijk (1978) argue that reading performance improves with greater semantic coherence, or declines with poor semantic coherence.

Texts vary at the microstructure level in at least three ways: the number of propositions, the degree to which propositions are linked to each other, and the pattern of superordinate and subordinate propositions. Previous research has demonstrated that these three microstructure factors affect reading performance.

TABLE 3

Examples of Propositional Analysis Utilizing the Kintsch (1974) System According to Turner and Green (1977)

Sample Text

Louise and Ann went to the movies last night. They met Charlie there. Afterwards they all went for a chocolate sundae, but the ice cream parlor was closed.

List of Propositions Illustrating Text Base

1. (CONJ: AND, LOUISE, ANN)
2. (GO, A: 1, G: MOVIES)
3. (QUALIFY, NIGHT, LAST)
4. (TIME: DURING, 2, 3)
5. (MEET, A: 1, O: CHARLIE)
6. (LOC: AT, 5, MOVIES)
7. (CONJ: AND, LOUISE, ANN, CHARLIE)
8. (GO, A: 7, S: MOVIES, G: 12)
9. (QUALITY OF, SUNDAE, CHOCOLATE)
10. (GET, A: 7, O: 9)
11. (PURP: FOR, 8, 10)
12. (QUALIFY, PARLOR, ICE CREAM)
13. (CLOSE, A: $, O: 12)
14. (NEGATE, 10)
15. (CAUS: BECAUSE, 13, 14)
16. (CONC: BUT, 11, 14)
17. (TIME: AFTERWARDS, 5, 11)

Note. This text base has 17 propositions.

Text structure variables associated with passage difficulty

Early research by Kintsch (1974) identified text structure variables which were theoretically related to the difficulty level of a passage. The early research provided the initial empirical foundation for the Kintsch and van Dijk (1978) theory of reading comprehension. Three experiments will be reviewed in this section which have examined several text structure variables which may account for why one text is relatively more difficult to comprehend than another.

Kintsch and Keenan (1973) conducted an experiment in which college students read text with or without time restrictions. The text consisted of sentences about classical history with between 4 to 9 propositions per sentence, but with nearly equal word length per sentence. Table 4 gives an example of sentences with nearly equal word length but variation in number of propositions per sentence. The sentences also varied in terms of propositional level. The level of a proposition refers to the relative importance of the proposition in reference to other propositions in the same coherence graph. Importance is defined by the order of propositions in the text base and whether propositions of lower order have the same argument as a higher order proposition. For example, Table 4 shows that sentence VIII has proposition 1 as superordinate, and propositions 2 and 3 at a subordinate level. But propositions 2 and 3 are at the same level to each other because they both share arguments with proposition 1. (However, propositions 6 and 8 are even more subordinate to proposition 1.) Therefore, propositions 1 in both sentences I and VIII of Table 4 would be considered superordinate propositions, while proposi-

TABLE 4

Text from Kintsch and Keenan (1973) Illustrating Variability in Propositions and Levels while Number of Words per Sentence is Held Constant, and Coherence Graphs

Sentences

I. Romulus, the legendary founder of Rome, took the women of the Sabine by force.

VIII. Cleopatra's downfall lay in her foolish trust in the fickle political figures of the Roman world.

Text Base

I.

1. (TOOK, ROMULUS, WOMEN, BY FORCE)
2. (FOUND, ROMULUS, ROME)
3. (LEGENDARY, ROMULUS)
4. (SABINE, WOMEN)

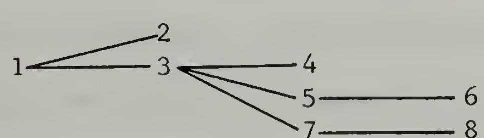
VIII.

1. (BECAUSE, @ , $)
2. (FELL DOWN, CLEOPATRA) = @
3. (TRUST, CLEOPATRA, FIGURES) = $
4. (FOOLISH, TRUST)
5. (FICKLE, FIGURES
6. (POLITICAL, FIGURES)
7. (PART OF, FIGURES, WORLD)
8. (ROMAN, WORLD)

Coherence Graphs

I.

VIII.



tions 2, 3 and 4 in sentence I and propositions 6 and 8 in sentence VIII would be considered subordinate propositions.

Kintsch and Keenan (1973) assessed reading difficulty using reading time and the proportion of correctly recalled propositions as a function of the number of propositions in the text. They found reading time increased as the number of text propositions increased. If subjects increased their reading time, the number of propositions recalled increased with an increase in the number of propositions in the text. However, with restricted time to read text, the number of propositions recalled remained constant when reading text with increasing propositions. Although the proportion of recalled propositions declined with an increase in the number of propositions per sentence (for restricted and unrestricted time conditions), the restricted time condition resulted in significantly poorer recall performance compared to the unrestricted reading time condition. Kintsch and Keenan (1973) also found that the mean proportion of superordinate propositions recalled was significantly higher than the mean proportion of subordinate propositions recalled.

In summary, Kintsch and Keenan (1973) demonstrated that an increase in the number of propositions per sentence increased text difficulty. They also provided evidence that propositional recall was related to reading time and that subordinate propositions are more difficult to recall compared to superordinate propositions.

Kintsch, Kozminsky, Streby, McKoon, and Keenan (1975) extended the research of Kintsch and Keenan (1973) by assessing whether the number of new arguments in text affected recall performance. Text

with many arguments was compared with text with few arguments. Table 5 gives an example of text which has either many arguments or few arguments. Kintsch et al. (1975) had college subjects read text with a short or long text base (short text bases consist of few propositions, while long text bases consist of many propositions). Within the short or long text base passages, propositions had either few repeated arguments or many different arguments. Therefore, Kintsch et al. (1975) assessed whether recall performance was affected by argument repetition, with the number of propositions in the text held constant. They found mean reading time was significantly greater for text with new arguments compared to the mean reading time for text with repeated arguments, suggesting the repeated argument text required less processing time compared to the amount of processing time required with the new argument text. There were no significant differences in the mean number of propositions recalled in the two conditions, although the absolute mean number of propositions recalled was lower for the new argument text.

Kintsch et al. (1975) provided additional support for the two major hypotheses from Kintsch and Keenan (1973): 1) reading time increased with an increase in the number of propositions in text, and 2) mean recall of superordinate propositions is significantly higher than mean recall of subordinate propositions.

A more recent study by Vipond (1980) investigated a considerably larger array of text structure variables than Kintsch and Keenan (1973) or Kintsch et al. (1975). Vipond (1980) assessed the extent to which microstructure and macrostructure text variables (derived from the

TABLE 5

Text from Kintsch et al. (1975) Illustrating Few or Many Arguments in Text Base with Similar Word Length

Text Base with Few Different Arguments

Text: The Greeks loved beautiful art. When the Romans conquered the Greeks, they copied them, and, thus, learned to create beautiful art.

1. (LOVE, GREEK ART)
2. (BEAUTIFUL, ART)
3. (CONQUER, ROMAN, GREEK)
4. (COPY, ROMAN, GREEK)
5. (WHEN, 3, 4)
6. (LEARN, ROMAN, 8)
7. (CONSEQUENCE, 3, 6)
8. (CREATE, ROMAN, 2)

Text Base with Many Different Arguments

Text: The Babylonians built a beautiful garden on a hill. They planted lovely flowers, constructed fountains and designed a pavilion for the queen's pleasure.

1. (BUILD, BABYLONIAN, GARDEN)
2. (BEAUTIFUL, GARDEN)
3. (LOCATION: ON, GARDEN, HILL)
4. (PLANT, BABYLONIAN, FLOWER)
5. (LOVELY, FLOWER)
6. (CONSTRUCT, BABYLONIAN, FOUNTAIN)
7. (DESIGN, BABYLONIAN, PAVILION, 8)
8. (HAS, QUEEN, PLEASURE)

Kintsch and van Dijk (1978) model of reading comprehension) accounted for reading performance. Vipond (1980) had college students read 25 non-fiction texts. The experiment extended research done by Kintsch and Vipond (1979) and Kintsch and van Dijk (1978). Kintsch and Vipond (1979) found that a comprehension index derived from theoretically relevant microstructure and macrostructure variables predicted the rank order of reading comprehension performance from four short texts better than a prediction based upon readability formulas. Kintsch and van Dijk (1978) provided a model for predicting estimates of the size of a STM buffer, the input size of propositions, and the number of cycles per text. The Kintsch and van Dijk (1978) model successfully predicted the probability of recalling a short paragraph. Vipond (1980) extended the previous research by utilizing a larger set of text and assessing the relationship between microstructure and macrostructure text variables in accounting for reading performance.

Table 6 lists the 5 microstructure and 5 macrostructure variables from Vipond (1980). Vipond (1980) determined values for each variable for the 25 texts in the following manner. Each text was analysed to derive a text base and a series of coherence graphs. (Table 4 illustrated text bases and the initial coherence graph for text used in Kintsch and Keenan (1973).) Vipond (1980) developed the series of coherence graphs based upon the Kintsch and van Dijk (1978) argument that reading comprehension processing occurs in cycles, with a set STM buffer size and a set propositional input size. Therefore, Vipond (1980) drew coherence graphs for each cycle. The number of cycles for the 25 texts ranged from 14 to 22. Once coherence graphs were drawn,

TABLE 6

Correlations Reported by Vipond (1980) between Microstructure and Macrostructure Variables and Microcomprehension and Macrocomprehension Efficiency

	Microcomprehension	Macrocomprehension
Microstructure Variables		
Reinstatements[a]	.437*	.459**
Propositions reinstated[a]	.521**	.579***
Maximum breadth of processing	.503**	.568**
Required inferences[a]	.221	.048
Reorganizations	-.021	.163
Macrostructure Variables		
Reinstatements[a]	.481**	.535**
Propositions reinstated	.487**	.576***
Maximum breadth of processing	.072	.243
Required inferences[a]	.041	.124
Reorganizations	.217	.247

[a]processing per cycle.

[b]processing per 100 propositions.

*$p < .05$
**$p < .01$
***$p < .001$

the Kintsch and van Dijk (1978) model predicted values for the number of reinstatements, the number of propositions per reinstatement, and the number of inferences for each text. Vipond (1980) defined maximum breadth of processing as the maximum number of levels in a coherence graph. Reorganizations were estimated by assessing whether the level of propositions of the final text base which is constructed through the processing cycles differs from the ideal text base. The ideal text base is constructed without memory limitations. The macro-variables were derived in a similar manner as the microvariables.

Vipond (1980) analysed the recall protocols of college readers as a function of reading time, using microcomprehension and macro-comprehension efficiency as dependent variables. Microcomprehension efficiency was the mean reading time per syllable divided by the mean micropropositional recall. Macrocomprehension efficiency was mean reading time per syllable divided by mean macropropositional recall. (Higher numbers indicate comprehension difficulty.) These scores were then correlated with the 10 predictor variables representing text structure, and analysed with stepwise multiple regression. Table 6 shows the matrix of statistically significant correlations between text structure variables and microcomprehension and macrocomprehension efficiency. Reinstatements, the number of propositions reinstated, and breadth of processing are positively associated with recall performance. Table 7 shows the stepwise multiple regression analysis by dependent variable by order of entry into the regression equation and the amount of reading efficiency variancy accounted for. Table 7 clearly shows that a combination of microstructure variables and

TABLE 7

Amount of Microcomprehension and Macrocomprehension Efficiency Explained by Text Variables in Stepwise Multiple Regression[a]

Step	Variable	Amount of Variance Explained (R^2)
Microcomprehension Efficiency		
1.	Micropropositions reinstated	27%
2.	Macropropositions reinstated	53%
3.	Breadth of macroprocessing	65%
4.	Microinferences	76%
Macrocomprehension Efficiency		
1.	Micropropositions reinstated	34%
2.	Breadth of macroprocessing	70%

[a]Table was reported in Vipond (1980).

macrostructure variables are needed to account for reading performance.

Vipond (1980) conducted another multiple regression analysis using the same data, but established separate sets of microvariables or macrovariables. The subjects were assigned to less skilled and more skilled reading ability groups. Skill level was determined by performance on the Davis Reading Test (comprehension scale). Grouping by reading ability indicated that microstructure variables were better predictors of less skilled reader performance and macrostructure variables were better predictors of more skilled reader performance. Vipond (1980) suggested poorer readers may be more sensitive to microstructure variables than to good readers, because good readers may process microstructure variables automatically, and therefore be less affected by structural variation.

Vipond's (1980) research provided strong support for the Kintsch and van Dijk (1978) model of reading comprehension. Vipond (1980) and Kintsch and van Dijk (1978) expanded the type of variables which contribute to identifying passage difficulty level. Whereas Kintsch and Keenan (1973) and Kintsch et al. (1975) did not estimate reader or memory characteristics, Vipond (1980) provided evidence that a variable such as reinstatements was an appropriate variable to consider in predicting reading performance.

In summary, the three experiments which followed the Kintsch perspective of reading comprehension have provided evidence of several text structure variables associated with passage difficulty. Kintsch and Keenan (1973) and Kintsch et al. (1975) found an increase in the

number of propositions per sentence increased reading time. Both experiments found evidence that mean recall of superordinate propositions was higher than mean recall of subordinate propositions. Kintsch et al. (1975) also reported that an increase in new arguments increased reading time. Finally, Vipond (1980) provided support for the following arguments: 1) the difficulty of text increases with an increase in the number of reinstatements, an increase in the number of propositions per reinstatement, and the number of coherence graph levels of a text; 2) microvariables and macrovariables contribute together to account for reading comprehension efficiency of heterogenous samples of readers; and 3) less skilled reader performance is affected by microvariables whereas more skilled reader performance is affected by macrovariables.

The research cited above supports the assumption that variation in microstructure of text is associated with variation in reading performance. This suggests that analysing text microstructure is a valid method of identifying certain structural factors which affect reading peformance.

This section of the chapter has described microstructure of text which is often cited in research investigating reading comprehension performance. To clearly identify the hypothetical relationships between working memory during reading and text microstructure, the next section of the chapter describes basic assumptions about memory structures and assumptions regarding the processing of micro-propositions during reading comprehension.

Processing micropropositions

Research investigating reading comprehension or reading recall performance (see Kintsch, 1974; Vipond, 1980; Spilich, Vesonder, Chiesi, & Voss, 1979; Meyer, Brant, & Bluth, 1980) is often based upon certain assumptions about memory structures and cognitive processing during reading and recall. This section of the chapter organizes these assumptions into two "sets" of assumptions. The first set of assumptions addresses how a limited capacity STM system presumably processes an extensive network of micropropositions. The second set of assumptions describe how connections may be made between micro-propositions in generating a coherent text message.

The first set of assumptions stem from the assertion that a limited capacity STM system is unable to retain all of the propositions derived from a text and then process the propositions simultaneously. There is considerable evidence that the STM system cannot retain unrehearsed units (such as unrelated words) for more than a few seconds (see Baddeley, 1976). Although a meaningful string of words may be retained in STM longer than unrelated words, most researchers also assume the STM system has a limited capacity for retaining text propositions. In order to describe the processing system, Kintsch and van Dijk (1978) have adopted the concept of a limited capacity STM buffer. A STM system with a limited capacity buffer was previously described by Atkinson and Shiffrin (1968).

Kintsch and van Dijk (1978) also suggest that propositions are processed in cycles. The first part of the cycle is deriving propositions by decoding the text and placing these input propositions in the

STM buffer. Kintsch and van Dijk (1978) suggest that propositions are processed systematically according to a strategy which maintains important and recent propositions to be processed in the STM buffer. Kintsch and van Dijk (1978) termed this selection process the "leading edge strategy". (The term leading edge refers to the position of propositions on the edge of coherence graphs in the Kintsch (1974) notation system.) The second part of the cycle consists of interrelating propositions from previous sentences with new input propositions. When the limited capacity STM buffer is full, propositions are passed on to LTM. The third part of the cycle is the interaction of STM propositions with propositions in the LTM system.

Kintsch's description of a limited capacity STM buffer filled with propositions may imply a STM system consisting of slot capacity rather than functional capacity. Kintsch and van Dijk (1978) do not address the distinction drawn in Chapter I between functional and slot capacity. Kintsch and van Dijk utilized a computer simulation model of STM buffer size which retained 4 to 5 propositions during each processing cycle. Therefore, a working memory system operating at optimal capacity could not retain more than 5 propositions.

In contrast to the computer model, the concept of functional capacity suggests the number of propositions maintained in working memory may vary between readers. Nevertheless, there still is an upper limit to the effectiveness of processing propositions in working memory. A "full" STM buffer may refer to a STM system which is operating with maximal processing resources. At this maximal level, additional demands would presumably interfere with processing of

propositions currently in working memory.

If propositions are only retained temporarily in a STM buffer, the cognitive system must have some means for establishing the coherence of a text message across sentence boundaries. Therefore, the second set of assumptions address the theoretical processes which account for connections between micropropositions. Kintsch and van Dijk (1978) suggest there are propositions residing in the STM buffer and propositions which are being "input" into the STM buffer from the immediate decoding of text. If there is argument overlap between input propositions and propositions already in the buffer, Kintsch and van Dijk (1978) contend there is an automatic semantic connection, or coherence in the text base. However, if input propositions do not have an automatic connection with the buffer propositions, two different processes may be used to establish semantic coherence: 1) searching LTM for previous text derived propositions and 2) generating inferences.

Kintsch and van Dijk (1978) label the process of searching LTM for previous text derived propositions a "reinstatemnet search". Reinstatement searches presumably place propositions in the STM buffer to establish coherence. Vipond (1980) has demonstrated that variables assessing micropropositional and macropropositional reinstatement searches accounted for 53% of the variance in reading recall performance, a reading efficiency variable which was a function of reading time and the mean number of reproduced propositions on recall protocols.

As indicated above, Kintsch and van Dijk (1978) and Vipond (1980)

have addressed the assumptions about memory processes and text structure during reading comprehension. The next section of this chapter presents research which has investigated Kintsch's (1974) text structure variables associated with reading comprehension performance. This provides a foundation for identifying text structure variables which may account for reading performance differences of readers with good or poor working memory.

The previous two sections of this chapter have presented a substantial amount of evidence that reading comprehension performance is affected by variation in the semantic structure of text. Chapter I reviewed research which supported the argument that individual differences in working memory affects reading comprehension. The issue to investigate further is whether readers with individual differences in working memory exhibit significant differences in reading comprehension performance as a function of text microstructure. The next section of this chapter suggests several semantic variables which may interact with working memory differences resulting in variation in reading comprehension performance.

Differences in Reading Comprehension Performance Due to Semantic Structure of Text Interacting with Individual Differences in Working Memory

While previous sections of this chapter have been grounded in experimental research, there is no research which has specifically investigated the relationship between individual differences in working memory and text processing. However, there are two plausible ways in which individual differences in working memory may affect

reading comprehension of text which vary in microstructure.

The Kintsch and van Dijk (1978) theory of reading comprehension suggests that propositions are input into a STM buffer. They also contend the coherence of a text is closely related to the argument overlap of the propositions in the STM buffer. Therefore, one way that individual differences in working memory may affect reading comprehension is if readers with poor working memory are less proficient in holding propositions in the STM buffer. Perfetti and Goldman (1976) found that poorer readers were less able to report target words from text which had an intervening clause or sentence boundary between the target word and the recall point. The difficulties could arise if input propositions are not retained in the buffer when new "unconnected" propositions are processed. According to Kintsch and van Dijk (1978), when argument overlap does not occur automatically, the reader must either search LTM for previously input propositions or generate inferences to establish coherence. In either case, the reader presumably must expend additional cognitive resources compared to the reader with a more efficient working memory who may process the propositions automatically. This difference between readers may be evident in text which vary in number of propositions and argument overlap.

A second way in which individual differences in working memory may affect text processing is related to the degree to which text microstructure is explicit. One example of variation in the explicitness of text microstructure was the with-signal and without-signal experiment by Britton et al. (1982) reviewed in Chapter I. Readers

used less cognitive capacity when reading text with signal words compared to text without signal words.

Readers with poor working memory may have relatively more difficulty comprehending the without-signal text compared to readers with good working memory. A text without signals may require retaining more input propositions and generating relatively more retrieval searches or inferences to establish the semantic coherence of the text.

CHAPTER III

AN INVESTIGATION OF READING COMPREHENSION PERFORMANCE AS A FUNCTION OF INDIVIDUAL DIFFERENCES IN WORKING MEMORY FOR TEXT OF VARYING READING DIFFICULTY

In its most general form, the experiment in this dissertation assesses whether reading comprehension performance varied as a function of individual differences in working memory when subjects read text which vary in reading difficulty. The experiment had fourth grade subjects read six passages and then respond to a reading comprehension task called the sentence verification technique (SVT). Two of the passages were written to be of easy reading difficulty, two of moderate difficulty, and two of greater difficulty. The experiment also assessed the working memory of each student.

This chapter extends the research presented in Chapters I and II. A brief review of the arguments presented in those chapters will clarify the line of reasoning leading to the experiment. Chapter I presented the argument that working memory is a valid construct to investigate to identify individual differences in reading performance. Working memory was defined as active processing of stimuli by the short term memory (STM) system. Three methods have been used to assess working memory during the reading of texts: the memory span task, the probe memory task, and the cognitive capacity task. Having examined the research which utilized these three tasks in some detail, the following comments relate to the decision of how to assess working memory in the experiment.

The memory span task used by Daneman and Carpenter (1980) required

readers to recall final words of sentences. The experimenter increased the number of sentences in a set and therefore increased the demands upon recall. Even though Daneman and Carpenter (1980) found a high positive correlation between performance on the memory span task and performance on factual and pronominal reference questions, further research is needed. This research is necessary because there was little evidence provided by Daneman and Carpenter (1980) supporting the interpretation that one factual and one pronominal reference question per passage (with a mean length of 140 words per text) are valid measures of reading comprehension of the entire passage. Evidence is needed to establish the association between memory span and reading comprehension. This research might investigate the association between memory span performance and performance on more conventional tasks assessing reading comprehension (e.g., free recall, norm referenced reading comprehension tests, etc.).

The cognitive capacity task used by Britton and his colleagues (Britton, Piha, Davis & Wehausen, 1978; Britton, Westbrook, & Holdredge, 1978; and Britton, Glynn, Meyer, & Penland, 1982) assessed STM cognitive capacity during reading by collecting reaction time data to a secondary task (the time to remove one's hand from a telegraph key having heard a click). If working memory is considered active processing of stimuli by the STM system, this task may be sensitive to differences in working memory capacity. While the research cited above usually found evidence that more cognitive capacity is used for processing difficult text compared to less difficult text (varying vocabulary, syntax and signal words), reaction

time to respond to a click may not be reliable given certain text. Britton, Westbrook, and Holdredge (1978) found the counterintuitive pattern that mean reaction time to respond to a click while reading easy passages was slower than mean reaction time to respond to a click while reading the more difficult passages. Given the experiment presented here, the cognitive task technique of measuring working memory capacity may be an inappropriate index of individual differences in working memory.

The memory probe task used by Perfetti and Goldman (1976) assessed working memory by having subjects listen to a text. Having heard part of the text, subjects were given a probe word from the text and asked to report the text word which followed the probe word. Working memory performance was the proportion of correctly recalled target words. Perfetti and Goldman (1976) found that good and poor third and fifth grade readers varied significantly in their working memory performance. They also found that poorer readers were less proficient in recalling target words if there was a clause or a sentence boundary between the probe word and the recall point. This suggests that poorer readers may have difficulty in maintaining words or propositions in a STM buffer. If the probe memory task is sensitive to individual differences in maintaining propositions in a STM buffer, it may be a valid method of identifying individual differences in working memory in the dissertation experiment.

Chapter II reviewed the Kintsch (1974) system of identifying the semantic structure of text and research evidence supporting the Kintsch and van Dijk (1978) theory of reading comprehension. Much of

this research has investigated microstructure variables which account for differences in reading comprehension performance. Reading comprehension performance is usually assessed by the proportion of correctly recalled propositions in recall protocols. Kintsch and Keenan (1973) and Kintsch, Kozminsky, Streby, McKoon and Keenan (1975) found that reading performance declined with an increase in the number of propositions in text. They also found that mean recall of superordinate propositions was higher than mean recall of subordinate propositions. Kintsch et al. (1975) reported that reading time increased with an increase in new arguments. Vipond (1980) conducted an extensive experiment assessing micro and macroprocesses in text comprehension. He found support for the following arguments: 1) The difficulty of text increases with an increase in the number of reinstatements and an increase in the number of propositions per reinstatement. Reinstatements require propositions to be recalled from long term memory to the STM buffer. 2) Microvariables and macrovariables contribute together to account for reading comprehension efficiency with heterogenous samples of readers. 3) Less skilled reader performance is affected by microvariables whereas more skilled reader performance is affected by macrovariables.

The research investigating reading comprehension as a function of text structure may relate particularly well to research investigating individual differences in working memory. Kintsch and van Dijk (1978) suggest that reading comprehension performance is closely related to the reader's ability to establish propositional coherence through the STM system. Therefore (as described in greater detail in Chapter II),

it seems reasonable that readers with poor working memory would have relatively greater reading comprehension difficulties compared to readers with good working memory when they read text with an increasing number of propositions or relatively more arguments per proposition.

The experiment to be reported extended previous research investigating the relationship between working memory performance and reading comprehension in three ways. First, the experiment investigated whether reading comprehension performance varies as a function of individual differences in working memory when readers read text varying in reading difficulty. Second, the experiment investigated whether reading comprehension performance of good and poor working memory readers varies as a function of text microstructure. Third, the experiment utilized the SVT technique to assess reading comprehension.

Previous research investigating working memory and reading passages of varying difficulty assessed working memory capacity (cf. Britton, Westbrook, & Holdgedge, 1978), but did not assess reading comprehension performance. The dissertation experiment extended previous research by utilizing a probe memory task of working memory performance to assess individual differences in working memory, and assessed the relationship between working memory and reading comprehension.

The second difference from previous research is the experiment assessed the association between working memory performance and reading comprehension of sentences which vary in text microstruc-

ture. Therefore, this experiment stems from the Kintsch and Keenan (1973) study which found an increase in reading time when subjects read text with increasing numbers of propositions per sentence. However, the experiment extended this research by relating working memory performance with reading comprehension performance as a function of variation in several text structure variables which are theoretically related to working memory during reading comprehension.

The third extension from previous research was that the experiment utilized the sentence verification technique (SVT) to assess reading comprehension. Reading performance data using the SVT is used in two ways: 1) normative SVT data contributed to the selection of easy, moderate and difficult text, and 2) the subjects responded to a SVT having read a text.

Other research which has assessed reading performance with passages of varying difficulty levels has used conventional methods of assessing reading difficulty levels. Britton et al. (1978) selected passages on the basis of cloze test performance. However, there is evidence that cloze test scores are more associated with syntactic predictability than reading comprehension (see Shanahan, Kamil, & Tobin, 1982; Leys, Fielding, Herman, & Pearson, 1983; Tuiman, 1973, 1974; Tuiman & Gray, 1972; Carroll, 1972). Researchers often assess reading comprehension by using reading scores derived from norm referenced reading comprehension tests (cf. Perfetti & Goldman, 1976). Norm referenced reading comprehension tests often assess reading comprehension with multiple choice test items. Examinees must read text which consists of a passage portion and a question and response

portion. However, Drum, Calfee, and Cook (1981) found norm referenced reading comprehension test performance was more highly associated with text structure characteristics of the questions and reponses of multiple-choice test items compared to text structure characteristics of the passage. Given the problems with conventional methods of measuring reading comprehension, and the growing body of evidence suggesting that the SVT is a valid method of measuring reading comprehension (Royer, 1984), the SVT was selected as the most appropriate method of assessing reading comprehension performance.

The SVT consists of four test sentences. The four test sentences are original, paraphrase, meaning change, and distractor. Each test sentence is based upon a sentence in a text. An example of these sentence types from a passage about trapping wolves is shown in Table 8. Original sentences are exactly the same as sentences from the passage. Paraphrase sentences are constructed to express the same meaning as a passage sentence, but with different words. Meaning change sentences have one or two words changed from the original sentence altering the meaning of the sentence. Distractor sentences are constructed to be consistent with the general theme of the text, and they have a similar syntactic structure and word length as the original sentence, but the meaning of the distractor sentence is unrelated to the text sentence.

The administration of a SVT consists of subjects reading or listening to a passage and then responding to a set of test sentences. The subject's task is to decide whether a test sentence has the same meaning or a different meaning from the original text sentence.

TABLE 8

An Example of Sentence Verfication Technique
Test Sentences from Royer and Cunningham (1981)

Original:	But morning after morning as I rode forth to learn the result, I found that all my efforts had been useless.
Paraphrase:	But day after day at early sunrise as I went forth to discover the outcome, I learned that all of my attempts had failed.
Meaning Change:	On morning after morning as I rode forth to learn the result, I found that all my efforts had been successful.
Distractor:	The cowboys and I traveled the length and breadth of the great mesa, but our prey always avoided us.

Sentences with the same meaning should be marked "old" while sentences with changed meaning should be marked "new". Therefore, original and paraphrase test sentences are considered old sentences and meaning change or distractor sentences are new sentences.

Royer, Hastings, and Hook (1979) conducted two studies which provided results consistent with the interpretation that the SVT was measuring reading comprehension. In their first experiment, Royer et al. (1979) had fifth and sixth grade subjects read text which were assessed at readability levels two grade levels below, on grade level, and two grade levels above the reading level of the subjects. SVT performance declined with increasing difficulty of text and sixth grade readers scored higher than fifth grade readers. In their second experiment, Royer et al. (1979) replicated the first study, but used fourth and sixth grade subjects. This design allowed SVT performance on the same text to be compared across grade levels. Passages which were on grade level for fourth grade subjects were below grade level for the sixth grade subjects. In a similar manner, below grade level passages for sixth grade subjects were on grade level for fourth grade subjects. Royer et al. (1979) replicated the text difficulty effect of the first study, and also found sixth grade subjects had higher mean SVT scores when both groups read the same text.

A more recent study by Royer, Kulhavy, Lee, and Peterson (1983) found evidence that the SVT is a valid method of measuring both reading and listening comprehension. Royer et al. (1983) is particularly relevant to this dissertation because the experimental text was selected from the same set of materials. Royer et al. (1983) was

designed to investigate the unitary process theory of reading comprehension. The unitary process theory describes reading comprehension as a special case of more general language comprehension (see Carroll, 1977; Danks, 1980; Klienman & Schallert, 1978; Sticht, Beck, Hanke, Kleiman & James, 1974). The theory suggests that listening comprehension places an upper limit on reading comprehension, and that the relative difference between listening and reading comprehension would vary with reading skill development.

Royer et al. (1983) used SVTs to measure both listening and reading comprehension on the same passages. Fourth and sixth grade subjects read and listened to increasingly difficult text: (third, fifth and seventh grade readability levels). Both listening and reading comprehension performance declined with an increase in text difficulty level. Moreover, as predicted by unitary process theory, the decline in reading comprehension performance was more precipitous than the decline in reading comprehension performance as passage difficulty increased. Royer et al. (1983) also found that the point of precipitous decline was earlier (i.e., at an easier level text) for fourth grade readers compared to sixth grade readers.

The research by Royer, Hastings and Hook (1979) and Royer, Kulhavy, Lee, and Peterson (1983) supports the interpretation that the SVT is a valid method of measuring the reading difficulty levels of text as well as assessing reading comprehension.
These two studies have been reviewed here since both assessed the reading performance of elementary school readers. Several other studies which used college readers have found additional construct

validity evidence which is relevant to the experiment. Royer, Lynch, Hambleton, and Bulgarelli (in press) conducted four experiments, two of which are particularly relevant to the experiment to be reported. In their first study, graduate students in psychology, undergraduate students with little psychology education (labeled "naive") and undergraduate students with considerable psychology education ("advanced") read psychology and non psychology passages. Five Kintsch text microstructure variables were computed for each sentence of each passage. Then a correlational analysis was conducted between mean SVT proportion correct per sentence and the Kintsch text microstructure variables. Naive undergraduate reading comprehension performance was significantly correlated with propositional density (the number of propositions in a sentence divided by the number of words) and serial position of a text sentence. The same analysis using the mean SVT scores of the advanced undergraduates indicated no significant correlations between reading comprehension performance and text microstructure.

The third study in Royer et al. (in press) extended the investigation of the relationship between Kintsch text variables and SVT performance. Text was selected from the first study which represented good, moderate, and poor Kintsch coherence indices, where degree of coherence referred to a more comprehensible text according to Kintsch (1974) and Kintsch and van Dijk (1978). The good and poor passages were rewritten to alter the microstructure of text, creating very good and very poor passages. Although the passages were altered, the manipulation only resulted in subtle changes between the good and very

good passage or the poor and the very poor passage. The moderate passage was not rewritten. A group of naive undergraduate psychology students read either a set of good, moderate or poor passages or a set consisting of the very good, moderate or very poor passages. After reading each passage, subjects responded to SVTs. The mean proportion correct SVT performance was significantly higher for the passages with relatively good Kintsch coherence indices compared to SVT performance on passages with relatively poor Kintsch coherence indices. Also, performance improved on the very good passages compared to the good passage and SVT performance on the very poor passage was lower than the poor passage.

The two studies in Royer et al. (in press) presented evidence that reading comprehension of subjects with less knowledge in a content area is more affected by propositional density of text and alteration of text microstructure compared to readers with more expertise in a particular area of knowledge. If the naive subjects were considered poor readers and the advanced subjects were considered good readers, this research complements Vipond's (1980) study. Vipond (1980) found that reading comprehension performance of poor readers was associated with variation in microstructure while good reader performance was not associated with variation in microstructure.

Recent research by Royer and Hambleton (1983) has identified a set of passages which vary in reading difficulty level. Royer and Hambleton (1983) conducted a norming study assessing SVT performance of 1100 urban school students from grades 3 to 8. The subjects in this study read six passages, responding to a SVT after reading each

passage. The passages and SVTs were arranged in test booklets consisting of passages of easy, moderate and difficult reading levels according to a Dall-Chall readability analysis. Each subject read two passages which were one readability level below their grade level, two passages of the same readability level as their grade, and two passages one readability level above their grade. For example, fifth grade students were tested with booklets consisting of passages with readability level indices of grades 4, 5, and 6. This norming study provided SVT performance indices on passages suggesting which passages were relatively easy, moderate and difficult reading levels for different grade levels. The Royer and Hambleton (1983) study also provided item analysis data of the SVT test items.

In summary, there is considerable evidence that the SVT is a valid method of measuring reading comprehension as well as assessing the difficulty level of text. The research of Royer et al. (1983) suggests that reading comprehension performance as measured by the SVT may be sensitive to variation in text microstructure. The dissertation experiment assessed variation in reading comprehension as a function of text microstructure as one factor related to difficulty levels of text.

Description of the Experiment

As mentioned at the beginning of this chapter, the experiment had fourth grade subjects read two easy, two moderate, and two difficult passages. After reading each passage, the students responded to SVTs. Working memory performance was assessed by using a probe memory task

similar to that reported in Perfetti and Goldman (1976). Therefore, the experiment allowed a comparison of reading comprehension performance on passages of varying difficulty level as a function of individual differences in working memory performance.

Given this design and the previous research suggesting a relationship between working memory and reading comprehension, two hypotheses were investigated in the experiment. The first hypothesis was that reading comprehension performance as measured by the SVT should decline more precipitously as difficulty increases for the poor working memory subjects compared to the good working memory subjects. The second hypothesis was SVT performance of poor working memory readers would be highly influenced by variation in text microstructure. In comparison, SVT performance of good working memory readers would not be influenced by text microstructure.

The prediction that poor working memory readers would be more influenced by text microstructure than good working memory readers stems from research presented earlier in the dissertation. Vipond (1980) and Royer, Lynch, Hambleton, and Bulgarelli (in press) found poor readers reading comprehension performance was more highly associated with text microstructure than the reading comprehension performance of good readers. Other research (Perfetti & Lesgold, 1977; Perfetti & Goldman, 1976; Daneman & Carpenter, 1980) suggested differences in reading comprehension performance of good and poor working memory readers were due to differences in functional working memory during reading comprehension. This research argued good working memory readers utilized their STM system more efficiently during

reading comprehension than poor working memory readers. Since readers presumably have greater cognitive demands upon their working memory as text difficulty increases (cf. Britton et al., 1978), the experiment predicted the poor working memory readers would have relatively poorer reading comprehension performance compared to good working memory readers.

CHAPTER IV

METHOD

Subjects and Design

Fifty seven fourth grade students participated in the experiment. The subjects were from two schools (four classrooms) in a small Maine town. Each subject participated in two one hour sessions. In the first session, subjects read two easy passages, two moderately difficult passages, and two difficult passages. Reading time and SVT for each performance was collected for each passage. In the second session, subjects responded to the working memory test and the digit probe test. Subjects were divided into good and poor working memory groups according to their performance on the working memory test. Good working memory reading comprehension performance was compared to poor working memory reading comprehension performance across easy, moderate and difficult passages.

The between subject factor in the design was working memory group. Within subject factors were reading difficulty levels, passage, and SVT item type. There were two passages at each of the reading difficulty levels, and four item types (original, paraphrase, meaning change, and distractor) for each passage. Passage was nested within reading difficulty level, and passage was assessed with the four different SVT item types.

Materials and Test Items

The materials in the experiment were passage with SVT test items,

sentences used for the working memory test, and digit probe task items. The materials are reproduced in the Appendix.

Passages

The passages in the experiment were selected from a larger set of passages which had been used in a study by Royer and Hambleton (1983). Royer and Hambleton (1983) constructed passages which varied in readability levels, using the Dale-Chall readability formula. Each passage consisted of twelve sentences. The passages were written to represent common experiences for elementary school students. The titles of the passages reflect this property: "Billy washed his father's car"; "Sally's black cat was missing"; "Grandma tells a story about Tim's mother"; "Kevin wants a dog"; "Ginny was tempted to steal a doll that has been promised to her but not given"; "Roberta doesn't want to go to camp."

SVTs were written for each of the passages, and normative SVT performance data was collected from several large urban school districts. The passages that were used in this study met two criteria: 1) The data collected by Royer and Hambleton (1983) indicated they varied in difficulty as indicated by proportion correct SVT performance, 2) There were two passages at approximately grade three readability level, two at grade five readability level, and two at grade seven readability level. The difference in readability levels provided the basis for the labels of easy, moderate, and difficult reading level passages.

Identifying text structure

Each of the passages was analysed to identify text structure variables which have been previously shown to be related to reading comprehension performance. Text structure variables were identified for each sentence of each passage, yielding 72 sets of indices across the six passages.

Both surface structure and semantic structure variables were identified for each passage. Surface structure variables were: 1) the number of words, 2) mean word length, and 3) the proportion of unfamiliar words to the total number of words per sentence. Unfamiliar words were defined as words not listed in the Clarence R. Stone Revision of the Dale List of 769 Easy Words. Klare (1974-1975) suggested this list was appropriate for identifying readability levels of elementary school text. The semantic structure variables were identified by conducting a Kintsch text analysis of each passage.

Kintsch text analysis

Each sentence was analysed for text microstructure according to the Kintsch system of semantic structure analysis specified by Turner and Green (1977). This process involved constructing a list of text propositions for each sentence. Kintsch (1974) refers to the list as the text base. Using the text base, coherence graphs were constructed identifying propositional connections within the same sentence and with earlier sentences in the passage. This procedure has been used by other researchers assessing semantic structure of text and reading comprehension (see Kintsch, et al. in Chapter II). The Kintsch

analysis identified the following variables: 1) the number of propositions per sentence, 2) propositional density (the number of propositions divided by the number of words), 2) propositions per clause (the number of propositions divided by the number of independent and dependent clauses per sentence), 4) redundancy (the number of repeated arguments plus embedded propositions divided by the total number of arguments per sentence), 5) intersentence connections (the number of repetitions of arguments from the previous sentences), 6) coherence graph levels (the number of coherence graph columns required to represent a sentence) and 7) serial position of the sentence in the passage.

While both the surface structure variables and the semantic structure variables may be related to reading performance, several variables are theoretically related to working memory processing during reading comprehension. As described previously, the Kintsch and van Dijk (1978) theory of reading comprehension suggests the number of propositions, coherence graph levels, and intersentence connections are related to ability to comprehend text. Previous research suggests that reading comprehension may be related to the speed of accessing unfamiliar words in working memory (Perfetti & Lesgold, 1977) and retaining propositions in working memory across clause boundaries (Perfetti & Goldman, 1976). Therefore, the following text structure variables were considered theoretically relevant for identifying text structure features which would affect working memory during reading comprehension: propositions, intersentence connections, coherence graph levels, the proportion of unfamiliar words, and propositions

per clause.

SVT test items

The original test sentences were developed by Royer and Hambleton (1983). An examination of the SVT performance data from Royer and Hambleton (1983) indicated a few of the test sentences were poorly written. Therefore, new test sentences were written for the current experiment to replace the few poor ones. Royer and Hambleton (1983) wrote a paraphrase sentence, a meaning change sentence and a distractor sentence based upon each of the sentences in the passage. Then they selected four original, paraphrase, meaning change, and distractor sentences for the SVT test form. The next step in constructing the SVTs was to arrange the 16 test sentences according to the following rule. The first eight test items represented the first six sentences from the passage, while the second eight test sentences represented the last six sentences from the passage. The purpose of this ordering was to increase the amount of time intervening between the reading of the original text sentences and responding to the SVT test items, thereby reducing the possibility that the response to the test sentence would be based on the contents of short term memory. The final step in constructing the SVTs was to randomize the test sentences within the first six sentences and the second six sentences. The result of this procedure was a test in which the order of the test sentences did not correspond to the order of the sentences in the text.

Probe memory test stimuli

The principle hypotheses of this experiment were based upon

performance on a working memory test using sentence stimuli. In addition, a second probe memory test was administered to assess recall of digits.

Working memory test. The working memory test consisted of 36 items. The test items were either single sentences or pairs of sentences drawn from the Royer and Hambleton (1983) materials which had similar mean and standard deviation scores to those for the reading passages selected for use in the current study. Twenty-seven of the items were single sentences, with most of the items drawn from moderate and difficult reading level text. Nine of the items were pairs of sentences, with 5 of the 9 items of moderate level difficulty. The pairs of sentences were in the same order as in the original passage, which meant that the second sentence of each paired item would have semantic coherence with the first sentence in the item. The 36 items were randomly ordered on the working memory test with the restriction that no two consecutive items were drawn from the same passage.

The working memory test involved having the subjects listen to a test sentence or sentences and then recall a target word after having been told a probe word. The probe word was the word immediately prior to the target word in the sentence. The target words for the working memory test were selected in accordance with three decision rules. The first rule was to select a target word which presumably would be represented by a propositional predicate or argument in the STM system. The procedure eliminated target words such as: the, of, but, etc. The second rule was to select a target word which was relatively free from the semantic or syntactic constraint of the probe word, or previous

string of words in the sentence. For example, given the sentence "Danny hurried to school of Friday because he was going on a Field Trip.", the word "school" would be rejected as an appropriate target word because common experience might suggest the response, allowing the subject to utilize previous world knowledge rather than respond on the basis of the contents of the STM buffer. The third rule was to vary the position of the target word according to an intuitive analysis of the pilot study working memory test performance results. Since working memory performance was very high on easy level single sentence items, target words were selected from the primacy region of the sentence. In order to assess working memory performance across sentence boundaries, all of the paired sentence items had target words selected from the first of the two sentences. In effect, all of the paired sentence items will have targets from the primacy region of the item. Finally, in order to equalize the number of items with target words from the primacy region with the number of items with target words from the recency region, 3 moderate and 3 difficult single sentence items also had target words from the primacy region of the sentence.

In summary, there were 18 target words from the primacy region of the item, and 18 target words from the recency region of the item. Furthermore, target words were selected which presumably would be processed as propositions in a STM buffer, and they were relatively free from predictive knowledge effects.

Digit probe test. A digit probe test was administered to each subject to assess whether probe recall of non-verbal stimuli was

related to reading comprehension performance. An association between recall of non-verbal stimuli and reading comprehension (as well as poor performance on both the working memory task and the probe digit task) would suggest a general STM processing deficit.

The digit probe test consisted of 20 items. Each item was a string of 10 single digits randomly generated from zero to nine. No digit could be repeated within the same item. There were equal proportions of target digits in the following serial positions: 6, 7, 8 and 9. Target digits were equally represented across the test (with the exception of three 2 and 9 target digits). Probe digits were never in natural counting sequence (e.g., A probe such as 7 could not be followed by the target 8).

Procedure

All of the subjects were tested in small groups. They were tested on two days, with the SVT testing the first day, and the working memory test and digit probe test the second day.

Prior to reading the passages and responding to the SVTs, each subject read and discussed an eight page introduction with practice test items which was previously used by Royer and Hambleton (1983). After the experimenter was assured the students understood the task, the passages and SVTs were presented. Subjects received one passage and SVT at a time, and were not allowed to read the passage until everyone could start reading. The order of the passages was randomly administered within each classroom. Therefore, the order of easy, moderate and difficult text was the same for a single test session,

but varied for different test sessions.

The subjects started reading each passage at the same time. While the subjects read the passage, the experimenter showed consecutively numbered cards every five seconds. The subjects wrote the number of the card on their test booklet when they finished reading the passage.

The working memory test and the probe digit test were presented by having subjects listen to a tape recording of the test items and probes. Having heard the probe word or number, subjects wrote their responses.

CHAPTER V

RESULTS

The experiment investigated reading comprehension performance of good and poor working memory readers on passages of increasing reading difficulty. The hypothesis was that working memory subjects' reading comprehension would decline more rapidly than the reading comprehension performance of the good working memory readers with increased passage difficulty. The results section is divided into four sections. The first section presents analyses of passage text structure indicating that the passages varied in semantic text features relevant to working memory processing during comprehension. The second section describes evidence used to identify good and poor working memory subjects. The third section presents analyses of reading comprehension performance. The final section presents analyses of text structure features associated with reading comprehension performance of good and poor working memory readers.

Text Structure and Reading Comprehension

As mentioned in the materials section, each passage was analysed to identify surface structure and semantic structure variables. The text structure variables were used to investigate text factors which account for differences in reading comprehension performance of good and poor working memory readers.

Surface structure variables

Three surface structure variables were identified: 1) the

number of words per sentence, 2) mean word length per sentence, and 3) proportion of unfamiliar words to the total number of words per sentence.

Semantic text structure variables

These seven variables were identified following a Kintsch text analysis of each sentence in the six passages: 1) the number of propositions per sentence, 2) propositional density (the number of propositions divided by the number of words), 3) propositions per clause (the number of propositions divided by the number of independent and dependent clauses per sentence), 4) redundancy (the number of repeated arguments plus embedded propositions divided by the total number of arguments per sentence), 5) intersentence connections (the number of repetitions of arguments from the previous sentences), 6) coherence graph levels (the number of coherence graph columns required to represent a sentence), and 7) serial position of the sentence in the passage.

Five of these indices were selected from the larger set of text structure variables because they were theoretically related to working memory processing during reading comprehension. They were propositions, intersentence connections, coherence graph levels, the proportion of unfamiliar words, and propositions per clause. Each passage sentence was analysed to identify the five text structure scores. This provided 360 values across all the passages (12 sentences x 5 text structure variables x 6 passages). Each text structure variable related to each passage sentence was converted to

a *z* score based upon mean and standard deviation values across all the passage sentences. *Z* scores allowed direct comparisons between text structure variables at the sentence level across all passages. The *z* scores were then adjusted to a positive scale by adding a constant of 10 to each score. Table 9 presents *z* scores of both the surface structure and semantic structure variables by reading difficulty level.

A multivariate ANOVA was conducted to assess whether the following text structure variables differed significantly with an increase in reading difficulty level. The five *z* scores were analysed with a MANOVA, using reading difficulty level as the independent variable. Entering the five variables, there were significant differences in text structure across all passage difficulty levels ($F(10, 128) = 2.55$, $p < .05$), as well as between easy and difficult level passages ($F(5, 65) = 11.82$, $p < .0001$).

Univariate analyses were performed comparing the text variables across all three levels, contrasting easy to moderate level passages, and easy to difficult level passages. The univariate analysis showed propositions, intersentence connections, coherence graph levels and the proportion of unfamiliar words were significantly different across the three reading difficulty levels. Table 9 shows these variables increase with an increase in reading difficulty level. Univariate contrasts also indictated there were significant differences between easy and moderate levels of intersentence connections and coherence graph levels. The contrast between easy and difficult level passages found significant differences for each of the following: propositions,

TABLE 9

Text Structure Z Scores by Reading Difficulty Level

Text Structure Variables	Reading Difficulty Level		
	Easy	Moderate	Difficult
Words	9.59	9.89	10.52
Word length	9.70	10.08	10.22
Unfamiliar words	9.76	9.74	10.50
Propositions	9.55	10.08	10.37
Propositional density	9.88	10.42	9.70
Propositions per clause	9.89	10.06	10.05
Redundancy	9.58	10.15	10.28
Intersentence connections	9.28	9.94	10.78
Coherence graph levels	9.54	10.15	10.30

Note: Z scores were adjusted to a positive scale by adding 10 to each score.

intersentence connections, coherence graph levels, and the proportion of unfamiliar words. These analyses found the number of propositions per clause did not differ significantly between easy and moderate levels, or between easy and difficult levels. Table 10 presents the appropriate $\underline{F}$ values and probability estimates for each text variable.

Identifying Good and Poor Working Memory Readers

The experimental hypothesis required identifying readers with good and poor working memory. The criteria for selecting good and poor working memory readers was their total proportion of correct responses to the working memory test.

Working memory test performance

Subject responses to the working memory test were considered correct if the subjects' written response was clearly representative of the target word. This allowed students to misspell the target word. Omitted responses were scored as incorrect. The proportion of omitted responses in the entire sample was .048.

Before selecting good and poor working memory subjects, two analyses were done to assess the sensitivity of the working memory task. The first analysis involved calculating discrimination indices that identified items which were functioning in a different manner than the total test performance. Responses to item 9 on the working memory test were negatively correlated with the total test proportion correct scores. Therefore, item 9 data was eliminated from further analysis. The second analysis of the working memory test was to

TABLE 10

$\underline{F}$ Values from Univariate Analyses of Text Structure Differences between Reading Difficulty Levels

Text Structure	Comparisons between Reading Difficulty Levels		
	All Levels	Easy-Moderate	Easy-Difficult
Propositions	4.45*	3.64[a]	5.27*
Intersentence Connections	21.38***	8.09**	34.68***
Coherence Graph Levels	4.28*	4.90*	3.67[a]
Unfamiliar Words	5.02**	n.s.	10.04**

*$p < .05$
**$p < .01$
***$p < .001$

[a]marginally significant at $p < .06$

determine the reliability coefficient. Based upon the Kuder-Richardson (KR-20) criteria of assessing the internal consistency of a measure, the 35 item working memory test had a reliability coefficient of .82.

The selection of good and poor readers was based upon mean proportion correct scores on the 35 item working memory test. Table 11 shows the mean proportion correct frequency distribution on the working memory test. The mean proportion correct for all readers was .513. The poor working memory subjects were selected from the lower portion of the distribution with mean proportion correct less than .44. Good working memory subjects had proportion correct scores greater than .58. This selection resulted in two equal groups of 18 subjects, with each group representing 32% of the distribution. The analyses presented below were based upon these 36 subjects, having initially examined the performance of all 57 subjects. Poor working memory readers' mean working memory test performance (.314) was significantly lower than good working memory readers' mean performance (.691), $F(1, 34) = 134$, $p < .0001$.

An analysis of the mean proportion correct performance for the "average" working memory subjects (working memory scores between .44 and .58) showed their SVT test performance was consistently more accurate than the poor working memory subjects, but less accurate than the good working memory subjects. Since the hypotheses of interest compare good with poor working memory readers, the data from the average working memory readers will not be reported unless it presents an unusual pattern. The mean proportion correct SVT performance for all fourth grade subjects divided into poor, average and good working

TABLE 11

Mean Proportion Correct Working Memory Frequency Distribution

Mean Score	Frequency	Cumulative % Frequency
.03	1	1.8
.11	1	3.5
.20	1	5.3
.23	1	7.0
.26	1	8.8
.29	1	10.5
.31	2	14.0
.34	2	17.5
.37	2	21.1
.40	3	26.3
.43	3	31.6
.46	4	38.6
.49	3	43.9
.51	6	54.4
.54	3	59.6
.57	5	68.4
.60	3	73.7
.63	4	80.7
.66	2	84.2
.69	2	87.7
.71	2	91.2
.74	1	93.0
.80	2	96.5
.83	2	100.0

memory groups is reported in the Appendix.

Digit probe test performance

As previously mentioned, the digit probe test was administered to investigate whether reading comprehension performance was related to a general STM processing deficit. Responses to the digit probe test were subjected to the same analyses as the working memory test responses. All of the digit probe items were positively correlated with the total digit probe test score. However, the reliability of the digit probe test was only .32. Mean digit probe test performance across all subjects was .460. Analyzing mean digit probe test performance by selecting subjects according to their working memory test performance found good working memory readers scored significantly higher (.553) than poor working memory readers (.403), $F(1, 35) = 6.617$, $p < .05$.

A correlational analysis was conducted between mean digit probe test performance, working memory test performance, and total reading comprehension test performance. The total reading comprehension test score was mean proportion correct SVT performance across all six passages. Digit probe test performance was not significantly correlated with reading comprehension performance ($r = .20$, $p < .18$), but was correlated with working memory performance, $r = .35$, $p < .01$. Working memory test performance was signficantly correlated with total reading comprehension performance, $r = .59$, $p < .001$.

Given the poor reliability of the digit probe test scores, the lack of association between digit probe test scores, and the lack

of association between digit probe test performance and reading comprehension, the digit probe test scores were not used to identify working memory proficiency.

Reading Comprehension Performance

Reading comprehension performance was assessed with reading comprehension accuracy and reading comprehension efficiency. Reading comprehension accuracy was defined as the proportion of correct responses to the SVT test items. Reading comprehension effeciency was reading comprehension accuracy as a function of reading time (in minutes) per passage.

Repeated measure ANOVAs were used to analyse reading comprehension performance. The ANOVA design consisted of the following factors: 2 (Poor and good working memory groups) X 3 (Easy, moderate, and difficult reading difficulty levels) X 6 (Passage) x 4 (SVT test items: original, paraphrase, meaning change, and distractor). Working memory group was a between subject factor, while reading difficulty level, passage, and SVT test item were within subject factors. Passage was nested within reading difficulty level, and SVT item was nested within passage. The ANOVA of reading comprehension accuracy used all of the factors mentioned above, but the ANOVA for reading comprehension efficiency did not have the SVT test item factor.

Reading comprehension accuracy

Reading comprehension was measured by average proportion correct responses to the SVT test items. Omitted responses were considered

incorrect. The proportion of omitted responses across the six tests (96 items) was .004. The proportion of omitted responses was not significantly greater for the SVT tests taken late in the test session compared to those early in the test session.

The mean proportion correct for good and poor working memory subjects across all passages was .706. SVT performance declined significantly with an increase in reading difficulty from .770 for the easy reading level text, .714 for moderate level text, to .635 for the difficult level text ($F(2, 68) = 27.33$, $p < .0001$). Good working memory readers had much higher mean proportion correct scores across all passages (.803) compared to poor working memory readers (.610), $F(1, 34) = 37.21$, $p < .001$. Table 12 shows mean proportion correct as a function of good and poor working memory. Figure 2 depicts the same pattern as Table 12, illustrating that poor working memory reading comprehension performance declined more than the decline in reading comprehension performance of good working memory readers with an increase in reading difficulty level. The difference between good and poor working memory reader performance increased from easy (.148) to moderate (.226) and difficult (.203) reading level passages. The predicted reading level X working memory group interaction was marginally statistically significant, $F(2, 68) = 2.45$, $p < .08$.

SVT performance was also assessed for differences in accurate responses to the four SVT item types. Mean proportion correct responses varied with SVT test item: distractor (.778), original (.770), paraphrase (.661) and meaning change (.616). The mean difference as a function of SVT item type was statistically signifi-

TABLE 12

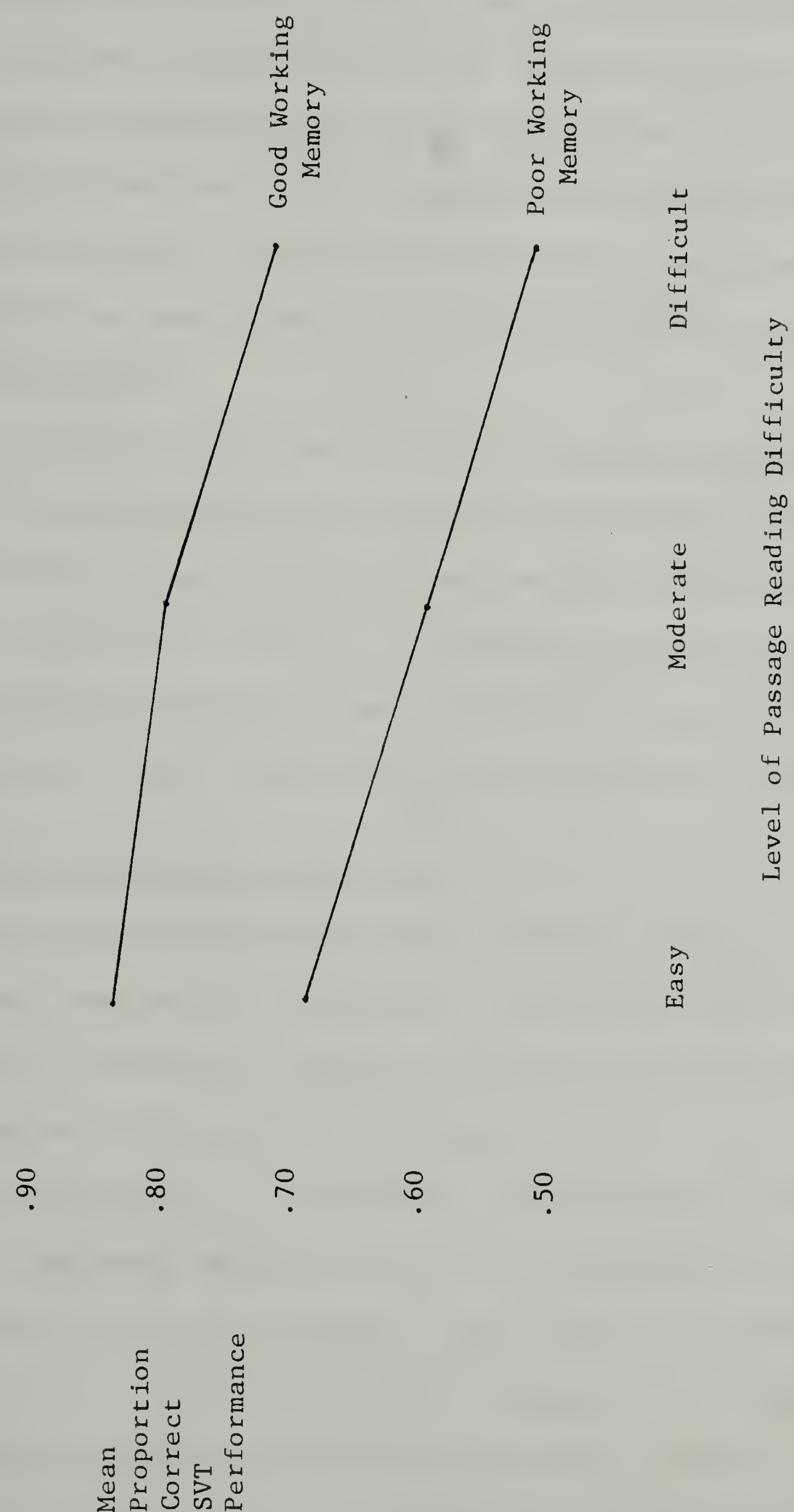
Mean SVT Proportion Correct by Level of Reading Difficulty as a Function of Working Memory

Difficulty Level	Working Memory Group	
	Poor	Good
Easy	.696	.844
Moderate	.601	.828
Difficult	.533	.736

Note: *N* = 18 for both working memory groups.

Figure 2

Mean Proportion Correct SVT Performance by Reading Difficulty Level as a Function of Working Memory.


Mean
Proportion
Correct
SVT
Performance
.90
.80
.70
.60
.50
Good Working Memory
Poor Working Memory
Easy
Moderate
Difficult
Level of Passage Reading Difficulty

cant, $F(3, 102) = 14.41$, $p < .0001$. Table 13 reports mean proportion correct by item type for good and poor working memory groups. Both groups responded more accurately to original and distractor items compared to paraphrase and meaning change items. Table 14 presents mean SVT proportion correct scores by item type across reading difficulty levels as a function of working memory performance. The complete source of variance table of reading comprehension accuracy is reported in the Appendix.

A simple effects test of SVT performance as specified by Winer (1962) indicated there were significant differences between good and poor working memory readers at each reading difficulty level: easy level, $F(1, 68) = 7.99$, $p < .01$; moderate level, $F(1, 68) = 21.3$, $p < .0001$; and difficult level, $F(1, 68) = 17$, $p < .001$). Figure 2 illustrates these differences at each reading difficulty level.

Reading comprehension efficiency

The second dependent variable assessing reading performance was reading comprehension efficiency. The reading comprehension efficiency variable divided mean proportion correct SVT performance on each passage by reading time per passage.

Reading time. As described in the procedure section, each subject wrote the number shown on a card by the experimenter when the subject finished reading each passage. These numbers represented five second intervals. A raw score measure of reading time in minutes per passage was constructed from the student responses. The mean reading time across all passages for all subjects was 1.55 minutes per passage.

TABLE 13

Mean SVT Proportion Correct by Item Type as a Function of Working Memory Performance

Item Type	Working Memory Group		
	Poor	Good	Difference
Original	.667	.874	.207
Paraphrase	.583	.738	.155
Meaning Change	.495	.737	.242
Distractor	.694	.861	.167

TABLE 14

Mean Proportion Correct by SVT Item Type Across Reading Difficulty Level as a Function of Working Memory Performance

Level and Item Type		Poor	Good	Difference
Easy				
	original	.757	.924	.167
	paraphrase	.694	.729	.035
	meaning change	.590	.847	.257
	distractor	.743	.875	.132
Moderate				
	original	.660	.898	.238
	paraphrase	.590	.792	.202
	meaning change	.417	.725	.308
	distractor	.736	.896	.160
Difficult				
	original	.583	.799	.216
	paraphrase	.465	.694	.229
	meaning change	.479	.639	.160
	distractor	.604	.813	.209

Table 15 and Figure 3 show mean reading time across reading difficulty level for the good and poor working memory groups. Good working memory readers were consistently more rapid readers compared to the poor working memory readers, but the difference was not statistically significant. Reading time in minutes increased significantly with an increase in reading difficulty level from 1.20 for easy level text, to 1.38 for moderate level text, to 1.94 for difficult level text, $F(2, 170) = 42.73$, $p < .0001$. The sources of variance table of mean reading time is reported in the Appendix.

Reading comprehension efficiency. The reading comprehension efficiency variable was constructed by dividing mean proportion correct SVT performance per passage by mean reading time per passage. This resulted in an index of passage reading comprehension accuracy per minute of reading time. Mean reading comprehension efficiency decreased significantly from easy (.800) to moderate (.598) to difficult (.398) reading levels, $F(2, 170) = 4.95$, $p < .001$. Contrary to the expected direction of the interaction, Figure 4 and Table 16 show the difference between good and poor working memory reader performance declined from the easy level passages (.293) to moderate (.216) to difficult (.170) level passages. This working memory group X reading difficulty level interaction was statistically significant, $F(2, 170) = 11.36$, $p < .01$. Reading comprehension efficiency also varied significantly between passages within reading difficulty levels ($F(3, 170) = 44.24$, $p < .001$. Table 17 reports mean reading comprehension efficiency by passage. The interaction of working memory group by passage within each reading difficulty level was statistically

TABLE 15

Mean Reading Time (mins) Across Reading Difficulty Levels as a Function of Working Memory Performance

Difficulty Level	Working Memory Group		
	Poor	Good	Combined
Easy	1.356	1.044	1.200
Moderate	1.452	1.308	1.380
Difficult	2.019	1.857	1.938

Figure 3

Mean Reading Time by Passage Difficulty Level as a Function of Working Memory

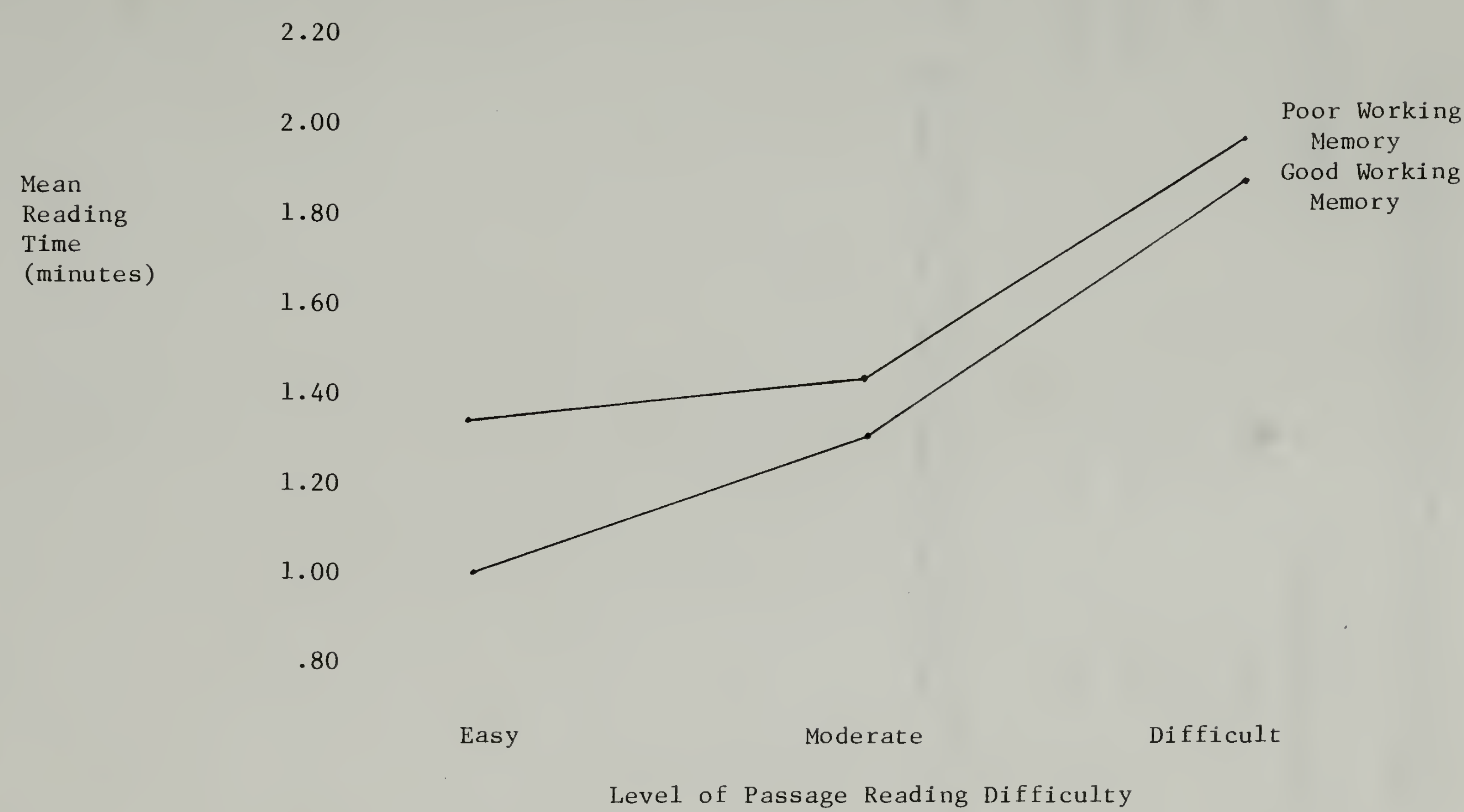

Mean
Reading
Time
(minutes)
2.20
2.00
1.80
1.60
1.40
1.20
1.00
.80
Poor Working Memory
Good Working Memory
Easy
Moderate
Difficult
Level of Passage Reading Difficulty

TABLE 16

Mean Reading Efficiency Across Reading Difficulty Levels as a Function of Working Memory Performance

Difficulty Level	Working Memory Group		
	Poor	Good	All
Easy	.654	.947	.800
Moderate	.490	.706	.598
Difficult	.313	.483	.398

Note: Mean reading efficiency was mean SVT proportion correct divided by mean reading time in minutes per passage.

Figure 4

Mean Reading Comprehension Efficiency by Reading Difficulty Level as a Function of Working Memory

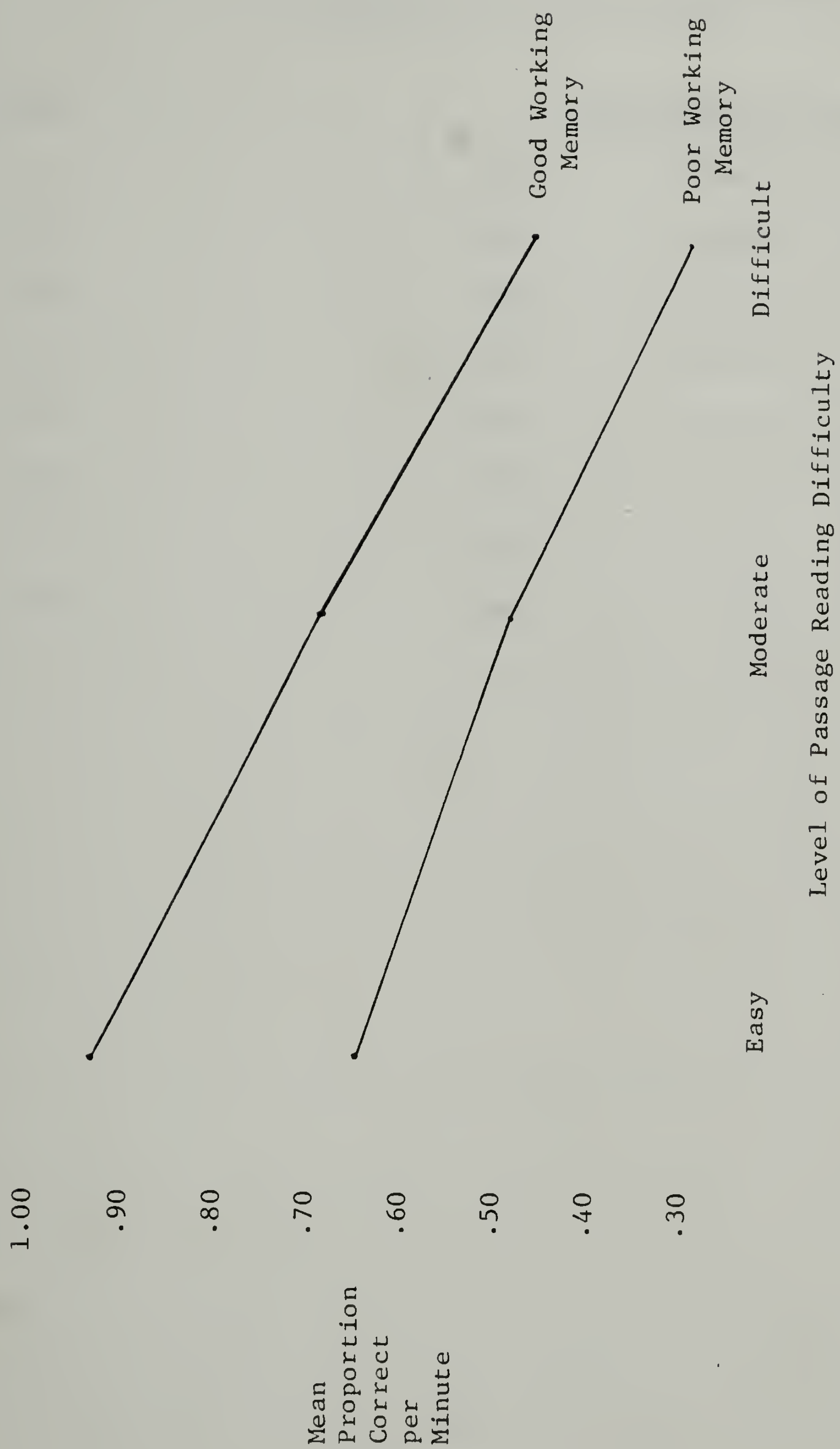

Good Working Memory
Poor Working Memory
1.00
.90
.80
.70
.60
.50
.40
.30
Mean Proportion Correct per Minute
Easy
Moderate
Difficult
Level of Passage Reading Difficulty

TABLE 17

Mean Reading Comprehension Efficiency by Passage as a Function of Working Memory

Passage	Working Memory Group		
	Poor	Good	All
E1	.581	.857	.719
E2	.728	1.038	.883
M1	.425	.700	.562
M2	.556	.713	.635
D1	.356	.547	.451
D2	.270	.419	.344
All	.486	.712	.599

significant, $F(3, 170) = 4.23$, $p < .05$. The complete source of variance table for reading comprehension efficiency is listed in the Appendix.

The reading comprehension efficiency variable described above was selected from several other indices relating reading comprehension performance with reading time. The reading comprehension variable seemed the most clear representation of cognitive processes associated with reading comprehension which was relatively interpretable. However, analyses were also conducted with one other variable relating reading comprehension with reading time: effective reading rate. Effective reading rate was defined as mean SVT proportion correct multiplied by reading rate. Reading rate was the number of words per passage divided by the reading time in minutes. Good working memory readers had a significantly higher effective reading rate compared to poor working memory readers ($F(1, 34) = 11.03$, $p < .01$). However, the predicted working memory group X level of reading difficulty interaction was not significant. Mean effective reading rate scores are reported in the Appendix.

Text Structure and Reading Comprehension

Analyses were conducted to investigate whether text structure was associated with reading comprehension performance of good and poor working memory readers. These analyses used the text structure variables mentioned previously: number of words, word length, proportion of unfamiliar words, number of propositions, propositional density, propositions per clause, redundancy, intersentence connec-

tions, coherence graph levels, and serial position. As described for the MANOVA analysis, each sentence of the six passages was assessed to yield 12 text structure scores. Each score was converted to a z score (plus a constant of 10) based upon mean and standard deviation scores across all 72 sentences. The dependent variables used to represent reading comprehension was SVT proportion correct per sentence for each sentence. Mean proportion correct scores were computed for three samples: all readers, good working memory readers, and poor working memory readers. Each SVT score variable was transformed to a z score based upon mean proportion correct and standard deviation of the 57 subjects. All the z scores were converted to a positive scale by adding a constant of 10. These transformations resulted in three variables representing reading comprehension performance differences (Z scores for all, good and poor readers), and the nine variables representing text structure features, for each of the 72 sentences.

A Pearson correlation was computed to assess the relationship between reading comprehension and text structure. As shown in Table 18, three variables had signficant correlations with reading comprehension performance. All of the significant correlations were negatively associated with reading comprehension performance. The number of intersentence connections was associated with reading comprehension performance of both the good (r = -.19, p < .01) working memory readers. The proportion of unfamiliar words per sentence was associated with reading comprehension performance of good working memory readers (r = -.22, p < .05), but not poor working memory

TABLE 18

Significant Correlations Between Reading Comprehension Performance and Text Structure Variables as a Function of Working Memory

Text Structure Variables	Working Memory Group	
	Poor	Good
Intersentence Connections	-.258**	-.191*
Unfamiliar Words	-.100	-.216*
Propositions per Clause	-.231*	-.003

*$p < .05$
**$p < .01$

readers. However, the number of propositions per clause was associated with poor working memory readers ($r = -.23$, $p < .05$) and not good working memory readers.

The text structure variables were entered as predictor variables in a forward stepwise multiple regression analysis. Table 19 presents the results of the regression analysis. Intersentence connections and propositions per clause were significant predicators of the reading comprehension performance of the poor working memory readers ($R = .34$). No combination of variables was associated with reading comprehension performance of the good working memory readers. Intersentence connections and the proportion of unfamiliar words were significantly associated with reading comprehension of the entire sample of readers ($R = .365$).

TABLE 19

Multiple Regression of SVT Performance on Individual Sentences and Text Structure Variables as a Function of Working Memory

Variable Entered by Group	R	Increase in R^2	P
Poor Working Memory			
Intersentence Connections	.258	.067	.029
Propositions per Clause	.340	.049	.055
Good Working Memory			
Unfamiliar Words	.216	.047	.069
All Subjects			
Intersentence Connections	.269	.072	.022
Unfamiliar Words	.365	.061	.031

CHAPTER VI

DISCUSSION

This experiment found evidence of significant differences in reading comprehension performance as a function of individual differences in working memory, using text which varied in text microstructure. The passages used in the experiment varied in reading difficulty from easy, to moderate to difficult. Evidence was presented that the three levels of text had significant mean increases in propositions, intersentence connections, coherence graph levels, and the proportion of unfamiliar words per sentence. The mean number of propositions per clause increased with reading difficulty level, but the difference was not significant. Each of these variables was theoretically related to assumptions about the role of working memory when processing coherent text.

The experiment assessed working memory with a probe recall test consisting of sentences which were constructed from passages parallel to the experimental text. Evidence was also presented supporting the reliability of the test. Mean proportion correct working memory test performance was used to identify good and poor working memory readers.

There were two experimental hypotheses. The first hypothesis was reading comprehension performance of poor working memory readers would decline more rapidly with an increase in reading difficulty level compared to the reading comprehension performance of the good working memory readers. The second hypothesis was reading comprehension performance of poor working memory readers would have a larger

association with theoretically relevant text structure variables compared to the association between reading comprehension performance of the good working memory readers and text structure.

Reading Comprehension Performance

Reading comprehension performance was assessed with reading comprehension accuracy and reading comprehension efficiency. Reading comprehension accuracy was mean proportion correct SVT performance. Reading comprehension efficiency was mean SVT performance divided by mean reading time.

Reading comprehension accuracy was significantly higher for good working memory readers compared to poor working memory readers. This main effect due to working memory was also found in a pilot study completed prior to the research reported in the dissertation. In the pilot study, 53 fifth grade readers responded to a similar working memory test (but with 24 items), read the same text and responded to the same SVTs as th dissertation experiment. Subjects with working memory performance from the top or bottom 36% of the working memory test distribution were defined as good or poor working memory readers. The pilot study found good working memory subjects' reading comprehension accuracy (.889) was significantly higher than poor working memory reading comprehension accuracy (.786), $F(1, 36) = 13.96$, $p < .001$.

The difference between good and poor working memory reading comprehension performance increased with an increase in text difficulty, resulting in a marginally significant interaction. This provided modest support for the predicted hypothesis. The reading comprehension

performance was in the predicted direction of the interaction, but the interaction was small. Poor working memory readers had significantly lower mean scores than good working memory readers even at the easy text difficulty level. Reding comprehension evidence from the pilot study also supported the interaction hypothesis. Figure 5 shows poor working memory mean SVT proportion correct declined more rapidly with increased text difficulty compared to the mean proportion correct performance of the good working memory readers [$F(2, 828 = 4.15$, $p < .05$).

Reading time increased significantly with an increase in text difficulty for both good and poor working memory readers. However, as shown in Figure 3, the relative difference between good and poor working memory readers declined with increasing text difficulty.

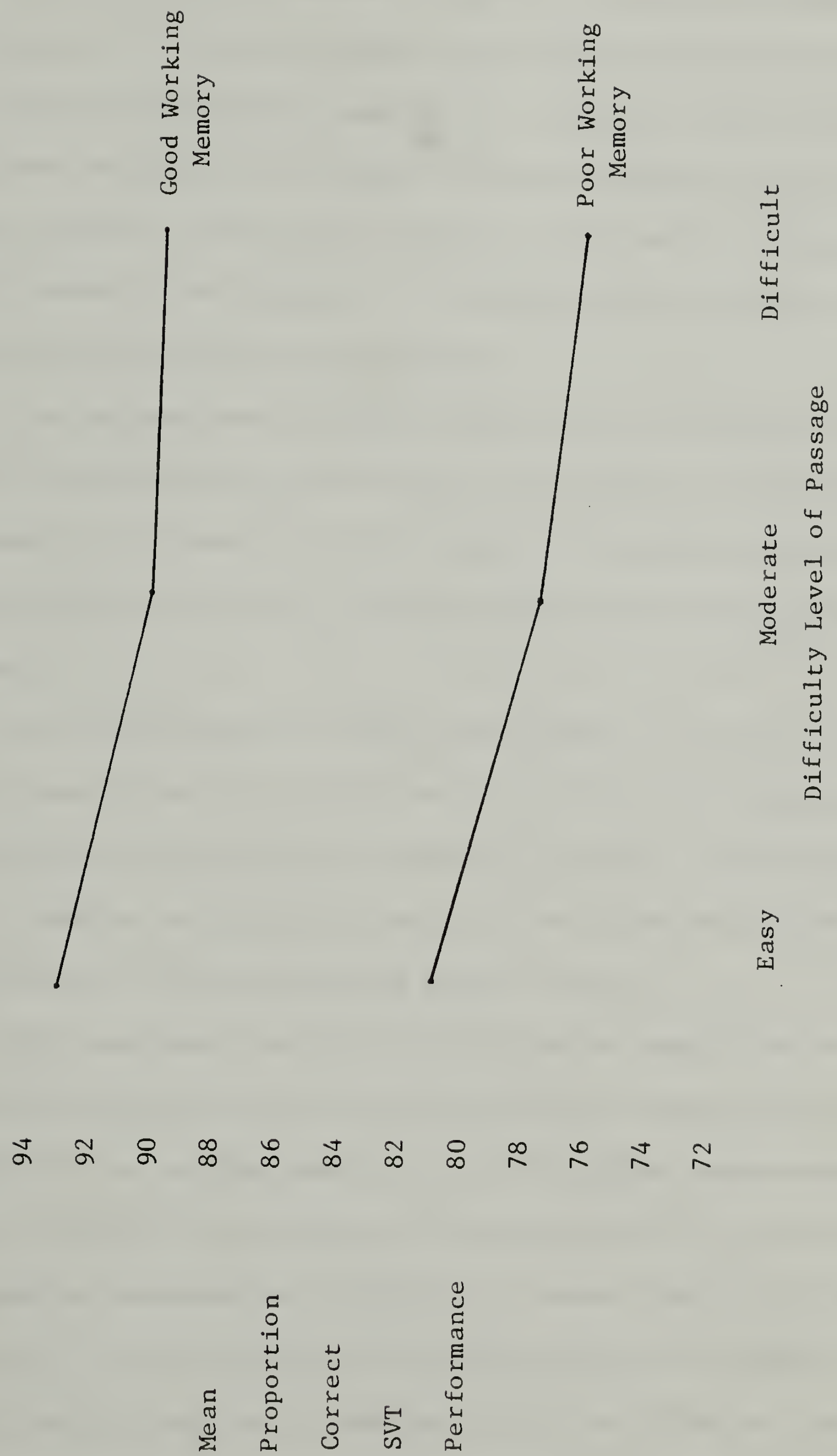
The second dependent variable in the dissertation experiment was mean reading comprehension efficiency, which was defined as reading comprehension accuracy divided by reading time per passage. Good working memory readers had significantly higher mean reading efficiency performance than poor working memory readers. There was a significant group by level interaction with a decline in mean reading efficiency differences between good and poor working memory readers with increased text difficulty. Mean reading efficiency data resulted in significant passage differences within difficulty levels, and an interaction of working memory group by passage within reading difficulty level.

Reading Comprehension and Text Microstructure

The second hypothesis was text structure variables of theoretical relevance to working memory processing during reading comprehension

Figure 5

Mean Proportion Correct SVT Performance for
Good and Poor Working Memory Subjects across
Difficulty Levels of Text



Mean
Proportion
Correct
SVT
Performance
94
92
90
88
86
84
82
80
78
76
74
72
Good Working Memory
Poor Working Memory
Easy
Moderate
Difficult
Difficulty Level of Passage

would be more negatively associated with reading comprehension of poor working memory readers compared to good working memory readers. The experiment did not find a significant correlation between propositions per sentence and reading comprehension. However, there was evidence that poor working memory readers were more sensitive than good working memory readers to text microstructure. Furthermore, the poor working memory readers were sensitive to different text structure features than the good working memory readers.

Poor working memory reading comprehension performance was negatively associated with intersentence connections of propositions and the number of propositions per clause. The combined effect of these two variables accounted for 15% ($\underline{R}$ = .34) of the reading comprehension variance.

Good working memory reading comprehension performance was negatively associated with intersentence connections of propositions and the proportion of unfamiliar words per sentence. No combination of text structure variables was associated with the reading comprehension performance of the good working memory readers.

This experiment has contributed evidence supporting two generalizations presented earlier in the dissertation about individual differences in working memory related to reading comprehension. First, individual differences in working memory are clearly related to reading comprehension performance. Second, there is evidence that different text structure features affect poor working memory reading comprehension performance compared to the text structure features affecting reading comprehension performance of the good working memory

readers.

The first generalization is grounded in the evidence that good working memory readers were consistently more proficient readers than poor working memory readers. The experiment extended the research of Perfetti and Goldman (1976) by demonstrating that individual differences in working memory are associated with reading comprehension performance as measured by the SVT. As discussed earlier in this chapter, previous research has provided strong evidence that the SVT is a valid method of measuring reading comprehension.

The experiment also provided modest support for the hypothesis that individual differences in working memory lead to a relatively greater decline in reading comprehension performance of poor working memory readers compared to good working memory readers as text difficulty increases.

While the differences in reading comprehension accuracy between good and poor working memory readers increased slightly with text difficulty, mean reading time of good and poor working memory readers became more similar with increasingly difficult text. This pattern is different from what one might expect. Presumably readers would increase their reading time to compensate for comprehension difficulties. Increasing reading time would improve comprehension by increasing the amount of time propositions are processed in the STM buffer, thereby increasing the probability of links between buffer propositions, reinstated propositions or inferences.

However, good and poor working memory readers may vary in their awareness of utilizing reading time strategies (such as skimming easy

sections of text, and rereading more difficult text). There is a growing body of research investigating the role of metacognition in reading comprehension (see Anderson & Armbruster, 1982; Golinkoff, 1976; Ryan, 1981; Sullivan, 1978). This research suggests good readers have a more purposeful approach during reading comprehension compared to poor readers. Paris, Lipson, and Wixson (1983) suggest that good readers monitor their comprehension more accurately than poor readers, adjusting reading behaviors (such as reading time) to maintain an acceptable comprehension level. Investigations of readers' awareness of the utility of cognitive strategies in improving reading comprehension have found poor readers often do not reread text they fail to comprehend (Brown, Campione, & Barclay, 1979) and may even say that they understand text which is incoherent (Canney & Winograd, 1979; Paris & Myers, 1981). If the poor working memory readers were deficient in comprehension monitoring, they may not have been aware of the beneficial effects of increased reading time upon comprehension. Therefore, they did not increase their reading time significantly above the reading time of the good working memory readers.

Poor working memory subjects' reading comprehension accuracy declined with an increase in propositions per clause. If poor working memory readers maintained a small number of input propositions, their reading comprehenson performance would decline given a text base with many propositions. The association between propositions per clause and reading comprehension suggests poor working memory readers may be less proficient in maintaining propositions in the STM buffer across clause boundaries. This result is similar to Perfetti and Goldman

(1976), who found poor readers were less able to report target words from text which had an intervening clause or sentence boundary between the target word and the recall point.

Good working memory readers had comprehension difficulties with text having an increased proportion of unfamiliar words. Unfamiliar words may not have been available in the lexicon, or may have been accessed too slowly. Slow access may have placed the unfamiliar word propositions in the STM buffer after considerable decay of other propositons (Perfetti and Lesgold, 1977). In sum, either lacking the knowledge of word meanings or slow lexical access rate relative to decay rate of input propositions may have resulted in an incomplete text base, and poorer reading comprehension.

Propositions per clause and unfamiliar words had different effects upon reading comprehension of good and poor working memory readers. However, there was strong evidence that all readers were affected by the number of intersentence connections of a passage sentence. The intersentence variable measured the number of propositions in a passage sentence which shared arguments with propositions from earlier passage sentences.

The intersentence connection variable in this experiment has some similarities with the operational definition of reinstated propositions or reinstatement searches from previous research. In Kintsch and van Dijk (1978) and Vipond (1980), a computer simulation of reading comprehension set the size of the STM buffer and identified the specific propositions residing in the buffer. Propositions which were in the STM buffer, but lacking a common argument with other

buffer propositions required the reinstatement of propositions from earlier sentences to establish coherence. The intersentence connection variable of the dissertation may be a less elegant way of identifying text requiring reinstatement searches.

If one accepts the suggestion that intersentence connections are related to reinstatement searches, the dissertation provided additional support for Vipond's (1980) argument that text requiring reinstatement searches affect reading comprehension performance. Reinstatement searches may affect reading comprehension in two detrimental ways. First, the search process may use processing resources which are necessary to provide propositional coherence among the buffer propositions. Second, reinstatement searches may increase the amount of time required to process a sentence. Increased time may inhibit reading comprehension if the reader is inefficient in maintaining propositions in the STM buffer. If buffer propositions are not maintained, they may decay in STM before argument overlap with the reinstated propositions. These processes may account for why intersentence connections were associated with both good and poor working memory reading comprehension.

If intersentence connections are related to reinstatement searches, there is a plausible explanation for the combined negative effect of intersentence connections and propositions per clause on reading comprehension accuracy. Poor working memory readers may be inefficient in maintaining propositions in working memory. This inefficiency may become particularly evident when additional processing resources are used. Given a sentence which requires the processing

demands of a reinstatement search, the buffer propositions may decay prior to completing the search, resulting in poorer comprehension.

Most of the discussion presented above has interpreted the results of the experiment from the perspective of working memory affecting reading comprehension. However, there were two problems with the experiment which weaken this interpretation. The first problem was methodological: the reading comprehension data suggests a possible floor effect. The poor working memory mean SVT proportion correct performance with difficult text was near chance performance level. This reduced the possibility of a significant interaction by inhibiting a more pronounced difference between good and poor working memory readers. The pilot study SVT proportion correct results with fifth grade readers were in an appropriate range to eliminate the floor effect, but the SVT performance of the good working memory readers with easy level text may have been influenced by a ceiling effect. The problem of ceiling or floor effects may be alleviated by testing 5th grade subjects and slightly altering the microstructure of the easy level passages. The microstructure of the easy level passages may be altered to increase the difficulty level of the text.

The second problem with the experiment was data was not collected representing factors other than working memory which may have produced the same reading comprehension performance results. Previous research investigating individual differences between good and poor reading comprehension (cf. Golinkoff, 1976) has shown that poor readers are less proficient than good readers in many skills and cognitive operations. Good and poor working memory readers may differ system-

atically on a factor (or several factors) which are highly related to both working memory and reading comprehension.

One factor which may be associated with both working memory and reading comprehension is general language ability. General language ability may vary with a reader's language experience, including knowledge of specific vocabulary. Poor working memory subjects may have had more limited exposure to text such as the experimental passages and working memory test items. This may contribute to individual differences in maintaining propositions in STM (affecting performance on the working memory test) and poor reading comprehension.

The argument may be made that differences in reading comprehension and working memory may parallel differences in intelligence. It is well known that reading comprehension test performance (as measured by norm referenced reading comprehension tests), is often correlated with performance on IQ tests with correlations ranging from .40 to .84 (see Thorndike, 1973-1974; Harootunian, 1966; Guice, 1969). The most common way of accounting for differences in intelligence is to match subjects on IQ test performance. But, matching on IQ performance does not solve the theoretical problem of identifying factors which differentiate good readers from poor readers. There is little consensus of what cognitive factors (or knowledge factors such as vocabulary) account for the association between reading comprehension and intelligence. However, recent research integrating cognitive and psychometric theory may lead to the use of intelligence tests which are theoretically related to reading comprehension (see Sternberg and Powell, 1983; Sternberg, in press).

The differentiation between working memory and alternative factors affecting reading comprehension is particularly important to clarify the theoretical role of working memory during reading comprehension. Future research needs to investigate whether working memory operations are independent processes or whether working memory is merely a new name for other factors which have been previously found to be related to reading comprehension performance. If individual differences in working memory are indistinguishable from individual differences in vocabulary or world knowledge, there is little theoretical advantage to attributing reading comprehension differences to working memory proficiency. Future research investigating working memory could identify the role of working memory in reading comprehension by assessing individual differences in factors which are theoretically associated with working memory (e.g., lexical access speed, probe recall, memory span) and factors which are less theoretically related to working memory (e.g., metacognition, prior world knowledge). Research such as this could investigate whether deficits in reading comprehension performance were associated with one factor or with several factors, and identify functional relationships among factors which affect reading comprehension.

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A P P E N D I X

Table 20

Reading Comprehension Test Materials

Reading Comprehension Test[1]

General Directions

The purpose of this test is to measure your ability for understanding passages. The test consists of six passages and 16 questions about each passage. Your task is to read each passage and then turn the page and answer the sixteen questions. It should take about 35 minutes to finish the test. You should have no difficulty in finishing the test in the time allowed.

On pages 2 to 8 are specific directions and a few practice questions. Now turn the page and read this page.

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[1]Prepared by Mike Royer and Ronald K. Hambleton, from the University of Massachusetts, Amherst. This instrument is intended for research purposes only and is not to be copied in any form without permission of the authors.

Specific Directions

Carefully read the introduction to the story:

> This story is about a family who lives in the hills of Vermont. There is a heavy snowfall which stops all cars. The children cannot go outside because of the snow.

Now read carefully the story below:

> The morning paper didn't come. The milkman didn't come. The mailman didn't come. Just more and more snow came.
>
> The children stood at the windows in the living room. Needie said, "I wish we could go out in the snow. I'd like to see how deep it is. I'll bet it's up above my knees."
>
> Susan said, "I guess Star wouldn't be able to walk in it at all."
>
> Betsy said, "Mother says we can't go out until it stops snowing. Let's look at television. My favorite program is on every Saturday morning."

Go back and read the story again. When you have read the story twice, turn the page. Do not turn back to look at the story.

Questions

Below is the first sentence from the story you read and four other sentences. Your task is to mark those sentences that are "OLD" and those sentences that are "NEW".

A sentence is OLD if:

- it is taken from the story.
- it has the same meaning to a sentence in the story.

A sentence is NEW if:

- it is unrelated to the story.
- it has a different meaning to a sentence in the story.

The first sentence in the story is:

The morning paper didn't come.

Now mark each of the sentences below as OLD or NEW.

OLD NEW 1. The paper that comes in the morning did not arrive.

OLD NEW 2. The morning paper did come.

OLD NEW 3. The tree branches were coated with ice.

OLD NEW 4. The morning paper didn't come.

Now, let's review your answers.

1. You should have marked the first sentence "OLD" because it has the same meaning as the first sentence in the story.

2. You should have marked the second sentence "NEW" because it has a different meaning to the first sentence in the story.

3. You should have marked the third sentence "NEW" because it is unrelated to the first sentence in the story.

4. You should have marked the fourth sentence "OLD" because it is the same as the first sentence in the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW".

OLD	NEW	5.	The postman hadn't been there.
OLD	NEW	6.	If it kept snowing the schools would be closed next week.
OLD	NEW	7.	The morning paper did come.
OLD	NEW	8.	Neddie said, "I wish we could go out in the snow."

Turn the page and read it to see if your answers to sentences 5 to 8 are correct.

Now let's review the answers:

1. The story says, "The mailman didn't come." Sentence 5 says, "The postman hadn't been there." Since sentence 5 has the <u>same meaning</u> to a sentence in the story you should have circled "OLD" beside sentence 5.

2. Sentence 6 is, "If it kept snowing the schools would be closed next week." The story does <u>not</u> say anything about school, or closing school if the snow continued, and so sentence 6 is "NEW". Did you circle "NEW" beside statement 6?

3. The 7th sentence said, "The morning paper did come." But, in the story, it was said that "The morning paper <u>didn't</u> come." Sentence 7 has a different meaning from any sentence in the story and so you should have circled "NEW".

4. The 8th sentence above is <u>exactly</u> the same as a sentence in the story and so you should have circled "OLD" beside sentence 8. Did you?

Now let's read a couple of more sentences. Circle one of the two answers, "OLD" or "NEW", to each sentence.

OLD NEW 9. The sky was a dark gray.

OLD NEW 10. The snow just got deeper and deeper.

OLD NEW 11. The children stood at the windows in the livingroom.

OLD NEW 12. The milkman had come.

Turn the page and read it to see if your answers to sentences 9 to 12 are correct.

Now let's look at the answers.

9. Nothing is said in the story about the sky or that it is dark gray. Therefore, sentence 9, "The sky was a dark gray," is "NEW".

10. In the story it is said that "More and more snow came." Therefore, sentence 10, "The snow just got deeper and deeper," has a similar meaning and so you should have marked sentence 10 "OLD". Did you?

11. Sentence 11 is "The children stood at the windows in the livingroom." This sentence is from the story and so you should marked it "OLD".

12. Sentence 12 is "The milkman had come." But, the story says that "The milkman didn't come." So, you should have marked the sentence "NEW".

Now turn the page.

In the remainder of this test are stories, introductions to the stories, and sentences. Your task with each story is to

- read the introduction
- read the story twice carefully
- read the 16 sentences that follow the story and mark them as "OLD" or "NEW".

After you begin answering the questions, do not turn back to look at the story.

REMEMBER

"OLD" sentences are

- from the story
- have the same meaning as sentences in the story

"NEW" sentences are

- different in meaning from sentences in the story
- are unrelated to the story

Now go ahead with the test. Good luck!

Carefully read the introduction to the story:

This is a story about Maria's ninth birthday present.

Now read carefully the story below:

Maria was so excited! Today was her ninth birthday and her mother had promised her a special present for this day.

Maria's three older sisters all wore beautiful golden rings in their ears. Maria's mother had told her that when she was nine, she was old enough to have her ears pierced like her sisters. Maria had been eagerly waiting for that day to come.

After school that afternoon, Maria and her mother walked down the street to the jewelry store of their friend, Mr. Ramos. He greeted them and wished Maria a happy birthday. Maria sat on a tall stool, and Mr. Ramos carefully pierced her ears with a special needle. Maria had been afraid it would hurt, but it was very easy. Then Maria chose some beautiful golden earrings, and Mr. Ramos helped her put them in her ears.

With shining eyes, Maria thanked her mother, and together they walked back down the street to their home. She could not wait to show her sisters her beautiful golden earrings.

Go back and read the story again. When you have read the story twice, turn the page. Do not turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW".

OLD NEW 1. Maria's mother had told her that when she was nine, she was old enough to have her hair cut like her sisters.

OLD NEW 2. After school in the afternoons, Maria liked to play volleyball with the other children on her street.

OLD NEW 3. Maria's three younger sisters all wore beautiful golden rings in their ears.

OLD NEW 4. Maria was so excited.

OLD NEW 5. Maria had been looking forward to her ninth birthday with great excitement.

OLD NEW 6. After school that afternoon, Maria and her mother walked down the street to the jewelry store of their friend, Mr. Ramos.

OLD NEW 7. Birthdays were always special occasions at Maria's house and they always had a big party.

OLD NEW 8. Today Maria turned nine and her Mom had told her that she would receive a special gift for her birthday.

OLD NEW 9. With shining eyes, Maria thanked her mother and together they took the bus back to their home.

OLD NEW 10. Maria's new gold earrings were made of two golden strands, twisted together.

OLD NEW 11. She could not wait to show her sisters her beautiful golden earrings.

OLD NEW 12. He met them at the door and said "Why, Happy Birthday, Maria."

OLD NEW 13. Maria sat on a tall stool while Mr. Ramos carefully cleaned her ears with a special soap.

OLD NEW 14. Maria and her mother had known Mr. Ramos ever since they had moved to the neighborhood five years ago.

OLD NEW 15. Maria then picked out some pretty gold earrings and put them on, with the aid of Mr. Ramos.

OLD NEW 16. Maria had been afraid it would hurt, but it was very easy.

Carefully read the introduction to the story:

This story is about the day when Billy washed his father's car.

Now read carefully the story below:

> Billy had a job to do that Saturday morning. His father had asked him to wash the car. If he did a good job, his father said there would be a surprise for him that afternoon.
>
> Billy filled a pail with hot, soapy water and found a large sponge. He sponged soapy water all over the car. He was careful to scrub the very dirty places. When he had washed the whole car, he turned on the hose and rinsed the car thoroughly. Then he wiped it dry with a soft, clean towel. He polished the glass and the chrome parts so that they would not streak. When he was finished, the car looked beautiful. Billy was proud of a job well done.
>
> His father was very pleased, so he took Billy and a friend to the circus that afternoon as a reward for doing such a good job.

Go back and read the story again. When you have read the story twice, turn the page. Dq <u>not</u> turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW".

OLD	NEW	1.	He sponged wax all over the car.
OLD	NEW	2.	His dad wanted Billy to wash the car for him.
OLD	NEW	3.	His father had never before asked him to work on Saturday mornings.
OLD	NEW	4.	Billy liked to take soap bubbles, and blow them into the air.
OLD	NEW	5.	Billy filled a pail with hot, soapy water and found a large sponge.
OLD	NEW	6.	It was Saturday morning, and Billy had some work to get done.
OLD	NEW	7.	If he did a good job, his brother said that there would be a surprise for him that afternoon.
OLD	NEW	8.	He was careful to scrub the very dirty places.
OLD	NEW	9.	Billy was proud of a job well done.
OLD	NEW	10.	When the entire car was all scrubbed, he sprayed off all the soap with the hose.
OLD	NEW	11.	He polished the glass and the chrome parts so that they would not streak.
OLD	NEW	12.	Then he wiped it dry with the sponge.
OLD	NEW	13.	Billy liked washing the car.
OLD	NEW	14.	His father was very pleased, so he took Billy and a friend to the zoo that afternoon as a reward for doing such a good job.
OLD	NEW	15.	He found it tiring to put all this effort into cleaning a car.
OLD	NEW	16.	After the car was cleaned, it looked great.

Carefully read the introduction to the story:

Grandma tells a story about Tim's Mother.

Now read carefully the story below:

> One wonderful thing about grandparents, Tim decided, was the stories they could tell about his parents when they had been young. His favorite story about his mother was the famous pillow caper. "Nowadays," Grandma said, "a feather pillow is something of a rarity or a luxury. Most people seem content with polyester fillings and such. When your mother was small, we had nothing but feather stuffed pillows in our house. You don't know what comfort is until you've sunk your head into 3,000 bits of goose down.
>
> "Once when your mother had nothing to do, she saw the point of one little feather sticking out of a tiny hole in the corner of her pillow. She pulled it out and another came right along to take its place. You can imagine the rest of this story!"
>
> "Yes," laughed Tim, "she pulled out all the feathers."
>
> "I went to her room" said Grandma, "and there I found 3,000 feathers flying around. All your mother could say was: 'I didn't know there would be so many of them!"

Go back and read the story again. When you have read the story twice, turn the page. Do <u>not</u> turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW."

OLD	NEW	1.	Most people seem content with polyester fillings and such.
OLD	NEW	2.	You don't know what comfort is until you've sunk your head into 3000 bits of polyester.
OLD	NEW	3.	One great thing about visiting grandparents was that they always took you someplace exciting, like the zoo or the circus.
OLD	NEW	4.	Being able to hear stories of when his mom and dad were kids was one of the nice things about having grandparents around, Tim concluded.
OLD	NEW	5.	His favorite grandparent was his mother's mother.
OLD	NEW	6.	All we had on our beds when your mom was young were pillows filled with feathers.
OLD	NEW	7.	"Now-a-days," grandma said, "feather pillows are very common and not considered a luxury."
OLD	NEW	8.	His favorite story about his father was the famous pillow caper.
OLD	NEW	9.	Once when your mother had nothing to do, she saw the point of one little feather sticking out of a tiny hole in the corner of her pillow.
OLD	NEW	10.	"I didn't realize how many feathers there would be," was the only thing she could say.
OLD	NEW	11.	You can guess what happened next!
OLD	NEW	12.	"I went outside," said grandma, "and there I found 3000 feathers flying around."
OLD	NEW	13.	She poked it in but another came right along to take its place.
OLD	NEW	14.	"Yes," laughed Tim, "she pulled out all the feathers."
OLD	NEW	15.	If I remember right I told her: "I'd send you to your room if I knew where it was!"
OLD	NEW	16.	"I wish," said Tim, "that I lived back in the old days."

Carefully read the introduction to the story:

> Kevin wants a dog.

Now read carefully the story below:

> For about four years, Kevin had been brooding about the unfairness of the pet situation in his house. His sister Kathy had been given a kitten one summer to help her recuperate from a broken leg she'd suffered in a fall from a tree. His mother had said that the cat was really the whole family's now; it had just been especially Kathy's during the summer.
>
> But Kevin desparately wanted a dog, though his parents were opposed.
>
> "Cats and dogs can get along in the same house," Kevin said. "Lots of my friends have both."
>
> "That's not it," said his father. "We can't keep both because it's a huge expense to board them every time we leave town. You know that with our relatives so widely scattered that we are often away visiting. A cat can easily be left alone for a day or two but certainly not a dog. . . ."
>
> Kevin felt very unhappy. Maybe the thing to do was fall out of a tree and hope for a broken arm.

Go back and read the story again. When you have read the story twice, turn the page. Do <u>not</u> turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW".

OLD NEW 1. But Kevin desparately wanted a dog, though his parents were opposed.

OLD NEW 2. His mother had said that the cat was really the whole family's now; it had just been especially Kathy's during the summer.

OLD NEW 3. For about four years, Kevin had been brooding about the unfairness of the housework situation in his house.

OLD NEW 4. One summer, when his sister Kathy fell out of a tree and fractured her leg, she was given a kitten to help her recover.

OLD NEW 5. Kevin argued, "Dogs and cats can live together peacefully."

OLD NEW 6. When the cat was young it required quite a lot of care; now it mostly took care of itself and, in fact, preferred to be ignored.

OLD NEW 7. His sister Kathy was the youngest in the family and also the only girl, so always got what she wanted.

OLD NEW 8. "Lots of my friends have puppies for sale."

OLD NEW 9. "We can't keep both because it is a huge headache to take them with us when we leave town."

OLD NEW 10. Cats can take care of themselves for a couple of days but dogs can't.

OLD NEW 11. He started bringing nice dogs home in hopes of changing his parents opinion about them.

OLD NEW 12. Maybe the thing to do was fall out of a tree and hope for a broken arm.

OLD NEW 13. "You've missed the point," his dad replied.

OLD NEW 14. You know that with our relations so widely scattered that we are often away visiting.

OLD NEW 15. Kevin felt very angry.

OLD NEW 16. Dogs take a long time to house train, and in the mean time it can be quite a job.

Carefully read the introduction to the story:

> Ginny is tempted to steal a doll that has been promised to her but not given.

Now read carefully the story below:

> The Garsons resided in an apartment building in Chicago; unfortunately there were not other children besides Ginny living there. It was relatively easy to meet kids out at the park in decent weather; in inclement weather it would have been nice to have a friend right in the building. About once a week, Ginny who was ten, stopped in to visit old Mrs. Dross who lived down the hall. She was ancient, probably well ov· · eighty and almost crippled with rheumatism, she didn't appear to have much company. What she did have was a dazzling collection of antique dolls that she loved to show Ginny.
>
> This would have been completely satisfying to them both if Mrs. Dross hadn't each time promised to let Ginny choose one of the dolls for her own. For almost a year now, Mrs. Dross had been making this tantelizing offer, but whenever Ginny would hint, "Yes, I think I'd like the one in the maroon dress," Mrs. Dross would snap shut her big glass-fronted display case with a whispered "next time." Mrs. Dross was a big tease! She was also obviously lonely. Ginny's parents suggested that her continued promise was her way of persuading Ginny to keep visiting.
>
> Perhaps that was true but Ginny had boasted about getting the doll at school and now her friends thought she had lied. She began to believe it would be okay to just take the doll when Mrs. Dross wasn't looking.

Go back and read the story again. When you have read the story twice, turn the page. Do <u>not</u> turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW."

OLD NEW 1. She had been collecting the dolls since her early childhoood which she loved to talk about.

OLD NEW 2. This would have been completely satisfying to them both if Mrs. Dross hadn't each time promised to let Ginny take one of the dolls to show her friends.

OLD NEW 3. Ginny could play with the youngsters in the park when it was sunny but if the weather was bad she wished she had a playmate in the apartment building.

OLD NEW 4. Mrs. Dross, who was severely rheumatic, appeared to be in her eighties and to have few visitors.

OLD NEW 5. It caught her quite by surprise the first time, and she had thought Mrs. Dross must be the kindest person in the world.

OLD NEW 6. What she did have was a dazzling collection of modern dolls that she loved to show to Ginny.

OLD NEW 7. About once a week, Ginny, who was ten, stopped in to visit old Mrs. Dross who lived down the hall.

OLD NEW 8. The Garsons resided in an apartment building in Chicago; unfortunately there were no other children besides Ginny living there.

OLD NEW 9. For almost a year now, Mrs. Dross had been making this tantalizing, but whenever Ginny would hint, "Yes, I think I'd like the one in the maroon dress," Mrs. Dross would snap shut her big glass-fronted display case with a whispered "not that one."

OLD NEW 10. There was no question that she was lonesome.

OLD NEW 11. Mrs. Dross was a big tease!

OLD NEW 12. One time Mrs. Dross snapped shut the display case so hard to prevent Ginny from reaching in and taking the doll dressed in the maroon outfit, that she cracked one of the glass doors.

OLD NEW 13. Ginny's parents suggested that her continual promise was her way of persuading Ginny to keep visiting.

OLD NEW 14. She began to believe it would be okay to break the doll when Mrs. Dross wasn't looking.

OLD NEW 15. Ginny asked her parents if they would buy her an antique doll for her birthday.

OLD NEW 16. Ginny understood her parents' explanation, but she had bragged to her school friends that she was getting the doll and now they believed she had fibbed.

Carefully read the introduction to the story:

Roberta doesn't want to go to camp.

Now read carefully the story below:

> Easily the last thing in the world Roberta Wellman wanted to do was go to overnight camp. Her parents had talked about it for years as a great privilege. There had been a time when Roberta wanted to go very badly; at that time her parents simply couldn't afford it.
>
> Since that time, her mother had obtained a good job as a computer programmer and her father's upholstery business had improved. Now they were determined to make it up to her. It was obvious that it meant a great deal to them to finally have the necessary funds at their disposal.
>
> But what Roberta really wanted to do with her summer was assist the new neighbors with their beekeeping hobby. She was fascinated by the manner in which the Bordens had erected the wood cabinets which held the bee colonies and the honey crop they intended to harvest. She was intrigued with the whole process of handling the organized insect colonies.
>
> Her parents on the other hand, were less than delighted with the Bordens and their hundreds of bees. Roberta had heard her mother mutter something like: "Just let one of those sting once . . ." How could she inform them that instead of summer camp, her greatest aspiration was for a bee colony of her own?

Go back and read the story again. When you have read the story twice, turn the page. Do <u>not</u> turn back to look at the story.

Now go ahead and read the sentences below and show your answer to each by circling "OLD" or "NEW".

OLD NEW 1. It was apparent that, after all this time, they valued having the money that was required.

OLD NEW 2. Her parents had talked about it for years as a great curse.

OLD NEW 3. Roberta Wellman would rather do anything than to go to overnight camp.

OLD NEW 4. There had been a time when Roberta wanted to go very badly; at that time her parents thought she was too young.

OLD NEW 5. Roberta lived in a nice home that had everything she wanted, and she had lots of friends close by to play with.

OLD NEW 6. Now they were determined to make it up to her.

OLD NEW 7. Since that time, her mother had obtained a good job as a computer programmer and her father's upholstery business had improved.

OLD NEW 8. Roberta didn't mind going away to visit places as long as she could be home in time to sleep in her own bed.

OLD NEW 9. Roberta had overheard her mom say something to the effect; "If one of those bees ever stings someone. . ."

OLD NEW 10. Roberta wanted very much to spend her summer vacation helping the new people next door take care of their bees.

OLD NEW 11. Her parents were delighted that the Bordens accepted their invitation for dinner.

OLD NEW 12. She was fascinated by the manner in which the Bordens had erected the wood cabinets which held the bee colonies and the honey crop they intended to harvest.

OLD NEW 13. She figured that her dad would take the news a little better than her mom, and that she would therefore tell him first.

OLD NEW 14. She was intrigued with the whole process of handling the organized insect colonies.

OLD NEW 15. How could she inform them that instead of summer camp, her greatest aspiration was for a dog all her own?

OLD NEW 16. Her parents on the other hand were delighted with the Bordens and their hundreds of bees.

TABLE 21

Working Memory Test[a]

1. The ocean-side cottage that they rented every summer was directly across the road from a beach rich in mussels and clams which were theirs for the taking.
2. He greeted them by saying Happy Birthday to Maria.
3. Julie was still asleep, but the wonderful aroma of camp coffee soon roused her from sleep.
4. He picked up his knife and began to trim the corners of the soap bar, hoping that some recognizable image would appear.
5. Soon he was ready for the test. With his brothers on either side, he struck out for the float, anchored way out in the dark, deep water.
6. This was her first real babysitting job and she felt the burden of responsibility pressing on her small shoulders. She had taken care of the Trent children, Amy and Joe, in the afternoons, while their mother worked in her study.
7. Mrs. Aaron finally stopped by his desk and tapped him on the shoulder.
8. Alex did not tell Susan his plan to use her gerbils for the experiments in the art of mousetrapping.
9. She tiptoed out to the hall and left the door ajar so that she could hear them if they needed her. The Trents would be home in an hour, and as she tidied up the living room, she felt the glow of a job well done.
10. With shining eyes, Maria thanked her mother, and together they walked back down the street to their home. She could not wait to show her sisters her beautiful golden earrings.
11. The forms are heavy and solid, but they can also be light and soaring as in this seagull.
12. Tim was afraid to swim in deep water, so he was left alone to build sand castles or paddle around in the shallows.
13. It seemed to take forever, but soon he was climbing up the wooden ladder, and standing proudly in the warm golden sunshine.

14. That morning, Todd helped his mother by giving toys to little children that had been good while their teeth <u>were</u> checked. He also talked to a man that needed two false teeth.

15. Tim wanted so badly to go along. Tim's father said that if he could overcome <u>his</u> fear of deep water and show that he could swim out to the float and back, he would be allowed to go.

16. Mrs. Aaron <u>always</u> appeared enthusiastic, Arthur thought.

17. He regarded with gloom the bar of soap and the <u>small</u> carving knife in front of him.

18. <u>One</u> summer morning Todd went to work with his mother.

19. Their packs grew heavy on their shoulders, as <u>they</u> climbed up the steep trail.

20. Every day they had hiked a longer and longer distance to get <u>into</u> condition for the trek they had planned for today.

21. Hours later, when it seemed like they could go no further, a lightening in the gloom of the <u>forest</u> ahead appeared.

22. Their cabin fronted on a wide crescent beach which sloped down to a stretch of <u>water</u>, beautifully clear and blue.

23. The mouse would advance to a platform on which <u>some</u> delicious morsel rested.

24. Jenny was making breakfast over the camp stove, when her mother poked her <u>head</u> out of the tent.

25. For the Pearsons, who lived a very citified existence, going to the shore was one way <u>of</u> feeling like farmers.

26. Tim's brothers worked with him all afternoon, <u>swimming</u> beside him so he would feel confident.

27. Then Maria chose some <u>beautiful</u> golden earrings and Mr. Ramos helped her put them in her ears.

28. Sweating slightly, <u>he</u> began to carve in earnest and with increasing energy. The bar of soap grew inevitably smaller.

29. They soon became involved in the story and she could feel them relax <u>against</u> her. Joey brought his baby blanket up to his nose which was a sure sign he was ready for bed.

30. Five miles up the mountain lay a <u>beautiful</u> meadow cupped in the bowl of an ancient glacier.

31. Arthur looked around the room; everyone seemed to be purposefully at work.

32. When the story was finished, Mary helped the two sleepy toddlers up to bed and tucked them into bed with a good-night kiss.

33. Mr. Pearson enjoyed cooking as many variations as possible of his basic seafood chowder. The family had experimented with bits of seaweed and some wonderful wild chives that grew between the rocks in front of their cottage.

34. As the front door closed behind Mr. and Mrs. Trent, Mary felt her heart lurch in her throat.

35. Somebody had made a mistake at the pet store because there were now sixteen gerbils in Susan's room.

36. Though their vacation was always the same two weeks in July, they never tired of it or wanted it to be otherwise.

[a] Probe words are underlined.

TABLE 22

Digit Probe Items

Items		Probe
1.	1962534078	5
2.	3850712946	2
3.	3647108529	3
4.	2948571360	4
5.	8741530629	2
6.	0264807351	4
7.	7385692041	2
8.	5384162970	3
9.	0948631572	4
10.	7120854639	3
11.	9721356480	2
12.	9451780263	2
13.	9236154870	5
14.	2186053974	3
15.	5607129348	4
16.	6532194870	3
17.	0852739146	5
18.	1053974682	5
19.	8364925107	5
20.	1034692857	4

TABLE 23

Mean SVT Proportion Correct by Level of Reading Difficulty as a Function of Working Memory

Difficulty Level	Working Memory Group		
	Poor	Average	Good
Easy	.696	.799	.844
Moderate	.601	.764	.828
Difficult	.533	.660	.736

Note: *N* = 18 for poor and good working memory groups, but *N* = 21 for the average working memory group.

TABLE 24

Source of Variance Table of Mean SVT Proportion Correct

Source	df	SS	MS	F
Working Memory Group (G)	1	8.009	8.009	37.21**
Error 1	34	7.318	.215	
Difficulty Level (L)	2	2.668	1.334	28.43**
Passage within L: P(L)	3	.068	.023	.48
SVT Test Item (S)	3	4.181	1.394	29.70**
L X S	6	.531	.088	1.89
P(L) X S	9	1.674	.186	3.96**
G X L	2	.239	.120	2.55
G X P(L)	3	.313	.104	2.22
G X S	3	.253	.084	1.80
G X L X S	6	.466	.078	1.66
G X P(L) X S	9	.421	.047	1.00
Error 2	782	36.690	.047	

*$p < .05$

**$p < .01$

TABLE 25

Source of Variance Table of Mean Reading Time

Source	df	SS	MS	F
Working Memory Group (G)	1	2.285	2.285	1.59
Error 1	34	48.936	1.439	
Difficulty Level (L)	2	21.312	10.656	42.73**
Passage within L: P(L)	3	1.8860	.629	2.72
G X L	2	.3082	.1541	.62
G X P(L)	3	.3442	.1147	.49
Error 2	170	39.282	.2311	

*p < .05

**p < .01

TABLE 26

Source of Variance Table of Reading Comprehension Efficiency

Source	df	SS	MS	F
Working Memory Group (G)	1	2.77	2.77	10.22*
Error 1	34	9.20	.27	
Difficulty Level (L)	2	5.85	2.92	495.42***
Passage within Level: P(L)	3	.784	.261	44.24**
Group X Level	2	.14	.07	11.36**
Group X P(L)	3	.08	.03	4.23*
Error 2	170	8.89	.006	

*$p < .05$

**$p < .01$

TABLE 27

Mean Effective Reading Rate across Reading Difficulty Levels as a Function of Working Memory

Difficulty Level	Working Memory Group	
	Poor	Good
Easy	95.46	138.17
Moderate	84.70	122.17
Difficult	71.20	109.87
All Levels	83.79	123.40

Note: Effective rading rate was SVT proportion correct multiplied by words per minute reading time.

TABLE 28

Source of Variance Table of Effective Reading Rate

Source	df	SS	MS	F
Working Memory Group (G)	1	84741	84741	11.03**
Error 1	34	261124	7680	
Difficulty Level (L)	2	24859	12430	8.95**
Passage within Level: (P(L)	3	20519	6840	4.92*
G X L	2	271	135	.09
G X P(L)	3	2364	788	.587
Error 2	170	236063	1389	

*$p < .05$

**$p < .01$