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An Investigation into the Phonology-related Processes Associated with Developmental Dyslexia

by

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A thesis submitted to the School of Graduate Studies and Research of the University of Ottawa, in partial fulfillment of the requirements for the degree of Master of Arts.

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ISBN 0-315-60610-X

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Acknowledgements

Sincere thanks are extended to my thesis advisor, Professor P.G. Patel for his guidance and encouragement
throughout the writing of this thesis.

Special thanks to Leigh Thorpe for statistical advice and access to computer programming for graphs and tables.

Special thanks to the Kenney Family for their inspiration, help and encouragement.

Many thanks to all the children who participated in the study and to their parents.

Abstract

Developmental Dyslexia (DD) is a phenomenen which refers to otherwise normal children who experience significant difficulty in reading acquisition. Many studies investigating DD commonly find the same characteristics associated with DD: (1) readers who are reading significantly below age level but whose IQ does not predict this (2) abnormalities associated with speech which may include speech delay or articulation problems (3) a larger number of males are afflicted than females.

The present research involves an examination of the phonology-related processes hypothesized to be deficient in a certain sub-group of DDs. These phonological processes include: (1) the storing or encoding of phonological codes (2) the retrieval of phonological codes from long term memory (3) the ability to maintain phonological codes in working memory while blending or synthesizing is ongoing. These processes are examined using the following tasks: (1) the ability to name letters of the alphabet (2) the ability to associate sounds to graphemes using nonsense words (3) the ability to discriminate auditorily presented minimal pairs (4) the ability to delete a sound from an auditorily presented word and reblend the remaining sounds, or add in two sounds units and reblend the word (5) the ability to

repeat real and nonsense words of varying phonological complexity (6) the ability to decide if a word is real or not. These tasks were presented to an experimental group consisting of six, 10 year old, girls (DDs) and a control group of ten, 10 year old girls, reading in the normal range. Results of the study indicate that a certain sub-group of DDs are deficient in certain phonological processes. To reiterate, these phonological processes could include: (1) the storing or encoding of phonological codes (2) the retrieval of phonological codes from long term memory (3) the ability to maintain phonological codes in working memory while blending or synthesizing is ongoing. A deficiency at any one level or at a combination of these levels could disrupt the acquisition of the reading process.

Introduction

The objective of this research is to examine some possible linguistic deficiencies which underlie dyslexia. Developmental dyslexia (DD) is a phenomenon which characterizes otherwise normal children who experience significant difficulty in reading acquisition. In severe cases the child can lag two years behind in his grade level in reading tests, although not all children who experience problems in acquiring reading skills are this far behind (Leong, 1988). Vellutino (1979), hypothesizes that children who experience difficulty in learning to read have a "verbal deficit" or a "verbal processing" deficiency. These are broad general terms which could include the following areas of language processing: (1) phonological processing, (2) syntactic processing, and (3) semantic processing. The research reported here will focus on the following phonological processes: (1) encoding of phonological material in long term memory (2) retrieval of phonological codes from long term memory (3) working memory in relation to segmenting and blending phonological codes (4) speech perceptual ability. These phonological processes are examined using the following tasks: (1) the ability to name letters of the alphabet (2) the ability to associate sounds to graphemes using nonsense words (3) the ability to discriminate auditorily presented minimal pairs (4) the ability to delete a sound from an auditorily presented word

and recode the remaining sounds, or add in two sound units and recode the remaining sounds (5) the ability to repeat real and nonsense words of varying phonological complexity (6) the ability to decide if a word is real or not. Two measures used in the present research to assess a subject's ability on these tasks are: the number of correct responses and latency. The Word Identification Test (Woodcock 1973), was included to test approximate reading level for all subjects.

For a certain sub-group of DDs it is hypothesized that some or all of these processes underlie the "verbal deficits" referred to by Vellutino (1979), and that DDs will be found to perform more poorly than a control group of normal readers, when given tasks which require these phonological skills. These language processes are conceptualized and operationalized in terms of current psycholinguistic theory and research.

Defining Dyslexia and its population

Dyslexia is a Greek term which broken down into its component parts describes DDs in a general way. "Dys" refers to "poor or inadequate", "lexis", to language as words, related to speech and to lexicon" (Rawson 1981:15). Other terms found in the literature referring to the same phenomenon are the following: "specific reading disability", "specific developmental dyslexia", and "specific reading

retardation". "Specific" in the aforementioned terminology refers to the fact that the difficulties are specific to reading. There are two approaches to defining the dyslexic population: the "exclusionary approach" and the "inclusionary approach" (Just & Carpenter 1987). The definition by Critchley and Critchley (1978), as cited in Just and Carpenter (1987) exemplifies the exclusionary approach. It excludes from the dyslexic population individuals who have the following characteristics: low IQ, poor schooling, hearing or visual problems, neurological damage, or emotional problems. The exclusionary approach defines as dyslexic, only those readers for whom there is no other explanation for poor performance. For example, perhaps a child has missed a lot of schooling or been exposed to very poor schooling and is not up to grade level in reading. Consequently, the lower acheivement in reading cannot be necessarily attributed to a specific disability: it just may be that he/she has not had enough exposure or instruction in that skill. The other approach to viewing the dyslexic population is the "inclusionary approach". This is the approach taken by Rutter and Yule (1975), who examined the entire population of 10-year-olds from the Isle of Wight and a large sample from inner London. Each subject who was sampled had his/her IQ recorded plus his/her reading level. The measured reading level, based on age and IQ, was compared to the expected reading level in order to identify children who were reading far below expected level. As a result of this study they found two groups of disabled

readers. The first group, labelled "backward readers" were children whose reading was significantly below age norms, but whose performance was consistent with I.Q. The second group, labelled "retarded readers", were reading significantly below age level but their reading abilities were inconsistent with their IQ. Rutter & Yule found a greater than expected percentage of this last group of children whose achievement in reading was two standard deviations below expectation. Assuming a normal distribution, one would predict 2.28% of the population to be reading at a level of two standard deviations below expectation, but Rutter & Yule found 3.09% which constitutes a "hump" at the lower end of the distribution curve. An associated finding indicates that there is a larger proportion of males to females with this disability; for every 3 males afflicted there is only one female. This survey does not address the specific causes associated with retarded reading. However, the strength of this large epidemiological data is that it reveals that there is a larger than expected percentage of the population whose reading achievement is below expectation based on age and IQ.

DD and brain structure

There has been much speculation and research directed at the possible source of the verbal processing deficiencies associated with DD. It has been suggested that there is a

constitutional basis for the disability (Sladen 1981). Related to the issue are the possible neurological dysfunctions and the location within the brain of these dysfunctions (Bakker & Vinke, 1985). "Samuel Orton's (1925, 1928, 1937) pioneering work in the laboratory and the clinic has led directly or indirectly to our recognition of reading disorders as being part of the speech language continuum and also to our understanding of specific language disabilities within the context of the functional organization of the cerebral hemispheres" (Leong 1987:69). This relates to Sladen's proposal that differences in brain organization, particularly those related to the left hemisphere (the centre for language and language related functions), may explain differences in reading ability. It is interesting to note that Rutter and Yule (1975), found that both the specific reading retardation group and the backward reading group were associated with abnormalities in speech and language which included speech delay and articulation problems. There was also a family history of reading difficulties and speech delay associated with both groups. However, only the reading backward group was associated with overt neurological disorder and the reading retarded group was not. This implicates possible subtle deviations in brain structure of those in the reading retarded group (Gibson & Levin (1976). Many studies investigating DD have also found language difficulties to be associated with disabled readers: these sometimes subtle language difficulties may indicate problems with phonological processing before the

task of reading is encountered. Language difficulties may include: delayed language development, articulation problems and difficulties in orally repeating unfamiliar words (Frith 1985). "The hypothesis assumes that a problem exists in speech regardless of whether reading is acquired or not" (Frith 1985:317).

Some discussion of brain organization and how this is related to the reading process shall follow. It is generally agreed upon that the major language centre of the brain is the left hemisphere. "the left hemisphere is, relatively speaking, specialized for analytic, time-dependent, sequential functions, it thus provides a suitable substrate for the subsequent development of language processes" (Bradshaw & Nettleton 1981:63). The right hemisphere's holistic processing is viewed as complementary to this overall analytic process. In reading it is the angular gyrus and Wernick's area of the left hemisphere which are implicated. This is confirmed through EEG (electroencephalogram) studies, BEAM (brain electrical activity mapping) studies and measurements of cortical blood flow which were used during reading (Leong, 1987). A different pattern of brain organization was found in the brain of a 20 year-old youth who had had a life-long history of dyslexia (Galaburda & Kemper 1979). The temporoparietal (Tpt) portion of his brain bordering on Wernick's area was found to have a marked disorder of cortical organization although no gross abnormalities were found. Also, other

areas of his brain involving written language were found to have subtle cortical irregularities. Although there were no gross abnormalities it is possible that "this unusual brain organization likely led to a different and probably an inferior reading strategy for this dyslexic" (Leong 1987:80-81). The two hemispheres have their own specialities but it is also important to note that the right and left hemiphere have rich interconnections and also function as a whole (Kinsbourne & Hiscock 1983).

Considering the above observations it seems that overt neurological disorder may not be present in most cases of DD. More subtle structural differences (as in the above case) offer a better explanation of the problem. The literature concerned with the relationship between the brain, its structure and functions, suggests certain possibilities which may be related to DD and are also related to the physiological structure of the brain: (1) it has been suggested by Geschwind (1982), that the testosterone effect when present in an extreme form, (in utero) suppresses the development of the left hemisphere. The result of this factor may lead to unusual or subtle differences in the brain physiology of the left hemisphere of DDs. (2) It may also be that chemical imbalances due to unknown causes influence the brain's development. (3) DD may be the result of a lag in the maturation of the left hemisphere due to the above reasons or due to other unidentified ones (Satz & van Nostrand 1973).

Dyslexics as a heterogeneous population

Since the above factors may affect different parts of the left hemisphere, which is intricately related to language processing, it is reasonable to expect distinct sub-groups of DDs. This is generally found in the study of DD. Doehring, Trites, Patel and Fiedorowicz (1981), suggest that DD can be associated with subtle neurological dysfunctions but it is not necessarily a unitary disorder with a single cause. They describe reading as a complex, interactive, cognitive and linguistic process. Doehring et al., (1981), administered neuropsychological tests, reading tests and language tests to clinic-referred disabled readers. Using a Q-factor analysis of these tests they discovered three different subgroups of dyslexic readers. The Type O (oral reading disability) the largest group, tended to be poorest in oral reading of words, syllables and letters, Type A (associative reading disability), tended to be poorest at auditory-visual matching tasks, Type S (sequencing reading disability) tended to be poorest at reading syllables and words rather than single letters. Boder and Jarrico (1982), also distinguished between subgroups of disabled readers/spellers. The first and largest group, called "dysphonetic", experienced difficulty reading analytically or making letter-sound correspondences; they experienced great difficulty with nonsense words. The second group, called "dyseidetic", over-relies on

graphological-phonological correspondences. The third group is a mixed "dysphonetic-dyseidetic" group. These studies point to the heterogeneous nature of DD and also imply the complexity of the associated deficient brain mechanisms related with DD.

Phonological processes related to DD

The phrase "segmental awareness" (sometimes called "phonological awareness"), "refers to the child's explicit knowledge that speech consists of syllable and phonemic segments" (Jorm & Share 1983:116). This explicit awareness contrasts with the tacit knowledge that children have of the speech stream. This tacit knowledge is demonstrated by many studies such as Eimas, Siqueland, Jusczyk and Vigorito's (1971) study which shows that very young infants (1-3 months old) can discriminate different speech sounds. Mattingly (1972), as well as many others have reflected on the nature of the relationship between speaking, listening and reading.

Segmental awareness forms a part of the relationship which exists between first language acquisition, the acquisition of reading and DD. In order to clarify this relationship, I will firstly consider some related aspects of first language acquisition. In first language acquisition, awareness of meaningful word (or syllable) units precedes awareness of individual sound segments. Ferguson and Farwell (1975) found

that children had a variable pronunciation of words and segments in early speech. The child intends consistent meaning, but interchanges individual segments as reflected by his/her pronunciations. This suggests that a purely segment-based characterization of early pronunciations, which assumed early phonological differentiation would be inappropriate. It has been observed that meaningful units (or words) are the first units abstracted by the child in first language acquisition (Gibson & Levin 1976). Learning of smaller units is influenced by acquisition of larger units (syllables) or words (Menyuk, Menn & Silber, 1986; Macken, 1979). The results of studies by Liberman, Shankweiler, Fischer and Carter (1974) and Fox and Routh (1975), indicate that preschool, kindergarten and first-grade children found it harder to analyze words into segments than into syllables. The ability to segment words into sound units develops at about the same time they learn to read. The child can tell one word from another based on a single phonemic contrast, but he/she has difficulty in realizing that the word is composed of a sequence of segments. One reason segmental awareness is more difficult for younger children has to do with the nature of the acoustic signal. The acoustic information of segments in a word overlaps and interacts. This is referred to as "encodeness" or " parallel transmission of information" (Liberman, Cooper, Shankweiler and Studdert-Kenndy 1967). Although tacit knowledge is available for speech comprehension, knowledge required for conscious segmentation

appears to be less accessible for children before a certain age. The relatively late acquisition of this skill for the general population implies it may be more critical for those children who may have phonological processing problems.

Reading adds a visual component to an already established language system. If a child has an inadequate representation of the phonological composition of his/her language, the addition of the visual component would add further confusion. (The phonetic representations are influenced by the quality of speech perception Mann (1984). With the addition of the visual component the child must learn correspondences between graphemes and sounds and encode this information efficiently. To begin to process in this way, a certain level of verbal maturity must already be attained by the child. That is, that he/she realizes that words are made up of individual sound segments and attached to graphemes--the first phase of segmentation awareness. This is where a differentiation must be made between different segmentation awareness tasks so that the nature of the task is realized. In some segmentation tasks the child is required to tap out how many sounds he/she hears (Liberman et al. 1974). In this segmentation study the researchers found that phonological units were more difficult to analyze than syllable units and syllable and phonological segmentation ability increased with grade level. (Preschool, kindergarten and first-grade children were tested in this study). Fox and Routh (1980), tested the ability of first

grade children of varying reading abilities to segment spoken syllables into individual speech sounds. These researchers found that children with severe reading disabilities were unable to segment spoken syllables into individual speech sounds. Normal readers were able to do the task. These tasks test first and foremost the awareness the child has that words are made up of separate sound units. Another type of segmentation task involves more complex phonological processes, this includes the retrieval of phonological codes and the ability of working memory to hold phonological codes in memory while segmenting or blending, or a combination of both processes are ongoing. (It is this type of task with its associated phonological processes which is of relevance in this study.) A task which might demand the above processes may be the following: A child is auditorily presented with a word then asked to delete one sound from the word and repeat the word without the sound. This task is more complex because it requires that phonological codes be retrieved from long term memory, the deletion of one phonological unit and the reblending of the remaining units which implicates working memory. Poor readers have been found to be deficient in their use of phonological codes in working memory (Shankweiler, Liberman, Mark, Fowler and Rischer 1979; Byrne & Shea 1979).

Frith (1985), hypothesizes that the development of reading is divided into three phases. The first two are relevant to the present argument. Logographic reading is the first stage

in which words are read holistically. In the second phase alphabetic reading is added to the first stage; this involves sound to grapheme correspondences. This stage strongly implicates the phonological route because unfamiliar words are continually being encountered and decoded. Phonological recoding is a self-teaching mechanism whereby beginning readers learn to use the more efficient visual route (Jorm & Share 1983). The English writing system based on the alphabetic principle is demanding on the skill of retrieving individual phonological codes and the ability to hold these codes in working memory. This task is demanding for beginning readers as well as for readers encountering unfamiliar words. This skill is related to many of the tasks which DDs are found to be deficient in. These tasks, often called segmentation tasks, could more appropriately be called tasks of phonological ability which include tasks of segmentation and blending, because they consist of more than the ability to isolate one phonological unit.

There are reading programs that emphasize these phonological processes and have been shown to be effective in teaching DDs. These programs share the same theoretical framework that the Russian psychologist Elkonin (1963, 1973), (cited in Leong 1988), emphasized in reading instruction. That is, to demonstrate the sound structure of spoken words in a concrete fashion and emphasize ways to show the basic units and how the language is constructed from them, in other

words analysis and blending. The following programs have taken the same approach: Wallach & Wallach (1976); Williams (1980). It is interesting to note that the training involved in these programs is related to explicit teaching of the encoding of phonological codes, retrieval of phonological codes and blending and segmenting which involve working memory processes. There is also evidence from many longitudinal training studies and longitudinal correlational studies which involve DDs, they show certain phonological skills are directly related to later reading ability, independent of general cognitive ability. The following studies show a significant correlation between phonological processes and later reading achievement with IQ held constant: Bradley and Byrant (1985), (training study), (task-sound categorization with letter-sound training); Fox and Routh (1984), (training study), (task-segmenting and blending); Lundberg, Olofsson & Wall (1980) cited in Wagner and Torgeson (1987), (tasks-blending phonological units and syllables, segmenting phonological units, identification of phonological position, phonological reversal, rhyme); Stanovich, Cunningham & Cramer (1984), (task-delete initial phonological unit, sound categorization, segmenting & blending). A common result of these studies is that tasks which include the manipulation of phonological units are more highly correlated with later reading skill than tasks involving syllables. The studies of Bradley & Byrant (1985) and Lundberg et al. (1980) support a causal role between the ability to manipulate phonological units and the acquisition

of reading skills. These studies indicate the need to bring to the focal point to those children experiencing problems with reading, those phonological skills related to the association of graphemes and their sounds: (1) encoding in long term memory (2) retrieval of phonological codes and (3) practise in those skills related to segmenting and blending which involve working memory.

"All word learning is mediated through sound initially when letters are being amalgamated to the word's phonological structure" (Ehri 1980:169). As readers advance, this initial sounding-out process is substituted by a direct access route whereby images replace sound as the means of identifying a word from its printed form. However, these lower level skills of graphological-phonological association must be solidified for the decoding of unfamiliar words which will be encountered by individuals at any level of reading ability. It appears that it is at this stage in the reading process that a certain sub-group of DDs is arrested.

The phonological processes which will be examined in this study are those processes hypothesized to be deficient in DDs. They are: (1) encoding of phonological material in long term memory (2) retrieval of phonological codes from long term memory (3) working memory in relation to segmenting and blending phonological codes (4) speech perceptual ability.

Method

Subjects

The study involved a sample of sixteen female subjects all of whom were ten years old at the time of the study. The experimental group included six subjects, who were selected on the basis of having had significant difficulty in learning to read. The control group consisted of ten subjects of average or slightly above average readers, who had experienced no difficulty in learning to read and who were all in grade five at the time of testing. Recruiting was done partially through the help of individuals within the school system and partially through contacts within the neighborhood. Parents of children participating in the study were informed of the subject matter of the study and signed a consent form agreeing to allow their child to participate in the study. Control and experimental subjects were told the study was being carried out to better understand some processes associated with reading. (A summary of the results of the study will be made available to interested parents.) Parents were asked via a questionnaire to provide information regarding:(1) any special medications used by the child, (2) any possible history of ear infections or tubes in ears, (3) the profession of mother and father, (4) handedness, (5) date of birth,(6) grade, and (7) present level of reading ability. The whole sample was drawn from a

homogeneous population with respect to socio-economic status and all were from the Ottawa area. All children in the sample were attending schools within the Ottawa Board of Education and therefore had access to approximately equivalent standards in educational facilities.

All experimental subjects with the exception of one were in a special class to remediate their reading difficulties. The experimental subject who was not in a special class attended a regular class but was withdrawn regularly from the class for remedial help in reading. The parental questionnaire provided the following information: (1) no special medications were being used by any individuals in the experimental group, (2) one experimental subject was reported to have experienced frequent ear infections when she was quite young, but scored well within the normal range on the auditory discrimination test, (3) the sample was drawn from a homogeneous population in relation to socio-economic status, (4) experimental subjects were all reported to be right handed, (5) all experimental subjects were born in 1978, (6) three subjects were reported to be two years behind in reading achievement compared to their age matched peers and three were one year behind. An IQ test was not administered; however, in order to qualify for attendance in the type of special class they were in at the time of testing, all experimental subjects had to be of at least average intelligence. In many instances children in this type of special class are above average in

intelligence. Information concerning history of reading difficulties in the family was not formally solicited. However, in informal discussion with the parents of two children in the experimental group, it was apparent there had been quite extensive problems in the family with learning to read. In the two instances both mothers and their brothers had experienced significant difficulty in learning to read.

Tests

Pilot testing was carried out to insure that interpretations of individual tests were adequate and to work out any other problems associated with test administration. Five additional subjects who were average or slightly above average readers and within the same age group participated in the pilot testing.

Apart from the Letter Identification Test (described below) all tests which were presented visually used lower case Roman letters. Several tests included nonsense words. Nonsense words were defined to the subjects as a word which has no meaning but that can be pronounced according to the rules of English Orthography. Tests which were timed did not include the sample items in the timing. See Appendix A for all tests used in this study. These same forms were used as response forms. In recording responses to tests, a "|" indicated a correct response and a "()" an incorrect

response. This method was used consistently with all tests. A description of the tests follows.

Standardized tests

The Letter Identificaton, Word Identification and Word Attack subtests of the Woodcock Reading Mastery Tests/Form A were administered. These three tests were presented using the specially designed ring binder "Easel-Kit". When opened the Easel-Kit has an easel shape which simultaneously allows presentation of the test items to the subject on one side, and on the other side, provides the examiner with instructions, a copy of the items and a key to acceptable answers. All these tests were timed, time refers to time taken by the subject to complete the test. There was no fixed time set by the examiner for the subjects to complete the test. Where possible incorrect responses were recorded.

(1) The Letter Identification Test measures the subject's ability to name letters of the alphabet. It contains 45 letters arranged in order of difficulty. All subjects started at the beginning of the test. The items include both common and uncommon styles of type. They are: upper and lower case Roman letters, upper and lower case serif letters, upper and lower case cursive letters and upper and lower case specialty typefaces. The subject was required to provide the letter name, not the case. Appendix B shows the

letters as they were presented to the subjects. By the end of fourth grade most normal students will obtain perfect or near perfect scores on the Letter Identification Test.

(2) The Word Identification Test establishes estimated reading grade level. The original test consisted of 150 words which went up to a grade 12 level. For the purposes of the study, this test consisted of 120 words ranging in difficulty from those presented in beginning reading programs to words which would appear in a late grade 5 reading program. The subject's task was to name the word.

In this test the easier items (grade three level and below) were selected from seven basal reading programs using preprimers and those readers used in third grade (Woodcock, 1971). The more difficult items were derived from the Thordike-Lorge list (Thorndike and Lorge, 1944). Suggested starting points related to estimated reading grade level are provided in the manual to assist the experimenter in choosing an appropriate level of difficulty which corresponds to basal level. Ceiling level is established when the subject has failed five or more consecutive items. In administering the test, the experimenter started at item 81 with the control subjects which corresponded to a grade 3 level. The experimenter started at the beginning of the test for all experimental subjects.

(3) The The Word Attack Test measures the subject's ability to pronounce nonsense words. It contains 50 items which are arranged in order of difficulty. Each subject begins with the sample item and proceeds to item 1 of the test. Ceiling level was established after five incorrect responses. The easier items in this test are VC and CVC combinations such as "ut" and "kak". More difficult items are multisyllabic words such as "fubwit" and "wubfambif". Represented in this test are most consonant and vowel sounds and some common prefixes and suffixes. The experimenter familiarized herself with the pronunciation of the list items before testing subjects to become accustomed to their expected sound. Also, each test page on the experimenter's side included a pronunciation guide for each of the words on that page.

The subject must possess graphological to phonological conversion abilities in order to do the test. This is the same ability used by an individual when encountering a new word and one found to be deficient in DDs.

Non-standardized Tests

Included in all the non-standardized tests were sample items to insure directions were understood. For timed tests, timing began after the administration of any sample item. Care was taken not "to teach" the test. Many of them were timed in order to test the hypothesis that DDs have a

problem with accessing verbal material as quickly as normal readers.

(4) The Auditory Discrimination Test measures the ability to discriminate minimal pairs in ideal conditions with no background noise. The test consists of 64 sets of paired words. There are forty pairs which have a consonantal contrast, five which have a vocalic contrast and nineteen which have no contrast. Those with a consonantal contrast have the contrast in either initial or final position. Those with a vocalic contrast have the contrast in medial position. The pairs were presented in random order.

This test was based on the Wepman ADT (Revised 1973), but changed to include a wider range of phonemic contrasts which included contrasts based on voicing and manner of articulation. The consonantal contrasts in the Wepman ADT involve two phonemes whose production differs by just one phonetic feature, that of place of articulation. The Wepman ADT which excludes contrasts involving voicing and manner of articulation cannot claim to fairly sample the contrasts of English. Research does seem to indicate though that the most difficult one to discriminate is the place feature (Miller and Nicely 1955). The auditory discrimination task was included because proper perceptual ability is an important precursor to the development of appropriate phonological/orthographic relationships.

The experimenter familiarized herself with the minimal pairs by reading them aloud before administering the test. In this test the subject sat directly in front of the experimenter but facing away from her, so there was no possibility of making the discrimination based on visual cues such as lip reading.

There are three tests to measure segmentation awareness ability . Three tests to measure this ability are included because considerable research has been directed in the area of "segmentation ability" and its relationship to reading disability. This number of tests is necessary to obtain an insight into the phonological processes underlying segmentation ability. They are:

(5) The Initial Sound Segmentation Test measures the individual's ability to isolate an initial sound from a word presented auditorily and then select a picture of an object (three pictures to choose from) whose name has the same initial sound. The test consisted of 25 auditorily presented items. All cued words were real words. Both vocalic and consonantal sounds were used as initial sounds.This test was timed.

(6) The Sound Deletion Test measures the subject's ability to delete a consonantal sound from an auditorily presented word, hold verbal material in working memory and blend the remaining sounds together. (Both the Sound Deletion Test and

the Ubby Dubby Test whose description follows were introduced to the subjects as word games.) This test was adapted from that of Bruce (1964). It consisted of 9 real words and 7 nonsense words. Consonantal sounds which were deleted occurred in initial, medial and final positions in the word. On each trial the subject is auditorily presented with a word, then the subject is asked to delete one sound which is named by the tester. The subject then says the word or nonsense word that remains after the sound has been deleted. The real and nonsense trials were scored separately.

(7) The Ubby Dubby Test measures the subject's ability to add in two sound segments (ab) after the initial sound of a word, hold verbal material in working memory and blend all remaining sounds together. There were ten items in this test all consisting of real words. This test may also test the subject's ability to make use of syllable structure.

(8) The Test of Phonological Memory measures one area of phonological processing. This test was adapted from Snowling, (1981). The stimuli consisted of 15 real and 15 nonsense words. The 15 real words consisted of 5 words of two syllables, 5 words of three syllabies and 5 words of four syllables. The 15 nonsense words consisted of the same number of words containing two, three and four syllables. In this test, subjects are required to repeat the real and nonsense words of two, three and four syllables which were

presented auditorily to them. Articulation difficulties associated with pronouncing infamiliar words has been reported in association with DDs (Miles, 1982). In order to validly compare the real and nonsense words, real words chosen were those that one would expect the subjects to be familiar with. The nonsense words were constructed through analogy with real words and had the same phonological complexity as the real words. For example "tewstaber" was derived from "newspaper". The nonsense words were of comparable difficulty because two or more sound segments were replaced by others which shared place of articulation or manner of articulation. The same vocalic segments were always retained. The changes were made in this way to minimize changes in the difficulty of production. Speech-motor programs were most likely available for the articulation of the real words, but none of the subjects were familiar with the nonsense words so speech-motor programs were not available for them. In order for the nonsense words to be repeated the auditory stimulus had to be processed, sound segments decoded and then recoded as instructions to form a speech-motor program. The verbal material must also be held in working memory while other processes are on-going.

Items on this test were practised for consistent pronunciation before administering to subjects and diacritics on nonsense words to indicate stress were used as an aid for consistent pronunciation. In this test the

subjects sat facing away from the experimenter so that there was no possibility they were responding to visual cues.

(9) The Lexical Decision Test is a timed test and measures lexical retrieval and encoding ability. The stimuli consist of 30 lexical items which include 10 real words of one or two syllables, 10 pronounceable nonsense words of one syllable and 10 non-pronounceable words comprised of four consonants. The non-pronounceable nonsense words are constructed from real words by keeping the consonants and leaving out the vowels. For example "bgng" is constructed from "beginning". The stimuli are presented individually on 3 1/2 by 5 inch index cards. The subject then responds by saying "yes" if the item presented is a real word and "no" if the word is a nonsense word. The subject is not required to say the lexical item printed on the card therefore overt pronunciation is not entailed.

(10) The Oral Recognition Test measures graphological to phonological conversion abilities as in the Word Attack Test when nonsense words are presented. The test consists of 10 real words and 10 nonsense words of either one or two syllables. The stimuli are presented individually on 3 1/2 by 5 inch index cards and the subject reads them. This is a timed test.

Procedure

The subjects were all tested in the informal environment of either the subject's house or the experimenter's. The tests were administered in a quiet, well lit area with a table for materials used with the experiment. Testing was done either in late afternoon around 4:00 P.M. or in early evening no later than 7:00 P.M. to insure the subject was not tired. An attempt was made to put each subject at ease with informal conversation before testing. Standardized instructions were used for every sub-test. The time required to test each subject varied from about 30 to 45 minutes to do the whole test. The subject was seated diagonally across the corner of a table from the experimenter. The experimenter recorded responses on a form out of view of the subject. A stopwatch was used to time certain tests to the nearest second. Raw scores were calculated by adding up the correct responses.

Results

Statistical Background

The data from each measure is presented through graphical representation of descriptive statistics for each group to illustrate differences between them. Analysis consists of the construction of confidence intervals about the mean. As the sample size is relatively small, inferential statistics were not generally employed. However, when the confidence intervals were not intersecting for some tests, Student's *t* statistic, which allows comparison of means for small samples, was calculated. Also, a test of homogeneity of variance was used when the standard deviations, and therefore the variances, were observed to be very different for the two groups within the same test. A test of homogeneity of variance took precedence over a *t* statistic, even though confidence intervals were not intersecting in some cases, but where it was also observed the standard deviations were significantly different. A positive result of the test of homogeneity of variances violates an assumption made when a *t* test is done, thus a positive result in the test of homogeneity of variance obviates the use of the *t* test. To calculate a test of homogeneity of variance, the ratio of the variances for the two groups was computed, and the result compared to the F

distribution with appropriate degrees of freedom. In cases where the variance is shown to be reliably different, it is concluded that the two groups were drawn from different underlying distributions. In addition, the Pearson Product-Moment Correlation (r) coefficient was computed to detect possible relationships between results of different tests. An (r) value was calculated and from this a (t) number in order to see if the correlation was significant. The significant correlations reported are non-directional, that is, predictions could be made from test A to test B or vice versa. Because of the size of the sample in this study, the correlation had to be larger than .80 (when comparing two tests which included only the experimental group) before it was significant. If there was a significant relationship the significance level (p) was determined. Following is a description of the statistical results of each test, along with the related graphs and tables, which follow the description of each test. Numerical means are given for each measure; following this statistic in parentheses is the standard error of the mean.

(1) Letter Identification Test

The data consisted of the number of letters read correctly by each subject and the time, in seconds, each subject took to complete the list of 45 items.

The mean number correct for the control group is 44.8 (.133). Individual letters read by the experimental group

were read with a higher error rate. The mean number correct for the experimental group is 43.3 (.422). These means are shown in Figure 1 on page 30a. The confidence intervals do not intersect which indicates significant differences in scores, but the standard deviations for the two groups indicate the two populations have different underlying distributions. The standard deviation for the control group is .422 and 1.033 for the experimental group. A test of homogeneity of variance shows $F(5,9) = 5.99$, $p < .025$.

The mean time of completion for each group is shown in Figure 2 on page 30a. There were slight time differences between the two groups, the experimental group took slightly longer to complete the test. The mean time for the control group is 43.9 seconds (2.046), the mean time for the experimental group is 50.5 seconds (2.952).

A correlation was found between the letter identification test and the word identification test. Where $r = .59$ (less than .80 here because both experimental and control groups were included) and $t(14) = 2.75$, $p < .02$. Both the experimental and control groups were used in this correlation in order to obtain a wider range of scores. Depending on how well the experimental group did on one of these tests would predict how well they would do on the other. This implies the same or similar skill was most likely necessary to do both tests.

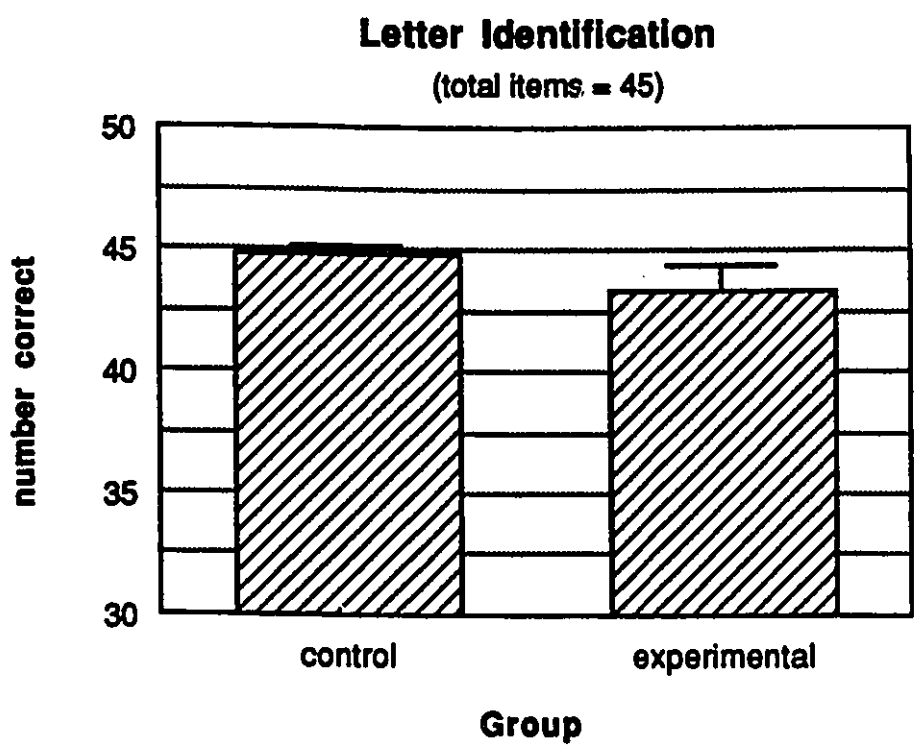


Figure 1. Letter identification test: number of items correct for each group ($p < 0.025$).

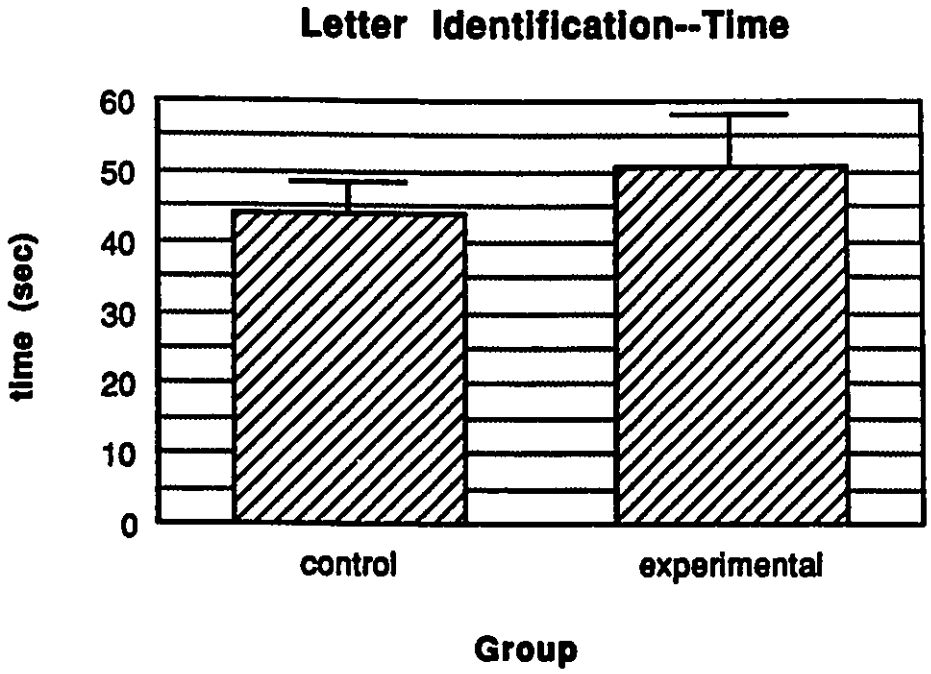


Figure 2. Letter identification test: time taken to complete test.

(2) Word Identification Test

The Word Identification Test establishes estimated reading grade level. The raw data, the numbers of words read correctly, were transformed to reading grade equivalent for each subject. Reading grade equivalent was obtained by comparison to the standardized tables in the manual of the Woodcock Reading Mastery Tests (1973). The reading level for the control group may be somewhat deflated as all control subjects could go no further than item 120 which is equivalent to a 5.7 grade reading level. The group means for grade equivalent are shown in Figure 3 on page 32a. Mean grade equivalent for the control group is 5.2 (.141); the mean for the experimental group is 3.57 (.351). The control group and the experimental group are two distinct groups as the confidence intervals do not intersect. A t -test between two independent means confirmed this, with $t(14) = 2.58$, $p < .05$.

Raw time differences were not analyzed, as this measure would have been misleading. Each subject in the control group started at item 81 of the test and finished at item 120 making a total of 40 items read by this group. All subjects in the experimental group started at the beginning of the test and finished at various places. Therefore each subject in this group read a different number of words.

Instead, the mean time taken to read each word was calculated. This was done by dividing the total time taken by each subject by the number of words that subject read. These times were used in turn to calculate a group mean time taken per word. For the control group, the mean time taken per word was 1.8 seconds; the mean time taken by the experimental group was 2.3 seconds.

There was no correlation between the mean amount of time an experimental subject spent on each item and how well they did on the test. On this test $r = .054$. One could not predict from the amount of time they spent on each item how well they would do on the test.

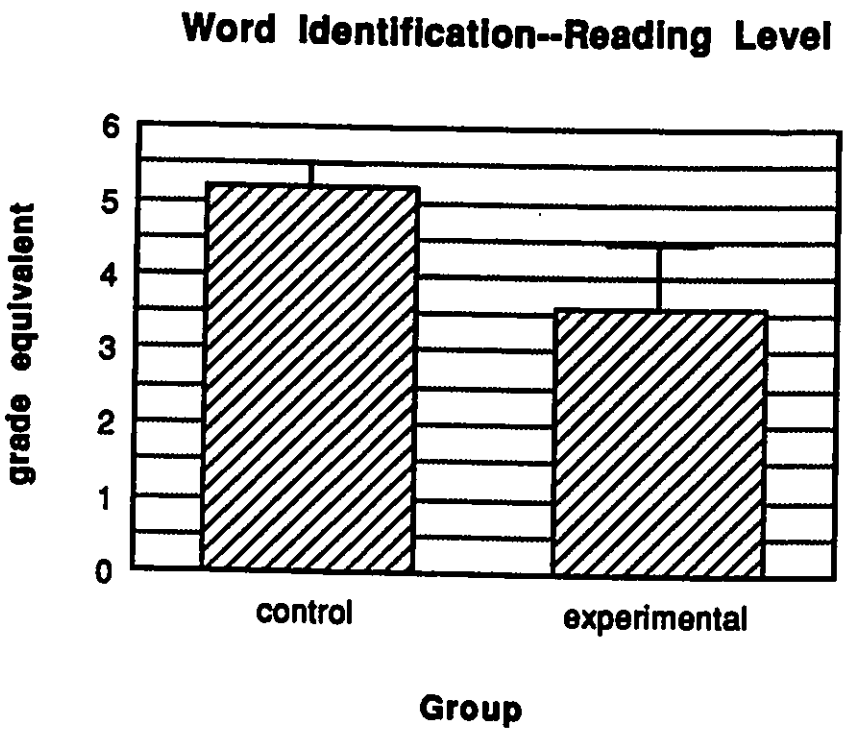


Figure 3. Word identification test: grade equivalent score ($p < 0.05$).

(3) Word Attack Test

This test measures the subject's ability to pronounce nonsense words. The data consisted of the percentage of nonsense words read correctly by each subject out of a total of fifty words and the time taken to complete the test. Most experimental subjects performed poorly on this test. Mean percentage correct for the control group is 88% (2.251), mean percentage correct for the experimental group is 55% (12.1). Inspection of Figure 4 on page 35a reveals that the confidence intervals do not intersect. Futhermore, examination of the standard deviations for these groups points to an important difference in the two samples. The standard deviation for the control group is 7.118 which describes a comparatively homogeneous population. The standard deviation for the experimental group is 29.6, which describes a population quite different from that of the control group and secondly indicates the heterogeneous nature of the experimental group. A test of homogeneity of variance shows $F(5,9) = 17.3$, $p < .001$.

An examination of individual subject's performance in the experimental group on the Word Attack Test will demonstrate it to be a heterogeneous population. Table 1 on page 35b gives the number correct out of 50, the total number of words read and the time taken to complete the test. The

table shows the range of abilities demonstrated by the experimental group with this test. One subject performed in the upper range of the controls while two others performed almost as well as the controls. The remaining three performed very poorly.

Three subjects in the experimental group did not complete this test, thus mean times could not be calculated to compare the two groups based on the completion of the test. Instead, the average time taken by each subject in a group to read a word was calculated. These individual times were added up and divided by the appropriate group number to obtain a group mean time taken per word. The mean time taken by the control group to read a word is 1.8 seconds (.145), mean time taken by the experimental group is 5.4 seconds (1.12). Inspection of the standard deviations for these two groups points to a difference in the two samples. Standard deviation for the control group is .460 and for the experimental group it is 2.74. A test of homogeneity of variance shows $F(5,9) = 35.5$, $p < .001$. This indicates that these two groups are drawn from populations having different underlying distributions and the experimental population is a heterogeneous one with respect to this test.

There was a significant correlation between the Word Attack Test and the Oral Recognition Test for the experimental subjects. Where $r = .94$ and $t(5) = 5.69$, $p < .01$. Both of these tests have nonsense words. One could predict how well

an experimental subject would do on one test knowing the results of the other. The same or similar skill most likely underlies performance on both tests.

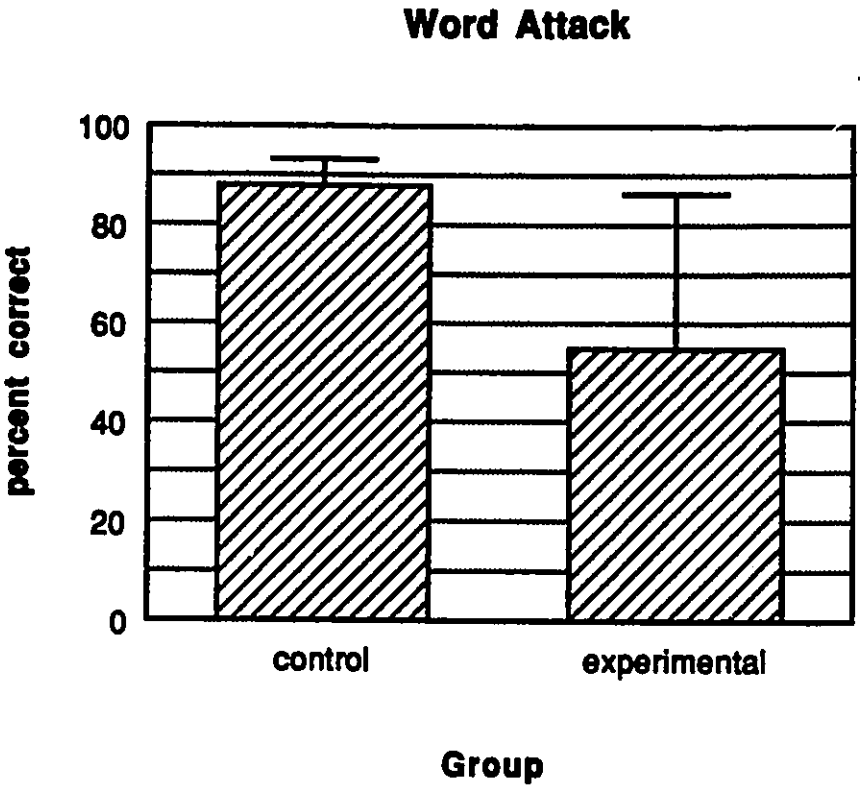


Figure 4. Word Attack test: percent correct ($p < 0.001$).

Table 1
Word Attack Test

Subject #	*Words read*	*No. correct*	*Time (min:sec)*
Experimental Group			
1	30	17	2:22
2	37	21	6:00
3	50	36	2:17
4	50	46	1:52
5	39	9	2:45
6	50	38	5:31
Control Group			
1	50	41	2:00
2	50	42	1:30
3	50	39	1:23
4	50	39	1:53
5	50	49	1:02
6	50	46	1:19
7	50	46	2:00
8	50	45	1:20
9	50	48	1:08
10	50	45	1:05

(4) Auditory Discrimination Test

This test measures the subject's ability to discriminate minimal pairs in ideal conditions with no background noise. The data consists of the number of correct responses recorded for each subject. Trials consisted of 45 pairs of words with a consonantal or vocalic contrast and 19 pairs of words that have no contrast. The word trials were presented in a random order. Both the control and the experimental group performed equally well on this test on both types of trials. The means are shown in Figure 5 on page 36a. Mean number correct (for pairs of words having a contrast) for the control group is 41.9 (.567), mean number correct for the experimental group is 41.33 (.615). Mean number correct (for pairs of words with no contrast) for the control group is 18.4 (.221), and for the experimental group is 18.8 (.167).

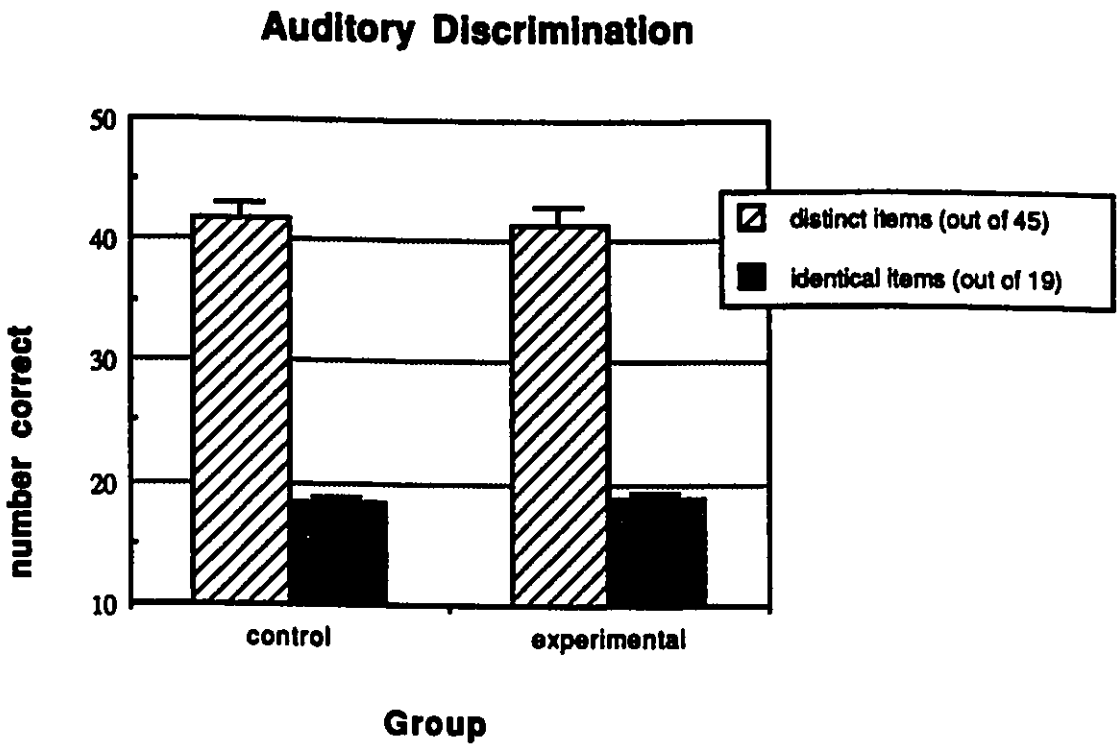


Figure 5. Auditory discrimination test: number correct

(5) Initial Segmentation Test

This test measures the subject's ability to isolate an initial sound from a word presented auditorily and then select a picture of an object (three pictures to choose from) whose name has the same initial sound. The data consists of the total number of correct reponses converted to percentage correct for each subject and the time in seconds needed to complete the test. Both groups reached the ceiling of this test for correct reponses. Figure 6 on page 37a illustrates this. The experimental group took slightly longer to respond. The mean time taken in seconds to complete the test by the control group was 242.6 seconds (12.73), the mean time taken by the experimental group was 281.33 seconds (17.52). The mean time of completion for each group is shown in figure 7 on page 37a. As a test of segmentation ability this test was probably too simple for this age group of disabled readers.

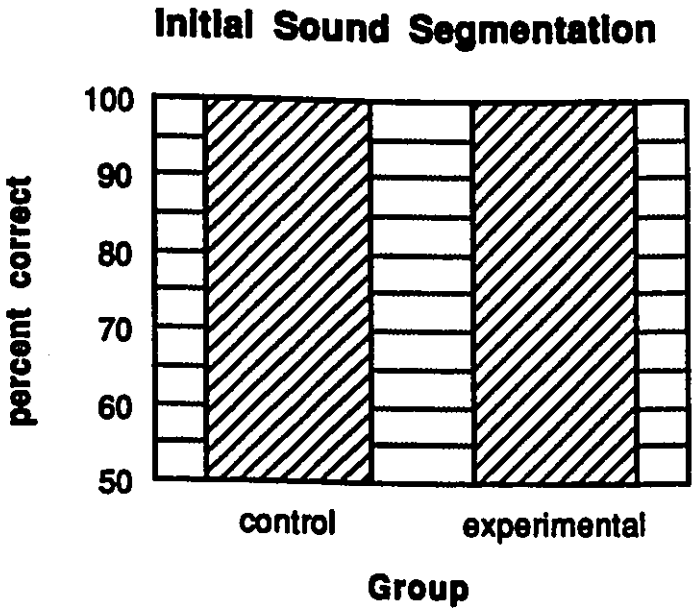


Figure 6. Initial sound segmentation test: percent correct.

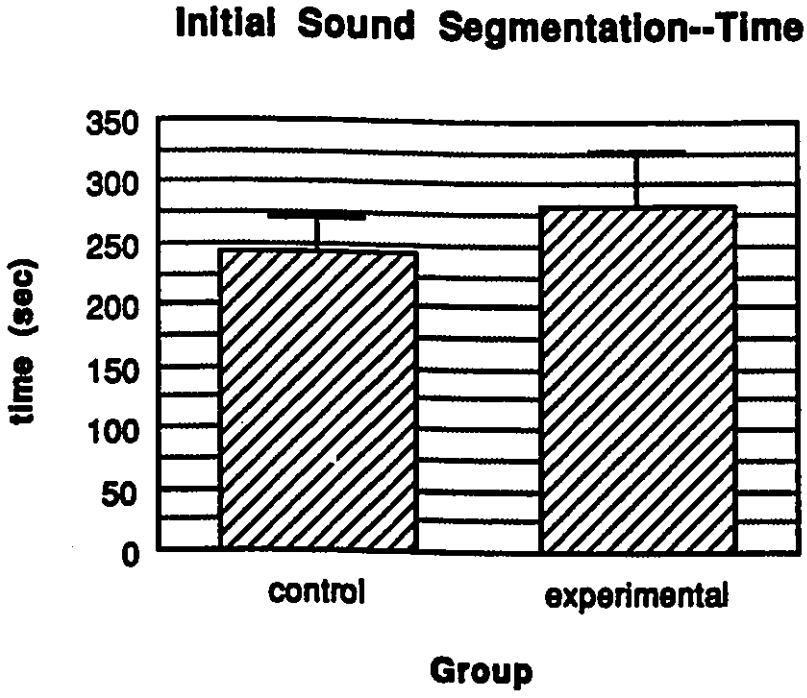


Figure 7. Initial sound segmentation test: time taken to complete.

(6) Sound Deletion Test

This test measures the subject's ability to delete a consonantal sound from an auditorily presented word, hold verbal material in working memory and blend the remaining sounds together. There are a total of sixteen items, nine of these items are real words and seven are nonsense words. The data consisted of the number of words of each type correctly reconstructed by each subject. The group means were determined for each item type, as well as for the combined scores. For the combined scores, the mean number correct for the control group is 14.5 (.45), and the mean number correct for the experimental group is 9.83 (1.579). These means are shown in Figure 8 on page 40a. The standard deviations were different enough for these two groups to be viewed as having different underlying populations. The standard deviation for the control group is 1.43 and for the experimental group it is 3.869. Based on these numbers a test of homogeneity of variance shows $F(5,9) = 7.31$, $p < .01$. The experimental group scored almost as well as the control group on the real word items (total items= 9). The mean number correct for the control group on these items is 8.1 (.233), and for the experimental group it is 7.17 (.601). On the nonsense word items the experimental group did not fare as well. On these items (total items= 7), the mean number correct for the control group is 5.4 items (.267) and for the experimental

group it is 2.0 (.816). The mean number correct for separately scored real and nonsense items are shown in Figure 9 on page 40a. A test of homogeneity of variance demonstrates these two groups to be drawn from different underlying populations and also points to the heterogeneous nature of the experimental group. Table 2 on page 40b shows the range of scores. Standard deviation for the control group is .843 and for the experimental group it is 2.0. A test of homogeneity of variance shows $F(5,9) = 5.63$, $p < .025$.

A correlation was found to exist between the experimental group's performance on the real and nonsense word trials. One could predict how an experimental subject would do on the real word trials by knowing how they performed on the nonsense word trials and vice versa. Where $r = .95$ and $t(5) = 6.01$, $p < .01$.

A correlation was found to exist between the nonsense word trials of the Sound Deletion Test and the Oral Recognition Test for the experimental subjects. Knowing how well an experimental subject did on the nonsense word trials on one test would predict how well they would do on the other test. This implies that the same or a similar skill is likely to be required to do both tests. Where $r = .84$ and $t(5) = 3.11$, $p < .05$.

A correlation was found to exist between the Sound Deletion Test and the Ubby Dubby Test. If a subject did poorly on one test one could predict that she would do poorly on the other. Causal relations cannot be inferred from correlation, meaning one can predict from either test the results of the other, but results on one test cannot be identified as causing the results on the other. (Both could be caused by a third, unidentified factor.) Again, the same or similar skill is likely required to complete these tests. Where $r = .82$ and $t(5) = 2.85$, $p < .05$.

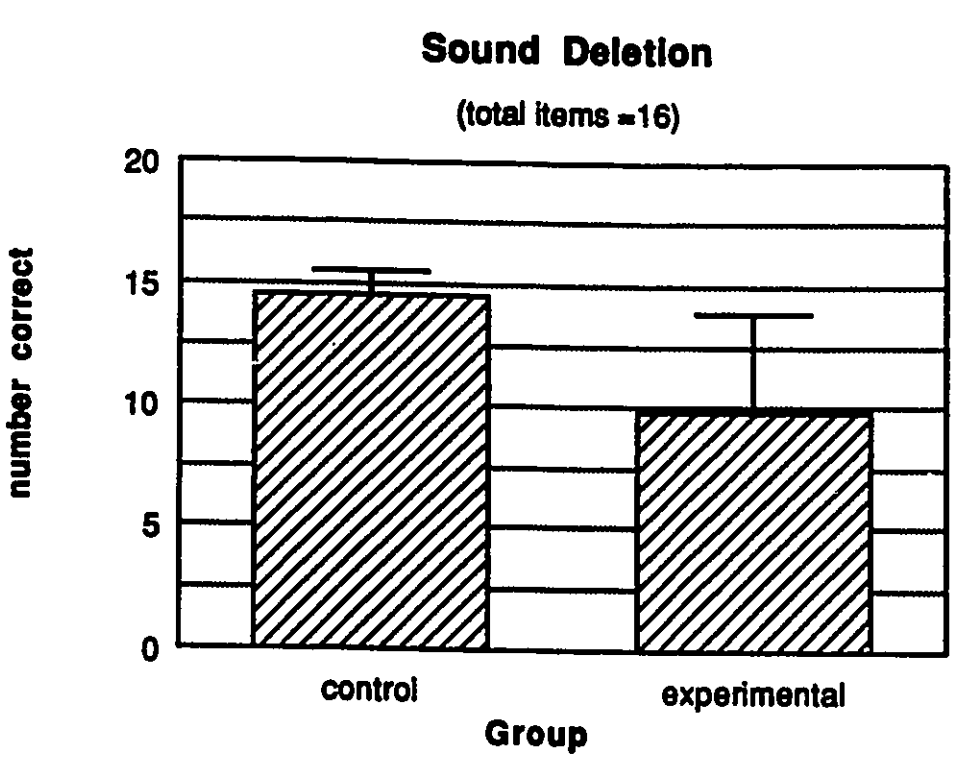


Figure 8. Sound deletion test: number correct ($p < 0.005$).

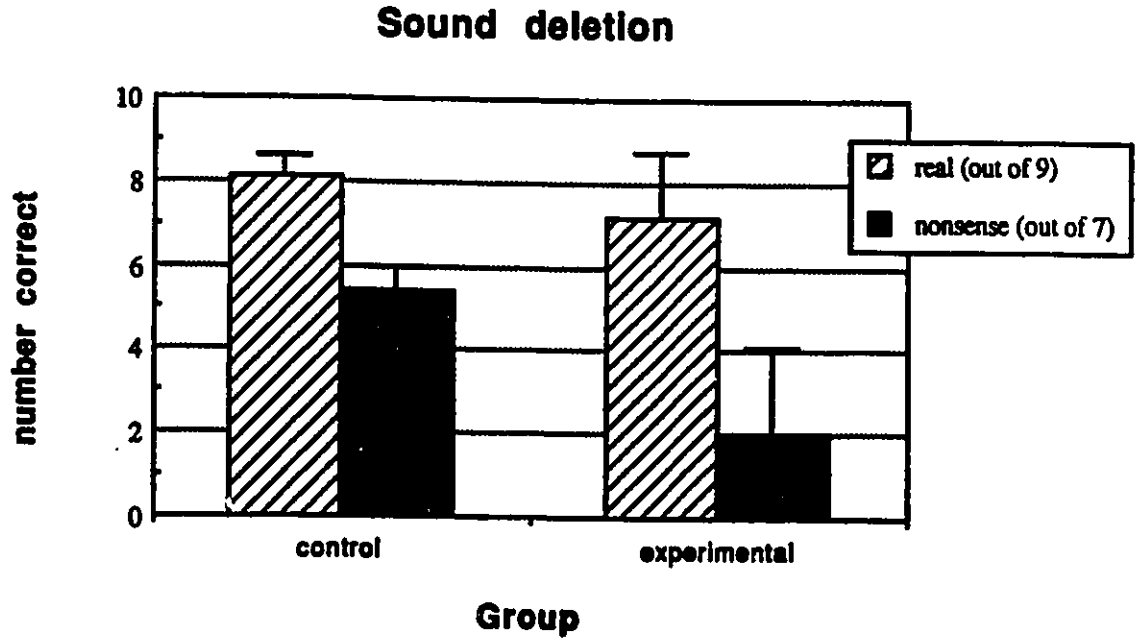


Figure 9. Sound deletion test: number correct for separately scored real and nonsense items (nonsense items: $p < 0.025$)

Table 2
Sound Deletion Test

Number of items correct in each word category

Subject #	*Real words (items = 9)*	*Nonsense words (items = 7)*
Experimental Group		
1	8	4
2	5	1
3	9	6
4	8	4
5	6	1
6	7	2
Control Group		
1	9	7
2	8	5
3	8	7
4	7	5
5	8	7
6	9	7
7	8	6
8	9	7
9	8	7
10	7	6

(7) Ubby Dubby Test

This test measures the subject's ability to add in two sound segments (ab) after the initial sound of a word, hold verbal material in working memory and blend all remaining sounds together. There are a total of 10 items on this test. The data consisted of the number of words constructed correctly by each subject. The means are shown on Figure 10 on page 41a. The mean number read correctly by the control group is 8.8 (.249), mean number read correctly by the experimental group is 5.83 (1.138). There was a wide range of performances within the experimental group with one subject performing with only one error and another with nine errors. Table 3 on page 41b demonstrates this range of scores. Even though the confidence intervals intersect a test of homogeneity of variance shows $F(5,9) = 12.48$, $p < .001$ which implies the two samples are drawn from populations having quite different distributions.

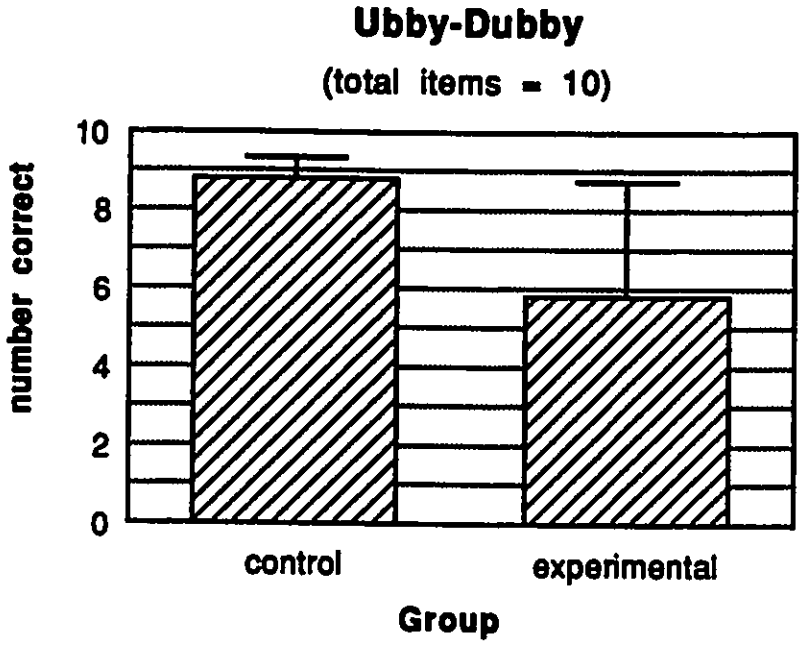


Figure 10. Ubby-dubby test: number correct ($p < 0.001$).

Table 3
Ubby Dubby Test

Subject #	*Number correct (items = 10)*
Experimental Group	
1	6
2	1
3	8
4	9
5	5
6	6
Control Group	
1	8
2	9
3	8
4	8
5	9
6	10
7	10
8	9
9	9
10	8

(8) Test of Phonological Memory

This test measures one area of phonological processing. There was a total of 30 items on this test. The data consisted of the total number of words repeated correctly by each subject. The data included real word trials and nonsense word trials, each comprised of 15 words. The nonsense word trials and the real word trials were each comprised of 5 words with two syllables, 5 words with three syllables and 5 words with four syllables. Words repeated by the experimental group were repeated with a higher error rate especially when they were nonsense words. The mean number of correct reponses made by the control group for the whole test is 27.9 (.458), the mean mumber of correct reponses for the experimental group is 23.67 (.92). The means are shown in figure 11 on page 43a. The two groups are distinct as the confidence intervals do not intersect. A t -test between two independent means yields $t(14) = 2.46$, $p < .05$.

The means for the two groups on the real word trials which included words of two and three syllables were the same and consisted of perfect scores. The mean number correct for the control group on the real word (4 syllable) trial is 4.9 (.1), and for the experimental group is 3.8 (.477). The means for the real word trials are shown in Figure 12 on page 43a.

The mean number of correct reponses for the control group for nonsense words of two syllables is 4.3 (.213), and for the experimental group is 3.167 (.477). The mean number of correct responses for the control group for words of three syllables is 4.3 (.213), and for the experimental group is 3.8 (.307). The mean number of correct reponses for the control group for words of four syllables is 4.4 (.267), and for the experimental group is 2.83 (.307). The means for the nonsense word trials are shown in Figure 13 on page 43b.. The confidence intervals for the four syllable nonsense trials do not intersect. They are two distinct groups where this particular trial is concerned. A t -test between two independent means confirms this, with $t(14) = 2.43$, $p < .05$.

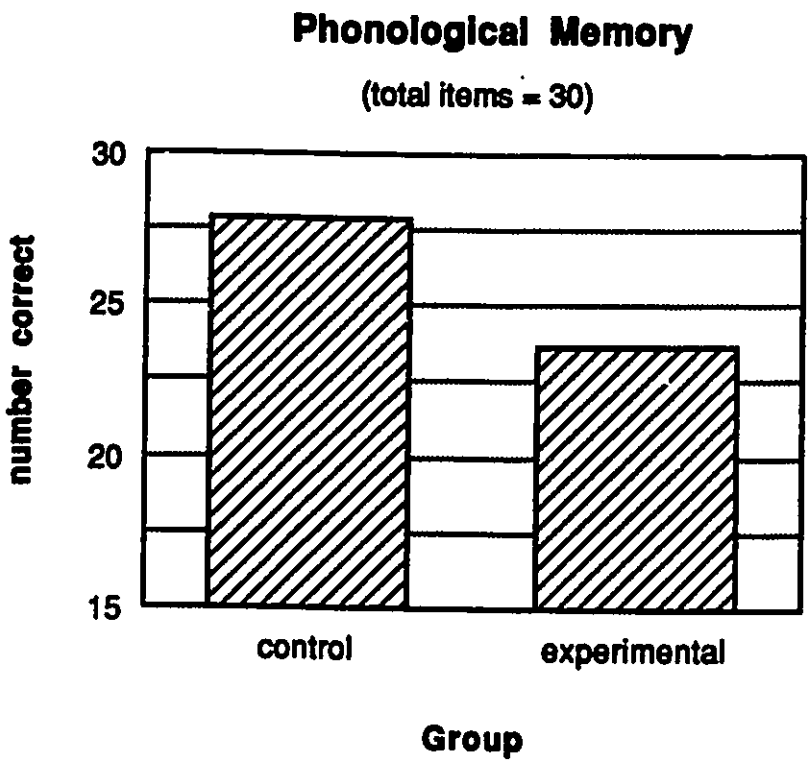


Figure 11. Test of phonological memory: number correct ($p < 0.05$).

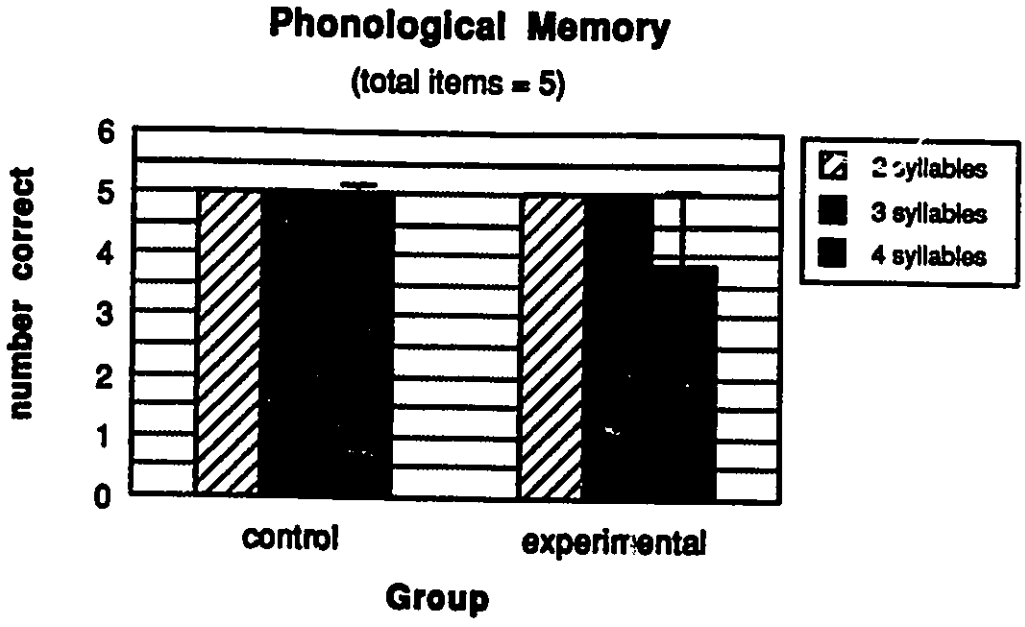


Figure 12. Test of phonological memory: number of real words correct.

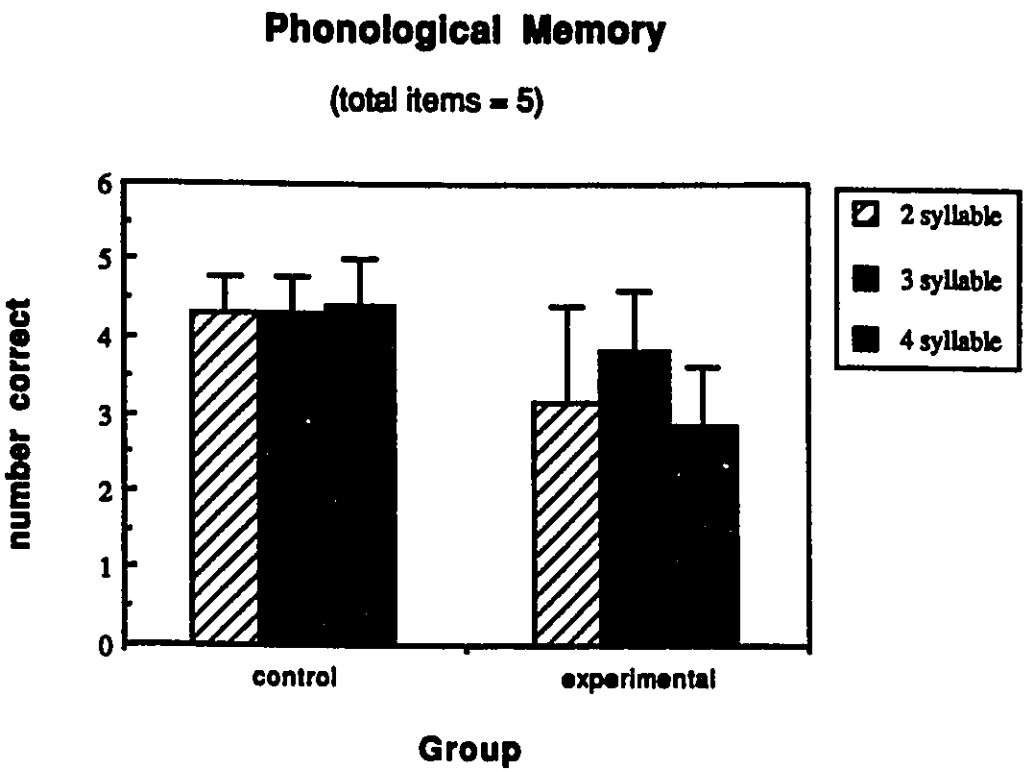


Figure 13. Test of phonological memory: number of nonsense words correct ($p < 0.05$)

(9) Lexical Decision Test

This test measures lexical retrieval. There were 30 items on this test. The data consisted of the number of items correctly identified as real or non-real words and the time taken to complete the test. The two groups scored approximately the same in terms of correct responses. The mean number of correct reponses for the control group is 28.2 (.573), and for the experimental group it is 27.83 (.654). The means are shown in Figure 14 on page 44a. The experimental group took longer to do the test. The mean amount of time taken by the control group to do the test is 85.1 seconds (3.132), the experimental group took a mean time of 123 seconds (16.515). The mean time for each group is shown in Figure 15 on page 44a. A wide range of times within the experimental group indicates a heterogeneous population. The times are shown in table 4 on page 44b. This is further demonstrated by the differences in standard deviations. Standard deviation for the control group is 9.905 and for the experimental group it is 40.452. Based on these figures a test of homogeneity of variance shows $F(5,9) = 16.68$, $p < .001$. This again indicates that the two samples are drawn from populations having different underlying distributions.

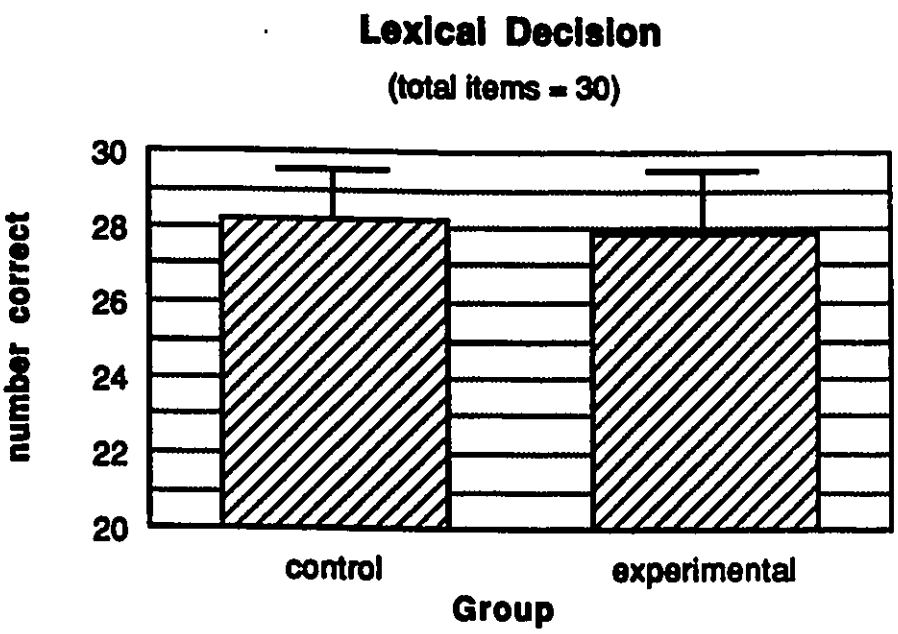


Figure 14. Lexical decision test: number correct.

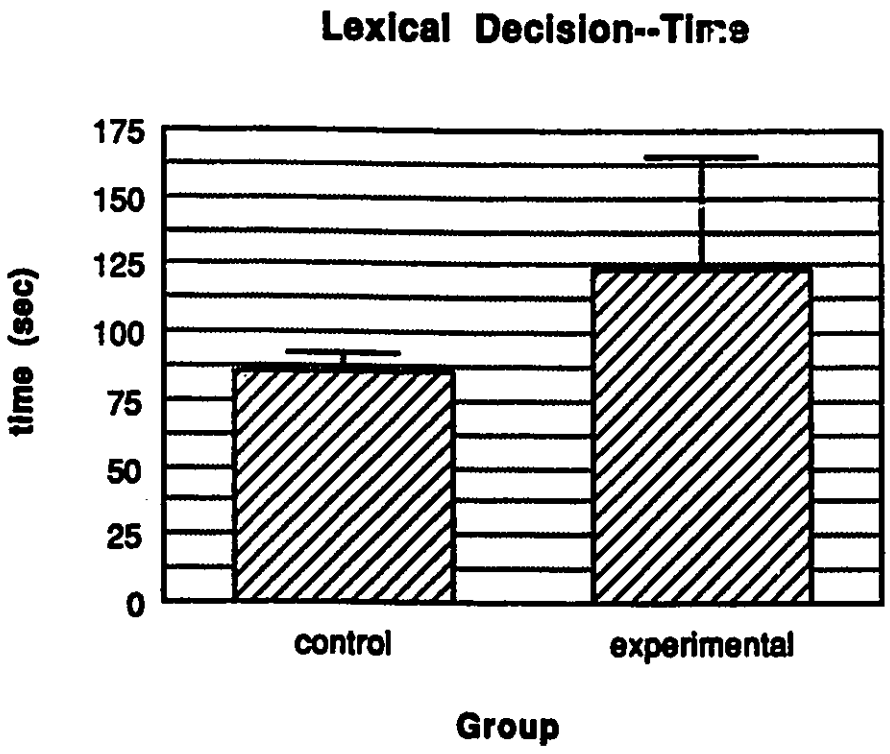


Figure 15. Lexical decision task: time taken to complete test ($p < 0.001$).

Table 4
Lexical Decision Test

Subject #	*Time (min:secs)*
Experimental Group	
1	3:18
2	1:48
3	1:28
4	1:32
5	1:58
6	2:14
Control Group	
1	1:27
2	1:24
3	1:27
4	1:42
5	1:10
6	1:30
7	1:22
8	1:35
9	1:10
10	1:25

(10) Oral Recognition Test

This test in part measures graphological to phonological conversion abilities as a section of the test demands the reading of nonsense words as in the Word Attack Test. There were a total number of 20 items in this test. The data consisted of the total number of real and nonsense words read correctly by each subject and the time in seconds taken to complete the list. The 10 real words were read with the same accuracy by the two groups. The mean number of real words read correctly by the control group is 9.8 (.13), the mean number read correctly by the experimental group is 9.67 (.33). The 10 nonsense words were read less accurately by the experimental group in spite of the fact that they were relatively simple and contained a maximum of two syllables. The mean number of nonsense words read correctly by the control group is 8.7 (.26), the mean number read correctly by the experimental group is 6.17 (.87). The means for the real and nonsense word trials are shown in Figure 16 on page 46a. A variety of scores within the experimental group show it to be a heterogeneous population. These scores are shown in Table 5 on page 46b, along with the time taken to do the test. This is further demonstrated by the differences in the standard deviations. Standard deviation for the control group is .82 and for the experimental group is 2.14. A test of homogeneity of variance shows $F(5,9) = 6.81$, $p < .01$. The

mean time taken by the control group to finish the test is 51.2 seconds (1.861), mean time taken by the experimental group is 93.33 seconds (15.461). The mean time taken to complete the test is shown in Figure 17 on page 46a. The experimental group took almost twice as long to complete the test as the control group did. Within the experimental group there was a range of different times taken to complete the test whereas the control group showed itself to be a homogeneous group. A comparison of the standard deviations (5.684 for the control group vs 37.872 for the control group) indicates the underlying distributions are different. A test of homogeneity of variance shows $F(5,9) = 41.43$, $p < .001$.

On this test if an experimental subject did poorly on the real word trials it could not be predicted how she would do on the nonsense word trials and vice versa due to a correlation coefficient of .17.

A correlation was found for the experimental subjects between the time taken to do the test and total number of errors made on the test. The more time they took to do the test the more errors they made. Where $r = .82$ and $t(5) = 2.92$, $p < .05$.

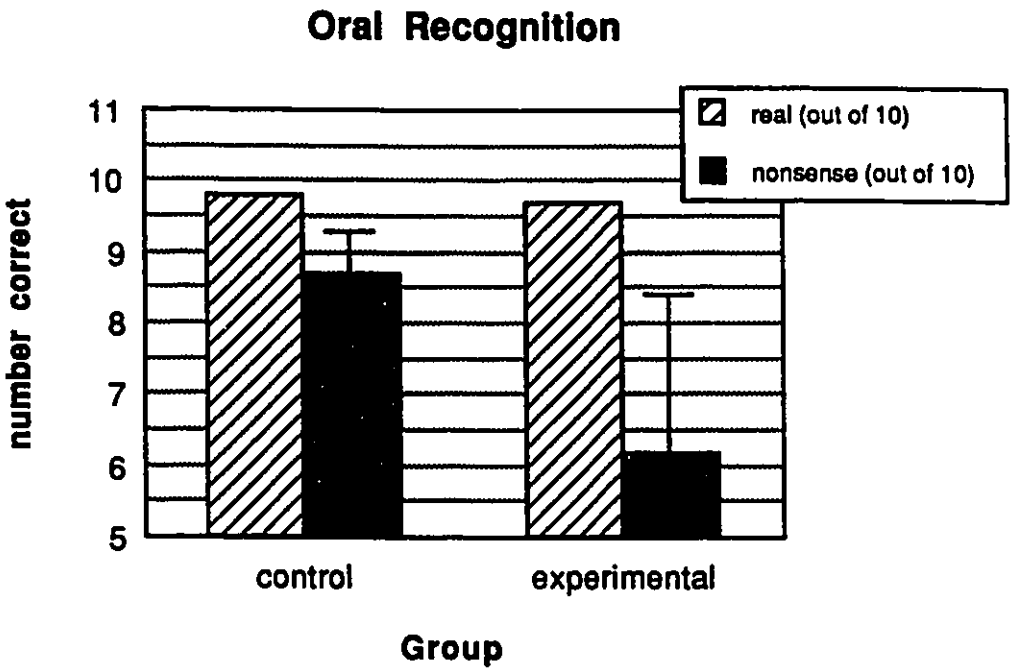


Figure 16. Oral recognition test: number correct of separately real and nonsense items (nonsense items $p < 0.01$).

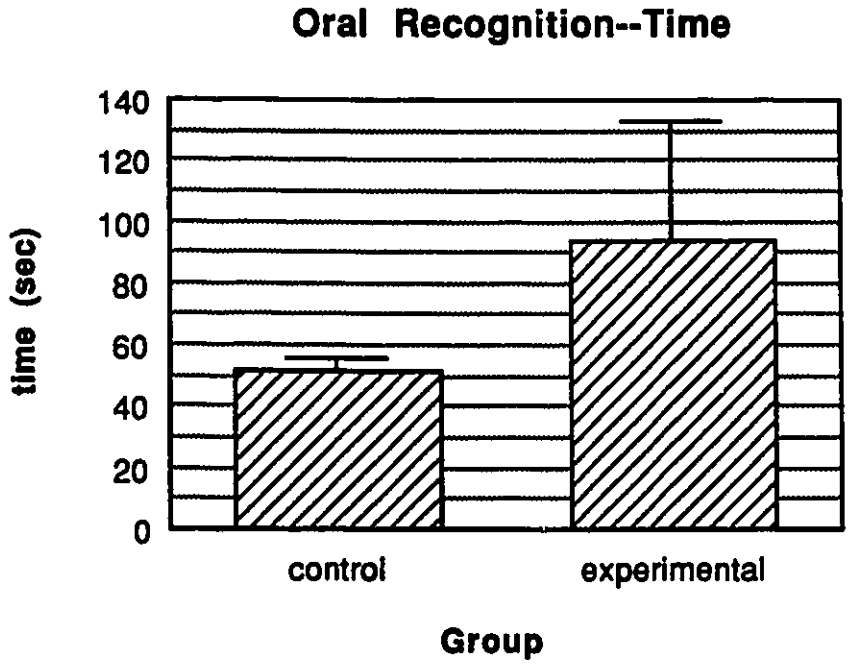


Figure 17. Oral recognition test: time taken to complete test ($p < 0.001$).

Table 5
Oral Recognition Test

Number of items correct in each word category

Subject #	*Real words (items = 10)*	*Nonsense words (items = 10)*	*Time (min:secs)*
Experimental Group			
1	8	7	1:54
2	10	4	1:30
3	10	10	0:51
4	10	8	0:51
5	10	3	2:28
6	10	7	1:46
Control Group			
1	10	10	1:00
2	9	9	0:54
3	10	10	0:52
4	10	9	0:59
5	10	8	0:50
6	10	8	0:48
7	10	8	0:51
8	10	8	0:46
9	10	9	0:40
10	9	8	0:52

Discussion

Introduction

Many of the subtests in this study had a positive result for the test of homogeneity of variance. This positive result indicates that the control group and the experimental group are two distinct populations with different underlying distributions, and secondly indicates the heterogeneous nature of the experimental group who had a broader range of scores for many of the subtests. This replicates the results of many researchers concerned with the investigation of DD. It appears to be a phenomenon that involves a heterogeneous population (Doehring et al., 1981; Boder & Jarrico 1982). This lack of homogeneity implies a different profile of deficiency for different subjects and therefore a broader range of scores for many of the subtests. There are two subjects in the experimental group, (#3 and #4), who scored in most subtests as well as or nearly as well as the controls. The scores of these two subjects resulted in most cases in demonstrating the experimental group to be a heterogeneous population. The two experimental subjects who did well on most tests do not appear to have the same profile of deficiencies as those who did poorly. Those experimental subjects who did poorly can be hypothesized to be much more significantly deficient in certain phonological

processes which are hypothesized to underlie many of the tests of the present study. This hypothesis is further supported by the positive correlations demonstrated between many of the tests. The source of the deficiencies of the two subjects who performed as well as the controls on some tests and almost as well on others, but who were significantly behind in reading level and both in special classes, cannot be as clearly established. The tables in this section follow the discussion of the particular test to which they are related.

(1) Letter Identification Test

A positive result in a test of homogeneity of variance indicates that in relation to this test, the experimental group is a distinct group and they consist of a heterogeneous population. The same letters are consistently problematic for this group. These are: (39) "V", (44) "Z" and (45) "Q" which are all in cursive writing. The one problematic lower case printed letter is (18) "J". The experimental group was reading at the 3 year and 6 month reading level according to the Word Identification subtest of the Woodcock. This may indicate why they scored as they did on the Letter Identification Test. Because they were not as advanced in their reading as the control group their exposure to many different forms of writing may not have been as diverse either. On the other hand both groups had experienced the same number of years of exposure to print.

The manual for the Woodcock Reading Mastery Tests states that by the end of grade one, "most pupils are able to generalize letter identification skills to many of the cursive and specialty-type letter forms even though this may be the subject's first experience with a specific type style (Woodcock, 1973:3)." By the end of grade four most pupils receive perfect or near perfect scores on this test (Woodcock Manual 1973).

It is significant to note that the naming of individual letters by the experimental group was slower in this test. Many researchers have had similar results when investigating the object naming or letter naming abilities of DDs (Jansky and de Hirsh, 1973; N.C. Ellis, 1981; Denckla and Rudel, 1974; Spring and Capps, 1974). Ellis (1981), has shown that dyslexic children aged 10-14 years are slower than controls at naming single letters of the alphabet. Their deficiency also appears to be specific to accessing name representations rather than processing the visual properties of letters (Ellis and Miles, 1981). When letters were being named by the experimental group there was no indication that a visual perceptual problem existed. There were no observed reversals of letters, for example confusing a "b" with a "d" or a "p" with a "q". "The hypothesis that dyslexics are subject to perceptual problems at an early stage of processing has largely fallen from favour (Snowling 1987:16,17)."

Ellis (1981), conducted a pertinent study which demonstrates that DDs have a deficiency specific to retrieving names rather than processing the visual properties of letters. In the experiment, normal and dyslexic readers took about the same amount of time to judge if two letters of the same case were the same or different. Upper case letter combinations such as the following were to be judged same or different on the basis of their visual characteristics: (BB-visually identical), (OB-visually dissimilar), and (RP-visually similar). It took the dyslexics significantly longer and they were more error prone to judge different case letters such as (Bb-phonologically identical), (Ba-phonologically dissimilar), and (Bd-phonologically similar) as being the same or different. The dyslexics made judgements on same case letter pairs on the basis of their visual characteristics as quickly as contols but were slower at judging the different case pairs where the comparison is one of name codes ($t = 5.69$, $p < .01$), (Ellis 1981). The extra time taken by the dyslexics indicates the time taken to retrieve letter names from memory. Disabled readers are not disadvantaged when no verbal labelling is required (Vellutino, Harding, Phillips and Steger 1975; Vellutino, Steger, Harding and Phillips 1975). In tasks that require subjects to encode phonological information in long term memory poor readers have consistently been shown to learn more slowly than good readers. These types of tasks include paired-associate learning which use visual forms as stimuli and spoken nonsense words as responses (Done & Miles, 1978).

If DDs have difficulty in encoding phonological information in long-term memory we can hypothesize that possibly their storage and retrieval of phonological codes may be deficient as well. These phonological processes are strongly implicated in reading and shall be closely examined throughout the analysis.

The positive correlation between the Letter Identification Test and the Word Identification Test indicates the two tests most likely rely on the same skill. On both tests the experimental group was less accurate and took longer to do the tests. The Letter Identification Test requires the retrieval of name codes for a single letter, whereas, in the Word Identification Test the task is similar but more demanding. As will be discussed below, the Word Identification Test requires retrieval of phonological codes or name codes for the decoding of unfamiliar words. This is where most experimental subjects experienced problems.

(2) Word Identification Test

The control group and the experimental group are two distinct groups as the confidence intervals do not intesect. A t-test confirmed this. There is slightly more than a one and a half grade level difference in reading ability between the two groups.

Some experimental group errors were recorded by the

experimenter. They appear to indicate that DDs will sometimes attempt to respond to the word's overall shape or contour (Smith, 1971, Glushko 1979,) rather than using an analytical process to reading words. For example: subjects 5 and 6 of the experimental group both read "confront" for "comfort". Subject 5 of the experimental group made the following substitutions: "energy" was read for "engine", "twelve was read for "twilight", "place was read for "peace" and "what" was read for "that". Subject 6 of the experimental group read "board" for "drawl". Most of the words involved were words of one and two syllables which were not phonologically complex. These errors appear to indicate an over dependence on "wholistic" reading in these particular instances, where words of a similar shape were substituted for the target words. Rack (1985), has compared dyslexic readers to reading age matched controls in a cued recall paradigm. He found that dyslexics better recalled a paired word when it had been matched with another that was orthographically similar, (eg., "warm-harm"). Reading matched controls recalled best words which rhymed, (eg., "head-said"), regardless of orthographic similarity. The dyslexics used the visual or orthographic features of words to recall them, the controls used phonetic codes. Using the word's overall shape is a normal reading process but in the above instances the subjects appear to be over-compensating with this process. Perhaps this is because processes are deficient at another level, that of phonological processing which involves reading grapheme by grapheme and associating

sounds to graphemes. This analytical approach allows even skilled readers to decode unfamiliar words by associating graphemes to sounds. There was no context in this test to help in the reading of these words, another compensatory process used by DDs (Stanovich 1980, 1982; Perfetti; Goldman and Hogaboam 1979; Perfetti 1985). The use of context and word shape are both normal processes used when individuals read. However, an over-reliance on these processes points to a deficiency in other processes. Frith (1985), hypothesizes that the development of reading is divided into three phases. The first two of these are relevant to the present argument: Logographic reading is the first phase in which words are read holistically and context cues are used to assist recognition. This is why beginning reader's books often have pictures associated with the stories. In addition to the continued use of logographic skills, the addition of the use of alphabetic skills are added. This is a necessary step because new words are continually being encountered. At this stage phonological processing skills are strongly implicated. It is at this stage that the reader must make the correct associations between graphemes and sounds. The appropriate sound-grapheme associations must be retrieved from long term memory and held in working memory so the pronunciation of a word can be completed. This ability is tested more rigorously when a list of nonsense words are to be read. The following test involves nonsense words.

(3) Word Attack Test

Most experimental subjects performed poorly on this test. A positive result for the test of homogeneity of variance test indicates that the experimental group in relation to this test is a population quite different from the control group and secondly indicates the heterogeneous nature of the experimental group. A look back at Table I on page 35b, in the results section shows the range of abilities. Subject #4 performed as well as the control group and subject #3 performed almost as well. The scores of these two subjects appear to indicate that the profile of their deficiencies associated with reading is different from the rest of the experimental group. Because of the heavy reliance on phonological skills in this test, their particular deficiencies are shown to be less strongly related to phonological processing than the other subjects in this group, and the source of their difficulties cannot be as clearly established.

The control group subjects experienced little difficulty with this test, their reponses were generally without hesitation and they moved at a fairly rapid rate through the word list. Since this group scored as a homogeneous group an average of their correct responses was calculated and compared to the standardized scores in the Woodcock manual. Their score as a group was equivalent to that of an individual who was reading at the mid grade 5 level. The poor performance of the experimental

subjects demonstrates that this task was very difficult for them. Mean time taken by an experimental subject to read a word is 5.4 seconds, mean time taken to read a word by a subject in the control group is 1.8 seconds. A close look at the processes involved in reading nonsense words will clarify why certain experimental subjects experienced such difficulty.

Instructions to the experimental and control group before this test was administered were essentially that this particular test consisted of nonsense words, that is, words without meaning. In spite of this, there were several instances where experimental subjects attempted to substitute a real word for the nonsense one; this same process was never observed with the control subjects. Table 6 on page 60a, indicates the real word substitutions made for the nonsense words in this subtest. The number after the real word indicates the number of subjects who read it the same way. The substitutions made are consistent with the word shape strategy discussed above. There was the tendency by some experimental subjects to attempt to instill meaning as an aid to the decoding of these words, whereas the control subjects did not use this strategy at all. It is possible that because some of the experimental subjects' phonological encoding processes are deficient, they resort to encoding semantically. This same strategy has been observed in paired-associate learning tasks where nonsense words were required as responses. Good readers' errors were novel combinations of the graphemes in the target word, poor readers often gave real words as responses (Vellutino, Steger, et al., 1975). Other studies with tasks

which test how verbal material (presented both auditorily and visually) is encoded have had similar results. Poor readers encode semantically and good readers encode phonologically (Byrne & Shea, 1979). Semantic encoding can be an appropriate strategy for remembering verbal material where the meaning of words is necessary. Phonological encoding is implicated in the decoding of nonsense words because it is the phonetic features of the verbal material which must be processed and held in working memory.

Normal readers exhibit what is called the phonetic confusability effect because their performance deteriorates considerably when trying to remember a rhyming list of letters (V,B,D..), compared to a non-rhyming list (R,D,S..). Shankweiler et al. (1979), found no phonetic confusability amongst poor readers. Their recall of a rhyming list of letters was almost as good as their recall of non-rhyming letters. These differences between good and poor readers were maintained whether input was auditory or visual. A similar study which contained spoken sentences and word strings had the same result for good and poor readers. The performance of the good readers did not excel when sentences and word strings contained many rhyming words, they exhibited the phonetic confusability effect to a markedly greater extent than poor readers, (Mann, Liberman & Shankweiler, 1980). When poor readers were tested for memory of non-linguistic material, there was no difference between poor and good readers. However, good readers were significantly better than poor readers for their recall of linguistic material, in this case nonsense syllables

(Liberman, Mann, Shankweiler & Werfelman 1982).

The results of this study replicate the finding of Shankweiler et al., (1979), in that, through whatever mode (auditory or visual) verbal material is processed, phonological deficiencies are observed. This implies a generalized language problem related to phonological processing that goes beyond just reading and which shall be explored further on in the discussion. The results of the present study and those above indicate that poor readers do not appear to make use of phonetic codes appropriately in working memory in contrast to normal readers. DDs do, however, appear to make use of other strategies, such as orthographic images and encoding semantically, processes which have already been described above. In an alphabetically written language such as English, the reader who is able to efficiently use phonological codes in the decoding of unfamiliar words is at an advantage and is making efficient use of the alphabetic system.

By their nature, nonsense words have no entry in the mental lexicon so they must be analyzed grapheme by grapheme, phonetic codes must be retrieved and held in working memory while blending processes are ongoing. The task in this test is approximately equivalent to what most beginning readers experience at the analytical stage or phonological pathway to word pronunciation (Frith, 1985). If there is a deficiency in phonological processing, then an individual will certainly experience difficulty in adding to his/her sight vocabulary at

the rate a normal reader would and quickly fall behind. Experienced readers rely less and less on the phonological pathway as their sight vocabulary grows and words are accessed by the whole word visuel pathway to lexical access (Ehri, 1980). A study done by Olson, Kliegel, Davidson and Davies (1984) demonstrates the hypothesis that older, experienced readers rely less on a phonological process. His subjects ranged in age from seven to sixteen years and included both disabled and normal readers. An interesting result from his study is that the phonetic confusability effect decreased with age for normal readers but increased with age for disabled readers. This implies that dyslexic readers lag behind normal readers in their acquisition and use of phonological codes. It was in comparing sixteen year olds that a difference emerged. Dyslexics showed a larger phonetic effect than normal readers. The possiblity exists that DDs can eventually catch up in this ability. Snowling (1980), in a study which matched dyslexics (aged 9:2 to 15 years) with reading age controls (aged 6:6 to 10:9) found that dyslexics have a specific difficulty with grapholegical-phonological conversion. For dyslexics, an increase in reading age is a result of an increase in size of sight vocabulary with no increase in grapholegical-phonological conversion abilities.

A look at table 6 on page 58a, shows the target nonsense word and some of the attempts by experimental subjects to read the word. Phonological processing difficulties are reflected in the attempts at reading these words. The difficulties encountered

Table 6
Word Attack Test: Sample errors made on nonsense words

Target word	*Response*	*Target word*	*Response*
Nonsense Word Substitutions			
ift	ifet	maft	mafit
nen	ned, nent	tash	tast
plen	plent	ziz	zig, zim
ott	otto	plen	plent
twib	twibble	beb	beeb
rejune	redune, rejane	tob	tobe
hets	hins	lundy	lundery
expram	experam	stabe	stabery
imbaf	imbraf	eam	eram
shenning	slean	fubwit	fubawit, futwit
pertome	proteme	subcrote	surobole, scub
pipped	peript	etbom	etboom
eldop	edop	cigbet	cigpet
Real Word Substitutions			
ift	infant	tash	dash
chen	chin	expram	experiment (2)
sloy	slow, slowly (2)	nen	red
lundy	laundry, landing	stabe	stable
beb	bled		

could implicate one or a combination of the following processes: (1) being able to encode or store phonological material efficiently in long term memory. This skill is tested in paired-associate learning when visual forms are used as stimuli and spoken nonsense words as responses, (2) the retrieval of phonetic codes from long term memory and their association with the graphemes, (3) retention of phonetic codes in the proper sequence in working memory while blending processes are ongoing. This working memory store is sometimes referred to as an articulatory loop because it is speech sounds that are being held in memory (Jorm & Share 1983). A deficiency at any one of these levels could cause problems in decoding the word. A deficiency in retrieval of phonological codes from long term memory appears to be involved because these subjects have trouble with one syllable nonsense words of three letters. They also appear to have a problem with working memory because the order of graphemes is often confused. There was a significant correlation between the Word Attack Test and the Oral Recognition Test. Both of these tests have nonsense words; this lends further support to the hypothesis that the same or a similar skill is most likely required to do both tests. Could it be that the phonological material was not efficiently stored to begin with? This has implications for speech perceptual ability which is explored in the following test.

(4) Auditory Discrimination Test

Both the control group and the experimental group scored equally

well on this test on both types of trials. As stated before this test was included because proper speech perceptual ability is an important precursor to accurately storing these sounds in long term memory and then using them in the development of appropriate phonological/orthographic relationships.

The following tests are more subtle in testing discrimination ability and did detect differences in perceptual auditory ability. Tallal (1980) tested poor readers on an auditory perception test called the Repitition Test. They were firstly taught to push a button in response to a high or low pitched sound which they did successfully. They then were tested on two-sound sequences with long interstimulus intervals which they also did successfully. Their performance deteriorated when they were asked to make decisions on two-sound sequences with a very short interstimulus interval. Their performance on this task was highly correlated with a nonsense-word reading task. Tallal hypothesizes that auditory perceptual deficits of this sort cause children to have difficulties learning symbol-sound relationships required for decoding. She hypothesizes that if they have difficulty perceiving the sound they will have difficulty in storing it in long term memory. Godfrey, Syrdal-Lasky, Millay and Knox (1981) report that the degree of sharpness with which phoneme categories are distinguished from one another was lower in the poor-reader group. These researchers both conclude that the subtle difficulties poor readers have in storing phonological speech sounds may be related to speech perception difficulties. There may be differences in auditory ability between DDs and normal readers

when more finely tuned tests are administered. However, the auditory discrimination test the experimenter used in this study based on the Wepman found no differences in the auditory skills of DDs and normal readers.

(5) Initial Sound Segmentation Test

Both groups reached the ceiling of this test for correct responses. As a test of segmentation ability this test was too simple for this age group of disabled readers. Mean time taken in seconds to complete the test by the control group was 242.4 seconds, the mean time taken by the experimental group was 281.33 seconds. Mean extra time taken by each subject in the experimental group to complete the test was 39 seconds. The experimenter expected time differences between the two groups because of the phonological processes involved in doing the test. The test measures the subject's ability to isolate an initial sound from a word presented auditorily and then select a picture of an object (three pictures to choose from) whose name has the same initial sound. To do the test the subject must first of all isolate the initial sound from the auditorily presented word, hold it in working memory and associate that sound with the same initial sound of another word depicted pictorally. Phonological processing demands in this test were not difficult enough for this group of DDs. The following segmentation tests more rigorously test these phonological processes.

(6) Sound Deletion Test

A test of homogeneity of variance demonstrates the experimental group and the control group to be drawn from different underlying populations and points to the heterogeneous nature of the experimental group when we compare these two groups on the Sound Deletion Test as a whole and on the nonsense word trials. In this test, the experimental group scored considerably less well than the control group on the nonsense word trials. An examination of the processes required to complete the test indicates why the experimental subjects did not fare as well. This test requires the subjects to delete one sound from an auditorily presented word then blend the remaining sounds together. Firstly, it can be argued that the experimental subjects scored better on the real word trials than on the nonsense word trials because the real words were familiar to them. All the real and nonsense words in this test were one syllable words. The subjects in the experimental group were most likely familiar with the real words in print considering their reading level. This fact, together with an explanation of how orthographic images are stored in the mental lexicon will clarify why most experimental subjects experienced more difficulty with the nonsense words. Ehri (1980:156), conceptualizes the mental lexicon as "a store of abstract word units having several different facets or identities." They are related to the word's phonological (relating to the word's acoustic, articulatory and phonemic structure), syntactic (indicating grammatical function) and semantic (which specifies

the word's meaning) identities. The orthographic form is also established in memory with experience in reading. "The term amalgamation refers to the processes by which this orthographic identity merges with the word's other identities to form a single unit in lexical memory" (Ehri 1980:156). When a subject heard a real word, the acoustic signal had the potential to stimulate the word's orthographic image--with corresponding phonological structure, which appears was the case for the experimental subjects, because their performance was considerably better on the real word trials than on the nonsense words trials. By their nature the nonsense words have no lexical entry in the mental lexicon. For the nonsense word trials the subjects had to process the auditory stimulus, do implicit segmentation, retrieve these sound units from long term memory, perform the deletion and synthesize the remaining sounds while being held in working memory. These are the very processes that DDs are hypothesized to be deficient in. A look at some of the experimental group errors reveals the difficulty they had with one or a combination of the above phonological processes. These are shown in Table 7 on page 63a.

There was a correlation between the experimental groups's performance on the real word trials and the nonsense word trials. As the task difficulty increased with the nonsense words, it could be predicted which experimental subject's performance would decline. This shows that a similar skill is most likely being used to perform both parts of this test whether it involves real or nonsense words. As the task demands

Table 7
Sound Deletion Test: Sample of errors made by experimental group.

The word with the underlined letter indicates the word orally presented to the subjects. The underlined lettter was the letter to be deleted by the subject.

Word presented	*Response*
plate	pate, ate
went	we (2)
scream	eam
noral	nor, oral
misk	mit
slip	sit
lant	at, sat
gathod	gasho
zalp	zel, zilp, zapad
snat	amp

more from that particular skill, the performance decreases. Because the nonsense words do not have an orthographic image, there is more demand placed on both retrieval mechanisms for phonological codes and maintenance of phonological codes in working memory as segmentation and blending processes are being carried out.

Another correlation was found between the nonsense word trials of the Sound Deletion Test (auditory presentation) and the Oral Recognition Test (visual presentation) for the experimental subjects. This again implies the same or similar skill is likely to be required to do both tests and strengthens the hypothesis that whatever mode verbal material is presented through, verbal or auditory, a certain type of DD shows the same deficiencies (Shankweiler et al., 1979). An experimental subject who performed poorly on one test could be predicted to perform poorly on the other. The correlation most likely has to do with how nonsense words are processed. By their nature nonsense words have no entry in the mental lexicon. As a result, in both subtests implicit segmentation, retrieval of phonological units, and retention of these units in working memory in order to synthesize the units were required processes in order to carry out the task. Therefore any one process or a combination of them are implicated in these subtests.

The Sound Deletion Test and the Ubby Dubby Test, both of which are segmentation tests, were also found to be correlated. The words used in the Ubby Dubby Test were all real, single syllable

(except for one with two syllables) words most likely previously encountered in print by the experimental subjects. The aid of orthographic images may have put less of a strain on phonological retrieval mechanisms. The processes more strongly implicated would be the following: (1) implicit segmentation (2) retention of phonological units in working memory while synthesis of the units is ongoing.

(7) Ubby Dubby Test

There was again a wide range of peformances on this test by the experimental group and confirmed by a test of homogeneity of variance. Table 3 on page 41b, demonstrates these scores. In the Ubby Dubby Test, two sound segments (ab) had to be added after the initial sound of each word in this test. There were ten words in this test all consisting of real words. I would argue that the same skills are required to do this test which would be required to complete the Sound Deletion Test. Retrieval of phonological codes would be less implicated because all the words in this test were real words which had been most likely encountered in print by the subjects and which most likely had an orthographic image.

A thorough analysis of the processes involved in the segmentation tests has lead me to rethink the significance of these tests and try to infer the phonological processes involved which now have taken precedence. Rather than labelling these tests "tests of segmentation ability", they should rather be

labelled "tests of phonological ability" which involve segmentation and blending. In both the Sound Deletion Test and the Ubby Dubby Test due to the nature of the task, phonological processes are strongly implicated. They are: (1) the retrieval of phonological codes from long term memory (2) maintaining phonological codes in working memory so blending or synthesizing processes can be carried out.

(8) Test of Phonological Memory

The two groups are distinct on this test as the confidence intervals do not intersect. A t-test between the two independent means yields $t(14) = 2.46$, $p < .05$. On the real word trials the experimental group scored almost as well as the controls. The factor that contributed most to the two groups being distinct were the scores of the experimental group on the nonsense word trials. Their performance deteriorated considerably with their misrepetitions of the nonsense words of four syllables. Here, the confidence intervals for the four syllable nonsense trials do not intersect. A t - test between two independent means confirms this, with $t(14) = 2.43$, $p < .05$. The results of the nonsense word trials of four syllables on this test replicates that of Snowling (1981), on whose test this one was based. "Dyslexic readers made more misrepetitions of nonsense words with four syllables than normals - $F(1,144) = 6.5$, $p < .05$" (Snowling, 1981:226). The experimental subjects scored as well as the controls on the real word trials of two and three

syllables and almost as well on the real word trials of four syllables which indicates their familiarity with these words made the task easy enough for them. The differences between the two groups showed up with the misrepetitions of nonsense words and particularly with the misrepetitions of nonsense words of four syllables. A look at the phonological processes implicated in repeating the more complex nonsense words will explain why the experimental subjects experienced difficulty with them. Firstly, there is no lexical entry for these words so reference to the internal lexicon would not be an aid to their pronunciation. This task would be equivalent to learning a new, real, complex word since it is plausibly constructed using the rules of English. In order to repeat these words successfully, subjects would have to process the auditory stimulus, segment the word into phonological units (retrieve phonological units from long term memory), hold the sound segments in working memory and synthesize or reblend the units as instructions for a speech-motor program. Articulation problems as such do not appear to be a problem, but it is the phonological processes that precede the output that appears to be deficient.

Snowling, Goulandris, Bowlby and Howell (1986), results complement the results of the above study. In the experiment, they tested dyslexic children and compared them with normal readers of the same age and reading age matched control. The stimuli were high frequency words, low frequency words and non-words, all of one syllable. One third of the stimuli were presented in each of three noise conditions--high noise, low

noise and no noise. Subjects had to repeat the words, all subjects' performance deteriorated with increase of noise, the dyslexics did not differ from the controls in this respect. This finding appears to confirm that it is not at the level of auditory input of verbal material that the problem exists, but afterwards with the implied phonological processes. All subjects were at ceiling with high frequency items in all noise conditions. Differences showed up between groups for low frequency items and nonsense words. Dyslexics made more errors on low frequency items than age-matched controls who were normal readers and a similar number of errors to reading age matched controls. Dyslexics made significantly more mistakes than age matched controls and reading age matched controls on the nonsense word trials. Both studies support the claim that when DDs are forced to use a non-lexical access route their performance deteriorates. The non-lexical access route implies segmentation, the retrieval of phonological codes for the units and the synthesis process in working memory. "A direct consequence of this processing deficit would be to slow the acquisition of new words into the spoken vocabulary" (Snowling, 1987:34). See also Done & Miles (1978) for a related hypothesis on late acquisition of vocabulary by dyslexics. The source of the problem related to reading likely shares some of the same phonological processes related to the auditory processing and repeating of speech because both are related to the same phonological processes. A deficiency in these areas might also explain why DDs have been hypothesized to have problems with other speech-related activities: (1) delayed speech acquisition,

(2) poor sound categorisation skills such as rhyming and alliteration, (3) phonological inaccuracies in paired associate learning with nonsense words, (4) slowness in picture naming, (5) slowness in name-code as opposed to physical-code matching, (6) poor speech acoustic-cue discrimination abilities, (Frith 1985).

(9) Lexical Decision Test

This timed test measures the ability of the subject to decide if a string of letters is a real word or not. Vocalization of the words was not required, only a "yes" if the word was a real one or a "no" if it was not. It is suggested that this test measures lexical retrieval and encoding ability. The fact that the two groups scored about the same on the test indicates it was too easy for this group of disabled readers. A significant result of this test was that in spite of both groups scoring approximately the same, some individuals in the experimental group took much longer to complete the test, and on average, the experimental group subject took 38 seconds longer to do the test. Times are shown in Table 4 on page 44b. A positive result in a test of homogeneity confirms the heterogeneous nature of the experimental group in relation to the time scores. The extra time it took most experimental subjects to complete the test indicates the ineffecient use of processes involved in this test. The experimenter noticed that decisions about non-pronounceable nonsense words (eg., lmbt) were quickly made. These experimental subjects knew enough about the structure of

English words to make rapid judgements on these kinds of words. The real words were well within their sight vocabulary even for this group of disabled readers. A look at the experimental group's reading results for the real words on the Oral Recognition Test lends support for this. The words on that test and on the Lexical Decision Test were equivalent in difficulty and they scored almost perfectly on the words on the Oral Recognition Test. Because of their familiarity with these words, the printed word could be quite quickly matched to the entry in their mental lexicons. The increased time taken by the experimental group can quite accurately be attributed to their decisions about the nonsense words. It has already been established that DDs are particularly deficient at reading (and repeating) nonsense words which requires the retrieval of phonological codes. The experimenter did notice sub-vocalization of the nonsense words by most subjects but particularly by those in the experimental group. One experimental subject said that she "had to say them in her head" before responding yes or no. This is a familiar process called "phonological recoding in lexical access"; it is an analytical process by which the graphemes are associated with their corresponding phonetic codes to obtain a pronunciation. This skill appears to be significantly deficient in a certain sub-group of disabled readers.

Olson, Kliegel, Davidson and Foltz (1985), examined lexical access and phonological skill. This test was presented to both disabled and normal readers. The subjects viewed two

pronounceable letter strings side by side on a television monitor (eg. caik-dake). The subject then had to push a button to the left or right to indicate the pseudohomophone letter string that sounded like a real word. The correct pseudohomophones with a lexical entry were taken from grade 2 level readers. The two groups were reading-matched, his older group of disabled readers (mean age = 15.4 years) was matched with his younger group of normal readers (mean age = 10.2 years). On the test, the older, disabled readers made 30.1% errors on the test, the young normal readers performed at a 17.8% error rate. On another test, Olson et al., (1985), compared the two groups' skill on an orthographic task. The objective was to judge, which word, when the subject was presented with a real word and a pseudohomophone (eg., rain-rane), matched his/her entry in the mental lexicon. On this test, the older disabled readers made 12.4% errors, the young normal readers performed at a 12.9% error rate. The two groups scored about the same on the orthographic test, indicating that the orthographic skills of the older, disabled readers are at least as good as those of their younger reading matched controls. This study like many others supports the hypothesis that the phonological skills of disabled readers lag considerably behind those of normal readers.

(10) Oral Recognition Test

The 10 real words were read with the same accuracy by both groups. The 10 nonsense words were read less accurately by the

experimental group even though they were not of complex structure and contained a maximum of two syllables. A positive finding for a test of homogeneity of variance indicates the experimental group to be a heterogeneous population in relation to the nonsense word part of this test. This test had a positive correlation with the Word Attack Test, a test which also has nonsense words and which also had a positive result for the test of homogeneity of variance. The experimental group is not a homogeneous population, a finding that replicates that of many researchers who investigate DD. Within this group, there are at least two sub-types of DDs. They are all experiencing difficulty with acquiring the reading skill, but the source of their difficulties appears to be different. Another possibility is that those subjects in the experimental group who have better phonological skills are overcoming a phonological deficit at a faster rate.

Time differences between the two groups for completing this test were significantly different. It took the experimental group almost twice as long to complete the test. There was a significant enough range of times within the experimental group to give a positive result for a test of homogeneity of variance. Since the experimental group scored almost perfectly on the real word trials (because these words were within their sight vocabulary) it can be hypothesized that the extra time it took most subjects to complete the test was expended on the nonsense word trials. By their nature, nonsense words have no entry in the mental lexicon. Phonological codes must be retrieved and

matched up with individual graphemes in order for the word to be read. As with the Word Attack Test, working memory and blending processes are also implicated. It appears to be these phonological processes that are deficient with a certain sub-group of deficient readers.

There was a negative correlation for the experimental subjects between the nonsense word trials and the real word trials on this test. The explanation for this result is simple. The real words in this test were well within the experimental group's sight vocabulary. Because of this, they did well on this part of the test. It could not be predicted from this part of the test how they would do on the nonsense word trials and vice versa. It can be hypothesized that different skills were used for each part of the test. Nonsense words imply grapheme by grapheme analysis and the retrieval of phonological codes and the subsequent processes required to blend the phonetic units. Words within one's sight vocabulary are read wholistically or orthographically.

There was a positive correlation on this test for the experimental subjects between the time taken to do the test and total number of errors made on the test. The more time they took to do the test, the more errors they made. This indicates that a skill required to complete the test successfully was lacking in the experimental subjects. Because it can be argued quite accurately that more time was spent on the nonsense word trials of this test it appears it is the phonological processes

required to read these words that is deficient in a particular sub-group of DDs.

Overview

The DDs in this study are not a homogeneous population of disabled readers. Four subjects of the experimental group performed fairly consistently as a group and appear to have similar deficiencies. These same four subjects did poorly in the subtests that taxed the phonological processes hypothesized to be deficient in a certain subgroup of DDs. This is supported by the positive correlations between subtests. It appears these subjects are having difficulty proceeding beyond the logographic stage of reading (Frith 1985). This type of DD fits the description of "dysphonetic dyslexic", Boder (1973); Boder & Jarrico (1983). This group of DDs comprises the largest sub-group and are characterized by difficulties establishing graphological-phonological or letter-sound correspondences. They tend to rely on "whole word" reading or the use of a "sight vocabulary". This group of DDs contrast with another group labelled "dyseidetic dyslexics" who are characterized by their relative skill in letter-sound correspondences but have difficulties with recognizing whole words automatically.

The remaining two subjects of the experimental group scored in the normal range on many subtests and almost as well as the controls in many cases. These subjects do not appear to have the same profile of deficiencies as the other four subjects

described above. Specifically, they do not show deficiencies in phonological-graphological conversion skills which entail retrieval of phonological codes from long term memory and maintenance of these codes in working memory while blending is ongoing. Their scores on the nonsense word trials in several of the subtests especially lends support for this hypothesis. The possibility may exist that they were "developmentally delayed" (Snowling 1987), but were catching up in deficient phonological processses at a more rapid rate than the other experimental subjects, due perhaps to a lag in the maturation of the left hemisphere (Satz & van Nostrand 1973). These children might not have been ready to read at the time the present educational system starts reading instruction. However, their phonological difficulties were not as severe as the other group of DDs. It may also be that the source of their deficiencies is different and may be associated with Boder & Jarrico's (1983) description of a "dyseidetic" or mixed "dysphonetic-dyseidetic" dyslexic. Experimental subjects in the present study although exhibiting different profiles can be hypothesized as having a "verbal processing" deficit (Vellutino 1979). This verbal deficit is demonstrated in results of testing utilizing the Wechsler Intelligence Scale for children (WISC). This test is divided into a Verbal IQ and a Performance IQ. DDs consistently score lower on the verbal part of the WISC (Doehring et al., 1981; Vellutino,1979).

The phonological processes which appear to be deficient in the larger subgroup of DDs are: (1) the storage or encoding of

phonological material (2) retrieval of phonological codes from long term memory (3) the ability to maintain phonological codes in working memory, so blending or synthesizing can be carried out. Processes one and two are interrelated because the problem that these DDs may have in retrieving codes may have to do with the fact that the codes were not efficiently stored to begin with (Jorm & Share 1983). This may be related to subtle speech perception difficulties (Godfry et al., 1981; Tallal,1980).

Two processes, that implicate working memory and verbal processing, have been found to be deficient in disabled readers. The first one is a rehearsal strategy used in working memory prior to storage of verbal material in long term memory (Bauer & Emhert 1984). The second process involves retrieving phonological codes from long term storage. The faster phonological codes can be activated from long term memory, the better the working memory capacity. Studies have shown that dyslexics have a deficiency in retrieving phonological codes from long term memory (Spring & Capps 1976; Bauer & Emhert 1984). The speed with which phonological codes can be retrieved from long term memory "influences the efficiency of working memory, or to be more specific, the functional capacity of the buffer within the working memory system which holds information in a phonologically coded form" (Jorm & Share 1983:129). Poor readers are less able to adopt speech-based strategies to the task of reading as exemplified in their deficient use of phonetic codes in working memory tasks (Shankweiler et al., 1979; Byrne & Shea 1979). Consequently, poorer readers rely on

context more, because word recognition associated with the above phonological processes are deficient (Stanovich 1980, 1982; Perfetti 1980). The slow retrieval of codes into working memory will also leave less capacity for working memory to devote to comprehension. Thus, fast, efficient retrieval of phonological codes plays an important part in the area of phonological processing related to reading. In normal readers, working memory can be used to a far greater extent to facilitate reading, because phonological codes rather than visual material can be held longer in short term memory (Baddeley 1976). Phonological codes have been hypothesized to have certain roles in reading comprehension: they are utilized by adults in working memory for comprehending relations expressed in a story (Slowiaczek & Clifton 1980), and they are used by children to integrate concepts across sentences (Swanson 1984).

Using phonological codes in working memory serves as an important process for the beginning reader who comes to this skill with experience in oral language, and therefore, commences reading with a reliance on phonological codes (Reitsma 1984). Phonological recoding serves as a self-teaching mechanism (Jorm & Share 1983), whereby unfamiliar words can be sounded out, recognized and added to the beginning reader's mental lexicon, and eventually be accessed directly through visual representations (Doctor & Coltheart 1980). The inability to efficiently use these phonological processes--retrieving phonological codes from long term memory and using phonological codes in working memory to blend sounds--will slow down the

acquisition of the reading skill and the acquisition of a sight vocabulary. Phonological recoding is a process used by both beginning readers and skilled readers for identifying unfamiliar words.

The phonological processes related to segmentation and blending abilities imply the efficient storage and retrieval of phonological codes and the efficient use of working memory necessary to process verbal material. These are the phonological skills hypothesized to be deficient in DDs. Wagner & Torgesen (1987), have reached similar conclusions related to the deficient phonological processes in DDs. They based their conclusions on many of the same longitudinal correlational and longitudinal training studies which were reported in the introduction.

A closer look at some of the training studies will demonstrate the phonological processes being trained. Bradley and Bryant (1985), performed an extensive training study. They taught phonological skills to 65 children (mean age 6 years 1 month) who had poor sound categorization skills. Training was on an individual basis, once a week for two years. The children were divided into four groups with different groups getting different forms of training in sound categorization or letter-sound training. The first group received training on activities to teach categorization of words based on sound. This included placing words together that rhyme or placing words together that share the same initial, medial or final sound. The second group

received the same training as the first group, but they used plastic letters for concrete demonstration of shared sounds amongst words. The third group used the same words as the two other groups, but they were trained to categorize words based on conceptual category rather than based on sound categories. There was a fourth group control group which received no training. Reading and spelling tests were used after training to test for effect of training. The best performance was by the sound-letter group which used plastic letters to reinforce training, thus supporting evidence for training that involves concrete material and explicit connection with the alphabet. The combination of their longitudinal correlational study (which measured the children's sound categorization skills before and after they learned to read) and their training study (1985), support a causal link between early phonological skills related to sound categorization and later reading acheivement. Fox and Routh (1984), found 31 kindergartens who were not able to segment before they participated in a training study. One group was trained to segment words, another group was trained to segment and blend words. A third group was given no training. After training, the groups were compared on a reading test, the Roswell-Chall blending test and a segmenting test, they found that the group trained to segment only performed no differently than the control group. The group trained to segment and blend performed better on all the above tests. It is not known if the results are an interaction of segmenting/blending training, or if the result was mainly due to blending training, as there was not a blending only trained group used in the study. These

training studies trained phonological skills which did not exist before training and had subsequent correlations with reading ability, they support a causal role between trained phonological processes and reading. (There is always the possibility that there is another unidentified factor underlying the above phonological processes which has a causal role). Rosner (1975) found that beginning readers given segmental awareness training became better readers than those who received none. A close look at the phonological processes involved in the training studies reveals quite clearly what is being trained. These include the phonological processes of training the efficient storage or encoding of phonological material in long memory, practise with the retrieval of phonological codes and their storage in working memory. This is done with the repetition of sounds, their explicit association with the alphabet and with the many-faceted manipulation of words which share sounds.

Other studies which support a causal role between phonological skills and reading ability are: Lundberg, Olofsson & Wall (1980) as cited in Wagner & Torgeson (1987); Torneus (1984). The study by Torneus (1984) extends that of Lundberg et al.'s by utilizing the research design—the powerful linear structural relationship (LISREL) analysis capable of identifying those factors most relevant in a causal relationship. Torneus found the phonological abilities most necessary for learning to read were sound segmentation and sound blending (Torneus 1984). Olofsson and Lundberg (1985), found that phonological training "contributes to the long-term development of accurate concepts

of reading in the preschool child and to the cognitive clarity of formal reading instruction in school" cited in Leong (1987:191). The ability to segment and blend implicates the efficient use of working memory. Before blending processes can be initiated phonological codes must be retrieved from long term memory, a long term memory with efficiently stored phonological codes. I propose for a certain subgroup of DDs that a deficiency at any one level or at a combination of these levels could disrupt the reading process where sound-letter conversion processes are implicated.

Conclusion

The largest group of DDs in the present study appear to be disabled in one or a combination of phonological processing deficiencies. These deficiencies are language based and may be related to subtle speech perceptual difficulties. Proper perceptual ability is necessary in order to properly store these sounds in long term memory. This is also a precursor to effectively retrieving codes from long term memory. The Auditory Discrimination Test found no differences in auditory discrimination ability between the control group and the experimental group. More finely tuned tests did-- Tallal (1980) and Godfrey et al.(1981) Further research in this area may find more conclusive evidence linking speech perceptual ability and DD.

A significant finding in the present research is related to the extra time it took most experimental subjects to complete many of the subtests. For example, it took significantly longer for an experimental subject to read a nonsense word in the Word Attack Test compared to the time it took a control subject. This test particularly, demonstrates the phonological processes necessary for fluent reading. By their nature nonsense words have no entry in the mental lexicon, therefore they must be analyzed grapheme by grapheme. The phonological processes that are tested in this subtest are: (1) retrieval of phonological

codes from long term memory and their association with graphemes (2) the retention of phonological codes in the proper sequence in working memory while blending processes are ongoing. Most experimental subjects not only took considerably longer to process the nonsense words they did so significantly more inaccurately compared to the control group pointing to phonological processsing deficiencies in the above proccesses. Another result of this study indicates that DDs, in order to make up for deficient phonological processing used alternative strategies. These include trying to read a nonsense word by encoding semantically or using the general configuration of the word--its orthographic shape to decode
the nonsense word rather than analyzing it grapheme by grapheme. Using the word's overall shape to read a word was also observed in the Word Identification Test where the words to be read were all real words. For example two subjects of the experimental group read "confront" for "comfort". Again a weakness in analytical skill was being over-compensated for by a strategy they had within their capabilities--reading "wholistically". A weakness in the analytical strategy of letter-sound correspondence, with a preservation in the skill of reading wholistically is what defines Boder and Jarrico's (1982), "dysphonetic" disabled reader. There was a positive correlation between the Word Attack Test and the Oral Recognition Test, both tests contained nonsense words.

The results of this study indicate that through whatever mode (auditory or visual) verbal material is presented phonological

deficiencies are observed. This replicates Shankweiler et al.'s (1979) finding. This finding is confirmed by a positive correlation between the nonsense word trials of the Sound Deletion Test (an auditory test) and the nonsense word trials of the Oral Recognition Test (a visual reading test). Although these two tests are processed through two different channels—the auditory and the visual, the same phonological processes are required to complete the test. These are: (1) retrieval of phonological codes from long term memory (2) retention of codes in working memory while blending is ongoing. Most experimental subjects did poorly on the Test of Phonological Memory which involved the repetition of four syllable nonsense words presented auditorily. This test may be tapping a weakness in speech perceptual ability, a deficiency in this area would be to slow down the acquisition of vocabulary in DDs. Delayed speech acquisition has been found in DDs, Rutter & Yule (1975); Done & Miles (1978).

Many longitudinal correlational and longitudinal training studies reported in the introduction support a causal role for phonological processes related to later reading acheivement. An examination of the phonological processes involved in these studies and in reading programs which involve DDs involve the following phonological processes: (1) the efficient encoding or storing of phonological codes (2) practise in the retrieval of phonological codes from long term memory (3) practise in the retention of phonological codes in working memory while blending is ongoing. A deficiency at any one level or at a combination of

levels could disrupt the acquisition of the reading process. Proper speech perceptual ability, on which these processes are built is an important prerequisite for these processes to be effectively carried out.

Because of the relatively small sample size of the present study the results on their own would not be predictive. However, taken together with the results of the other longitudinal correlational studies, longitudinal training studies and teaching methodologies, a stronger statement can be made. This involves the necessity of bringing to the focal point, to that sub-group of DDs experiencing problems with sound-letter association, practise with those phonological skills related to the association of graphemes and their sounds: (1) encoding in long term memory (2) retrieval of phonological codes and (3) segmenting and blending exercises which involve working memory.

(1) Woodcock Letter Identification Test

(1)_____X
(2)_____B
(3)_____S
(4)_____I
(5)_____C
(6)_____Z
(7)_____K
(8)_____M
(9)_____T
(10)_____P
(11)_____U
(12)_____R
(13)_____G
(14)_____Y
(15)_____L
(16)_____N
(17)_____A
(18)_____J
(19)_____H
(20)_____R
(21)_____W
(22)_____V
(23)_____G
(24)_____T
(25)_____N
(26)_____A
(27)_____M
(28)_____D
(29)_____W
(30)_____E
(31)_____A
(32)_____Q
(33)_____K
(34)_____Y
(35)_____L
(36)_____N
(37)_____P
(38)_____S
(39)_____V
(40)_____R
(41)_____X
(42)_____J
(43)_____I
(44)_____Z
(45)_____Q

Time_____

(2) Woodcock Word Identification Test

(1)_____is
(2)_____come
(3)_____the
(4)_____look
(5)_____up
(6)_____big
(7)_____down
(8)_____that
(9)_____she
(10)_____on
(11)_____my
(12)_____jump
(13)_____something
(14)_____at
(15)_____book
(16)_____him
(17)_____of
(18)_____work
(19)_____what
(20)_____rabbit
(21)_____out
(22)_____was
(23)_____man
(24)_____be
(25)_____as
(26)_____fly
(27)_____away
(28)_____cake
(29)_____water
(30)_____sheep
(31)_____mitten
(32)_____duck
(33)_____name
(34)_____sit
(35)_____bear
(36)_____farm
(37)_____night
(38)_____could
(39)_____food
(40)_____high
(41)_____walk
(42)_____told
(43)_____street
(44)_____much
(45)_____still
(46)_____pony
(47)_____love
(48)_____morning
(49)_____ship
(50)_____surprise
(51)_____wife
(52)_____most
(53)_____better
(54)_____city
(55)_____always

(2) Woodcock Word Identification Test con't

(56)_____found
(57)_____learn
(58 _____once
(59)_____front
(60)_____meaning
(61)_____listen
(62)_____paper
(63)_____until
(64)_____peace
(65)_____remember
(66)_____strange
(67)_____angry
(68)_____while
(69)_____watch
(70)_____leap
(71)_____quick
(72)_____crash
(73)_____body
(74)_____piece
(75)_____public
(76)_____brought
(77)_____busy
(78)_____surface
(79)_____groan
(80)_____gravy
(81)_____comfort
(82)_____engine
(83)_____soapy
(84)_____human
(85)_____design
(86)_____crime
(87)_____warning
(88)_____zigzag
(89)_____twilight
(90)_____produce
(91)_____smolder
(92)_____professional
(93)_____delayed
(94)_____inventor
(95)_____amazement
(96)_____drawl
(97)_____broadcast
(98)_____departure
(99)_____gruffly
(100)_____giggle
(101)_____vehicle
(102)_____cauliflower
(103)_____lagoon
(104)_____rudely
(105)_____valid
(106)_____relapse
(107)_____jeopardize
(108)_____excusable
(109)_____urgent
(110)_____sociable
(111)_____zenith

(2) Woodcock Word Identification Test cont'd

(112)_____balmy

(113)_____penetration

(114)_____dignify

(115)_____occasionally

(116)_____frigid

(117)_____clerical

(118)_____radioactivity

(119)_____skeletal

(120)_____recurrence

Time_____

(3) Woodcock Word Attack Test

Sample item: "tat".

(1)_____ift

(2)_____bim

(3)_____ut

(4)_____rayed

(5)_____kak

(6)_____maft

(7)_____nen

(8)_____ab

(9)_____tash

(10)_____wip's

(11)_____ziz

(12)_____ott

(13)_____nudd

(14)_____weet

(15)_____plen

(16)_____twib

(17)_____beb

(18)_____rejune

(19)_____knap

(20)_____ain

(21)_____tob

(22)_____chen

(23)_____hets

(24)_____plon

(25)_____lundy

(26)_____hode

(27)_____expram

(28)_____stabe

(29)_____imbaf

(30)_____eam

(31)_____telequik

(32)_____shenning

(33)_____quib

(34)_____laip

(35)_____fubwit

(36)_____pertome

(37)_____sloy

(38)_____subcrote

(39)_____pipped

(40)_____etbom

(41)_____polybendable

(42)_____dinlan

(43)_____eldop

(44)_____wubfambif

(45)_____wotfob

(46)_____cigbet

(47)_____conration

(48)_____biftel

(49)_____bafmotbem

(50)_____nolhod

Time_____

(4) Auditory Discrimination test

Samples:		Different	Same		Different	Same
	(1) man - man			(3) tea - tea		
	(2) hat - pat			(4) sack - sat		

Test Items	Different	Same		Different	Same
(1) tub - tug			(26) par - par		
(2) rake - lake			(27) symbol - thimble		
(3) lack - lack			(28) boss - boss		
(4) web - wed			(29) moon - noon		
(5) chap - chap			(30) sip - zip		
(6) pin - tin			(31) soon - soon		
(7) leg - led			(32) base - vase		
(8) din - bin			(33) breeze - breathe		
(9) zest - zest			(34) pole - pole		
(10) cut - cat			(35) thin - fin		
(11) pack- pat			(36) tag - tack		
(12) face - vase			(37) soul - soul		
(13) cap - cap			(38) din - din		
(14) king - kihg			(39) chip - gyp		
(15) vow - thou			(40) bum - bomb		
(16) cat - cap			(41) sip - sip		
(17) gum - dumb			(42) lease - leash		
(18) jam - jam			(43) pig - big		
(19) coast - toast			(44) skill - skill		
(20) clothe - clove			(45) shack - sack		
(21) wretch - wretch			(46) sheath - sheaf		
(22) bass - bath			(47) cab - cap		
(23) dim - din			(48) bat - bad		
(24) wake - lake			(49) shake - shape		
(25) run - rung			(50) spill - spill		

(4) Auditory Discrimination Test cont'

Test Items cont'd	Different	Same
(51) shoal - shawl		
(52) bet - bed		
(53) pat - pet		
(54) tall - tall		
(55) cab - cab		
(56) ring - wing		
(57) those - doze		
(58) pen - pin		
(59) see - see		
(60) me - bee		
(61) pork - cork		
(62) muff - muss		
(63) bale - gale		
(64) sought - fought		
Total		

(5) Initial Sound Segmentation Test

Samples: (1) lamp_____load

(2) iron_____ice

(3) table____tent

Test Items: (1) drum_____deck

(2) glass_____gather

(3) apple_____amber

(4) pen_____patch

(5) jacket_____jet

(6) bed_____button

(7) violin_____vase

(8) elephant_____entrance

(9) star_____search

(10) igloo_____idiot

(11) zebra_____zipper

(12) candle_____cage

(13) television_____tail

(14) fork_____fight

(15) rabbit_____ridge

(16) hat_____herd

(17) whale_____where

(18) jug_____jewel

(19) umbrella_____under

(20) mitten_____man

(21) ostrich_____olive

(22)lemon_____lawn

(23) dog_____dice

(24) necklace_____novel

(25) yo-yo_____yard

Time_____

(6) Sound Deletion Test

Samples:	(1) nest	net	
	(2) fairy	fair	
	(3) hill	ill	
	(4) plean	pean	
	(5) stabe	sabe	
	(6) lunt	lun	
Test Items:	(1) plate	late	
	(2) card	car	
	(3) stand	sand	
	(4) lost	lot	
	(5) lawn	law	
	(6) cold	old	
	(7) went	wet	
	(8) scream	cream	
	(9) noral	nora	
	(10) misk	mik	
	(11) fepity	epity	
	(12) slip	sip	
	(13) lant	lat	
	(14) gathod	gatho	
	(15) zalp	zap	
	(16) snat	nat	

(7) Ubby Dubby Test

Samples:	(1) nut - nabut	
	(2) sheet - shabeet	
	(3) ring - rabing	
Test Items:	(1) soon - saboon	
	(2) sock - sabock	
	(3) chair - chabair	
	(4) candy - cabandy	
	(5) pen - paben	
	(6) book - babook	
	(7) lamp - labamp	
	(8) store - stabore	
	(9) toy - taboy	
	(10) cup - cabup	

(6) Test of Phonological Memory

Samples:	(1) cluster				
	(2) pecknace				
	(3) anything				
	(4) ponpense				
Test Items:	(1) progress		(16) pérestoke		
	(2) poból̀low		(17) gommést		
	(3) pedestrian		(18) kebéstrian		
	(4) connect		(19) particular		
	(5) telescope		(20) difference		
	(6) brókred		(21) túbshect		
	(7) important		(22) background		
	(8) téwstaber		(23) kippiculty		
	(9) magnificent		(24) pímmerense		
	(10) subject		(25) insómptant		
	(11) sácktrount		(26) experiment		
	(12) pronounce		(27) bagmívisent		
	(13) difficulty		(28) tomorrow		
	(14) karpínular		(29) estéripend		
	(15) newspaper		(30) brómounge		

(9) Lexical Decision Test

Samples:	yes	no
(1) mat		
(2) plip		
(3) vcbl		
(4) chair		

Test Items:	yes	no
(1) crash		
(2) lmbt		
(3) sloy		
(4) quick		
(5) rslt		
(6) city		
(7) nen		
(8) brdg		
(9) ktfl		
(10) high		
(11) paper		
(12) eam		
(13) hode		
(14) stmk		
(15) hets		
(16) walk		
(17) grth		
(18) bgng		
(19) body		
(20) tosh		
(21) quih		
(22) dvlp		
(23) ship		
(24) qkly		

	yes	no
(25) nudd		
(26) trdl		
(27) watch		
(28) plon		
(29) piece		
(30) stahe		

Time_____

(10) Oral Recognition Test

Samples:	(1) smill	
	(2) stay	
	(3) bim	
	(4) water	
Test Items:	(1) most	
	(2) still	
	(3) kag	
	(4) once	
	(5) plen	
	(6) doby	
	(7) street	
	(8) love	
	(9) pony	
	(10) loso	
	(11) maco	
	(12) night	
	(13) knap	
	(14) fubwit	
	(15) farm	
	(16) nussle	
	(17) ship	
	(18) learn	
	(19) neek	
	(20) tove	

Time_____

X B S i C

Z K m T p

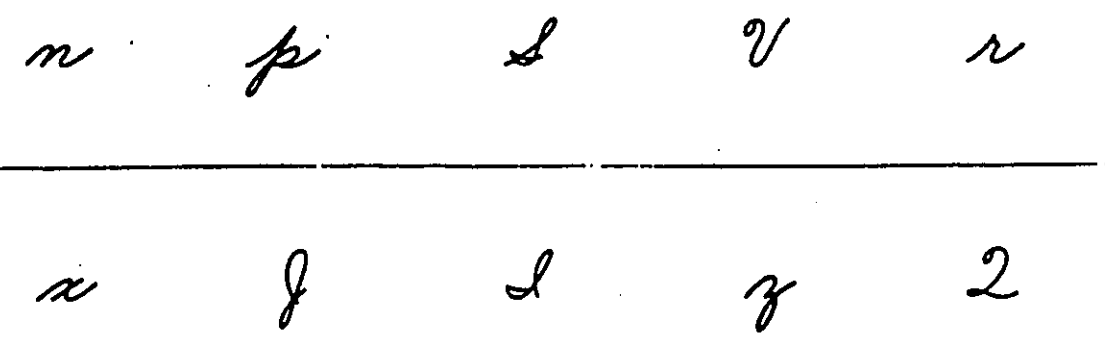
U r G y L

n a j H R

W v g t n

a m d w e

A q k Y L



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