7-1984

An investigation of the relationship between processing rate and memory span in learning disabled children

Jeffrey Wayne Gray
University of Nebraska at Omaha

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN PROCESSING RATE AND MEMORY SPAN IN LEARNING DISABLED CHILDREN

A Thesis

Presented to the

Department of Counseling and Special Education

and the

Faculty of the Graduate College

University of Nebraska

In Partial Fulfillment

of the Requirements for the Degree

Master of Arts

University of Nebraska at Omaha

by

Jeffrey Wayne Gray

July, 1984

THESIS ACCEPTANCE

Accepted for the faculty of the Graduate College, University of Nebraska, in partial fulfillment of the requirements for the degree Master of Arts, University of Nebraska at Omaha.

Committee

Name	Department
[illegible]	Couns. & Spec. Educ.
[illegible]	Psychology
Scott Harrington	Couns. & Spec. Educ.

Don [illegible]
Chairman

7/6/84
Date

AN INVESTIGATION OF THE RELATIONSHIP BETWEEN PROCESSING RATE AND MEMORY SPAN IN LEARNING DISABLED CHILDREN

Jeffrey W. Gray

Thomas C. Lorsbach Thesis Supervisor

ABSTRACT

Slow rate of information processing has been offered as an explanation for the short-term memory problems of learning and/or reading disabled children (e.g., Spring & Capps, 1974). The present investigation used an item identification task and a memory span task to determine whether, when learning and/or reading disabled and non-disabled children are equated with regard to the speed with which they process information, their measured memory spans are also equal. It was hypothesized that the observed memory span differences would be eliminated by equating the two groups on a measure of processing rate.

ACKNOWLEDGMENTS

The writer wishes to express appreciation to his thesis committee for their guidance and expertise: Dr. Thomas Lorsbach, Dr. Scott Harrington, Dr. Richard Blake, and Dr. Gregory Simpson.

Gratitude is also expressed to the administrators, teachers, and students of the Millard Public School District, Omaha, Nebraska, for their cooperation throughout this study.

Finally, a special note of thanks is extended to the writer's wife. Her love, patience, and encouragement greatly facilitated the completion of this project.

TABLE OF CONTENTS

LIST OF TABLES

Chapter 1

THE PROBLEM

Introduction to the Problem

A considerable amount of evidence indicates that learning and/or reading disabled children experience difficulty on a number of short-term memory tasks. For example, it has been demonstrated that these children are consistently deficient on digit span tests (Klasen, 1972) and various other serial memory tests (Doehring, 1968). At least two factors may contribute to this observed deficit. First, learning and/or reading disabled children may fail to utilize important mnemonic strategies such as rehearsal, grouping, and chunking. For example, Bauer (1977) and Tarver, Hallahan, Kauffman, & Ball (1976) have demonstrated that learning disabled children fail to spontaneously utilize rehearsal strategies. Second, learning disabled children may utilize these strategies, but because they process information slowly, they may not have enough time to employ them efficiently. For example, Spring and Capps (1974) have demonstrated that dyslexic children display unusually slow speech-motor encoding which decreases the amount of time available for effective rehearsal. Several studies have concluded that mnemonic strategies cannot account for the developmental and individual differences that exist on short-term memory tasks (Cohen & Sandberg, 1977; Keating & Bobbitt, 1978; Lyon, 1977; Huttenlocher & Burke, 1976; Torgesen & Houck, 1980). Most of these studies have tentatively suggested that the rate with which information is processed is an important factor in these short-term memory difficulties (Keating & Bobbitt, 1978; Lyon, 1977; Huttenlocher & Burke, 1976; Torgesen & Houck, 1980). The following literature review will examine the relationship between rate of processing and short-term memory span.

Definition of Terms

The term rehearsal referred to a strategy which facilitated the transfer of sensory information from a transient limited capacity short-term store to a more permanent large-capacity long-term store.

The term grouping ("chunking") referred to a strategy by which a subject imposed grouping or "chunking" on a list of items that were to be remembered.

The term information processing referred to the sequence of mental operations that were used to analyze and interpret incoming information.

The term information processing rate referred to the rate with which an individual moved through the sequence of mental operations.

The term "automatic" processing referred to processing which required minimal amounts of cognitive capacity.

The term "effortful" processing referred to processing which required a significant amount of mental resources.

The term item identification speed referred to a measure of information processing rate which primarily measured the speed with which a subject was able to identify a given item of information.

The term naming or vocalization latency referred to the minimum amount of time required for a subject to identify or orally name a single item.

The term memory span referred to the number of items that an individual recalled immediately, in their original order, following a single presentation.

The term learning disabled referred to those children in the Millard Public School District who had been identified according to the following definition:

> Specific learning disability means a disorder in one or more of the basic psychological processes involved in understanding or in using language, spoken or written, which may manifest itself in an imperfect ability to listen, think, speak, read, write, spell, or do mathematical calculations. The term does include such conditions as perceptual handicaps, brain injury, minimal brain dysfunction, dyslexia, and developmental aphasia. The term does not include children who have learning problems which are primarily the result of visual, hearing, or motor handicaps, or mental retardation, or emotional disturbance, or of environmental, cultural, or economic disadvantage (Office of Education, Department of Health, Education, and Welfare, 1977, p. 65803).

The term non-learning disabled referred to those students in the Millard Public School District who had not been identified as learning disabled and who were demonstrating normal school progress.

The term nominal equivalence referred to those stimuli that were from a specific class (e.g., digits, letters, colors, shapes, animal pictures, "use" objects, toys, and nonsense words) and that produced significantly different naming latencies in learning disabled and non-learning disabled children.

The term functional equivalence referred to those stimuli that were obtained from different stimulus classes, but produced comparable naming latencies in learning disabled and non-learning disabled children.

Statement of the Statistical Hypotheses

The following null hypotheses were tested at the .05 level of significance.

HO_1 No significant difference exists between the vector of means for learning disabled and non-learning disabled children when the dependent variable of naming latency is considered.

HO_2 No significant difference exists between the vector of means for the effects of stimulus type (digits, letters, colors, shapes, animals, "use" objects, toys, and nonsense words) upon the performance of learning disabled and non-learning disabled children when the dependent variable of naming latency is considered.

HO_3 No significant interaction exists among the vector of means for learning disabled and non-learning disabled children and stimulus type (digits, letters, colors, shapes, animals, "use" objects, toys, and nonsense words) when the dependent variable of naming latency is considered.

HO_4 No significant difference exists between the vector of means for learning disabled and non-learning disabled children when the dependent variable of naming latency for nominal stimuli (letters) is considered.

HO_5 No significant difference exists between the vector of means for learning disabled and non-learning disabled children when the dependent variable of naming latency for functional stimuli ("use" objects and toys) is considered.

HO_6 No significant difference exists between the vector of means for learning disabled and non-learning disabled children when the dependent variable of memory span is considered.

HO_7 No significant difference exists between the vector of means for the effects of stimulus type (letters, "use" objects, and toys) upon the performance of learning disabled children and the performance of non-learning disabled children when the dependent variable of memory span is considered.

HO_8 No significant interaction exists among the vector of means for learning disabled and non-learning disabled children and stimulus type (letters, "use" objects, and toys) when the dependent variable of memory span is considered.

Chapter 2

REVIEW OF RELATED LITERATURE

Information Processing

Cognitive psychologists have described the sequence of mental operations that are used to analyze and interpret incoming information. For example, Wickens (1974) has utilized a four-stage of information processing model which consists of a sensory store, a perceptual system, a response selection mechanism, and a response execution mechanism. During the initial stage of processing an exact replica of the sensory stimulus information is received and stored for a brief period after the removal of the stimulus. At the second stage of processing, only certain parts of the total sensory stimulus information is attended to. Within this stage, the attended stimulus information is both received and encoded for future use. The third stage of processing involves analysis of information received from the perceptual system and selection of appropriate responses. Finally, it is during the fourth stage of processing that the selected response is executed or carried out.

A central feature of recent models (e.g., Kahneman, 1973; Norman & Bobrow, 1975) is that one's cognitive capacity is limited. At any given moment, only a limited amount of cognitive capacity is available for performing various mental operations. Therefore, it is imperative that conscious, "effortful" processing is eventually replaced by more "automatic" processing. The rate with which an individual moves through the sequence of mental operations is taken as an indicator of the automaticity of the processing. There is a developmental component associated with the rate with which individuals execute stages of information processing. Younger children initiate memory processes in a rather deliberate, "effortful" fashion. Later, with development and/or practice, processing becomes more automatic (Sternberg & Wagner, 1982). Several studies indicate that while normal children learn to perform tasks automatically, learning and/or reading disabled children continue to perform tasks in a controlled, "effortful" manner (Eakin & Douglas, 1971; Guttentag & Haith, 1978; Sternberg & Wagner, 1982).

Developmental Differences in Processing Rate

A considerable amount of evidence indicates that younger adults are faster than children on a variety of tasks (Bisanz, Danner, & Resnick, 1978; Bisanz & Resnick, 1978; Blake & Beilin, 1975; Chi, 1977; Eckert & Eichorn, 1977; Fairweather & Hutt, 1978; Henderson, 1974; Herrman & Landis, 1977; Keating & Bobbitt, 1978; Naus & Ornstein, 1977; Schvaneveldt, Ackerman, & Semlear, 1977; Surwillo, 1977). Virtually all of the developmental studies on reaction time have shown that reaction time decreases as children mature.

A variety of experimental procedures have been used to measure processing rate in children. One group of procedures primarily measures the speed with which a subject is able to identify a given item of information. Dempster (1981) has examined four measures that involve the speed with which an individual identifies items: item recognition time, naming/vocalization latency, retrieval of name codes from long-term memory, and speed of short-term memory. Item recognition time refers to the minimum exposure duration required for a subject to correctly recognize a stimulus at least 50 percent of the time. Several studies have compared younger and older subjects on the measure of item recognition time. Samuels, Begy, and Chen (1975-76) required fourth graders and college undergraduates to read aloud ten previously learned target nouns. The college students exhibited significantly faster response times than the fourth graders. The investigators inferred from these results that adults recognize familiar words almost twice as fast as children. Consistent with these findings are the results of a study by Chi (1977). This investigator employed a familiar face recognition task designed to compare the item recognition times of five-year-old and adult subjects. She found that children exhibited significantly longer item recognition times than adults. From these results, Chi concluded that item recognition time appears to decrease throughout childhood.

Naming or vocalization latency refers to the minimum amount of time required for a subject to identify or orally name an item. Several studies have compared younger and older subjects on the measure of naming or vocalization latency. For example, Hess and Radtke (1981) measured the item identification speeds of children in the third through eighth grades. They presented the children with twenty line-drawings of common animals and objects and instructed them to name each picture as quickly as possible. The pictures were presented simultaneously on separate sheets of paper with five rows of four pictures on each sheet. The total response time for each set was recorded, from initial presentation to the onset of the subject's response. These investigators found that naming latencies decreased significantly with age. They concluded from their results that younger children are slower than older children in the retrieval of higher-level semantic information.

Similarly, Biemiller (1977-78) examined and compared the oral reading rates of children in grades 2-6 and adults. He presented each subject with a 100-word text passage, two 50-word lists, and two 50-letter lists and instructed them to orally read each as quickly as possible. The words and letters were presented simultaneously from left to right with single spaces between each word or letter. Reading speeds were recorded from the onset of reading to the conclusion of the list and were reported in terms of mean response time per letter or word. Second graders exhibited significantly slower reading rates than adults. The results were interpreted to indicate that the time required to identify letters and words decreases as children develop.

Finally, Case, Kurland, and Goldberg (1982) measured the word vocalization speeds of children ranging in age from 3 to 6 years. Each subject was presented with three blocks of seven common nouns and instructed to repeat each word back as quickly as possible. The words were presented successively via a tape recorder. The tape recorder was connected to a millisecond timer which was triggered by inaudible "beeps" that were placed immediately following each item. A hand held microphone, which was also connected to the timer, was adjusted to stop the timer at the onset of the subject's voice. This procedure enabled them to measure the subject's response speed for each individual item. Three-year-olds exhibited significantly slower naming speeds than six-year-olds. The investigators interpreted their results within a limited cognitive capacity context and suggested that younger children are less efficient at executing a set of mental operations than older children. Therefore, younger children presumably require a larger amount of operating space which limits the space available for storage.

The letter-matching task developed by Posner and Mitchell (1967) also may be used as a measure of processing rate. Subjects are presented with pairs of letters and are requested to judge the similarity of the letters on the basis of certain criteria. Subjects typically require more time to judge that letters are identical in name (e.g., Aa or Bb) than they do to judge that letters are physically the same (e.g., AA or BB). This difference reflects, or is an indication of, the additional time needed to retrieve name information from long-term memory. Three studies have utilized this paradigm with children and have demonstrated that significant developmental improvement in name retrieval speed does occur (Bisanz, Danner & Resnick, 1979; Keating & Bobbitt, 1978; Reitsma, 1978). Using a slightly different paradigm, Duncan and Kellas (1978) found corresponding developmental increases.

Consistent with the hypothesis that younger children process information more slowly than older children and adults are the results of Surwillo (1977). This investigator employed a modified version of the Posner and Mitchell task to assess the subject's total decision time. An estimate of decision time was made by subtracting the average simple reaction time from the average choice reaction time. Decision time was defined as the amount of time required to process one "bit" of information. An analysis of the data indicated that five-year-old boys took nearly three times longer than seventeen-year-old boys to process one "bit" of information. Surwillo interpreted these results as evidence that processing rate, as measured by the amount of time needed to process one bit of information, is a function of age.

One of the more common indices of processing rate is the Sternberg task. Subjects are presented with a set of items to be remembered and then presented with a probe item that is to be rapidly judged as to whether or not it was included within the initial set. Developmental studies employing the Sternberg task have been rather conflicting. For example, Harris and Fleer (1974) demonstrated that no developmental change in speed of scanning exists for 8, 16, and 24-year-olds, whereas Herrman and Landis (1977) found a substantial increase in the speed of scanning for 7, 12, and 17-year-olds.

To summarize this section, the above studies have utilized various procedures to compare younger and older subjects on measures which serve as indices of the rate of information processing. One group of studies has used item recognition time tasks to assess the rate of information processing. Dempster (1981) and Chi (1977) have suggested that item recognition time is a rather superficial measure of item identification, but does assess the speed of at least the initial stage of item identification. Studies using this procedure have provided evidence that item recognition time decreases throughout childhood.

A second group of studies has compared younger and older subjects on tasks measuring naming/vocalization latency. Various procedures and stimuli have been utilized to obtain naming/vocalization latencies. Dempster (1981) has suggested that naming or vocalization latency is the most appropriate and accurate index of information processing rate. Studies using this measure have concluded that time required to identify stimulus items decreases as children develop.

A third group of studies utilized rate of name retrieval from long-term memory as an index of information processing rate. These studies found that significant developmental increases in retrieval speed do occur.

Finally, a group of studies has used a rate of scanning paradigm to measure item identification speed. Studies utilizing this paradigm have produced conflicting results. A number of these studies found developmental increases in the rate of scanning items, whereas others found no significant increase. Salthouse (1983) suggested that these inconsistencies may be attributed to differences in the amount of practice that subjects received prior to the test trials.

Virtually all of the previously cited studies have shown that reaction time decreases significantly with development. Wickens (1974) has tentatively concluded that the results of these studies suggest that developmental differences do exist in processing rate, but that non-processing factors such as incentive, motivation, attentiveness, and practice cannot be ruled out.

Processing Rate in Language-Learning Disabled Children

Numerous studies have measured the speed with which learning and/or reading disabled children name various stimuli. Given that naming/ vocalization latency is a valid measure of processing rate, these studies suggest that learning and/or reading disabled children are significantly slower to process information than non-disabled children. For example, Spring and Capps (1974) measured the naming speeds of dyslexic and non-dyslexic boys ranging from 7 to 13 years old. They presented each child with 50 randomly sequenced digits, 30 color patches, and 25 line-drawings of common pictures, and instructed the child to name each item as quickly as possible. Each type of stimulus was presented simultaneously in a horizontal row. Naming speeds were reported in terms of items per second. The investigators found that dyslexic boys were significantly slower at naming all three stimulus types than their non-dyslexic peers. They inferred from these results that dyslexic children have unusually slow speech-motor encoding skills.

Using the same stimuli and procedure, Spring (1976) assessed the naming speeds of dyslexic and non-dyslexic boys ranging from 7 to 12 years old. Again, dyslexic boys were slower than their non-dyslexic peers. The results indicated that the differences between the two groups were proportionately larger on digit naming speed than on speed of naming colors and pictures. Spring used these results as support for the hypothesis that dyslexic children experienced greater difficulty on tasks requiring perception of verbal, as opposed to concrete, stimuli.

Similarly, Denckla and Rudel (1976a) measured the naming speeds of learning disabled and non-disabled children between the ages of 8 and 11. The learning disabled subjects were divided into dyslexic and non-dyslexic groups. The children were successively presented with 36 line drawings of common objects and were instructed to name each picture as quickly as possible. The pictures were divided into high and low frequency groups. Naming speeds were reported in terms of the mean response latency for each frequency group. These investigators found that both dyslexic and non-dyslexic groups of learning disabled children were significantly slower in the naming of high frequency pictures than the normal control group. However, only the dyslexic group exhibited naming speeds slower than the normal control group for low frequency pictures. These findings, in combination with obtained error results, were interpreted to suggest that the dyslexic group may be experiencing linguistic retrieval problems, whereas the non-dyslexic group may be experiencing perceptual problems.

In a second study, Denckla and Rudel (1976b) compared the rapid "automatized" naming capabilities of normal and learning disabled children between the ages of 7 and 12. The learning disabled subjects were again divided into dyslexic and non-dyslexic groups. The investigators utilized four classes of stimuli: colors, numbers, "use" objects, and common lower-case letters. Each class of stimuli was presented on a 50-item chart, consisting of rows of five items repeated in random order. The stimuli were presented simultaneously proceeding left to right, row by row. Subjects were instructed to name each item on the chart as quickly as possible. The total naming time for each chart was recorded, from the experimenter's instruction to commence to the completion of the child's last spoken word. They found that the groups differed on latency but not on accuracy measures. The learning disabled group (both dyslexic and non-dyslexic) took significantly longer to generate stimulus names than the normal group. The investigators suggested that these results may indicate that dyslexic children experience a basic word-retrieval problem.

In a related study, Perfetti and Hogaboam (1975) compared the vocalization latencies of third and fifth grade children who were classified as either skilled or less-skilled in reading comprehension. These investigators presented each subject with 40 experimental words which had previously been classified as high frequency, low frequency, and pseudowords. The children were instructed to say each word with the highest degree of accuracy and speed. The words were presented successively on 2 X 2 inch slides. Projection of the word on the screen started a timer that was terminated with the onset of the child's vocalization. Skilled readers exhibited shorter vocalization latencies than less skilled readers for all word classifications. Likewise, it was found that less-skilled readers exhibited significantly slower vocalization latencies for low frequency and pseudowords than they did for high frequency words. Skilled readers, on the other hand, exhibited only small differences between the three classes of words. Perfetti and Hogaboam offered these results as evidence that skilled readers decoded oral words more rapidly than less-skilled readers. Because less-skilled readers do not have automatic decoding skills, more of their central processing capacity is needed on tasks demanding these skills.

Consistent with the findings of the previously cited studies are the results of a study by Torgesen and Houck (1980). These investigators compared the naming speeds of learning disabled and non-learning disabled fifth graders. The learning disabled group was divided into two subgroups. The first subgroup (LD-S) consisted of learning disabled children who had previously been diagnosed as experiencing short-term memory difficulties. The second subgroup (LD-N) consisted of learning disabled children who were not experiencing short-term memory difficulties. The investigators presented each child with line drawings of animals and digits and instructed them to name each item as quickly as possible. The stimuli were presented simultaneously in horizontal rows. Naming speeds were calculated for each trial by dividing the total naming rate by 36 and were reported in terms of seconds-per-item. The results indicated that the LD-S group named the animal pictures significantly slower than the LD-N and non-LD groups. These investigators suggested that their results indicated that learning disabled children who encounter short-term memory difficulties may experience slow access to name codes.

Tarver and Ellsworth (1980) measured the naming speeds of first, third, fifth, and seventh grade learning disabled children. Each child was presented with a number of familiar animal pictures and was asked to name each picture as quickly as possible. The pictures were presented simultaneously in a horizontal row. Naming speeds were recorded to the nearest half-second and were reported in terms of mean response time per item. The results indicated that the first graders took twice as long to name the pictures as did the other children, and that the other three grades did not significantly differ. The investigators suggested that their results were consistent with the hypothesis that learning disabled children experience slow stimulus name retrieval which contributes to limited verbal rehearsal under rapid stimulus presentation rates.

Finally, Wiig, Semel, and Nystrom (1982) utilized two separate experimental naming tasks to compare the rapid naming abilities of learning disabled and non-disabled eight-year-olds. Learning disabled children used in this study all experienced word-finding difficulties. The two experimental tasks were taken from the Clinical Evaluation of Language Function (Semel & Wiig, 1980a, 1980b). The first task, Naming Pictured Objects, required each subject to rapidly name eight common objects. The stimuli were presented simultaneously in four horizontal rows which were randomly arranged on 8 X 11 inch cards. The second task, Producing Names on Confrontation, required each subject to rapidly name 36 colored indexes, shapes, and color-forms. Each stimulus class was randomly sequenced on three separate cards and was presented simultaneously in horizontal rows. Naming speeds for both tasks were recorded and reported in terms of total response time per task. The total number of items named correctly was also recorded. The investigators found that the learning disabled children were both slower and less accurate at naming stimulus items than the non-disabled control group. From these findings, the investigators concluded that the previously mentioned experimental measures could to some extent differentiate children with diagnosed language and learning difficulties from their non-disabled peers. They also suggested that total naming time was a more powerful or sensitive index of individual differences than accuracy.

In summary, the above studies used various procedures and stimuli to compare the naming/vocalization latencies of language/learning disabled and non-disabled children. The results of these studies suggest that learning disabled children are significantly slower at retrieving stimulus information than their non-disabled peers. These results support the hypothesis that learning disabled children process stimulus information more slowly than non-disabled children. The next question to be addressed is whether the rate with which information is processed is related to short-term memory span.

Relationship Between Rate of Information Processing and Memory Span

Memory span has generally been defined as the number of items that an individual can recall immediately, in their original order, following a single presentation (e.g., Blankenship, 1938; Bremer, 1940). Although there are several theoretical models that can be used as a framework for understanding memory span, it may be perhaps best understood within the working memory framework developed by Baddeley and Hitch (1974).

Working memory corresponds to the common definition of short-term memory, but places a greater emphasis upon the role of short-term memory as an available working storage system. Working memory is divided into two components: A central executive and an articulatory loop. Within this framework, the central executive is responsible for information processing and decision making. The articulatory loop is under the control of the central executive and stores a small amount of verbal information in correct serial order by encoding it in phonological forms. The articulatory loop is responsible for sub-vocal rehearsal of stored information and can function as a supplement to the central executive. The central executive may facilitate articulatory loop storage by recoding material in a more efficient form, or can store information itself. According to the working memory model, performance on a memory span task is dictated by the capacity of the articulatory loop and the ability of the central executive to supplement its limited capacity. Baddeley and Hitch (1977) suggest that the memory span difficulties of learning and/or reading disabled children may be due to inadequate utilization of the articulatory loop.

There have been several theories relating memory span and the rate of information processing. Salthouse (1983) has hypothesized that if one individual can carry out the fundamental operations of either rote or elaborative rehearsal more rapidly than a second individual, the first individual will experience superior recall. The recall advantage is due to the fact that the first individual is able to perform more total rehearsals than the second individual in a given amount of time. This example indicates that the stability and stature of the short-term memory trace is influenced by the rate with which relevant short-term memory operations can be executed.

Case et al. (1982) have discussed two theoretical constructs (storage space and operating space), both of which were conceptualized within a limited processing framework. Storage space was defined as the hypothetical amount of space that an individual has available for storing information in short-term memory. Operating space was referred to as the hypothetical amount of space that an individual has available for carrying out memory operations. Given these constructs, Case et al. hypothesized that as children develop, the amount of operating space required decreases as a result of increased efficiency in the execution of memory operations. Thus, as less space is required for operations, more becomes available for storage. The observed developmental improvement in memory span is due to a reduced requirement in operating space which increases the available storage space.

Cavanagh (1972) has hypothesized that an inverse relationship exists between short-term memory span and processing rate. Thus, the greater the memory span, the faster the rate of processing.

Several developmental studies have examined the relationship between processing rate and short-term memory span. For example, Chi (1977) compared five-year-olds and adults on measures of naming speed, encoding speed, and memory span. This investigator found that it took children more than twice as long to retrieve and encode familiar face names. The children also exhibited inferior memory span performances. The investigator concluded from these results that the observed slowness in initial processing may be responsible for the observed memory span differences. To test this hypothesis, Chi shortened the adults exposure duration for each item to half its original length. Presentation of stimuli at shorter durations dramatically reduced the previous memory span differences between children and adults.

Consistent with these findings are the results of a study by Case, Kurland, & Goldberg (1982). A memory span task and a naming speed task were used to determine whether the development of short-term memory span is monotonically related to the rate with which subjects can process information. The subjects were children in the age range from 3 to 6. Three-year-old children were slower to name and had an inferior span performance than 6-year-olds. A correlational analysis indicated that the relationship between speed and span was monotonic and approximately linear.

In a second experiment, Case et al. (1982) addressed the important issue of whether or not a causal relationship exists between processing rate and memory span. They used the previously mentioned tasks to determine whether measured memory spans are equal when adults and children are equated with regard to the rate of naming items. The investigators reasoned that if adults could be equated with children on memory span by equating them on naming speed, there would be no reason to hypothesize the existence of some other variable to account for the age-related development of memory span. Naming speed was manipulated by presenting adults with a list of nonsense words. Case et al. predicted that the adult's naming speeds for nonsense words would correspond to a value normally attained by a younger group. Thus, the adult's memory span should be the same as that for the age group having the same mean naming speed. The results indicated that neither adults' speed nor span was significantly different from the 6-year-old groups'. The investigators inferred from these results that a causal relationship existed between naming speed and memory span.

In a similar, but non-developmental study, Mackworth (1963) found a significant correlation between subjects's serial recall performance and reading rate. These findings were thought suggestive of a relationship between memory span and rate of reading, so that the number of items remembered depended upon the rate at which they could be identified.

The above studies uniformly suggest that a significant relationship exists between the rate with which information is processed and short-term memory span. In other words, subjects who recall more items during a serial recall task typically require less time to read or name a list of items.

Several studies examining individual differences have assessed the relationship between the rate of processing information and short-term memory span. For example, Spring (1976) compared dyslexic and non-dyslexic boys, ranging from 6 to 12 years old, on measures of naming speed and digit span. Dyslexic boys were significantly slower to name stimulus items than their non-dyslexic peers. In addition, dyslexic boys exhibited inferior memory span performance. A correlational analysis indicated that naming speed and digit span accounted for a large portion of the variance of reading ability. The results of this study were offered as partial support for the hypothesis that memory span impairment in dyslexic children can be attributed to slow speech-motor encoding (cf. Baddeley & Hitch, 1974, 1977).

Torgesen and Houck (1980) employed both a digit span task and a naming speed task to examine the relationship between short-term memory span and rate of processing information. A correlational analysis indicated that a relatively stable relationship existed between digit span recall and naming speed. The investigators concluded that their results supported the hypothesis that differences in the rate of access to name codes may underlie part of the recall differences between learning disabled children who are experiencing short-term memory difficulties and those children who are not.

In contrast to the above findings are the results of a study by Tarver and Ellsworth (1980). These authors utilized a naming speed task and a modified version of Hagens' (1967) central-incidental task to determine the relationship between the rate of information processing and serial memory. The central part of Hagens' task consists of a serial memory task which uses line drawings of animals and objects as stimuli. The naming speed measure was correlated with seven different serial position-presentation conditions (refer to section on Individual Differences in Processing Rate for a detailed explanation). The results indicated that few of the correlations were significant, and those which were significant were moderate in magnitude. These results were thought to suggest that factors other than naming speed contribute to serial recall performance.

To summarize, two of the above studies examining individual differences have concluded that a significant relationship exists between the rate with which information is processed and short-term memory span. The third study has suggested that factors other than naming speed may have an important effect on short-term memory span.

General Summary and Reaction

Three areas of cognitive processing have been examined, namely developmental differences in the rate with which information is processed, individual differences in the rate with which information is processed, and the relationship between short-term memory span and rate of processing information. The evidence which has been presented suggests that significant developmental and individual differences do exist in the rate of processing sensory information and that short-term memory performance is significantly affected by differences in the rate of processing.

Developmental studies have utilized speed of item identification as an index of the rate of information processing. Various measures of item identification have been used, such as speed of memory-scanning (Harris & Fleer, 1974; Herrman & Landis, 1977; Naus & Ornstein, 1977), speed of letter identification (Bisanz, Danner, & Resnick, 1979; Keating & Bobbitt, 1978; Reitsinz, 1978), and naming/vocalization latency (Biemiller, 1977-78; Case, Kurland, & Goldberg, 1982; Hess & Radtke, 1981). The results of these studies provide evidence for the observation that the speed with which information is processed shows developmental improvement.

Studies examining individual differences have focused predominately upon naming/vocalization latency as an index of the speed of information processing (e.g., Spring, 1976; Spring & Capps, 1974). Dempster (1981) suggests that naming/vocalization latency is the most appropriate measure of item identification because it assesses the speed with which all aspects of the identification process are completed. Thus, naming/vocalization latency appears to be the most concise and accurate index of the rate of information processing. Results from studies using this measure suggest that learning and/or reading disabled children are significantly slower to process information than their non-learning disabled peers.

One critical variable in the investigation of naming/vocalization latency is the method of item presentation. The majority of the studies in this area have presented stimulus items simultaneously (Biemiller, 1977-78; Blumenthal, 1980; Denckla & Rudel, 1976a; Hess & Radtke, 1981; Spring, 1976; Spring & Capps, 1974; Tarver & Ellsworth, 1980; Wiig, Semel, & Nystrom, 1982), while a few studies have utilized a successive mode of presentation (Case, Kurland, & Goldberg, 1982; Perfetti & Hogaboam, 1975). Dempster (1981) suggests that successive presentation of stimulus items is superior to simultaneous presentation because it allows the investigator to measure the identification speed up until the onset of the subject's response for each individual item. In other words, successive presentation helps to guarantee that the subject perceives every item and spends a nominal amount of study time on each item. Simultaneous presentation, on the other hand, allows the subject more flexibility and increases the likelihood of subject imposed grouping or "chunking". This phenomenon could confound the item identification speed results and thus provide an inaccurate measure of processing rate.

Additional support for the use of successive presentation can be found in studies suggesting that learning and/or reading disabled children experience selective attention difficulties. A considerable amount of evidence (e.g., Tarver, Hallahan, Cohen, & Kauffman, 1977; Tarver, Hallahan, Kauffman, & Ball, 1976) indicates that learning and/or reading disabled children experience difficulty in attending to relevant rather than irrelevant features of a task. Several investigators (e.g., Shiffrin & Gardner, 1972) suggest that successive presentation requires the subject to focus his full attention on each individual item. Simultaneous presentation, on the other hand, requires the subject to divide his limited processing resources among several inputs. Learning and/or reading disabled children would most likely be somewhat distracted by the other items,and therefore, would not be able to focus a sufficient amount of attention on each individual item.

Studies were also examined which assessed the relationship between short-term memory span performance and information processing rate in both learning disabled and non-disabled children. Substantial correlations between the rate of processing information and short-term memory span were found in the majority of these studies (Case, Kurland, & Goldberg, 1982; Chi, 1977; Spring, 1976; Torgesen & Houck, 1980). Thus, there appears to be a significant relationship between the rate with which information is processed and short-term memory span such that the greater the memory span, the faster the rate of processing. Case, Kurland, and Goldberg (1982) conducted an experiment which focused upon the issue of the causal relationship between processing rate and memory span. Their results support the hypothesis that memory span performance is a direct function of the rate with which relevant information can be processed.

Most of the research which has been presented indicates that learning and/or reading disabled children process information more slowly than their non-disabled peers. Therefore, additional time that is needed for naming preempts the use of time consuming memory strategies. Based upon the fact that strategies improve short-term memory performance, learning and/or reading disabled children have typically been found to be deficient on short-term memory span tasks. Several of the studies examining individual differences have indicated that a significant relationship exists between the rate with which information is processed and short-term memory span. Additional research is needed to determine whether a causal relationship exists between rate of processing and memory span. This issue can be examined by determining whether, when learning disabled and non-disabled children are equated with regard to the speed with which they process information, their measured memory spans are also equal. Finally, the naming/vocalization latencies might be best obtained by utilizing successive presentation of stimulus items. These considerations could increase our understanding of the observed short-term memory difficulties of learning and/or reading disabled children.

Chapter 3

GENERAL PURPOSE OF THE STUDY

Although previous research (e.g., Spring, 1976; Spring & Capps, 1974) has found a relationship between the rate with which learning and/or reading disabled children process information and their observed short-term memory difficulties, research has not directly resolved the issue of causality. The purpose of the current study was to examine the cause and effect relationship between processing rate and short-term memory span by equating learning disabled and non-learning disabled children on memory span by equating them on processing rate. If most of the individual differences in short-term memory span are attributable to differences in processing rate, then equating the two groups on the later variable should eliminate performance differences in this important short-term memory task. Finally, the majority of these studies (e.g., Spring, 1976; Spring & Capps, 1974) have obtained naming/vocalization latencies, which serve as an index of information processing rate, by presenting stimulus items simultaneously. The current study presented stimulus items successively, therefore, assuring that each individual item was measured with regard to identification speed.

Chapter 4

EXPERIMENT I

The purpose of the first study was to compare the naming/vocalization latencies of learning disabled and non-disabled children in an attempt to identify from eight classes of stimuli those stimuli that were nominally and functionally equivalent. Nominal equivalence was defined as those stimuli that were from a specific class (e.g., digits, letters, colors, shapes, animal pictures, "use" objects, toys, or nonsense words) and that produced significantly different naming latencies in learning disabled and non-learning disabled children. Significant differences were measured by the use of t-tests. Functional equivalence was defined as those stimuli that were obtained from different stimulus classes, but produced comparable naming latencies in learning disabled and non-learning disabled children. Comparable referred to the absence of a statistically significant difference as measured by a t-test.

Methodology

Research Design. The design for this experiment was a 2 X 8 mixed factorial. Subject group (learning disabled or non-learning disabled) was the between subjects factor, while stimulus type (digits, letters, colors, shapes, animal pictures, "use" objects, toys, and nonsense words) was the within subjects factor.

Subjects. Forty-eight male subjects participated in the experiment, 24 learning disabled and 24 non-learning disabled, each from the sixth grade of a predominantly white suburban school district. The two subject groups were equated with respect to age and IQ. The mean chronological ages for the two groups were 11-8 for the learning disabled and 11-9 for the non-learning disabled. Results obtained from standardized tests (Slosson Intelligence Test, Wechsler Intelligence Scale for Children-Revised) provided a mean IQ score for each group: learning disabled (103) and non-disabled (107).

All learning disabled subjects had been previously identified by school district personnel and were receiving special education services at the time of testing. The learning disabled subjects who were selected did not manifest speech problems nor were they currently receiving prescribed medication. Verification of a learning disability by school personnel was based primarily upon two criteria: (1) the child scored above the minus one standard deviation level on an individually administered intelligence test and (2) the child's standard score in one or more major academic area was 1.3 or more standard deviations below the child's ability level. The average total reading grade level (Woodcock-Johnson Achievement Test) was 4.5 for the learning disabled children.

The children who were assigned to the non-learning disabled group were functioning at their approximate expectancy level in all academic subjects and were not receiving any special education services at the time of testing. The average total reading grade level for the non-learning disabled subjects was 7.1 (California Achievement Test).

Materials and Apparatus. Stimulus pictures used in the experimental trials were created from eight types of stimuli, namely digits, letters, colors, shapes, animals, "use" objects, toys, and nonsense words. Stimulus materials consisted of black and white line-drawings, except for colors which were made up of color patches. Nine pictures for each type of stimulus were selected using the norms of Snodgrass and Vanderwart (1980). Those pictures that were high in their familiarity and which consistently produced a specific name were chosen as stimuli.

Each picture was presented on a 2 X 2 inch (5.08 X 5.08 cm) slide by means of a Kodak carrousel projector equipped with a solenoid-operated shutter. Slides were projected on a white posterboard screen. The onset of each stimulus picture activated a Hunter Klockounter (Model 120C). The timing mechanism was terminated through a voice activated relay system when the subject verbalized his response into a microphone. Response latency was measured to the nearest millisecond. To eliminate the possibility of order or practice effects, the eight classes of stimuli were presented in Latin square order. The pictures within a given stimulus class were presented once in a random order.

Practice stimuli were black and white line-drawings of various modes of transportation (e.g., car and bus). Based upon the normative data of Snodgrass and Vanderwart (1980), five pictures were selected as the practice stimuli. The same criteria used to select experimental stimuli were used in the selection of practice stimuli. Again, these pictures were presented once in a random order.

Testing Procedure. Each subject was tested individually by the experimenter. The procedure involved one session for each participating child, with each session lasting approximately 10 minutes. The subject was first given general instructions (Appendix B), which emphasized the prompt, yet accurate naming of each stimulus item, and then was asked to paraphrase the instructions. Following the general instructions, the subject was presented with a series of 5 practice trials. Both learning disabled and non-learning disabled subjects quickly learned the procedure and seemed to enjoy the task.

Following the practice trials, testing began. First, the microphone was placed in front of the subject, and the subject was instructed to respond directly into it. Prior to the presentation of each stimulus, the experimenter said "ready". Following the subject's response to each item, the experimenter recorded the naming/vocalization latency and advanced the projector to the next slide.

Scoring. Speed of identification was calculated for each subject by determining the median response time for each of the eight stimulus types.

Results and Discussion

The mean naming latencies and error proportions for both learning disabled and non-learning disabled children are displayed in Table I. Analysis of the naming latencies revealed a significant main effect of subject group, F (1, 46) = 13.391, $p < .001$, as learning disabled children required more time than non-learning disabled children to name stimulus items. The mean naming latencies for learning disabled children and non-learning disabled children were 819 msec and 690 msec, respectively. The overall error rate on the naming tasks was negligible for both

TABLE I

MEAN NAMING LATENCIES, STANDARD DEVIATIONS, AND ERROR PROPORTIONS

BY STIMULUS CLASS AND SUBJECT TYPE

	Digits	Letters	Colors	Shapes	Animals	Use[a]	Toys	Non[b]	Overall
Learning Disabled									
Naming Latency msec/item	567	612	872	1045	905	785	859	911	819
Standard Deviation	.10	.10	.28	.36	.16	.11	.15	.30	.195
Error Proportions	.00	.005	.055	.08	.02	.01	.02	.06	.03
Non-learning Disabled									
Naming Latency msec/item	488	516	728	860	815	715	762	638	690
Standard Deviation	.05	.05	.28	.20	.14	.06	.09	.09	.12
Error Proportions	.00	.005	.08	.03	.02	.01	.01	.03	.025

[a] use objects

[b] nonsense words

learning disabled and non-learning disabled children, .03 and .025, respectively. Therefore, no separate analysis was performed on error rates. These results indicate that, although learning disabled and non-learning disabled children were apparently equivalent with respect to their knowledge of the stimulus materials, learning disabled children required significantly more time to emit their identification decisions. This result is consistent with previous research, which has demonstrated that learning disabled children are slower than their non-disabled peers on verbal labeling tasks (Denckla & Rudel, 1976a, 1976b; Perfetti & Hogaboam, 1975; Spring, 1976; Spring & Capps, 1974; Tarver & Ellsworth, 1980; Torgesen & Houck, 1980; Wiig, Semel, & Nystrom, 1982).

The main effect of stimulus type was also significant, F (7, 322) = 42.482, $p < .001$. A post hoc comparison using the Newman-Keuls test revealed that digits and letters both differed significantly from the remaining stimuli (i.e., "use" objects, nonsense words, colors, animals, toys, and shapes), but they did not differ significantly from each other. In addition, shapes also differed significantly from all other stimuli. Finally, animals differed significantly from both nonsense words and "use" objects. None of the other levels of stimuli type differed significantly from each other. The main effect of stimulus type demonstrated that the eight stimulus classes produced different naming latencies. This is consistent with previous research which has indicated that verbal stimuli such as letters and digits are typically identified more rapidly than concrete stimuli such as colors and shapes (Mackworth, 1963).

Finally, the subject group x stimulus type interaction was significant, F (7, 322) = 2.496, $p < .01$, indicating that the learning disabled children were not uniformly slower than non-learning disabled children in naming the various classes of stimuli.

From the 8 classes of stimuli, two types of stimuli were selected, those designated as "nominally equivalent" and those termed "functionally equivalent". Letters were selected as the nominally equivalent stimuli based upon several criteria. First, letters produced the greatest difference in mean naming latency between learning disabled and non-learning disabled children. An independent t-test indicated that the difference between learning disabled and non-learning disabled in the naming of letters was significant ($t = 4.026$, $p < .001$). Second, they exhibited relatively small variance. Finally, letters were chosen over digits because letters would be less likely to be grouped or chunked in a short-term memory task.

Toys (for the non-learning disabled) and "use" objects (for the learning disabled) were selected as the functionally equivalent stimuli. The selection of these stimuli was based upon the following criteria. First, they produced comparable naming latencies between the learning disabled and non-learning disabled children. An independent t-test indicated that the difference between learning disabled and non-learning disabled in the naming of "use" objects and toys was not significant ($t < 1$). Second, they also exhibited relatively small variance.

These two stimulus types were used in the second experiment in an attempt to measure the causal relationship between naming speed (processing rate) and short-term memory span.

Chapter 5

EXPERIMENT II

The purpose of the second experiment was to examine the extent to which processing rate affects the memory span performance of both learning disabled and non-learning disabled children. If individual differences in memory span performance is a direct function of processing rate, then the two groups should exhibit comparable memory span scores for functionally equivalent stimuli (toys and "use" objects), but significantly different memory span scores for nominally equivalent stimuli (letters). Thus, in the current experiment a significant interaction should be found between subject type and stimulus type when memory span scores are analyzed.

Methodology

Research Design. The design was a 2 X 2 mixed factorial, with subject group (learning disabled or non-learning disabled) as the between subjects factor, and type of stimulus equivalence (functional or nominal) as the within subjects factor.

Subjects. The subjects were the same 48 children from the first experiment.

Materials and Apparatus. Sixteen picture sets were created for both the nominally equivalent (letters) and functionally equivalent (toys and "use" objects) stimuli. In each case, sets of stimuli were generated by randomly selecting items from the 9 possible stimuli within each stimulus type (nominal and functional). Items were randomly assigned to each set with the restriction that no item appeared twice in the same set, nor did two items appear together in the same order in any two adjacent sets. Sets increased from two to nine pictures in length, with two trials at each level. Stimulus pictures were presented successively on 2 X 2 inch (5.08 X 5.08 cm) slides by means of a Kodak carrousel projector. In addition, to eliminate the possibility of order or practice effects, the order of presentation for nominal and functional stimuli were alternated across subjects, resulting in the two presentation orders being used equally often with both groups of subjects.

Practice materials were selected from an unused stimulus class from Experiment I. Shapes served as the practice class. Stimulus items were randomly arranged within the practice set. The set increased from two to five pictures in length, with two trials at each level. The practice materials were presented in the same manner as above.

Testing Procedure. Each subject was tested individually by the experimenter. The procedure involved one session for each participating child, with each session lasting approximately 10 minutes. Each subject was informed that he would be seeing a set of pictures which he would have to recall in the correct serial order. The subject was instructed to watch all of the pictures before responding. Each subject was also instructed to sub-vocally rehearse each set. To assure understanding, the investigator described and demonstrated this strategy using 3 sets of animal pictures. Demonstration sets increased from two to four pictures in length. Following this demonstration, each subject was asked to practice rehearsing 3 sets of animal pictures. As in the previous demonstration, sets increased from two to four items, and each item was presented at a one second rate. Observation of subjects throughout the practice session indicated that both groups understood and utilized the rehearsal strategy.

Following the demonstration and practice trials, each subject was then given the experimental trials at a steady rate of one picture per second. Prior to the increase of set size, the subject was informed that the set would increase by one additional item. The task began with the two-item set and concluded when the subject made errors on two consecutively presented set sizes. Finally, the subjects were periodically reminded about the importance of rehearsal.

Scoring. Because traditional scoring methods (i.e., scoring an item as correct only when it is recalled in its original ordinal position) may not provide a totally accurate estimate of what a subject remembers about a list of items, the current investigator utilized a scoring procedure which was developed by Huttenlocher and Burke (1976). This scoring procedure gives partial credit to incorrect memory spans if part of the response is given in the correct serial order. Partial credit is also given to individual items even if they were recalled out of order. Thus, the adjusted scoring procedure of Huttenlocher and Burke provides an estimate that is much more sensitive to memory for the relative order of stimuli.

Results

The mean memory span scores for the two groups at each of the stimulus types is presented in Table II. Analysis of the memory span

TABLE II

MEAN MEMORY SPAN SCORES AND NAMING LATENCIES

BY STIMULUS TYPE AND SUBJECT TYPE

	Functional	Nominal
Learning Disabled		
Memory Span Score	23.50	26.00
Naming Latency msec/item	785	612
Non-learning Disabled		
Memory Span Score	23.84	34.92
Naming Latency msec/item	762	516

scores revealed a significant main effect of subject group, F (1, 46) = 5.951, $p < .01$, as learning disabled children exhibited significantly smaller overall mean memory span scores than non-learning disabled children. In addition, the main effect of stimulus type was also found to be significant, F (1, 46) = 33.635, $p < .001$, with nominally equivalent stimuli producing a greater mean memory span score than functionally equivalent stimuli. This result is consistent with previous research which has found that a stimulus type (e.g., digits) that requires a shorter naming latency than a second stimulus type (e.g., words) will also yield a larger memory span score than the second type of stimuli (Mackworth, 1963; Case, 1978).

An interaction of subject group x stimulus type was found to be significant, F (1, 46) = 13.431, $p < .001$. The interactive effects of subject group and stimulus type may be clearly seen in Table II. For functionally equivalent stimuli, the mean memory span scores were comparable for the two groups. Nominally equivalent stimuli, on the other hand, produced significantly different mean memory span scores in learning disabled and non-learning disabled children.

General Discussion

The major objective of the present investigation was to examine the extent to which differences in processing rate between learning disabled and non-learning disabled children affect memory span performance. The first experiment of the study presented subjects with item identification tasks which yielded measures of both the speed and accuracy with which pictures were identified. The second experiment of the study measured the number of pictures that were correctly recalled during a short-term memory task. The results indicated that when learning disabled children and non-learning disabled children were equated with regard to processing rate, as measured by item identification speed, their measured memory span scores were comparable. On the other hand, when learning disabled children exhibited naming latencies that were inferior to those of non-learning disabled children, they experienced inferior memory span performance. Thus, it appears that the measured memory span score was a direct function of the speed with which the two groups could identify stimulus items.

The current findings may be explained by using the model of Case et al. (1982). These investigators have discussed two theoretical constructs (storage space and operating space), both of which were conceptualized within a limited capacity framework. Storage space was defined as the hypothetical amount of cognitive space that an individual had available at any given time for storing stimulus information. Operating space, on the other hand, referred to the hypothetical amount of cognitive space that an individual had available at any given time for carrying out mental operations. Given these constructs, Case et al. hypothesized that as individuals develop, the amount of operating space that is required decreases as a result of increased efficiency in the execution of cognitive operations. With this increase in operational efficiency, as measured by the speed of item identification, comes a concomitant increase in the amount of space available for storage.

The current findings suggest that for nominally equivalent stimuli (letters), learning disabled children proved to be less operationally efficient, as measured by the speed of item identification, than the non-learning disabled children, and, therefore, exhibited inferior memory span scores. Apparently, learning disabled children initiated memory processes in a rather deliberate, "effortful" fashion, and had less cognitive capacity available for storage in short-term memory. The non-learning disabled children, on the other hand, initiated memory processes in a more automatic fashion, leaving more cognitive capacity available for short-term memory storage. On the other hand, when the two groups were equated with regard to their efficiency in carrying out memory operations through the use of functionally equivalent stimuli, their memory span scores were comparable. The obvious logical conclusion is that a causal relationship exists between processing rate and short-term memory span performance. Furthermore, the present findings indicate that the inferior memory span performance of learning disabled children in the current experiment is largely attributable to differences in processing rate.

The results of the present study would indicate that sixth-grade learning disabled children can utilize important mnemonic strategies such as rehearsal, but because they process information slowly, they do not have enough time to employ them efficiently. Salthouse (1983), for example, has hypothesized that if one individual can carry out the fundamental memory operations of either rote or elaborative rehearsal at a faster rate than a second individual, the first individual will exhibit superior short-term memory. He has suggested that the superior recall is due to the fact that the first individual was able to carry out more total rehearsals than the second individual in a given amount of time. Apparently, in the current study, with the nominally equivalent stimuli (letters), the learning disabled children were not able to complete as many rehearsals as the non-learning disabled children in the limited amount of time provided. Therefore, their short-term memory performance was inferior to that of non-learning disabled children. The two group's performance with the functionally equivalent stimuli ("use" objects and toys) suggested that a comparable number of rehearsals were completed by both groups, which in turn led to equivalent short-term memory span scores.

The effects of processing rate on short-term memory span performance has implications for difference in reading comprehension skill. The basic processes of reading comprehension interact with each other and must share a limited capacity system. Thus, if a reader requires a significant amount of cognitive capacity for any single process (e.g., coding), less processing capacity is available for other important reading processes, such as memory for a recently coded word, memory for the preceding phrase, and the ability to predict the contents of the remainder of the printed page.

Perfetti and Lesgold (1977) have suggested that the capacity for reading comprehension is limited by the data-handling requirements of the working memory (short-term memory). These investigators (1978) have also hypothesized that poor readers utilize the limited capacity working memory in a rather deliberate and inefficient manner. This "effortful" processing may require much of the limited capacity needed for higher order processes of comprehension. Perfetti and Lesgold (1977) have also suggested that the time needed to retrieve a name, as well as the time required to retrieve semantic information associated with a name is the source of working memory (short-term memory) differences between good and poor readers. These investigators suggested that efficient reading comprehension requires both availability of information (i.e., the existence of word meanings in semantic memory) and also rapid access to this information. They have agreed that the slow retrieval of a label, as well as the slow retrieval of semantic information associated with the label during reading, may cause the less-skilled reader to "fall behind in the cycle of comprehension events, revert to less efficient patterning of the various reading comprehension process components, and finally fail to comprehend some of the discourse" (pp. 170-171). This inability of the working memory to keep up with the coding demands placed upon them may cause the poor comprehender to experience considerable interference from previous traces that he did not have time to erase and thus, to be slower at encoding new information.

If short-term memory span is dependent upon speed of processing, then both learning disabled and non-learning disabled subjects should have experienced an improvement in memory span as identification speed increased. The data presented in Table II however, indicate that only the non-learning disabled subjects manifested significant improvement in memory span performance as their naming speed improved. For example, non-learning disabled subjects experienced a 32% improvement in memory span as their naming speed increased from 762 milliseconds for functionally equivalent stimuli (toys) to 516 milliseconds for nominally equivalent stimuli (letters). Learning disabled subjects, on the other hand, experienced only a 10% improvement in memory span as their naming speed increased from 785 milliseconds to 612 milliseconds.

Although these data appear to be inconsistent with the hypothesized relationship between processing rate and memory span, an explanation may be found from the studies of Baddeley and Hitch (1974, 1977) and Perfetti and Lesgold (1977). Baddeley and Hitch (1974) have developed a working memory framework which is divided into two components: a central executive and an articulatory loop. The central executive is responsible for information processing and decision making, while the articulatory loop stores a small amount of verbal information in correct serial order by encoding it in phonological forms. Memory span performance is determined by the capacity of the articulatory loop and the ability of the central executive to supplement its limited capacity. Baddeley and Hitch suggest that the observed memory span problems of learning disabled children may be due to inadequate or inefficient utilization of the articulatory loop. Inefficient use of the articulatory loop leads to phonological confusion. Previously encoded information interferes with the encoding of phonologically similar information.

Perfetti and Lesgold (1977) have suggested that slow retrieval of a label, as well as the slow retrieval of semantic information associated with the label, may cause the less-skilled reader to be more affected by the interference. The less-skilled reader does not have enough time to erase old memory traces, therefore he experiences interference from this previously encoded information. Apparently, in the current study, the learning disabled children were affected by interference from prior memory traces that were phonologically similar to certain letters that they were attempting to recall.

Although a concerted effort was made to select consonants that did not have overlapping visual or acoustic features (Conrad, 1964), the learning disabled subjects still experienced confusion. Two types of intrusions or confusions were identified: intraexperimental list intrusions and extraexperimental list intrusions. Intraexperimental list intrusions were defined as those letters within the test list (e.g., B, L, G, W, H, F, Z, R, K) that interfered with the subjects memory for certain phonologically similar letters (e.g., the subject responded G when B was the appropriate response). Extraexperimental list intrusions, on the other hand, referred to those letters outside of the test list that interfered with the subjects' memory for specific phonologically similar letters (e.g., the subject responded C when Z was the appropriate response). Thirteen of the 24 learning disabled subjects committed phonological intrusion errors. Seventy-two percent of the intrusions were intraexperimental list errors, while 28 percent of the intrusions were from outside of the test list. None of the non-learning disabled subjects experienced either type of interference.

Future studies may want to examine the relationship between phonological confusion and information processing rate. For example, a subsequent study could determine whether additional practice can eliminate these phonological errors.

The results of the current study have indicated that the inferior short-term memory performance of learning disabled children may be largely attributed to differences in the rate of processing information. Previous research has focused upon strategy differences between learning disabled and non-learning disabled children. The current results indicate that future research may want to focus more upon the importance of processing rate. Future studies will have to delineate the other ways that processing rate may affect learning disabled children.

Chapter 6

CONCLUSIONS AND IMPLICATIONS

Conclusions

Conclusions should only be generalized to the population of learning disabled children who possess characteristics which are similar to those of the sample used in this study. The results of this study led to the following conclusions:

1. Learning disabled children require a significantly greater amount of time than non-learning disabled children to identify most stimulus items.
2. Accuracy of performance on item identification tasks does not differentiate learning disabled children from non-learning disabled children.
3. A strong relationship exists between the speed with which learning disabled and non-learning disabled children process information and their measured short-term memory span.

Clinical and Educational Implications

The results of this study warrant several clinical and educational implications. Clinically, these results may have some utility for school personnel (typically school psychologists and resource room teachers) who are attempting to identify children with potential learning problems. Wiig, Semel, and Nystrom (1982) have suggested and demonstrated that measures of rapid naming ability can differentiate children with diagnosed language and learning disabilities from academically achieving age peers. The results of their study indicate that an item identification task may be a useful addition to the instruments currently used in the diagnosis of language-learning disabilities.

Comparisons of response latencies suggested that learning disabled children may experience a slower rate of access to information in long-term memory than non-learning disabled children. This finding has several educational implications. First, slower retrieval and use of word names and meanings may play a significant role in the reading problems of learning disabled children (Perfetti & Lesgold, 1976, 1977). Perfetti and Lesgold (1976) have suggested that educators should measure three levels of skill facility in regard to the ability of retrieval and use of word names and meanings: "inaccurate performance; slow, accurate performance; and automated performance" (p. 32). Movement from inaccurate word recognition to a more "automatic" level may be facilitated by drills that emphasize rapid (automatic) processing. Classroom teachers may want to incorporate these rapid identification drills into various classroom activities.

Secondly, the findings of the present study suggest that learning and/or reading disabled children may perform poorly on timed tests because they experience slow access to information in long-term memory. Therefore, classroom teachers may want to avoid using timed or speeded tests for evaluation purposes. In the event that timed testing procedures are necessary, the results of the test must be interpreted cautiously and in conjunction with the results of untimed tests and subjective observations.

REFERENCES

Baddeley, A. D., & Hitch, G. (1974). Working memory. In G. H. Bower (Ed.), The psychology of learning and motivation, Vol. 8. New York: Academic Press.

Baddeley, A. D., & Hitch, G. (1977). Commentary on working memory. In G. H. Bower (Ed.), Human memory: Basic processes. New York: Academic Press.

Bauer, R. H. (1977). Memory processes in children with learning disabilities: Evidence for deficient rehearsal. Journal of Experimental Child Psychology, 24, 415-430.

Biemiller, A. (1977-1978). Relationship between oral reading rates for letters, words, and simple text in the development of reading achievement. Reading Research Quarterly, 13, 223-253.

Bisanz, J., Danner, F., & Resnick, L. B. (1979). Changes with age in measures of processing efficiency. Child Development, 50, 132-141.

Bisanz, J., & Resnick, L. B. (1978). Changes with age in two components of visual search speed. Journal of Experimental Child Psychology, 25, 129-142.

Blake, J., & Beilin, H. (1975). The development of same and different judgements. Journal of Experimental Child Psychology, 19, 177-194.

Blankenship, A. B. (1938). Memory span: A review of the literature. The Psychological Bulletin, 35, 1-25.

Blumenthal, S. H. (1980). A study of the relationship between speed of retrieval of verbal information and patterns of oral readings errors. Journal of Learning Disabilities, 13, 42-44.

Brener, R. (1940). An experimental investigation of memory span. Journal of Experimental Psychology, 26, 467-482.

Case, R. (1978). Intellectual and linguistic development in the preschool years. Unpublished manuscript, Department of Applied Psychology, The Ontario Institute for Studies in Education, University of Toronto.

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

Cavanagh, J. P. (1972). Relation between the immediate memory span and the memory search rate. Psychological Review, 79, 525-530.

Chi, M. (1977). Age differences in memory span. Journal of Experimental Child Psychology, 23, 266-281.

Cohen, R. L., & Sandberg, T. (1977). Relation between intelligence and short-term memory. Cognitive Psychology, 9, 534-554.

Collins, A. M., & Loftus, E. F. (1975). A spreading-activation theory of semantic processing. Psychological Review, 82, 407-428.

Conrad, R. (1964). Confusions in immediate memory. British Journal of Psychology, 55, 75-84.

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

Denckla, M. B., & Rudel, R. G. (1976a). Naming of object-drawings by dyslexic and other learning disabled children. Brain and Language, 3, 1-15.

Denckla, M. B., & Rudel, R. G. (1976b). Rapid automatized naming: Dyslexia differentiated from other learning disabilities. Neuropsychologia, 14, 471-479.

Doehring, D. G. (1968). Patterns of impairment in specific reading disability. Bloomington, IN: Indiana University Press.

Duncan, E. M., & Kellas, G. (1978). Developmental changes in the internal structure of semantic categories. Journal of Experimental Child Psychology, 26, 328-340.

Eakin, S., & Douglas, V. I. (1971). Automatization and oral reading problems in children. Journal of Learning Disabilities, 4, 31-37.

Eckert, H. M., & Eichorn, D. H. (1977). Developmental variability in reaction time. Child Development, 48, 452-458.

Fairweather, H., & Hutt, S. J. (1978). On the rate of gain of information in children. Journal of Experimental Child Psychology, 26, 216-229.

Farnham-Diggory, S., & Gregg, L. W. (1975). Short-term memory function in young readers. Journal of Experimental Child Psychology, 19, 279-298.

Guttentag, R. E., & Haith, M. M. (1978). Automatic processing as a function of age and reading ability. Child Development, 49, 707-716.

Hagen, J. W. (1967). The effect of distraction on selective attention. Child Development, 38, 685-694.

Harris, G. J., & Fleer, R. E. (1974). High speed memory scanning in mental retardates: Evidence for a central processing deficit. Journal of Experimental Child Psychology, 17, 452-459.

Henderson, S. E. (1974). Speed of letter conceptualization on the basis of visual and name identity in young children. Journal of Experimental Child Psychology, 17, 347-352.

Herrman, D. J., & Landis, T. Y. (1977). Differences in the search rate of children and adults in short-term memory. Journal of Experimental Psychology, 23, 151-161.

Hess, T. M., & Radtke, R. C. (1981). Processing and memory factors in children's reading comprehension skill. Child Development, 52, 479-488.

Huttenlocher, J., & Burke, D. (1976). Why does memory span increase with age? Cognitive Psychology, 8, 1-31.

Kahneman, D. (1973). Attention and effort. Englewood Cliffs, NJ: Prentice Hall.

Keating, D. P., & Bobbitt, B. L. (1978). Components of mental ability. Child Development, 49, 155-167.

Klasen, E. (1972). The syndrome of specific dyslexia. Baltimore, MD: University Park Press.

Lyon, D. R. (1977). Individual differences in immediate serial recall: A matter of mnemonics? Cognitive Psychology, 9, 403-411.

Mackworth, J. (1963). The relation between visual image and post-perceptual immediate memory. Journal of Verbal Learning and Verbal Behavior, 2, 75-85.

Naus, M. J., & Ornstein, P. A. (1977). Developmental differences in the memory search of categorized lists. Developmental Psychology, 13, 60-68.

Norman, D. A., & Babrow, D. G. (1975). On data-limited and resource-limited processes. Cognitive Psychology, 7, 44-64.

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

Perfetti, C. A., & Lesgold, A. M. (1976). Coding and comprehension in skilled reading and implications for reading instruction. Paper presented at the Conference on Theory and Practice of Beginning Reading Instruction, University of Pittsburgh, Learning, Research, and Development Center.

Perfetti, C. A., & Lesgold, A. M. (1977). Discourse comprehension and sources of individual differences. In M. A. Just and P. A. Carpenter (Eds.), Cognitive processes in comprehension. Hillsdale, NJ: Lawrence Erlbaum Associates.

Perfetti, C. A., & Lesgold, A. M. (1978). Coding and comprehension in skilled reading and implications for reading instruction. In L. B. Resnick and P. Weaver (Eds.), Theory and practice in early reading. Hillsdale, NJ: Lawrence Erlbaum Associates.

Posner, M. I., & Mitchell, R. F. (1967). Chronometric analysis of classification. Psychological Review, 74, 392-409.

Reitsma, P. (1978). Changes in letter processing in beginning readers. Journal of Experimental Child Psychology, 25, 315-325.

Salthouse, T. (1983). Memory development throughout the life span: The role of processing rate. Life-Span Development and Behavior, 5, 4-44.

Samuels, S. J., Begy, G., & Chen, C. C. (1975-76). Comparison of word recognition speed and strategies of less skilled and more highly skilled readers. Reading Research Quarterly, 1, 72-86.

Schvaneveldt, R., Ackerman, B. P., & Semlear, T. (1977). The effect of semantic context on children's word recognition. Child Development, 48, 612-616.

Semel, E. M., & Wiig, E. H. (1980a). CELF Screening Tests. Columbus, OH: Charles E. Merrill.

Semel, E. M., & Wiig, E. H. (1980b). Clinical evaluation of language functions. Columbus, OH: Charles E. Merrill.

Snodgrass, J. G., & Vanderwart, M. (1980). A standardized set of 260 pictures: Norms for name agreement, image agreement, familiarity, and visual complexity. Journal of Experimental Psychology: Human Learning and Memory, 6, 174-215.

Spring, C. (1976). Encoding speed and memory span in dyslexic children. The Journal of Special Education, 10, 35-40.

Spring, C., & Capps, C. (1974). Encoding speed, rehearsal, and probed recall of dyslexic boys. Journal of Educational Psychology, 66, 780-786.

Sternberg, R., & Wagner, R. (1982). Automatization failure in learning disabilities. Topics in Learning and Learning Disabilities, 2, 1-11.

Surwillo, W. W. (1977). Developmental changes in the speed of information processing. The Journal of Psychology, 96, 97-102.

Tarver, S. G., & Ellsworth, P. S. (1980). The effects of stimulus presentation rate on the short-term memory of learning disabled children. Unpublished manuscript, Research and Development Center for Individualized Schooling, University of Wisconsin-Madison.

Tarver, S. G., Hallahan, D. P., Kauffman, J. M., & Ball, D. W. (1976). Verbal rehearsal and selective attention in children with learning disabilities: A developmental lag. Journal of Experimental Child Psychology, 22, 375-385.

Torgesen, J. K., & Houck, D. G. (1980). Processing deficiencies of learning disabled children who perform poorly on the digit span test. Journal of Educational Psychology, 72, 141-160.

Wickens, C. (1974). Temporal limits of human information processing: A developmental study. Psychological Bulletin, 81, 739-754.

Wiig, E. H., Semel, E. M., & Nystrom, L. A. (1982). Comparison of rapid naming abilities in language-learning disabled and academically achieving eight-year-olds. Language and Hearing Services in Schools, 13, 11-23.

APPENDICES

APPENDIX A

STIMULUS LISTS

STIMULUS LISTS

The following tables present both the practice and test stimuli used in the two experiments.

PRACTICE LIST

"Modes of Transportation"

boat
bus
tractor
car
rocket

TEST LIST

"Digits"	"Letters"
1	H
2	F
3	K
4	Z
5	W
6	B
7	L
8	R
9	G

"Colors"	"Shapes"
Orange	Diamond
Blue	Star
Brown	Circle
Purple	Triangle
Green	Cross
Pink	Square
Yellow	Heart
Red	Arrow
Black	Cone

"Animals"

Horse
Bear
Dog
Lion
Squirrel
Cat
Cow
Pig
Mouse

"Use Objects"

Saw
Glass
Shoe
Comb
Chair
Key
Watch
Fork
Bed

"Toys"

Skate
Airplane
Ball
Truck
Drum
Bicycle
Gun
Wagon
Sled

"Nonsense Words"

Swib
Kaks
Plon
Ziz
Hud
Flut
Moft
Nen
Tash

APPENDIX B

ITEM IDENTIFICATION TASK: INSTRUCTIONS TO SUBJECTS

GENERAL INSTRUCTIONS

I want you to listen to my instructions very carefully. After I have finished these directions, I will ask you to tell me what you are supposed to do.

You will be seeing eight different classes of pictures projected on the screen in front of you. There will be nine pictures within each class. I will tell you what class you will be seeing before I project them on the screen. Your task will be to name each picture as quickly <u>and</u> as accurately as possible.

Now, can you tell me what you are supposed to do?

Before I show you some practice pictures, I want to describe exactly how your answers should be given.

1. Be sure that you do not get too close to the microphone. Just sit in a normal comfortable position.
2. If you have difficulty naming a picture, simply give your best answer.
3. Once you name a picture out-loud, you cannot change it. For example, you cannot say, "Triangle--no, I mean diamond."
4. Do not say anything or make any sounds until you are ready to name the picture. For example, do not say "Mmm, . . .bird", "Uhh, . . .flower", or "the kite."

Do you have any questions before I show you the practice pictures?

<u>Practice Pictures</u>

Now, I am going to show you some practice pictures. You will be seeing five pictures of different modes of transportation. When you see the picture, name it as quickly as you can. Remember, do not make a sound until you are ready to name each picture and give your answer loud and clear.

Test Pictures

You will now be seeing more pictures. When you see each picture, name it as quickly and accurately as you can. Remember, there are eight classes of pictures with nine pictures in each class. I will remind you before the class changes. Again, do not make any sound until you are ready to name each picture and give your answer loud and clear.

APPENDIX C

MEMORY SPAN TASK: INSTRUCTIONS TO SUBJECTS

GENERAL INSTRUCTIONS

I want you to listen to my instructions very carefully. After I have finished these directions, I will ask you to tell me what you are supposed to do.

You will be seeing several groups of pictures projected on the screen in front of you. These pictures were chosen from the various classes of pictures that you saw the last time we met. I will tell you what class of pictures you will be seeing before they appear on the screen. You will first see two pictures, and then you will see one additional picture added to each group of pictures. Your task will be to watch all of the pictures projected on the screen and try to remember them in the correct order that you saw them. In order to help you remember all of the pictures in their correct order, I want you to rehearse each group of pictures. Do you know what I mean by rehearsal? A good example of rehearsal is when actors practice their lines over and over in order to remember them. I want you to say the names of the pictures to yourself as you see them. Repeat them to yourself as quickly and as many times as possible. I will demonstrate this strategy using animal pictures.

Now, can you tell me what you are supposed to do?

Practice Pictures

Now, I am going to show you some practice pictures. You will be seeing several different groups of shapes. The first group contains two pictures and each additional group increases by one picture. I want you to try to remember these pictures in the correct order. Be sure to watch all of the pictures before responding. Rehearsal will help you in this task. Be sure to rehearse each group of pictures.

Test Pictures

You will now be seeing more groups of pictures. There are two different classes of pictures. I will tell you what class of pictures you will be seeing before they appear on the screen. I want you to try to remember the pictures within each group in the same order that you saw them. Be sure to watch all of the pictures before responding. Remember to rehearse each group of pictures.

APPENDIX D

LETTER REQUESTING PERMISSION FROM PARENTS

PARENTAL CONSENT FORM

Dear Parent:

I am asking permission of some of the children at your child's school (in the sixth grade) to conduct a brief study concerning memory skills. The study will be conducted at your child's school, and will take no more than two ten-minute sessions. I would like to ask your child to participate in the study.

The purpose of the study is to determine the relationship between a child's performance on a short-term memory task and the rate with which he processes incoming sensory information. The child will be asked to remember a list of pictures and to then name each picture within that list. Each child will be tested individually.

The study will be presented as a game, and I hope that the children will have fun participating. However, your child may refuse to participate or withdraw at any time if he wishes. I want you to know, and will emphasize to your child, that "perfect" memory performance is not expected, so your child will not be under any undo pressures. I believe that there is no risk or harm of any kind to your child in the study. Please be assured that your child's name will not be involved in any way with the research findings, and nothing that we learn about your child will be divulged to anyone. Naturally, there is no fee charged to yourself or your school district.

May I have your permission for your child to participate in this study if he wishes? In addition to this form, I will get your child's permission directly before including him in the study. If you have any questions, please feel free to call Tom Lorsbach, Ph.D. or me , at 554-2727 (U.N.O.) or at 397-5868 (home).

Thank you in advance for your consideration.

Sincerely,

Jeffrey W. Gray
Graduate Assistant,
Counseling and Special Education
University of Nebraska at Omaha

____
(school attending)

____
(child's name

Does not have my permission to participate in the memory study of Jeff Gray and Dr. Lorsbach

____
(child's name)

Has permission to participate in the memory study of Jeff Gray and Dr. Lorsbach

____
(date)

____
Signature of Parent or Guardian

University of Nebraska at Omaha

College of Education
Department of Counseling (402) 554-2727
and Special Education (402) 554-2201
Omaha, Nebraska 68182

April 2, 1984

Dear Parent:

I am a Graduate Assistant in the Counseling and Special Education Department at the University of Nebraska at Omaha and my research partner is an Assistant Professor in the College of Education there. We are very interested in how children's memory processes operate in different situations. We wish to conduct a memory study at your child's school. The purpose of this letter is to ask for your support of this project by giving permission for your child to participate in this study. The tasks we use are very brief (10-15 minutes each) and places no pressure on your child. The attached consent form describes the study in more detail.

We wish to begin our study around the third week of April, 1984. Therefore, we would deeply appreciate it if you would be so kind as to return the enclosed consent form by Friday, April 20th. No postage is necessary with the enclosed envelope.

We deeply appreciate your time and your consideration.

Sincerely,

Jeffrey W. Gray

Jeffrey Gray
Graduate Assistant