RELATIONSHIPS BETWEEN WORKING MEMORY AND READING COMPREHENSION IN BEGINNING AND INTERMEDIATE READERS

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ABSTRACT

This study investigated the relationships between working memory and reading comprehension. Two non-linguistic (digit span and modified digit span) and two linguistic (word span and reading span) memory measures were used. These measures were comprised of 11 tests. From these tests, predictors of reading comprehension were sought. Two subtests from the Woodcock Reading Mastery Tests (W.R.M.T.) were used as a measure of reading comprehension. Age related differences between the 30 Grade 2 and 30 Grade 6 subjects were also investigated. Significant differences in the mean scores of the Grade 2 and 6's were found of all 5 of the non-linguistic tests but only on 1 of the linguistic tests. Familiarity with the lexicon used in the linguistic tasks may account for this. No significant interactions were found between grade measures. The modified digit span, word span and reading span tasks were found to be significant predictors of reading comprehension. The complex reading span measure had the highest level of significance of the three. This suggests that linguistic working memory task that had a capacity and processing component best predicts reading comprehension.

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CHAPTER 1

INTRODUCTION

Purpose

A considerable body of research exists which examines the relationships between reading comprehension and short-term or working memory. Much of this research has its basis in the university laboratory setting, using undergraduate psychology students as its subjects. It involves, for the most part, the use of linguistic and non-linguistic measures of short-term or working memory and standardized measures of reading comprehension. The results of these studies have shown a range of correlations from highly significant relationships to no relationships at all.

Daneman and Carpenter (1980) presented the view that short-term or working memory has both a storage and a processing component and that individual differences in the components can exist. They also looked at previous measures of short-term or working memory as only tests of storage capacity. They argued that if individual differences in short-term or working memory were to be observed a task that measures not only storage but processing capacity must be used. Since that study was published many extensions and replications with extensions have been performed with varying results. Few of these studies have investigated the relationship between reading comprehension and short-term or working memory in school-age children.

The purpose of the present study was to determine the extent to which some selected linguistic and non-linguistic memory tasks predict reading comprehension in beginning and intermediate readers. This study attempted to answer two questions. The first question was which of the linguistic or non-linguistic tasks best predict reading comprehension ability. Linguistic tasks are defined in this study as tasks using words or sentences (i.e., language), while non-linguistic tasks are defined as tasks using digits or numbers (i.e., symbols). The second question raised was with regards to the possibility of a difference in the relationships between reading comprehension and working memory in the two reading grade groups (i.e., Grade 2 and 6).

Background

Traditional measures of short-term or working memory have involved simple word span or digit span tasks that were considered to assess only the capacity of this type of memory. Research into short-term memory or working memory, looked at this component of memory as a passive temporary storage for information that is eventually transferred to long term storage or lost through decay or replacement. More current theories of memory view short-term memory as more active and being comprised of a storage and a processing component. The term working memory has in many instances come to replace the name short-term memory and is used from this point on in this thesis. Working memory in this study is used to refer to an active working memory where storage and processing both can take place.

After the publication of the Daneman and Carpenter (1980) study, research into working memory span and tasks to measure the span, and its relationship to reading comprehension, broadened. Many new and varied tasks were designed and tested with conflicting results. Baddeley, Logie, Nimmo-Smith and Brereton (1985) spent much time and effort investigating the reading span task that Daneman and Carpenter (1980) used and then designing what they stated to be a modified reading span task. Word span and digit span tasks gave way to more and more complex measures of working memory with varying degrees of success. Current research by Yuill, Oakhill and Parkin (1989) has returned to the digit span task and revised it. Their findings appear to indicate a significant relationship between a modified digit span task (non-linguistic task) and reading comprehension in young readers. While Turner and Engle (1989) and LaPointe and Engle (1990) have investigated a number of word span, digit span, operation span and sentence span tasks, the results of their research indicates that the simple word span task (linguistic task) shows evidence of being significantly related to working memory. These findings and others in the literature do not seem to present a clear picture of working memory's role in reading comprehension. Therefore, the present research was designed to reexamine the relationship between reading comprehension and working memory, as measured by two classes of memory measures, with particular reference to beginning and intermediate readers.

CHAPTER 2

WORKING MEMORY AND READING

While traditional theories of short-term memory have previously been based on a stoic, non-active storage buffer, more contemporary views see this storage facility as much more active and refer to it as working memory (Best 1986). This thesis takes the latter view. It also emphasizes that there are differences existing between individuals with respect to the utilization of the capacity component of working memory and the utilization of working memory processing, particularly in reading. This chapter will be divided into four parts. It will look at (1) the capacity component of working memory, (2) the processing component of working memory, (3) individual differences in reading comprehension ability and (4) recent research in the area of working memory and reading comprehension.

Capacity

Working memory has a limited capacity and as a storage facility is not large enough to hold and comprehend all of a text base presented orally or visually at once (Vipond, 1980). Information previously stored in working memory has a short duration and may decay or be displaced. Decay results from information not being retrieved, rehearsed or activated for a period of time. Displacement occurs when too much information is entered or processed and "old" information is removed or replaced.

Input for working memory is auditory and visual. Once information begins to be stored in working memory, problems with capacity begin to develop. We cannot keep adding information without some displacement occurring. A substructure (a buffer) to working memory appears to select what information is to be held in working memory and what is to be displaced (Kintsch & Van Dijk, 1978). Rehearsal, recency and plans and goals are among the strategies used to select and keep information for the buffer (Fletcher, 1981). Even with a buffer to assist in maintaining and working with information in working memory, some information decays or is displaced.

When measurements of capacity of short-term memory are mentioned in cognitive psychology literature the word "chunk" is generally given as the prevalent and functional unit. The number of chunks available in working memory is limited to 7 and/or -2 chunks (Miller, 1956) and does not appear to change with age (Chi, 1976). Though some authors like Simon (1974), have argued for a number more in the area of 5 chunks. What does vary with maturity is the complexity, richness and the degree to which one can elaborate from a chunk. Children chunk input in a more simplistic manner than adults (Chi, 1976). There are fewer concepts contained in their chunks and they have more difficulty making a coherent representation of the text or passage in their working memories. Less of the processes involved in chunking have reached a stage where they are automatic to the child (LaBerge & Samuels, 1974). When developing tasks to measure the capacity component of children's working memory, these factors must be taken into account.

Traditionally, to measure the capacity of working memory, tests like the digit or word span tasks and the digit memory test were used. The results were conflicting (Perfetti & Goldman, 1976). Daneman and Carpenter (1980, 1983) argue that these tests do not correlate well with reading ability nor do they tax the processing component of working memory. They suggest that a reading span test, that correlates with reading comprehension, be used instead. Little evidence can be found in the literature to contradict their view. Their conclusions are that a significant reason why good readers have larger working memory storage capacity than poor readers is because the former process more efficiently. This finding is consistent with theories of processing presented by Vipond (1980) and Kintsch and Van Dijk (1978). It is obvious that good readers use more of what Vipond (1980) calls automatic processes and thus their processing requirements are less. Poor readers would have fewer automatic processes. Therefore, they would have more difficult processing demands, less storage space and more trouble reading. Processes such as decoding and inferencing are not always automatic to the poor reader, while the good reader spends less effort on these and can spend additional resources producing rich chunks and appears to have more capacity.

Processing

The emphasis of this section will be on processing and comprehension. In the words of LaBerge and Samuels (1974, p.320): "(T)he complexity of the comprehension operation appears to be as enormous as that of thinking in general." Despite this complexity research into reading comprehension continues.

Comprehension processing itself takes place, according to the literature, in both serial and parallel. Once these processes become automatic then reading becomes easy. Though, it should not be forgotten that reading is a complex process.

When we read, written information is translated into propositions. For good readers this translation is almost automatic. From these propositions a text base is created that must be referentially coherent (Kintsch and Van Dijk, 1978). The base is constrained by; deletion of inessential propositions, replacing groups of propositions with generalizations and construction of "global" propositions that connect overlapping propositions. With these constraints in mind, it is fairly clear that many types of additions and alterations, such as inferencing, cannot be done within the limitations of working memory capacity. What this means for good readers is that the construction of a coherent text base is easier because of their smaller allotment of resources due to automated processes.

Control processes for reading comprehension, such as the reader's use of knowledge, purpose, interest, and set, affect the reader and they will interact (Fletcher, 1981, Recht & Leslie, 1988). It follows that if you have an interest or goal in what you are reading you will comprehend better, if only because you concentrate and focus your attention on it. Attention is one of the required resources for comprehension. As stated by LaBerge and Samuels (1974, p. 313), "the goal of a fluent reader is to maintain his attention continuously on the meaning units of semantic memory, while decoding from visual semantic systems proceeds automatically." This stresses the role of attention in reading comprehension. Attention is a factor that can be selective and does have a limited capacity. We may always focus on what we attend to but we still process many different things at the same time. In reading it is essential to pay attention to the text since so many component skills are involved. Along with attention, memory, consciousness and the decisions involved are also required resources for comprehension (Kintsch & Van Dijk, 1978). The allocation of these resources is restricted by the capacity of working memory. From this it becomes fairly evident that capacity and processing both play an integral part in reading comprehension.

Good and Poor Comprehenders

Reading is a set of complex skills that most adult readers take for granted. However, for children learning to read, acquiring these skills is a long process. Even after many years of practising these skills, some children do not become fluent readers. These failures have been of concern to both educators and researchers. As a result, there has been much research into the relationship between reading and memory over the past 20 years. The results have shown that a positive correlation exists between skilled reading and the effective use of memory processes and in particular, working memory processes.

As stated earlier, the findings point to the basis of working memory as being composed of a storage and a processing facility, and having limited capacity. In addition, the two components compete for the available resources within working memory. Much early research looked for differences in working memory capacity between good and poor readers. It was thought that poor readers had a deficit in working memory capacity but, Chi (1976) and others (Daneman & Carpenter, 1983) found that there is similar capacity in children over 5 and adults. Thus the emphasis of more recent research has shifted away from the stoic view of a storage capacity and looks towards differences in processes and procedures between the two types of readers.

Individuals differences in working memory appear to reflect differences in processing efficiency (Daneman & Carpenter, 1983). Processes in working memory that are more demanding require more capacity and therefore reduce the amount of storage available for information to be maintained. Attention is such a process. It can be broken down into two parts: overt and covert characteristics (Samuels 1987). Overt attention characteristics are the physical attributes that are "directly observable." On the other hand, covert attention is not as "observable" from the outside. Samuels (1987) breaks covert attention into 4 parts: level of arousal, alertness, vigilence and selective attention. Each of these components of attention assists in the successful decoding and comprehension of text, but, there are only limited resources available in working memory for attention. Thus like many other processes, to reduce the burden on working memory, attention must be as automatic as possible.

Many of the differences between good and poor readers appear to be the lack of automated processes. Decoding and encoding are also processes that need to be automatic. Successful decoding and encoding of text in working memory are necessary for a meaningful representation of propositions in a "text base." Much attention by the reader is required for decoding. Slow and difficult decoding by poor readers places a heavy demand on working memory. The poor reader is constantly shifting form decoding to comprehension in order to read and get meaning (Samuels, 1987). Good readers though, can simultaneously switch between the two processes thus reducing demand on working memory and leaving more capacity for storage. This makes the poor readers's working memory capacity appear smaller. More coding process difficulties for poor readers have been identified that support this conclusion. Stanovich (1982a) states that poor readers have deficient phonological coding processes such as: rehearsal, imagery and elaboration. While Daneman and Carpenter (1983) found less efficient readers devote so much capacity to processing incoming words that they are less likely to have relevant and meaningful information still in working memory. Poor readers commit too much capacity to these lower functions and therefore do less higher level coding. That is, the poor reader recognizes smaller units of print like letters or digraphs and not larger units like whole words. Again, this places a heavy demand on working memory. Good readers process larger or smaller units dependent on need (Samuels, 1987). They are also more adept at detecting context and using it to facilitate memory and comprehension of text. On semantic matching tasks such as letter matching, and identifying synonyms and homonyms poor readers respond slower (Daneman & Carpenter, 1980, 1983). Poor readers also remember less spoken words and linguistic material than good readers (Mann, Cowin & Schoenheimer, 1989). As well, these readers differ in ability to store text in working memory after it is encoded.

Differences among good and poor readers have been found in the process of maintaining information in working memory. To incorporate new propositions into the "text base" they must relate to previously stored material. This proves more difficult for poor readers who use much of working memory capacity for lower level processing and not for storage. Poor readers are also less prone to employ active, planful memorization strategies and phonological processes to help themselves. On the topic of syntactic ability, poor readers have been found to be less adept at text scanning, less sensitive to text structure and lack linguistic awareness (Stanovich, 1982b). Deficits in comprehension of poor readers appear to be caused by taking too much time to "encode and retrieve meaning." If too much time is taken by poor readers it could also result in some decay of information in working memory (Daneman & Carpenter, 1983). Working memory capacity plays an important role in text processing particularly in integrating new information with prior text. The more capacity you have for new information the more likely you can relate it to previous text propositions. Samuels (1987) argues that poor readers have limited access to lexical information. He states that inefficient naming and sequential processing interfere with the ability to simultaneously **decode** text and **process** for meaning, two processes that are critical for skilled reading.

Another area of differences among readers is recall or retrieval. Effective retrieval is dependent on the initial coding of material within the knowledge structure in long-term memory. It also leaves retrieval cues in working memory (Daneman & Carpenter, 1983). Recht and Leslie (1988) found that prior knowledge of content domain is a powerful determinant of amount and quality of information recall, powerful enough to compensate for low ability. Iff text is familiar to good and poor readers both will have similar short term recall. To the authors, prior knowledge creates a scaffolding for information in memory. In poor readers it helps compensate for inefficiency of processing.

In short to quote Samuels (1987, p. 20) factors that account for poor reading include "failure to maintain overt attention during instruction; defects in arousal, alertness, vigilance, and selective attention; lack of accuracy and automaticity in decoding; inability to use both large and small visual units in word recognition; lack of accuracy and automaticity in mapping sounds on to visual units and finally, difficulty in accessing lexical word information."

Recent Research

A great deal of research continues to be generated in the area of reading comprehension and working memory and a variety of tasks to measure working memory have been utilized. Both linguistic and non-linguistic tasks have been developed and tested with varying degrees of success and a range of correlations from non-significant to very significant. The task that seems to draw the most research attention is the reading span task of Daneman and Carpenter (1980). It was designed to measure both the storage and processing components of working memory. Daneman and Carpenter felt that tasks like digit span and word span did not adequately predict reading comprehension and did not access the processing aspect of working memory. Digit Span and word span were believed to be simply measures of capacity. Baddeley, Logie, Nimmo-Smith and Brereton (1985) supported the research findings of Daneman and Carpenter using a reading span measure (and other tasks). Baddeley et al.'s measure was a variation of Daneman and Carpenter's task with a verification component (processing) and a word span component (capacity) in it . Even though there are differences in the procedures the authors used in their tasks, there is agreement on their findings.

In evaluating the results of their own research, Baddeley et al. pose the question: Is there a general working memory system or are there specific working memory systems (e.g., a specific language-based system)? This line of inquiry has been followed up in studies by such authors as Oakhill, Yuill and Parkin (1988), Yuill and Oakhill (1988), LaPointe and Engle (1990), and Turner and Engle (1989). Yuill, Oakhill and Parkin's (1989) research looked at a modified digit span task that they felt would tax both the processing and the storage components of working memory. Their results would appear to indicate that a digit span task of the nature they proposed can predict reading comprehension with correlations that were similar in magnitude to those found by Daneman and Carpenter (1980, 1983).

Yuill, Oakhill and Parkin state that if this is accurate and replicable it would support a general working memory system theory. After reviewing the task's procedure a number of concerns were left unanswered. The first concern is that reading out digits is considered by the authors as a processing task, yet reading digits is a recognition or memory retrieval task not a processing task for many subjects even at seven or eight years of age. A second concern is: With young children would the results of using a traditional digit span task be any different that what Yuill et al. (1989) found with their digit span task? Also of concern is: Can their findings be replicated with older children who are at a more intermediate level of reading and mathematical ability? With the older group of children, the task of recognition of digits would be less demanding than with younger children (in most cases). The modified digit span task is also less likely to be a much better predictor of reading comprehension than a regular digit span task.

Extensive research with digit span tasks already exists with experienced and skilled adult readers (ie. undergraduate psychology students) and children with varying results.

Another area of recent research in the field of reading comprehension and working memory has involved the use of a variety of word span and reading span type tasks. Authors like Turner and Engle (1989) have investigated Daneman and Carpenter's (1980, 1983) findings. Turner and Engle looked at the possibility that "people are good readers because they have a large W(orking) M(emory) capacity independent of the tasks being performed" (pg. 129). To test this theory they used complex span tasks varying the background task (processing) between mathematical operations and sentences and the primary task (capacity) between digits and word. They also looked at simple digit span and word span tasks. The results of the studies support their hypothesis that a "complex span reflecting W(orking) M(emory) capacity does not have to be 'reading' related to generate a significant correlation with reading comprehension (pg. 149). Yet their significant correlations were with the complex tasks that had a word span as the primary task and not a digit. They can not account for this finding other than to state "the differences in the to-be-remembered items appear to be crucial." In addition to this, they are not sure of the accuracy of the results of the operation-word task. Turner and Engle (1989) believe that the strong predictability of the operation span task is because the operation component of the task may lead to a spurious correlation between this task and reading comprehension. The reason for this is that good readers also have good **quantitative skills** (Turner and Engle (1989). Thus the task that still most consistently predicts reading comprehension is the reading span task.

In addition to using a reading span task, LaPointe and Engle (1990) re-examined the simple word span task as a possible predictor of reading comprehension. They looked at the effect of word length on simple and complex tasks. In a series of five well laid-out and developed experiments LaPointe and Engle demonstrated that the simple word span task can predict comprehension.

Conceptual Relationships Between Working Memory and Reading Comprehension and Predicted Findings

Working memory is comprised of a storage and a processing component. The two components constantly strive for the limited resources available to working memory. The capacity is limited by the amount of information it can maintain at anytime, while the amount and type of processing that can be accomplished in working memory is also limited. To best utilize working memory, processing needs to be as automatic as possible. This allows the storage component of working memory to be maximized. In this way capacity and processing are interrelated and interdependent.

Reading comprehension can be viewed in a somewhat similar vein to working memory. It is a complex operation and can be conceived of as the ability to decode and establish meaning from text or messages. For this to be accomplished, decoded and encoded information must be stored. As information is being stored, integrated processing of the pieces is taking place such as establishing meaning of words or establishing context. Like working memory, reading comprehension is limited, thus meaning for all of the text base cannot be established at once. The more automated the processes for reading are , the more information that can be stored and, therefore, the more efficient the reader. Thus the efficient use of working memory and being an efficient reader have parallels. Both operations involve storage and processing of information and are complex in nature. When looking at the relationships between working memory and reading comprehension one question that arises is: Do non-linguistic or linguistic memory measures best predict reading comprehension ability?

Traditional non-linguistic measures like the digit span are simple capacity measures and would not be expected to predict a complex operation like reading comprehension. (Perfetti & Goldman, 1976). Yet a backward digit span which requires reverse seriation (processing of the digits during the reversal stage as well as storage) may predict better. This is because the backward digit span task has a capacity and a processing component similar to a reading span task. Yuill, Oakhill and Parkin (1989) developed a modified digit span task that they argue has a capacity and a processing component. If this is the case then it should predict reading comprehension better than a strict capacity testing digit span tasks. Yet, since their task is non-linguistic and thus not as closely related to reading comprehension as a linguistic task, like reading span, it should not predict as well as a reading span task. When linguistic measures of working memory are mentioned in the literature, word span and reading span are generally the ones discussed. Word span is again a capacity measure and is not felt to measure processing in working memory (Daneman & Carpenter, 1980, 1983). But, because it is linguistic it should predict reading comprehension better than a non-linguistic capacity measure. In the literature, the measure that most consistently predicts reading comprehension ability is the reading span task. This may be because it is the most similar to reading comprehension in its demands on working memory (Baddeley, Logie, Nimmo-Smith and Brereton, 1985). Because the task has a storage and a processing component and it is linguistic, it should significantly predict reading comprehension.

Relationships between working memory and reading comprehension may vary depending upon age differences. Age related differences seem to play a part in both working memory and reading comprehension. Capacity in working memory appears to increase until adolescence (Best, 1986). This may be the result of more efficient processing and the ability to generate richer chunks of information (Chi, 1976). The maturation of readers parallels the development of working memory ability. As readers mature and gain more experience with the complex operations involved in reading, their ability to process text becomes more automatic and they then have more capacity for storage.

A second question posed is: Do differences exist in the relationships between working memory and reading comprehension in the two grade groups? A number of the measures used in this study, should show significant differences between the two grades. This is particularly true of the non-linguistic memory measures (digit span and modified digit span) which are context independent and basically tax the storage component of working memory. The literature would seem to predict that the older children, who have more capacity in working memory, would remember more digits than the younger children. With regard to the linguistic measures, word span and reading span, differences in the word span scores may not be a significant predictor of reading comprehension. This is because the word lists involved should be familiar to most of the children in both grade groups and the words are context independent of reading comprehension ability. In contrast, the reading span task is context dependent and should prove to be more difficult at the higher levels (RS2 and RS3) for younger children. The Grade 2 group should have more difficulty with the increased demands of the complex reading span task than the word span task. The reading span task because of its background and primary task does not allow for as much use of strategy (such as rehearsal) as a word span or digit span task and this should prove to make it more difficult for these intermediate level readers. The reading span task would thus seem to be the best overall predictor of reading comprehension for both groups and in particular the older of the two groups.

Another possible finding is that the predicted regression slopes of the scores of the Grades 2 and 6 subjects should be differentially affected by the exclusion of a number of Grade 2 children. The children that were eliminated as subjects had below average vocabulary ability. The use of only the selected Grade 2 children in the study should result in shorter range of scores with the bottom end truncated. This should probably results in a flatter slope of the regression lines for Grade 2 than Grade 6. Therefore it would also be expected that the interaction terms between grade and memory subtests scores would be significant. Yet, also because of the restrictive selection process for subjects, the level of familiarity with reading is more similar between the grade groups. This similarity in reading ability is more likely to result in the slopes of regression lines for Grade 2 and 6 being parallel and no significant interactions between grade and memory scores being found.

CHAPTER 3

METHODOLOGY

Subjects

The subjects are 30 seven and eight year olds in Grade 2 and 30 eleven and twelve year olds in Grade 6. The subjects are in two suburban elementary schools in middle class neighbourhoods. The number of boys and girls was not defined as a factor in the study. There were 13 boys in the younger grade and 17 boys in the older grade. In Grade 2 there were 17 girls and 13 girls were in Grade 6. All subjects have at least average reading decoding ability as defined by the Yuill, Oakhill and Parkin (1989) model. The subjects were divided into the two groups on the basis of their grade. The Grade 2 group was chosen to replicate and extend the Yuill,Oakhill and Parkin (1989) results. The choice of the Grade 6 group was because they are more experienced readers while still at the elementary school level.

Test Materials

Reading Comprehension Test: The reading comprehension test used was the Woodcock Reading Mastery Tests (W.R.M.T., Woodcock, 1973). The W.R.M.T. is a norm-referenced standardized test of reading. It consists of five subtests; letter identification, word identification, word attack, word comprehension and passage comprehension. The word identification and passage comprehenison subtests were administered to the subjects. Reading vocabulary (word identification) scores are included as the baseline selection measure for all subjects. All subjects to be included in the study were to have at least average reading decoding skills, regardless of comprehension ability. Those subjects who were not selected had word identification skills that were more than one standard deviation below the mean (< 16 %ile). This selection process is a modified version of the one used by Yuill, Oakhill and Parkin (1989). The passage comprehension subtest is cloze format and includes 85 items.

Digit Span (DS): The digit span is a variation of the task included in the Stanford-Binet Intelligence Scales: Fourth Edition (SBIV). The variation are that some of the digits in the items are changed and an equal number of trials is given for both parts of the task. (The SBIV has two more items in the digit forward than the digit reverse section.) Both a forward (FDS) and backward digit span (BDS) were given. The number of digits was 70 for the forward task and 58 for the backward task (including samples). Both sets had two sample questions of two digits each. The forward span ranges from three to eight digits and the backward span from two to seven digits long. Two items of each length were generated for both the forward and backward spans. (Appendix 1).

Modified Digit Span (MDS): This task was designed using the guidelines set out in by Yuill, Oakhill and Parkin (1989). Lists of three digit numbers were generated from random number tables. Eight lists of two (MDS2), three (MDS3) and four (MDS4) groups of three digits and two sample and a pair of practice items at each of the three levels were used. Restrictions in the selection of groups of digits were the same as those used by Yuill, et al. (1989). Those restrictions are: the same digit never appeared twice in a group, the final digits are never zero, the digits do not form an obvious sequence (e.g. 2-3-4) and the digits are not phonologically confusable (e.g., 5-9). (Appendix 1).

Word Span (WS): The word span task is a variation of the task used by LaPointe and Engle (1990). They referred to it as a "simple" word span task. The words used for the task are one syllable words selected from the lists presented by LaPointe and Engle (1990). The words chosen were randomized in their groupings. Eight lists of two (WS2), three (WS3) and four (WS4) words were generated to match the structure of the modified digit span task. There were 76 words generated for the task. The words for the lists were generated from the most common three to five letter words published in Francis and Kuchera (1982) and used in LaPointe and Engle's (1990) research. (Appendix 1).

Reading Span (RS): The task for the reading span measure was based on the model established by Daneman and Carpenter (1980) and modified similar to the method used by Baddeley, Logie, Nimmo-Smith and Brereton (1985). The task involves a background task (reading a sentence and verifying whether or not it makes sense) and a primary task (remembering the last word in the sentence). Sentences are short in nature (five to eight words) with half of them sensible and half nonsensical. The structure of the sentences was; noun (animal), verb then object. Twenty-eight sentences were generated, two as samples and four sets of one (RS1), two (RS2) and three (RS3) sentences. The sentences were generated using primary levels of basal readers from the Impressions series (Booth, Booth, Pauli, & Phenix, 1985). (Appendix 1).

Procedure

In order to examine the relationship between working memory and reading comprehension this research used both non-linguistic (standard digit span and modified digit span) and linguistic (word span and reading span) memory span tasks. Reading comprehension is viewed in this proposal as reading vocabulary and reading comprehension both measured by standardized reading achievement tests.

As previously mentioned, Grade 2 and 6 subjects were selected in terms of reading achievement based on their scores on the word identification subtest of the Woodcock Reading Mastery Tests (W.R.M.T.). To be selected as subjects, students had to have at least average vocabulary ability. This was to ensure they would be able to perform the reading span and reading comprehension tasks. All subjects were then tested on the passage comprehension subtest of the W.R.M.T. Subjects were tested in groups of 15 at a time in random assignment on the reading comprehension subtest (as they were on the word identification subtest). Study materials (i.e., activity sheets) were provided for those students who finished early. Prior to beginning the tasks all subjects were presented with test booklets for recording their responses and given directions for the tests (for the W.R.M.T.). This part of the testing procedure was administered as outlined in Tuinman, Kintzer and Mahtadi (1980) and in the test manual. The Tuinman et al. variation is to administer the passage comprehension subtest as a written test as opposed to an oral one. They found that the "resulting scores were every bit as valid as those obtained by following the Woodcock's original format" (p. 105). The materials used for this part of the research were not modified in any other way. The average administration time was approximately 30 minutes.

Once the reading comprehension testing was complete, the subjects were then assessed individually or in small groups (two to five in number) using the four memory tasks. Assignment to the test groups was random using tables of random numbers. Answer sheets were provided for the subjects' use. These sheets were standard forms developed by the experimenter. A separate answer sheet is designed for each of the four memory tasks (Appendix 1).

The first of the memory tasks to be administered was the digit span task. Subjects were tested on the digit span task in small groups of three to six, at individual seats. Subjects were facing the experimenter and two assistants so that all their responses can be monitored. (The assistants were used here because of the age of the children, to help reduce the instruction time.) Sample items were presented on an overhead projector, to enable the examiner and assistants to check that the subjects understood what the task requirements were. Two sample items were presented for both the forward and the reverse digit span parts of the task (see pp. 57 & 61). During the actual testing, items were given orally by the experimenter, at the rate of one digit per second and the answer sheet was turned face down. After each individual item was presented the answer sheet was turned over and the subject recorded as much of the item as they remembered. Answer sheets were turned face down between items. Twelve items were presented in the forward span and the same number in the reverse span task. Subjects were instructed to put down on the paper as many of the digits as they could remember even if they could not remember all the digits.

A similar procedure was used with the modified digit span task (see pp. 58 & 62). An overhead projector was again used to present the sample and practise items to ensure that all subjects understand what was to be done in the task (as was done in the previous task). Two sample items were used and two practise items were presented at each of the three levels. The subjects were to write down the final digits of the groups on the answer sheet provided. Group size was again from three to six with two assistants present. Each group was orally presented with eight experimental trials at each of the three levels of difficulty. The digits were presented at a rate of one digit per second with a two second pause between groups of digits. The blocks of digits in the two-group trials were presented first, then the three-group trials and finally the four-group trials. All the subjects performed the tasks in the same manner for this and all the tasks presented.

Each of the subjects also completed a word span and a reading span task. The word span task was administered in a format similar to the previous two tasks (see pp. 59 & 64). Sample items were orally presented along with an overhead projector, by the examiner on an individual basis. All the word span task were administered individually. Responses were recorded for the subject on an answer sheet by the examiner. The words for the task were presented in two-group, three-group and then four-group trials, the same as was done in the digit span tasks. The rate of presentation was one digit per second.

The reading span task was presented to subjects again on an individual basis (see pp. 60 & 66). The sample items were presented in large print on manilla tag cards. As the sentences were presented, the experimenter read the sentence to the subject. The sentences were presented at a slow steady rate (approximately two words per second). The subject first responded as to whether or not the sentence made sense and then stated what the last word in the sentence was. The tasks were presented on one-group, two-group and three-group trials. All responses were recorded by the experimenter on data sheets.

The presentation methods and task designs were decided upon after preliminary pilot samples were conducted. The subjects tested were not the same subjects as those to be used in this study. Additional consultation and advice on the tasks to be used was provided by a school district speech/language pathologist and the district's primary language development teacher.

Design and Analysis

A two age group (seven and eight year olds and eleven and twelve year olds) x twelve measures repeated-measures design was used. The twelve measures were: (1) reading comprehension f(from the W.R.M.T.), (2) forward digit span (FDS), (3) backward digit span (BDS), (4) modified digit span 2 (MDS2), (5) modified digit span 3 (MDS3), (6) modified digit span 4 (MDS4), (7) word span 2 (WS2), (8) word span 3 (WS3), (9) word span 4 (WS4), (10) reading span 1 (RS1), (11) reading span 2 (RS2) and (12) reading span 3 (RS3). General linear model analyses were performed on the data set using the SAS statistical package (1985). This package uses four types of partitioning the sums of squares. Type I are model-order dependent; each effect is adjusted only for the preceding effects in the model. In Type II, each effect is adjusted for all other effects possible. The predicting (dependent) variable was reading comprehension score (W.R.M.T.). Type III is used to calculate two types of sums for squares and Type IV is used for designs with cells missing. The predicting (independent) variables included: grade, the number of correct item responses total for the digit span and sentence verification tasks and the number of correct words or digits at each level of the modified digit span, word span and reading span tasks. The main effect of the independent variable (grade) and the predicting variables, as well as their interaction, with grade as a categorical variable were analyzed.

Scoring

A method of scoring was to sum all of the words or digits correctly recalled by the subjects on each of the subtests. Words or digits were counted whether or not the entire trial was correct (absolute score). This method of scoring is considered by Broadbent (1971) to be "the best way to measure STM." Each trial type is recorded separately (e.g., forward digit span total , backward digit span total and word span 2 total, etc.). Serial order is considered part of a correct response because of the digit span task. In the digit span task serial order is part of the standardized procedure for the scoring of these tasks as in the Stanford-Binet Intelligence Scales: Fourth Edition (Thorndike, Hagen & Sattler, 1985). An index of the sentence verification task was obtained. The scores for this task were kept to check and see if subjects focused on the reading span task or were responding in a frivolous manner.

The overall scoring method was used for the purpose of calculating descriptive statistics and the general linear model analyses. This was done to be in keeping with the aforementioned suggestion by Broadbent (1971) and also to enhance the sources of validity in measurement operations if equal weighting for trials was to be used (Borg & Gall, 1983).

CHAPTER 4

RESULTS

Four memory span measures (two linguistic and two non-linguistic) comprising 11 subtests, were administered to 60 subjects who had previously been assessed on the W.R.M.T. passage comprehension subtest. The tests administered were: forward digit span (FDS), backward digit span (BDS), modified digit span 2 (MDS2), modified digit span 3 (MDS3), modified digit span 4 (MDS4), word span 2 (WS2), word span 3 (WS3), word span 4 (WS4), reading span 1 (RS1), reading span 2 (RDS2), and reading span 3 (RS3). The scores of reading comprehension using the W.R.M.T. ranging from 11 to 75 were obtained. The maximum total for the subtest is 85. A score of 20 would be considered average for a Grade 2 and a score of 56 is average for a Grade 6. An examination of the analysis of the results determined the relative strengths of each of the measures as predictors of reading comprehension level across two grade levels.

The observed means of all scores of Grades 2 and 6 subjects under the various conditions is presented in table 1.

TABLE 1

Observed Means by Grade and the Statistical Significance of their Differences

Variables	Grade 2 n = 30		Grade 6 n = 30		F(1,58)	p value
		Non-linguistic Measures of Memory Span				
FDS	4.07	(1.22)a	5.30	(0.98)	18.34	<.0001
BDS	2.80z	(1.44)	4.50	(1.54)	19.30	<.0001
MDS2	13.17	(3.22)	15.87	(0.43)	20.62	<.0001
MDS3	15.77	(7.27)	23.03	(1.71)	28.49	<.0001
MDS4	17.40	(9.24)	27.37	(5.32)	26.16	<.0001
		Linguistic Measures of Memory Span				
WS2	15.57	(0.85)	15.90	(0.30)	4.02	<.0497
WS3	23.10	(1.80)	23.07	(1.28)	0.01	<.9347
WS4	25.47	(7.78)	27.20	(5.22)	1.03	<.3154
RS1	3.90	(0.30)	3.96	(0.18)	1.05	<.3087
RS2	7.10	(1.93)	7.37	(1.18)	0.41	<.5228
RS3	6.73	(3.77)	10.23	(2.60)	17.44	<.0001
		Comprehension Measures				
Reading comprehension	35.43	(13.81)	60.63	(7.30)	78.03	<.0001
Sentence verification	22.43	(1.94)	23.63	(0.55)	10.59	<.002

a - Numbers in parentheses stand for standard deviations.

Analysis of Observed Means Differences between Grade 2 and 6

The means of Grade 2 and 6 were compared by ANOVA on the non-linguistic and linguistic measures of memory span as well as the comprehension measures. The test results are also shown in Table 1. Grade 2 and 6 children's performance differences on the non-linguistic measures are highly significant in favor of grade 6 children, as indicated by the large F-values and very small p-values that can be seen in Table 1. In contrast, their performance differences on all the linguistic measures, except for the reading span 3, were found to be nonsignificant. Their difference in reading span 3 was significant, $\underline{F}(1,58) = 17.44$, $\underline{p}<.0001$. In view of the significance of the difference in the reading span 3 test, the lack of significant differences in the other linguistic measures is most likely to be due to the floor effect of the tests used.

As to the index of sentence verification of the reading span task, Grade 2 and 6 children performed well. To correctly identify the sentences as sensical or nonsensical, with any degree of success, the children must comprehend it. Both grade groups of children correctly verified more than 22 out of a total of 24 sentences, with Grade 6 children verifying one more sentence (22.63 vs. 22.43) correctly than Grade 2 children, $\underline{F}\ (1,58) = 10.59$, $\underline{p}< .002$.

Despite the high level of judgemental verification of each sentence (as to its sensical or nonsenensical meaning status) by both grade groups, Grade 6 children's reading comprehension, as measured by the W.R.M.T., was far superior to grade 2 children (means of 60.63 vs. 35.43), F (1,58)= 78.03, $p < .0001$. A question that arises from these observations is: What factors contribute to this significant difference in reading comprehension between the grade groups? A common sensical explantation for the difference is the maturation of the readers. In the pursuit of the relevant factors involved, an interesting finding is that the difference in the non-linguistic measures between grade 2 and 6, but not that in linguistic measure corresponds to the difference in reading comprehension scores. Thus, it is highly tempting to infer that the former measures are the responsible factors for the difference in reading comprehension. It should be noted, however, that the data analysis necessary for addressing this question requires more than nomothetic analyses.

Analysis of Predictive Relations between Two Classes of Memory Measures and Reading Comprehension

In order to obtain adequate analyses of the data to determine the relative predictive relations, the general linear model including interaction terms was established to predict reading comprehension from both the non-linguistic and linguistic measures of memory span. The statistical selection of sensitive and potent predictors from these two classes needs to be made first since all predictors are too numerous to be entered in the model. This is especially true in view of the small sample size employed in this study, that is, the small number of degrees of freedom available for testing the final hypothesis of interest. Therefore, it was decided to perform two linear model analyses, one with the non-linguistic measures, and the other with the linguistic measures. The two analyses were made using the SAS program (1985). The level of significance for each variable test was set at the .05 level. Results of these two analyses can be seen in Tables two and three.

From a review of the Anova tables, three findings become apparent. The first of these is that there are two results significant in the analysis of the non-linguistic measures. The overall forward digit span score was a significant predictor, $F(1, 48) = 5.26$, $p < .26$, while the backward digit span was not. Of the modified digit span scores the only significant predictor was the modified digit span 4, $F(1, 48) = 4.05$, $p < .050$. The second finding is from the linguistic trials, where two of those results are significant as well. Of the linguistic measures, the word span 4 trial was significant $F(1, 46) = 4.14$, $p < .048$, while the other two word span trials were not. The reading span 1 and 2 were not significant predictors, but the reading span 3 score was a significant predictor $F(1, 46) = 9.62$, $p < .003$. The third finding is from a review of the F values of the interactions of memory trials and grade. Neither the linguistic nor the non-linguistic measures were shown to have any significant interaction with grade levels.

TABLE 2

Summary Test Results of the General Linear Model Analysis of Reading Comprehension as the Function of Grade and Non-linguistic Memory Span Measures

Measures (df 1,48) (n for all measures = 60)	*F* values	*p* values
Intercept	0.03	0.853
Grade	0.02	0.890
Forward digit span	5.26	0.026*
Backward digit span	1.34	0.253
Modified digit span 2	2.67	0.109
Modified digit span 3	2.98	0.091
Modified digit span 4	4.05	0.050*
Interactions		
Forward digit span by Grade	0.25	0.622
Backward digit span by Grade	0.04	0.841
Modified digit span 2 by Grade	0.72	0.399
Modified digit span 3 by Grade	3.48	0.068
Modified digit span 4 by Grade	0.15	0.704

* significant at *p* >.05

TABLE 3

Summary Test Results of the General Linear Model Analysis of Reading Comprehension as the Function of Grade and Linguistic Memory Span Measures

Measures (df 1,46) (n for all measures = 60)	$\underline{F}$ values	$\underline{p}$ values
Intercept	0.31	0.582
Grade	0.36	0.553
Word span 2	0.00	0.951
Word span 3	0.06	0.804
Word span 4	4.14	0.048*
Reading span 1	0.01	0.935
Reading span 2	0.00	0.949
Reading span 3	9.62	0.003*
Interactions		
Word span 2 by Grade	0.01	0.917
Word span 3 by Grade	0.08	0.778
Word span 4 by Grade	0.52	0.473
Reading span 1 by Grade	0.34	0.563
Reading span 2 by Grade	0.83	0.367
Reading span 3 by Grade	0.09	0.764

* significant at $\underline{p} < 0.05$

Another linear model analysis was conducted to test the four significant predictions without separating the linguistic and non-linguistic measures, but removing the nonsignificant measures to economize the degrees of freedom for a statistical summary. When this was completed the results showed that three of the four measures continued to yield significant results. As can be seen in Table 4 the forward digit span was not a significant predictor $F(1, 50) = 1.76$, $p < .19$. The modified digit span 4 task was a significant predictor $F(1, 50) = 4.17$, $p < .047$, as was the word span 4, $F(1, 50) = 4.83$, $p < .033$ and the reading span 3, $F(1, 50) = 12.55$, $p < .0009$. In this final model, including the interaction terms of grade with other memory measures, the interaction terms were found nonsignificant as in the previous model. This means that the predictabilities of reading comprehension are largely from three predictors, namely the modified digit span 4, word span 4, and especially reading span 3. They are significant irrespective of grade differences.

In order to get unbiased estimates of their regression coefficients, the last most parsimonious linear model (without the nonsignificant interaction terms between grade and the four selected memory span measures) was obtained. As can be seen in table 5 the regression coefficients of the FDS, MDS4, WS4 and RS3 thus determined are 1.29, 0.37, 0.45 and 1.32, which were mostly significant, ts (54) = 1.36, 2.71, 2.56 and 3.94, ps < .18, .01, .014 and .0002, respectively. In general, the linguisitc measures of memory span appear to predict reading comprehension more than the non-linguistic measures. It requires, however, some caution in interpreting these findings for two reasons. The estimate of grade effect is still a biases estimate, and the regression coefficient of FDS is nonsignificant, despite its estimate (1.29) being larger than that of MDS4 (0.37). It may well be due to its larger variance, relative to MDS4.

TABLE 4

Summary Test Results of the General Linear Model Analysis of Reading Comprehension as the Function of Grade and FDS, MDS4, WS4 and RS3.

Measures (df 1,48) (n for all measures = 60)	*F* values	*p* values
Intercept	0.03	0.853
Grade	0.02	0.890
Forward digit span	1.76	0.1908
Modified digit span 4	4.17	0.0465*
Word span 4	4.83	0.0326*
Reading span 3	12.55	0.0009*
Interactions		
Forward digit span by Grade	0.43	0.5164
Modified digit span 4 by Grade	0.00	0.9918
Word span 4 by Grade	0.04	0.8435
Reading span 3 by Grade	0.84	0.3641

* significant at $p > .05$

TABLE 5

Summary Test Results of the General Linear Model Analysis of Reading Comprehension as the Function of FDS, MDS4, WS4 and RS3, Regression Coefficients and t scores.

Measures (df 1,54)	(n for all measures = 60	
	F values	p values
Intercept	5.80	0.0194
Grade	37.29	0.0001
Forward digit span	1.84	0.1810
Modified digit span 4	7.34	0.0090*
Word span 4	6.54	0.0134*
Reading span 3	15.53	0.0002*
	Regression cofficients	
Interactions		
Forward digit span	1.29*	
Modified digit span 4	0.37*	
Word span 4	0.45*	
Reading span 3	1.32*	
	t scores	p scores
Forward digit span	1.36	0.1810
Modified digit span 4	2.71	0.0090*
Word span 4	2.56	0.0134*
Reading span 3	3.94	0.0002*

* significant at $p > .05$

CHAPTER 5

DISCUSSION

The purpose of this research was to examine the relationships between working memory and reading comprehension in beginning and intermediate readers. After reviewing the literature two questions were developed. The questions were: 1. Which of these memory measures best predict reading comprehension? 2. Is there a difference in relationships between reading comprehension and working memory in Grade 2 and Grade 6 subjects? These questions were examined in the present research.

Summary and Conclusions

From the initial general linear model analysis, four memory subtest scores were found to produce significant results. Two of the measures were non-linguistic (forward digit span and modified digit span 4) and two linguistic (word span 4 and reading span 3). Thus one measure from each of the four types of memory measures was found to be a good predictor of reading comprehension ability. The first of these measures, forward digit span, was a significant predictor in the initial analysis of all the non-linguistic trials. It was not found to be a significant predictor in the second analysis, which compared only the four significant results. This may be because some of its predictability was taken care of by the linguistic measures. The backward digit span score did not prove to be a significant predictor despite the more complex nature of the task. The task may have proven to be too difficult for even good comprehenders. The results of these digit span measures support the findings of Daneman and Carpenter (1980) and Perfetti and Lesgold (1977). They found digit span tasks to either not be correlated at all or only weakly correlated to reading ability. The three significant predictors (MDS4, WS4 and RS3) were all the highest level of their respective measures. The failure of the lower levels of these measures (MDS2, MDS3, WS2, WS3, RS1 and RS2) to significantly predict reading comprehension may be the result of a floor effect. From the second analysis of the three significant findings, the reading span 3 subtest score is observed to be the strongest predictor. The modified digit span 4 and the word span 4 subtest scores, are significant predictors, but not to the extent of the reading span 3 score. Both of those scores though, still indicate that they are good predictors of reading comprehension ability.

The significant results of the MDS4 and the WS4 scores were predicted by Yuill, Oakhill and Parkin (1989) and LaPointe and Engle (1990), respectively. Yuill, Oakhill and Parkin argue that the modified digit span task does tap processing ability as well as capacity and predicts reading comprehension as well as a reading span task. Yet, the evidence in the literature and in this research does not support their view. The LaPointe and Engle simple word span task is strictly a measure of capacity with no processing. Since both of these tests appear to measure only capacity, it is expected that they would yield similar results, which they do. The significant results found here, though, should be viewed with caution. This is because these results may be influenced by the use of strategies like rehearsal and regrouping that may allow subjects to "circumvent the capacity limitations of short-term memory" (Turner and Engle, 1989) and "obscure any relationship between short-term memory capacity and higher level cognitive tasks" (LaPointe and Engle, 1990). Evidence of rehearsal and regrouping subvocalization by subjects on these tasks was heard by the examiner. Similar strategies (such as rehearsing key numbers and rehearsing words) were used by subjects on both of these measures. During the administration of the reading span task there was no auditory evidence of rehearsal or regrouping strategies being employed by the subjects.

Overall, the reading span 3 subtest is the strongest predictor of reading comprehension. This finding supports the results of Daneman and Carpenter's studies (1980, 1983), but with beginning and intermediate readers. The reading span task seems to predict reading comprehension in beginning and intermediate readers as well as it does for adult readers. From the results of this research it is apparent that the best memory measure to clearly predict reading comprehension ability is still the reading span task. It would seem that the best measure of a complex operation (such as reading comprehension) is a complex task (such as the reading span task used in this study).

The second findings are from the observed means differences and the regression analysis of the Grade 2 and Grade 6 scores on each of the measures. The findings indicate that there are significant differences between the grades on all the non-linguistic measures (FDS, BDS, MDS2, MDS3 and MDS4). The results are in favour of the Grade 6 subjects. Given that these measures basically tax the storage component of working memory and that its capacity increases with age (up to adolescence), these results were expected. The linguistic measures, with the exception of reading span 3, were not found to be significant. The lack of significant differences may be accounted for by the fact that the word lists were comprised of the most frequently used words in the English language (LaPointe & Engle, 1990; Francis & Kucera, 1982) and the reading span sentences were developed from Primary grade readers (Booth, Booth, Pauli & Phenix, 1985). Both grade groups would thus be familiar with some items in the tasks and this may have made it easier for all subjects (Recht & Leslie, 1988). The significant results found with the reading span 3 test can be accounted for because of its high level of difficulty. It would seem that the capacity and processing demands of the measure were more arduous for the Grade 2 than the Grade 6 subjects. The developing capacity of working memory would appear to play a part in this, since the more capacity available the more information that can be stored and processed. The reading span 3 finding was expected. The reading comprehension and sentence verification means were both significantly different, also in favour of the Grade 6 subjects. This is an expected result as well. It can be accounted for because of the maturation process with respect to reading. That is to say, the Grade 6 students have had more experience and years of practising the skills involved in reading comprehension.

From the first general linear model analysis it was found that regardless of which type of memory measure was tested, none were found to have significant interaction with the grade variable. The second analysis using only the initial four significant results (forward digit span, modified digit span 4, word span 4 and reading span 3) also yielded no significant interactions and the forward digit span score (as previously mentioned) was not found significant. This would seem to indicate that regardless of grade, modified digit span 4, word span 4, and reading span 3 are the significant predictors of reading comprehension ability in this study. The regression coefficients of the forward digit span, modified digit span 4, word span 4, and reading span 3 were all significant, with the linguistic measures appearing to be better predictors of reading comprehension than the non-linguistic measures. Because of the restrictions of the study's subject selection, it was expected that no significant differences in the slopes of the regression lines for the two grades would be found. This was the case after the results were analyzed. Therefore Grade 2 students in this study performed in a similar manner to Grade 6 students on working memory measures.

The majority of the studies reviewed in this thesis used university undergraduate psychology students as subjects not children. Children were used as subjects to try to replicate the results of previous research that examined the relationships between working memory and reading comprehension ability. Many types of linguistic and non-linguistic memory measures have been developed and tested on groups of adult subjects. Of these measures the one that appeared to best and most consistently predict reading comprehension was the reading span task developed by Daneman and Carpenter (1980). They argued that to test working memory, a task must tax both the capacity and storage components of working memory. Traditional memory measures such as digit span and word span tasks were considered by Daneman and Carpenter to be only measures of capacity and did not predict reading comprehension ability. The results of Daneman and Carpenter's (1980, 1983) research supported their claims. Many replications and extentions or their research have been conducted with varying degrees of success.

Recently, researchers such as; Baddeley, Logie, Nimmo-Smith and Brereton (1985) and Turner and Engle (1989) found that a variation of the reading span task (still comprised of capacity and processing components) predicted reading comprehension as well as Daneman and Carpenter's task did. Other researchers such as Yuill, Oakhill and Parkin (1989) reported significant results using a modified digit span task. LaPointe and Engle (1990) re-examined simple and complex word span memory measures and used them to attempt to predict reading comprehension ability. The results of their research seem to point to a significant relationship between word span tasks and reading comprehension. None of the research reviewed above used all of these apparent significant memory measures in the same study with children as subjects, unlike this thesis. The results of this study support the Daneman and Carpenter (1980, 1983) finding that the reading span task is the best predictor of reading comprehension ability.

Suggestions for Future Research

Four suggestions for future research are presented here. The first one deals with future replications and extentions of this study. Since very little past research with beginning and intermediate readers has done more replication of the findings would seem warrented. A larger and more randomized sample in both grade groups would allow for more generalizability of the results. An extention of the research using only one grade group or the other would also provide information since no interaction of grade and memory measure was found in this study. This study could also be extended to use Grade 6, 10 and adults as subjects.

The second suggestion comes from a review of the memory measures. The lowest level subtests of the modified digit span (MDS2), word span (WS2) and reading span (RS1) did not prove to be difficult for either the grade two or the grade six group. These levels should be removed and another level of subtests should be developed and added (i.e., MDS5, WS5 and RS4) at the higher end of the subtests. This may help to better differentiate the abilities of the subjects.

The third suggestion comes from the results of the research and a review of the literature. Turner and Engle (1989) in their word span research used both reading span and operation span tasks to measure the relationship between reading comprehension and working memory. They found that an operation span task could "generate a significant correlation with reading comprehension." This finding could be tested in a future study of memory measures with beginning and intermediate readers. Because of the inexperience of a Grade 2 group with mathematical operation sentences, it might be more informative to use this task with a Grade 6 group.

The fourth and final recommendation is also for future research. Changes could be made in the administration of the digit span, modified digit span and word span tasks. The development for the digit span test could be changed so that the forward and backward items are mixed together. Subjects would not be told which way to respond (i.e., forward or backward) until after the sequence of digits was given. The examiner would then signal the subjects by raising one for forward or two fingers for backward or saying "forward" or "backward". The modified digit span could be changed so that subjects did not know which digits in each sequence they were to recall again until the item was presented. The digits to be recalled could be varied (i.e., first digits or last digits). The word span task could be modified so that words could be recalled in either forward or backward order. A signal system similar to the one suggest above, could be used. These changes would help to reduce the use of strategies, like rehearsal and regrouping, by the subjects. If this was done, the predictabilities of these measures may change, thus providing better refined and more clear-cut pictures of the predictive relationships.

REFERENCES

Baddeley, A. Logie, R. Nimmo-Smith, I. & Brereton, N. (1985). Components of fluent reading. Journal of Memory and Language, 24, 119-131.

Best, J. B. (1986). Cognitive Psychology. St. Paul: West Publishing.

Borg, W. R., & Gall, M. D. (1983). Educational Research. New York: Longman.

Booth, J., Booth, D., Pauli, W., & Phenix J. (1985). Impressions: East of the Sun. Canada: Holt, Rinehart and Winston.

Booth, J., Booth, D., Pauli, W., & Phenix J. (1985). Impressions: Over the Mountain. Canada: Holt, Rinehart and Winston.

Booth, J., Booth, D., Pauli, W., & Phenix J. (1985). Impressions: West of the Moon. Canada: Holt, Rinehart and Winston.

Broadbent, D. E. (1971). The magic number seven after fifteen years. In R. A. Kennedy & A. Wilkes (Eds.), Studies in ling-term memory. New York, Wiley.

Chi, M.T. (1976). Short-term memory limitations in children: Capacity or processing deficits? Memory and Cognition.4, 559-580.

Daneman, M., & Carpenter, P.A. (1980). Individual differences in working memory and reading. Journal of Verbal Learning and Verbal Behavior, 19, 450-466.

Daneman, M., & Carpenter, P.A. (1983). Individual differences in integrating information between and within sentences. Journal Of Experimental Psychology: Learning Memory and Cognition,9, 561-584.

Fletcher, C.R. (1981). Short-term memory processes in text comprehension. Journal of Verbal Learning and Verbal Behavior, 20, 564-574.

Francis, W.N., & Kucera, H., (1982). Frequency Analysis of English Language. Boston: Houghton Mifflin.

Kintsch, W., & Van Dijk, T.A. (1978). Toward a model of text comprehension and production. Psychological Review, 85, 363-394.

LaBerge, D., & Samuels, S.J. (1974). Towards a theory of automatic information processing in reading. Cognitive Psychology, 6, 293-323.

LaPointe, L.B., & Engle, R.W., (1990). Simple and complex word spans as measures of working memory capacity. Journal of Experimental Psychology: Learning, Memory and Cognition, 16, 1118-1133.

Mann, V.A., Cowin, A. & Schoenheimer, J. (1989). Phonological processing, language comprehension and reading ability. Journal of Learning Disabilities. 22, 76-89.

Miller, G.A., (1956). The magic number seven, plus or minus two: Some limits for our capacity for processing information. Psychological Review. 63, 81-97.

Oakhill, J., Yuill, N., & Parkin, A. (1988). On the nature of the difference between skilled and less skilled comprehenders. Journal of Research in Reading. 9. 80-91.

Perfetti, C.A. & Goldman, S.R. (1976). Discourse memory and reading comprehension skill. Journal of Verbal Learning and Verbal Behaviour. 14, 33-42.

Perfetti, C.A., & Lesgold, A. (1977). Discourse comprehension and sources of individual differences. In M. Just & P. Carpenter (Eds.), Cognitive Processes in Comprehension (pp. 141-183). Hillsdale, NJ: Erlbaum.

Recht, D.R., & Leslie, L. (1988). Effect of prior Knowledge on good and poor readers' memory of text. Journal of Educational Psychology. 80, 16-20.

Samuels, S.J. (1987). Information processing ability and reading. Journal of Learning Disabilities. 20, 18-22.

Simon, H.A. (1974). How big is a chunk? Science. 183, 482-488.

Stanovich, K.E. (1982a). Individual differences in the cognitive processes of reading: I. Word decoding. Journal of Learning Disabilities, 15, 485-493.

Stanovich, K.E. (1982b). Individual differences in the cognitive processes of reading: II. Text Level Processes. Journal of Learning Disabilities, 15, 549-554.

Thorndike, R.L., Hagen, E.P. & Sattler, J.M. (1985). Stanford-Binet Intelligence Scale: Fourth Edition. Riverside, CA. Riverside Publishing.

Tuinman, J.J., Kinzer, C.K. & Muhtadi, N.A. (1980). A shortcut to testing reading comprehension. Reading Horizons, 20, 103-105.

Turner, M.L., & Engle, R.W., (1989). Is working memory capacity task dependent? Journal of Memory and Language, 28, 127-154.

Vipond, D. (1980). Micro- and macroprocesses in text comprehension. Journal of Verbal Learning and Verbal Behavior, 19, 276-296.

Woodcock, R.W. (1973). Woodcock Reading Mastery Tests. Circle Pines, MN: American Guidance Service.

Yuill, N., & Oakhill, J. (1988). Understanding of anaphoric relations in skilled and less skilled comprehenders. British Journal of Psychology, 79, 173-186.

Yuill, N., Oakhill, J., & Parkin, A. (1989). Working Memory, comprehension ability and the resolution of text anomaly. British Journal of Psychology. 80. 351-361.

BIBLIOGRAPHY

Alegria, J., Pignot, E., & Morais, J. (1982). Phonetic analysis of speech and memory codes in beginning readers. Memory & Cognition. 10. 451-456.

Anderson, J.R. (1983). The Architecture of Cognition. Cambridge, MA: Harvard University Press.

Baddeley, A. (1981). The components of working memory: A view of its current state and probable future development. Cognition, 10, 17-23.

Baddeley, A. (1986), Developmental Applications Of Working Memory. In A. Baddely (Ed.), Working Memory. New York: Oxford University Press.

Baddeley, A., & Hitch, G. J. (1974). Working Memory. In G. Bower (Ed.), The Psychology of Learning and Motivation (pp. 47-90). New York: Academic Press.

Brady, S. (1986). Short-term memory, processing, and reading ability. Annals of Dyslexia, 36, 138-152.

Brady, S., Shankweiler, D., & Mann, V. (1983). Speech perception and memory coding in relation to reading ability. Journal of Experimental Child Psychology, 35, 345-367.

Carr, T. (1981). Building theories of reading ability: On the relation between individual differences in cognitive skills and reading comprehension. Cognition, 9, 73-113.

Case, R., Kurkland, D., & Goldberg, J. (1982). Operational efficiency and the growth of short-term memory span. Journal of Experimental Child Psychology, 33, 386-404.

Chen, H.C. (1986). Effects of reading span and textual coherence on rapid-sequential reading. Memory and Cognition, 14, 202-208.

Craik, F., & Byrd, M. (1982). Aging and cognitive deficits: The role of attentional resources. In F. I. M. Craik & S. E. Trehub (Eds.), Aging and Cognitive Processes (pp. 191-211). New York: Plenum Press.

Curtis, M.E. (1980). Development of components of reading skill. Journal of Educational Psychology, 72, 656-669.

Daneman, M., & Green, I. (1986). Individual differences in comprehending and producing words in context. Journal of Memory and Language, 25, 1-18.

Dempster, F. N. (1981). Memory span: Sources of individual and developmental differences. Psychological Bulletin, 89, 63-100.

Ehri, L. C., & Wilce, L. S. (1979). The mnemonic value of orthography among beginning readers. Journal of Educational Psychology, 71, 26-40.

Gick, M.L., Craik, F.I.M., & Morris, R.G. (1988). Task complexity and age differences in working memory. Memory and Cognition, 16, 353-361.

Johnson-Laird, P.N. (1983). Mental Models: Towards a Cognitive Science of Language, Inference, and Consciousness. Cambridge: Harvard University Press.

Jensen, A. (1980). Bias in Mental Testing. New York: Free Press.

Johnson, M.K. & Hasher, L. (1987). Human learning and memory. Annual Review of Psychology, 38, 631-668.

Just, M.A., & Carpenter, P.A. (1980). A theory of reading: From eye fixations to comprehension. Psychological Review, 87, 329-354.

Katz, R., Shankweiler, D., & Liberman, I. (1981). Memory for item order and phonetic recoding in the beginning reader. Journal of Experimental Child Psychology, 32, 474-484.

Kintsch, W., & Mross, E.F. (1985). Context effects in word identification. Journal of Memory and Language, 24, 336-349.

Lesgold, A., & Perfetti, C. (1978). Interactive processes in reading comprehension. Discourse Processes, 1, 323-336.

Lesgold, A.M., & Resnick, L.B. (1982). How reading disabilities develop: Perspectives from a longitudinal study. In J.P. Das, R. Mulcahy, & A.E. Wall (Eds.), Theory and research in learning disability, New York: Plenum.

Masson, M., & Miller, J. (1983). Working memory and individual differences in comprehension and memory of text. Journal of Educational Psychology, 75, 3141-318.

Perfetti, C.A., (1985). Reading Ability. New York: Oxford University Press.

Perfetti, C.A., Beck, I., & Hughes, C. (1981). Phonemic Knowledge and Learning to Read. Paper presented at the Biannual Meeting of the Society for Research in Child Development, Boston.

Perfetti, C.A., Goldman, S.R., & Hogaboam, T.W. (1979). Reading skill and the identification of words in discourse context. Memory and Cognition, 7, 273-282.

Perfetti, C.A., & Hogaboam, T. (1975). Relationship between single word decoding and reading comprehension skill. Journal of Educational Psychology, 67, 461-469.

Perfetti, C.A., & Roth, S.F. (1981). Some of the interactive processes in reading and their role in reading skill. In A.M. Lesgold and C.A. Perfetti (Eds.), Interactive Processes in Reading. Hillsdale, NJ: Erbaum.

Salthouse, T. (1990). Working memory as a processing resource in cognitive aging. Developmental Review. 10. 101-124.

Shankweiler, D., Liberman, I., Mark, L., Fowler, C., & Fischer, F. (1979). The speech code and learning to read. Journal of Experimental Psychology: Human, Learning and Memory, 5, 531-545.

Van Dijk, T.A., & Kintsch, W. (1983). Strategies of Discourse Comprehension. New York: Academic Press.

Vellutino, F. (1979). Dyslexia: Theory and Research. Cambridge, MA: MIT Press.

APPENDIX 1

Working Memory Span Tasks
Task Data Sheets

The Digit Span Task

Numbers Forward

Sample	5-1	Sample 2	3-8
Items	5-2-8		4-9-1
	2-7-6-3		5-2-8-3
	3-5-8-1-9		4-7-8-2-5
	2-8-3-9-5-4		7-9-1-5-6-3
	3-1-9-6-8-4-7		2-8-5-1-3-6-9
	7-3-9-2-8-5-1-2		1-7-2-8-3-6-9-5

Numbers Backward

Sample 1	4-2	Sample 2	3-8
Items	6-3		4-9
	2-7-5		8-3-6
	8-4-2-7		4-9-1-7
	8-3-1-7-9		4-2-5-8-3
	4-9-7-5-1-2		6-2-5-7-3-8
	1-8-4-2-5-7-3		4-7-3-9-1-6-2

Modified Digit Span Task

Samples

		2's
	a.	453, 318
	b.	189, 412

Practise items

2's	3's	4's
472, 157	396, 125, 068	854, 367, 301, 165
504, 496	824, 537, 261	467, 725, 281, 986

Items

192, 795	726, 021, 304	083, 927, 519, 246
104, 832	245, 198, 074	548, 306, 721, 567
198, 765	364, 158, 216	218, 931, 247, 465
638, 534	643, 321, 398	695, 708, 312, 174
915, 728	067, 296, 948	092, 728, 637, 916
694, 927	931, 638, 085	492, 106, 274, 526
952, 754	236, 798, 863	693, 735, 972, 046
647, 703	167, 594, 361	863, 928, 285, 597

Word Span Task

Samples

a. fun, like

b. rod, boat

Items

2's	3's	4's
gas, key	need, sea, taste	aid, break, door, forth
king, out	small, tree, bird	cut, file, jump, own
stay, wire	camp, east, head	near, snake, add, cause
form, lock	scene, trade, buy	far, log, score, type
close, gun	mouth, talk, blue	fact, miss, sum, bomb
brown, fly	pale, week, cross	knee, seat, act, end
meet, cry	test, lock, shoe	base, farm, nod, why
deep, sole	lean, box, list	train, dry, roof, bad

READING SPAN TASK

SAMPLES

A.	THE CAT RAN UP THE TREE.	(S)
B.	THE MOUSE ATE THE CAR.	(NS)

ONE'S

1.	THE DOG JUMPED OVER THE LOG.	(S)
2.	THE CAT ATE THE RADIO.	(NS)
3.	THE RABBIT SWAM UNDER THE ROCK.	(NS)
4.	TWO EAGLES FLEW OVER THE LAKE.	(S)

TWO'S

1.	THE PUPPY SLEPT IN THE HOUSE.	(S)
	THE ELEPHANT READ THE SIGN.	(NS)
2.	ALL THE LIONS WENT TO THE DANCE.	(NS)
	A SQUIRREL SKIPPED TO THE STORE.	(NS)
3.	SOME OF THE BEARS ATE HONEY.	(S)
	THE FISH SWAM IN THE OCEAN.	(S)
4.	OUR HORSE SANG IN THE BARN.	(NS)
	RATS HID UNDER THE SHED.	(S)

THREE'S

1.	THE CHICKEN PECKED AT THE SEEDS.	(S)
	THE SHEEP WENT TO THE PARTY.	(NS)
	THE THREE PIGS BUILT A BUSH.	(NS)
2.	A DONKEY DROVE THE BUS.	(NS)
	ONE TURKEY SPOKE TO THE WALL.	(NS)
	THE PENGUIN SWAM IN THE WATER.	(S)
3.	A COW STOOD BY THE FENCE.	(S)
	THE OWL RAN BESIDE THE TRAIN.	(NS)
	KITTENS PLAYED WITH THE BALL.	(S)
4.	TWO DEER STOOD IN THE FIELD.	(S)
	THE WOLF WAITED IN THE CAVE.	(S)
	MANY DUCKS PLAYED THE PIANO.	(NS)

NS - NONSENSE SENTENCE S - SENSIBLE SENTENCE

DIGIT SPAN DATA SHEET

NAME: ______________________________

FORWARD

SAMPLES

a. ____________________ b. ____________________

DIGITS

1. ____________________ 2. ____________________
3. ____________________ 4. ____________________
5. ____________________ 6. ____________________
7. ____________________ 8. ____________________
9. ____________________ 10. ____________________
11. ____________________ 12. ____________________

BACKWARDS

SAMPLES

a. ____________________ b. ____________________

DIGITS

1. ____________________ 2. ____________________
3. ____________________ 4. ____________________
5. ____________________ 6. ____________________
7. ____________________ 8. ____________________
9. ____________________ 10. ____________________
11. ____________________ 12. ____________________

MODIFIED DIGIT SPAN DATA SHEET

NAME: ______________________________

SAMPLES

a. ____________ b. ____________

PRACTISE ITEMS

a. ____________ b. ____________

TWO'S

1. ____________ 2. ____________
3. ____________ 4. ____________
5. ____________ 6. ____________
7. ____________ 8. ____________

PRACTISE ITEMS

a. ____________ b. ____________

THREE'S

1. ____________ 2. ____________
3. ____________ 4. ____________
5. ____________ 6. ____________
7. ____________ 8. ____________

PRACTISE ITEMS

a. ______________________ b. ______________________

FOURS'S

1. ______________________ 2. ______________________

3. ______________________ 4. ______________________

5. ______________________ 6. ______________________

7. ______________________ 8. ______________________

WORD SPAN DATA SHEET

NAME: ____

SAMPLES

a. ____________________ ____________________

b. ____________________ ____________________

TWO'S

1. ____________________ 2. ____________________

3. ____________________ 4. ____________________

5. ____________________ 6. ____________________

7. ____________________ 8. ____________________

THREE'S

1. ____

2. ____

3. ____

4. ____

5. ____

6. ____

7. ____

8. ____

FOUR'S

1. ____________________
2. ____________________
3. ____________________
4. ____________________
5. ____________________
6. ____________________
7. ____________________
8. ____________________

READING SPAN DATA SHEET

NAME: ______________________________

SAMPLES

	YES	NO	WORDS
a.	________	________	______________________
b.	________	________	______________________

ONE'S

1.	________	________	______________________
2.	________	________	______________________
3.	________	________	______________________
4.	________	________	______________________

TWO'S

1.	________	________	______________________
1.	________	________	______________________
2.	________	________	______________________
2.	________	________	______________________
3.	________	________	______________________
3.	________	________	______________________
4.	________	________	______________________
4.	________	________	______________________

THREE'S

1. ________ ________ ______________________________

1. ________ ________ ______________________________

1. ________ ________ ______________________________

2. ________ ________ ______________________________

2. ________ ________ ______________________________

2. ________ ________ ______________________________

3. ________ ________ ______________________________

3. ________ ________ ______________________________

3. ________ ________ ______________________________

4. ________ ________ ______________________________

4. ________ ________ ______________________________

4. ________ ________ ______________________________

APPENDIX 2

Initial Parent Contact Letter
Parent Permission Letter

(PARENT PERMISSION LETTER)

July 15, 1991

Dear Parents,

With the permission of School District #37 Delta and your school principal, I would like to ask for your support and permission in allowing your child to take part in a study.

This study will be looking at the relationships between reading and short-term memory. The study results will be used as a component of my thesis entitled "The Relationships Between Reading Comprehension and Working Memory in Beginning and Intermediate Readers". The thesis will complete the requirements for my Masters of Arts degree (Educational Psychology) from the University of British Columbia.

The study will involve students trying to remember series' of words and digits. It will be done individually and in groups within the classroom or in the school learning assistance center. There will be five sessions (approximately 35 minutes each). They will be conducted with the classroom teachers and teaching assistants present and helping. This study will be performed at times that are coordinated with the teachers so that little or no instructional time will be lost.

Please note that the information collected will be strictly confidential and names will not be used. Students will be assigned a number and information collected will be recorded using these numbers. Pupils may withdraw at any time from the study or not take part at all.