UNIVERSITY OF ALBERTA

READING DISABILITY, SPEECH PROCESSES AND MEMORY

BY

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A THESIS SUBMITTED TO

THE FACULTY OF GRADUATE STUDIES AND RESEARCH

IN PARTIAL FULFILLMENT OF THE REQUIREMENT FOR

THE DEGREE OF MASTER OF EDUCATION

IN

SPECIAL EDUCATION

DEPARTMENT OF EDUCATIONAL PSYCHOLOGY

EDMONTON, ALBERTA

FALL, 1993

ISBN 0-315-88240-9

UNIVERSITY OF ALBERTA

RELEASE FORM

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TITLE OF THESIS: Reading Disability, Speech Processes and Memory

DEGREE: Master of Education

YEAR THIS DEGREE GRANTED: Fall, 1993

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The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies and Research for acceptance, a thesis entitled Reading Disability, Speech Processes and Memory submitted by Marion Mok in partial fulfillment of the requirements for the degree of Master of Education in Special Education.

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ABSTRACT

The purpose of the present study was twofold. The first one was to investigate the performance of poor and normal readers on naming time, speech rate, phonemic segmentation, and word series recall, the interrelationships of these tasks and their relation to reading. The second one was to investigate the differences in performance on naming time, a task well established in distinguishing reading disabled in studies on the condition. The twofold purpose of the study was achieved via two experiments.

Subjects were selected according to their scores on the Matrix Analogies Test-Short Form, which is a performance IQ test, the Word Attack and Word Identification tests of the Woodcock Reading Mastery Tests-Revised. They were year 3 and 4 elementary students from the Edmonton public schools.

Experiment 1 involved 60 subjects grouped according to IQ and reading level. Experiment 2 used the audio-taped protocols of naming time of 30 subjects who were selected on reading level only. A computer equipped with sound analysis applications was used to analyze the tapes.

The result of Experiment 1 showed that IQ level did not affect the performance of naming time, speech rate, and phonemic segmentation in the two reading groups. The results of regression analysis and correlation indicated a significant interrelationship among the tasks, which were in line with studies that investigated similar relationship based on the working memory model. The multiple regression analysis showed

that naming time and speech rate were two tasks which could best predict decoding scores in reading. The general conclusion reached is that naming time and speech rate are two reliable measures to use in studies on reading disabled.

The results of Experiment 2 showed a difference in performance on the naming time between the two reading groups. A pattern was observed in the performance of the normal readers while no specific pattern was observed in the poor readers.

The results of the two experiments indicated a need to take the developmental approach in the investigation of reading disability. The findings were discussed in terms of their practical applications and in terms of possible direction for future studies.

ACKNOWLEDGEMENT

I would like to express my sincere gratitude to the following individuals for their help in completing this thesis.

To Dr. J.P. Das for his patience, guidance, and support from the preparation to the completion of the thesis.

To Dr. Jack Goldberg for his participation on the examining committee, asking interesting and probing questions.

To Dr. Joseph Kirman for his participation as the external examiner.

To Rama Mishra for his patience and assistance in the statistical computations.

To Allan Richardson for assisting in the use of the computer sound analysis program.

To my room-mates, Christine Ho, Debbie Chau, and Teresa Yeung for their assistance and emotional support throughout the preparation of the thesis.

My final and greatest debt is to my family, my parents, my sisters and my brother. This piece of work could never be completed without their continuous encouragement, their love and their prayers.

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1. INTRODUCTION

Keogh (1987) stated that "lack of a consensual conceptualization of learning disabilities... has muddied research directed at understanding the condition(s)..., there is often a confounding of learning disability and other handicapping conditions. There is little argument that a substantial number of individual have serious and unexpected problems in achieving at a normative level. Yet the specifics of who they are, why they have problems, and what to do about the problems remained unanswered, even controversial" (p.225). The uncertainties which characterize children with reading difficulties are partly due to lack of clear differentiation from other boundary conditions such as mental retardation, emotional disturbance or general underachievement. She argued that the understanding of the condition is further limited by possible confounds of economical, social, and cultural influences on achievement and a multitude of treatment practices.

Similar to Keough's statement, Frith (1992) argued that a wide range of characteristic behavioral phenomena can be derived from the unique and particular cognitive deficit of dyslexia because of adaptations to the deficit, some of which is supplied by the environment. Demonstration of poor performance on a particular task is not enough. It can be due to some other impairment but not to the specific underlying deficit. Conversely, if there is a cognitive deficit in a particular mechanism, impairment will be observed in only those behaviours that depend on this mechanism. Therefore it is important to find the right tasks to measure this specific and unique deficit.

Traditional studies on reading disabilities showed that reading disabled had poor performance on short-term memory tasks than normal readers of the same age (Rugel, 1974; Torgesen, 1978). Several studies on normal subjects, from young children to adults, demonstrated that memory span varied linearly as a function of cognitive processing speed (Baddeley, Thomson & Buchanan, 1975; Case, Kurland & Goldberg, 1982; Nicolson, 1981). Hulme, Thomson, Muir & Lawrence (1984) even argued that observed developmental increase in memory span could be explained in terms of an increase in the operational efficiency of articulation rate, instead of an increase in memory space.

The working memory model conceptualized by Baddeley and others (Baddeley, 1992; Baddeley & Hitch, 1974; Baddeley & Liberman, 1980) provides a theoretical link between cognitive processes and memory. The working memory consists of the central executive which is aided by two active slave system, the phonological loop and the visual-spatial scratch pad. The loop has two components: a brief speech-based store which holds a memory trace that fades within approximately two seconds; and an articulatory control process which maintains the material in the store by a recycling process.

Gathercole & Baddeley's two studies (1989, 1990a) relating language development to the working memory demonstrated that vocabulary development was closely related to the phonological encodings and the phonological storage of the working memory. Their study (1990b) on 7-8 years old children with language disorder provided further support to their argument.

Other studies focused on the investigation of phonological deficits in the reading disabled. Ellis (1981) ruled out a deficit in the visual-perceptual area in reading disabilities. He concluded that the deficit was in the complex processes of name coding which included an internal phonological code, lexical access and retrieval of pronunciation. Snowling (1981) found that her reading disabled subjects had phonemic segmentation difficulty. This difficulty affected that the attainment of automatic decoding abilities. Bradley & Bryant (1981) also came up with similar conclusions that the reading disabled have deficits in the phonological processing skills.

Denckla & Rudel (1976) designed a conventional method for measuring item identification speed, the Rapid Automatized Naming (R.A.N.). It included naming of colours, digits, letters and objects. They found that it was a sensitive measure to identify people with reading disabilities. Later studies that looked into the phonological skills deficits of reading disabled used similar or adapted version of the R.A.N.

(Bowers, Steffy & Tate, 1988; Bowey, Cain & Ryan, 1992; Cornwall, 1992). However Das & Siu (1989) and Das & Mishra (1991) were the only two studies that used words as the stimulus item for this task.

Based on the argument by Hulme and his colleagues (1984) that speech rate is predictive of memory span, Das & Mishra (1991) suggested that it might be a more dependable measure on phonological coding than memory span. The result of their study showed that the reading disabled group did have a poorer performance than the normal readers. Based on the conceptual framework of the working memory model, Torgesen, Wagner, Simmons Laughon (1990) suggested that the best measure of phonological coding difficulties is a combination of naming time/rapid naming and speech rate instead of the traditional memory span measures. Naming time is closely related to the phonological representation in memory while articulation rate has close ties to the phonological loop in the working memory model.

Phonemic segmentation is another task used to measure the phonological skills deficits in the investigation of reading disabilities. The task measures the more basic phonological awareness level (Bowers & Swanson, 1991; Cornwall, 1992; Frith, 1992; Hurford, 1990). Again reading disabled subjects showed a poorer performance on this task.

Short-term memory tasks continued to be a measure used frequently in reading disabilities studies although there are mixed findings, particulary in the area of phonological confusions in memory span. Jorm's review (1983) indicated that reading disabled were less prone to this problem. However Bisanz, Das & Mancini's study (1984) and Johnston, Rugg & Scott's study (1987) indicated otherwise. As Torgesen and his colleagues (1990) suggested, memory span may not be the best measure for phonological coding abilities. Some studies suggested that as compared to naming time, phonemic segmentation which measured the decoding ability of reading, the memory span tasks measure a separate mechanism in reading. It may be more involved in comprehension, a higher level of processing in reading (Bowers et al, 1988; Bowey et al, 1992; Jorm, 1983).

A number of studies also compared the contribution of the three tasks, namely, phonemic segmentation, naming time and memory span tasks to the correlation and variance of a few measures on reading ability (eg. Bowey et al, 1992; Cornwall, 1992; Das & Siu, 1989).

In summary, the difficulty in phonological processing observed in reading disabled is well established. A number of conventional measures are used to compare the performance between reading disabled and normal readers. The most commonly used are naming time, phonemic segmentation/phonological awareness tasks and memory span. Several studies also reported contribution of variances by these tasks to several reading ability measures. If as Frith (1992) argued that dyslexia/reading disabilities is a specific and unique cognitive deficit, then are these the measures that can distinguish the underlying processes from other impairments which may result in similar behavioral phenomena as she suggested? Does the cognitive processes associated with IQ level have any influence on/relationship with the processes associated with this unique cognitive deficit? Most studies reviewed so far involved subjects with similar IQ level. Therefore one way to answer the question is by comparing the performance of different IQ group on these tasks. There have been relatively few studies on the relationship among the four tasks, naming time, phonemic segmentation, speech rate and memory tasks and a comparison of their relationship to reading. Little has been done on a more detailed analysis on the naming time task especially when it is supposed to be a sensitive measure of phonological coding skills. Such an analysis may provide valuable information in reading (decoding) especially when words are used as the stimulus item.

This study is, therefore, twofold. The first part will focus on the comparison of performance of naming time, speech rate, phonemic segmentation and memory recall between poor and normal readers based on IQ level. The result might provide insight into the hypothesized nature of reading disabilities as a unique cognitive deficit. The interrelationship among the four tasks and their relationship to reading will also be analyzed for more contribution to the knowledge on reading. The second part will focus on an in-depth analysis of the naming time performance Some indication might be obtained as to the probable existence of any pattern/trend differences in reading between the reading disabled and the normal readers. The results obtained in both parts of the study might contribute to the knowledge of test measurement and cognitive processes in reading disabilities.

2. LITERATURE REVIEW

The main purpose of this study is to investigate the nature of relationship between the four tasks of speech rate, naming time, phonemic segmentation, memory span and reading disabilities. This chapter will provide a review of literature related to this purpose. It is divided into three sections. The first section will focus on the relationship between memory and cognitive processing in the general population. The second section will focus on the same relationship in the reading disabled population. And the last section will focus on the type of conventional tasks used in the investigation of the condition of reading disabilities and the tasks' relationship to the abilities involved in reading.

2.1 Memory and Cognitive Processing

2.1.1 Relationship between memory span and processing speed

It has been established that memory span increases with age (Chi,1976). Different studies were carried out to investigate if this developmental increase in span was due to an increase in memory space or due to some other factors. Baddeley, Thomson & Buchanan (1975) investigated the relationship between memory span and reading rate which was calculated from the time taken to read aloud a list of 50 words from 5 pools of words each consisted of 10 equi-syllabic words. Both the memory span and reading rate decreased significantly when the number of syllables increased in the words. They also found that memory span varied linearly as a function of reading rate (RR), that is, the 5 pairs of memory span and reading rate points, one pair for each number of syllables, lay on a straight line. MS=k.RR + C where k, the slope, which has the dimensions of time was 1.87 and C was close to zero. Baddeley and his colleagues concluded that a person was able to recall as many words, regardless of the number of syllables, he could read in the 1.87 capacity.

Nicolson (1981) reworded the linear relationship as : Memory span = capacity x processing speed + constant. He replicated closely Baddeley et al's study. Instead of adults, he used 3 groups of 10 children aged 8, 10 and 12 years old as subjects. The pattern of results was very similar to that of Baddeley et al's. As with the adults, both the memory span and the reading rate decreases as the number of syllables increases. He also found that overall memory span and reading rate were lower than the adults' but improved with age. The relationship between memory span and reading rate was linear for all 3 age groups. He found that his 3 groups and Baddeley et al's adult data could be well-fitted by a straight line. The best fit is MS=2.08xRR -2.04 When the data were collapsed over syllables and memory span was plotted directly as a function of reading rate, Nicolson found no difference between the age in the mean memory span for the 5 levels of reading rate. He therefore argued that the increase in mean reading rate (processing speed) with age is a sufficient explanation of the developmental increase in memory span.

Using different terminology, Case, Kurland & Goldberg (1982) attempted to explain the relationship of developmental increase in memory span and processing speed. They defined storage space as the hypothetical amount of space that a person has available for storing information; operating space as the hypothetical amount of space that a subject has available for executing intellectual operation; and total processing space as the total control processing resources which is the sum of his storage space and operating space. They used young children from 3 to 6 years old to minimize the effects of mnemonic strategies. Operational efficiency was assessed by having the children repeat recording of single words as quickly as possible. They found a significant linear correlation, even when age was partialled out. They argued that if memory span increases because operational efficiency increases, the groups widely separated in age should have same spans when their operational efficiency are equal. Based on this argument, they used adults as subjects in their attempts to investigate the possibility of a causal relationship. By using nonsense words, the researchers manipulated the adults' familiarity with the words, thereby equating the speed of word repetition with that of the group of young children. The results showed that when the word repetition speed was reduced to a value corresponding to that normally attained in the younger group, the spans of the adult group were no longer different. The size of the drop in span could be predicted from the speed of repeating the nonsense words. They therefore concluded that a causal relationship exists between span and word repetition speed. Similar pattern of findings were reported for a test of M space called "Counting span", that is, a linear correlation between counting span and counting speed and that when the operational efficiency was controlled, the spans of the adults and the young children were no longer different. Case et al concluded from the four experiments that developmental increase in memory span is not a result of an increase in total processing space. Rather, operational efficiency improves with development, thereby meaning that a person requires less processing space, and that more space becomes available for storage as a result.

When Hulme, Thomson, Muir & Lawrence (1984) investigated the relationship between memory span and processing, they manipulated the word length effect on the subjects. One, two, three and four-syllable words were used. Instead of repeating once for individual words as in the Case et al's study, Hulme and his colleagues had the subjects repeat each pair of words of a particular length 10 times. The results showed that increases in recall are accompanied by a corresponding increase in speech rate and there was no interaction between age and word length effect. The slope of the function thus calculated was 1.5 seconds, meaning that the subjects in the study, regardless of age (from 4 to adults) could recall as much as they could say in 1.5 seconds. They then compared the repetition of single words and word triads in the second part of the study to find out if the memory load involved in speech rate measure was important. They could not find any stronger relationship between speech rate of word triads and memory span than speech rate of single words and span. This indicated that the observed relationship between speech rate and recall does not depend upon the memory load. They therefore concluded that developmental increase in memory span could be explained in terms of increase in speech rate and that there is no evidence for an increase in short-term memory capacity.

In a recent study by Kail (1992) to investigate the proposed link between processing speed and memory performance in nine-years old children and adults, he found that age was correlated positively with memory (measured by free recall) but it was correlated negatively with processing speed and articulation rate. The results of path analysis showed that age and processing speed independently contributed to articulation rate which in turn determine memory.

The studies reviewed above demonstrated the existence of a relationship between memory and processing. The following section will attempt to look at this relationship from the perspective of a theoretical model.

2.1.2 The working memory model

The measure of memory span and operational processes can be theoretically linked together through the working memory model conceptualized by Baddeley and others (Baddeley,1992; Jorm,1983). The model evolved out of a series of experiments by Baddeley & Hitch (1974) which attempted to assess the function of short-term memory in various information processing tasks. In their experiments, the subjects were required to remember a sequence of digits while performing simultaneously other tasks such as reasoning, comprehension which were thought to require short-term memory capacity for their completion. They predicted that a concurrent digit load would impair performance. As predicted, they found small impairment across the range of tasks. They also looked at the role of phonological coding in information processing tasks. They were interested in the effect of phonological confusion on short-term memory since the latter often seems to involve storage in a phonological code. Again, they found that there was slightly impaired performance on tasks which involved phonologically confusing information (cited in Baddeley, 1992; Jorm, 1983). To account for these results, Baddeley & Hitch (1974) proposed that the short-term memory system be divided into 2 components: a central executive which is responsible for control processes and an articulatory loop which stores a small amount of speech based information in a phonological code. The loop is under the control of the central executive (cited in Jorm, 1983).

In later development of the model, Baddeley & Hitch (1974) and Baddeley & Liberman (1980) suggested that there is also a visuo-spatial scratch pad which holds a limited amount of information in a visuo-spatial code. Therefore according to Baddeley (1992), the working memory consists of the central executive which is in turn aided by 2 active slave system: the phonological loop which maintained speech based information and the visuo-spatial scratch pad which is capable of holding and manipulating visuo-spatial information.

In relating memory to processing, Baddeley (1992) theorized that the phonological loop has 2 components, a brief speech-based store, coupled with an articulatory control process. The former component holds a memory trace that fades within approximately 2 seconds. The latter component resembles subvocal rehearsal and is capable of maintaining the material in the phonological store by a recycling process. The working memory model therefore provides a theoretical framework to interpret the results of the aforementioned studies in section 2.11.

Does the working memory model and the relationship between memory and processing speed in the general population apply to the reading disabled also?

2.2 Memory and cognitive processing in the reading disabled

2.2.1 Language development and the phonological loop

When he reviewed studies on the relationship between the phonological loop, memory and learning in adults, Baddeley (1992) noticed that the effects of word length, phonological similarity substantially disrupted their acquisition of novel phonological materials. He argued that these results provide evidence on the notion that the phonological loop is particularly important for the acquisition of novel vocabulary. He explained the failure to find major impairments in everyday functioning in short-term memory deficit patients is a result of these patients having already acquired a language, and they are not usually required to learn a new one after their brain damage. Following this line of reasoning, Baddeley suggested that one might expect deficits in the phonological loop to be partially problematic in children.

Gathercole & Baddeley (1989) used nonword repetition as a measure of phonological storage of the working memory to investigate 4 and 5 years old children in vocabulary acquisition. They found that the nonword repetition was highly correlated with vocabulary score at both ages. The score obtained at age 4 even accounted for a significant amount of variance in vocabulary score at age 5, over and above that was accounted for by the vocabulary score the previous year.

Gathercole & Baddeley (1990a) suggested that nonword repetition requires accurate encoding and storage of phonological sequence in absence of support by lexical process. Therefore it is a sensitive measure of an individual's capacity for temporary phonological storage.

Based on this assumption, they explored the possible causal relationship in their previous study. They found that children with low nonword repetition scores were slower at learning phonologically unfamiliar names (a simulated vocabulary learning task), thereby providing support that the phonological store is directly involved in learning new vocabulary items in young children. They argued that to acquire a new word, a child has to establish a stable long term representation of a sequence of sounds. Before this can be done, a temporary representation presumably has to be achieved first. The phonological store would be an appropriate medium for this temporary representation. They suggested that the individual variation in phonological memory between the low and high repetition children lies in either the quality of the phonological encodings or in the storage of the phonological representation.

Gathercole & Baddeley (1990b) also looked into the possibility of causal connection of phonological memory deficit and language disorder in 7 and 8 year old children. These children were defined as having delayed language development by at least 2 years but normal range of general intelligence. They found that there was more delay in nonword repetition skill, by 4 years, than in the vocabulary and reading skills, by 20 months than their age controls. These children were also matched in vocabulary and reading skills with a non-verbal IQ group. Their nonword repetition skills were still delayed even when compared to this younger group. Gathercole & Baddeley argued that nonword repetition was a sensitive measure of the phonological storage, the results therefore indicated that disordered language development was a reflection of an impairment in the phonological storage.

The studies reviewed above indicated the importance of phonological awareness in the language development of young children.

2.2.2 Phonological deficits in the reading disabled

There is considerable evidence that the reading disabled show phonemic deficits or difficulties in phonological coding (eg. Ellis, 1981; Snowling, 1981).

Ellis (1981) conducted 4 experiments in his investigation of dyslexic children's reading slowness. He was interested in finding out if the slowness is a result of problems in the visual encoding and analysis of stimulus information, or in the creation of name representation for visual stimuli. The first experiment looked into the difference in performance between the control and the reading disabled groups on a letter matching task in which the similarity on the visual or phonological characteristics of the letters were manipulated. They found that the reading disabled did not respond more slowly than the control on letter pairs which were compared on visual features. However, the reading disabled were slower at judging the letter pair when the comparison was phonologically based. The reading disabled therefore performed less well in this task that required grapheme to phoneme translation. In the second experiment, Ellis controlled the possibility of the subjects' learning overlay of the letters by using confusable non-alphanumeric stimuli. He found no significant difference in performance between the two groups, thereby providing more evidence that there was no visual code problems in the reading disabled. Ellis used matrices of cells with inter-stimuli interval to measure the possible visual coding problem with respect to capacity and decay rate of visual code in the reading disabled. There was no significant main effect, again strengthening the argument that there was no major impairment of visual code in reading disabled children. When the subjects were asked to articulate single words presented auditorily, Ellis found no difference in performance between the reading disabled and the control groups. He therefore concluded that reading disabled children's deficit lay not in the simple articulatory code but in the more complex processes involved in name coding, namely an internal phonological code, lexical access and retrieval of pronunciation.

Snowling (1981) used matched reading age groups for her study on phonemic deficits in reading disabilities. When she compared the performance on reading nonwords between the reading disabled and the control group, the reading disabled not only had more difficulty with 2- syllable nonwords over 1-syllable ones than did the control group, they were also more affected by the number of consonant clusters in the 2-syllable nonwords. Though the reading disabled had the ability to read the same range of real words as the reading age matched control, the results indicated that the reading disabled were less efficient decoders than their younger control. The deficit was therefore independent of their reading ability to read real words and could not be predicted by their reading age. They showed a deficit in grapheme-phoneme conversion ability. As there was an interaction effect between the number of syllables and the number of consonant clusters, Snowling argued that segmentation problems alone may not be a sufficient cause of the reading difficulty, a general difficulty in dealing with phonetic clusters was just as important in understanding the cause. She further argued that if the underlying phonemic deficits affect the reading disabled's full attainment of automatic decoding ability, then the reading disabled should have difficulties in other tasks that require phonemic processing: spoken language tasks as well as written language task.

In the second part of her study, Snowling tested the subjects on repeating real words as in Ellis' 1981 study. However she also included repetition of nonwords with equal number of syllables and similar phonological complexity as the real words. The assumption is that more phonemic processing is required for unfamiliar nonwords. The results showed that the reading disabled were as good as the control group at repeating real words, but they were significantly worse at repeating nonwords. Similar to Ellis' conclusion, Snowling argued that it was unlikely that the reading disabled's difficulty lies in the articulatory-motor ability. Rather the results provide further support that the reading disabled have a phonemic deficit, which is noticeable even in speech.

Bradley & Bryant (1981) also looked into the phonological skills of reading disabled in their study. The subjects were required to choose the odd word out of a group of 4 spoken words, 3 of which had a phoneme in common. It was a test of children's ability to detect alliteration and rhyme. The reading disabled made more errors than the reading age matched group and the difference was significant. The subjects were also tested on visual memory. Four-letter, phonetically regular but unfamiliar words were used. The visual-auditory condition closely resembled reading. The subjects were asked to read the stimulus word made up with letter cards. The auditory-visual condition resembled spelling. After the experimenter said one of the stimulus words, the subject had to reproduce the word as a written word with the letter cards. Although the reading scores were the same for the reading disabled and the reading age matched control group, the reading disabled still performed worse. Bradley & Bryant argued that this anomaly could be explained as another example of a phonological difficulty. The traditional reading/spelling tests use familiar words which were not constructed on a letter by letter basis using phonological rules and which therefore were recognized as familiar patterns. The words used in the study relied more on phonological coded than the reading tests. Therefore they were relatively more difficult for the reading disabled.

The studies reviewed have been consistent with the notion that reading disabled children demonstrated some difficulties in the phonological coding skills.

2.2.3 Researches on memory deficits of the reading disabled

In contrast to researches on the phonological skills of the reading disabled, studies on the memory difficulties of the reading disabled yielded inconsistent results.

Traditionally, studies on reading disabled focused on their memory difficulties. Generally they found reading disabled have shorter immediate memory spans than average readers of the same age (eg. Rugel, 1974; Torgesen, 1978). In his review of studies on memory span as a measure of short term memory capacity, Jorm (1983) found that reduced memory span has been frequently found to be related to reading retardation but the relationship was not always a strong one. In a more recent study (Bowey et al, 1992) to investigate verbal working memory of less skilled fourth grade readers, it was found that these readers performed at the same level as their younger reading age-matched control. The correlational analysis also indicated that the memory skills (measured by the Digit Span subtests of the WISC-R) contributed less to the subjects' reading skills than the phonological analysis skills.

Jorm (1983) observed in his review of studies on memory deficits in reading disabled that though the group differences in memory span have frequently been found between retarded and normal readers, there was considerable overlap between the groups on this task. In fact, a memory span deficit was not found in all retarded readers. There were studies which included reading disabled subjects who showed a consistent digit span deficit and those who did not.

In the area of phonological confusions in memory span, there were again inconsistent findings on the reading disabled's difficulty. From the studies that Jorm (1983) reviewed, he concluded that reading disabled children were less prone to phonological confusions. However, in Bisanz, Das & Mancini's study (1984), they did not find interactions which would have indicated group differences in size of phonological similarity effect in their immediate recall task for their grade 4 and grade 6 subjects.

Jonhston, Rugg & Scott (1987) noticed that few studies which investigated phonological similarity effects took into account the immediate memory impairment of the reading disabled. They argued that the reduced phonological similarity effects observed in poor readers could be a result of the string lengths employed placing more demands on the subjects than on the controls. They therefore equated the span length by determining a criterion level of performance for each subject. As in Bisanz et al's study, they could not find the reduced phonological similarity effects in their 8 and 11 year old poor readers. The effects were comparable in size to both the chronological and reading age control groups. Furthermore, they could not find any relationship between the size of phonological similarity effect and reading ability. They argued that the results of the study could not support the hypothesis that reading disabled's difficulties in immediate memory tasks were primarily due to a deficiency in the use of phonological coding.

2.2.4 Relationship between phonological deficit and memory deficit

Many studies quoted above all pointed to the phenomenon that reading disabled experienced some difficulties in phonological skills. Jorm (1983) attempted to explain how a phonological coding deficit in the working memory could adversely affect the reading process. First he argued that such a deficit would probably affect reading at a single-word level. He quoted studies that readers can access the lexical entries for single words by either mechanism: graphemic analysis of the word, or by recoding the word into a phonological representation. The latter mechanism is necessary for identification of unfamiliar words. It is very important for beginning readers in achieving lexical access because many printed words are unfamiliar. Therefor lexical access via phonological recoding would be adversely affected if retrieval of phonological information from long term memory was slow. The second area that a phonological deficit in the working memory could affect the reading process is in the extraction of meaning from text. Jorm reviewed studies that provide evidence that phonological recoding may play an important role in reading comprehension. Then he argued that reading disabled who have phonological coding problems would be expected to have comprehension difficulties because they could not adequately store information about words previously identified.

Though Johnston et al (1987) could not find any reduced phonological similarity in their 4th grade poor readers, their study confirmed the existence of the relationship between reading and memory difficulties. They further questioned the attribution of a memory span component in word recognition in the association found between memory span and reading age. Instead they suggested that future research should attempt to isolate the elements that memory span and word recognition tasks have in common. Baddeley and Lewis (1981) and McCutchen & Perfetti (1982) suggested that the effortful phonemic processes tapped by short-term memory tasks are qualitatively different from processes essential in the reading of skilled adults.

Based on the framework of the working memory model, Torgesen and his colleagues (1990) argued that reading disabled children's difficulties on short-term memory tasks are primarily the result of inefficient or degraded phonological representation. They found related studies showing that groups of reading disabled children could recall normally other types of information which did not require or allow phonological coding. Therefore they suggested that it is not the memory system per se that is deficient in these children but rather the representation they have available for a specific type of information. In this conceptualization, both the memory span and the reading difficulties are caused by the fundamental problems of establishing distinctive phonological codes. This implies that reliable measures of verbal memory span would be a useful part of diagnostic batteries for reading disabled. However, they argued that except at extreme ranges of performance difficulty, span tasks are not very stable because momentary fluctuation of attention and effort can have a significant impact on the span score. Therefore sufficient trials must be given to ensure reliable measurement.

From the studies reviewed we have much evidence that reading disabled have difficulties in phonological skills and there is also evidence that they also exhibit some short-term memory difficulties. There are inconsistent results on the phonological similarity effects on the performance of immediate recall. Investigators such as Johnston et al (1987), Bisanz et al (1984) have questions regarding the phonological skills tapped by these short-term memory tasks are different from those required in reading. There is a need to look at what abilities these phonological coding and memory tasks measure, how are they related to each other and how are they related to the reading ability of reading disabled.

If the traditional memory span task may be measuring skills different from those required in reading, are there any other more sensitive tasks that can predict reading ability better? The following section will review studies that attempt to answer the question raised.

2.3 Relationship between tasks used and reading ability

2.3.1 Measurement tools

This section will review the different tasks commonly used in the different investigation of the problems experienced by the reading disabled. The review will attempt to look at what underlying abilities these tasks measure.

Naming time has been a conventional method for measuring item identification speed. In a typical experiment, 50 items printed on a page are given to the subject to read as quickly as possible. The time taken to read all the items is naming time (Denckla & Rudel, 1976). According to other studies (McRae, Jared, & Seidenberg, 1990; Nicolson, 1981), naming time involves all the routine input, lexical access and output process. Therefore it can be considered a composite of phonological coding time, articulatory programming of speech and the reaction time for speech activation. And a number of studies have found that reading disabled are slower to name letters, objects and pictures (Denckla,1972; Denckla & Rudel, 1976; Spring, 1976; Spring & Capps. 1974). Jorm et al (1986) even found that some preschoolers who subsequently had difficulty with reading were slower and less accurate in naming pictures and colours (cited in Johnston et al, 1987). A study that looked into the neuropsychological profile of reading disabled in adulthood found that only 3 tests were significant discriminating measures (Felton, Naylor & Wood, 1990). One of them was naming time (which was based on Denckla & Rudel's design in 1976). It appears that naming time is a sensitive measure of reading disabled's underlying difficulty in phonological coding.

Torgesen and his colleagues (1990) reviewed several studies that compared memory span with rapid automatic naming in predicting reading skill acquisition. They concluded that naming rate tasks may provide more sensitive measures of phonological coding difficulties.

Speech rate is the rate a subject repeats word/words as fast as possible. The studies by Case et al (1982) and Hulme et al (1984) established the fact that the developmental increase in speech rate corresponds with the developmental increase in memory span. Hulme et al even showed that speech rate is predictive of memory span. In a later study, Hulme &

Tordoff (1989) further investigated the effects of word length and acoustic similarity on speech rate and serial recall performance in children. And they found that the partial correlation between the acoustic similarity effect and speech rate, partialling out the effect of age, remained quite substantial. They argued that the important link was between acoustic similarity effect and speech rate rather than age. They further suggested that if speech rate was interpreted as a measure of rehearsal speed, the correlation would therefore tie the size of the acoustic similarity effect to this rehearsal process. This argument provided further support to the function of the phonological loop of the working memory model.

The repetition of individual words or small groups of words as a measure of speech rate is independent of the time taken for item recognition (Das & Mishra, 1991; Hulme & Tordoff, 1989). Though speech rate requires phonological coding, unlike naming time, it does not require reading. It involves to a greater extent a direct use of articulation (Das & Mishra, 1991; Torgesen et al, 1990).

Das & Mishra (1991) stated that item identification and memory for order are the two variables that determine span. Individuals who are slow in item identification will have a relatively reduced capacity for storing item and consequently a shorter memory span. In discussing order memory, Das (1985) suggested that order memory for digits or words depends on a speech related process that is used to keep the item in the articulatory loop for about 2 seconds.

Several researchers questioned the possible common factors/ links between span, phonological coding and reading. Johnston et al (1987) questioned the attribution of a memory span component in word recognition found between memory span and reading age. Bowers, Steffy & Tate (1988) argued that separate mechanisms are involved whereby the size of memory storage and naming speed affect reading. They suggested that poor short-term memory for auditory speech might affect reading partly through its greater reciprocal effect on general storage of verbal information and verbal comprehension while slow naming speed reflected inefficient transfer of orthographic information to a phonological code, which therefore have effects more limited to lower-level reading skills. As a result, naming speed can affect reading without having a broad impact on verbal comprehension. Bowey et al (1992) summarized from the studies they reviewed that there is a possibility that both phonological analysis and verbal working memory contribute independently to decoding skill. Das & Mishra (1991) suggested that it is possible that phonological coding is not the critical common factor between memory span and reading competence for some individuals. They and Torgesen et al (1990) suggested that naming time could be a more dependable measure of phonological coding than memory span.

Phonemic segmentation is a task in which a subject is asked to pronounce a word/nonword with a letter-sound omitted. It is used frequently to assess phonological awareness skills (Bowers & Swanson, 1991; Cornwall, 1992). Frith (1992) argued that if reading disabled have problems with phonological analysis of speech sound, then this deficit would lead to problems in phonemic segmentation. However Montgomery (1981) found that the 10 years old subjects used in the study did not differ significantly from the reading-age matched control on the task. Hurford (1990) found that his grade 3 reading disabled improved on the phonemic segmentation scores after an intervention in phonemic discrimination. In fact the improved performance was not significantly different from the age-matched control group. The grade 2 reading disabled also improved after intervention but the perf mance was still significantly inferior to their age-matched normal readers.

If naming speed, speech rate, phonemic segmentation and memory span all relate to reading and they may involve different mechanism in reading, then it is interesting to find out if any relationship exists between these tasks at all and how they are related to reading.

2.3.2 Relationship of naming time, speech rate, memory span, phonemic segmentation and reading scores

Cornwall (1992) examined the relationship of phonological awareness (a phonemic deletion and blending task), naming speed (letter naming) and verbal memory to 5 tests which assess word attack, word identification, reading comprehension and spelling skills in 7 years to 12 years old dyslexics. After controlling for age, SES, behavioral problems and intelligence, the phonological awareness task added significance to the prediction of word attack, spelling and reading comprehension scores. Letter naming speed added significance to the prediction of word identification, prose passage speed and accuracy scores while the memory task to the prediction of word recognition scores. Cornwall concluded that the results indicated that these tests measured skills which were related to a wide variety of reading subskills. She further suggested that several independent processes interact to determine the extent and severity of reading problems.

Bowers & Swanson (1991) found that their phonological awareness tasks (measured by the Auditiory Analyses Test and the Odd Word Out task) correlated with the Woodcock Word Identification and Word Attack results. They suggested that while memory span may play a role in a few phonological awareness-reading relationships, it is not likely to be the basis for most such relations because the forward digit span was related significantly only to the Odd Word Out scores and Word Attack only. The regression analyses showed that while digit naming and phonological awareness tasks both contributes to the variance of Word Identification, they also tend to predict individually different aspects of reading skills. Digit naming predicts no independent variance to Word Attack while the phonological awareness tasks contributed no unique variance to comprehension.

Bowers et al (1988) argued that studies that match reading disabled with normal readers on performance IQ measures inevitably resulted in selecting a sample of reading disabled who have a lower verbal IQ. And verbal IQ is typically more highly correlated with reading than is performance IQ. They questioned that whether analyses of differences between the reader groups can isolate any deficits specific to reading disabilities because any measure differentiating groups could be a function of the verbal IQ. They therefore investigated how well measures of verbal short-term memory and naming speed for digits and colour predict a child's reading achievement under various IQ control conditions. The reading measures were the Word Identification and Word Attack subtests from the Woodcock-Johnson Test of Educational Achievement. The memory tests used were Digit Span subtest from the WISC-R and the Sentence Memory test from the Detroit Tests of Learning Aptitude. They found that both short-term memory and naming speed were effective predictors of performance on the two reading subtests even when nonverbal IQ was statistically controlled. However when verbal intelligence was controlled either statistically or by stringent selection criteria, the contribution of memory measures to reading reduced considerably. Yet digit naming speed remained a significant contributor to reading achievement. They concluded that there was evidence that reading disabled may have a specific deficit in naming automaticity. This is consistent with the conclusion reached by Johnston et al (1987) in their study.

Bowers and his colleagues further suggested that the results supported the argument that there are separate as well as shared mechanism whereby naming speed and memory affect reading skills.

Wolf, Bally & Morris (1986) found a developmental pattern of strong, general predictions to highly differentiated ones in the naming speed and reading relationships in the normal readers. The correlation between single word reading (lower level of reading) and digit and letter name-retrieval remained constant in the 2-years investigation; comprehension correlation with name-retrieval appeared to decline across time. The reading disabled in the study performed slower than the normal readers on all name retrieval measures (digit, letter, colour and object), particularly on the graphological symbols.

Bowey et al (1992) used the Word Identification subtest of the Woodcock Reading Mastery Tests (1987) to allocate children to age and reading level controls for less-skilled fourth grade readers. They used a phonological oddity tasks to assess the subjects' sensitivity to subsyllabic and phonemic units, the Digit Span subtest of the WISC-R to assess verbal working memory and the Word Attack subtest (pseudoword reading) to assess phonological recoding skills. Consistent with other studies, the less skilled readers performed lower than the 2 control groups on the phonological oddity and pseudoword reading tests. With the test on verbal memory, the less skilled readers performed at the same level as the reading control. They found that correlational analyses were consistent with the results that phonological analysis skills contribute more strongly than verbal memory skills to children's decoding abilities.

The studies on reading disabilities reviewed so far uses digit or colour naming as measures of naming speed only. Little had been done to relate naming time to memory span. Das & Siu (1989) used one, two and three syllable words as naming time measures and explore the relationship with memory span. They found a significant difference between the good and poor readers in naming the three-syllable words. They hypothesized that for the subjects to read out the 3-syllable words, they might have broken the words into smaller visual units, tried to pronounce each part, and then blended the parts together to form the word. They did not process the whole word as a unit because it was long. For the good readers, the operation of these processes might be automatic, whereas for the poor readers, it might be clumsy and slow. They was also a significant difference between the two reader groups on word span task. They also found that naming time for two and three-syllable words were significantly negatively correlated to span. They argued that the results provided further support to Baddeley's working memory model, that is, the slower one processes incoming information, the less is the capacity for storing and maintaining that information in working memory. Similar to the results obtained by Bowers et al (1988), they could not find any significant relation between naming time and listening comprehension; however there was some positive relationship between memory span and comprehension performance. The results may provide some evidence on what Cornwall (1992) has suggested that these measures tap into different mechanism of reading.

Following Das & Siu's (1989) line of reasoning on the relation between naming time and performance on memory span, Das & Mishra (1991) attempted to investigate the relationship further. Based on review of studies that failed to show phonological similarity difference between poor and good readers. Therefore they argued that memory span may not be a dependable measure of phonological coding. They hypothesized that naming time may be a better choice as phonological information on the word is rapidly activated when a word is recognized during reading. They argued that reading is much closer to speed of articulation than memory span. Therefore the motor programming of speech becomes an important factor on sighting a word. They hypothesized that prediction of reading as measured by word attack and word identification (decoding) should be stronger from speech rate and naming time than memory span. From the results, they found a strong relationship between reading and the naming time and speech rate tasks, with naming time having a better prediction than speech rate, while memory span had only a weak prediction on reading. They used a path analysis to further examine the close connection between naming time and speech rate. The connection was represented by a latent variable which has two components: phonological activation on confronting a word and its articulation, the strongest link to reading (decoding). They suggested that the link between short term memory and decoding competence was mediated by this latent variable as shown in the weak correlation between individual differences in short-term memory, naming time, speech rate and reading.

The studies reviewed so far presented a picture that these tasks share a common variable or have a link between them, such as the latent variable shared by naming time and speech rate, the theoretical link between speech rate and memory span. The review also presented us a picture that in spite of the relationship between them, these tasks also individually and independently tap into the different abilities required in reading, suggesting that separate mechanisms are involved in reading.

2.4 Summary

The linear relationship of processing speed, measured by reading rate or speech rate in the studies reviewed, and memory is well established. The working memory model with the phonological loop component for rehearsal and storage provides a theoretical link for this relationship. The phonological loop also provides the basis of understanding the probable underlying cognitive deficit in reading disabilities. Indeed the studies reviewed in this chapter have been consistent with the notion that the reading disabled have some phonological processing difficulties. Different tasks have been used in an attempt to measure the deficit. The most commonly used tasks were naming time, memory recall tasks, and some phonological awareness tasks. These tasks were also compared with some reading ability skills, usually decoding tasks and some comprehension tasks. Some studies found that memory recall tasks was not as sensitive a measure in predicting reading ability, thus providing more support for the argument that naming time and speech articulation might be the more sensitive measures for phonological coding.

Though many studies have made extensive investigation into the different aspects of reading disabilities, especially in finding out the underlying deficits and any tasks to identify them, there are still a few gaps that need to be filled.

1. The conventional definition of reading disabilities is the existence of a discrepancy between intelligence and

reading achievement. If reading disabilities involve some cognitive processing deficits, then there is a need to investigate whether IQ may have any influences over these cognitive processing deficits. Most studies of reading disabilities involved subjects within the average range of IQ. The studies reviewed in this chapter did not compare any task performance between high IQ and average IQ groups.

2. A few studies established that speech rate/articulation rate is predictive of memory span. Some researchers even suggested that it may be a more sensitive test to identify the reading disabled than memory span tasks. However, very few studies have been conducted on the relative contribution of the task in predicting reading.
3. If speech rate is closely related to memory span, and if naming time and phonemic segmentation involve some phonological processing, then there should be some interrelationships between these tasks. The present review indicated that this is an area that required further investigation. Most studies involved either two or three of the tasks named but not all of them.
4. Though naming time, adapted from Automatized Rapid Naming by Denckla & Rudel (1976), has been frequently used in reading disabilities studies, the task usually involved digits, letters, colours and objects. Only two studies by Das & Siu (1989) and Das & Mishra (1991) involved words

in the task. The task itself may then be closer to the rhythm and pattern of reading. However there have been no analysis on the pattern of performance of this task using word as the stimulus item.

3. RATIONALE, DEFINITIONS, and HYPOTHESES

3.1 Rationale

3.11 Rationale of the study

It has been shown in Chapter 2 that extensive research has been done to understand more about the underlying processing deficits in reading disabilities. As summarized at the end of that chapter, there are still a few gaps which need to be filled. One of them is the question of any influences of the IQ factor on the performance of tasks which appear to be able to distinguish the reading disabled from the normal readers. These studies used subjects with average range of IQ and IQ-matched control group. The second gap is in the area of further understanding of the interrelations among these tasks. There appears to be close connections between these tasks on the basis of theoretical argument and empirical evidence put forward in the review in the previous chapter. Yet they seem to be measuring the different mechanisms involved in reading based on results obtained from correlation and regression analyses. Though investigations of interrelations among these tasks were conducted in previous studies, they included only some, not all of the four tasks which were presented in Chapter 2 as either conventional or more sensitive identification tools in distinguishing reading disabled. An analysis of the interrelationship of the tasks and their relative contributions to the decoding ability may shed more light on the difficulties the reading disabled experience in reading. the results generated may help in the construction of and the selection of more sensitive tests to identify the underlying deficits.

The first purpose of the study, therefore, is to investigate the interaction of IQ and tasks performance; and the relationship between tasks performance and reading.

Rapid naming has been frequently quoted as the task that can be used to distinguish reading disabled, from childhood to adulthood. The performance on this task is usually measured by using a stop watch to calculate the time taken to name the items. Stop watch itself is usually a very accurate instrument, but the human error involved in the timing of starting or stopping the stop watch may affect the results obtained especially when most stop watches measures in seconds. And it takes seconds only to finish naming the items. Only two studies involved the use of words as the stimulus item which may be a closer simulation to actual reading.

The second purpose of the study, therefore, is to conduct an in-depth analysis of the task. The time to read each line of words, as well as involuntary pauses between the lines can be measured by the computer, which can also eliminate some of the human errors mentioned above.

3.12 Statement of the problems

Several specific research questions will be studied.

1. What is the difference in the performance of the four tasks which can distinguish the reading disabled: naming time, speech rate, phonemic segmentation, and word series recall? Will the high IQ and average IQ groups of poor and normal readers differ on each of the task?
2. Is there any interrelationship between these four tasks since they are supposed to tap into the same underlying deficits of reading disabilities?
3. Related to the question raised above, what is their relationship with reading? Are these tasks measuring distinct core problems in reading, or are they measuring similar core problems? Should one task or some tasks be chosen over another to measure these core problems?
4. Is there a different pattern of performance between the poor readers and normal readers in the naming time task? Do the poor readers simply take longer to finish the task?

3.2 Definitions of terms

For the purpose of this study, the major terms are defined as follows:

High IQ readers: The subjects who scored at least 6 months or above than their chronological age in the IQ test.

Average IQ readers: The subjects who scored at their chronological age level in the IQ test

Poor readers: The subjects who scored at least 12 months below their chronological age level on the reading ability test.

Normal readers: The subjects who scored at their chronological age level on the reading ability test.

Reading ability: It refers to the decoding ability as measured by the Word Identification and Word Attack tests from the Woodcock Reading Mastery Tests (1987).

Word series recall: The recall of lists of words in the order in which they are presented.

Naming time: The speed the subjects are able to orally name words.

Speech rate: The speed the subjects are able to pronounce a set of words repeatedly.

Phonemic segmentation: The pronunciation of words or nonwords with a sound omitted.

3.3 Hypotheses

On the basis of the previous discussion, the following hypotheses are formulated:

Hypothesis 1

It is hypothesized that there will be no significant difference on the performance of the 4 tasks of naming time, speech rate, phonemic segmentation, and word series recall between the high IQ and average IQ poor readers but a significant difference between the poor and normal readers.

Hypothesis 2

It is hypothesized that there will be a significant relationship among the 4 tasks of naming time, speech rate, phonemic segmentation, and word series recall.

Hypothesis 3

Since naming time and speech rate involve phonological coding, and since phonemic segmentation involves phonological awareness, then these tasks will closer to the skills required in the performance of the decoding task. It is therefore hypothesized that phonemic segmentation, speech rate, and naming time have more contribution than word series recall to the variance of the reading ability scores.

Hypothesis 4

It is hypothesized that the poor readers take longer than the normal readers to read each line and take longer pauses between the lines in the naming time task.

4. METHOD

4.1 General Method

The study is divided into two parts, Experiment 1 and Experiment 2. The data collected for both experiments were from a larger research study.

4.1.1 Subjects

The research sample was drawn from the subjects from in the larger research study. They were 8 to 10 years old students in year 3 and 4 of the elementary schools in the Edmonton Public School District.

The nonverbal IQ of the students was assessed by the Matrix Analogies Test-Short Form (MAT-SF). High IQ was defined by a performance of at least 6 months above the chronological age level on the MAT-SF. Reading level was determined by the performance on the Word Identification and Word Attack tests (Form H) from the Woodcock Reading Mastery Tests-Revised (1987). Poor reading was defined by a performance on the two tests at a level of 12 months or more below the chronological age.

With the above criteria, 60 students were selected from the original pool of subjects. For Experiment 1, the division of the subjects into four groups based on IQ and reading ability limited the number of subjects available for the concomitant matching of subjects based on gender. Therefore in Experiment 1 the poor reader group and the control group were not matched on gender. There were 15 subjects for each of the group of high IQ-normal readers (4 males and 3 females), high IQ-poor readers (3 males and 2 females), average IQ-normal readers (6 males and 2 females), and average IQ-poor readers (7 males and 3 females). For Experiment 2, the division of subjects into groups was based on reading ability only. Reading disability is observed more often in male while the level of severity is often more pronounced in females. The confounding factor of gender was controlled by selecting 10 males and 5 females for the poor reader group. The control group was matched in gender.

4.1.2 General test instruments and procedures

All subjects were first given the MAT-SF and the Word Identification and Word Attack tests (Form H) for screening purpose. These tests were administered individually.

The MAT-SF is designed to provide a measure of non-verbal reasoning. It uses 34 abstract designs of the standard progressive matrix type. There are 4 kinds of items and they appear in a varying order in the MAT-SF. They are pattern completion, reasoning by analogy, serial reasoning, and spatial visualization. The test was normed in 1984 on 4468 U.S. students between the ages of 5 and 17. The manual provides information on the reliability data and validity measures of the test. It also outlines the instruction on the administration of the test. The test provides 3 types of not matched on gender. There were 15 subjects for each of the group of high IQ-normal readers (7 males and 8 females), high IQ-poor readers (11 males and 4 females), average IQ-normal readers (6 males and 9 females), and average IQ-poor readers (12 males and 3 females). For Experiment 2, the division of subjects into groups was based on reading ability only. Reading disability is observed more often in male while the level of severity is often more pronounced in females. The confounding factor of gender was controlled by selecting 10 males and 5 females for the poor reader group. The control group was matched in gender.

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Example: The examiner say the word "BUG".

"Now say BUG without the /b/ sound"

The response was scored either correct or incorrect and a score of '1' was given for a correct answer. The maximum score was 24. (Refer to Appendix A for the complete list of words used.)

Word Series

The subject was required to repeat a series of one-syllable nouns, drawn from a pool of 9 words, in the same order in which they were verbally presented by the examiner. (Refer to Appendix B for the complete list of words used.) The words were randomized and grouped in 18 sets of words. The number of words increased progressively in the set, with a minimum of 2 words to a maximum of 6 words.

The following instruction was given:

"I am going to say some words. They are Girl, Car, Dog, Shoe, Book, Key, Man, Cow, and Wall. Listen carefully because when I am through, I want you to say them just as I did. Listen, say 'Book Car'".

The examiner then paused and allowed the child to respond. If the child responded correctly, then the examiner proceeded to item 1. If not, the examiner explained the task further until the child fully understood what he/she was supposed to do. He/she would provide help if necessary to obtain a correct response for item 1 and no further help would be provided for the remaining item.

The examiner presented the items at a rate of one word per second. The subject was asked to recall all of the words of a set in the exact order of presentation. Word series of increasing length were administered and discontinued after the subject had 4 consecutive failure. Only perfect recall was considered as a success. Each series of words was scored in the correct serial position. For example, if the item was Wall-Cow-Car-Girl and the response was Wall-Car-Girl-Cow, then the score was 1. The maximum score was 79.

Naming Time

36 words were presented on each card containing a matrix of 6 rows x 6 columns. The first 2 cards had identical 1-syllable words. The words were arranged differently for the 2 cards for the purpose of obtaining reliability. Similarly, the other 2 cards had identical 1-syllable words arranged differently on each card. The words on the first set of two cards were drawn from a pool of 9 simple common nouns while the words on the second set of cards were drawn from a pool of 9 colour names. (Refer to Appendix C for the complete lists of words.)

The subjects were asked to read the rows of words from left to right aloud without stopping and as quickly as possible. The following instruction was given.

"I have 36 words on each card that I would like you to read. Please read the rows of words from left to right aloud without stopping, and do so as quickly as possible. Let us do a practice trial to help you with the words."

(The examiner showed the demonstration card A which had 2 rows of 6 words each. The words were from the first pool of words.)

"Let me see you read these words."

(The examiner gave the correct pronunciation when the child failed to read any word.)

"Now let me see you read them as fast as you can."

(The examiner showed the child the first card and turned the tape recorder on.)

"Are you ready? When I tap the desk begin reading."

(The examiner tapped the desk loudly enough to record that sound on the audio tape.)

When the subject finished Card 1, the same instruction to read as fast as possible was given for Card 2. After Card 2, the examiner showed the demonstration card B for the colour names of Card 3 & 4 and repeated the above instructions.

A stop watch was used to record separately the time taken to read each card. The stop watch button was pressed to start timing as soon as the child started naming the first word and the stop was stopped as soon as the child finished the last word. Each subject's performance was also audio-taped with a tape recorder.

<u>Speech Rate</u>

In this task, the subject was asked to repeat sets of 1-syllable, 2-syllable, and 1-2-3-syllable words as fast as possible. Each set of 3 words was to be repeated 10 times. (Refer to Appendix D for the complete lists of words). The following instruction was given.

"I am going to say some words. The words are Egg, Bus, Leaf. I am going to ask you to say 'Egg-Bus-Leaf' as fast as you can without stopping. You will say 'Egg-Bus-Leaf" over and over again until I tell you to stop. Start to speak as fast as you can when I tap the desk."

(The examiner turned the tape recorder on.)

"Ready"

(The examiner tapped the desk loudly enough to record that sound on the audio-tape.)

When the subject finished the last word of the sequence on the 10th repetition, the examiner said "stop". After the child finished the demonstration exercise, the same instruction was given for the 6 sets of words.

A stop watch was used to record separately the time taken to read each set of word triads. The stop watch was pressed when the child began the first word and stopped when he finished the last word of the sequence on the 10th repetition.

4.3 Experiment 2

4.3.1 Instrument

An Apple MacIntosh IISi microcomputer equipped with a

MacRecorder Sound System was used to transmit the audio-tape protocols of the subjects on the naming time task from the tape to the computer. The sound from the tape would be displayed as an oscillographic form on the computer screen for precise calculation of speed of naming. The MacRecorder Sound System includes the MacRecorder Digitizer, a hand-held sound input device and 3 applications, Hypersound, Hyper-sound Toolkit, and SoundEdit which allow recording and playing back of the sound. The SoundEdit application was used as it includes tools for analyzing sounds and tools for visual display of waveform of sounds.

4.3.2 Procedure

The subject's audio-tape protocols of the naming time task were transmitted from the tape recorder directly to the MacRecorder Digitizer through a wire connection. The audio-taped responses of each card were transmitted separately. First of all, the recording level was adjusted by turning the input level knob on the MacRecorder Digitizer so that the waveform displayed on the screen would not be too narrow, indicating that the sound was too soft when recorded; or too wide, indicating that the sound was too loud when recorded. The optimum recording level was achieved when portion of the waveform just barely reached the top and bottom of the window on the computer screen as shown in Figure 1. After the audio-taped response of each card was digitized in single pass from the cassette deck to the computer, it was displayed in oscillographic form on the screen at the standard magnification, which was set by the recording input level through the MacRecorder Digitizer.

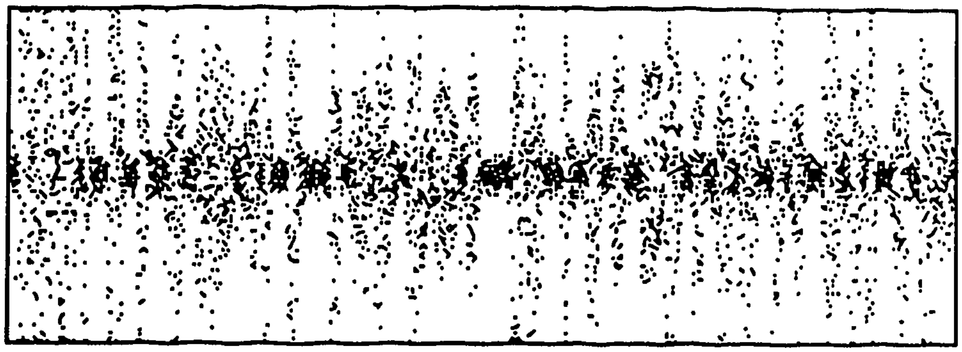
The SoundEdit application provides the tools for sound analysis. Dots were selected as the display style for the waveform representation. The display unit for the length/ duration of a sound was measured in seconds. Segments of the waveform could be selected for analysis by using the computer mouse clicks to highlight the segment on the screen. The computer provides a digital readout of the time duration from the beginning to the end location of the highlighted segment. The readout measures to two decimal points of a second. Sounds of the highlighted portion could be played back by clicking the play button. This provided a check that the word boundaries of the segment were accurately determined. Two types of segment were highlighted for a digital readout, the lines, represented by a waveform of sound, and the pauses, represented by a straight line of dots for the silence. The pause is the time lapse between the end of pronunciation of the last word of the previous line to the beginning of pronunciation of the first word of the next line. There were altogether 6 digital readouts for lines and 5 digital readouts of pauses for each card.

The segment of each line was determined by locating the beginning of the line first. The approximate location was determined by listening to the play back of sound and then highlighted. Then that particular segment of the waveform was enlarged by clicking on the zoom control (zoom in). The enlarged waveform allowed a more detailed display of where the silence ended (represented by a horizontal line of dots) so that the exact location of the beginning of pronunciation of words could be determined as shown in Figure 1. The playing back of this highlighted segment provided another check whether the subject actually began the pronunciation of the first word at the identified location. Once the location of the beginning of the line was determined, the computer mouse click was used to mark the location on the screen to create an insertion point, and the highlight was then cancelled.

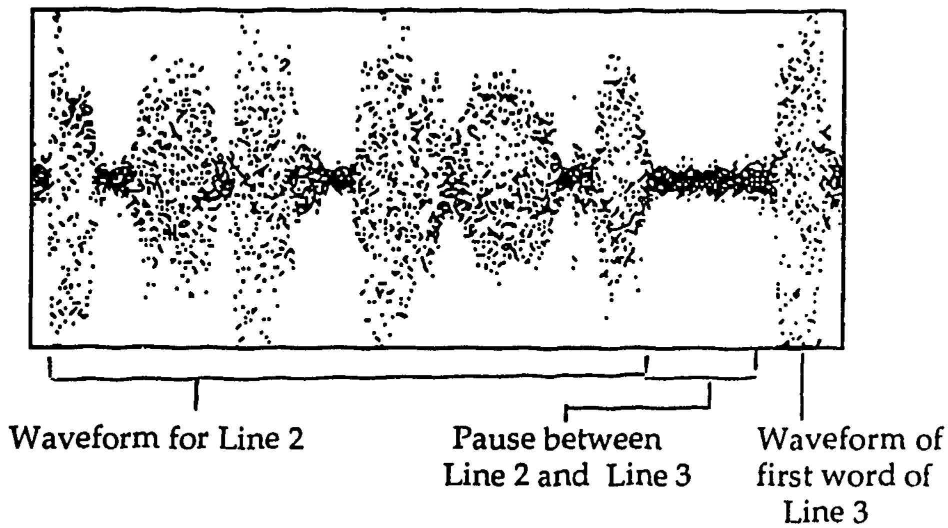
The approximate location of the end of the line was next highlighted with listening to the play back as another check. The zoom control was used again to locate the end of the pronunciation of the last word. The waveform display would change suddenly into a straight line as the pause began. The play back was used to ensure the location of the complete pronunciation of the last word was accurately determined. Once the end location of the line was determined, the computer mouse click was used to mark the location on the screen to create an insertion point. The segment between the two insertion points was then h[illegible]ed for the computer to provide a digital readout of t[illegible]uration in seconds. The segment was then played b[illegible]other check of the line boundaries. It was colour coded next for easier identification on the screen.

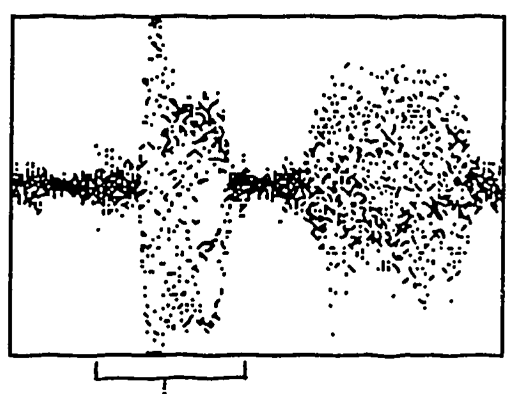
The duration of the pauses was determined in a similar fashion as the line. Instead of highlighting the waveform, the horizontal line which represented the silence between the lines was used for analysis. The approximate location of the pauses was highlighted. The zoom control and play back functions were used to locate accurately where the pause began, after the end of pronunciation of the last word of the line. An insertion point was created next for the location. The end of the pause was determined in the same way and an insertion was also created. The segment between the two insertion points was then highlighted for a digital readout. The pauses were not colour coded.

The whole waveform of the response of each card was displayed on the screen with the use of the zoom control (zoom out). With the colour coded waveform of lines alternated with the black horizontal line of pauses, any pattern of performing the task that might emerge, could easily be identified. The information thus obtained could be useful for qualitative analysis.



Waveform for Card 2 of Naming Time Task





Zoom in waveform of first word of Line 2

Figure 1. Illustration of SoundEdit waveform display

5. RESULTS AND DISCUSSIONS

The statistical analyses were divided into four parts.

To test the first hypothesis, two-way analysis of variance was used to see whether there was any main or interaction effects between IQ level and reading ability for the four tasks performed.

To test the second hypothesis, Pearson-product correlation and linear regression were used to find out the interrelationship among the four tasks.

To test the third hypothesis, multiple regression analysis was used to find out the contribution of the four tasks performance to variances in reading scores.

To test the fourth hypothesis, multivariate analysis of variance with repeated measures was used to find out the between and within subject variances for the two reading groups on the duration to read the lines and to take pauses for the naming time task.

5.1 Experiment 1

The means and standard deviations of the age, and the age equivalent scores of the MAT-SF, Word Identification and Word Attack tests were presented in Table 1.

The means and standard deviations of the speech rate, naming time, phonemic segmentation and word series recall were presented in Table 2.

Table 1

Means and Standard Deviations of Age, MAT-SF, Word Attack, and Word Identification Age Equivalent Scores in Months

	Group			
	High IQ		Average IQ	
	Poor	Normal	Poor	Normal
	N=15	N=15	N=15	N=15
Age	104.67 (5.86)	110.07 (4.50)	110.87 (11.75)	107.67 (5.51)
MAT-SF	120.80 (15.52)	132.07 (15.92)	95.00 (14.49)	99.73 (9.35)
Word Identification	94.27 (6.30)	138.93 (15.84)	91.47 (7.16)	122.00 (15.00)
Word Attack	84.87 (6.64)	177.60 (46.11)	85.00 (10.29)	139.47 (37.39)

Note: Standard deviations are in parentheses

Table 2

Means and Standard Deviations of the Raw Scores of the Tasks

	Group			
	High IQ		Average IQ	
	Poor	Normal	Poor	Normal
Task	N=15	N=15	N=15	N=15
Naming Time (seconds/card)	27.34 (11.05)	18.67 (3.26)	32.71 (12.63)	18.69 (2.61)
Speech Rate (seconds/card)	22.14 (4.39)	17.80 (3.55)	22.48 (2.17)	17.05 (2.17)
Phonemic Segmentation	10.57 (1.90)	11.07 (0.80)	9.68 (2.85)	11.10 (0.89)
Word Series Recall	40.60 (13.62)	56.80 (14.66)	25.93 (8.45)	55.13 (18.29)

Note: Standard deviations are in parentheses

5.1.1 Task Comparison

5.1.1.1 Naming Time

Consistent with studies that compared naming time with reading disabled and normal readers, from younger readers to adults, using digits, colours, letters, or object naming (eg. Bowers & Swanson, 1991; Wolf, Bally & Morris, 1986), the two-way ANOVA indicated that there was a main effect of reading ability, $F(1,56)=25.81$ $p<0.001$. There was a significant difference between the poor and normal reading group on the time taken to finish the task, with the poor readers taking more time. The results were shown in Table 3.

Though this study and the study by Das & Siu (1989) both used words as the stimulus item, the results of the present study were different from the latter study. Das & Siu found a significant difference between their good and poor readers on the 3-syllable words naming time only, but not the 1- and 2-syllable words. A different grade comparison could be the explanation for the observed difference in the results obtained between the two studies. 5th graders were used in their study as compared to students in year 3 and 4 used in the present study. The more exposure and familiarity of the words used in the task may make 1- and 2-syllable word naming less sensitive as compared to 3- syllable ones in distinguishing 5th grade reading disabled children.

The main effect of IQ did not reach a significant level and there was no significant interaction between IQ level and

Table 3

Two-way ANOVA for Reading Group and IQ level on Naming Time

Source	D.F.	M.S.	F	P
Main Effects				
IQ	1	108.663	1.452	0.233
Reading Ability	1	1930.862	25.809	0.000*
Interaction	1	107.054	1.431	0.237
Error	56	4189.529	74.813	

N=60

* $p<0.001$

the reading ability. This indicated that IQ level has no effect on the cognitive processing involved in the performance on this task. Naming time distinguished groups of readers according to reading ability level only. These results therefore provided more evidence to Frith's argument (1992) that reading disability is a specific and unique cognitive deficit and that naming time could be a reliable task that can measure one of the core problems exhibited by this deficit.

5.1.1.2 Speech Rate

Similar to Das & Mishra's finding (1991), there was a significant main effect of reading ability on the speech rate performance $F(1,56)=34.70$ $p<0.001$ as shown in the results presented in Table 4. The poor readers took a longer time to repeat the series of words than the normal readers. As in naming time, the main effect of IQ and the interaction effect did not reach a significant level.

Hulme & Tordoff (1989) argued that the repetition of words provides a measure of speech rate which is independent of the time taken for item recognition. Das & Mishra (1991) also argued that though speech rate requires phonological coding, it also involves to a greater extent a direct use of articulation. As the task does not require reading nor item recognition, the cognitive processes measured by IQ may not be relevant to the difference observed between the poor and normal readers in the performance of this task. In fact, Wolff, Michel & Ovrut (1990) found that reading disabled

Table 4

Two-way ANOVA for Reading Group and IQ Level on Speech Rate

Source	D.F.	M.S.	F	P
Main Effects				
IQ	1	0.595	0.058	0.811
Reading Ability	1	357.875	34.701	0.000*
Interaction	1	4.435	0.430	0.515
Error	56	10.313		

N=60

* p<0.001

adolescents and adults have rate dependent deficits of motor timing control which are distributed over different domains of the motor system, including motor speech. They further argued that impaired motor coordination in tasks such as the nonsense words repetition in their study which depend minimally on linguistic achievement may therefore be one outward manifestation of a more general impairment of motor timing control. This impairment of motor timing control could distinguish reading disabled from normal readers and learning disabled students without reading difficulties. Though the task used in this study was different from the one by Wolff and his colleagues, it was a measure that depend minimally on linguistic achievement as they argued. Therefore speech rate may be as good a measure for distinguishing reading disabled as naming time.

5.1.1.3 Word Series Recall

The results of the two-way ANOVA shown in Table 5 indicated that the main effects of both the IQ factor $F(1,56)=4.964$ $p<0.05$ and the reading ability factor $F(1,56)=38.350$ $p<0.01$ were significant. The interaction effect did not reach a significant level. The significant difference between the poor and normal readers on the number of words recalled was consistent with studies that compared memory span between reading disabled and normal readers (eg. Bowey et al, 1992; Das & Siu, 1989; Johnston et al, 1987).

Although the IQ level measured in the present study was

Table 5

Two-way ANOVA for Reading Group and IQ Level on Word Series Recall

Source	D.F.	M.S.	F	P
Main Effects				
IQ	1	1000.417	4.964	0.030*
Reading Ability	1	7729.350	38.350	0.000**
Interaction	1	633.750	3.144	0.082
Error	56	201.548		

N=60

* $p<0.05$

** $p<0.001$

performance IQ and not verbal IQ, there is a possibility that there is a common link between the underlying cognitive processes involved in the performance of the two tasks, IQ test and word series recall.

Torgesen and others (1990) argued that memory span may not be a sensitive measure of phonological coding ability as compared to naming time and articulation because memory span tasks are not stable measures which can be affected by momentary fluctuations of inattention. The results here supported the above argument from the other side of the coin. The performance of the word series recall can be affected by the IQ factor and therefore may not be as reliable or sensitive a measure to distinguish the reading disabled regardless of IQ.

5.1.1.4 Phonemic Segmentation

In contrast to Montgomery's findings (1981), the two-way ANOVA results presented in Table 6 indicated that the main effect of reading ability was significant $F(1,55)=4.186$ $p<0.05$. Montgomery used similar age group reading disabled and similar phonemic segmentation task as the present study but no significant difference was found between the reading disabled and the reading age matched control. However, the F ratio in this study just barely reached the significant level. The phonological awareness task used in Snyder & Downey's study (1991) was a pig latin measure which used more complex major English syllable structures than the task used in this study.

Table 6

Two-way ANOVA for Reading Group and IQ Level on Phonemic Segmentation

Source	D.F.	M.S.	F	P
Main Effects				
IQ	1	2.592	0.811	3.72
Reading Ability	1	13.378	4.186	0.046*
Interaction	1	3.128	0.979	0.327
Error	55	3.196		

N=60

* p<0.05

Their result showed a significant difference between the 8-14 year old reading disabled and their age-matched control. The more simple CVC words and nonwords used in the present study might be relatively easy for year 3 and 4 elementary students and therefore it is possible that a ceiling effect was resulted for some reading disabled subjects, leading to a barely significant effect. In fact Hurford's experiment (1990) on phonological awareness intervention for the reading disabled showed that Grade 3 students had a more dramatic improvement than the Grade 2 students on the phonemic segmentation task. He suggested that the difference in rate of improvement could be a difference in the proximity of threshold of acquiring the phonemic segmentation skill.

The main effect of the IQ factor and the interaction effect did not reach a significant level, indicating that like naming time and speech rate, phonemic segmentation may be another 'pure' test that is not influenced by IQ and can therefore measure the specific underlying cognitive deficit of reading disabilities.

5.1.1.5 Summary

The results showed support for hypothesis 1 which stated that the poor readers had a poorer performance on the tasks. None of the interaction effect of IQ factor and reading ability of the four tasks reached a significant level, as presented in Figure 2. Except for word series recall, the main effect of the IQ factor for the other three tasks were not

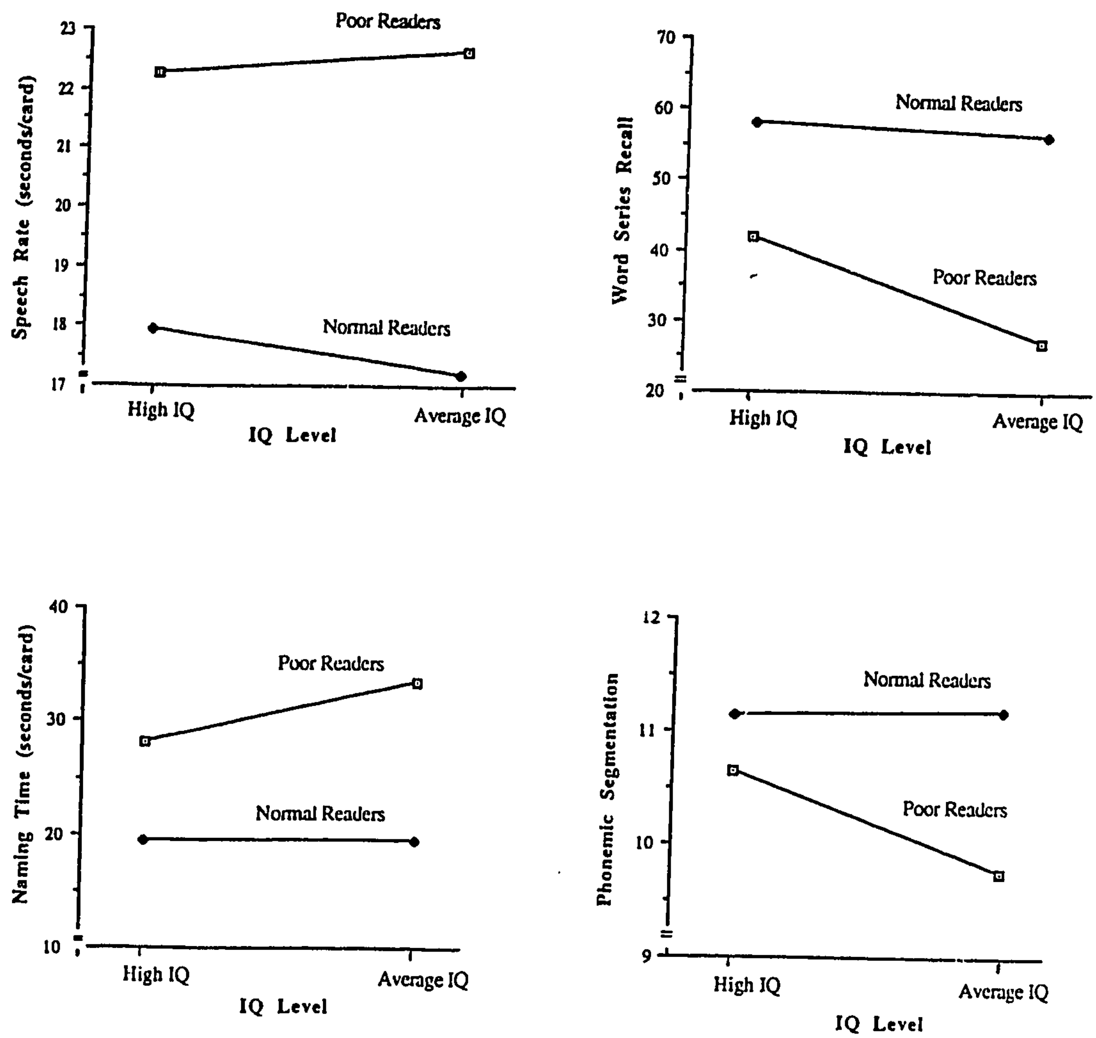


Figure 2 Comparison of the results of the four tasks between IQ level and reading group

significant. This indicated that naming time, speech rate and phonemic segmentation, not being influenced by other cognitive process such as IQ which is irrelevant to the condition, may be more dependable measures to use for identifying reading disabled. The main effect of reading ability was significant for all four tasks; however, it just reached significant level for phonemic segmentation. The difficulty level for the items may have to be raised for the grade level in the present group to minimize the influence of ceiling effect. In this way, the F-ratio may be increased to a more significant level.

5.1.2 Interrelationship of Tasks

As shown in the correlation matrix in Table 7, most of the Pearson-product moment correlations based on individual differences were significant but the magnitude of the relationship in general was small.

5.1.2.1 Word Series Recall

According to the working memory model, the phonological loop is involved in the phonological encoding/processing and in the articulatory control process to hold the information in the working memory. Speech rate is related to the articulation process while phonemic segmentation and naming time are related to the phonological processing. With the use of simple linear regression, the relationship, based on group means, between naming time, speech rate and phonemic segmentation is shown graphically in Figure 3. It is evident from the graphs

Table 7

Correlation Matrix for Naming Time, Speech Rate, Phonemic Segmentation, and Word Series Recall

Test	S.Rate	N.Time	Recall
N.Time	0.4262**		
Recall	-0.5195***	-0.3448**	
Ph.Seg	-0.2999*	-0.0613	0.3641**

Note: N=60 for S.Rate, N.Time, Recall
N=59 for Ph.Seg

* p<0.05
** p<0.01
*** p<0.001

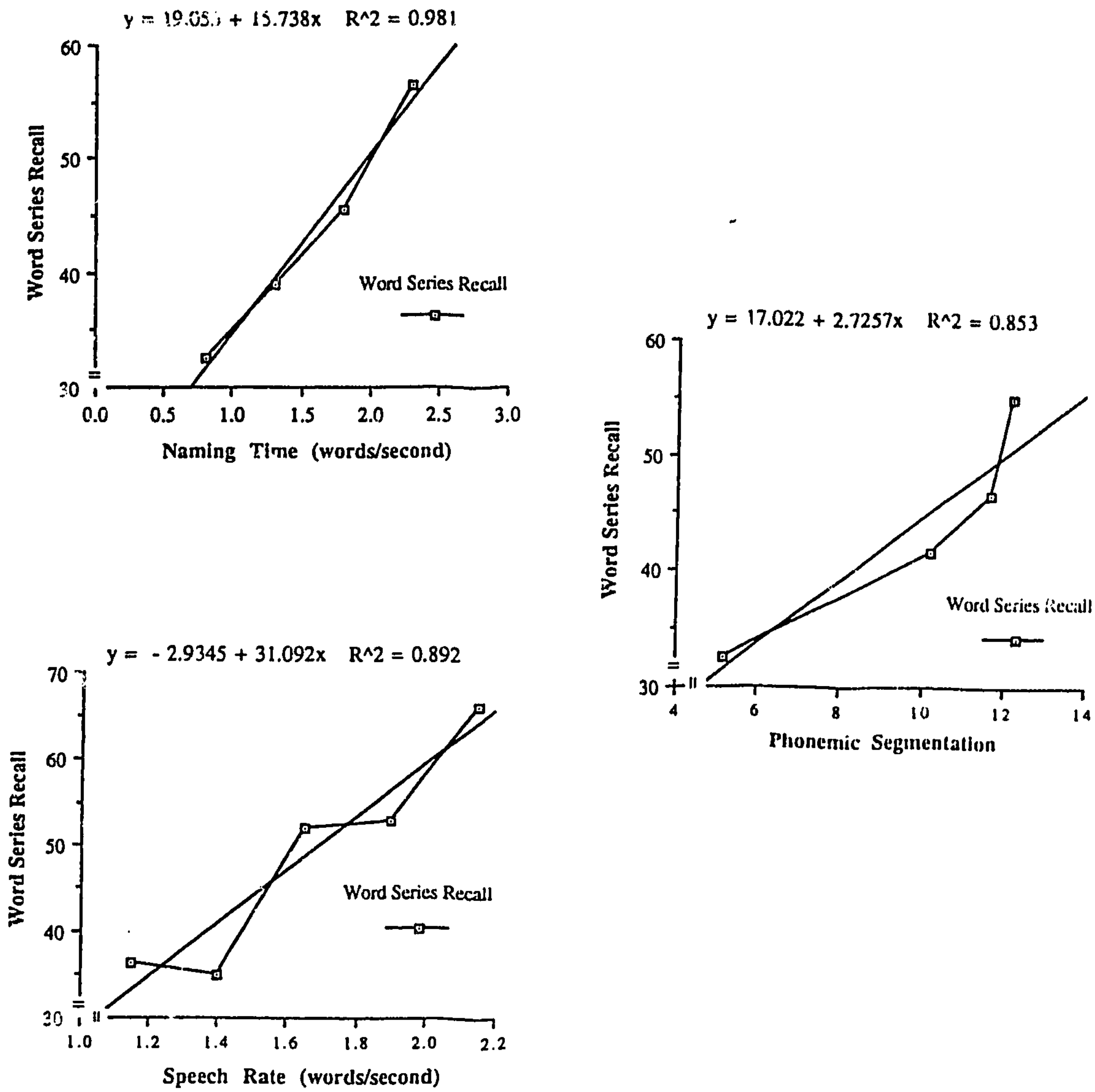


Figure 3 The linear relationship between naming time, speech rate, phonemic segmentation and word series recall

that word series recall was a linear function of naming time, phonemic segmentation, and speech rate. The coefficients of determination, R^2 were all very high, for phonemic segmentation ($R^2=0.853$), naming time ($R^2=0.981$) and speech rate ($R^2=0.892$).

The results obtained in this study showed that word series recall was highly correlated with the speed of articulation. This is in line with the investigation by Hulme et al, 1984) and Hulme & Tordoff (1989) on the contribution of speech rate to memory span, that the former determines the latter. Hulme & Tordoff regarded the phonological loop of the working memory as a recirculatory tape loop, through which a person rehearses the stimulus words by reactivation of speech motor program to overcome the decay in the working memory store.

Das & Siu (1989) found a significant correlation between naming t and memory span in their study. They related their results to the working memory model by suggesting that the slower one processes incoming information through item identification, the less is the capacity for storing and maintaining that information in working memory. The linear regression results obtained for the present study showed an even stronger relationship than that obtained in the above study.

As for the highly correlated linear relationship between phonemic segmentation and word series recall, it indicated that the better the subject could provide a phonological representation of the stimulus word in the phonemic segmentation task, the better it can be represented in the working memory.

5.1.2.2 Naming time, speech rate and phonemic segmentation

Based on individual data, there was a significant correlation between speech rate and naming time. Though the correlation was not strong, the result is in line with Das & Mishra's findings (1991). They found that the close connection between naming time and speech rate is represented by a latent variable which has two components: phonological activation on confronting a word and its activation.

There was a significant but weak correlation between speech rate and phonemic segmentation. Since both tasks involved the articulation of the stimulus words, the motor-speech program could be their common basis to result in the significant relationship.

Both naming time and phonemic segmentation involve some phonological processing. It is presumed that there should be a correlation, not a strong one, if they are supposed to be measuring different skills. However, the present result indicated that no relationship could be established between them. One possible explanation is the restriction of range on the phonemic segmentation performance. As mentioned in section 5.1.1.4, the reading group difference on this task just reached significance, which may be a result of ceiling effect on the task performance. The correlation which is based on individual difference is therefore affected by the limited variability in the phonemic segmentation task.

5.1.2.3 Summary

The results showed support for hypothesis two which stated that there would be a significant relationship among the four tasks of naming time, speech rate, word series recall, and phonemic segmentation. The linear regression of word series recall with naming time, phonemic segmentation, and speech rate showed a strong correlation. The results fitted nicely with the theoretical link between the phonological loop and the working memory. There was also significant but weak correlation between naming time and speech rate, speech rate and phonemic segmentation, indicating that they have some common links between them but they are at the same time measuring different skills.

5.1.3 Multiple Regression Analyses of Reading Scores

The decoding aspect of reading was used as a measure of reading skills in this part of the analysis. The Word Attack and Word Identification raw scores obtained in the screening test were the indicators for decoding skills. The contribution, relative to each other, by naming time, speech rate, word series recall, and phonemic segmentation to variance in reading scores was estimated by stepwise multiple regression.

5.1.3.1 Word Identification

The stepwise multiple regression results showed that naming time contributed the most, R=0.6664, accounting for 44% alone of the variance of the score. This was followed by speech rate, which increased the R value to 0.7707, together with naming time, accounting for 59% of the variance of the Word Identification score. Phonemic segmentation was entered next with the R value increased to 0.8016 and word series recall came last with the R value increased to 0.8155. The R for the last two tasks was substantially smaller than naming time or speech rate. Owing to a relatively high correlation between speech rate and word series recall. There is a possibility that the contribution of recall was suppressed. Therefore in the next multiple regression analysis, word series recall was forced entered first, R=0.5592 accounting for only 31% of the variance. The subsequent forced entry of speech rate increased R to 0.6898, a substantial increase to the contribution of variance by 16%.

The close link between naming time and speech rate by a latent variable, established in Das & Mishra's study (1991), may have also suppressed the contribution of speech rate in the above stepwise multiple regression. Therefore in the next multiple regression analysis, speech rate was forced entered first and R=0.6339. Word series recall was entered next, increasing the contribution of variance by 7% only, with R increased to 0.6898. The subsequent entry of naming time increased R to 0.7973 which was substantial. The contribution of naming time and speech rate to the Word Identification score variance appeared similar. The R was substantially smaller for word series recall than when either naming time or speech rate was entered first.

The significance of the naming time task which used words in this study as the predictor variable for the Word Identification scores was consistent with results obtained in Cornwall's study (1992) using letter naming as the stimulus item. Different studies using young children (Bowers & Swanson, 1991) and older children (Bowers et al, 1988) also found contribution to variance in Word Identification scores by naming speed on digits and letters.

5.1.3.2 Word Attack

The stepwise regression analysis showed a different pattern of contribution to the variance of Word Attack scores by the 4 predictor variables. Speech rate alone contributed 36% of the variance R=0.5991, followed by phonemic segmentation, an increase of 9% to the variance R=0.6698; then naming time, an increase of 9.7% R=0.7379, and lastly word series recall, an increase of 2.1% R=0.7522. The increase in the contribution to Word Attack score variance were similar for both phonemic segmentation and naming time. Again the contribution by naming time and word series recall may be suppressed by speech rate which has a high correlation with the two tasks.

In the next multiple regression analysis, word series recall was forced entered first, R=0.5407. When speech rate was entered subsequently, R=0.6577, a substantial increase. Forcing naming time to be entered first yielded R=0.5137 with a contribution of 26% to the variance of the Word Attack score only. Lastly, when phonemic segmentation was forced entered first, R=0.4653, with a contribution of 21% to the score. The subsequent entry of naming time increased R to 0.6728, which was substantial.

5.1.3.3 Summary

The results supported part of hypothesis 3 in that both naming time and speech rate were better predictors on the reading ability scores. Consistent with investigation by Bowers et al (1988), Das & Mishra (1991), Felton et al (1990), the present study showed that word series recall is a relatively weaker predictor variable than naming time or speech rate. The different pattern of contribution to the Word Identification and Word Attack scores by the four tasks could be argued in terms of the different demand of the two tests. Word Identification requires more item identification as real words are use, therefore naming time has more contribution to the score variance. Word Attack involves pronunciation of nonwords, and therefore the importance of the contribution of speech rate, a task which reflects the activation of speech-motor programming. The equal contribution of phonemic segmentation and naming time for Word Attack also indicated the importance of phonological coding skills and phonemic awareness in performing the task. These different patterns of variable contributions supported Bower & Swanson (1991) and Cornwall's (1992) arguments that different variables predict different aspects of reading skills.

5.2 Experiment 2

The means and standard deviations of the age, MAT-SF, Word Identification and Word Attack age equivalent scores were presented in Table 8. The means and standard deviations of the for the duration of lines and pauses were presented in Table [illegible].

Card 1 & 2, Card 3 & 4 were essentially the same. They had identical words, common nouns for the former set and colour names for the latter set. Correlated t-tests were used to compare the means of naming speed line by line between Card 1 & 2, Card 3 & 4. Except for line 1 in Card 3 & 4 for the poor reading group t=2.45 p=0.03, there was no significant difference in the means between the cards in either reading group. Similarly, correlated t-tests were used to compare the mean time taken for pauses between the lines, pause by pause, between Card 1 & 2, Card 3 & 4. There was no significant

Table 8

Means and Standard Deviations of Age, MAT-SF, Word Attack, and Word Identification Age Equivalent Scores in Months

	Group	
	Poor Reader N=15	Normal Reader N=15
Age	107.73 (10.44)	108.07 (4.77)
MAT-SF	104.13 (12.21)	108.80 (13.63)
Word Identification	91.80 (6.81)	118.27 (10.27)
Word Attack	85.13 (6.89)	140.33 (43.94)

Note: Standard deviation in parenthesis

Table 9

Means and Standard Deviations for Lines and Pauses for Card 12 and Card 34

	Group			
	Poor Reader		Normal Reader	
Line/Pause	Card 12 N=15	Card 34 N=15	Card 12 N=15	Card 34 N=15
Line 1	4.2287 (1.791)	4.4647 (1.455)	2.9960 (0.633)	2.8363 (0.538)
Line 2	4.3100 (1.522)	4.9803 (2.131)	3.0830 (0.657)	3.0590 (0.587)
Line 3	4.0843 (1.786)	5.2567 (2.827)	3.4710 (0.753)	3.3057 (0.836)
Line 4	4.4437 (1.484)	5.4360 (2.356)	3.2330 (0.643)	3.3797 (0.531)
Line 5	4.6630 (1.674)	5.2397 (1.891)	3.2993 (0.875)	3.3337 (0.626)
Line 6	4.7940 (2.103)	4.8900 (2.121)	3.1437 (0.744)	3.1767 (0.596)
Pause 1	0.5617 (0.351)	0.7127 (0.411)	0.2253 (0.158)	0.2797 (0.224)
Pause 2	0.6230 (0.343)	0.9147 (0.617)	0.3237 (0.259)	0.3370 (0.313)
Pause 3	0.8213 (0.686)	0.7717 (0.430)	0.4077 (0.299)	0.4133 (0.250)
Pause 4	0.8477 (0.712)	0.8493 (0.598)	0.3573 (0.261)	0.3260 (0.212)
Pause 5	0.5683 (0.374)	0.7577 (0.441)	0.3277 (0.289)	0.2643 (0.163)

Note: Standard deviations in parenthesis difference in the mean time taken for pauses in either reading group. Therefore the data were collapsed together for Card 1 & 2 (will be called Card 12 hereafter) and for Card 3 & 4 (will be called Card 34 hereafter) for statistical analysis.

5.2.1 Analysis of Reading Group and Line Effect

The MANOVA results in Table 11 indicated, as expected, a significant between subject effect, $F(1,28)=7.55$ $p<0.01$ for Card 12 and $F(1,28)=13.01$ $p<0.001$ for Card 34. This meant that in general the poor readers took more time to read each line in each card than the control group. The result was consistent with studies that compared naming time between reading disabled and normal readers on digits and letters with younger subjects (eg. Bowers & Swanson, 1991; Wolf et al, 1986); digit, colour or letter naming time on 7-11 year old children (Bowers et al, 1988; Cornwall, 1992); and on digit, colour, letter and object naming in adults (Felton et al, 1990).

The result provided support that with 1-syllable word naming in the present study, naming time remains a sensitive measure to distinguish poor and normal readers in year 3 and 4 of elementary school. In fact, it can be further argued that naming time using words may be a more sensitive and appropriate tool to use than letter or digit for older children. By year 3 and above, children should have automatized reading of digit and letter. Their phonological encoding skills, lexical retrieval of the phonological

Table 10

Summary of MANOVA with Repeated Measures for Reading Group on Line Effect

Source	D.F.	M.S.	F	P
Card 12				
Between Subjects				
Group	1	66.57	7.55	0.01**
Error	28	8.81		
Within Subjects				
Line	5	0.65	1.78	0.121
Line x Group	5	0.86	2.36	0.043
Error	140	0.37		
Card 34				
Between Subjects				
Group	1	156.14	13.01	0.001***
Error	28	12.00		
Within Subjects				
Line	5	2.25	3.39	0.006**
Line x Group	5	0.19	0.29	0.918
Error	140	0.66		

* $p<0.05$
** $p<0.01$
*** $p<0.001$

representation, articulatory programming of speech and its activation in naming the digit or letter, may be over-shadowed by their familiarity and overlearning of the items. The naming time resulted may not therefore reflect as fully and sensitively as it should be of the children's underlying ability/deficit.

The within subject effect of the line showed different results for the two sets of cards. It was insignificant for Card 12, $F(5,140)=1.78$ $p>0.05$, that is, the time taken to read each line for Card 12 was not significantly different from one another. However, the within subject effect was significant for Card 34, $F(5,140)=3.39$ $p<0.01$. When results of within subject effect on individual card were examined, an interesting pattern emerged. Both the conservative multivariate test of significance and the more liberal univariate tests of significance of line effect was insignificant for Card 1 but significant for Card 2. The same pattern was observed for the other set of cards, insignificant for Card 3 but significant for Card 4. A possible explanation was that after the practice of Card 1 and 3, the subject adjusted to the demand of the task and tended to revert back to their individual habit/pattern of reading. Their different rhythm of reading resulted in difference in time taken to read each line.

The interaction of group and line effect just reached significant level for Card 12 only, $F(5,140)=2.36$ $p<0.05$. As

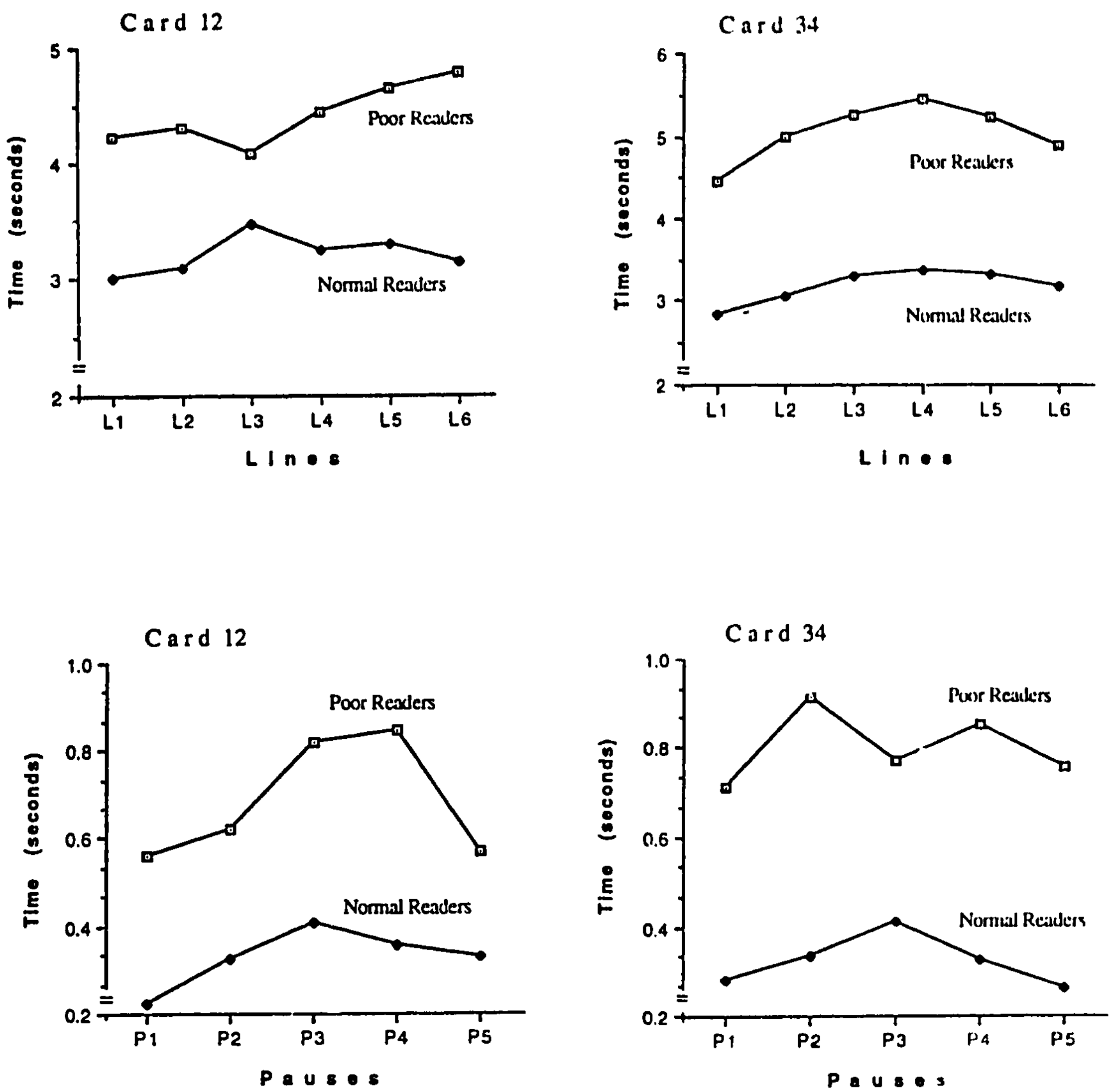


Figure 4 Means of line and pause duration for poor and normal readers

shown in Figure 4, the interaction was in line 3 in which there was an increase in time taken to read for normal readers while it was a decrease in time for the poor readers. When the graphs of the two sets of cards were compared, a pattern arose for the normal readers. There was a gradual increase in time taken to read each line up to around line 3 and 4, then there was a gradual decrease in time. However, the pattern for the poor readers was very irregular. There was a decrease around line 3 and then agradual increase in time taken until the end for Card 12 but the pattern for Card 34 was very different. The pattern was very similar to that of the normal readers, a gradual increase in time around line 4 and then a gradual decrease in time. This observation will be further discussed with the analysis of the pauses.

5.2.2 Analysis of Reading Group and Pause Effect

The MANOVA results on the pauses presented in Table 11, similar to the line effects, were significant for the two reading groups, $F(1,28)=11.73$ $p<0.01$ for Card 12 and $F(1,28)=20.84$ $p<0.001$ for Card 34. The poor readers in general took longer pauses between reading the lines than the normal readers.

The pauses can be explained in terms of blocks or involuntary rest pauses produced by reactive inhibition during massed practice (Eysneck, 1971a, 1971b). The naming time task in this study required rapid and continuous naming of four

Table 11

Summary of MANOVA with Repeated Measures for

Reading Group on Pause Effect

Source	D.F.	M.	F	P
Card 12				
Between Subjects				
Group	1	4.75	11.73	0.002**
Error	28	0.41		
Within Subjects				
Pause	4	0.29	2.60	0.04*
Pause x Group	4	0.07	0.65	0.627
Error	112	0.11		
Card 34				
Between Subjects				
Group	1	8.54	20.84	0.000***
Error	28	0.41		
Within Subjects				
Pause	4	0.09	1.01	0.406
Pause x Group	4	0.05	0.57	0.684
Error	112	0.09		

* p<0.05
** p<0.01
*** p<0.001

cards. It can therefore be considered as a massed practice. Reactive inhibition is a temporary work decrement and rests/ pauses are for dissipation of reactive inhibition. These rests may or may not depress the actual level of performance (depending on certain properties of the task). When the results of the pauses were compared with those of the lines between the two reading groups, it was found that the inhibition was dissipated faster by the normal readers through shorter duration of pauses and the performance of the task remained superior to the poor readers (indicated by the shorter duration of line effect).

When the graphs of pauses and lines in Figure 3 were compared, two different patterns were observed for the two reading groups. The pattern of pauses matched closely with the pattern of lines for the normal readers. There was a gradual built up of reactive inhibition with longer pauses taken with the matched increase in time taken to read the lines which peaked around line 3 for both sets of cards. Then there was a gradual decrease in duration of pauses with the matched decrease in time taken to read the lines. However, the pattern of pauses was irregular for the poor readers. The faster the reactive inhibition was dissipated as indicated by the shorter pauses did not necessarily matched with a better performance, which should be indicated by a decrease in time taken to read the following lines. Like the pattern for line effect, the pattern of pause for Card 12 was very different for Card 34.

The within subject effect for pauses just approached significance for Card 12, $F(4,112)=2.6$ $p<0.05$. The significance was found with the control group for Card 1 only between the first and the last pauses with the liberal correlated t-test analysis. No other comparison between pauses approached significance. In general the duration of pauses was similar within each group. The interaction between group and pauses were not significant for either sets of cards.

5.2.3 Comparison of the Two Sets of Cards

Card 1 & 2 used simple, common nouns as stimulus words while Card 3 & 4 used colour names as stimulus words. Although the words used in both cards are very simple nouns, and the subjects who were in year 3 ar ' 4 would have much exposure to them, the colour names may not be used as often as the common nouns in Card 1 & 2. One would expect the subject need more time to read Card 3 & 4, then Card 1 & 2. However, when correlated t-tests were used to compare the means for the combined cards, there was no significant difference between the two sets of combined cards for both the time to read the lines, and the time to take pauses for either group. For the present study, there was no indication that one type of stimulus words was more difficult than the other set.

5.2.4 Summary

The results provided support hypothesis 4 which stated that the poor readers took longer to read each line and took longer pauses between the lines. There was also a pattern observed for the normal readers in performing the task: a gradual increase in time taken to read the lines which peaked around line 3 & 4, then a gradual increase in the duration. The pattern of pauses coincides with the pattern of lines. However, no pattern emerged, neither the line nor the pause, for the poor readers in this study. The sample size of the poor reading group in the present study is small and therefore individual variation may affect the formation of a pattern. Future studies using a larger sample size may find the existence of a pattern.

6. GENERAL DISCUSSION AND IMPLICATIONS

6.1 General Discussion

Reading can be analyzed at various levels. These levels form a smooth progression from the visual detection of lines or curves of which letter are composed to the interpretation of complex themes and messages (Kirby & William, 1991). Some researchers (eg. Wolf et al, 1986) view reading as a multi-componential processes in which components are divided into lower-level and higher-level processes. Lower-level processes include word recognition or decoding skills while the higher-level processes involve comprehension skills. The present study focused on the decoding component or the lower level of reading.

The studies reviewed in Chapter 2 provided many evidence that the reading disabled experienced some phonological processing skills deficit. Frith (1992) argued that behavioral symptoms of a particular underlying deficit vary and change with development. Therefore diagnosis of the disorder is only guided by behavioral symptoms, towards the hypothesis of the particular underlying problem. Results of this study showed that naming time, speech rate and phonemic segmentation are tasks that can distinguish reading disabled. These are the tasks that involve the targeted cognitive mechanism of phonological processing. Unlike word series recall, which in this study showed a main effect of both IQ and reading ability, the performance of the three tasks is influenced by reading ability only, indicating that they are measuring the specific underlying deficit of reading disabled.

From the results obtained, it is evident that besides the well established naming time as a measure for phonological coding skills, speech rate is also a good one for distinguishing reading disabled. Wolff and others (1990) used the repetition of nonsense word strings to measure the deficits in motor-speech timing control in adolescents and adults reading disabled. Das & Mishra (1991) used 5th and 6th grade students in their study comparing speech rate performance between poor and good readers. This study used year 3 and 4 elementary school students. If this task does not require reading as Das & Mishra argued, and depends minimally on linguistic achievement processes as Wolf et al argued, then it may also be a sensitive measure for distinguishing reading disabled in younger children. This is particularly important for development of tests for early diagnosis of the condition.

Though phonemic segmentation, like naming time and speech rate, is not influenced by IQ level, the present study showed that it is not as powerful a measurement tool as naming time and speech rate in distinguishing reading disabled and in predicting decoding skills. It was explained in Chapter 5 that the items could have been too easy for both reading groups leading to a ceiling effect. Just as Frith (1992) argued that favourable effects of factors such as experience, instruction, maturation and compensation can affect performance, it is therefore important to consider these confounding factors in item selection. A careful selection of items, taking into consideration of the developmental factors can reduce the probability of ceiling and floor effect, thereby making the measurement tool more sensitive.

The results of this study showed that memory span (measured by word series recall here) is a less sensitive measure for decoding skills and IQ level can also influence the performance of poor readers. The present study also found a strong linear relationship of naming time, speech rate and phonemic segmentation which measure decoding skills with memory span tasks. Das & Siu's study (1989) found a positive relationship between memory span and reading comprehension performance. Jorm (1983) attempted to provide a theoretical link between comprehension and working memory based on the phonological coding deficit, from reading at a single word level to extraction of meaning from text. If memory span and the other 3 tasks are measuring different components of reading and if these tasks are also closely related, then there is a need to investigate the relationship further. The results may then help to link the reading skills/components these tasks measure to provide a better understanding of the processes of reading, as well as answer how decoding ability may affect comprehension.

Gathercole, Willis, Emslie & Baddeley (1992) found in their longitudinal study that phonological memory skills had a direct causal influence on vocabulary development between 4 to 5 years of age. However, subsequently vocabulary knowledge became more important in the developmental relation with phonological memory subsiding to a nonsignificant level. Wolf and others (1986) also found a developmental pattern of automaticity of retrieval processes and reading in the average readers, from kindergarten to grade 2. The relationship moved from strong, general prediction to highly differentiated ones. They also observed a different developmental pattern for the impaired readers from kindergarten onwards. These readers had both a general naming deficit and a particular deficit for graphological symbols. Though they made dramatic gain in the early years, by the end of grade 2, they still could not approach the speed achieved by average grade 1. If there is a pattern differentiation in retrieval speed and reading in normal readers, and the pattern for the impaired readers is different, then it will be interesting to find out if there is also a developmental pattern of the reading disabled on the naming time using words, speech rate and phonemic segmentation tasks on the prediction of decoding. Like Hurford's argument (1990), we may then understand whether there is a threshold or critical period for certain skills learning and therefore can provide intervention at the most appropriate time.

Snyder & Downey (1991) noticed a different pattern of reading comprehension among the reading disabled at different age level. They found that for the younger reading disabled, the lower-level reading skills, which are deficient, accounted for most of the variance in comprehension scores while for the older reading disabled children, they seem to use both lower-level and higher-level processes in reading. When compared to the normal readers, the poor readers in this study showed no specific pattern in performing the naming time task. Besides the conventional comparison between reading disabled and normal readers, either age or reading age matched, the same naming time task analysis should be carried out at different age level of reading disabled similar to what Snyder & Downey did. A pattern or even a developmental pattern within this group of children may then emerge from the results.

There is a need therefore, for not only comparing reading disabled with normal children but also for a comparison within this group of children at different age level. The investigation of the developmental lag theory or the deficit theory of reading disabled is usually confounded by the development and experiences factors. It is possible that there is originally just a developmental delay but with influences of developmental factors such as experiences, instruction, and maturation, the lag interacts with the unfavourable conditions and the gap between too large. When the threshold of learning such skills is passed, no amount of intervention may bridge the gap and the delay will therefore become a deficit. For those reading disabled who have a favourable conditions working for them, they may be able to catch up with the lag. With cross-sectional studies, some of these confounding factors can be controlled and researchers may then be able to obtain a developmental pattern of the reading disabled. With a developmental pattern, educators may then be able to know the type of intervention to be provided at each level of development.

6.2 Implication

6.2.1 Implication for Education

Based on the comparison of IQ and reading level on task performance, it is found that naming time, speech rate and phonemic segmentation three tasks which are sensitive to distinguish the reading disabled. These are tasks that will not be influenced by the IQ level, whether average or above average. The performance of these three tasks, especially naming time and speech rate are also good predictors for a student's ability in word decoding. Since speech rate does not reading, it will be particularly useful for assessing students, who due to the reading disabilities, lose motivation to perform any task that require reading. In this case, speech rate will be a more appropriate test to use than naming time.

The better predicting power of naming time, speech rate and phonemic segmentation on decoding as compared to memory span task provides further support to the need of connecting the two sets of tasks to different levels/components of reading. Even though these tasks are measuring different skills, they are also linked together as shown by the strong linear relationship between them. This indicated that the different components/levels of reading are also closely connected.

With words as stimulus items used in naming time in the study, the task is a close simulation to reading. The lack of a pattern for the reading disabled observed in the analysis showed the difficulty they have as they struggle with decoding simple, common nouns only. This can help teachers to understand the difficulty the reading disabled may have when required to read a passage when they do not have the skill or strategy to use a top-down level or interactive approach to compensate for their difficulty in decoding.

6.2.2 Implication for Future Research

There is a definite need to investigate a pattern of development, if any, of the reading disabled. Future studies should therefore not only compare them with normal readers, but also with other reading disabled at different age level.

This study found that naming time, speech rate and phonemic segmentation can distinguish poor readers in year 3 and 4 of elementary school students. With experience and instruction in remediation class, will they remain sensitive measure as these children grow? There is also a need to find out if these tasks, especially with speech rate, are sensitive measures in identifying younger reading disabled. If a pattern of development emerges, we may be able to understand more whether there are any threshold or critical time of certain skills development.

It is evident from the results that naming time and speech rate are good predictors of decoding skills but not memory span. The results also indicated that there is a strong linear relationship between memory span, with the three tasks of naming time, speech rate and phonemic segmentation. If memory span is measuring a different component of reading, such as comprehension, then future studies should look at the link between these components of reading.

The naming time used in this study is a close simulation of reading. The poor readers are not only slower in performance, their pattern of performance is also irregular. A larger sample size may help to find out if there is a pattern or the decoding difficulty is more of a deficit than a delay. This may provide more insight for educators the remediation provided for these students: to catch up with the delay with emphasized training on the difficult area or to teach strategy to compensate or go around the deficit.

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APPENDIX A

PHONEMIC SEGMENTATION TASK

Word	Nonword
BUG	VIT
CAT	MAG
DOT	WEB
SIT	TOB
DOG	DIZ
BED	FOB
MEAT	KAF
BALL	MIP
GAS	LOV
FOOD	REG
LED	KIL
DOOR	BOG

Underlined letters are to be omitted during segmentation by the participant

APPENDIX B

WORD SERIES RECALL TASK

Sample: book car

1. key shoe
2. car wall
3. dog girl book
4. man cow key
5. shoe dog man book
6. wall cow car girl
7. book wall key dog
8. girl car shoe cow
9. man wall car shoe
10. cow key book dog girl
11. shoe car dog man key
12. wall man book girl cow
13. book shoe girl dog car
14. cow key man wall dog
15. book cow car wall man key
16. girl key shoe dog wall book
17. man girl shoe car cow wall
18. dog key man cow shoe girl

APPENDIX C

NAMING TIME TASK

Card 1

dog girl car shoe key wall
cow car dog key book shoe
girl book dog car cow wall
key shoe wall girl dog man
book car girl key cow dog
shoe wall key car man cow

Card 2

key dog wall book girl shoe
car key man cow book girl
key cow dog wall man car
shoe dog book cow girl man
wall key car dog shoe cow
man shoe book car girl wall

Card 3

blue green red white brown tan
grey blue pink black white brown
blue black green red pink grey
tan green white black brown pink
red blue grey green tan black
pink tan white grey brown red

Card 4

green brown grey tan blue red
black grey green blue white tan
brown white green grey black red
blue tan red brown green pink
white grey brown blue black green
tan red blue grey pink black

APPENDIX D

SPEECH RATE TASK

Sample card: egg bus leaf

Card 1: girl dog book

Card 2: brown red green

Card 3: pocket donkey ribbon

Card 4: tractor garden picnic

Card 5: dog kitten crocodile

Card 6: tub market gingerbread