THE RELATIONSHIP BETWEEN SHORT-TERM MEMORY AND READING IN
LEARNING DISABLED AND AVERAGE LEARNERS

By

KAREN ENG

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Department of School Psychology

The University of British Columbia
Vancouver, Canada

Date July 17, 1990
ABSTRACT

The purposes of the present study were to investigate the relationship between short-term memory and reading in learning disabled and average learners, and to determine whether this relationship is different between ages 8 to 10 and ages 11 to 13 in these two populations.

Studies have shown that children with learning disabilities tend to perform poorer on short-term memory tasks compared to children with no disabilities. The present study was conducted because the short-term memory component in the Stanford-Binet Intelligence Scale is new and it was felt that information regarding this test's usefulness with learning disabled students would be beneficial for individuals in the field of educational assessment.

A total of 80 children, 39 average and 41 learning disabled were selected from the five public elementary schools that have learning disabilities classes in the Langley School District. For each group of learning disabled children selected from the learning disabilities class, an equal number of average learners was chosen from the same school. The children were divided into two age groups: 8- to 10-year-olds and 11- to 13-year-olds and then further divided into their two learning categories.
Four short-term memory subtests of the Stanford-Binet Intelligence Scale: Fourth Edition: Bead Memory, Memory for Sentences, Memory for Digits and Memory for Objects and three reading comprehension subtests, from BC Quick Individual Educational Test, Peabody Individual Achievement Test and Test of Reading Comprehension respectively, were administered to all groups to measure short-term memory and reading.

The Multivariate Analysis of Variance and the Pearson Product-Moment Correlation were used to analyse the data. Results showed that the average learners scored significantly higher than the learning disabled group in both short-term memory and reading. There was no interaction effect of learning group and age on reading or short-term memory. Significant relationships were found between short-term memory and reading for the average learning group but none was found for the learning disabled group.
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CHAPTER I

INTRODUCTION

Memory is vital to all information processing and learning. Every task, from the simplest to the most complex, requires the efficient functioning of the memory system. However, one is usually not consciously aware of the vital role played by memory, especially in the performance of routine activities that do not place a heavy demand on it. It is only in the learning of new materials that one becomes cognizant of the importance of memory to the successful execution of that task. The performance of any task depends on the efficacy of three forms of memory storage: sensory register, short-term memory and long-term memory.

It is in the sensory register that environmental input, first perceived either through one or more of the five senses, is stored very briefly. Information in the auditory register has the duration of about two seconds, while information in the visual register has about one-quarter second. This information then journeys to short-term memory storage before it is permanently stored in long-term memory. Short-term memory is a fascinating device, especially since it interwines closely with consciousness itself. The primary function of short-term memory is to "hold information in momentary abeyance and possibly transform it somewhat to conform to one's long-term storage mechanisms (assimilation) or change one's long-term storage mechanisms to conform to new
In view of this interpretation of the function of short-term memory, problems in this intermediate storage may result in distortion or loss of information to the long-term storage.

Short-term memory is known for its limited capacity -- just seven items, plus or minus two (Miller, 1956). The items in residence are displaced for incoming input when the capacity is filled. In the limited capacity theory, operation and storage share a predetermined amount of space in the memory system; hence, an individual's greater attention to the processing of information means less available space for maintenance and storage of that information (Atkinson & Shiffrin, 1971). However as individuals age and expand their knowledge base, they become more proficient in processing information. Consequently the amount of storage space increases (Barclay & Hagen, 1982).

Short-term memory is measured by memory span, an immediate recall of a series of items in its exact order of presentation. Results from psychometric studies show that learning and reading disabled children experience greater difficulties in short-term memory tasks than children with no difficulties (Lerner, 1976). However, the reasons for performance difference between the two groups cannot be discerned from psychometric studies due to the nature of this approach. Information regarding the processes that underlie the storage and processing components in short-term memory derives mainly from experimental studies. Unlike psychometric studies, experimental studies allow manipulation of variables that are assumed to relate to memory
processing. Explanations for the poorer performance of reading disabled children are best addressed through the framework of encoding, storage and retrieval, the three processes which are integral to memory functioning and which are inter-dependent and cyclical. At least three factors influence how well encoding and retrieval processes are carried out. These factors are the type of encoding; the richness and relevance of the knowledge base; and the use of appropriate control strategies.

The encoding process involves information being transformed into some representational form that can be stored in memory (Torgesen, 1985). This process requires contact of the dormant features in long-term storage and activation of them. Environmental stimuli may be encoded either in or a combination of visual, auditory, semantic, or phonological features. Of all these features, phonological coding has been proposed to be the most stable memory code in short-term memory (Baddeley, 1979).

The facility with which an individual linguistically labels stimuli depends on the elaborateness of the knowledge base which facilitates organization in memory. Bjorklund & Bernholtz (1986) attributed the performance difference between good and poor readers in free recall in their study to the difference in the knowledge bases of these two groups. According to these authors, strategic organization requires much attention from the processing aspect of the limited capacity, leaving it little space to perform other strategies.
The speed of encoding determines the amount of time an individual can allot to the application of memory strategies to facilitate information storage. Studies by Farnham-Diggory & Gregg (1975) and Spring and Capps, (1974) have shown that poor readers tend to take a longer time to recognize the stimuli and translate them into a linguistic representation. If the operating space is used up for this process, little is left for the storage of information.

Memory storage refers simply to the durability of the memory code once it has been created, and retrieval processes refer to the operations that are involved in the attempt to extract an item from memory (Torgesen, 1985). Mnemonic strategies are reported to influence retrieval ability; these strategies include rehearsal, chunking, grouping, and coding. Rehearsal is the repetitious, often cyclical, naming of stimuli to be remembered (Torgesen & Kail 1980). Chunking is the process of combining information so that it takes up as little as possible of the limited space in short-term memory (Klatzky, 1975). Grouping is a process whereby an individual actively parses a lengthy string of stimuli into subgroups. According to Chi (1981), this process is more consciously used by adults than by children. Atkinson and Shiffrin (1971) defined coding as a class of control processes in which the information to be remembered is put in a context of additional, easily retrievable information. Chunking, grouping and coding facilitate rehearsal of information in short-term memory.

Researchers have noted that reading and learning disabled children do not use strategies as readily or as proficiently as children with no
disabilities (Atkinson & Shiffrin, 1971; Bauer, 1977; Dempster & Zinkgraf, 1982; Case, Kurland & Goldberg, 1982). They believe that the memory performance difference between reading and learning disabled children and non-disabled children is due to the former group's inactive use of the mnemonic strategies mentioned earlier. Torgesen (1977) advanced the idea that the reading disabled group's inefficient use of strategies was due not to an ability deficit but to a performance deficit. This proposal was supported by Wong's (1978) study with normal readers and learning disabled children who had reading problems. Wong found that, although directive cues improved the performance of both groups, the normal readers still performed better than the poor readers because the former group applied another strategy, namely rehearsal, to assist their memory recall. She further elaborated that learning disabled children possessed similar memory strategies to normal readers but were less organized and efficient in the management of these cognitive resources.

These theories provide a framework for understanding the poor performance of reading disabled children on short-term memory tasks. As memory is an integral part of all learning, reading disabled children frequently have problems with memory related tasks. Das, Bisanz and Mancini (1984) suggested that reading, which includes decoding and comprehension, involves similar major cognitive processes to those found in memory tasks.

One process in memory that has been viewed to be also important in reading is phonological coding. Some researchers reported it as the
most vital component in reading (Katz, Shankweiler & Liberman, 1981; Shankweiler, Liberman, Mark, Fowler & Fischer, 1979; Lunzer, 1978). "It is obvious that perception of language, whether written or spoken, the reader or listener must hold a sufficient number of individual words and their order of arrival long enough to permit interpretation of each sentence" (Shankweiler et al. 1979, p. 531). This theory is in accordance with Baddeley’s (1979) theory of articulatory loop. Baddeley believed that short-term memory consisted of two components: a central executive and an articulatory loop. The articulatory loop functions as an output buffer and uses verbal coding obtained from long-term memory to temporarily hold the verbal information in serial order. He claimed that proper use of this loop helps free some of the space for processing and for further storage. In the framework of Baddeley’s theory, good readers are able to increase the rate and amount of information processed by converting visual stimuli into phonological codes. Furthermore, Baddeley suggested that the articulatory loop allows subvocal rehearsal. In word decoding, the parts of a word are kept fresh in the memory until other parts are added for insertion.

Proficient utilization of the appropriate strategies is important in memory skills and acquisition of beginning reading skills (Torgesen & Kail, 1980). Case et al. (1982) believed that basic to the application of learning skills is attention. Hence, the greater proficiency one has in the use of attention, the more operating space there is available for either storage of information or text comprehension. However, the application and proficient use of the appropriate strategies may be a
function of age (Flavell, Beach & Chinsky, 1966; Chi, 1981). Torgesen (1977) found that older children were more adept in the application of a greater variety of strategies than younger ones.

It appears then that reading disabled children's poor short-term memory performance may have several causes. First, poor performance may be the result of weak access to phonological coding, a form of encoding that supports long-term retention. Second, reading disabled children require greater attention from the limited capacity to encode and to strategically organize for easy retrieval, leaving little room for mnemonic strategies. Lastly, reading disabled children are demonstrated to be passive users of mnemonic strategies which can facilitate retrieval of information.

The purpose of the present study is to investigate the relationship between short-term memory and reading and to determine whether that relationship changes with age.
INTRODUCTION

Memory is quintessential to learning activity. Knowledge in any particular area is the product of assimilation and synthesis of previously acquired information or experiences. Individuals with recall difficulties will have greater problems with memory related tasks than those with no difficulties. Ongoing studies in short-term memory attempt to delineate the cognitive processes required in memory related tasks (Das, Bisanz & Mancini, 1984). Results from these studies will have significant impact on the understanding of short-term memory performance difficulty experienced by children with learning problems. As some learning disabled children also have difficulty with reading, knowledge of the processes required for memory tasks will also clarify the nature of relationship between reading and memory.

The purpose of this chapter is to provide an overview of the theory of short-term memory, the two approaches through which it is studied, short-term memory and age, and short-term memory and reading; research related to variables that influence the outcome of short-term memory related tasks is reviewed in detail.
THEORETICAL BACKGROUND

Processes in Short-term Memory

Short-term memory is a system that stores information for current attention and in which actual information processing is carried out (Dempster, 1981). Prior to information entering short-term memory storage, environmental input is first received by the sensory register via the visual, auditory, or haptic channel or a combination of the three sensory modalities. Information on its way to short-term memory storage is not raw information but information that has made contact with its corresponding representation in the long-term memory storage. If the short-term memory malfunctions, the long-term memory will also be impaired. The primary memory has a fixed capacity of 7 items (Miller, 1956) and items in residence are displaced by incoming items when the capacity is filled. It is at this crucial point that an individual decides whether the information should be retained for further processing or dismissed. Hence, the short-term memory is also called a working memory (or a primary memory) because it functions as a processing center: a system in which decisions are made, problems are solved and information flow is directed. If the information is to be retained, certain memory skills and processes must occur before such information is further transferred to long-term memory storage.

The emergence of the information processing model of cognition made it possible to explain the plausible role of memory functions in a variety of thinking and problem solving activities. Torgesen (1978)
explained that this model views the structure and function of an individual's memory to be similar to that of a computer. Like a computer, it consists of 3 main components. The first component is the structural or constraint component and defines the parameters which decide the information to be processed at a particular stage (eg. sensory storage, short-term memory or long-term memory). This component is akin to the hardware of a computer. The structural part of the memory system is made up of operating space and storage space. Operating space is a hypothetical amount of space an individual has available for executing intellectual operations. The storage space refers to a hypothetical amount of space that a subject has available for the storage of information. Operating and storage spaces amount to a total processing space; hence, in order to balance the equation, an increase in operating space would mean a decrease in storage space and vice versa. The total processing aspect of memory does not vary with age and is fixed from one situation to another. But Torgesen added that with age, the operating space decreases due perhaps partially to mnemonic strategies which in turn increases the storage space in the short-term memory system. The structural aspect is responsible for the basic capacity of the system and perhaps for the speed with which the processes are executed.

Torgesen (1978) further explained that the second component is the control or strategic component, and may be likened to the software of a computer. The control process aspect of short-term memory is perhaps studied more frequently than the structural part. This aspect of
short-term memory is under the conscious control of the individual. It describes the activities which the individual engages in to maximize the performance of a limited capacity system. Mnemonic strategies are thought to be the activities that influence the storage and retrieval of information from the short-term memory. Some of the mnemonic strategies that have been examined in research are: coding, grouping, chunking and rehearsal.

In summary, the information processing model provides the theoretical framework to explain some of the results from short-term memory studies. Many short-term memory studies involve tasks that require subjects to retain relatively small amounts of information (up to seven or eight items) for brief periods of time (usually less than 10-15 seconds). These tasks are designed to assess the length of an individual's memory span.

Memory Span - A Measurement of Short-term Memory

Memory span is a measure of an individual's short-term memory ability. In the serial memory span test found in psychometric tests such as Wechsler Intelligence Scale for Children-Revised (WISC-R) (Wechsler, 1974) and Stanford Binet Intelligence Scale-Fourth Edition (SB-IV) (Thorndike, Hagen & Sattler, 1986), the investigator tells a subject that a series of items (numbers, words or pictures) will be presented and instructs the subject to then recall the items in the same order. A short list is first used, to which single items are added until the subject can no longer reproduce all the items in their correct
order. The quantity of items that the subject can remember varies from one trial to another even though there is some constancy of the number of items an individual can recall. Hence, memory span is defined as a statistical average, the number of items that have a probability of 50 percent of being correctly reproduced (Hall, 1971).

The first person to study memory span was Hermann Ebbinghaus (1885) (cited in Bauer, 1977). Ebbinghaus used himself as a subject to test the number of items an individual could remember within a few seconds upon presentation of the stimuli. He found that he could remember about 7 items and he concluded that an adult's memory span was approximately 7 items. Furthermore, he discovered that the number of items remembered depended on the interval time between the items. The items that were used in Ebbinghaus's study were nonsense syllables and meaningless three-letter units, each consisting of a vowel between two consonants. Meaningless items were used because he wanted to obtain a pure measure of memory, uncontaminated by previous learning or associations. He found that the first and last items were remembered more readily than those in the middle. This pattern of recall is now called the serial position effect. The probability of recalling the first few items in the list is labelled the primacy effect and the probability of recall for the last few items is called the recency effect.

Investigators noticed memory performance differences between individuals of different scholastic achievement. Jacobs (1887) and Hawkins (1897) (cited in Dempster, 1981 and Zimbardo & Ruch, 1975 respectively) had found from their studies of memory span, a marked
relationship between an individual's educational attainment and his/her memory span. Galton (1897) (cited in Zimbardo & Ruch, 1975) presented evidence to show that memory performances differed between normal and retarded individuals.

These early studies provided information for future research in the study of individual differences in memory. One of the most important developments was the inclusion of various short-term memory tasks in standardized diagnostic instruments. The earliest standardized test which included a short-term memory task was the 1905 Binet-Simon Scale, the grandfather of all intelligence tests and the predecessor of the Stanford-Binet Intelligence Scale. Binet reasoned at the time that a memory test would provide information about the powers of acquisition, concentration, attention, tastes and tendencies, general mental disposition (reflected, for example, in errors or omissions), and comprehension (Binet & Henri 1895) (cited in Sattler, 1982). He also viewed memory as an intellectual process that was facilitated by understanding. In two papers published by Binet and Henri in 1895, verbal memory was given special emphasis as it was perceived to be the chief foundation of all forms of language. The serial memory span test (Memory for Digits) that Binet developed required the immediate repetition of a series of digits of increasing length. Although the Stanford-Binet test has undergone several revisions (1916, 1937, 1960, 1972 and 1986), the digit span test, has been retained in each revision.

Other standardized tests such as Wechsler Intelligence Scale for Children-Revised (WISC-R), Illinois Test of Psycholinguistics Abilities
(ITPA) (Kirk, McCarthy, & Kirk, 1968), and McCarthy Scales of Children’s Abilities (McCarthy, 1972), also incorporated a digit span measure. Popularity of the digit span perhaps lies in its task characteristics. As explained by Bauer (1977), a digit span task has simple requirements. It is easy to administer and it is reliable. The average reliability coefficient quoted for the WISC-R is .78. (Wechsler manual, 1974, p. 28). Digit span, a measure of short-term memory, has been examined in the context of psychometric and experimental studies.

**Approaches to Short-term Memory Studies**

Psychometric and experimental approaches are two ways of investigating short-term memory and each offers a different perspective. In the psychometric approach, standardized tests such as the ITPA and WISC have been used often to obtain performance profiles of reading or learning disabled children and normal learners for the purpose of comparison between the two groups; although the purpose of early psychometric studies was not to examine short-term memory exclusively, the psychometric data generated from these studies inadvertently provided additional knowledge of learning disabled children’s recall ability. However, as this approach does not permit systematic manipulation of task parameters, factors that may be responsible for the poor memory performance of learning disabled children can not be isolated for further study. This limitation may explain the gradual decline in its use in the last two decades (Torgesen, 1982).
Unlike the psychometric approach, experimental studies provide a better understanding of the cognitive processes and skills that are required in the execution of short-term memory tasks. Researchers examine variables that may influence the retention and retrieval of information from short-term memory. Although the concept of short-term memory is not new in experimental studies of memory, the procedures involved in the measurement of short-term memory were only introduced at the end of the fifties by Brown (1958) and Peterson and Peterson (1959). Some of the options available are free recall (subjects need not recite the items in the same order of presentations), probed recall (subjects must recall the item that followed a specific item), serial recall (subjects must recite items in exact order of presentations) and differential recall of various types of materials (linguistics vs non-linguistics, visual vs auditory presentation, etc.).

**Short-term Memory and Age**

Experimental studies have provided some insight into memory span differences between individuals. Two variables, strategies and knowledge base, have been suggested to explain some of the span differences between reading disabled and non-disabled groups in different age groups. However, the development and sophistication of both strategies and knowledge are functions of the individual's age. Digit and word span measures in standardized tests such as the WISC (Digit Span Subtest) and SB-IV (Memory for Digits and Memory for Sentences) are developmental in nature; that is, span size increases with age. The developmental trend for spans as outlined by Dempster (1981) is that children at the age of
two have only a word span of three words and a digit span of 2.3 numbers. But as they get older, their spans steadily increase and by adulthood they will have reached the ceiling of five words for a word span and seven digits for a digit span.

Some researchers believe that the age-related increase in span size is related to the individual's improvement in the proficiency and use of memory strategies (Swanson, 1987; Howe, Ceci & Falls, 1978; Siegel & Allik, 1973). Flavell, Beach and Chinsky (1966) found that rehearsal is more apparent in older subjects than in younger ones; children between three and six years of age do not use strategies. They speculated that children before the age of nine tend to rehearse single items or in combination with a minimum number of other items while older children tend to cumulatively rehearse several items together. Older children are also more active in using a greater variety of strategies and in using them more effectively (Torgesen 1977; Howe et al, 1978). As well, older individuals are more metacognitively aware of the type of strategies required for solving each type of problem (Torgesen & Goldman, 1977). Howe and his colleagues (1978) speculated that when older children exhaust one set of strategies, they automatically search through another set for assistance. Consequently, due to their greater flexibility and better management of strategies, they improve in recall.

Tarver, Hallahan, Kauffman and Ball (1976) attributed age-related improvement in verbal encoding strategies to the increase in selective attention of individuals on memory tasks. In their (1976) study, they found that the older subjects, both learning disabled and normal,
recalled less of incidental information and more of central information than their younger counterparts. In this study, while both sets of information, incidental and central, were presented on the same card, the subjects were asked only to memorize the designated portion. Children were first tested for central recall, then for incidental recall. Tarver et al, concluded that the increase in selective attention for the older subjects was due to encoding strategies which facilitated selective attention, rather than to an increase in selective attention per se.

The ability to activate the appropriate strategies to assist memory recall is also an age-related phenomenon. Younger and reading disabled children tend to perform less well in memory tasks compared to older and non-disabled readers. But in studies where examiners imposed strategies on younger and reading disabled children, there was no performance difference between these groups and their counterparts (Wong, 1978; Ceci, 1984). Hence, younger children and reading disabled children use strategies but fail for some reason to activate them at the appropriate time to facilitate their recall. Flavell used the phrase 'production deficiency' to describe this group. Production deficiency refers to an inability of the reader to produce the relevant words at the instant required, although he/she is familiar with the words required and can produce them in other situations.

However, there is no general consensus that age-related improvement in memory strategies is solely responsible for span differences between different age groups of children. Huttenlocher and Burke (1976) believe
that there is inconclusive evidence to support the claim that improvement in strategies accounts for the span difference. These authors feel that the differences in memory performances between the age groups are a reflection of the groups' different knowledge bases. Their assumption is in accordance with the fact that acquisition of knowledge is a developmental process, and input entered into the short-term memory must interact with previously learned materials. Consequently, the greater the repertoire of knowledge accumulated over time, the greater the chances were for matching between input and internal knowledge, and for elaboration of existing strategies. Bjorklund (1987) also believed that age differences in semantic memory affect the ease with which information in permanent memory can be activated, which in turn influences the amount of mental effort available for other cognitive operations. Bjorklund further elaborated that having detailed knowledge about a set of items can influence memory performance by increasing the accessibility of specific items; by activating more easily the relations among the sets of items; and by facilitating the use of deliberate memory strategies. Bjorklund concluded that with age an individual requires less space for processing information, leaving more space available for storage.

Relationship between Short-term Memory and Reading

Memory span differences are most pronounced between children with reading or learning problems and those with normal reading ability. As children who have difficulty in reading also have difficulty in memory related tasks, researchers such as Das, Bisanz and Mancini (1984)
assumed that both memory and reading share some major cognitive processes and that "...a reading deficit may imply corresponding deficits in these processes, only some of which determine memory span" (p.549). Stanovich (1986) suggested that there was a causal relationship between short-term memory and reading. However, Perfetti and Lesgold (1977) disagreed with the theory that reading and short-term memory are related. They cited Perfetti and Goldman's (1976) study on probed digit recall to substantiate their claim. In Perfetti and Goldman's study, probed digit recall did not differentiate between skilled and less skilled readers. The difference between the two groups' memory scores was insignificant (t = .98, df = 22). Daneman and Carpenter (1980) explained that the lack of correlation between reading and memory might be due to the relatively simple demand of the digit span task used in Perfetti and Goldman's (1976) study. Daneman and Carpenter believed that in a limited capacity system, structure and processing compete for space; only a task with heavier processing demands can show the marked trade-off between processing and structure. They believed that it is this trade-off in the memory system which differentiates good and poor readers. They further suggested that good readers require fewer processes than poor readers, thus, leaving more capacity for storage of necessary intermediate and final products of the reading process. Good readers may omit the processes such as decoding, lexical accessing, parsing, inferencing and integrating that are required by poorer readers.
Although individual researchers delineate many different memory processes that are included in reading, Torgesen (1978) believed that there are three basic ones: sensory visual trace, iconic image and short-term memory. Sensory visual trace and iconic image make up the structural features of the memory system. These processes facilitate memory, but they are not under the conscious control of the individual. Torgesen defined sensory visual trace as a very briefly stored (250 msec.) visual image of the input resulting from one eye fixation. Iconic image results from matching the visual input to a stored visual image. The image lasts for about one to two seconds and during this time the input is verbally or phonologically coded. The speed of phonological coding has been established at three to four elements per second for unrelated digits, and perceptual span is limited to the number of elements that can be phonologically coded during the short time that the iconic image persists (Klatzky, 1975). The third memory process suggested by Torgesen is the short-term memory. Unlike the first two processes, retention and retrieval of information stored in short-term memory are under the control of the individual. It is in the short-term memory that phonologically encoded information is stored for several seconds while sentences are being processed for meaning. In beginning readers or less skilled readers, short-term memory is the site for assembling smaller units of words.

Phonological coding is the component in short-term memory that is most vital for skillful reading. According to Das, Snart & Mulcahy (1982), phonological representation preserves the memory of the word
while a sentence is being processed. In addition, it gives intonation
and emphasis to the print. But most importantly, it converts print,
which is visual-spatial, to an articulatory sequential mode. Das et al
(1982) believe that it is in the conversion to sequential order that the
poor readers are weak. As poor readers have inadequate and inconsistent
phonological coding strategies, these researchers state that they may
rely on the visual-orthographic strategies for reading.

Phonological coding serves as a reservoir for linguistic storage
state that during reading, sequences of words must be held in short-term
memory while comprehension processes operate on the words to integrate
them into a structure that can be stored in long-term memory. The
short-term memory, these authors suggested, may rely on phonetic coding
to retain this information.

Selection of Children with Reading Problems—Methodological Problems

In many memory studies, children with reading problems appear to
share two common factors: they have average intelligence and are two
years lower in reading performance than the children who serve as the
study’s controls in the same study. The selection criteria are similar,
but the methods used by researchers are as varied as their choices of
nomenclatures (backward readers, less skilled readers, reading
disables, and poor readers). The main differences in methodologies
among the studies are in the reading tests used, the educational
settings from which these individuals were chosen and the performance
discrepancy between good and poor readers. Many of the subjects with reading problems came from regular classes (Spring & Farmer 1975; Das et al, 1984, Brady, Shankweiler & Mann, 1983, Bayliss & Livesey, 1985) or from referral agencies such as the Department of Psychology at the Children’s Hospital (Cohen & Netley, 1981), or the Parent/Child Learning Clinic at a university (Fay, Trupin & Townes, 1981). Many also were sampled from resource centers such as Learning Assistance Centers and Learning Disabilities classes (Wong, 1978). As the educational environment from which the subjects were sampled would reflect the severity of the subjects’ reading problems, poor readers in one study may be very different from poor readers in another study. A survey of the literature shows that average intelligence, one of the criteria in the selection process, was determined by one of these instruments: WISC-R, Slosson Intelligence Test, Otis Lennon Tests, or Lorge-Thorndike Intelligence Tests, whereas discrepancy in reading levels was measured by one of the following common reading instruments: Spache Diagnostic Reading Scale, Wide Range Achievement Test, Metropolitan Achievement Test, Woodcock Reading Mastery (Word Attack and Word Recognition), Durrell Reading Analysis, Cognitive Test of Basic Skills, Gates McGinitie, and Schonell Graded Reading Vocabulary Test. Teacher nomination was used by some researchers (Fay, et al 1981; Brady, et al 1983; Katz et al, 1981) as an added measure of selection while Farnham-Diggory & Gregg’s study (1975) used only the teachers’ nominations and records as determinants of reading ability. Although poor readers showed a two year lag behind the controls in most studies, that difference could be very misleading. For example, Brady et al
(1983) designated their poor readers as those students who scored .5 year below their expected level on the Word Attack and Word Recognition subtests in the Peabody Individual Achievement Test. The reading difference between the good and poor readers in this particular study was approximately three years. Hence, good readers scored approximately 2.5 years above their expected level. However, in Torgesen's (1977) study, his designated reading disabled children showed a 3.2 year lag as measured on the Wide Range Achievement Test and his designated good readers showed an average or above reading level. To determine whether the scores between any of the reading tests used are comparable, the correlation between them must first be established.
STUDIES ON SHORT-TERM MEMORY AND READING

Psychometric Studies

Psychometric studies on memory has a longer history than experimental studies. This approach involves the use of common standardized tests to produce a performance profile of a group of individuals. The finding usually highlights the areas of strengths and weaknesses of the subjects but seldom provides any explanation for the results. Two common standardized tests such as the Illinois Test of Psycholinguistic Abilities (ITPA) and Wechsler Intelligence Scale for Children (WISC) have been used to determine areas of significant difference between learning disabled children and non-disabled children.

Kass's (1966) study used the ITPA with 21 reading disabled subjects ranging in age from seven to ten. Nine of the subtests in the ITPA and five supplementary measures were administered. One intent of the study was to confirm that reading disabled children were different from the non-disabled group on tests at the integrational level. These tests purported to assess the child's ability in more automatic and less meaningful use of symbols. Two memory subtests, Auditory and Visual Sequential Memory, of the ITPA were used. The Auditory Sequential Memory test is a digit span test and each digit is presented at one-half second rather than the one second intervals used in the WISC. The Visual Sequential Memory test requires the subject to reconstruct sequences of abstract designs which are viewed in their entirety for five seconds. The results from using these two tests supported Kass's hypothesis that
children with reading problems perform poorly on both visual and auditory sequencing.

Badian (1977) used only the Auditory Sequential Memory subtest of ITPA to test the hypothesis that a memory deficit might be related to auditory-visual integration inferiority. Thirty retarded and 30 adequate readers, ten from each grade between grades 3 and 5, were involved in this study. Students' scores from reading tests such as the Gray Oral Reading Test and Standard Diagnostic Reading Test, Reading Comprehension subtest, determined their group placement. The results showed that the ITPA Auditory Sequential Memory was the best differentiator of the two reading groups.

Huelsman (1970) reviewed 23 studies that were done between 1952 and 1967 using the WISC. Of the 23 studies, the ten that used the WISC and all its subtests for the purpose of extracting subtest patterns showed that children with reading difficulties scored, without any exception, lower on the Digit Span test than on other subtests.

Rugel (1974) did a similar review of 25 studies which reported WISC subtest scores of disabled readers. He reclassified the subtests into three categories: Spatial, Conceptual and Sequential. In these studies, disabled readers scored the lowest in the subtests (Digit Span, Coding and Picture Arrangement) in the Sequential category. In 11 of the 25 studies, subtest scores for both disabled and normal readers were available and the scores of these two groups were compared. Disabled
readers scored significantly lower than normal readers on the Digit Span subtest.

Studies using the ITPA and WISC have shown that reading disabled children to perform lower on digit span tests. Reading or learning disabled children's lower scores on Digit Span may not be due solely to poor short-term memory. Rather, poor scores may be the result of one or a combination of factors that Digit Span purportedly measure: poor sequencing, poor facility with numbers, lack of attention, high anxiety, high distractibility, lack of interest and slow speed of item identification (Mishra, Ferguson & King, 1985). Psychometric studies provide no information as to the processes that are deficient in reading disabled children which can account for the poor scores. However, experimental studies do provide some insight into the processing deficiencies underlying the poor performance of many learning or reading disabled children.

Experimental Studies

Many of the plausible explanations of the memory performance discrepancy between the two learning groups come from a broad base of theory available from experimental and developmental psychology. One important point that emerged from the field of psychology is that memory is not a unitary phenomenon. There are several different kinds of memory (e.g. semantic memory, episodic memory and long-term memory), and many different types of intellectual processes are involved in executing good memory performance. One broad distinction that provides the
beginnings of a framework for understanding deficient memory performance is the distinction between encoding, storage and retrieval processes (Torgesen, 1985). These three processes are interdependent and cyclical. Efficient encoding assists permanent storage of information; permanent storage facilitates easy retrieval of information; easy retrieval speeds up the encoding process and then the cycle repeats itself. This latter section reviews experimental studies that examined factors that influence encoding, storage and retrieval of information. This section also includes studies that focus on problems in perceptual processing as one possible cause to poor memory and reading performances.

**Encoding and Storage**

Encoding refers to the process of transforming environmental input into some representational form that can be stored in memory. Memory storage refers to the durability of the memory code once it has been created (Torgesen, 1985). Information must be coded in a form that would support long term retention. Incoming stimuli can either be encoded in terms of their semantic features (Howe et al, 1978; Sanford, Garrod & Bell, 1978) or in terms of their phonological features (Kochnower, Richardson & DiBenedetto, 1983; Barron, 1978) Most current conceptualizations of memory processes in children with reading difficulties emphasize the role of phonological encoding in accounting for poor memory performance (Shankweiler et al, 1979). Baddeley (1979) believes that the most stable code in short-term memory is the phonetic
code. Phonological coding represents the sound units that correspond to their graphemic representation (Samuels, 1987).

Byrne and Shea (1976) tested 30 students from grade 2 with equal numbers of poor and good readers to ascertain whether a continuous recognition task could detect phonemic encoding in the sample of poor readers if pseudowords were used. Twelve clusters of nonwords were formed. For each antecedent item there was a rhyming foil and a control nonword. The antecedent item was repeated twice and an additional 18 filler items (nonwords that did not rhyme with any other items) were placed strategically throughout the list. The subjects were to listen to the words on a tape and respond 'new' after any item that had not been heard before and 'old' after any item that had occurred. Two kinds of errors could be made: false positives and false negatives. False positive was saying 'old' upon the first presentation of any item, and false negative was saying 'new' to any item on its second or third presentation. The study showed the two groups of readers were indistinguishable in terms of false negatives. However, the good readers made more false positive errors on the rhyming foil words than poor readers. The authors attributed the greater errors to phonetic confusion.

Barron (1978) showed that good readers could generate phonological codes faster and easier than poor readers. In this study, 32 good and 32 poor readers were administered 160 stimulus items; 80 were words that required a 'yes' response and 80 were nonwords and required a 'no' response. Of the 80 real words, 40 were less frequent members of
homophone pairs and the remaining 40 words that formed the control items, were identical to the homophone in length and in word frequency. Of words that required a ‘no’ response, 40 were double pseudohomophones and the remaining 40 that formed the control items were words that were pronounceable and differed from the double pseudohomophones by one letter. Response time was recorded for each subject and the results indicated that good readers were significantly slower on the pseudohomophones than on the control items suggesting that they used a phonological code in deciding that an item was not a word. Poor readers, however, did not show a reliable pseudohomophone effect, suggesting that they did not use a phonological code in making their decision about nonwords. Both good and poor readers made significantly more errors on the double pseudohomophones than on the controls. But the good readers were faster and more accurate than the poor readers in pronouncing nonwords.

The ease with which an individual phonologically encodes the stimuli depends on whether the stimuli can be coded. The implicit suggestion related to phonological coding or item identification is that poor readers have an underlying linguistic problem which hinders their ability to label objects. Torgesen & Kail (1980) stated that poor readers did not label stimuli as readily as good readers of the same age and general intelligence.

Katz et al (1981) hypothesized that good and poor readers differed in their ability to apply phonological coding to maintain the serial order of stimuli in short-term memory, but not in their ability to order
nonlinguistic stimuli that do not lend themselves to phonetic recoding in short-term memory. In the study by Katz and his colleagues, two sets of drawings comprising equal numbers of phonetically recodable and unrecodable drawings, were administered to 21 good readers and 21 poor readers from grade 2. Shortly after each set of five stimuli was exposed on the screen for four seconds, the subjects were asked to rearrange the five cards before them in the order as seen on the screen. Results indicated that good readers performed better than poor readers in both phonetically codable and noncodable tasks but with insignificant group difference on the noncodable task. The authors suggested that the poorer performance of the poor reading group might have been due to the use of inappropriate or inefficient strategies, or due to the slowness in the initial conversion from pictorial to phonetic form.

Done and Miles (1978) also believed that the difference between poor and good readers on memory tasks was due to verbal encoding. In the first experiment in their study, they presented three types of stimuli to 18 dyslexic subjects aged 13 and 18 control subjects also of the same age. The three kinds of stimuli were sequences of digits which were readily encodable; series of pictures which were partially encodable; and series of nonsense shapes which were noncodable. All three types of stimuli were presented in an Electronic Developments 2-field tachistoscope for two seconds. The subjects were required to respond immediately after the stimulus was shown. The researchers also took note of the order in which the subject presented the stimuli. The results showed that the control subjects performed better than the
dyslexic readers in all three conditions but only the difference between the two groups' mean scores in digit recall was significant. The results demonstrated that good readers had an advantage over poor readers on memory tasks that could be easily coded in words.

Lewis and Kass's (1982) study also showed that children with learning disabilities had a labelling deficit. The purpose of their study was to compare the ease with which poor and good readers label objects and pictures. The study also investigated whether the difference in memory performance of these two groups would still be present if they were to generate and recall their own labels for the objects and pictures. This study enlisted 44 learning disabled and 44 normal learners who were between the ages of four and nine years of age. The two groups were matched on age, sex and language spoken at home. The subjects were asked to recall the names of the objects and pictures immediately after their presentation. The results indicated that the poor readers generated the same number of labels as good readers but they tended to give more inappropriate labels. The researchers wanted to test whether memory recall for objects and pictures would improve for both groups of children if they were to generate and recall their labels for the objects and pictures. Each group provided synonymous labels for the same objects and pictures and the same procedures were employed for the recall of the new labels. Results showed that both groups were equally successful in the recall of their own labels. Lewis and Kass concluded that perhaps short-term memory deficits found in learning disabled children reflected a qualitative rather than a quantitative
difference between the two learning groups. They also added that hyperactivity might be a confounding factor in the study because learning disabled children might not have been able to inhibit the selection of inappropriate or irrelevant labels from the memory storage.

Lindgren and Richman (1984) conducted a study to ascertain whether recall could be attributed to verbal processing deficit. In their study, fifteen 8- and fifteen 12-year-old reading disabled children and non-disabled children were tested on recall of color names in sequence of increasing length. The four presentation conditions were visual presentation - visual response; visual presentation - verbal response; verbal presentation - visual response and verbal presentation - verbal response. The 8- and 12-year-old disabled readers recalled significantly fewer colors than their age counterparts on tasks via the verbal modality. They showed better performance on the visual presentation and visual recall task. Individual means indicated significant difference only under the verbal-verbal condition. Hence, the investigators concluded that reading disabled children had difficulty in immediate sequential memory; and there also appeared to be a developmental difference in the relative influence of specific modalities on memory function.

Spring (1976) believed that memory span impairment of dyslexic children was due to slow-speech-motor encoding. As item identification requires cognitive capacity and since there is a fixed capacity, an individual who is slow to identify incoming information presumably will
have relatively less capacity left over for storing items. Consequently, he will have a shorter memory span (Spring, 1976).

Spring and Perry (1983) conducted an experiment with 30 nine year olds, 15 poor and 15 adequate readers, to test their hypothesis that there was a strong correlation between naming speed and short-term serial recall of verbal information because both tasks required high speed of phonetic coding. The children were asked to say the names of 50 randomly ordered digits as rapidly and accurately as possible. The test was given twice, each time with a different sequence of digits and each trial was timed with a stopwatch. Immediately following the digit naming task, the children were shown series of pictures made from two sets of drawing. One set consisted of six rhyming pictures and the other consisted of six nonrhyming pictures. There was a total of six trials, three were pictures that came from the rhyming set and the remaining three came from the nonrhyming set. The children's task was to recall each series of pictures and to place each face down card on its matching picture attached to a response strip. There were six response strips and each contained different random orders of all six rhyming or nonrhyming pictures.

Results of this study indicated that normal children from grades three to five had higher mean digit naming speed ($M = 2.29$ digits/sec) than that of the disabled readers from the same grades ($M = 1.59$ digits/sec). The difference between the two mean scores was significant. In the picture memory test, adequate readers recalled significantly more pictures from
the nonrhyming set than the poor readers. Although adequate readers also recalled more pictures from the rhyming sets, the difference between the two groups was not significant. When digit-naming speed was correlated with nonrhyming and rhyming memory scores, digit-naming speed was significantly correlated with nonrhyming memory ($r = .57$) but not with rhyming memory ($r = .17$). Spring and Perry concluded that naming speed correlated only when the memory test was given under conditions which were not expected to cancel the effectiveness of phonetic coding. They also surmised that individual differences in short-term memory span were the result of differences in phonetic coding speed.

**Retrieval**

Retrieval processes are the operations involved in the attempt to extract an item from memory (Torgesen, 1985). The facility with which an individual retrieves information from the short-term memory depends on the memory strategies that are used (Atkinson & Shiffrin, 1971). Some of the memory strategies that have been theorized to affect retrieval are rehearsal, coding, grouping and chunking. Rehearsal strategies are popularly used to explain the longer memory span demonstrated by normal learners compared to that of learning disabled children. Rehearsal strategy generally involves a cyclical repetition of information in short-term memory in order to keep the information fresh for easy retrieval. Researchers believe that rehearsal is one of the variables that influences the size of memory span. Chi (1981) defined rehearsal as an iterative process by which materials in short-term memory are continually attended to in a serial fashion. This process is under the
subject’s conscious control and it is analogous to subvocal or implicit speech. He found that rehearsal can proceed at the rate of 250 milliseconds per item. Flavell et al (1966), working with groups of children from kindergarten, grade 2 and grade 5, found that the number of items sequentially recalled accurately increased with age. Although most of the kindergarten children knew the names of all items (pictures), they did not verbalize or code the items, as did the children in the higher grades. The possible explanation for the absence of rehearsal was that the kindergarten children were too young to engage in this kind of cognitive process. Flavell and his co-workers labelled these young subjects as having production deficiency, meaning that these children’s difficulty may not lie in an ability to produce the words but rather, they lack an ability to produce them on appropriate occasions. Flavell and his colleagues also found that the children who rehearsed more tended to remember the information more accurately. Their experiment with unfilled delay showed that children rehearsed during the intervals.

Some researchers extended the finding that rehearsal differentiated between good and poor readers by further suggesting that a suppression of rehearsal would eliminate the differences. One way of suppressing rehearsal was through the use of a distractor. Bauer’s (1977) study with twelve 10-year-old learning disabled and twelve non-disabled children of the same age was to investigate whether a disruption to the subjects’ rehearsal would affect their recall. In this study, immediately upon presentation of a list of words, the subject was asked
to count forward at a maximum rate before the list was recalled serially. The result showed that normal readers were superior in recall, but both groups forgot the information at the same rate. The primacy effect in the non-disabled reader was significantly higher than that of the disabled readers, but the recency portion was similar. Based on the serial position curve, Bauer concluded that learning disabled children were weaker in rehearsal because of a lack of primacy effect but they attended to the stimuli as well as the non-disabled children did because of similar recency effect.

Bauer's experiment was replicated two years later but the purpose of the more recent study was to measure the primacy and recency effects of each child for subsequent use as an estimate of elaborative encoding and attention. In his 1979 study, Bauer selected 24 learning disabled and 24 non-disabled children between ages 9 and 10. The result of this later study was the same as his 1977 study. The recall of non-disabled children was superior to that of learning disabled children. The non-disabled children had a greater primacy effect than the disabled children, but the recency effect of both groups was similar. Again, Bauer attributed the lack of primacy effect of the disabled children to deficiency in elaborative encoding processes such as rehearsal.

Done and Miles (1978) did a similar study with two exceptions: the population consisted of 15 dyslexic and 15 normal readers (both 13 years of age) and the distractor or the articulatory suppression was that the subjects had to say the word 'the' during the interval. The verbal retention task was that of recalling tachistoscopically presented
sequences of digits under six different recall conditions. The six conditions under which the subjects had to respond were the following: immediately after the stimulus offset, five seconds (with articulatory suppression) after the stimulus offset, ten seconds (with articulatory suppression) after stimulus offset, 15 seconds (with articulatory suppression) after stimulus offset, 20 seconds after stimulus offset and 20 seconds (no articulatory suppression) after stimulus offset. Contrary to the assumption that verbal suppression would eliminate performance difference between poor and good readers, the results of this study showed that the control group performed significantly better than the dyslexic group in all conditions. However, the significant group by conditions interaction indicated that control also suffered more under verbal suppression than the dyslexic children because good readers were deprived of their chance to rehearse. An examination of the serial graph showed that both groups diverged in positions one and six but converged in positions between two and five.

Despite the apparent popularity of rehearsal as a viable source of short-term memory difference between good and poor readers, there are arguments against this theory. Dempster (1981) claims that rehearsal was not a profitable way of processing information in a running memory span task. He believed that grouping, another memory strategy, was the source of span difference. However Dempster's view was not supported by Cohen and Netley (1981) who believed that the poor readers' short-term memory deficits were due to their inability to encode serial items in the form of serial phonological patterns. Their experiment included two
groups of reading disabled children of average intelligence (full scale IQ on WISC between 97.5 and 109.9). One group had a Performance IQ that was 15 points higher than Verbal IQ on the WISC (N=11). As the researchers could not locate children with a Verbal IQ that was 15 points higher than their Performance IQ, an ideal reversal of the first sample, they included as a second group children who had a Verbal-Performance discrepancy of 5 points or less (N=10). Two groups of control subjects were also included. Each was matched with the reading disabled group that was similar in Performance-Verbal discrepancy. Ten lists of auditory digits, varying in length between 16 and 26 items comprised the test series. They were presented at 5 different rates: 2.3 digits/sec, 4.6 digits/sec, 7.3 digits/sec, 10 digits/sec, and 13.2 digits/sec. Each subject received the lists in ascending order of presentation rate, beginning with the rate of 2.3 digits/second. The subject's task was to repeat the last three digits in each list in order as soon as the presented list was complete. The reading disabled group with the slightly higher Verbal IQ and its counterpart shared similar performance when the digits were presented at the slowest rate (2.3 digits/sec). However, the difference between the groups increased as the presentation rate increased to 7.3 digits/sec and then decreased again at the two highest rates. The control did better than their counterparts at those faster rates. The comparison between the two groups with a higher Performance IQ was similar except at the lowest presentation rate. Even at 2.3 digits/sec, the poor readers performed less well than their controls. When comparing both control and reading disabled groups, the control and disabled group that
scored a higher Verbal IQ performed better than their respective control and disabled group. As the faster rate prevents rehearsal to take place, the authors concluded that subjects' performances were influenced by their ability to encode the lists of digits into a store which holds items-in-order in the form of phonological patterns.

Torgesen & Houck (1980) systematically studied the recall of digit span of three groups of children. The 24 subjects were divided into 3 equal groups according to their performance on the Digit Span subtest of the WISC-R. Sixteen were learning disabled students as diagnosed by their school district. Of this number, 8 scored below average and 8 scored average on the Digit Span test. They were labelled the LD-S and LD-N respectively. The remaining 8 students, average learners who scored average on the Digit Span test, were labelled the N group. A series of digit spans was administered to these subjects auditorially, comparable to the procedures used in the WISC-R, but using a tape recorder. The digit spans were given under several different circumstances.

In one situation, money was used as an incentive to ascertain whether poor scores of the LD-S group was in any way due to a lack of interest. A span series began with three digit spans and the subjects received spans of increasing length until they made errors on three consecutively presented span. After the administration of 2 three series of digit span the children were told they could earn money if they could do better on the second three series than they did on the first. Dimes were presented on the table for proof. The result showed
that while the incentives did seem to improve recall of children in the LD-N and N groups, they made no significant difference for the LD-S group. Subsequent interviews with the LD-S group indicated that they did try to work harder for the money, but they couldn't improve their performance.

In the same experiment but under another circumstance, Torgesen & Houck investigated whether or not presentation rate would affect digit span performance. They hypothesized that if mnemonic strategies were used by the LD-N and N groups, a decrease in time would result in poorer performance. As the LD-S group was hypothesized to be passive users of strategies, faster rates of presentation would decrease the performance difference between LD-S and the two groups. The four rates were 4 digits per second, 2 digits per second, 1 digit per second and finally, 1 digit per 2 seconds. Results showed that the faster rate of presentation did not change the difference in performance between LD-S and the other two groups. However, the performance of LD-N and LD-S group was similar at the 1 digit per 2 second rate. Unlike the N group, both LD-S and LD-N showed a drop in performance. The conclusion drawn by the researchers was that failure to use mnemonics in situations where it could aid recall did not appear to be a factor uniquely associated with the LD-S subjects but rather appeared to be a more general characteristic of LD children.

Engle and Marshall (1983) conducted a study which examined the extent of the interaction of grouping and rate of presentation of digits with age of subjects. The subjects in this study were 12 males and 12
females in each of three groups: 6-year-old first graders, 11-year-old sixth graders and 20-year-old college students. Ten sets of 3-9 item lists at 1 digit per second and 2.5 digits per second were administered under three group conditions: grouped by one digit, grouped by 2 digits, and grouped by 3 digits. The mean of the longest list to be recalled perfectly for each of the 10 sets of lists was determined to be the memory span for that subject.

The results showed a developmental pattern for digit span. The mean digit span for adults was 7.5, for the 11-year-olds was 6.3 and for the 6-year-olds was 4.1. Under the faster presentation, the age by group interaction was significant. Going from group size 1 to size 3, the first graders showed no effect; the sixth graders showed a 10% improvement and the adults showed a 26% improvement. At 2.5 digits per second rate, grouping benefitted the adults most but did not benefit the youngest group. However, when the performance of the three groups for the one digit grouping condition was examined alone, the faster rate of presentation showed a decrease of 6% for the adults, while the first and third graders showed increases of 23% and 30% respectively. These results showed that adults performed better at a faster rate if the stimuli were grouped. If the stimuli were given individually, then they performed better at a slower rate. The converse was true for the younger children. They performed better at a faster rate for ungrouped digits and if the stimuli were grouped, they performed better at a slower rate.
According to the authors, the outcome of the study showed that grouping facilitated rehearsal most for the grade 6 students. Engle and Marshall speculated that adults already possessed those strategies and thus the imposed grouping did not enhance their performance as much. However with the grade 1 students, despite the available strategy, they failed to capitalize on it. The authors surmised that a certain level of cognitive maturity was necessary before subjects would make use of grouping.

Rose, Cundick and Higbee (1983) investigated the effects of verbal rehearsal, visual imagery and "unaided" instruction on recall of stories. The subjects included 30 learning disabled children, each of whom was randomly assigned to one of three equal sized treatment groups (N=10). The three treatment conditions into which children were assigned were "unaided" instruction, verbal rehearsal, and visual imagery. Children in the "unaided" group were simply told to concentrate hard on the selected passage in preparation for comprehension questions which would follow the reading. Children in the verbal rehearsal condition were instructed to pause after reading a few sentences and talk to themselves aloud about what they were reading. Children in the visual imagery condition were asked to pause after the reading of a few sentences in order to conjure the images of what they had just read. Children in the visual image condition and verbal rehearsal condition performed significantly better in comprehension and retention than those in the "unaided" condition.
Perceptual Processes and Short-term Memory in Good and Poor Readers

In the reading process, the initial stages of perception and memory encoding involve word recognition (Elbert, 1984). Perceptual problems have been blamed for reading difficulties in children (Reid & Hresko 1981). The role of visual processing in reading has received much attention amongst theorists in the field of learning disabilities. Many of these theorists were visually oriented and felt that most academic functioning was related to the processing of visual material.

Perceptual span and fixation rate were examined as possible variants to account for the differences between good and poor readers in short-term memory and reading. Carrow-Woolfolk and Lynch (1982) believe that reading begins with eye fixation. The fixation allows interaction between visual input and internal knowledge. The reader's eyes focus on a part slightly indented from the beginning of the line of print and remain there for approximately 250 milliseconds. Some theorists believe that the perceptual spans of poor and good readers are identical but their rate of processing is different due to the good readers' greater knowledge of the language and material, speed of verbal encoding, and hence their ability to extract more meaning from each fixation (Spring & Farmer, 1975).

Spring and Farmer (1975) wanted to verify in their study that poor readers have narrower perceptual span for non-meaningful material and that narrow perceptual spans may be due to slow phonological coding rather than to brief iconic images. Their subjects included poor
readers and normal readers as determined by the Wide Range Achievement Test. The subjects were asked to name 50 randomly sequenced digits quickly and their naming speed was recorded. The results confirmed the hypothesis that poor readers have smaller perceptual span than the normal readers. The authors further concluded that the poor readers' small perceptual span was due to their slower phonological coding.

Another aspect of perceptual processing investigated in memory research is perceptual modality processing. According to some researchers, the modality through which stimuli enter can influence the rate of retention. As visual trace is shorter (250 msec) than acoustic trace (1-2 seconds), an assumption has been made that stimuli that are presented auditorially are remembered better. However, Klatzky (1975) was unable to find evidence to support the assumption that retention of auditorially presented linguistic information was superior in the short-term memory to retention of visually presented material. The lack of evidence as explained by Klatzky was that cumulative rehearsal is more restricted when presentation is auditory than when it is visual.

Siegel and Allik (1973) explained that rehearsal (verbal auditory) is interfered with if material is presented via the auditory mode. In other words, the next auditory input displaces the item in the acoustic memory. This theory was based on their 1973 experiment with subjects from kindergarten, grade two, grade five and college. Siegel and Allik set out to investigate the differential influence that modalities have on the retention and retrieval of information. They found from their study that subjects remembered better if material was presented via the
visual mode, and their mean response latency was least with visual presentation and auditory recall cues, but longest with auditory presented material and visual recall cues. The four conditions which they devised to test their hypotheses were visual presentation - visual recall cue, visual presentation - auditory recall cue, auditory presentation - auditory recall cue; and auditory presentation - visual recall cue. The interval time between stimuli was four seconds to permit rehearsal. Overall performance on both visual and auditory stimuli improved with age, and with significant increase between grades two and five. The modality in which the stimuli were presented had a clear effect on performance; whereas, the effect of the modality of the recall was negligible. Siegel and Allik attributed the visual advantage to labelling which they observed in all subjects. By labelling, the subjects inadvertently converted the visually presented material into acoustic traces which have a longer trace time. Consequently, the subjects gained an extra access to the retrieval of information.

A similar experiment was done by Elbert (1984) with sixteen 8- to 12-year-old learning disabled children and sixteen normal children with the same age span. The subjects were presented with arrays of words via two perceptual modalities: visual and auditory. Then the subjects received a target word and had to decide whether or not it was a member of the array. Three combinations of conditions were set up for the arrays of words and target words: visual-visual presentations, auditory-auditory presentations, and auditory-visual presentations. The results from this study showed that good readers did well in all
cross-modality situations and not just in visually presented ones, whereas, poor readers did better in only the auditory presented and auditory recall cue. Similar to Siegert and Allik (1973), Elbert concluded that good readers were able to encode all visual stimuli into auditory ones and thus converted all three conditions into auditory ones.

SUMMARY

The present chapter reviewed theories and research on the subject of short-term memory and its relationship to reading. A large percentage of the information on short-term memory and reading is generated mainly from experimental studies, the results of which provided some possible explanations for the differential performance between reading disabled and nondisabled children. Although memory strategies such as rehearsal have been a popular explanation, the theory that rehearsal accounts for individual span differences is currently being challenged. Recently, phonological coding, other mnemonic strategies and the speed of this coding appear to explain the performance differences between good and poor readers. Although the results of many current studies come from working with children with reading problems and children with learning disabilities, the tools and criteria used in the selection process of these subjects differed tremendously from study to study. Consequently, the difference in subject selection does not permit comparison between studies. Aside from this methodological problem, the results from the experimental
studies only provide insight to some possible causes of short-term memory deficits in some reading disabled children; they have no immediate application in the educational realm in terms of either remediation or identification of children with short-term memory problems. But the information that is available will assist in the interpretation of short-term memory performance of individuals on standardized tests.

Although previous psychometric studies using standardized tests have been restricted to performance profile comparison of groups of individuals, the reason perhaps is due to the scope of the short-term memory component which consists of one to two memory related subtests. However, the recently revised Stanford-Binet Intelligence Scale - IV incorporates a more extensive short-term memory component, consisting of four subtests. The subtests within this component also share some similarity to those memory tasks used in experimental studies. For example, the short-term memory component in the SB-IV consists of Memory for Digits, Memory for Sentences, Memory for Objects and Bead Memory. Memory for Digits and Memory for Sentences are similar to Digit and Word Spans that have been used in experimental studies. Although the presentation rate or demand may be different, the factors that influence retrieval of these stimuli may still be the same. Furthermore, the items in the four subtests are presented via auditory and visual channels which share some similarity to the format of those experimental studies which investigate the effect of modality presentation on recall. In Memory for Sentences and Memory for Digits, the items are presented
auditorially but in Bead Memory and Memory for Objects, the stimuli are presented visually.

Statement of the Problem

The short-term memory component in the subtest from the recently revised edition of the Stanford-Binet Intelligence Scale provides an interesting area of investigation. Present studies mainly focus on the variables that are responsible for memory span differences between groups of individuals. Review of recent short-term memory studies shows that there has been little examination of the correlational relationship between the reading tests used to select reading disabled subjects and the short-term memory tasks used in the same studies.

If the premise is that reading and short-term memory share common cognitive processes, then the correlation between reading and memory should be established to affirm the strength of this relationship. Furthermore, the strength of the correlation will also indicate the degree of similarity in the task demands of the two activities. In some memory studies, reading subtests that measure word recognition or word attack skills were used in the selection of reading disabled or poor readers. The reason for emphasizing word decoding skills rather than comprehension skills perhaps reflects the belief that the automatic aspect of decoding determines the level of comprehension of the text. As explained by Samuels and LaBerg (1974), an individual who needs to decode a word letter by letter does not have any attention free to access the lexicon from long-term memory storage. Word decoding has
been found to be strongly correlated with comprehension (Stanovich, 1986). However, good word decoding skills should not be perceived as an index of comprehension as many individuals who have excellent decoding skills can not understand the text (Seidenberg, 1982). Also conversely, individuals who may have lower word decoding skills can attain higher comprehension levels than those who can word call perfectly. Consequently, the use of word decoding subtests alone to select subjects for memory studies will not provide true samples of reading or learning disabled children.

In recent years, the psychometric approach has lost its popularity in its use with the learning disabled population. Experimental studies have generated many interesting theories to explain the relationship between reading and short-term memory, but the utilization of these theories depends on a short-term memory test that can validly and reliably differentiate between poor and good readers. An instrument that exhibits this psychometric property would be useful to school personnel who would gain a diagnostic tool that could provide additional information on the individual being tested. Most importantly, the wealth of information regarding reading and short-term memory that has emerged from experimental studies can help extend the traditional limited interpretation of short-term memory subtests such as those found in the newly revised Stanford Binet.

A third aspect that is worthy of investigation is the developmental relationship between reading and memory in good and poor readers. Psychometric tests may be of benefit in such investigation. Das et al
(1984) used an experimental approach to show that growth in reading was parallel to growth in other cognitive areas for normal and reading disabled children. What this study did not show was whether this correlational relationship changes with age. It is then worthwhile to examine whether age affects the magnitude of correlation between reading and memory and whether it is mitigated by the disability/ability factor.

This present study investigated the following:

1. the relationship between reading and memory as measured by three reading comprehension subtests and by the four memory subtests of the Stanford-Binet Intelligence Scale - Fourth Edition.

2. the differences in performance between good and poor readers on the four short-term memory subtests.

3. the relationship between age and short-term memory.

4. the effect of age on the magnitude of correlation between short-term memory and reading.
CHAPTER III

METHODOLOGY

PURPOSE

The purpose of the present study was to investigate the relationship between short-term memory and reading in two groups of children - one that had been designated by school authorities as Learning Disabled children and the other that had been designated as Average Learners. A complete description of the methodology is presented in this chapter. The design and the sampling procedures are described. Similarly, the tests are presented.

OPERATIONAL DEFINITIONS

**Average Learners**: Children who obtained a reading grade between 'C' and 'B' on their current report cards and a verbal score between 85 and 120 on the Canadian Cognitive Ability Test (C.C.A.T.)

**Learning Disabled**: Children who have been tested and labelled as Learning Disabled by the Langley School District school psychologists according to the criteria currently practiced by the district. Langley District adheres to the definition advanced by the Ministry of Education which states:
"Learning disabilities is a processing disorder involved in understanding or using symbols or spoken language. These disorders result in a significant discrepancy between estimated learning potential and actual performance. Generally, a discrepancy of two or more years on grade equivalent scores or a similar discrepancy on standardized score comparisons is recognized as significant. This discrepancy is related to basic problems in attention, perception, symbolization and the understanding or use of spoken or written language. These may be manifested in extreme difficulties in thinking, listening, talking, reading, writing, spelling or computing." (Section number/page 7.30 Policy 3.26.3)

HYPOTHESES

The newly revised Stanford-Binet Intelligence Scale: Fourth Edition (Thorndike et al 1986) which contains four short-term memory subtests presents an additional diagnostic instrument for the school psychologist to measure a student's performance on short-term memory. As three of the four memory subtests (Memory for Objects, Memory for Sentences and Bead Memory) are new to this particular test, information regarding their validity is not yet documented. In the present study, hypotheses have been generated to provide information on the relationship between reading and short-term memory in two groups of children: children with learning disabilities and children with average learning abilities.
The hypotheses in this study were divided as non-directional and directional hypotheses. The directional hypotheses were advanced when there was sufficient information from prevailing research in this topic area to indicate that a certain relationship between the variables being studied was expected to emerge. However, in cases where there was insufficient information, non-directional hypotheses were formulated.

**Non-directional Hypotheses**

**Hypothesis 1.0**

There will be significant correlational relationships between reading and short-term memory as measured by the three reading comprehension subtests and the four short-term memory subtests for the average learners.

**Hypothesis 1.1**

There will be significant correlational relationships between reading and short-term memory as measured by the three reading comprehension subtests and the four short-term memory subtests for the learning disabled children.

**Hypothesis 2.0**

There will be significant interaction effect of learning group and age on short-term memory.
Hypothesis 2.1

There will be significant interaction effect of learning group and age on reading comprehension.

Hypothesis 3

The magnitude of correlation between short-term memory and reading will be affected by age.

Directional Hypotheses

Hypothesis 4.0

Average learners will perform significantly better than learning disabled children on the four short-term memory subtests.

Hypothesis 4.1

Average learners will perform significantly better than learning disabled children on the three reading comprehension subtests.
THE DESIGN

There were two independent variables - age and learning groups. There were two groups of dependent variables: the reading comprehension subtests scores and the memory subtests scores. The design for this study is presented in Figure 1.

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*The three reading comprehension subtests: B.C. QUIET (British Columbia Quick Individual Educational Test), T.O.R.C. (Test of Reading Comprehension) and P.I.A.T. (Peabody Individual Achievement Test) are dependent variables. As well, the four short-term memory subtests: B.M. (Bead Memory), M.S. (Memory for Sentences), M.D. (Memory for Digits) and M.O. (Memory for Objects) are dependent variables in this study.*

Pearson correlation was used to establish the degree of relationship between short-term memory and reading in the two groups.
Two separate multivariate analyses of variance were used to test the significance of age and learning group and the interaction: one for the short-term memory variables and one for the reading scores.

THE SAMPLE

A total of 80 children, 39 average learners and 41 learning disabled children, were selected for the present study. The sample was selected from the five schools that have learning disabilities classes in the Langley School District. Students' test scores were provided by the Special Education Department and by the school principals of the five participating schools. Selection of both learning disabled and average learners was achieved through close co-operation with the participating Learning Disabilities and regular classroom teachers. The criteria for the selection of subjects were discussed with each teacher who then decided the individuals best qualified for the study. For each group of Learning Disabled children selected from the Learning Disabilities classes, an almost equal number of Average Learners matched on age and sex was also chosen from the same school.

The rationale for assembling both groups from the same school was to minimize the differences in the students' socio-economic backgrounds. Even though the socio-economic status was not a variable included in this study, it was felt that a more comparable socioeconomic background could minimize variations due to individuals which may confound the results.
The criteria for selection of learning disabled children were that the children must be between ages 8 and 13, with a current placement in a Learning Disabilities class, and have reading problems as one of the stated reasons for the original referral for psychological testing. A wide age span was used to ensure that the sample size for learning disabled learners was sufficiently large. Those who were placed in classes for learning disabled children were all between the ages of eight and thirteen. Another selection criterion was that the subjects must have an intelligence quotient between 85 and 115 as measured on the Wechsler Intelligence Scale for Children - Revised.

The criteria for selection of average learners included children between ages 8 and 13, with a placement in a regular class, a reading grade between 'C' and 'B' on their current report card, and C.C.A.T. full-scale scores between 85 and 120. All students scored between 85 and 115 but one. As it was difficult to find thirteen year olds in a regular class in an elementary school, this student was accepted in this study.

TESTS

Selection Criteria - Reading Comprehension Subtests

The main criteria used for the selection of reading measures were as follows:

1. It is a valid test of reading comprehension;

2. It is a power test, i.e. no time limit is imposed that
can influence the comprehension measure;

3. The scoring is objective;

4. It is a silent reading test so that poor word decoding skills or poor oral reading skills are not a confounding factor to comprehension;

5. Each is different in test format so that the interest of the students is maintained.

Description of Tests

Short-term memory was measured through the use of the Short-term Memory subtests (Bead Memory, Memory for Sentences, Memory for Digits and Memory for Objects) of the Stanford-Binet Intelligence Scale: Fourth Edition (SB:FE) (Thorndike et al, 1986) and reading comprehension was measured on the reading comprehension subtests of the B.C. QUIET Individual Educational Test (B.C. QUIET) (Wormell, 1983), Test of Reading Comprehension (T.O.R.C.) (Brown, Hammill & Wiederholt, 1978) and Peabody Individual Achievement Test (P.I.A.T.) (Dunn & Markwardt, 1970).


The Stanford-Binet is an individually administered test. It consists of four areas: Verbal Reasoning, Abstract/Visual Reasoning, Quantitative Reasoning and Short-Term Memory. For the purpose of this study, only the Short-Term Memory subtests were used. The Short-Term Memory subtests on the Stanford-Binet are Bead Memory, Memory for
Sentences, Memory for Digits and Memory for Objects. For all the subtests, the basal is no errors in two consecutive levels and the ceiling is 3 errors in two consecutive levels.

According to the Technical Manual of the Stanford-Binet (Thorndike et al, 1986), Short-Term Memory subtests such as Bead Memory, Memory for Sentences and Memory for Digits show strong reliability coefficients ranging from the lowest .80 to the highest .91 for the age range of 8 to 13 year olds in the study. Memory for Objects for the same age groups shows slightly lower reliability coefficients ranging from .66 to .75. The Kuder Richardson Formula 20 was used to calculate the coefficients. The standard error of measurement for these coefficients range from 2.4 on Memory for Sentences to 4.4 on Memory for Objects. The Test-Retest reliability coefficients on these subtests are all in the moderate range - from .61 to .72. Factor Analysis of these subtests by age group shows Bead Memory loads very weakly on memory (from .05 for ages 7 to 11 to .17 for ages 12 to 23). The remaining subtests load moderately on memory and they range from .29 (for ages 12 to 23) on Memory for Sentences to .50 (for ages 7 to 11) on Memory for Digits.

Short-term Memory Subtests in the Stanford-Binet Intelligence Scale: Fourth Edition

The Stanford-Binet Intelligence Scale: Fourth Edition uses a multistage testing format. In the first stage, a routing test, which is the Vocabulary test, is used to determine the entry level at which testing should begin on the remaining fourteen tests. The rules for
determining the ceiling and basal levels for this subtest is the same for all other subtests. The basal level is the level at which the examinee passed the first four items at two consecutive levels. The ceiling is when the examinee failed three out of our items at two consecutive levels.

**Bead Memory**

This is a visual-motor short-term memory task. The subject is asked to replicate the configuration of beads as depicted in the picture. The exposure time of the picture is 5 seconds. There are 4 different shaped beads of 3 different colours. The beads are round, ellipsoid, cone and saucer shaped and the colours are red, white and blue. The level of difficulty ranges from 2 beads of the same colour but different shapes, to 7 beads of different colours and shapes. The cone shaped bead can be put on the stick inverted with the apex facing the base or right side up; hence, there are two spatial orientations for this particular bead to which the subject must attend.

**Memory for Sentences**

This task requires the subject to repeat verbatim a series of sentences of different lengths and levels of difficulty. The examiner must read the sentences in a normal speaking manner and maintain a consistent speed throughout the subtest. There are a total of 42 sentences on this subtest and the level of difficulty ranges from a sentence that consists of 2 monosyllabic words to a sentence that consists of 22 words of varying number of syllables. The sentences near
the end are structurally more complex with dependent and independent clauses.

Memory for Digits

This subtest is further divided into two sub-components: Digits Forward and Digits Reversed. There are 14 items on the Digits Forward and the lists of digits are progressively longer with the more advanced items. The initial item has 3 digits and the last item has 9 digits. The subject must repeat the series of digits he/she hears in their exact order of presentation. The examiner must say the numbers at one second intervals.

On the Digits Reversed, there are 12 items in all. The subject must repeat the series of numbers he/she hears in their reversed order. The initial item has 2 digits and the last item has 7 digits. Again, the examiner is to say the numbers at one second intervals.

Memory for Objects

On this subtest, the subject is shown a series of pictures at one second intervals. There are 14 items in all and the lists of objects are progressively longer with the more advanced items. The examiner begins the showing of the series of pictures with a prompt word "look" and ends the series by a prompt phrase, "point to the # pictures just the way I showed them to you". Each picture is exposed to the subject at one second intervals. The subject must be able to identify the objects he/she saw amongst a number of non-relevant pictures or distractors and
be able point to the objects previously shown in their exact order of presentation.

The pictures used in this subtest are common objects with which most children are familiar. The objects can be categorized into the following groups: animals, appliances, utensils, clothings, parts of the body, furniture, plants, and musical instruments.

Reading Comprehension Tests

B.C. QUIck Individual Educational Test (B.C. QUIET) (Wormell, 1983)

B.C. QUIET was normed in six British Columbia geographic regions. The population targeted were children enrolled in elementary schools from grades one to seven. The test consists of four subtests: Spelling, Word Identification, Arithmetic and Passage Comprehension. For the purpose of this study only the Passage Comprehension was used. This subtest was constructed using words that appear in the Ginn 720 series, one of the prescribed readers use by most B.C. schools for reading. The internal consistency reliability coefficients for Word Identification are all in the 90s for all grades and the coefficients for Passage Comprehension range from .86 to .96 for all grades. According to the tables provided, the author of B.C. QUIET claims that the test is able to discriminate between remedial children (those who receive learning assistance for reading) and non-remedial children for grades 3 and 6 with at least 82 percent accuracy for grade 3 and 96 percent for grade 6. The data provides confidence that this test will also discriminate between learning disabled and average readers.
Passage Comprehension

The Passage Comprehension subtest begins with item difficulty at the grade two level and ends at the grade seven level. This particular subtest uses the cloze method to tap comprehension skills. Three item types were constructed for the blanks: transposition, transformation and supply. Transposition items contain exact answers in the stimulus material. Transformation items also contain answers in the stimulus material, but the answer must be changed before it is inserted into the blank space. Supply items do not contain answers in the stimulus material; subjects must devise responses to match the contextual cues contained in the item. (Wormell, 1983, p.6).

Each subtest is preceded by a set of administrative instructions. There is no time limit on the Reading Comprehension subtest. The basal of this test is 8 consecutive correct answers and the ceiling is 6 consecutive incorrect responses.

Peabody Individual Achievement Test (P.I.A.T.) (Dunn et al., 1970)

The Peabody Individual Achievement Test consists of 5 subtests: Spelling, Word Recognition, General Information, Reading Comprehension and Arithmetic. It is an individually administered test and it can be used with individuals from grades one to twelve. It is also suitable for the adult population. For the present study only the Reading Comprehension subtest was used. The Reading Comprehension subtest of the Peabody is different in format from that of the B.C. QUIET. The format almost parallels to a short-term memory task in that the subject
is required to read a sentence and then he/she is required to match what is read to the correct picture from a choice of 4 pictures on another page. The subject can not refer to the text again once the initial reading is done. It is a visual-verbal/motor task.

As cited in the P.I.A.T.'s manual (Dunn et al, 1970), the median test-retest reliabilities with retest intervals of one month, are .89 for Total Test, and .64 for Reading Comprehension. The median standard error of measurement for the Total Test is 12; for the five subtests, the median standard errors of measurement range from 3.06 to 6.51.

The concurrent validity of the P.I.A.T., using a variety of achievement and ability tests in a variety of populations, is excellent (Sattler, 1982). Thus, the evidence indicates that the P.I.A.T. measures general achievement areas. Studies of the WISC-R and the P.I.A.T. indicate that there is much overlap between the two tests and they share a general factor of verbal-educational development.

The Test of Reading Comprehension (T.O.R.C.) (Brown et al. 1978)

The Test of Reading Comprehension is a norm-referenced test standardized on an unselected sample of 2,520 children living in 10 different states. The intended population this test is designed for is between grades two and eight.

It consists of eight subtests but the main ones are General Vocabulary, Syntactic Similarities, Paragraph Reading, Mathematics, Social Studies and Science. For the purpose of this project, only
Paragraph Reading was administered to the subjects. This particular subtest is designed to measure the reader's ability to answer questions related to story-like paragraphs. There are six passages in this section and each has five questions. The format for each question is a multiple-choice item. The five questions for each passage follow the same "question-type" each time. The first question demands the reader to select the best title, i.e., the one that best conveys the overall theme, the second and fifth question requires factual recall of details from the story, the third question requires inferential reasoning and the fourth question requires a negative inference, i.e., the sentence that could not go with the story. The contents of the passages are chosen for their familiarity to most elementary age students. The author believes that success in reading is related to the children's knowledge background. If passages are heavily loaded with specific content material, this could lead to misinterpretation of the students' real ability. Hence, the passages are deliberately specific content free but with emphasis on the use of general knowledge to answer the questions.

Reliability of the TORC is reportedly high. Internal consistency reliability as measured by Kuder-Richardson 21 shows that eighty percent of the coefficients reach or exceed .80. Concurrent validity is established with other reading measures such as the California Achievement Test-Reading, Comprehensive Test of Basic Skills-Reading, SRA-Reading and Peabody Individual Achievement Test-Reading. The coefficients range from .33 to .81. Using intercorrelation of TORC
subtest with effects of age controlled, all coefficients are tested to be statistically significant at beyond the 1 percent level. In size, they range from .36 to .72, the Median being .48. The author believes that the coefficients of such magnitude are moderately large and indicate a substantial relationship. Hence, he concludes that the construct validity of the TORC is supported.

**Canadian Cognitive Abilities Test (C.C.A.T.) 1978**

The C.C.A.T. consists of three area scores: Verbal, Quantitative and Nonverbal. For this study, the C.C.A.T. was not administered but the scores of the Verbal Section were obtained from the students' files with the permission of the parents. The Verbal Battery has the four following subtests: Vocabulary, Sentence Completion, Verbal Classification and Verbal Analogies. There are 50 items for each subtest.

In the Vocabulary section, the subject is asked to pick the word that means most nearly the same as the word in the dark type. In the Sentence Completion section, the subject is asked to read the sentences carefully and then look at the five words that follow each sentence on the line below to pick the one word that best fits the empty space in the sentence. In the Verbal Classification section, the subject is asked to read a series of words and then choose one word from a choice of 5 below the series that belongs in the same category as the others. In the last subtest, Verbal Analogies, the test begins with a pair of words that are related to each other in some way. The subject is asked
to figure out how the first two words are related to each other and then right after the first two words, he/she is given a third word that is the first words of a second pair. From the five words in the line below the pair of words, the subject is to find a word that goes with the third word in the exercise in just the same way that the second word goes with the first.

The C.C.A.T. is the Canadian version of the Cognitive Abilities Test (C.A.T.) originally designed in Iowa, U.S.A. According to Buros (1985) the reliability coefficients of the C.A.T. as calculated by using KR-20 for both the primary battery and the multilevel edition are quite high, ranging from .89 to .96. When retesting with the same form after an interval of 6 months the obtained reliabilities ranged from .76 to .94. The construct validity was reported by determining correlations of the C.A.T. multilevel batteries with the Stanford-Binet for 550 individuals tested in the 1971-72 school year. The correlations were substantial (.65-.75).

Rationale for the Selection of the Test Instruments

Reading comprehension is often defined as a process by which a reader derives meaningful interpretation from printed symbols based on his/her background of experiences and, as such, is regarded as an ability to attach meanings to words, phrases, sentences and long passage selections (Hammill & Bartel, 1978). Authors of reading tests often attempt to incorporate this meaning in the construction of their tests.
This definition has influenced the selection of the reading comprehension tests in this study.

In the case of B.C. QUIET, the author created a subtest that samples the contents of one of the prescribed basal readers - Ginn 720 - currently used in the B.C. schools. Hence, the items are presumed to be within the realm of the student's knowledge. Further to the content validity of the B.C. QUIET, the cloze procedure used has been evaluated by Rankin and Culhane (1969) which showed that this method has substantial correlation with reading comprehension. In addition to these features, B.C. QUIET fulfilled the selection criteria previously mentioned.

Brown et al (1978), the authors of T.O.R.C. also presented a test that has contents that are familiar to the reader. In this case, the passages used are reported to be familiar to most elementary school children; hence, the ideas presented by the passages are within the reader's experiential background. The main thrust of the test is to tap the relational skills of the reader rather than the referential or recall skills. They believe that passages that are heavily loaded with specific content material can lead to misinterpretation of the student's real abilities. The authors also offered extensive evidence for both content and concurrent construct validity. The format used for this test is one with which the students are most familiar as they often encounter similar structure in many school administered group tests and reading exercises. In addition to these features, T.O.R.C. has most of the selection criteria.
The Reading Comprehension subtest in the P.I.A.T. purports to have content validity. The items were selected from the curriculum used in the United States. Hence, it may have questionable validity for the Canadian readers. The reason for the inclusion of this test, aside from the fulfillment of the other selection criteria with the possible exception of validity, is the built-in short-term memory component. The author is cognizant of this component and feels that this skill is an integral part of reading. Since this study is a comparison between short-term memory and reading, it was felt that the inclusion of this test might present interesting findings.

**Procedures**

All tests were administered and scored by the investigator, according to the procedures described in the test manuals. Each protocol was checked at a later time for error. However, the P.I.A.T. scores for all the learning disabled children were obtained from the these children's teachers. The children were given the P.I.A.T. in the Spring of that current school year as part of the district’s yearly progress review. Testing took place in the children's schools during a regular instructional day in the period between May 19 and June 23, 1987. Each administration required approximately one hour. All students were administered the memory subtests first, followed by B.C. QUIET, P.I.A.T. and T.O.R.C. There were approximately 5 cases which were not finished in one sitting and alternate days were arranged to complete the testing.
During the testing of short-term memory, observational notes were made of any visible strategies the children used to assist memory recall. Upon the completion of all the short-term memory sub-tests, all the children were asked to explain how they remembered all the information in each memory subtest.

DATA ANALYSIS

To find the degree of relationship between reading and short-term memory for each learning group, a Pearson Product-Moment Correlation was used. Intercorrelations among Bead Memory, Memory for Sentences, Memory for Digits and Memory for Pictures and B.C. QUIET, Peabody Individual Achievement Test and Test of Reading Comprehension were calculated. To determine if age was a significant factor in the correlation coefficient differences between the younger and older children in both learning groups, the correlation coefficients in each age group were converted to Z scores using Fisher r-to-Z' transformation formula (Hopkins & Glass, 1984, p.293) for the purpose of comparison.

Two separate Multivariate Analyses of Variance, learning group by age group (2x2), were performed to test for the significance of age and learning group and the interaction: one for the short-term memory variables and one for the reading scores.

Standard scores were used in all calculations except in the case of B.C. QUIET where no transformed scores were available; hence, this test was excluded in any analysis using standard scores. In the analyses
using B.C. QUIET, the raw scores of this test and all the short-term memory tests were used.
CHAPTER IV

RESULTS

This chapter presents the descriptive statistics and analyses of data of the study. The results of each hypothesis tested are also presented here. The hypotheses were tested at alpha equal to .05.

DESCRIPTIVE STATISTICS

Mean scores and standard deviations

The learning disabled and average learners selected for the present study were comparable in their mean ages (Tables 4.1). In the 8- to 10-year-old groups, the mean ages for the average learner and learning disabled groups were 9 years 6 months and 9 years 8 months respectively. In the 11- to 13-year old average learner and learning disabled groups, the mean ages were 12 years 6 months and 12 years 11 months respectively. The numbers of boys and girls in the average learner group were comparable to those in the learning disabled group for the two age categories (Table 4.2).

All subjects were tested to be in the average ability range (Tables 4.3, 4.4 and 4.5) but the mean ability scores of the learning disabled groups were lower than those of the average learner groups. The scores from the WISC-R were used as an index of cognitive ability for the learning disabled children and the scores from the Canadian Cognitive Abilities Test were used for that of the average learners.
Table 4.1
Age Means by Learning Groups

<table>
<thead>
<tr>
<th>Ages</th>
<th>Average Learners</th>
<th>Learning Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>8-10</td>
<td>114.05</td>
<td>7.40</td>
</tr>
<tr>
<td></td>
<td>(N = 19)</td>
<td></td>
</tr>
<tr>
<td>11-13</td>
<td>149.90</td>
<td>7.75</td>
</tr>
<tr>
<td></td>
<td>(N = 20)</td>
<td></td>
</tr>
</tbody>
</table>

Note: Ages are expressed in months

Table 4.2
Age and Sex by Learning Groups

<table>
<thead>
<tr>
<th>Ages</th>
<th>Sex</th>
<th>Number of Average Learners</th>
<th>Number of Learning Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td>8-10:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>13</td>
<td>14</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>6</td>
<td>4</td>
</tr>
<tr>
<td>11-13:</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>Boys</td>
<td>15</td>
<td>17</td>
</tr>
<tr>
<td></td>
<td>Girls</td>
<td>5</td>
<td>6</td>
</tr>
</tbody>
</table>
### Table 4.3

Short-term Memory and Reading Comprehension Test Means for 8- to 10-year old Average and Learning Disabled Learners

<table>
<thead>
<tr>
<th></th>
<th>Average Learners N = 19</th>
<th>Disabled Learners N = 18</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Bead Memory</td>
<td>50.16</td>
<td>8.06</td>
</tr>
<tr>
<td>Memory for Sentences</td>
<td>51.53</td>
<td>7.85</td>
</tr>
<tr>
<td>Memory for Digits</td>
<td>50.37</td>
<td>4.66</td>
</tr>
<tr>
<td>Memory for Objects</td>
<td>51.74</td>
<td>4.45</td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>13.63</td>
<td>1.38</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>108.47</td>
<td>10.13</td>
</tr>
<tr>
<td>C.C.A.T. (full score)</td>
<td>111.47</td>
<td>5.97</td>
</tr>
</tbody>
</table>

Note: All results are expressed in standard scores

### Table 4.4

Short-term Memory and Reading Comprehension Test Means for 11- to 13-year old Average and Learning Disabled Learners

<table>
<thead>
<tr>
<th></th>
<th>Average Learners N = 20</th>
<th>Disabled Learners N = 23</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>Bead Memory</td>
<td>47.85</td>
<td>7.88</td>
</tr>
<tr>
<td>Memory for Sentences</td>
<td>47.15</td>
<td>5.56</td>
</tr>
<tr>
<td>Memory for Digits</td>
<td>49.55</td>
<td>5.62</td>
</tr>
<tr>
<td>Memory for Objects</td>
<td>48.90</td>
<td>5.64</td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>12.25</td>
<td>1.67</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>104.40</td>
<td>9.03</td>
</tr>
<tr>
<td>C.C.A.T. (full score)</td>
<td>106.47</td>
<td>11.37</td>
</tr>
</tbody>
</table>

Note: All results are expressed in standard scores
Table 4.5
B.C. QUIET Test Results by Age and Learning Groups

<table>
<thead>
<tr>
<th>Ages</th>
<th>Average Learners</th>
<th>Learning Disabled</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mean</td>
<td>S.D.</td>
</tr>
<tr>
<td>8-10</td>
<td>20.16</td>
<td>4.82</td>
</tr>
<tr>
<td>11-13</td>
<td>29.50</td>
<td>5.50</td>
</tr>
</tbody>
</table>

Note: All results are expressed in raw scores
The learning disabled children were lower in ability and were also consistently lower than the average learners in all short-term memory and reading comprehension tests (Tables 4.3, 4.4 and 4.5).

TEST OF HYPOTHESES

Hypothesis 1.0

There will be significant correlational relationships between reading and short-term memory as measured by the three reading comprehension subtests and the four short-term memory subtests for the average learners.

Hypothesis 1.1

There will be significant correlational relationships between reading and short-term memory as measured by the three reading comprehension subtests and the four short-term memory subtests for the learning disabled children.

Table 4.6 presents the correlations between short-term memory and reading in the average learners (N = 39) which were found to be statistically significant for the following combinations of short-term memory and reading subtests:

a. Memory for Sentences and T.O.R.C.

b. Memory for Sentences and P.I.A.T.

c. Memory for Digits and P.I.A.T.

According to these results, Hypothesis 1.0 was supported.
Table 4.6
Pearson Correlation between Short-term Memory and Reading Subtests for the Average Learners

<table>
<thead>
<tr>
<th></th>
<th>Bead Memory</th>
<th>Memory for Sentences</th>
<th>Memory for Digits</th>
<th>Memory for Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.O.R.C.</td>
<td>.03</td>
<td>.33*</td>
<td>.06</td>
<td>.01</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>.19</td>
<td>.30*</td>
<td>.37*</td>
<td>.15</td>
</tr>
</tbody>
</table>

N = 39 ; *p < .05 (two-tailed)

Table 4.7
Pearson Correlation between Short-term Memory and Reading Subtests for the Learning Disabled Children

<table>
<thead>
<tr>
<th></th>
<th>Bead Memory</th>
<th>Memory for Sentences</th>
<th>Memory for Digits</th>
<th>Memory for Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>T.O.R.C.</td>
<td>-.06</td>
<td>.13</td>
<td>.02</td>
<td>-.10</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>.03</td>
<td>.12</td>
<td>-.07</td>
<td>-.10</td>
</tr>
</tbody>
</table>

N = 41 ; *p < .05 (two-tailed)
Table 4.8

Pearson Correlation between Short-term Memory and B.C. QUIET for the Average Learners and Learning Disabled Children

<table>
<thead>
<tr>
<th></th>
<th>Bead Memory</th>
<th>Memory for Sentences</th>
<th>Memory for Digits</th>
<th>Memory for Objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average Learners</td>
<td>.12</td>
<td>.32*</td>
<td>.37*</td>
<td>.25</td>
</tr>
<tr>
<td>Learning Disabled</td>
<td>.41*</td>
<td>.40*</td>
<td>.28</td>
<td>.35*</td>
</tr>
</tbody>
</table>

*P<.05 (two-tailed)
As for the learning disabled group, there was no significant correlation between short-term memory and reading as measured on the P.I.A.T and T.O.R.C. Based on the results presented in Table 4.7, Hypothesis 1.1 was not supported.

Since there were no standard scores available for the B.C. QUIET, raw scores of this reading test and all of the short-term memory tests were used for the calculation of correlation coefficients to determine if B.C. QUIET shared any relationship with any of the short-term memory tests. The results, shown in Table 4.8, indicated that there were significant relationships between B.C. QUIET and memory in the average learner group as well as in the learning disabled group. As raw scores were used instead of standard scores, the coefficients might be spuriously high because the age factor has not been taken into consideration. For example, a 12-year-old child will likely obtain a higher reading raw score than a 9-year-old. Hence, the coefficients must be interpreted with caution.

**Hypothesis 2.0**

There will be significant interaction effect of learning group and age on short-term memory.

**Hypothesis 2.1**

There will be significant interaction effect of learning group and age on reading comprehension.
**Hypothesis 4.0**

Average learners will perform significantly better than learning disabled children on the four short-term memory subtests.

**Hypothesis 4.1**

Average learners will perform significantly better than learning disabled children on the three reading comprehension subtests.

A (2x2) (learning groups x age) Multivariate Analysis of Variance was carried out on the results of the four short-term memory subtests to test Hypotheses 2.0 and 4.0.

A similar analysis was done to test Hypotheses 2.1 and 4.1 for the reading scores. The results relating to all these hypotheses are displayed in Tables 4.9 and 4.10.

The interaction effect (learning group x age) determines whether or not the rate of change over age in the performance of the two learning groups on short-term memory and reading is identical. As shown in Tables 4.9 and 4.10, there was no significant interaction effect of learning group and age on either short-term memory (p = .051) or reading (p = .31). No interaction effect was also observed for B.C. QUIET when raw scores were used (Table 4.11). Based on these results, it appeared that the rate of age-related change in the performance of the two groups on both measures was identical. Hypotheses 2.0 and 2.1 were not supported.
### Table 4.9

Multivariate Analysis of Variance Results on the Short-term Memory Scores

<table>
<thead>
<tr>
<th>Source</th>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>P</th>
<th>Hotellings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Group</td>
<td>Multivariate</td>
<td>4,73</td>
<td>12.95</td>
<td>&lt;.01</td>
<td>.71</td>
</tr>
<tr>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.M.</td>
<td>1,76</td>
<td></td>
<td>18.89</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>M.S.</td>
<td>1,76</td>
<td></td>
<td>23.41</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>M.D.</td>
<td>1,76</td>
<td></td>
<td>38.94</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>M.O.</td>
<td>1,76</td>
<td></td>
<td>10.19</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>Interaction:</td>
<td>Multivariate</td>
<td>4,73</td>
<td>2.49</td>
<td>=.051</td>
<td>.14</td>
</tr>
<tr>
<td>Learning Group</td>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.M.</td>
<td>1,76</td>
<td></td>
<td>1.19</td>
<td>=.28</td>
<td></td>
</tr>
<tr>
<td>M.S.</td>
<td>1,76</td>
<td></td>
<td>1.01</td>
<td>=.32</td>
<td></td>
</tr>
<tr>
<td>M.D.</td>
<td>1,76</td>
<td></td>
<td>1.02</td>
<td>=.32</td>
<td></td>
</tr>
<tr>
<td>M.O.</td>
<td>1,76</td>
<td></td>
<td>3.29</td>
<td>=.07</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05
Table 4.10
Multivariate Analysis of Variance Results on the Reading Scores

<table>
<thead>
<tr>
<th>Source</th>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>P</th>
<th>Hotellings</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Group</td>
<td>Multivariate</td>
<td>2,75</td>
<td>33.37</td>
<td>&lt;.01</td>
<td>.89</td>
</tr>
<tr>
<td></td>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T.O.R.C.</td>
<td>1,76</td>
<td>47.54</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P.I.A.T.</td>
<td>1,76</td>
<td>35.98</td>
<td>&lt;.01</td>
<td></td>
</tr>
<tr>
<td>Interaction: Learning Group by Age</td>
<td>Multivariate</td>
<td>2,75</td>
<td>1.19</td>
<td>=.31</td>
<td>.03</td>
</tr>
<tr>
<td></td>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>T.O.R.C.</td>
<td>1,76</td>
<td>2.31</td>
<td>=.13</td>
<td></td>
</tr>
<tr>
<td></td>
<td>P.I.A.T.</td>
<td>1,76</td>
<td>0.00</td>
<td>=.97</td>
<td></td>
</tr>
</tbody>
</table>

*p < .05

Table 4.11
Multivariate Analysis of Variance Results on B.C. QUIET

<table>
<thead>
<tr>
<th>Source</th>
<th>Test</th>
<th>df</th>
<th>F</th>
<th>P</th>
</tr>
</thead>
<tbody>
<tr>
<td>Learning Group</td>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.C. QUIET</td>
<td>1,76</td>
<td>123.99</td>
<td>&lt;.01</td>
</tr>
<tr>
<td>Interaction: Learning Group by Age</td>
<td>Univariate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>B.C. QUIET</td>
<td>1,76</td>
<td>.00</td>
<td>=.95</td>
</tr>
</tbody>
</table>

*p < .05
According to the results of the MANOVA, average learners scored better than learning disabled children on both short-term memory and reading. A significant difference ($F = 12.95$, $df = (4,73)$, Hotellings $= .71$, $p < .05$) was found for short-term memory and a significant difference ($F = 33.37$, $df = (2,75)$, Hotellings $= .89$, $p < .05$) was also found for T.O.R.C. and P.I.A.T. The two learning groups also showed a significant performance difference on the B.C. QUIET. Based on these results, Hypotheses 4.0 and 4.1 were accepted.

**Hypothesis 3**

The magnitude of correlation between short-term memory and reading will be affected by age.

The Pearson Product-Moment Correlation coefficients between short-term memory and reading for each age and learning group were converted to Z scores using Fisher r-to-Z' transformation formula for comparison. The Z test scores for both average and learning disabled groups are presented in Tables 4.12, 4.13, 4.14 and 4.15.

The results show that age did not affect the magnitude of any correlations between reading and short-term memory for both learning groups. Hypothesis 3 was not supported.
Table 4.12

Age Comparisons for Correlation between Short-term Memory Tests and Reading Comprehension Tests: Average Learners

<table>
<thead>
<tr>
<th></th>
<th>8- to 10-year-olds</th>
<th>11- to 13-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>r</td>
<td>Fisher's Z</td>
</tr>
<tr>
<td><strong>Bead Memory with:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C</td>
<td>.18</td>
<td>-.25</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>.23</td>
<td>.10</td>
</tr>
<tr>
<td><strong>Memory for Sentences with:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C</td>
<td>.39</td>
<td>-.01</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>.36</td>
<td>.09</td>
</tr>
<tr>
<td><strong>Memory for Digits with:</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C</td>
<td>-.02</td>
<td>.06</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>.38</td>
<td>.36</td>
</tr>
<tr>
<td><strong>Memory for Objects with</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C</td>
<td>-.02</td>
<td>-.22</td>
</tr>
</tbody>
</table>

*z-critical = 1.96
Table 4.13

Age Comparisons for Correlation between Short-term Memory Tests and Reading Comprehension Tests: Learning Disabled Learners

<table>
<thead>
<tr>
<th></th>
<th>8- to 10-year-olds</th>
<th>11- to 13-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 18</td>
<td>N = 23</td>
</tr>
<tr>
<td><strong>r</strong></td>
<td><strong>Fisher's Z</strong></td>
<td><strong>r</strong></td>
</tr>
<tr>
<td>Bead Memory with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>.05</td>
<td>-.19</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>-.37</td>
<td>.20</td>
</tr>
<tr>
<td>Memory for Sentences with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>.16</td>
<td>.11</td>
</tr>
<tr>
<td>Memory for Digits with:</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>.00</td>
<td>.01</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>-.12</td>
<td>-.12</td>
</tr>
<tr>
<td>Memory for Objects with</td>
<td></td>
<td></td>
</tr>
<tr>
<td>T.O.R.C.</td>
<td>-.19</td>
<td>.02</td>
</tr>
<tr>
<td>P.I.A.T.</td>
<td>-.21</td>
<td>-.04</td>
</tr>
</tbody>
</table>

*z-critical = 1.96
Table 4.14
Age Comparisons for Correlation between Short-term Memory and B.C. QUIET:Average Learners

<table>
<thead>
<tr>
<th>Age Group</th>
<th>8- to 10-year-olds</th>
<th>11- to 13-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 19</td>
<td>N = 20</td>
</tr>
<tr>
<td>r</td>
<td>Fisher's Z</td>
<td>r</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Bead Memory</td>
<td>.18</td>
<td>-.45</td>
</tr>
<tr>
<td>Memory for Sentences</td>
<td>.52</td>
<td>.09</td>
</tr>
<tr>
<td>Memory for Digits</td>
<td>.40</td>
<td>-.09</td>
</tr>
<tr>
<td>Memory for Objects</td>
<td>.10</td>
<td>.19</td>
</tr>
</tbody>
</table>

*z-critical = 1.96

Table 4.15
Age Comparisons for Correlation between Short-term Memory and B.C. QUIET:Learning Disabled Children

<table>
<thead>
<tr>
<th>Age Group</th>
<th>8- to 10-year-olds</th>
<th>11- to 13-year-olds</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>N = 18</td>
<td>N = 23</td>
</tr>
<tr>
<td>r</td>
<td>Fisher's Z</td>
<td>r</td>
</tr>
<tr>
<td>---------------------</td>
<td>--------------------</td>
<td>---------------------</td>
</tr>
<tr>
<td>Bead Memory</td>
<td>.05</td>
<td>.13</td>
</tr>
<tr>
<td>Memory for Sentences</td>
<td>.11</td>
<td>.31</td>
</tr>
<tr>
<td>Memory for Digits</td>
<td>.31</td>
<td>.11</td>
</tr>
<tr>
<td>Memory for Objects</td>
<td>-.21</td>
<td>.11</td>
</tr>
</tbody>
</table>

*z-critical = 1.96
INTRODUCTION

The present study was designed to investigate the relationship between short-term memory and reading and to determine whether that relationship changes with age.

Short-term memory was measured by the four short-term memory subtests (Bead Memory, Memory for Sentences, Memory for Digits and Memory for Objects) in the SB:FE. Reading was measured by the three reading comprehension subtests from B.C. QUIET, P.I.A.T. and T.O.R.C. These two sets of testing instruments were administered to 80 elementary school children in the age range of 8 to 13. Of the total population, 39 children were of average learning ability and 41 were diagnosed by the school district as learning disabled children. The data collected were subjected to Pearson Product-Moment Correlation and a (2 x 2) (learning group x age) Multivariate Analysis of Variance.

As the technical manual of the B.C. QUIET only provides raw scores, the students' scores on this test were not included with the other two reading tests in any of the statistical analyses; rather, the raw scores of B.C. QUIET were analysed and discussed separately.
DISCUSSION AND CONCLUSIONS

The following conclusions have been drawn from the analyses of the data collected, and have been organized according to the hypotheses for the present study.

Hypotheses 1.0 and 1.1

Significant relationships were found between reading and short-term memory only in the average learners. In this group no single reading test correlated significantly with all short-term memory tests but Memory for Sentences correlated significantly with both reading tests for the average learning group. Of the tests that showed significant correlations, Memory for Digits indicated the strongest correlation with P.I.A.T (r=.37), followed by Memory for Sentences with T.O.R.C. (r=.33), then Memory for Sentences with P.I.A.T. (r=.30).

The correlation coefficients achieved in this study were comparable with those obtained in Das et al (1984) study. In Das et al's study, significant correlation coefficients between The Schonell Graded Word Reading Test and four of the short-term memory tests: Digit Span, Memory for Design, nonconfusable and confusable letter spans were .578, .494 .356 and .411 respectively. Similar to Das et al's study, this study also obtained the highest coefficient between a digit span test and a reading measure. Although Das and his colleagues used two reading groups, only the scores of the normal readers were used in the
calculation. No reasons were provided for the exclusion of the learning disabled subjects.

In the learning disabled group, no significant relationships were found between short-term memory and reading. The difference in the results of the two groups in this study might be due to the different cognitive processes used by the two populations. Daneman and Carpenter (1980) stated that correlations between reading and memory are influenced by task demands: a task with heavier processing demands discriminates ability better because of its requirement of different cognitive processes. Research has repeatedly shown that reading or learning disabled children differ from their non-disabled counterparts in their memory encoding, storage and retrieval processes.

The difference in the results might also be a reflection of the two groups' cognitive styles. Researchers have observed that learning or reading disabled children are neither flexible nor active users of strategies (Wong, 1978; Torgesen & Kail, 1980). Non-disabled learners often transfer skills from one learning situation to another. But it appears that disabled learners treat each learning situation independently, failing to see any relationship between situations. Perhaps the label 'production deficiency' is an apt one to apply to this group. Flavell and his colleagues (1966) explained that an individual who demonstrated production deficiency was an individual who failed to produce the relevant strategies when he/she knew them. Wong (1978) found that reading disabled children performed as well as non-disabled children on short-term memory tasks where directive cues were provided.
If learning disabled children in this study approached the short-term memory and reading tasks with distinctly different and independent skills, this might explain the lack of relationship between the two tasks.

The finding that there is no correlation between short-term memory and reading as measured by the two sets of measures in the learning disabled group is interesting as studies have consistently shown that children with reading problems also have short-term memory problems. However, this theory is not supported by the use of these commonly used tests. One possible explanation may be due to the difference in the research approach and the nature of the memory tests used.

Discussion of the results of B.C. QUIET

Raw scores of the B.C. QUIET and the four short-term memory tests were used to calculate the relationship between reading and short-term memory as measured by these diagnostic tools. Results showed that B.C. QUIET correlated significantly with Memory for Sentences and with Memory for Digits for the average learners and it also correlated significantly with Memory for Sentences, with Bead Memory and with Memory for Objects for the learning disabled children. As raw scores were used instead of standard scores and the age factor has not been taken into consideration, this result should be viewed cautiously. However, it would be interesting to note whether or not this result would remain the same if standard scores were available for the analysis.
Hypotheses 2.0 and 2.1

No interaction effect of age and learning group was found for short-term memory and reading. The present findings are consistent with the current hypothesis that learning disabled children demonstrate a developmental lag in reading and memory relative to the non-disabled children (Lerner, 1976). Since there was no interaction effect, it also appeared that the developmental rate between ages 8-10 and 11-13 was similar between the two learning groups. The results of this study support those found in Das et al (1984) study. They found that by matching children who were two years different in age on one cognitive task (i.e. reading), they were also matched on another cognitive task (i.e. short-term memory). Similar results were also obtained in a study by Cohen, Netley and Clarke (1984). They matched 8-year-old reading competent children with 10-year-old reading disabled children on reading and found insignificant performance difference between the two groups on serial short-term memory tests.

The samples in the above two studies were children approximately between ages 7 and 12, similar to the ages used in the present study. As the samples are truncated, excluding children who are younger than 7 years and older than 12 years of age; it is inconclusive, based on these data, to make a general statement that learning or reading disabled children show a two-year developmental delay in cognitive tasks such as reading and short-term memory relative to their average counterparts.
Discussion of the results of B.C. QUIET

No interaction effect of age and learning group was found for short-term memory and B.C. QUIET. The reasons that were mentioned in the above sections for the other two reading tests would also apply to this particular reading test.

Hypothesis 3

In both the average learner and learning disabled groups, the magnitude of correlation between short-term memory and reading did not vary significantly with age. One reason for the lack of change might be that the skills and strategies the children used that were common to both short-term memory and reading were not substantially different between the two age groups to affect the correlations between these two tasks. Perhaps, the older children's better performance in both reading and memory was a reflection of the greater proficiency these children demonstrated in the use of these skills and strategies, rather than a change from these common strategies. Also, age related changes in the performance of any given task are most evident in tasks that call for the use of those skills that can be systematically applied. According to Ornstein and Naus (1985), in situations where one cannot systematically apply the strategies, only minimal age changes are found.

It has been observed that in the average learner group, only the correlations between T.O.R.C. and Bead Memory changed in direction and were not approaching zero. The correlation between T.O.R.C. and Bead
Memory for the younger children was positive but for the older children, it was negative. The directional change indicates that relative to the younger children, the older children improved their scores on one test (eg. T.O.R.C.) but decreased their scores on the other test (eg. Bead Memory).

In the learning disabled group, only P.I.A.T. and Bead Memory showed coefficients that changed directions and were not approaching zero. The directional change was from a negative correlation for the younger children to a positive correlation for the older children. The explanation for this change would be that the older children improved their scores in both reading and short-term memory.

Discussion of the results of B.C. QUIET

The correlation between short-term memory and B.C. QUIET did not vary significantly with age for both learning disabled and average groups. However, of the correlations that were not approaching zero in the average learner group, the correlations between B.C. QUIET and Bead Memory showed a change in strength and direction. The younger children showed a positive correlation; however, the older ones obtained a negative but stronger correlation. This shift in strength appeared to be unusually large.

For the learning disabled children, there was also one directional change in the correlations between B.C. QUIET and Memory for Objects. The correlations changed from a negative relationship for the younger children to a positive one for the older children.
The overall results obtained in this section appeared to be unusual as evident in the correlation between Bead Memory and B.C. QUIET in the average learner groups. The unusual nature of the findings may be due to the use of raw scores in the analysis since raw scores do not take the age factor into consideration.

Hypotheses 4.0 and 4.1

Average learners performed significantly better than learning disabled children in both reading and short-term memory tests. The poorer performance of the learning disabled group in this study is consistent with the present theories on the characteristics of this particular group of children. Of the two reading comprehension tests used, T.O.R.C. was the better discriminator ($F(1,76) = 47.54$) and of the four short-term memory tests, Memory for Digits ($F(1,76) = 38.94$) was the best differentiator.

The fact that Memory for Digits is the best discriminator amongst the four memory tests is in accordance with many of the results generated from experimental and psychometric studies which showed that children with reading and learning problem are more likely to do poorly on this task. Kass (1966) and Badian (1977) found that reading disabled subjects scored poorly in the Auditory Sequential Memory test in the Illinois Test of Psycholinguistic Abilities. Badian also believed that the Auditory Sequential Memory test was the best differentiator of the two reading ability groups. Huelseman (1970) and Rugel (1974) concluded from their extensive review of studies of reading
disabled children's performance profile on the WISC that reading
disabled children consistently scored significantly lower on the digit
span test relative to their non-reading disabled counterparts. Done and
Miles (1978) found that non-dyslexic children did better than the
dyslexic children on digit span, a readily codable stimulus.

Discussion of the results of B.C. QUIET

Average learners did significantly better than learning disabled
children on B.C. QUIET as indicated in the MANOVA results when raw
scores of this test were used for the calculation.

LIMITATIONS

Although the population of children with learning disabilities
selected have average intelligence, the overall intelligence quotients
of the learning disabled children are lower than those of the "average"
learners. As intelligence is related to the level of performance on
different cognitive tasks, it is important that the subjects be closely
matched in cognitive ability. As observed by Torgesen (1985), this
appears to be a common methodological problem in research with learning
disabled children. However, matching average children to learning
disabled children on measured IQ was difficult. Homogeneity in age is
also important; it was difficult to match 13-year-old learning disabled
children with 13-year-old average learners as the oldest elementary
students are predominately 12-year-olds. The lack of homogeneity in
cognitive ability and age is considered a limitation to this study.
The second limitation is that of collapsing six ages (8-, 9-, 10-, 11-, 12- and 13-year-olds) into two distinct groups (8- to 10-year olds and 11- to 13-year olds). Since age had been isolated as one of the variables for differences in short-term memory performance in memory studies, it was important to verify this finding with the newly revised Stanford-Binet Scale. As it was difficult to obtain an acceptable sample size for each age category, collapsing of six age categories into two age groups was the only alternative. Consequently, the performance of the younger children in the upper age range may show similarity to that of the older children in the lower age range and this could obscure the distinctive performance difference between the two age categories.

The third limitation in this study is the absence of standard scores for the B.C. QUIET. The B.C. QUIET's test manual presents a table for the distribution of means by grade. Consequently, transformation of raw scores to standard scores was not possible. If standard scores of the B.C. QUIET were also included in the statistical analyses, the results might be different. The absence of the B.C. QUIET standard scores is also considered as a limitation to this study.

OBSERVATIONAL DATA

Observations made during testing verified the findings of previous studies that children with average learning or reading ability exhibit more elaborate short-term memory skills. Age was also shown as a determining factor of the level of sophistication of strategies: older
children appeared to have a larger repertoire of skills than the younger ones.

Observational notes were made during the testing to record whether strategies such as subvocalization or other visible methods to aid recall were used. After the performance of all the short-term memory tasks, children were asked if they had used any strategies to help them with the recall. Review of the notes and answers from the subjects showed that children with no learning disabilities were more articulate in their explanation of their use of strategies. Almost all of the average readers employed some kind of strategies. The range of strategies included the use of fingers to keep track of the stimuli, continuous repetition of the stimuli, the use of objects in the room to associate with the stimuli on the test, grouping of words or numbers, the use of mental imagery, and the echoing of the rhythm of the words or numbers uttered. One strategy commonly used by the majority of the non-disabled subjects was continuous repetitions of the stimuli. The older non-disabled children were more articulate than the younger ones and were more methodical in their explanations.

Many of the children with learning disabilities used some kind of memory strategies, but some reported that they used none. The number of learning disabled children who claimed to have used no strategies varied with the type of short-term memory tests.

Despite the difference in group and age, there were many similarities amongst the strategies used by the subjects. The types and
frequencies of the two learning groups' responses are presented in the Appendix A.

IMPLICATIONS FOR EDUCATIONAL PRACTICE

The ideal function of tests is to provide additional information leading to a better understanding of an individual's academic performance and to the resultant decision making process. Sometimes additional testing data, together with other information, is required to confirm or dispute a tentative classification and to make recommendation for educational intervention. The tests used in this study are diagnostic tools that school psychologists frequently use for educational placement and educational intervention. The more information these individuals have on the testing instruments, the better equipped they will be in interpreting the data and using it appropriately.

This study has shown that there are some significant relationships between short-term memory and reading in the average learner group; however, there is no significant relationship between these two variables in the learning disabled group. In view of this finding, the poor performance of the learning disabled children in both reading and memory should not be used as an absolute indicator of learning disabilities. However, the administration of the short-term memory tests permits the diagnosticians to observe the performance behaviour of the subjects which can present some important information to assist in
the interpretation of these tasks. Sometimes, the additional information can help toward the planning of an educational intervention. Anecdotal records on subjects' behavior on the short-term memory tasks can reveal information that may be useful toward the planning of a reading program:

1. the learning style of the individuals: whether they rely on visual concrete object to make association with the abstract stimuli on the tests, whether they rely on verbal repetitions to maintain the same information; or if they impose meanings to retain information;

2. the speed of processing information: is the rate of visual and auditory presentations (usually one second per stimulus) too fast for the subjects? If subjects were struggling with cognitive processing of information under this time constraint, reading instructions might need to be given at a slower pace, to include shorter phrases, more paraphrasing of the same message or presentation of the information via other means;

3. the modality through which children process their input with the greatest ease;

4. the sequential ability of the child, as all short-term memory tasks demand sequential recall.

Use of short-term memory tests, if they help shed information on specific performance deficits of a disabled reader and the process that may be implicated in the disability, will be critical for the development of appropriate and relevant remedial material in reading.
Data and observation from this study have not isolated the specific deficits that are responsible for the poor performance in both reading and short-term memory tasks in the learning disabled children. It is still speculative that any single test can purport to isolate specific performance deficits in such heterogeneous groups as learning and reading disabled children, and the results here only provide some insight into how the data from these instruments can be useful in interpretation.

Based on the results of the MANOVA, both T.O.R.C. and P.I.A.T. significantly discriminated the two learning groups. However, MANOVA also shows that B.C. QUIET supports the author's claim that it can discriminate between reading ability groups although it does not have a table for conversion of raw scores to standard scores. Either T.O.R.C. or B.C. QUIET could be used in addition to P.I.A.T. which is currently used as part of a test battery for learning disabled children in Langley.

IMPLICATIONS FOR FURTHER RESEARCH

Taking into account of the limitations mentioned in this chapter, the present study could be replicated with the following changes. Discrete ages differing by two years should be used for both average and learning disabled learners. The sample size of each age group should be increased. With modification in these areas, a developmental pattern may emerge and a more accurate relationship between short-term memory
and reading in both groups may result. In addition, the magnitude of change in correlation between short-term memory and reading might also be different.

In addition to all the modifications aforementioned, the study could be replicated when there is available a conversion table in the B.C. QUIET for the transforming of raw scores to standard scores. As this test proved to be a good discriminator of learning groups and a correlate of short-term memory when raw scores were used, it would be interesting to test if the same performance could be obtained if standard scores were used instead.

In replicating this study, other commonly used reading comprehension tests, such as Gates MacGinitie Reading Tests, Woodcock Reading Mastery Tests and Stanford Diagnostic Reading Test should be used to correlate with the four short-term memory tests in SB:FE for comparative purposes and to provide more information on the relationship between short-term memory and reading. In addition to this modification, it would be worthwhile to match children of different reading ability on their reading performance within and between learning groups, similar to the procedure used by Das et al (1984) and Cohen et al (1986) to determine if the discrepancy between reading and memory is eliminated, therefore confirming the belief that reading and short-term memory share similar cognitive processes.

As mentioned in Chapter 2, research relating short-term memory and reading is plagued with subject selection problems. Learning and
reading disabled children have been defined differently in different studies; therefore, a comparison between studies is rendered difficult. For future research in the experimental realm, researchers should observe more closely the selection criteria for average and disabled learners.
REFERENCES


APPENDIX A

ANECDOTAL RECORD OF CHILDREN'S MEMORY STRATEGIES
Upon completion of all the short-term memory tests, the students were asked how they remembered all the pictures, words, numbers and beads that were shown to them earlier. No formal questionnaire was used to obtain this information. All query was done at the completion of all tests, rather than at the end of each subtest, to ensure that the subjects' short-term memory performance was not inadvertantly influenced in any way.

In recording the students' responses, only key phrases were noted. The following presents a variety of responses given by the students for each of the short-term memory tasks.

**BEAD MEMORY - LEARNING DISABLED CHILDREN (AGES 8 - 10)**

Only five individuals in this category claimed that they had no strategies. It was uncertain if they really had no strategies or that they could not articulate or remember them. Those individuals who claimed to have used some strategies cited the use of either one of these three strategies: rehearsal, naming and imagery or a combination of these strategies. Some students also stated that the association of some bead configurations with familiar objects assisted them in the recall of the stimuli. Short-term memory strategies expressed by this group included the following examples.

1. Say the color and only try to remember the shape.

2. Say the colors and shapes over and over again while looking at the picture.
3. Remember the picture. Say the names: long, circle and triangle.

4. Use finger up for triangle, finger down for upside down triangle. Keep colors in head by repeating, circle, white, blue, etc.

5. Look at them carefully and put them in the mind.

6. Picture the beads looking like a man, a soldier. Just say the colors over and over again. Say in the brain.

**BEAD MEMORY - LEARNING DISABLED CHILDREN (AGES 11-13)**

Only four individuals in this group claimed to have used no strategies. Some of the strategies that were applied by the older children shared some similarities to those articulated by the younger subjects. Some strategies included the following examples.

7. Repeat shapes and colors in mind.

8. Remember the colors first and then the shapes.

9. Try to match them with familiar pictures then just say the colors in head but don't say the the names of the shapes.

10. Just try to look at them and picture them in the head.

11. Look at them. Say their size, color and shape.

12. Form a picture in the mind that the beads made.
13. Keep saying the colors, shapes in mind, but if they are too long it is easy to forget. There isn’t enough time to keep all the pictures of beads in the head.

BEAD MEMORY - AVERAGE LEARNERS (AGES 8-10)

Many of the students in this group were able to express how they remembered the configurations. Only two claimed that they had used no strategies. One student used grouping as a strategy; but unlike the younger and older learning disabled children, none used concrete objects to associate with the more abstract configurations. However, naming, rehearsal and imagery were the most common strategies expressed by this group. Some strategies used by this group included the following examples.

14. Try to remember the beads group by group. Say the names of colors, shapes in order in head. Put pictures in the head.

15. Remember in the head, the shape and color; look at the pictures real hard.

16. Say them over and over again like arrow up and long thing and arrow pointing down. If more than one color, say colors first before shapes.

17. Pick all the right beads first then try to remember the shape that looks like the picture.

BEAD MEMORY - AVERAGE LEARNERS (AGES 11-13)
Everyone in this group claimed to have used some strategies. Their strategies were not very different from those used by the students in the other groups; however, more students in this group were attentive to the details of the pictures and were able to explain how they applied the strategies more concisely. Some examples mentioned by this group include the following strategies.

18. Say colors, shapes in order in head. Think of them in terms of real objects.

19. Try to see a pattern. Look at the triangles, up or down and say all the things in the head.

20. Name the shapes, like skinny round object or triangle, and try to remember the colors. Group similar shapes, then different ones.

MEMORY FOR SENTENCES - LEARNING DISABLED CHILDREN (AGES 8-10)

About half of the students in the group reported that they had no strategies. They claimed that they just regurgitated the sentences once they had been given by the examiner. The remaining students stated they repeated the words in their head as the words were being presented. The following are some examples of strategies given by the students.

1. Listen carefully and then say it.

2. Repeat all sentences after you.

3. Just from listening carefully. Going over the words while you are reading them and then I will say them.
4. While you are saying them, I just say them in my head.

MEMORY FOR SENTENCES - LEARNING DISABLED (AGES 11-13)

The responses from this group were quite similar to those of the younger learning disabled children. Many expressed that they used no strategies but simply listened to the sentences carefully and then reproduced them immediately. But for those students who did use some form of strategies, rehearsal and visual imagery of words were the two main ones. The following are some examples of strategies mentioned by the students in this group.

1. Repeat sentences once in head before saying them.

2. Read sentences in head at the same time that they were read out loud.

3. Try to think of the sentences in pictures.

4. Getting stuck on the first words and then forgetting the rest. The sentences understood are the ones remembered.

5. Listened. Tell you what I heard. Say the words in mind one time and try to say the whole sentence.

MEMORY FOR SENTENCES - AVERAGE LEARNERS (AGES 8-10)

The common response given by many of the students in this group was that they didn’t have any specific method. They merely listened carefully to the sentences and then repeated them; however, some
students claimed to have tried to rehearse the words in their heads prior to repeating them aloud. The following are some examples of responses from the children in this group.

6. Let sentence go through once and then say it.

7. Just remember the sentence over again before saying it out loud.

8. Listen and then repeat in the head one time or twice.

9. Think of words that are close to them.

10. Try to remember what I hear. Don't have time to practice them.

MEMORY FOR SENTENCES - AVERAGE LEARNERS (AGES 11-13)

It appears that the subtest Memory for Sentences is restricted in the number and type of strategies that can be systematically applied. The older average learners did not have strategies that were very different from the other three groups. The only difference appears that this group was able to present their information in more detail. However, some students included grouping as one strategy that was not mentioned by the other three groups of students. The following are some examples of strategies reported by the students in this group.

11. Study the sentence word by word and then repeat it. Say the words in mind.

12. Repeat words in mind once or twice. Sometimes say them in parts if it is a long sentence.
13. Try to think back on what you said and how you said it. Repeat in head and then say it out loud.

14. Remember some of the parts and the rest just flows. Sometimes repeat it in head for the especially long ones.

15. Try to remember the words in order and then say them in the head.

MEMORY FOR DIGITS - LEARNING DISABLED CHILDREN (AGES 8-10)

Three of the students in this group expressed that they did not know how they remembered the information aside from listening and trying to remember the digits. The remaining students claimed that they say the numbers in their head as they were presented. Only one tried to visualize the numbers prior to repeating them aloud. None made a differentiation in the way they remembered digits forward and digits backward. The following are some examples of strategies mentioned.

1. Just remember them and say them in my head.

2. By my imagination. My mind starts to wind up. I say them to myself then I say them out loud.

3. Say every number after you and after you have said it then say them back. Practice them while you are reading.

4. Say the numbers to myself and then give them back.
5. Repeat the numbers as you say them, just remember the last part and then try to remember the first part.

6. Practice the numbers in the head.

MEMORY FOR DIGITS - LEARNING DISABLED CHILDREN (AGES 11-13)

The strategies used by the older learning disabled children appeared to be more sophisticated. All were able to explain their methods of recalling the numbers. Similar to the younger learning disabled students, one of the common responses was that they tried to listen very carefully and then repeat the numbers aloud. However, a variety of methods such as using fingers to keep track of the number of digits, using visual imagery, and grouping were also echoed. Many of these older children made a differentiation in the strategies used between digits forward and backward. It seemed that visualization of numbers was a common strategy used in trying to recall the numbers backward. The following are some examples of the strategies given by this group.

7. Easy ones put on fingers and harder ones put in head.

8. Remember the tone of the voice. Repeat them forward in head and say them forward.

9. Say in head two times. Difficulty when repeating the numbers backward.

10. Repeat each digit after my eyes are closed. Just look at the
numbers backwards.

11. Group numbers together. Don't need to practice each number as it is given. Wait until all are given, then say them in head.

12. Say them forward and then repeat them backward in head.

13. Use the fingers to help remember how many numbers are there in all.

14. Try to see the numbers in the mind and then picture them forward and then say them backward.

MEMORY FOR DIGITS - AVERAGE LEARNERS (AGES 8-10)

The younger average learners appeared to have used rehearsal as the main strategy, either as single repetitions or cumulative repetitions, in this task. Different from the younger learning disabled children, some children in this group also used grouping as well as visual imagery. But similar to their counterparts, perhaps with the exception of one, most did not make any differentiation in the strategies used between digit forward and backward.

15. Group two numbers at a time.

16. Say them as you say them. Say them backward and then out loud.

17. Try to memorize them and say them in head several times and then say them out loud. Try to memorize them and once memorized, I say them backward.
18. Keep on saying front words and then keep going.

19. Say them with the examiner. There is a word on the street and I was walking backward saying the numbers and seeing the numbers in my mind.

20. Take the first numbers and the last numbers and put them together.

MEMORY FOR DIGITS - AVERAGE LEARNERS (AGES 11-13)

Everyone in this group was able to express some strategies. The strategies used by these subjects were more sophisticated than those used by the younger average learners and the older learning disabled children. Rehearsal was either used singularly or in combination with imagery or/and grouping. Some also recognized that certain part, such as the middle, was the hardest to memorize. The following are some examples of strategies used by this group.

21. Try to remember a telephone number, example, two at a time. Have image in mind and try to read it backwards. Repeat forward and then backward.

22. Try to see the numbers in head. Listen to the first part. Once finished hearing, then go to the last number and read that. Keep repeating the numbers.

23. Repeat the way the examiner says it. The sound of it and write the numbers in the mind and then say them either backward or forward.
24. Count the number of numbers and then say the numbers in head. Remember the last number and go backward. Only the middle is rehearsed as it is easy to remember the first and the last.

25. The last few is easy to remember. Just try to remember the first part.

26. Try to visualize the numbers in the head.

MEMORY FOR OBJECTS - LEARNING DISABLED CHILDREN (AGES 8-10)

Only one individual could not remember or articulate the method used in assisting recall of pictures. Naming and rehearsal were the two common strategies employed by this group. The following are some examples of the strategies reported.

1. Name the pictures

2. Look at them and memorize them


4. See it. Say it. Use the fingers to keep track how many there are.

5. Look at the pictures. Say them a few times. Chain all the pictures together.

MEMORY FOR OBJECTS - LEARNING DISABLED CHILDREN (AGES 11-13)
Similar to the younger children, naming and rehearsing were also the main strategies used by this group of children. Grouping and cumulative rehearsal were also evident. A few also used fingers to help them keep track of the order of the pictures. The following are some examples of strategies used.

6. If there are too many, it is hard to remember all of the pictures. Say the names but when I see the next one, I forget the last.

7. Say the pictures in head as they are shown.

8. Say them in mind once.

9. Say the names and combine it with the last ones.

10. Say the first, then first and second, then first, second and third.

MEMORY FOR OBJECTS - AVERAGE LEARNERS (AGES 8-10)

The strategies reported by this group were similar to those of the younger learning disabled children; mainly, rehearsal and naming were the two main methods. However, cumulative rehearsal, a strategy absent in the younger learning disabled children, was used by some of the younger average learners. The following are some examples of strategies listed.

11. Say each name once.

12. Count the pictures and say the names. Say each one once.
13. Watch carefully and remember the order.

14. Say the pictures in mind. Try to remember which picture came first.

15. Keep saying them. Say the first, then first and second, then first, second and third.

MEMORY FOR OBJECTS - AVERAGE LEARNERS (AGES 11-13)

Perhaps it was due to the restrictive nature of this particular task, the students' responses to the type of methods used to assist recall did not vary very much between age and ability groups. Again, naming and rehearsal were reported as the key strategies. The following are some examples of the strategies used.

16. Try to memorize in head in order.

17. Say them in head and try to remember after that.

18. Name the pictures and then remember their order.

19. Say them as they are presented. Once for each picture. Say the first with the second, then the first, second and third,...etc.

20. Name the object and when see the picture again, trigger the memory.

21. Say and print in mind when there are few objects. When there are more, can't say as many.