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THE RELATIONSHIP BETWEEN MEMORY SPAN AND READING ACHIEVEMENT

by

INDIRA GAJRAJ

A THESIS

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ABSTRACT

The issue of whether or not differences in working memory capacity can account for differences in reading achievement was investigated in the present study. Specifically, the role played by item identification and item order in performance on Memory Span and reading achievement was compared in groups of normal and disabled Grade 4 readers.

Two experiments were carried out. In Experiment 1, the question of whether or not item identification and item order are common to performance on memory span and reading was studied across two types of stimuli--digits and words. The results of Experiment 1 indicated that word span was qualitatively different for the two groups and that this difference may have arisen as a result of the presentation rate of one word per second on the span task being too fast for disabled readers to execute the performance requirements on this task. Experiment 2 was conducted to test whether the inter-group difference in word span could be eliminated if a slower presentation rate was used.

Two groups of subjects were used in both experiments. Group 1 consisted of forty Grade 4 readers who read at their grade-appropriate level. Forty Grade 4 readers who were approximately two years behind their grade-appropriate level in reading were included in Group 2. All subjects were within the average range of the non-verbal intelligence quotient of the Canadian Cognitive Abilities Test.

It was shown from the data obtained that word span was qualitatively different for the two reading groups. Both the speed of word identification and word order were related to word span in the disabled group while only word order was related to word span in the normal group. Digit span was only quantitatively different for the two groups and was defined by performance on digit order. It was also found that item identification time for both digits and words was negatively related to reading achievement in the disabled group. Performances on both word order and word span were related to reading achievement in the normal group.

The discrepant patterns obtained in the relationships between word identification, word span and reading achievement for the two groups were interpreted in terms of different methods of attacking words during identification. It was argued that while the normal group was using a visualisation strategy (identifying the word as a unit) to identify words, the disabled group was using a symbol-sound approach to do so. It was further suggested that these different methods may reflect the use or non-use of automatic processing in identification.

The relationships obtained between order and span and reading achievement were also discussed and it was suggested that the discrepancies obtained may have occurred because the measure of order used was methodologically flawed. An alternative measure of order was suggested.

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I. INTRODUCTION

Within the information processing literature, the issue of whether or not differences in working memory capacity can account for differences in reading achievement has been the focus of recent investigations (e.g. Daneman & Carpenter, 1980). Memory span tasks (tasks which require the recall of lists of stimuli in the order in which they are presented) are often used to index this capacity (e.g. Daneman & Carpenter, 1980). Hence, one research strategy commonly employed is to relate performance on memory span tasks to reading achievement as measured by psychometric tests. A major conclusion of this research is that individual differences in working memory capacity account for individual differences in reading achievement.

The present study is intended to extend and clarify this research using as a framework the working memory model proposed by Baddeley and Hitch (1974). While short-term memory has been traditionally viewed as a passive storage buffer (Atkinson & Shiffrin, 1968), working memory as it is conceptualized within this model, is viewed as an active part of the human information processing system (Baddeley & Hitch, 1974). It is a limited capacity system (one which has a fixed amount of attentional resources) which comprises of processing and storage functions. This system is made up of two parts, a central executive component which is responsible for processing activities and a phonemic buffer whose concern is the storage of the products of processing.

Activities of the central executive component include the setting up of appropriate rehearsal routines such as the loading up of the phonemic buffer and the retrieval of information from the buffer when necessary. The phonemic buffer is relatively passive and makes few demands on the central executive component as long as its capacity is not exceeded. When the capacity of the phonemic buffer is exceeded, the central executive component may become involved in storage activities such as the recoding of information held in the buffer so that proper maintenance of this information can take place. If this is not done, then the information in the buffer is subject to loss due to decay over time or displacement by new information.

Both processing and storage functions share the same limited capacity. Thus the faster processing activities are carried out, the more capacity can be devoted to storage. However, a slower speed of processing would result in little resources left over for storage and maintenance of processed information. But, the division of resources is not entirely flexible. It is assumed in this model that a fixed amount of capacity is assigned to storage functions with the remaining capacity being flexible. That is, resources are assigned to processing and storage functions depending on how fast processing can be carried out.

Baddeley and Hitch (1974) provided early evidence that working memory capacity has a span-like component. They studied the performances of adult subjects on reasoning, comprehension and free recall tasks. Three conditions were used. In the first condition, performances were studied with no concurrent memory load. In the second and third conditions, performances on these tasks were studied when subjects were required to perform a concurrent memory task, that is, subjects were required to remember a series of three and six digits respectively throughout performance on the tasks. It was found that only a concurrent memory load of six digits decreased performance considerably when compared to performance in the first condition. This was interpreted in terms of working memory being span-like in nature. That is, a suppression in performance was brought about by subjects having to hold a series of six digits (similar to the requirements of the span task).

As a result of such research, the memory span task has been used as an indicator of working memory capacity. According to Baddeley and Hitch (1974), information presented on the memory span task is processed in the central executive where it is transformed into a speech-like code. It is then stored in this speech-like form in the buffer until recall. During recall, the central executive retrieves information from the phonemic buffer. If processing is executed rapidly, then more capacity is left for storage and maintenance of the products of processing and this would result in a high degree of accuracy during recall. However, the slow execution of processing results in low accuracy during recall. Thus a fast speed of processing is functionally equivalent to a larger storage capacity.

The trade-off between storage and processing activities has also been used to explain differences in reading achievement. For example, Daneman and Carpenter (1980) investigated the hypothesis that individual differences in working memory capacity can account for individual differences in reading achievement amongst college students. They reasoned that slow processing of information on a reading comprehension task results in little time left for storage of products until recall of information is required. That is, the good reader may spend less time than the poor reader in the various stages of reading such as decoding, lexical access, parsing, inferencing and integrating, and therefore more capacity is available for storing the intermediate and final products of reading. Thus, the good reader may have more capacity to devote to the incorporation of currently processed information into representations of previously processed information. The recoding of processed information will enhance the quality of representation and will lead to better performance during recall on the comprehension task.

Given this framework, it can be hypothesized that the speed of processing is a determinant of span performance and reading achievement. This common factor would explain the finding that span performance is related to reading achievement (Torgesen, 1978-1979) and that span performance discriminates good and poor readers (Torgesen, 1978-1979).

The question thus arises as to what variables underlie the speed of processing. Four variables have been proposed -- temporal order perception, the application of mnemonic strategies, the speed of item identification and item order. These variables are discussed in detail in the next chapter. However, they are mentioned briefly in this chapter in order to develop the reasoning behind the present study.

Temporal order perception refers to the perception of serial order information (Bakker & Schroots, 1981). Bakker (1972) has proposed that this variable may account for temporal order disturbances in reading. However, the tasks used to measure temporal order perception are similar to the memory span task in that performance on both tasks requires the recall of ordered information. Thus, the relationship between temporal order perception as it is typically measured and reading achievement is equivalent to the relationship between span and reading achievement.

Traditionally, the efficiency with which strategies such as rehearsal (the iterative repetition of a series of stimuli) and chunking (the recoding of discrete stimuli into a single familiar unit) are applied was conceptualized as a major factor underlying span performance. However, this conceptualization has been disproved by recent investigations (Lyon, 1977; Torgesen & Houck, 1980). For example, Lyon manipulated the span task to eliminate conditions which were conducive to the application of rehearsal (fast rate of presentation of stimuli on span) and found that individual differences in span performance amongst college students were reduced but not eliminated. He (Lyon, 1978) tried another manipulation, chunking imposed by the experimenter, and demonstrated that even though all subjects were induced to chunk digits in a similar manner, individual differences in span performance were not eliminated. Likewise, Torgesen and Houck (1980) found that performance differences on Digit Span between groups of normal subjects, learning disabled subjects and learning disabled subjects with short-term memory problems could not be eliminated with either the removal of rehearsal or the use of experimenter-imposed chunking. These findings are in accordance with the tenets of the working memory model since mnemonic strategies are generally applied when speech-like material is held in the phonemic buffer (material stored in the buffer is recycled so as to keep it active) or when the capacity of the phonemic buffer is exceeded (recoding of material to reduce its length or complexity).

Alternatively, the speed with which items are identified has been proposed as a variable which underlies span performance (Baddeley, Thomson & Buchanan, 1975; Huttenlocher & Burke, 1976; Torgesen & Houck, 1980). It has been empirically demonstrated that this variable accounts for approximately 25 percent of variation in performance on the span task amongst college students (Baddeley et al., 1975); dyslexic subjects (Spring & Capps, 1974) and learning disabled subjects (Torgesen & Houck, 1980). Independent studies in the reading disability literature have also shown that the speed of item identification is related to reading achievement (see Stanovich, 1982 for a review). It would therefore seem that this variable may be common to both span and reading.

Speed of item identification, however, only accounts for 25 percent of the variation on span performance. The question therefore arises as to what may account for the remaining variation. Another variable which has been proposed is item order, that is, memory for the order in which items are presented (Huttenlocher & Burke, 1976; Torgesen & Houck, 1980). Even though this proposition has not been tested, it is plausible from a logical analysis of the performance requirements of the span task. That is, performance on the span task requires not only the recall of the items but also the order in which these items are presented. Again, it has been empirically demonstrated that this variable is related to reading achievement (Mason, Katz & Wicklund, 1975) and that poor readers may be insensitive to order (see Singer, 1982a for a review).

The purpose of the present study was to extend research related to the issue of whether or not individual differences in working memory capacity can account for differences in span performance and reading achievement. The specific concern of the study was to identify those variables that affect working memory capacity as it is indexed by span performance and reading achievement. It can be surmised from the above that the variables most likely to be common to span and reading are the speed of item identification and item order. Even though some studies have shown that the speed of item identification is related to span performance (Baddeley, Thomson & Buchanan, 1975; Torgesen & Houck, 1980) and other studies have shown that it is related to reading achievement (see Stanovich, 1982 for a review), in none of these , both span and reading have been combined. Again, it has been proposed that item order may underlie span (Huttenlocher & Burke, 1976; Torgesen & Houck, 1980) and that it is related to reading achievement (Mason et al.,1975). However, no study has shown that this variable is common to span and reading. Thus, the demonstration that memory for item order and the speed of item identification are common to span performance and reading achievement is novel.

In order to achieve this objective, two groups of Grade 4 readers, normal and disabled, were studied. These groups were selected since they represented two distinct levels of reading achievement. Thus the design enabled a comparison of the manner in which the two variables, the speed of item identification and item order are related to individual differences in span and reading within two distinct populations as well as allowing for comparision between the populations. It was expected that normal readers would perform better than disabled readers on these tasks. However, it was anticipated that the patterns of relationships between these variables would be the same for the two groups since this is most parsimonious with respect to the working memory model of Baddeley and Hitch (1974). That is, only quantitative differences between the groups are predicted by the working memory model. For example, on the span task slow speed of processing characteristic of disabled readers would result in lower accuracy of performance. On the other hand, a faster speed of processing would result in higher accuracy in recall on span. Again, in reading, the poor reader may go through more subprocessing stages involved in comprehension (decoding, lexical access, parsing, integrating) while the good reader may bypass some of these stages. Thus there maybe quantitative differences in the number of computational demands executed by good and poor readers.

Alternatively, there is always the possibility that the patterns of relationships may be qualitatively different. If qualitative differences do exist, the probability of finding them is enhanced by the design of this study, because the two groups used are representative of very distinct levels of reading achievement.

A visual rather than an auditory span task was utilised to examine the relationships between the above variables, since the demands of a visual task are most compatible with the principles of the working memory model. According to Baddeley and Hitch (1974) visual information is entered into the central executive component where it is transformed into speech-like codes for storage in the phonemic buffer until recall. If auditory information is used, this transformation stage is bypassed since information is already speech-like in nature (Baddeley et al., 1975). Again, visual presentation of items on a memory span task involves the same sensory modality as reading. The scores on visual and auditory span for subjects show almost perfect correlation, even though auditory span is usually higher (Daneman & Carpenter, 1980). Thus individual differences between reading and visual memory span should correlate to the same degree as if auditory memory span is substituted by visual.

A selective review of the literature is presented in the next chapter which discusses the variables common to performance on span and reading. It includes the serial order and reading disability literatures and excludes a discussion of many components of span which have been investigated in the individual differences and developmental literature (see Dempster, 1981 for an exhaustive review). This is followed by a statement of the problem and the hypotheses studied. Next, the two experiments conducted are described. In the final chapter, a general discussion of the issues which have arisen from the research is presented.

II. REVIEW OF THE LITERATURE: VARIABLES COMMON TO SPAN AND READING

As early as 1931, Saunders reported clinical observations which associated poor performance on span with difficulties in reading. Later, psychometric studies demonstrated that poor performance on the Digit Span subtest of the Wechsler Intelligence Scale for Children-Revised was a consistent characteristic of certain disabled readers (Torgesen, 1978-1979). The focus of recent investigations, as well as the present study, has been to identify those variables which are responsible for the poor performance of disabled readers on the Memory Span task (Bakker & Schroots, 1981; Mason, Katz & Wicklund, 1975; Torgesen & Goldman, 1977; Torgesen & Houck, 1980). Four variables-- temporal order perception, the use of mnemonic strategies, item identification speed and item order-- are hypothesized to underlie performance on span and reading. Each of these variables is discussed next in the context of extant research that links it to span performance and reading achievement.

Temporal order perception

Temporal order perception refers to the ability to perceive the temporal order in which information is presented (Bakker, 1972). It is distinct from item order in that while item order is usually measured by tasks which require the recognition of temporal order information (to be discussed later), temporal order perception requires the recall of the sequence in which information is presented. That is, in the recognition paradigm, a series of items is presented at a fixed rate and the subject's task is to reconstruct the the order of presentation from a randomly arranged set of identical items. In the recall paradigm, a series of items is also presented at a fixed rate. However, the subject's task is not only to remember the order but also the identity of the items presented.

Bakker (1970, 1972) has argued that the performance deficits on serial order tasks (such as span) demonstrated by disabled readers arise as a result of difficulties experienced by this group in the perception of temporal order information. Bakker and his colleagues (Bakker, 1970, 1972; Bakker & Schroots, 1981) have utilized a battery of tasks to measure temporal order perception (TOP). A common characteristic of these tasks is that they require the recall of the order in which a series of items is presented temporally. These tasks have been manipulated along three dimensions: stimulus-type (letters, digits, colors, meaningful figures, words); presentation modality (haptic, auditory, visual) and interstimulus intervals(75 msec to 4000 msec.). A major conclusion of the studies conducted in this area is that better performance on TOP is related to higher reading achievement (Bakker, 1970, 1972; Bakker & Schroots, 1981).

However; the validity of temporal order perception as a variable which can account for performance differences between normal and disabled readers on span tasks is questionable, because TOP tasks seem to be measuring the same construct as span. For example, the relationship between temporal order perception and reading was investigated in a longitudinal study by Bakker and Schroots (1981). The TOP tasks, Knox Cubes, Wordspan, Picture Matching, and Sentence Imitation, were administered to 411 nursery school children. Knox Cubes required the subjects to retap a series of cubes in an order demonstrated by the examiner. In the Wordspan task the subject was required to recall a series of nouns in the order spoken by the examiner. The Picture Matching task required that the subject match the series of nouns presented on the Wordspan task to a list of pictures presented on a card. The matching was to be done in the order of presentation. In the Sentence Imitation task, a ten sentence story was read to the subject. Each sentence was then read separately and the subject was required to recall as many words as possible irrespective of order. Reading achievement was assessed fifteen months later when 311 of these children had completed first grade elementary school. The data obtained indicated that performance on TOP tasks was significantly related to reading achievement. These results were interpreted to suggest that poor temporal order perception was predictive of poor reading.

However, if one carefully analyses the performance requirements of these tasks, it would seem that these are similar to the requirements of the span task itself. Both TOP tasks and span require the recall of serial order information. It would therefore seem that the relationship obtained between TOP and reading achievement is not different from that between span and reading achievement. The contention that TOP is a component which is common to span and reading is thus dubious.

Finally, these results seem to reinforce the need for an identification of those variables which may be common to TOP or span and reading since they suggest that serial recall is predictive of reading disability. The next three variables which will be discussed have also been considered to underlie span performance and to be important in predicting reading competence.

The use of mnemonic strategies

The efficiency with which mnemonic strategies are used to recall temporal order information has been hypothesized to account for performance differences between normal and disabled readers on span tasks (Dempster, 1981; Spring & Capps, 1974; Torgesen, 1978-79; Torgesen & Goldman, 1977).. Thus the manner in which two mnemonic strategies, rehearsal (the iterative repetition of information so as to keep it active in memory) and chunking (the recoding of two or more discrete units into a single familiar unit), are used in the recall situation by normal and disabled reading groups has been investigated.

A major conclusion of the earlier studies done in this area is that rehearsal is a factor contributing to performance differences between normal and disabled readers on span tasks (Dallago & Moely, 1980; Spring & Capps, 1974; Torgesen & Goldman, 1977). For example, Torgesen and Goldman (1977) examined the performance of normal and disabled Grade 2 readers on a task which required the delayed recall (15 second interval) of the order in which a series of pictures was pointed to by the examiner. Two conditions were used. In the baseline condition, a significant inter-group difference was found in performance and was attributed to the lower frequency with which the disabled readers used rehearsal as evidenced by lip movements and whispered words. In the support condition, both groups were induced to process information in a similar manner through the use of rehearsal. No differences were found in performance between groups on the same recall task. The results of this study were taken as support for the hypothesis that disabled readers are inefficient in using mnemonic strategies.

Recent research on individual differences in memory span among normal adults, however, has provided evidence against the hypothesis that rehearsal and chunking are the primary sources of variation in span (Dempster, 1981; Lyon, 1977). For example, Lyon (1977) manipulated the span task to eliminate rehearsal in order to examine whether individual differences in performance on Digit Span amongst college students would disappear. This was achieved by speeding up the presentation rate of items. Lyon found that the elimination of rehearsal does not lead to the disappearance of individual differences on span. He concluded that rehearsal was not a primary source of individual differences on span. In the same experiment, subjects were also induced to use experimenter-imposed chunking and grouping to perform on the Digit Span task. It was found that the use of these strategies could not account for performance variation on the span task. Therefore, it was concluded that the use of mnemonic strategies could not account for individual differences in performance on Digit Span.

More recent research focused on the issue of whether or not the differential use of the mnemonic strategies, rehearsal and chunking, can account for performance differences between normal and learning disabled groups on the span task is in agreement with this conclusion. For example, in a study by Torgesen and Houck (1980), the performance of three groups of subjects-- learning disabled children who performed within the average range on Digit Span; learning disabled subjects who performed below the the average range on Digit Span; and, a control group who performed within the average range on Digit Span-- was studied. It was found that a relative inefficiency in the use of rehearsal was characteristic of all disabled subjects, and was not specific to those who performed below average on Digit-Span. Torgesen and Houck (1980) also found that patterns of performance of normal and disabled subjects did not differ when experimenter-imposed chunking was applied. These findings led Torgesen and Houck (1980) to conclude that the use of mnemonic strategies could not have been a primary source of performance differences between groups on span.

The evidence which will be reviewed next will show that differences between normal and disabled readers on the span task may be accounted for by item identification and item order, and, that these variables may be common to span and reading.

Item identification

It has also been proposed that the speed with which items are identified is a primary source of variation in span performance (Dempster, 1981; Huttenlocher & Burke, 1976) and can account for some of the performance differences between normal and learning disabled groups on span tasks (Torgesen & Houck, 1980). This variable has been measured by the time taken to orally identify a list of items of the same stimulus category in studies of its relationship to span performance (Baddeley, Thomson & Buchanan, 1975; Nicolson, 1981; Torgesen & Houck, 1980).

Torgesen and Houck (1980) made an attempt to relate item identification speed to span performance in normal and learning disabled groups in order to address the issue of whether or not this variable is responsible for observed differences in performance on span between these groups. They found that digit identification speed accounted for approximately 25 percent of the variation on Digit Span in groups of normal and learning disabled and concluded that the speed of naming digits is a factor responsible for observed differences between these groups on the span task.

This latter finding is in need of replication for four main reasons. Firstly, even though this result is consistent across three groups, the sample size of each group was small (n=8). Secondly, the groups were chosen to be discontinous on the Digit Span variable and this may have caused an inflation in the correlation coefficients obtained. The third reason is that digit naming speed has not always been found to distinguish between normal and disabled groups (Stanovich, 1981) and as such the relationship obtained between this variable and span performance may be restricted to the specific sample used. Finally, if item identification is common to span performance and reading achievement, this relationship needs to be replicated using word stimuli since the basis of reading disability is a difficulty in interpreting symbolic stimuli, specifically, words.

Considerable evidence also exists to support the hypothesis that item identification is a factor responsible for a large proportion of the variation in span performance observed amongst normal populations of various ages (Baddeley, Thomson & Buchanan, 1975; Nicolson, 1981;

Standing, Bond, Smith & Isely, 1980). Baddeley et al. (1975) found that word identification speed accounted for approximately 25 percent of the variation in the span performance of a group of university students. It was also found in the same study (Baddeley et al., 1975) that span size (the longest list of words which an individual can immediately recall) can be predicted by the amount of words which can be named orally in approximately two seconds. This finding was replicated in a developmental study by Nicolson (1981), and across a variety of stimulus-types (words, binary and decimal digits, and letters) by Standing et al. (1980). In addition, Standing et al. (1980) found this relationship to be consistent when bilingual subjects were tested in their native or second language.

From the above discussion, it can be contended that item identification is a most probable primary source of variation on span. A great deal of evidence also exists which demonstrates that disabled readers perform poorly relative to their normal peers on item identification and that item identification is related to reading achievement. Studies which have utilized the time taken to read a continuous list of items as an index of item identification have shown significant differences in the speed of naming words, digits, color patches, letters and pictures (Biemiller, 1977-78; Denckla & Rudel, 1976; Spring & Capps, 1974). Other studies which have utilized vocalisation latencies or the time taken to identify a single item have found that only word identification time differentiated good and poor readers (Perfetti, Finger & Hogaboam, 1978; Perfetti & Hogaboam, 1975; Stanovich, 1980, 1981).

The manner in which slow word identification may affect reading achievement has been explored in the literature. Reading theorists (Laberge & Samuels, 1974; Lesgold & Perfetti, 1978; Rumelhart, 1977; Smith, 1978) generally agree that reading is a multicomponential process and that fluent reading can be accomplished only if some of these components are carried out at a very rapid rate. One commonality amongst these theories is that they all seem to agree that a rapid rate of recognizing words is important to fluent reading. For example, Smith (1978) has argued that slow word recognition speed puts a strain on short-term memory and this leads to words being read as isolated units.

Alternatively, Lesgold and Perfetti (1978) have developed a limited-capacity model and have argued that a breakdown in comprehension will occur if words are not decoded at a rapid rate. It is proposed in this model that a limited amount of attention is available for the execution of the reading act. If a large amount of attention becomes allocated to the recognition of words, then little is left for other processes such as the integration of words into meaningful units. Thus when a reader is asked questions about the information contained in the text, he resorts to guessing and this results in poor reading achievement.

There is some evidence which relates slow word identification to poor comprehension ability. The time taken by third and fifth grade readers, skilled and less in reading comprhension, to identify single printed words was studied by Perfetti and Hogaboam (1975). Three categories of words were used, psuedo-words, high-frequency words, and low-frequency words. The largest difference in performance between skilled and less skilled subjects at both grade levels was found for low-frequency words and the lowest for high-frequency words. This was interpreted to indicate the failure of poor readers to develop automatic word decoding skills as indexed by a fast rate of word identification.

The failure to develop automatic decoding skills has been further attributed to slow word-code access, that is, slow speed of accessing codes which represent words in memory. Support for the hypothesis that slow access may be responsible for slow identification speed comes from the studies of Jackson (1980) and McClelland and Jackson (1978) who investigated the relationship between accessing letter codes from memory and reading ability. Memory access was measured by the time taken to decide whether familiar and unfamiliar objects, letters and characters belonged to the same category or not. It is assumed in these studies that memory codes exist for familiar objects and letters. Better readers were found to possess a speed advantage only in the categorisation of familiar objects and letters. This finding was interpreted to suggest that better readers were faster at accessing memory codes, and, that slow accessing of memory codes may be a source of individual variation in reading performance.

The major conclusion of the studies cited above is that word identification is related to span and to reading achievement. However, this variable has been found to account for only 25 percent of the variance on word span (Baddeley et al., 1975) and on digit span (Torgesen & Houck, 1980). The question therefore arises as to what other variable(s) may account for the remaining variation on span. Item order has been proposed as a possible component of span performance. This is discussed next.

Item order

Item order refers to the reproduction of the order in which a temporal sequence of items is presented. Measurement of this variable has been a critical issue since most methods used are generally flawed. The issue centres on experimentally separating the encoding of identity and of order. Most methods used involve presenting the subject with a list of items, and, after presentation, the subject is required to remember the order in which items are presented. This necessarily involves the encoding of the identity of the items so as to remember the order in which they are presented. Thus, in order to obtain a pure measure of order, experimenters generally utilize a series of items whose identity requirements are minimal.

For example, Corkin (1974) utilized an identical set of Knox cubes. Here, the experimenter tapped a set of cubes in a predetermined order and the subject's task was to retap the cubes in the order of presentation. The problem with this version of item order is that the subject is required to encode temporal order from items in a fixed spatial order. As such there is a confounding of spatial and temporal orders in performance. Also, subjects generally utilize a counting strategy to remember order and as such, performance is dependent on the ability to count.

Merkel and Hall (1982) and Cohen and Sandberg (1977) utilized other tasks to measure item order. Both groups of researchers used the Probed Serial Recall task in which the subject is presented with nine digits and, upon completion, he or she is required to recall either the first three, the middle three or the last three digits. They also used the Running Memory task in which the subject is presented a series of digits varying in length, this length being unknown to the subject. Upon completion the subject is asked to recall the last three digits in the series. Even though in these tasks an attempt has been made to minimize identity by using a set of highly familiar items, subjects are required to encode as well as retrieve the identity of items during recall. As such the identity requirements are still relatively high. Again, in the Probed Serial Recall task, because subjects do not know which three digits they would have to recall, there is an element of surprise and subjects may be using strategic behavior, such as grouping the digits in threes, in order to perform well. Also, since subjects are unaware of the length of the lists in the Running Memory task, they may be using strategies to ensure that they retain the last three digits at all points during the presentation of the series. Thus, both of these tasks may be confounded with the use of strategies.

Perhaps the best method used to measure item order is the recognition method employed by Mason, Katz and Wicklund (1975) in their study of the relationship between item identity, item order and reading achievement. These investigators also utilized a fixed set of items (consonants and single digits) to minimize the identity requirements. In this experiment, subjects were presented a list of items. After presentation the subject was required to reconstruct the order of the items from an identical set of cards randomly placed in front of him/her. This method is superior to the other methods described because it does not require the retrieval of the identity of the items since subjects are given an identical set of items to arrange. A version of this method was used in this experiment.

Item order has been proposed as a source of variation in span performance (Dempster, 1981; Huttenlocher & Burke, 1976; Torgesen & Houck, 1980). Even though this proposition has not been tested so far, it seems plausible from a logical point of view. A logical analysis of the performance requirements of the span task would indicate that an individual must identify the items presented and retain the order in which they are presented so as to succeed on this task. Again, since item order and item identification can be distinguished experimentally (Healy, 1974; Mason, Katz & Wicklund, 1975), the hypothesis that item order accounts for a proportion of the variation observed on span is a testable one.

If item order accounts for variation in span performance, then this would imply that it may be a source of performance differences between normal and disabled readers on span. There is some evidence which is supportive of poor ability to order being implicated in reading disability. Studies which have generally used the reconstruction of the order of items to measure item order have consistently found significant differences in performance between good and poor readers (Corkin, 1974; Mason et al., 1975; Katz, Shankweiler & Liberman, 1981). For example, Mason et al. (1975) investigated the relationship between item identity, item order and reading achievement. Skilled sixth grade readers were much better at reconstructing the order of six and eight letter consonant strings and eight digit strings than their disabled peers. The skilled readers were also much better in identifying the items presented (item identity being scored by the recall of items regardless of the order of presentation). It was also found that only item order related significantly to reading achievement. In another experiment Katz et al. (1981)

contrasted the performance of good and poor readers on an order recognition task using linguistic (pictures of familiar objects) and non-linguistic (doodle drawings) drawings as stimuli. It was indicated from the results that poor readers performed worse on the recognition of the order of linguistic stimuli.

In other studies (Mason, 1975; Mason & Katz, 1976) the ordering ability of good and poor readers has been examined through the use of letter detection tasks. Two conditions were used. In the first condition, the performances of good and poor readers were compared on a task which required that subjects detect whether or not a target letter was embedded in a string of letters which did not conform to orthographic rules. For example, a _y_ would appear in the medial position of a letter string. These two reading groups performed equally well on these tasks. However, when the target letters were embedded in strings of letters which conformed to orthographic rules, the two reading groups performed significantly different. That is, the good readers were only better when the letter strings conformed to spelling patterns. These results would suggest that poor readers fail to exploit orthographic information which included the detection or remembrance of ordered information.

In addition, there is some indirect evidence from clinical work which would indicate that ordering may be implicated in reading disability. It has been observed clinically for quite some time now that there is a tendency amongst some disabled readers to make reversal errors in reading (Orton, 1937). Lieberman, Shankweiler, Orlando, Harris and Bertie (1971) analysed the reading errors made by Grade 2 good and poor readers with respect to reversal errors in reading (b for d; saw for was). It was found in this study that these errors occurred significantly amongst poor readers and accounted for about 10 per cent of the total errors made.

Studies of the role played by temporal-spatial integration in reading have generally demonstrated that poor readers may be insensitive to ordered information. Blank and Bridger (1966) and Blank, Weider and Bridger (1968) investigated whether tasks which require temporal-spatial integration in the same sensory modality were more difficult [illegible]ed readers than their normal peers. They found [illegible]eaders had difficulty in converting temporally d[illegible]ed stimuli (dots presented sequentially) to sp[illegible]y distributed stimuli (dots presented sim[illegible]neously) in the same sense modality. It was also foun[illegible] (Blank & Bridger, 1966; Blank et al., 1968) that poor rea[illegible]s experienced difficulty in the verbal reporting of tem[illegible]rally presented sequences of lights.

[illegible]t can be concluded from the above that item order is related to reading achievement (Mason et al., 1975). It has also been proposed from a logical analysis of the performance requirements on the span task that this variable may be a primary source of variation on the span task

(Dempster, 1981; Huttenlocher & Burke, 1976). It would therefore seem that item order is most probably a common component of both span and reading performance.

Summary

It can be contended from the research cited above that item identification and item order are two components which are most probably common to performance on both span and reading. It has been empirically demonstrated from some of the studies cited that item identification accounts for a significant proportion of the variation in span performance. Other studies have also shown that this variable is related to reading. Item order has been hypothesized to be a performance component on span and it has been demonstrated that this variable is related to reading achievement. That these two variables are common to both span and reading however, has not been demonstrated. This was addressed in the present research.

The next chapter presents the problem and hypotheses of this study.

III. PROBLEM AND HYPOTHESES

A. Statement Of The Problem

The general problem of the research conducted was to determine the nature of the interrelationships amongst performance on tasks which measured the speed of item identification, the retention of item order, memory span and reading achievement. Two specific research questions were studied. These are:

1. What is the relationship between the speed of item identification and the retention of item order on the one hand, and performance on memory span on the other?
2. Does performance on tasks which measure the speed of item identification, the retention of item order and memory span relate to reading achievement in both normal and disabled reading groups?

The research cited in the previous section indicated that the two variables, item identification speed and item order may be common to performance on span and reading achievement. In the present study, the relationships amongst performance on item order, on item identification, on span and on reading achievement were examined within groups of normal and disabled Grade 4 readers. This was done in order to establish whether or not performance on item order and on item identification is related to span performance and to reading achievement in each group. The patterns of correlations among these variables were compared across groups in order to establish whether or not the two groups were performing on item order and item identification in a similar manner.

Two experiments were carried out. In Experiment 1, the two research questions were examined across two types of stimuli, words and digits. Because performance on item identification, on item order and on memory span for word stimuli required that all subjects were familiar with a list of ninety words, a Word Reading task was administered. Here, the subject's task was to orally identify ninety words (each word on a separate card) correctly. A subject was eliminated from the study if he failed to identify a word correctly and did not spontaneously self-correct it.

Item identification was defined by performance on a Naming Time task which required that the subject orally name three sheets of thirty items of the same stimulus-type (single digits; familiar words). The average time taken per sheet was used as an index of performance.

Item Order was measured by having each subject reproduce the order in which a temporal sequence of items was visually presented at a fixed rate. Each subject was presented with a series of items (words, digits). Immediately after presentation, a set of identical items was placed in random order on a table in front of the subject. The subject's task was to rearrange these items in the order of presentation.

Span performance was indexed by the Memory Span task. This task required the immediate recall of a series of items (words, digits) in the order in which the items were presented visually.

Two measures of reading achievement were used. Schonell Graded Reading Vocabulary test (Schonell, 1968) was used to measure word recognition skills. This task required the subject to read a graded word list until ten consecutive errors were made. The comprehension subtest of the Peabody Individual Achievement Test (Dunn & Markwardt, 1970) was used to index comprehension skills. In this task, the subject was required to read a sentence and upon completion to choose one out of four pictures which best described the sentence read.

Experiment 2 essentially replicated Experiment 1 using only word stimuli. However, the presentation rate was varied from one word per second (Experiment 1) to one word every two seconds. The rate of presentation was slowed down since, based on the results of Experiment 1, it was suggested that the disabled group might not have been able to complete processing activities on the Memory Span and Item Order tasks when presentation rate was one word per second (See Discussion, Experiment 1).

B. Statement of Hypotheses

It was expected that the reading disabled children when compared to average readers would demonstrate inferior performance on item order, memory span and item identification for both types of stimuli. Previous studies have shown that disabled readers perform poorly on item order (Mason, Katz & Wicklund, 1975); on memory span (Torgesen, 1978-1979) and on item identification (Stanovich, 1982). However, in the present study, all three measures are included and both digits and words are used as stimuli for the same groups of subjects.

It was predicted that performance on item order, item identification and memory span tasks would be higher for digits than for words for both groups of subjects. This was expected since the digit stimuli (single digits) used were easier than words. Also the set of digits (9 digits) used was much smaller than the set of words (90 highly familiar words) and as such the probability of guessing the correct answer was greater for digits than for words.

It was hypothesized that the time taken for item identification would relate negatively to memory span performance and to reading achievement (that is, the faster the speed of identifying items, the higher the score on memory span and on reading achievement) and that item order would relate positively to memory span and to reading achievement. This was expected to be consistent across groups and stimulus-types. The relationship between item identification time and memory span as well as between item identification time and reading achievement was expected to be negative based on previous research (Nicolson, 1981; Stanovich, 1982; Torgesen & Houck, 1980). Item order has been hypothesized to relate to memory span (Dempster, 1981; Huttenlocher & Burke, 1976) and there was no reason to suppose that these variables would not be related in the present experiment. Mason et al. (1975) have also shown that this variable relates to reading achievement. However, it has not been shown that item order and item identification speed are components of span which relate to reading achievement.

It was also assumed that item identification time and item order would be independent of each other across groups and stimulus-types. This assumption was based on the fact that the stimuli used were highly familiar and as such the identity requirements on the order task would be minimal.

It was hypothesized that performance on item order and on item identification time would predict performance on memory span in each group for both types of stimuli. This was expected since these two variables were conceptualized as being components of span performance and as such they would account for a significant proportion of the variation on span. It has also been shown previously that item identification speed accounts for about 25 percent of the variation on span (Baddeley et al., 1975; Torgesen & Houck, 1980).

Finally, it was expected that performance on item order, on item identification speed and on memory span would predict reading achievement within groups and across stimulus-types. It was reasoned that if the variables, item order and item identification are common to span and reading, then they should account for a significant proportion of the variation on span. Again, if span and reading are related, then span performance should predict reading. It has been shown previously that span performance does relate to reading (Torgesen, 1978-1979).

The hypotheses in Experiment 2 were essentially the same as in Experiment 1 even though only word stimuli were used. It was also expected that performance on the item order and span tasks would be greater at the slower presentation rate (one card every two seconds) used in this experiment.

The next chapter describes Experiment 1.

IV. EXPERIMENT 1

A. Method

Subjects

The characteristics of the two groups of subjects used are shown in Table 4.1. The normal reading group was comprised of forty Grade 4 children (27 boys, 13 girls) who read at their grade-appropriate level as defined by a sixty or more percentile rank on both the Decoding and Comprehension subtests of the Elementary Reading Test (Edmonton Public Schools, 1978) in the previous three years of school. These subjects also attained a non-verbal intelligence quotient within the average range on the Canadian Cognitive Abilities Test (Thorndike & Hagen, 1974).

The reading disabled group included forty Grade 4 children (27 boys, 13 girls) whose non-verbal intelligence quotient was within the average range on the Canadian Cognitive Abilities Test (Thorndike & Hagen, 1974). These subjects read below their grade-appropriate level as defined by a forty or less percentile rank on both the Decoding and Comprehension subtests of the Elementary Reading Test (Edmonton Public Schools, 1978) in the previous three years of school. This percentile range was chosen as indicative of reading disability since in some schools it was used as a criterion for resource room placement. In addition, the subjects in this group received additional instruction in

TABLE 4.1
COMPARISON OF GROUPS ON SELECTION CRITERIA

CRITERIA	READING DISABLED			NORMAL READING			
	M	*SD*	*R*	*M*	*SD*	*R*	*t*
Age (Months)	111.600	4.156	15.000	109.850	3.884	15.000	1.92
CCAT - NVIQ[1]	101.650	7.698	32.000	104.500	7.278	30.000	1.70
CCAT - VIQ[2]	86.375	8.405	33.000	116.075	9.606	37.000	14.72***
ERT[3] - Decoding (Mean Rank)	15.650	9.757	36.000	83.500	13.476	39.000	25.79***
ERT[3] - Comprehension (Mean Rank)	16.475	10.547	38.000	81.500	11.989	37.000	25.76***
Sex							
No. of Males		27			27		
No. of Females		13			13		

Note. n = 40 for each group.
[1] Non-verbal Intelligence Quotient of the Canadian Cognitive Abilities Test
[2] Verbal Intelligence Quotient of the Canadian Cognitive Abilities Test
[3] Elementary Reading Test (Edmonton Public Schools, 1978)
*** $p < .001$

reading (resource room help) over the past three years. Children who had repeated a grade in school were not included in the sample. Also, children who had been enrolled in English as a Second Language classes, whose sole language of communicating at home was one other than English or who had speech problems were excluded from the sample.

Before the final selection of subjects was completed, teachers were consulted as to whether any of the children were undergoing emotional stress of any sort. Only those children who had no emotional problems were selected for study.

Tasks

Six tasks were administered to subjects individually. These were: Schonell Graded Reading Vocabulary Test (Schonell); Comprehension subtest of the Peabody Individual Achievement Test (PIAT); Word Reading; Naming Time; Memory Span; and, Item Order.

Schonell. The Schonell is a subtest of the Reading and Spelling Tests (Schonell, 1968). It measures an individual's ability to orally read single words. It was chosen here because it is quick to administer (10-15 minutes) and a wide ability range on word recognition (reading age of 5 to 15 years) can be measured with the same instrument. In this task the subject was required to read a graded word list until ten consecutive errors were made. The number of words correctly read was used to calculate the subject's reading age.

PIAT. The PIAT is the comprehension subtest of the Peabody Individual Achievement Test (Dunn & Markwardt, 1970). It requires the individual to read a sentence and upon completion, to choose one out of four pictures which best describes the sentence read. This task was chosen here to index performance in reading comprehension because it is quick to administer (10-15 minutes) and a wide range of ability can be measured.

The administration procedure was different to that described in the test manual (Dunn & Markwardt, 1970). All subjects began at the first item (item 19) and progressed until five errors were made in seven consecutive responses. This procedure was adopted because the Reading Recognition subtest (normally used as a starting point for administering PIAT) was not administered. The administration of the Reading Recognition test would have been redundant.

The scoring procedure is identical to that described in the test manual (Dunn & Markwardt, 1970).

Word Reading. The tasks, Naming Time for Words, Memory Span for Words and Item Order for Words (described below) required that every subject must be able to identify a list of ninety words. Word Reading was administered in order to ensure that all subjects fulfilled this requirement.

Ninety words taken from the Dolch Basic 220 Word List, pre-primer and primer levels, (Dolch, 1942) were printed in SERIF.BOLD.12.FIXED.PORTRAIT.1 font by the page printer of the Michigan Terminal System. Each word appeared in the centre of a 5-1/2 cm by 10 cm card.

The ninety word cards were shown individually in random order. Each subject was asked to read each word out loud. The criterion for passing this test was the correct oral reading of all ninety words. If the subject misread a word without engaging in spontaneous self-correction, he or she was eliminated from further participation in the study. Appendix A provides a list of the words used and detailed instructions for administering this test.

<u>Naming Time</u>. (10 minutes) This task measured the speed with which subjects are able to orally name items which are highly familiar to them. It has been used by various researchers to measure item identification (Baddeley et al., 1975; Nicolson, 1981; Spring & Capps, 1974).

Two types of stimuli were used, words and digits. The <u>word</u> stimuli utilized were the same as in Word Reading. These words were classified according to their parts of speech (33 verbs, 16 adjectives, 13 prepositions, 3 conjunctions, 9 adverbs, 13 pronouns and 3 exclamations). Three sheets of thirty words each were then prepared with the different parts of speech distributed evenly across sheets. The words on each sheet were arranged in such a manner that they did not conform to syntactical patterns of language.

Each sheet contained six lines of five words each. The words were printed in SERIF.BOLD.12.FIXED.PORTRAIT.1 font by the page printer of the Michigan Terminal System.

The digit stimuli were single digits 1 through 9. Three sheets each containing thirty single digits were used. These digits were arranged in random order (six lines of five digits each) subject to the restriction that no two digits occurred in a forward or backward sequence (1 followed by 2 or 2 followed by 1). Each digit-sheet was also printed in SERIF.BOLD.12.FIXED. PORTRAIT.1 font.

The method of administration was the same for digit and word sheets in both groups with the exception that on the digit task the practice items were from the same subset of items used on the actual task. For words, a practice trial was first administered which consisted of asking each subject to orally read ten words not included in the three sheets. The three sheets were then administered in five different orders (1,2,3; 3,2,1; 2,1,3; 3,1,2; 1,3,2), with eight subjects in each group being given each order. Subjects were asked to read each sheet out loud as quickly and as correctly as they could from left to right. Even though error rate was not recorded, subjects generally made few errors in reading words. This was expected since all subjects could read words as determined from performance on the Word Reading task.

The time taken to read each sheet was used as an index of performance. This was recorded to a hundredth of a second accuracy as measured manually by a stopwatch. Appendix B gives a detailed account of the method of administration and copies of the sheets used in this task.

M[illegible] Span. (10 minutes) This task measured the abili[illegible]all a list of items in the order in which they are pr[illegible] It has been used repeatedly to measure span [illegible]for[illegible] Torgesen, 1978-1979).

Tw[illegible]pes of stimuli were used, words and digits. The wo[illegible] s[illegible]uli were the same as those employed in the Word Re[illegible] Task. Word cards were also prepared as in the Word Rea[illegible] task. Words were organized into lists varying in leng[illegible] from three to nine words. Four sets of words at each list [illegible]ngth were used, the words in each list being arranged in su[illegible] a manner that they did not conform to syntactical patter[illegible] of language.

The digit stimuli were the same as in the Naming Time task. Di[illegible]t cards were prepared in a similar manner to word cards [illegible]pt that each digit appeared in the centre of a 5-1/2 cm by 5 cm card. Digits were organized into lists varying in length from 3 to 9 digits. Four lists at each length were used. The digits were arranged in random order subject to the restriction that no two digits occurred in a forward or backward sequence (3,4 or 5,4).

The method of administration and scoring procedures were the same for words and digits with the exception that on the digit task the practice items were from the same subset of items used on the actual task. Word cards were presented visually at a rate of one every second. This rate was chosen since it is the one most often used in the standard administration of the span task (Dempster, 1981). Initially, a practice trial was administered. This comprised of a list length of two words, these words not being included in the ninety words described above. Each subject was instructed to verbally recall the words in the order presented. A record of each subject's response was noted. The presentation of lists continued until a subject failed to correctly recall four lists of the same length.

Two methods of scoring-- list and item-- were used. The list method is a more conservative method of scoring and credit was only given to whole lists of items correctly recalled. This was therefore indicative of the subject's ability to recall lists of items. In the item method on the other hand, credit was given for complete sequences as well as for individual items recalled in the correct order. This score was representative of the subject's ability to recall ordered information at the level of individual items.

In the <u>list</u> method, a basal score of 2.00 was used and .25 points was awarded for each subsequent list correctly recalled. For example, if a subject correctly recalled four lists of three words and two lists of four words, he/she was awarded a total score of 3.50 (2.00 + 1.00 + .50). In the <u>item</u> method, the subject was awarded one point for each word correctly recalled in the order presented. A point was subtracted for each extra word added to the list since this was viewed as an error (the addition of irrelevant information). This method has been used by Torgesen and

Houck(1980).

Again, both serial and free recall scores were obtained for each subject. The serial recall list score measured the number of lists correctly recalled in the order in which the words were presented. The free recall list score measured the number of lists correctly recalled regardless of the order in which the words were presented. The serial recall item score measured the number of items correctly recalled in the order in which they were presented. The free recall item score measured the number of items correctly recalled regardless of the order in which the words were presented.

Appendix C presents the details of administration and scoring procedures as well as the word lists used.

Item Order. (20 minutes) This task was used to measure the ability to reproduce the order in which a list of items is presented. It is different from the Memory Span task in that after presentation of items, the subject's task is to reconstruct the order in which the items are shown from a set of identical items arranged randomly. This procedure has been used by Mason et al. (1975) and Katz et al. (1981) to measure item order.

Two types of stimuli, words and digits, were used. The word stimuli were those employed in the Word Reading task. Word cards and word lists were prepared as in the Memory Span task except that two identical sets of cards at each list length were prepared.

The <u>digit</u> stimuli were single digits 1 through 9. Digit cards and digit lists were prepared as in the Memory Span task except that two identical sets of cards at each list length were prepared.

The method of administration and scoring procedures were identical for word and digit stimuli with the exception that the practice items on the digit task were from the subset of items on the actual task. For word stimuli, each list was visually presented at a rate of one item per second. Subjects were instructed to silently read each word as it was presented. This was done in order to ensure that all children knew what to do. After presentation, the subject was quickly shown an identical list of word cards arranged in random order on a table in front of him (her). The subject was instructed to arrange these cards in the order in which they were presented. A record of the subject's response was noted.

Initially, a practice trial of list length two was administered. These words were not included in the ninety words described above. After this, lists of lengths three to nine words were administered. Administration ceased when a subject failed to correctly arrange four lists of words of the same length.

Both list and item scores were calculated. These were calculated in an identical manner to that described for serial recall scores in Memory Span task described above. Appendix D presents details of the method of administration, scoring procedures and lists used.

Procedure

All testing was conducted in the schools and took place in any available quiet room. The Schonell was initially administered and each child was subsequently seen for two sessions in the same day (one in the morning and one in the afternoon.

The order of administration of tasks was counterbalanced and the same order used for both groups as shown in Table 4.2.

TABLE 4.2
ORDER OF ADMINISTRATION OF TASKS
FOR NORMAL AND DISABLED READERS

Order of Tasks	NORMAL READERS Number of Subjects	DISABLED READERS Number of Subjects
3121	8	8
1312	8	8
3112	8	8
1321	8	8
2131	8	8

Note. 1 : Naming Time; 2 : Memory Span; 3 :Item Order

Naming Time for words and for digits was administered in both sessions while Item Order or Memory Span was administered in either session. Words and digits were also counterbalanced for the Naming Time, Item Order and Memory Span tasks. In the morning session if words were the stimuli in the first task administered, then digits were administered first in the second task. This procedure was reversed in the afternoon. Finally, PIAT was administered in the same session as Memory Span so as to limit the time per session to thirty minutes.

It was important that a non-threatening atmosphere be provided during testing since some subjects had previously experienced failure in learning to read. In order to create this atmosphere, the experimenter established rapport with the subjects. Subjects were told that the experimenter was studying how children learn to read. The subject's cooperation was then solicited. It was further emphasized that these were not tests in which one passed or fail. Rather, the subject was asked to do as much as he (she) could since this would greatly assist the experimenter in finding out how children learn to read.

B. Results

The results of Experiment 1 are presented in four parts. The mean performance on all tasks is compared across groups first. Next, a comparison of performance trends across stimuli on Naming Time, Item Order and Memory Span is presented. The relationships among performance on Memory Span, Item Order and Naming time are examined in the third part. The proportion of variation in span performance accounted for by performance on Naming Time and Item Order is also dealt with here. Finally, the relationships among performance on Memory Span, on Item Order, on Naming Time and reading achievement are examined.

<u>Comparison across groups</u>. It was predicted that the reading disabled group would demonstrate inferior performance on all five tasks. The means and standard deviations of performance on these tasks are presented in Table 4.3. As can be seen, the normal reading group demonstrated significantly higher performance on all tasks thereby confirming the predicted hypothesis.

<u>Comparison across stimuli</u>. Tables 4.4, 4.5, and 4.6 present the intercorrelations between performance on these tasks for digit and word stimuli in the reading disabled, normal and total (normal plus reading disabled) groups. It can be seen that performance on these tasks for word stimuli is significantly related (positively) to performance on digit stimuli.

It was expected that the mean performance of each group on all tasks would be greater for digits than for words. As can be seen from Table 4.3 above, the mean performance on tasks for digit stimuli is greater than for word stimuli.

Analyses were carried out to determine whether or not the differences obtained across stimuli reflected similar performance trends. Two 2 (groups) x 2 (stimulus-type) analyses of variance with repeated measures on stimulus-type were done using Memory Span, first with list and then with item scores. Significant main effects were obtained for

TABLE 4.3
COMPARISON OF GROUP MEANS ON EXPERIMENTAL VARIABLES

VARIABLE	DISABLED READING GROUP *M*	DISABLED READING GROUP *SD*	NORMAL READING GROUP *M*	NORMAL READING GROUP *SD*	*t*
Schonell	8.145	0.275	11.103	0.891	20.05**
PIAT	3.535	0.608	5.658	1.531	8.15**
Naming Time - Words	21.999	5.342	15.117	2.066	7.60**
Naming Time - Digits	17.204	3.366	13.812	2.426	5.17**
Memory Span - Words[1]	3.213	0.611	3.744	0.550	4.09**
Memory Span - Words[2]	26.075	10.764	37.650	13.537	4.23**
Memory Span - Digits[1]	3.850	0.571	4.181	0.755	2.21*
Memory Span - Digits[2]	40.250	12.905	49.275	18.723	2.51*
Item Order - Words[1]	3.388	0.623	3.938	0.518	4.29**
Item Order - Words[2]	29.400	12.983	38.950	11.345	3.50**
Item Order - Digits[1]	3.994	0.777	4.400	0.627	2.57*
Item Order - Digits[2]	41.425	16.539	48.625	2.452	2.01*

Note. $n = 40$ for each group.
[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
** $p < .01$
* $p < .05$

TABLE 4.4
CORRELATIONS BETWEEN DIGIT AND WORD SPAN

GROUP	READING DISABLED Memory Span - Digits[1]	 Memory Span - Digits[2]	NORMAL READING Memory Span - Digits[1]	 Memory Span - Digits[2]	TOTAL GROUP Memory Span - Digits[1]	 Memory Span Digits[2]
Memory Span (Words)[1]	.5205***	.5343***	.7161***	.6988***	.6439***	.6476***
Memory Span (Words)[2]	.5106***	.5519***	.6408***	.6313***	.6229***	.6407***

[1] Based on scores computed using the list method described in Chapter 4
[2] Based on scores computed using the item method described in Chapter 4
*** p < .001
** p < .01

TABLE 4.5
CORRELATIONS BETWEEN DIGIT AND WORD ORDER

GROUP	READING DISABLED		NORMAL READING		TOTAL GROUP	
TASKS	ITEM ORDER DIGITS[1]	ITEM ORDER DIGITS[2]	ITEM ORDER DIGITS[1]	ITEM ORDER DIGITS[2]	ITEM ORDER DIGITS[1]	ITEM ORDER DIGITS[2]
Item Order Words[1]	0.4754***	0.5277***	0.7050***	0.7031***	0.6124***	0.6262***
Item Order Words[2]	0.4290**	0.4656***	0.6720***	0.6755***	0.5753***	0.5892***

[1] Based on scores computed using the list method described in Chapter 4.
[2] Based on scores computed using the item method described in Chapter 4.
** $p < .01$
*** $p < .001$

TABLE 4.6
CORRELATIONS BETWEEN DIGIT AND WORD NAMING SPEED

GROUP	READING DISABLED	NORMAL READING	TOTAL GROUP
Tasks	Naming Time: Digits	Naming Time: Digits	Naming Time: Digits
Naming Time: Words	0.7002***	0.7459***	0.7790***

*** $p < .001$

groups, $F(1, 78) = 11.752$, $p < .01$, and for stimulus-types, $F(1, 78) = 75.229$, $p < .01$, on the Memory Span task using list scores. No significant interaction was found. Thus, even though performance means were different, the trends in performance variation did not change with stimulus-type. Similar results were obtained with item scores.

Similar analyses of variance were done using list and item scores obtained on the Item Order task. For list scores, significant main effects were found for groups, $F(1, 78) = 14.219$, $p < .01$, and for stimulus-types, $F(1, 78) = 62.128$, $p < .01$. No significant interaction was obtained indicating that performance patterns were the same across groups. Similar results were obtained when item scores were used.

The trends in performance across stimuli were also examined on the Naming Time task. A 2 (groups) X 2 (stimulus-type) analysis of variance with repeated measures on stimulus-type was done. Significant main effects were obtained for groups, $F(1, 78) = 51.069$, $p < .01$, and for stimuli, $F(1, 78) = 85.568$, $p < .01$. A significant groups X stimulus-type interaction was also obtained, $F(1, 78) = 28.018$, $p < .01$. It would seem that the groups are performing differently on the Naming Time task. The convergence of the means for digits and words on this task in the normal group would suggest that these subjects are naming words as rapidly as digits. The larger difference in mean performance obtained for the disabled group on these tasks as well as the poorer performance of this group compared to their normal peers would indicate that the disabled readers are experiencing some difficulty in naming items, especially words. This difficulty in naming items experienced by the disabled group is a probable source of the significant interaction.

Relationships between Naming Time, Item Order and Memory Span. It was predicted that performance on Naming Time and on Item Order would relate substantially to performance on Memory Span. Pearson Product Moment correlation coefficients computed for both groups are presented in Tables 4.7 and 4.8 with the ones relevant to the discussion being underlined. It can be seen from these tables that performance on Naming Time for Words is negatively related ($p < .05$) to Memory Span performance only in the disabled group and that Naming Time for Digits is not related to Memory Span performance in either group. The relationships predicted between performance on item identification and span are only supported by the marginal correlations obtained between Naming Time for Words and Memory Span for Words in the disabled group. This may have occurred as a result of the disabled group being too slow in identifying words within the presentation rate on the Memory Span task.

It can also be seen from Tables 4.7 and 4.8 that performance on Item Order and Memory Span are significantly related ($p < .01$) and this relationship is consistent across

TABLE 4 7
CORRELATION COEFFICIENTS AMONGST VARIABLES FOR DISABLED READING GROUP

VARIABLE	MEMORY SPAN - WORDS[1]	MEMORY SPAN - WORDS[2]	MEMORY SPAN - DIGITS[1]	MEMORY SPAN - DIGITS[2]
Naming Time (Words)	-0.2658*	-0.3417*	-0.1004	-0.1356
Naming Time (Digits)	-0.1137	-0.1481	-0.0321	-0.0120
Item Order - (Words)[1]	0.5626***	0.6192***	0.4290**	0.4487**
Item Order (Words)[2]	0.4729**	0.5770***	0.3031*	0.3860**
Item Order (Digits)[1]	0.4785**	0.3973*	0.5465***	0.5619***
Item Order (Digits)[2]	0.5844***	0.5232***	0.6604***	0.6678***

[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* $p < .05$
** $p < .01$
*** $p < .001$

TABLE 4.8
CORRELATION COEFFICIENTS AMONGST VARIABLES FOR NORMAL READING GROUP

VARIABLE	MEMORY SPAN - WORDS[1]	MEMORY SPAN - WORDS[2]	MEMORY SPAN - DIGITS[1]	MEMORY SPAN - DIGITS[2]
Naming Time (Words)	0.0234	0.0266	0.0206	-0.0969
Naming Time (Digits)	-0.1318	-0.1778	-0.2061	-0.2039
Item Order (Words)[1]	0.3752**	0.2555	0.4638**	0.5073***
Item Order (Words)[2]	0.4640**	0.4094**	0.4836**	0.5220***
Item Order (Digits)[1]	0.4670**	0.3490*	0.5465***	0.4734**
Item Order (Digits)[2]	0.5022***	0.3504*	0.6052***	0.5060***

[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* $p < .05$
** $p < .01$
*** $p < .001$

groups and stimuli. The positive correlation obtained would indicate that Memory Span performance varies directly with Item Order performance. This may be due to the fact that these two tasks have common elements. Both tasks required the identification of items as well as the retention of the order of the items. However, they differed in that the span task required the recall of items in the order in which they are presented, whereas the item order task required the reconstruction of the order of items.

Two unexpected correlations were also obtained. As can be seen from Table 4.9, Naming Time for Words is significantly related to Item Order for Words in the disabled group. Also, performances on Naming Time for Digits and on Item Order are related in the normal group. The reasons why these relationships might have occurred are presented in the discussion section.

It was predicted that performance variation observed on Naming Time and on Item Order would explain a substantial proportion of the variation observed in Memory Span performance in each group. Multiple regression analysis was done using performance on Item Order and Naming Time as predictors. The regression procedure used was a forward inclusion one where the order of inclusion of the independent variables was determined by the respective contribution of each variable to the explained variance. That is, the first variable to be included is the one which accounts for the largest portion of the explained variance.

TABLE 4.9
CORRELATION COEFFICIENTS AMONGST PERFORMANCE ON ITEM ORDER AND NAMING TIME FOR DISABLED AND NORMAL READING GROUPS

GROUP	DISABLED		NORMAL	
Variables	Naming Time - Words	Naming Time - Digits	Naming Time - Words	Naming Time Digits
Item Order-Words[1]	-0.4460**		-0.2226	
Item Order-Words[2]	-0.3619*		-0.1807	
Item Order-Digits[1]		0.0845		-0.4429**
Item Order-Digits[2]		0.0356		-0.4210**

[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4

* $p < .05$

** $p < .01$

Only those variables whose contribution was greater than one hundredth percent of this variance were included.

The results of this analysis are presented in Table 4.10. It can be seen from this table that performance on Item Order accounted for a significant percentage of variation observed on span. This is consistent across groups and stimulus-type. The inclusion of Naming Time after the contribution due to Item Order is removed does not increase the variance substantially. It can also be seen in Table 4.10 that Item Order for Words accounted for a much larger percentage of variance on Memory Span for Words in the disabled group than in the normal group. This may be attributed to the fact that Item Order for Words and Naming Time for Words are correlated in the disabled group (Table 4.9) and as such the variance accounted for by Item Order may have included some of the variance accounted for by Naming Time in this group.

A partial correlation analysis was done to determine whether or not the relationship between Naming Time for Words and Memory Span for Words was influenced by Item Order performance. As can be seen from Table 4.11, the significant correlation between performance on Naming Time for Words and Memory Span for Words disappeared when the influence of Item Order is removed in the disabled group. As will be discussed later, it seems there is a component of the Naming Time for Words task that is shared with the Item Order for Words task among disabled readers.

TABLE 4.10
PERCENT VARIANCE ON MEMORY SPAN ACCOUNTED FOR BY ITEM ORDER AND NAMING TIME

	PERCENT VARIANCE		
	ITEM ORDER	NAMING TIME	TOTAL[3]
Reading Disabled			
Memory Span-Words[1]	31.987***	0.023	32.010
Memory Span-Words[2]	33.294***	2.033	35.327
Normal			
Memory Span-Words[1]	14.076*	1.202	15.278
Memory Span-Words[2]	16.762**	1.045	17.807
Reading Disabled			
Memory Span-Digits[1]	29.865***	0.617	30.482
Memory Span-Digits[2]	44.593***	0.128	44.721
Normal			
Memory Span-Digits[1]	29.870***	0.161	30.031
Memory Span-Digits[2]	25.605***		25.605

Note. The order of inclusion of each variable is determined by its contribution to the explained variance.
[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
[3] Total = sum of variation accounted for by Item Order and Naming Time

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

TABLE 4.11
RESIDUAL CORRELATIONS BETWEEN PERFORMANCE ON MEMORY SPAN AND NAMING TIME TASKS WHEN THE INFLUENCE OF ITEM ORDER IS CONTROLLED IN BOTH NORMAL AND READING DISABLED GROUPS

VARIABLE	DISABLED GROUP				NORMAL GROUP			
	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Digits[1]	Memory Span - Digits[2]	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Digits[1]	Memory Span Digits[2]
Naming Time (Words)	-.0184 (0.2658)*				.1183 (.0234)			
Naming Time (Words)		-.1746 (-.3417)*				.1120 (.0266)		
Naming Time (Digits)			-.0938 (-.0321)				.0479 (-.2061)	
Naming Time (Digits)				-.0481 (-.0120)				.0117 (-.2039)

Note. Pearson Product Moment Correlation Coefficients are in parentheses
[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* $p < .05$
** $p < .01$

It was determined from another partial correlation analysis done that the relationship between Item Order and Memory Span was independent of the influence of Naming Time. The results are summarized in Table 4.12. The residual correlations obtained remain virtually unchanged from the correlation coefficients.

Relationship between Naming Time, Memory Span, Item Order and Reading Achievement. It was predicted that performance on Naming Time, on Item Order and on Memory Span would relate to reading achievement as measured by Schonell and PIAT within each group of subjects. The results are summarized in Table 4.13. It can be seen from this table that performances on Naming Time for Words and for Digits are significantly correlated with Schonell performance in the disabled group. Item Order for Words is marginally correlated with Schonell performance in this group also. Again, performances on Memory Span for Words, Item Order for Words, Naming Time for Words and Item Order for Digits are related to PIAT performance in the disabled group. Finally, Memory Span for Words and Naming Time for Words are marginally related to Schonell performance in the normal group.

A multiple regression analysis using a forward inclusion procedure was done to determine whether or not a significant proportion of the variance on Schonell and on PIAT could be accounted for by performance on Naming Time, on Item Order and on Memory Span. In this procedure the

TABLE 4 12

RESIDUAL CORRELATIONS BETWEEN PERFORMANCE ON MEMORY SPAN AND ITEM ORDER TASKS WHEN THE INFLUENCE OF NAMING TIME IS CONTROLLED IN BOTH NORMAL AND READING DISABLED GROUPS

VARIABLE	DISABLED GROUP				NORMAL GROUP			
	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Digits[1]	Memory Span - Digits[2]	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Digits[1]	Memory Span Digits[2]
Item Order (Words)[1]	5181** (5626)***				3903* (3752)**			
Item Order (Words)[2]		5174** (5770)***				4213** (4094)**		
Item Order (Digits)[1]			5515*** (5465)***				5189** (5465)***	
Item Order (Digits)[2]				6687*** (.6678)***				4732** (5060)***

Note. Pearson Product Moment Correlation Coefficients are shown in parentheses

[1] Scored using the list method described in Chapter 4

[2] S cored using the item method described in Chapter 4

* $p < .05$

** $p < .01$

*** $p < .001$

TABLE 4.13
CORRELATIONS BETWEEN READING ACHIEVEMENT AND EXPERIMENTAL VARIABLES FOR NORMAL AND DISABLED READING GROUPS

GROUP	DISABLED		NORMAL	
Variable	Schonell	PIAT	Schonell	PIAT
Memory Span - Words[1]	0.1930	0.3090*	0.2340	0.0118
Memory Span - Words[2]	0.2073	0.3613*	0.2671*	-0.0666
Item Order - Words[1]	0.2583	0.4781**	0.0909	-0.1384
Item Order - Words[2]	0.2659*	0.3510*	0.1927	-0.1150
Naming Time - Words	-0.5240***	-0.4530**	-0.2831*	0.0203
Memory Span - Digits[1]	-0.0375	0.2241	0.2024	0.0534
Memory Span - Digits[2]	-0.0379	0.1698	0.1497	0.0252
Item Order - Digits[1]	0.0193	0.1986	0.1213	-0.2128
Item Order - Digits[2]	0.0745	0.3033*	0.1447	-0.1792
Naming Time - Digits	-0.5438***	-0.1779	-0.2574	0.0999

[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* $p < .05$
** $p < .01$
*** $p < .001$

order of inclusion of variables is determined by the respective contribution of each variable to the explained variance. That is, the variable whose contribution is largest is first included. Only those variables whose contribution is greater than one hundredth percent of the variance are included in the analysis. Only list scores are reported in Table 4.14 since it was found that the results were similar for both list and item scores.

As can be seen from Table 4.14 both performance on Naming Time for Words and on Naming Time for Digits accounted for a significant proportion of the variation observed on Schonell performance in the disabled group. Performance on Item Order for Words accounted for a significant proportion of the variation on PIAT also in this group. The variance contribution on PIAT accounted for by Naming Time for Words after Item Order was removed was also significant (7 percent) for this group even though this value was much smaller than that obtained between Naming Time and Schonell. This is probably due to the fact that Naming Time for Words is correlated with Item Order for Words and this may have resulted in a portion of the variance due to Naming Time being accounted for by Item Order since the latter was the first variable included in the analysis.

Only Naming Time for Words accounted for a significant proportion of the variation on Schonell in the normal group. None of the other experimental variables accounted for a

TABLE 4.14
PERCENT VARIANCE ON SCHONELL AND ON PIAT
ACCOUNTED FOR BY ITEM ORDER, NAMING TIME AND MEMORY SPAN

	PERCENT VARIANCE			
	MEMORY[1] SPAN	NAMING TIME	ITEM[1] ORDER	TOTAL
<u>WORD STIMULI</u>				
<u>Reading Disabled</u>				
Schonell	0.311	27.463**	---	27.744
PIAT	0.175	7.176*	22.861**	30.212
<u>Normal</u>				
Schonell	5.793	8.013*	0.503	14.309
PIAT	0.473	0.036	1.915	2.425
<u>DIGIT STIMULI</u>				
<u>Reading Disabled</u>				
Schonell	1.192	29.569**	0.429	31.190
PIAT	5.023	2.916	1.266	9.205
<u>Normal</u>				
Schonell	2.330	6.626	0.691	9.647
PIAT	4.105	—	4.527	8.632

Note. The order of inclusion of each variable is determined by its contribution to the explained variance.
[1] Scored using the list method described in Chapter 4.
* $p < .05$
** $p < .01$

substantial proportion of variation in performance on Schonell or PIAT in the normal group.

C. Discussion

The purpose of the present experiment was to investigate the those variables which are common to span and reading. The relationships between item identification speed, item order and memory span were predicted to be the same for disabled and normal readers even though it was expected that there would be quantitative differences, that is normal readers would demonstrate superior performance on these tasks. It was found that quantitative differences did exist between the two reading groups on digit tasks, however only item order was related to digit span in both groups. In contrast, both quantitative and qualitative differences existed between groups for word tasks. That is, overall, normal readers performed better than disabled readers on word tasks. However, item order and naming time were related to word span in the disabled group while only item order was related to word span in the normal group.

The finding that word span is qualitatively different (i.e. is related to different component processes) for the two reading groups was unexpected. The source of this difference is word identification speed. The slow speed of word identification characteristic of the disabled reading group (Table 4.3) could have affected word span performance at either of two levels, accuracy or speed. It can be proposed that performance on word span could have been affected by slow speed at the level of accuracy, that is disabled subjects experienced difficulty in identifying words. However, this is highly unlikely since it was ascertained through performance on the Word Reading task that all subjects were accurate in pronouncing the words.

Alternatively, word identification speed could have affected span performance at the proficiency level. That is, even though disabled subjects were accurate in identifying words, they were not fast enough in doing so to successfully perform on the span task. As such, one second between successive presentations of words may not have allowed sufficient time to identify words as well as retain word order on the span task. Such an explanation can account for the confounding of item order and item identification on the word span task in the disabled group (Table 4.11). On the other hand, this was not found for digit stimuli since it would seem that the disabled group was able to identify digits fast enough to perform successfully on the span task.

A similar explanation is proposed to account for the unexpected relationship between word identification speed and word order among disabled readers (Table 4.9). Performance on the word order task required that subjects encode both identity and order so as to be able to reconstruct the order in which the words are presented. As in the span task, the one second interval between successive presentations of words on the order task may have been too fast and as such sufficient time was not allowed for the disabled subjects to complete performance requirements of this task. Thus, the unexpected relationship between word order and word identification speed was obtained.

Such an explanation cannot be proposed to account for the unexpected relationship between digit identification and digit order among normal readers (Table 4.9) since normal readers were identifying digits rapidly (Table 4.3). This relationship most probably represented the ordering strategy employed by normal subjects in reading the digit sheets of the Naming Time task. There was a tendency amongst normal subjects to read these sheets in an ordered manner, a line of digits followed by a pause. Some subjects also utilized a rhythmic strategy in reading similar to that used in Sesame Street productions.

So far it has been argued that qualitative differences in word span between groups may have occurred because disabled readers were slow in identifying words and as such one second between successive presentations of words on the span task may not have been sufficient to carry out the performance requirements of the span task. The hypothesis can thus be proposed that if disabled readers were allowed more time between successive presentations of words on the span task, this extra time would allow subjects to compensate for slowness in identification and the qualitative difference on word span between the two groups would disappear. Alternatively, even if a slower presentation rate was utilized on span, the qualitative difference would not disappear because the basic problem is in word identification speed and as such it is immaterial whether the presentation rate is fast or slow.

A supplementary experiment, Experiment 2, was thus carried out which is described in the next chapter.

V. EXPERIMENT 2

Based on the results of Experiment 1 it was determined that word span performance was qualitatively different for normal and disabled readers. This difference was attributed to a slowness in identifying words among disabled readers. It was reasoned that if the presentation rate of words on the span task was slowed down then the reading disabled may be able to compensate for their slowness and as such the qualitative difference between groups would be eliminated. However, even if more time was allowed, disabled readers still may not be able to overcome their basic difficulty in speed of identification and as such this difference would remain.

It was also found in the previous experiment that word identification speed and word order, originally conceptualised as independent of each other, were related. This was also attributed to a slowness in word identification speed when presentation rate on the order task was one word per second. It was reasoned that this may have occurred because a one second interval between the successive presentations of words was not sufficient to allow performance requirements on this task to be successfully completed. Thus, if the disabled readers are given more time to complete these requirements, the relationship between word identification speed and word order may be eliminated.

A second experiment was thus conducted. Two questions were studied. The first question was whether or not the qualitative difference between the two reading groups on word span would disappear when the presentation rate was slowed down from one word per second to one word every two seconds. The second question was whether or not the relationship between word order and word identification speed would disappear when the presentation rate was slowed down from one word per second to one word per two seconds. The method, results and a discussion of the results are presented in this section.

A. Method

Subjects

In Experiment 2 the same groups of subjects were used as in Experment 1. Testing was done two weeks after Experiment 1 and a total of three subjects were lost due to moving or illness. In Experiment 2, Group 1, the normal reading group, was comprised of thirty-eight subjects (27 males, 11 females) and Group 2, the disabled reading group was comprised of thirty-nine subjects (26 males, 13 females).

Tasks

The tasks used were Naming Time, Memory Span and Item Order for Words. The Naming Time task was identical to that

TABLE 5.1
ORDER OF ADMINISTRATION OF TASKS
FOR NORMAL AND DISABLED READING GROUPS

Order of Tasks	NORMAL READERS Number of Subjects	DISABLED READERS Number of Subjects
123	8	8
213	8	8
312	8	8
132	7	8
231	7	7

Note. 1 : Naming Time; 2: Memory Span; 3:Item Order

used in Experiment 1. Both Memory Span and Item Order were also identical to those used in Experiment 1, with one exception. That is, in both cases, the word cards were presented at a rate of one card every two seconds.

Procedure

The procedure was essentially a repetition of Experiment 1. All tasks were individually administered to subjects in any available quiet room in the school. Testing was completed in a thirty-minute session . The order of administration of tasks was counterbalanced and the same order was used for both groups. Table 5.1 summarizes the order of administration of tasks.

B. Results

The results of Experiment 2 are presented in four parts. Mean performances on the three tasks are compared across groups first. A comparison of performance trends on Item Order and Memory Span across presentation rates is discussed next. Thirdly, the interrelationships amongst performance on Item Order, on Naming Time and on Memory Span are dealt with. Finally, the relationships between reading achievement and performance on Item Order, Memory Span and Naming Time are examined.

Comparison across groups. It was predicted that the disabled group would demonstrate inferior performance on Naming Time, Memory Span and Item Order tasks. The means, standard deviations and level of significance of differences between the means of performance on all tasks for the normal and disabled groups are presented in Table 5.2. It can be concluded from the significant differences shown in this table that the disabled group performed poorly on all tasks. The prediction was therefore confirmed.

Comparison across presentation rates. It was expected that the mean performance of each group on Item Order and Memory Span tasks at a presentation rate of one word every two seconds would be greater than at a rate of one word every second. It was also predicted that trends in performance on the two tasks would be similar across presentation rates.

TABLE 5.2
COMPARISON OF GROUP MEANS ON EXPERIMENTAL VARIABLES

VARIABLE	DISABLED READING GROUP *M*	DISABLED READING GROUP *SD*	NORMAL READING GROUP *M*	NORMAL READING GROUP *SD*	*t*
Memory Span - Words[1]	3.474	0.584	4.230	0.669	5.28**
Memory Span - Words[2]	35.077	15.001	51.868	18.441	4.38**
Item Order - Words[1]	4.269	0.731	4.796	0.864	2.88**
Item Order - Words[2]	55.795	19.959	66.062	22.404	2.11*
Naming Time - Words	19.187	4.958	14.269	1.913	5.77**

Note. n = 39 for Disabled Reading Group; n = 38 for Normal Reading Group
[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* $p < .05$
** $p < .01$

Data obtained from experiments 1 (one word every second) and 2 (one word every two seconds) were compared. By comparing the means of each group at these two presentation rates (Table 5.3) it can be seen that performance at the slower presentation rate was better than at the faster rate. Also, the increase in item order performance in Experiment 2 for the disabled group was relatively greater than that of the normal group. This was not the case for span performance.

A 2 (groups) X 2 (presentation-rate) analysis of variance (ANOVA) with repeated measures on presentation rate was carried out to compare performance on Memory Span (list scores) across these rates. Significant main effects were obtained for reading groups, $F\ (1,\ 75) = 16.935$, $p < .01$, and presentation rate, $F\ (1,\ 75) = 5.589$, $p < .01$. No significant interaction effects were found, indicating that trends in performance were similar across the two rates of presentation. Similar results were obtained using item scores.

A similar analysis was done to examine the effect of slow presentation rate on Item Order. First an ANOVA using list scores was carried out. Significant main effects were found for reading groups, $F\ (1,\ 75) = 18.099$, $p < .01$ and presentation rate, $F\ (1,\ 75) = 79.018$, $p < .01$ and, as with for the Memory Span task, no significant interaction effect was obtained. The prediction that trends in performance would be similar across presentation rates even though the

TABLE 5.3
COMPARISON OF GROUP MEANS OF EXPERIMENTS 1 AND 2

	DISABLED READING		NORMAL READING	
TASKS	Experiment 1	Experiment 2	Experiment 1	Experiment 2
Memory Span Words[1]	3.213	3.474	3.744	4.230
Memory Span Words[2]	26.075	35.077	37.650	51.868
Item Order Words[1]	3.388	4.269	3.938	4.796
Item Order Words[2]	29.400	55.795	38.950	66.062
Naming Time Words	21.999	19.187	15.177	14.269

[1] Based on list scores described in Chapter 4.
[2] Based on item scores described in Chapter 4.

TABLE 5.4

CORRELATION COEFFICIENTS BETWEEN EXPERIMENTAL VARIABLES FOR NORMAL AND DISABLED READING GROUPS

GROUP	DISABLED		NORMAL	
Variable	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Words[1]	Memory Span - Words[2]
Naming Time (Words)	-0.3897** (-0.2658)*	-0.3305* (-0.3417)*	-0.1182 (0.0234)	-0.1167 (0.0266)
Item Order- (Words)[1]	0.4633** (0.5626)***	0.5717*** (0.6192)***	0.6331*** (0.3752)**	0.6422*** (0.2555)
Item Order (Words)[2]	0.4294** (0.4729)**	0.5709*** (0.5770)***	0.6724*** (0.4640)**	0.6752*** (0.4094)**

Note. Pearson Product Moment Correlation Coefficients computed between variables in Experiment 1 are shown in parentheses

[1] Scored using the list method described in Chapter 4

[2] Scored using the item method described in Chapter 4

* $p < .05$

** $p < .01$

*** $p < .001$

mean performance of each group on this task would be greater at the slower presentation rate was thus confirmed. Similar results were obtained using item scores.

Relationship amongst Item Order, Naming Time and Memory Span. It was hypothesized that significant correlations would be obtained between performance on Naming Time (negative), on Item Order (positive) and Memory Span. It was also expected that these variables would explain a substantial proportion of the variation observed on the span task. These hypotheses were tested using three types of analyses, Pearson Product Moment correlation coefficients, multiple regression analyses and partial correlations.

The correlation coefficients computed are presented in Table 5.4 with the values from Experiment 1 shown in parentheses. It can be seen that performance on Item Order is significantly related to Memory Span performance in both groups. Naming Time performance is only significantly related (negative) to Memory Span performance in the disabled group.

Multiple regression analysis using a forward inclusion procedure was done to determine whether or not a substantial proportion of the variation in span performance can be accounted for by performance on Naming Time and Item Order in each group. In this procedure, the order of inclusion of variables is determined by the respective contribution of each variable to the explained variance. Only those variables whose contribution is greater than one hundredth percent or more of the variance are included in this analysis.

The results of this analysis are summarized in Table 5.5. It can be seen from Table 5.5 that Item Order accounted for the largest percentage of the variation observed on Memory Span for both groups. For the disabled group only, Naming Time accounted for a fairly large percentage of the variation observed in span (9% - 12%) after the contribution due to Item Order was removed.

Partial correlation analysis was done to determine whether or not the relationship between Item Order and Memory Span was independent of Naming Time performance in both groups. The results are presented in Table 5.6 where it can be seen that the residual correlations between these two variables remain virtually unchanged from the Pearson Product Moment correlation coefficients. It can be therefore concluded that the relationship between span and order are independent of Naming Time.

Another partial correlation analysis was done to determine whether the relationship between Naming Time and Memory Span was influenced by Item Order performance. These results are summarized in Table 5.7. It can be seen here that the residual correlation between performance on Naming Time and Memory Span in the disabled group was independent of Item Order performance.

Finally, an examination of the Pearson Product Moment correlation coefficients obtained between performance on

TABLE 5.5

PERCENT VARIANCE ON MEMORY SPAN ACCOUNTED FOR BY ITEM ORDER AND NAMING TIME

	PERCENT VARIANCE		
	ITEM ORDER	NAMING TIME	TOTAL[3]
Reading Disabled			
Memory Span-Words[1]	21.469**	12.759**	34.228
Memory Span-Words[2]	32.595**	9.381**	41.977
Normal			
Memory Span-Words[1]	40.082**	1.838	41.920
Memory Span-Words[2]	45.589**	1.159	46.748

Note. The order of inclusion of each variable is determined by its contribution to the explained variance.

[1] Scored using the list method described in Chapter 4

[2] Scored using the item method described in Chapter 4

[3] Total = sum of variation explained by Item Order and Naming Time

** $p < .01$

* $p < .05$

TABLE 5.6

RESIDUAL CORRELATIONS BETWEEN MEMORY SPAN AND ITEM ORDER WHEN THE INFLUENCE OF NAMING TIME IS CONTROLLED IN NORMAL AND DISABLED READING GROUPS

GROUP	DISABLED		NORMAL	
Variable	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Words[1]	Memory Span - Words[2]
Item Order - Words[1]	0.4738** (0.4633)**		0.6411*** (0.6331)***	
Item Order - Words[2]		0.5904*** (0.5709)***		0.6783*** (0.6752)***

Note. Pearson Product Moment Correlation Coefficients are shown in parentheses.
[1] Based on scores computed using the list method described in Chapter 4
[2] Based on scores computed using the item method described in Chapter 4

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

TABLE 5.7

RESIDUAL CORRELATIONS BETWEEN MEMORY SPAN AND NAMING TIME WHEN THE INFLUENCE OF ITEM ORDER IS CONTROLLED IN NORMAL AND DISABLED READING GROUPS

GROUP	D I S A B L E D		N O R M A L	
Variable	Memory Span - Words[1]	Memory Span - Words[2]	Memory Span - Words[1]	Memory Span - Words[2]
Naming Time-	-0.4031**	-0.3731*	-0.1752	-0.1452
Words	(-0.3897)**	(-0.3305)*	(-0.1182)	(-0.1167)

Note. Pearson Product Moment Correlation Coefficients are shown in parentheses
[1] Based on scores computed using the list method described in Chapter 4
[2] Based on scores computed using the item method described in Chapter 4
** $p < .01$
* $p < .05$

TABLE 5.8
CORRELATION COEFFICIENTS BETWEEN
THE PERFORMANCE ON NAMING TIME AND ITEM ORDER
FOR NORMAL AND DISABLED READING GROUPS

GROUP	DISABLED	NORMAL
Variable	Naming Time Words	Naming Time Words
Item Order (Words)[1]	-0.0722	0.0274
Item Order (Words)[2]	-0.0430	-.0135

[1] based on scores computed using the list method described in Chapter 4
[2] based on scores computed using the item method described in Chapter 4

Item Order and Naming Time would indicate the independence of these two variables (Table 5.8). These variables were found to be related in Experiment 1 where it was proposed that this relationship may be due to fast presentation rate. It would seem that this proposition was confirmed.

<u>Relationship between reading achievement and experimental variables</u>. Two types of analyses were done to examine the relationship between reading achievement as measured by Schonell and PIAT and performance on Item Order, on Memory Span and on Naming Time. It was expected that performance on the three experimental variables would relate

to reading achievement within the two groups. The Pearson Product Moment correlation coefficients computed between these variables are summarized in Table 5.9. It can be seen from this table that performance on Naming Time is significantly related to reading achievement in the disabled group only. Performance on Memory Span is also marginally related to PIAT in this group. Again, performance on both Memory Span and Item Order are related to Schonell in the normal group.

A multiple regression analysis using a forward inclusion solution was done to determine whether or not a substantial proportion of variation in performance on Schonell and on PIAT can be accounted for by performance on the three experimental variables. The order of inclusion of each variable was determined by its contribution to the explained variance. Only those independent variables which account for one hundredth percent or more variance were included in the analysis.

As can be seen from Table 5.10, a large percentage of the variation in performance on Schonell and on PIAT can be accounted for by Naming Time performance in the disabled group only. In the normal group, performance on Memory Span accounted for a substantial proportion of the variation in Schonell performance. Thus the predicted relationships were only partially supported.

TABLE 5.9
CORRELATIONS BETWEEN READING ACHIEVEMENT AND EXPERIMENTAL VARIABLES FOR NORMAL AND DISABLED READING GROUPS

GROUP	DISABLED		NORMAL	
Variable	Schonell	PIAT	Schonell	PIAT
Memory Span - Words[1]	0.2537 (0.1930)	0.3408* (0.3090)*	0.4487** (0.2340)	0.1529 (0.0118)
Memory Span - Words[2]	0.2557 (0.2073)	0.1905 (0.3613)*	0.4723** (0.2671)*	0.1452 (-0.0666)
Item Order - Words[1]	0.0020 (0.2583)	0.0630 (0.4781)**	0.3543* (0.0909)	0.1106 (-0.1384)
Item Order - Words[2]	0.1360 (0.2659)*	0.0149 (0.3510)*	0.3586* (0.1927)	0.1226 (-0.1150)
Naming Time - Words	-0.5041*** (-0.5240)***	-0.4321** (-0.4530)**	-0.1712 (-0.2831)*	0.1838 (-0.0203)

Note. Pearson Product Correlation Coefficients computed in Experiment 1 are shown in parentheses
[1] Scored using the list method described in Chapter 4
[2] Scored using the item method described in Chapter 4
* *p* < .05
** *p* < .01
*** *p* < .001

TABLE 5.10

PERCENT VARIANCE ON SCHONELL AND ON PIAT ACCOUNTED FOR BY MEMORY SPAN, ITEM ORDER AND NAMING TIME

	PERCENT VARIANCE			
	MEMORY[1] SPAN	NAMING TIME	ITEM[1] ORDER	TOTAL[2]
Reading Disabled				
Schonell	0.386	25.413**	0.527	26.326
PIAT	3.505	18.671**	0.416	22.592
Normal				
Schonell	20.135**	1.156	1.417	22.708
PIAT	3.093	3.380	---	6.473

Note. The order of inclusion of each variable is determined by its contribution to the explained variance.
[1] Scored using the list method described in Chapter 4.
[2] Total = variation accounted for by Memory Span, Naming Time and Item Order.

** $p < .01$

* $p < .05$

C. Discussion

The purpose of this experiment was twofold: (a) to determine whether or not the qualitative difference in word span performance between normal and disabled groups would disappear when the presentation rate of words on the span task was slowed down; and, (b) to determine whether the relationship between word identification speed and word order obtained for the disabled group in Experiment 1 would disappear if presentation rate of words on the order task was slowed down. The results are discussed below.

The results of this experiment demonstrated that even though performance was higher for both groups when the presentation rate was slowed down, the components of performance on word span are still different for normal and disabled readers. However, slowing down of the presentation rate did allow the disabled subjects more time to meet the demands of the span task as can be seen from the increase in span performance (Table 5.3). Further, the independence of word identification speed and word order was obtained on the span task whereas in the previous experiment, performances on these variables was confounded.

Again, it would seem that slowing down the presentation rate on the order task must have allowed the disabled readers more time to successfully complete all of the performance requirements on the order task. This can be seen in the relatively greater increase in performance on the word order task in Experiment 2 among disabled readers

(Table 5.3).

Finally, the question may be asked if the differential use of mnemonic strategies may have influenced span performance in Experiment 2 since slower presentation rate is conducive to the application of these strategies (Torgesen & Houck, 1980). However, the comparision of group performance at the two presentation rates demonstrated that even though performance was higher in the second experiment, the trends in variation were similar across groups and across presentation rates. Thus, if mnemonic strategies were applied this was done in a similar manner across groups.

A general discussion of the results of the two experiments conducted is presented in the next chapter.

VI. GENERAL DISCUSSION

The purpose of the present study was to investigate the components skills in memory span as they relate to each other and as they account for differences in reading achievement. Children with average skill in reading were compared with those with reading disability. The major results obtained were: (a) significant correlations between word identification speed and word span in the disabled group only; (b) significant correlations between both digit and word identification and Schonell performance in the disabled group only; (c) a significant correlation between word identification speed and PIAT performance in the disabled group; (d) the absence of significant correlations between item identification and memory span and reading achievement in the normal group; (e) significant correlations between item order and memory span amongst both normal and disabled readers; and, (f) a significant correlation between word order and Schonell performance for the normal group only. A general discussion of these findings is presented below.

It can be concluded from the two experiments that the nature of word span performance is qualitatively different for normal and disabled readers. This difference involves the speed of word identification which is negatively related to word span performance in the disabled group only. This is most probably due to the use of different methods to identify words. It can be inferred from the mean performances obtained on item identification (Naming Time scores, Table 4.3) that the two groups are using different methods to identify words. The convergence of the means for digit and word identification speeds in the normal group would imply that this group is processing words almost as fast as digits. This would suggest that there is a tendency amongst normal readers to use a whole-word method to identify words. On the other hand, the large differences between these means for the disabled group would suggest that these readers may not be using a whole-word approach. Rather, these subjects may be identifying words by analyzing their parts.

That these two groups may be using different methods of attacking words during identification is supported by the work of Perfetti and Hogaboam (1975). These researchers investigated the relationship between single word decoding skills and comprehension among third and fifth grade students who were classified as high and low achievers in comprehension. Differences in the time taken to identify high frequency words were found between high and low achievers. It was reasoned that these differences reflected different methods of attacking words. That is, on the one hand, high achievers were using a whole-word approach to identify words. On the other hand, low achievers may attempt to use a whole-word approach and when this failed, they resorted to the analysis of parts of the word.

The utilisation of these two methods to identify words is not surprising when one takes into account instructional strategies. The approach commonly used to teach children to recognize the words used in this study is a visualisation one or the recognition of these words as wholes by sight (Hargis, 1982; Lerner, 1981). However, when children fail to successfully recognize these words by sight, alternative methods are taught such as the analysis of words at the level of letters or parts of words. These alternative methods are generally promoted in various kits which are used for supplementary instruction in reading (Hammill & Bartel, 1982). Thus, while normal subjects are successful in identifying words by visualisation, disabled subjects may be unsuccessful with this method of attack and as such resort to the use of other approaches which involve symbol-sound correspondences or phonological coding.

That the use or non-use of phonological coding is involved in the qualitative difference in word span performance between the two groups is also supported by the working memory model (Baddeley & Hitch, 1974). Baddeley et al. (1975) provided evidence that phonological coding underlies the relationship between identification speed and span performance. In a series of experiments which involved the manipulation of various task parameters, Baddeley et al. investigated the factors which affected word span performance among university students. One manipulation involved the syllabic length of words (one to five syllables) with recall of homogeneous lists of five words comprising span performance. It was found that span performance decreased with increasing syllabic length indicating the involvement of speech-like coding. In another manipulation, the effect of suppression (having subjects articulate a series of irrelevant items during span performance) on the visual and auditory span performances of university students was studied. Four conditions were used, auditory and visual control, and auditory and visual suppression. Words of two syllabic lengths (one and five) were used as stimuli. It was found that suppression decreased the performances of subjects on both auditory and visual span. However, the effect of word length on performance was only eliminated in the visual suppression condition. The elimination of the word length effect was taken by Baddeley et al. (1975) to mean that the articulation of irrelevant items suppressed the transformation of visually presented information into speech-like form for storage in the phonemic buffer. By comparision, material was already presented in a speech-like form in the auditory condition and as such suppression had no effect on word length.

If the involvement of phonological coding is basic to the relationship between word identification speed and word span, then this is consistent with the relationship obtained between these two variables for the disabled group in the present study since it has been discussed above that these subjects may have been using symbol-sound correspondences as a method of identifying words. The obtained relationship is consistent with the findings of other studies (Baddeley et al., 1975; Nicolson, 1981; Standing et al., 1980). These studies have demonstrated a relationship between word identification speed and word span across various groups: university students (Baddeley et al., 1975), community college students (Standing et al., 1980) and 8, 10, and 12 year old pupils (Nicolson, 1980).

The absence of relationships between word identification speed and word span for the normal group and between digit identification speed and digit span for both groups can be most probably attributed to the non-involvement of phonological coding since it was discussed that these items were being processed visually as wholes. However, the information processed cannot be stored in the phonemic buffer since it would have to be in a speech-like form. Thus the information will have to be stored in another buffer until recall, most probably a visual one. Baddeley and Hitch (1974) indicated the existence of such a buffer in working memory even though the evidence to support it was sparse.

One of the limitations of the present study is that it is focused on speed and not on the component processes which may underlie speed. As such it is difficult to conclude what types of processes the two methods of identification may represent. Nevertheless, it can be inferred that these methods may represent the use or non-use of automatic processing. It is proposed that there was a tendency amongst normal readers to identify items automatically, that is, they are identifying items without much conscious attention being directed to the type of item being identified. Such a proposition is based on the convergence of mean speeds for digit and word identification in this group (Table 4.3). However, this is not the case for the disabled group since the large differences between digit and word identification speeds would suggest that identification proceeds with the involvement of conscious attention.

The proposition that these two approaches may represent automatic and non-automatic processing, and that non-automatic processing may involve phonological coding is supported by the findings of other studies (Denckla & Rudel, 1974; Perfetti & Hogaboam, 1975; Rudel, Denckla & Broman, 1978). For example, Denckla and Rudel (1974) studied the performance of three groups of subjects-- learning disabled dyslexic subjects; learning disabled non-dyslexic subjects; and, a normal control group-- on the Rapid Automatized Naming (RAN) battery of tasks. In this battery, the subject's task is to orally identify sheets of fifty items (colors, pictured objects, upper- and lower-case letters and numbers). The time taken to identify each sheet of items is used as an index of performance. It was found that dyslexic subjects performed worst and normal controls best. Denckla and Rudel (1975) concluded that these differences may represent a failure of disabled subjects to automatize. In a subsequent study, Rudel et al. (1978) manipulated the RAN tasks in order to study the effect on performance of dyslexic and non-dyslexic children when the vocal response was eliminated from performance. The subject's task was now to cross out a target symbol (letters, numbers, triads of numbers and of letters) every time it appeared amongst a sheet of 140 items. The time taken to complete each sheet was used as an index of performance. It was found that only performance on sheets which contained letter and number triads as the target was able to distinguish between the two groups. A comparision of the findings of these two studies led Rudel et al. to conclude that the failure to automatize may be related to the relationship between speech and reading.

The use of automatic processing, that is, the execution of an activity without any conscious direction being directed to it, has been linked to the notion of limited-capacity (the availability of a fixed amount of attentional resources to perform on cognitive tasks) in current cognitive theories, particularly those that deal with skill acquisition (Neisser, Hirst & Spelke, 1981). For example, the notion that the speed of identifying words is crucial to successful performance in reading has been incorporated into current conceptualisations of how reading occurs (Gough, 1972; Laberge & Samuels, 1974; Lesgold & Perfetti, 1978; Perfetti & Roth, 1981). It is generally agreed that fluent reading requires the execution of many processes within a fixed amount of attentional resource. If less attention is directed to the execution of some of the lower-level component processes such as word recognition, then one can expect a greater allocation of attentional resources to higher level processes such as the integration of words into meaningful units in order to extract meaning. As such a fast rate of word identification or automatic identification may be crucial to successful performance on reading. The slow speed of item identification characteristic of the disabled readers in the present study may therefore be the key to an understanding of the nature of reading/disability.

If automatic processing within the framework of limited capacity is crucial to successful performance on cognitive tasks, then in the context of the present study, the question arises as to how to critically assess these two concepts in regard to performance on the Memory Span task. One method commonly employed to measure automatic processing is that used by McClelland and Jackson (1978) and Jackson (1980) to study individual differences in reading achievement amongst college students classified as high and low achievers in reading. Here, automatic processing was measured by the time taken to decide whether familiar objects, letters, unfamiliar objects and characters were the same or not. It is assumed in these studies that there are codes for familiar objects and letters in long-term memory (representations of familiar symbols in long-term memory) and that these codes are non-existent for unfamiliar objects and characters. These codes are formed after extensive exposure to the symbols they represent. Thus, if automatic processing is a factor contributing to individual differences in reading, only the time taken to decide whether familiar objects and letters are the same or not should differentiate between high and low reading achievers. This was found in these experiments and it was concluded that the use of automatic processing is a contributory factor to individual differences in reading achievement amongst college students. However, it would seem that this measure of automatic processing is somewhat superficial since one would assume that college students are automatic in accessing letter codes.

Alternatively, one can probably view automatic processing in terms of the involvement of the central processor in information processing. If no attentional resource is directed to identification of words on the span task, then this would suggest that cognitive activity is non-mediated through the central processor. If the activity is non-mediated, then the individual must be unaware of its processing. One possible way to critically assess these two notions on the span task is to test awareness of processing activity. If a subject is aware of the activity then it would mean that attentional resources are directed to it and that capacity or central processing time is involved. On the other hand, non-awareness of activity would suggest automatic processing and virtually no involvement of the central processor. This is suggested in the work of Hirst, Spelke, Reaves, Caharack and Neisser (1980) who devised simple tests (for example, recognition memory) to check whether subjects were aware of the material which was being processed automatically. One could consider incorporating such a test in the present study.

The speed of item identification was also found to relate to reading achievement in the disabled group (Table 5.9). There was virtually no such relationship between these two variables for the normal group (Table 5.9). It can be suggested from these results that identification or decoding speed predicts reading achievement in the disabled group and that reading achievement in this group is partially determined by what takes place at the level of the word. Such a conclusion is supported by the work of Shankweiler and Lieberman (1972) who in a developmental study tested the assumption that beginning readers may encounter difficulty at the level of the word rather than at connected text. The subjects comprised of second, third and fourth grade average readers who were of average or above average intelligence. Subjects were required to read word lists and paragraphs. Performance on word lists was found to be strongly related to paragraph reading and this finding led the researchers to conclude that a slow rate of reading words may contribute to inaccuracy in reading connected text.

The failure to obtain a significant correlation between order and reading achievement for the disabled group may have occurred as a result of the task used to measure order (Table 5.9). Informal observations would suggest that this task may not have been a pure measure of order in the disabled group. These subjects were using strategies such as rehearsal as evidenced by lip movements and the encoding of the initial letter of the words in order to remember the order of presentation of items. This may have occurred because the information content of the items were too high. Thus subjects were required to encode identity as well as order and this may have caused them to resort to the use of various strategies to remember the order of items. As such, a satisfactory method of assessing memory for order should be devised.

The development of a pure measure of order has been a critical problem in research in the area of order memory. The main problem centres around the development of a task which measures order without involving the encoding of identity. Various approaches have been used in other studies to solve this problem. Two of these approaches have been focused on minimizing the information content of stimuli on tasks which measure order so that identity requirements in performance are negligible. In the first approach, identical stimuli such as Knox cubes are used (Corkin, 1974). The cubes are placed in a left to right order on a table in front of the subject. The examiner taps the cubes in a pre-determined sequence and upon completion, the subject is required to retap the cubes in the same order. This manipulation is however methodologically flawed since the measurement of temporal order is confounded with spatial order. That is, the subject is required to encode temporal order from stimuli placed in a fixed spatial order. Subjects also generally use counting as a strategy to encode the order of the stimuli. Performance on the Knox cubes is thus dependent on at least two factors.

In the second approach, a fixed set of highly familiar items such as digits or consonants (Mason, Katz & Wicklund, 1975) is used. It is assumed that the use of highly familiar items minimizes the identity requirements of the task. However, the encoding of identity is still required in this procedure.

Cohen and his colleagues (Cohen & Gowen, 1978; Cohen & Sandberg, 1977, 1980) have used somewhat different measures of order memory. In the <u>probed serial recall</u> task, the subject is presented with a string of 9 digits and upon completion of presentation, he(she) is required to recall the first three digits (A digits), the middle three digits (B digits) or the final three digits (C digits) in the order of presentation. In the <u>running memory</u> task, the subject is provided with strings of digits varying in length. The subject, unaware of string length, is asked to repeat the last three digits in order. In these tasks, even though the identity requirements are minimized by the use of a fixed set of highly familiar items (9 single digits), performance may be confounded with the use of strategies because of the element of surprise in these tasks. For example, in the running memory task, the subject is unaware of when the presentation of digits will be terminated and as such he may try to ensure that that at all points during presentation the last three digits are active in memory. The development of a pure measure of order is thus a critical problem in research on order memory.

The relationship obtained between order memory and Schonell in Experiment 2 (Table 5.9) would suggest a link between the underlying processes in both tasks. This relationship would suggest that order and reading achievement are related at the level of the word. However, this finding must be interpreted with caution since it is not clear why order memory would relate to Schonell performance and not to PIAT. The question can be asked whether order is related to word recognition or to other behaviors associated with Schonell performance. The relationship between order and Schonell may have occurred as a result of directional constraints imposed on Schonell. Subjects are instructed to read the words from left to right on the Schonell test. It would therefore seem that the relationship between order and reading needs to be assessed in an appropriately designed experiment.

Mann, Lieberman and Shankweiler (1980) propposed the use of the Token Test (De Renzi & Vignolo, 1962) as an alternative to measure item order. This test has been used to measure impairment in receptive language comprehension in aphasics. Highly familiar stimuli (templates of circles and rectangles) are used and these are varied along the attributes of size and color. The subject is required to obey verbal commands of high information and increasing difficulty level. The commands are instructions which require the retention of ordered information so as to execute them correctly. For example, at the first level, the subject is only required to 'touch the green circle' while at the highest difficulty level, he is required to do the following 'before touching the yellow circle, pick up the red rectangle'. One advantage of using this test is that the commands are verbal and as such it eliminates the problem of visually processing the identity of items and as such these requirements should be minimal for the disabled subjects. Thus it may be useful in studying item order.

The major implication for practice which has arisen from this study is the necessity of training children to be both accurate and fast at recognizing words if successful achievement in reading is to be attained. Disabled readers in the present study were accurate in identifying words, however this was not enough to enable them to succeed on the span task. This suggestion is not novel. For example, Smith (1981) proposed that five elements should be incorporated in developing intervention strategies for learning disabled students. These are: acquisition, proficiency, maintenance, generalization and adaptation. The first two elements refer to the development of both accuracy and speed. Both Smith (1981) and Singer (1982b) provide concrete suggestions as to how teachers may incorporate speed in the curriculum for learning and reading disabled pupils respectively.

In summary, the present research was designed to address the issue of whether or not item identification speed and item order are components common to span and reading. The main conclusion of the present study is that the slow speed of item identification is common to performance on word span and reading achievement amongst disabled readers. It was suggested that the use or non-use of automatic processing may be central to understanding the issue of whether or not differences in working memory can account for differences in reading achievement. However certain key questions should be answered in regard to the concepts of speed of encoding, automaticity and the necessity of accepting a limited capacity in information processing (Neisser et al., 1981). There is also the unresolved problem of measuring memory for order without the burden of identifying the items whose order is to be recalled. The relative but separate contributions of item identification speed (naming time in the present study) and memory for order to individual differences in span have to be determined. It seems that only then can we begin to investigate into the connection, causal or otherwise, between reading on the one hand and the components of memory span on the other.

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APPENDIX A

Word Reading Task

APPENDIX A: Word Reading Task

Experimenter:

"I am going to show you some cards with words on them. I want you to say the word printed on each card as quickly and as correctly as you can.

Ready!...

Turn the cards over."

If a child misses a word, he is excluded from the sample.

DOLCH BASIC 220 WORD LIST

Pre-Primer	Pre-Primer
a	look
and	make
away	me
at	my
big	not
blue	one
can	play
come	red
down	run
find	said
for	see
funny	the
go	three
help	to
here	two
I	up
in	we
is	where
it	yellow
jump	you

DOLCH BASIC WORDS (Continued)

Primer

all
am
are
ate
be
black
brown
but
came
did
do
eat
get
good
have
he
into
like
must
new
no
now
on
our
out

Primer

yes
please
pretty
ran
ride
saw
say
she
so
soon
that
there
they
this
too
under
want
was
well
went
what
white
who
will
with

APPENDIX B

Naming Time

APPENDIX B: Naming Time

Naming Time for Words

Instructions:

1. Experimenter: "I am going to show you a sheet of words. I want you to read these words from left to right as quickly and as correctly as you can."

   First, we'll do a practice.

2. Have subject read the practice sheet and make sure he understands the instructions.

3. Experimenter: "*Now, I am going to time you. Ready!*"

   a. Give subject the first sheet.
   b. Start stopwatch when subject vocalizes the first word.
   c. Record the time taken to read each sheet.

Practice Sheet

let	old	of	his	give
may	put	his	over	then

blue	make	help	ran	two
up	good	came	now	at
eat	where	but	want	our
me	said	am	come	no
went	will	too	I	this
she	that	soon	into	pretty

can	three	is	saw	in
red	new	down	did	there
with	get	so	it	the
like	see	are	my	please
not	who	ride	one	they
white	on	run	must	black

look	go	ate	well	big
to	brown	say	away	funny
out	do	and	have	he
find	we	a	what	was
yes	play	be	jump	all
you	for	here	yellow	under

Naming Time for Digits

Instructions

1. Experimenter: "I am going to show you a sheet of numbers. I want you to read these numbers from left to right as quickly and as correctly as you can.

   First, we'll do a practice".

2. Have the subject read the practice sheet and make sure he understands the instructions.

3. Experimenter: "*Now, I am going to time you. Ready!*"

Practice Sheet

1	3	6	8	5
4	9	1	6	2

3	6	5	9	1
8	4	7	3	6
1	3	9	4	8
2	5	3	6	1
5	8	6	2	9
7	2	4	8	3

2	5	8	6	4
7	9	3	1	6
1	3	7	5	8
6	4	2	9	1
5	2	6	3	7
9	3	8	1	5

1	4	7	9	2
6	2	9	4	8
3	5	1	6	9
5	3	9	2	4
2	8	4	7	1
6	3	7	5	9

APPENDIX C

Memory Span

APPENDIX C: Word Span

Instructions

1. Experimenter: "I am going to show you some cards with a word printed on each. Read each silently as I show it to you. After I am finished, I want you to say the words in the same order as I showed them to you.

   Experimenter: *First, we'll do a practice.*"

2. Do practice trial.

   a. Present words at a rate of one word per second.
   b. After presentation, have subject tell you the words in the order presented.
   c. Record the subject's response.
   d. Make sure he understands the instructions, if not, do practice trial 2.

3. Do remainer of test.

   Experimenter: "*The lists will get longer as we go along. Ready!*"

4. Stop administering the test when child misses four consecutive responses of same length.

Word Span

Name:

2a. old,put	2b. may,let
3a. he,under,no 3c. three,at,can	3b. now,have,red 3d. make,am,my
4a. our,to,who,away 4c. one,be,under,good	4b. eat,black,say,my 4d. get,too,where,this
5a. blue,here,ride, are,well 5c. say,into,brown, is,have	5b. jump,soon,new, they,yes 5d. for,look,that, a,here
6a. said,red,well, with,do,help 6c. there,am,black go,must,my	6b. find,but,two,not went,yellow 6d. on,come,the,all, know,we
7a. please,out,funny, white,did,me, said 7c. will, yellow,up, ran,she,not,saw	7b. make,go,what, there,find,can, play 7d. want,come,brown, in,for,so,they
8a. big,saw,now, pretty,run,no, ate,down 8c. he,away,and,yes can,see,funny,new	8b. he,away,and,yes can,see, funny,new 8d. up,want,ran,white, blue,come, look,it
9a. she,three,what, all,play,too,was, 9c. came,one,into, are,went,this,at, he,was	9b. eat,did,two,I,now, the,jump,make,we 9d. good,where,get, be,you,down,red, to,three

Digit Span

Instructions

5. Experimenter: "I am going to show you some cards with a number printed on each. Read each silently as I show it to you. After I am finished, I want you to say the numbers in the same order as I showed them to you.

   Experimenter: *First, we'll do a practice.*"

6. Do practice trial.

   a. Present the digits at a rate of one per second.
   b. After presentation, have subject tell you the digits in the order presented.
   c. Make sure he understands the instructions, if not, do practice trial 2.

7. Do remainder of the test.

   Experimenter: "*The lists will get longer as we go along. Ready!*"

8. Stop administering the test when child misses four responses of the same length.

Digit Span

Name:

2a. 1,4

2b. 2,5

3a. 3,7.4

3b. 9,5,8

3c. 5,2,9

3d. 8,1,3

4a. 2,4,9,5

4b. 9,2,8,1

4c.8,6,9,3

4d. 3,8,2,4

5a. 4,2,6,9,5

5b. 5,1,7,4,8

5c. 8,2,9,3,6

5d. 9,4,6,8,5

6a. 5,1,9,4,8,2

6b. 7,2,8,6,1,4

6c. 9,3,1,8,2,7

6d. 6,8,4,2,9,1

7a. 2,6,3,8,5,9.4

7b. 3,1,6,2,4,9,7

7c. 3,5,8,4,6,9,1

7d. 9,4,1,5,8,2,6

8a. 2,7,3,5,9,6,1,4

8b. 8,6,1,3,7,4,2,9

8c. 9,4,6,3,8,5,1,7 8d. 6,8,3,7,9,5,1,4

9a. 4,8,2,6,3,9,5,7,1 9b. 8,1,9,4,6,3,7,5,2

9c. 9,5.7,3,6,1,8,2,4 9d. 5,7,4,9,3,8,6,1,3

Scoring Procedures

Two methods of scoring were used. Each is described separately below.

1. List Scores

   a. Serial Recall
      1) Basal Level = 2.00
      2) Each correct list in correct order = .25
      3) Total Score = 2.00 + x(.25) where x = number of correct lists recalled

   b. Free Recall

      1) Basal Level = 2.00
      2) Each correct list regardless of order = .25
      3) Total Score = 2.00 + x(.25) where x = number of correct lists recalled regardless of order

2. Item Scoring

   a. Serial Recall
      1) Number of items recalled in correct order = x
      2) Score = x points

   b. Free Recall
      1) Number of items recalled irregardless of order = x
      2) Score = x points

3. Penalties

   a. Subtract one point for each extra item added
      1) eg. "7,3,4,2,9,6"
         Subject's response: 7,3,4,**6**,2,9,6
         Score = 5 points

   b. This also includes repetition of digits
      1) eg. "7,3,4,2,9,6"
         Subject's response: 7,3,4,**3**,**4**,2,9,6
         Score = 4 points

APPENDIX D

Item Order

APPENDIX D: Item Order

Item Order for Words

Instructions

1. Experimenter: "I am going to show you some cards with a word printed on each. Read each silently as I show it to you. After I am finished, I am going to show you the same cards which are mixed up. I want you to put the words back in the same order in which I showed them to you.

   First, we'll do a practice trial."

2. Do practice trial.

   a. Experimenter: *"First, I'll show the cards to you. Read them silently."*
   b. Show the cards at a rate of one per second.
   c. Experimenter: *"Now, you give them back to me just as I showed them to you."*
   d. Experimenter: *"Is this how I showed them to you? Which was first? Which was last?"*
   e. Record the child's response.
   f. If child fails to understand the instructions, do trial 2.

3. Do the remainder of the test.

   a. Experimenter: *"The lists will get longer as we go along. Ready!"*

4. Stop administering the test when child misses four consecutive responses of the same length.

Item Order for Words

Name:

2a. know,after

2b. again,let

3a. funny,run,an
3c. ride,but,not

3b. up,yellow,we
3d. went,new,brown

4a. pretty,jump,will
are
4c. big,who,to,soon

4b. make,like,blue,
with
4d. where,ate,now,it

5a. she,out,do,
white,there
5c. they, out,with,
not,up

5b. but,can,funny,
into,down
5d. black,play,ride
said,help

6a. good,have,did
my,look,want
6c. but,that,new
saw,yellow,one

6b. say,and,have
brown,too,under
6d. big,must,find
eat,get,so

7a. ate,we,you,here
what,well,our
7c. that,no,come,help
at,me,three

7b. I,on,went,all
in,see,ran
7d. two,go,pretty,came
be,red,for

8a. was,eat,the,am
run,this,you,so
8c. yellow,come,white,
went,me,what
look,as

8b. he,to,is,yes,soon
see,who,too
8d. make,play,please,
there,two,brown
say,are

9a. on,under,it
down,well,not
at,ride
9c. he,all,red,will
where,yes,find,
blue,jump

9b. into,away,for,
want,go,must
funny,good,black
9d. saw,please,three,
said,run,came,
am,our,get

Item Order for Digits

Instructions

1. Experimenter: "I am going to show you some cards with a number printed on each. Read each silently as I show it to you. After I am finished I am going to show you the same cards which are mixed up. I want you to give the numbers back to me in the same order in which I showed them to you.

   First, we'll do a practice trial!"

2. Do practice trial.

   a. Experimenter: *"First, I'll show the cards to you. Read them silently."*
   b. Show the cards at a rate of one per second.
   c. Experimenter: *"Now, give them back to me just as I showed them to you."*
   d. Experimenter: *"Is this how I showed them to you? Which was first? Which was last?*
   e. Record the child's response.
   f. If the child fails to understand the instructions, do trial 2.

3. Do remainder of test.

   "The lists will get longer as we go along. Ready!"

4. Stop administering the test when the child misses four consecutive responses of the same length.

Item Order

Name:

2a. 1,3 | 2b. 2,9

3a. 3,8,5
3c. 6,1,4

3b. 9,5,2
3d. 1,8,5

4a. 3,7,9,4
4c. 4,7,2,8

4b. 5,2,9,3
4d. 6,3,1,7

5a. 2,1,8,5,3
5c. 4,2,8,6,1

5b. 5,7,3,8,2
5d. 1,6,9,2,5

6a. 1,9,2,6,8,5
6c. 2,6,4,9,1,3

6b. 5,3,1,9,2,6
6d. 8,1,7,5,2,6

7a. 1,9,2,6,3,5,8
7c. 2,9,3,7,5,8,4

7b. 1,6,4,8,2,7,5
7d. 7,3,9,2,8,5,1

8a. 8,1,7,3,5,2,4,9
8c. 1,6,3,9,4,2,5,7

8b. 4,9,3,1,6,2,7,5
8d. 8,4,7,3,5,2,6,1

9a. 7,1,8,2,6,4,9,5,3
9c. 7,9,4,6,2,8,1,5,3

9b. 4,1,7,2,5,9,3,6,8
9d. 5,3,9,4,6,1,8,2,7

Scoring Procedures

5. List Scoring

   a. Basal Level = 2.00
   b. Each correct list reproduced = .25
   c. Total Score = 2.00 + x(.25) where x = number of correct lists reproduced

6. Item Scoring

   a. Number of items reproduced in correct order = x
   b. Total Score = x points