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A study of paired associate learning and sequential memory in dyslexic and non-dyslexic subjects.

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A Study of Paired Associate
Learning and Sequential Memory in
Dyslexic and Non-Dyslexic Subjects

By

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ABSTRACT

The research described in this thesis involved a series of comparisons between dyslexic boys and chronological-age-matched and IQ-matched non-dyslexic boys.

In experiment 1 the subjects were required to recall the serial order of visually presented sequences of items that were either easy or difficult to name. The dyslexic subjects obtained lower scores only when the items were easy to name. In experiment 2 the subjects were required to recall the serial order of digit sequences after a specified time interval with and without articulatory suppression (AS). In the silent condition the serial order recall of non-dyslexic subjects was better than that of the dyslexic subjects but not in the AS condition. In experiments 3a and 3b, respectively, name latency and serial order recall were assessed for digits, letters and pictures. Dyslexic subjects were both slower at naming and poorer at recalling serial order, with there being some intra group correlation between these two measures. In experiment 3c picture name latency correlated with the age of picture name acquisition. In experiment 4 the subjects were required to learn auditorily presented CVC associates for nonsense-shape stimuli in a paired-associate learning (PAL) task and in experiment 5 they were required to learn visually presented nonsense-shape associates. Subjects were also assessed on their pre- and post-learning serial recall for sequences of these shapes. In the PAL tasks dyslexic subjects produced more recall errors in experiment 4, but not in experiment 5. Analyses of the errors in experiment 4 revealed that dyslexic subjects showed a greater tendency to use childlike phonological rules, to recall the wrong associate, and translocated phonemes between associates. The latter two measures correlated with post-learning serial order recall.

A theory of developmental dyslexia was discussed which implicated an impoverished development of the phonetic system.

INDEX

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CHAPTER 1

INTRODUCTION

.1.1 HISTORY OF DEVELOPMENTAL DYSLEXIA

Critchley(1964) reports that the first documented mention of a case of developmental dyslexia was a letter from Pringle Morgan to James Hinshelwood in 1896. The letter contained details of a fourteen year old boy patient who was incapable of learning to read. At this time acquired dyslexia in adults, resulting from brain damage, was a popular field of study and over a number of years it had become a well defined area of research from which the study of developmental dyslexia could grow. Numerous papers had already been published which described cases of acquired dyslexia. Lordat de Montpelier in 1843 reported in detail his own experience of a temporary loss of reading. Broadbent in 1872 reported a case studywhere a lesion in the left angular and supramarginal gyri had caused anomia and alexia without agraphia, although the patient could conerse normally. However Critchley(1964) credits Kussmaul in 1877 as the first person to deliver a conprehensive report of dyslexia, a phenomenon Kussmaul described as "....a complete text-blindness.........although the power of sight , the intellect and the powers of speech are intact ".(Critchley 1964). Soon after this the term "text-blindness" became inadequate since patients had been reported with specific loss of reading without loss of writing and vice versa. However, neurologists took specificity to the extreme in making reference to cases of "pure alexia" which assumed a faculty in the brain that subserved only the skills of reading. Such a notion has little credibility today since dyslexic patients usually manifest other kinds of language disability.

Such were the advances that had been made in the field of acquired dyslexia prior to Pringle Morgan's realization that dyslexia could be a congenital condition. The letter from Pringle Morgan stimulated interest in Hinshelwood who subsequently reported a number of his own case studies of "congenital wordblindness" between 1902 and 1917. By this time, Critchley(1964) reports, there was a shifting of emphasis away from studying anatomical defects in developmental dyslexia towards studying abnormal brain function. In 1925 Orton proposed from his observations of fifteen retarded readers that their condition was due to a failure in developing a normal pattern of cerebral dominance. In Orton's time there was considered to be a direct relationship between dominant hand and the cerebral hemisphere subserving speech and language. The prevalence of ambilaterality in Orton's sample suggested to him a genetically determined failure to develope normal cerebral dominance. He speculated that orthographic information in ambilaterals was laid down in both hemispheres in the form of engrams, the engram stored in the right hemisphere being a mirror image counterpart to that stored in the left hemisphere, such that the apparently frequent reversals in reading and spelling were regarded as resulting from activation of the engram stored in the non-dominant right hemisphere.

By the 1950's interest had developed in the area of backwardness in education as well as in reading retardation such that Burt, Vernon, Schonell and others had found a number of psychological factors that related to reading retardation in general with little mention of,or interest in, a specific reading retardation. However, in the 1960's the study of specific developmental reading and spelling retardation regained popularity essentially through the work of Critchley(1964) , Rabinovitch(1968) and a meeting of the World Federation of Neurologist's Research Group on Dyslexia and World Literacy(1968). Rabinovitch(1968) classified reading retardation into three general categories: 1. A primary retardation in which learning to read is impaired without definite evidence of brain damage from the history of the patient or as revealed by neurological examination. The defect lies in the capacity to deal with letters and words as symbols, appearing to reflect a basically disturbed pattern of neural organization. 2.Reading retardation secondary to brain injury in which the capacity to learn to read is impaired by brain injury manifested by clear-cut neurological deficits. The picture is similar to dyslexia in adults resulting from brain injury and is thought to be due to prenatal toxicity, birth trauma or anoxia , encephalitis or head injury.

3.Reading retardation secondary to environmental factors in which the capacity to learn to read is intact but is given insufficient opportunity to develope to a level commensurate with the child's intelligence.

With respect to Rabinovitch's categorization the first category describes the developmental dyslexic child. Anyone falling in this category would be considered as a developmental dyslexic but anyone falling into one of the other categories would be excluded.

1.1.2 Definition of Developmental Dyslexia

The most commonly referred to definition of developmental dyslexia has been that of the World Federation of Neurologists'(WFN) Research Group on Dyslexia and World Illiteracy (Dallas,Texas 1968). Developmental Dyslexia was defined as "A disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence and socio-economic opportunity. It is dependent upon fundamental cognitive disabilities which are frequently of constitutional origin."

1.1.3 The Inadequacy of the WFN Definition

The WFN definition was an attempt to unify different conceptions of the syndrome of features that constituted a case of developmental dyslexia. However, Eisenberg(1978) and Rutter(1978) criticized the definition on the grounds of imprecision and ambiguity.

Eisenberg(1978) reported a study in which the mean grade level score of sixth grade pupils in an urban state school was 5.0-5.5 , whereas similar pupils from a private school had a mean grade level score of 10.0-10.5. Therefore the problem of carrying out a study of reading retardation in the private sector is that the retarded reader, i.e one who is some two years behind his peers of the same IQ, will have a reading age similar to the national average. There is also the problem of selecting control subjects since the average reader in the school will fall into the above average category on a standard reading test. Conversely subjects drawn from state schools could be wrongly selected as dyslexic on the grounds of reading retardation alone. The studies of Rutter, Graham and Yule(1970), Yule,Rutter,Berger and Thompson(1974),Berger,Yule and Rutter(1975) have also shown a strong relationship between reading retardation and socio-economic status as well as family size, birth order, teacher turn over and area of residence. It is therefore crucial in a study of developmental dyslexia to control for as many possible socio-economic variables as possible. Therefore in the experiments reported in this thesis all subjects have been selected from private schools only and they are all male.

The definition should have specified the socio-economic variables that are of importance instead of the imprecise "adequate.......socio-economic opportunity" specification. There is also a need to elaborate on the term "adequate intelligence" used in the WFN definition. Reading and spelling abilities are strongly correlated with IQ (Yule,Rutter,Berger and Thompson(1974) ; Weinberg, Dieta, Penic, and McAlister(1974)) which is to be expected in view of the fact that IQ is a measure of general cognitive ability which should cover reading and spelling . Therefore a child with an average IQ of 100 or thereabouts is a special case if his performance in reading and spelling is below average. However a child with a below average IQ(i.e. below 85 IQ points) will be expected to have a below average reading and spelling ability too. It has therefore become a matter of convenience to exclude all subjects with below average IQ although few people would suggest that dyslexia does not occur in children with below average IQ'S. In such cases a comparisson should be made with the average performance level for that level of intelligence. The same rule should also apply to children of above average intelligence who would normally have above average reading and spelling ability. If there is a cause of constitutional origin which is inherited then children of above average IQ considered to be dyslexic might show a similar level of reading and spelling as a non-dyslexic child of below average intelligence. Therefore consideration should be given to reading and spelling relative to the level of intelligence before selecting dyslexic and non-dyslexic subjects.

1.1.4 Spelling and Reading Retardation as Criteria.

Follow up studies of dyslexic children have shown that although most dyslexic individuals remain poor spellers the majority improve in reading (Robinson and Smith(1962); Silver and Hagin(1964);Balow and Bloomquist(1965); Rawson(1968); Yule(1973); Herjanic and Penick(1972); Kline and Kline(1975); Shute and Graham(1977)). In the study of Naidoo(1972) a group of spelling retarded without any reading retardation were included along with a group retarded in both spelling and reading. Having administered numerous psychological tests Naidoo reported "Greater similarities than differences are found between boys who exhibit a severe dyslexia and those showing a lesser reading difficulty but whose spelling remains a handicap, suggesting that their disorders are of an essentially similar nature."(p.115). Further, in agreement with the follow up studies previously mentioned, Naidoo reported "Many of the children taught at the centre read tolerably well but their writing and spelling constituted a real educational handicap, and it was inordinately difficult if not impossible to improve their writing and spelling......".

In the experiments to be reported here all dyslexic subjects have been diagnosed as dyslexic by a recognized authority (i.e. an educational psychologist or some recognized centre of assessment). In addition gross spelling retardation was a necessary criterion for inclusion into the dyslexic group, although reading retardation was not a necessary criterion. Normal spelling attainment was a necessary criterion for inclusion in the non-dyslexic control group. In addition an attempt was made to adjust the criterion of spelling retardation according to IQ. By using spelling rather than reading retardation as the necessary criterion children could be included in the dyslexic group if in the past they had had a reading problem but had subsequently overcome their reading retardation. In such cases the improved reading skills cover up an underlying cognitive disability in processing orthographic material which is revealed by their spelling retardation. This procedure has received recent support from Rutter(1978) who commented "Since the very earliest papers on developmental dyslexia, there has been an emphasis on the very strong association between reading difficulties and problems in spelling..... This association has been confirmed in many systematic cross-sectional and longitudinal studies.........However, only relatively recently have researchers investigated the possibility of using spelling errors to subclassify within the dyslexic group.......It may be concluded that it is likely that spelling retardation and reading retardation are usually different facets of the same group of disord~~er~~ers"(p.18,19).

1.1.5 Neuroanatomical and Constitutional Causes of Dyslexia

There is a considerable amount of evidence to suggest a genetic component involved in the inheritance of developmental dyslexia. Benton(1975),Rutter and Yule(1973),and Hallgren(1950) have shown that reading difficulties run in the family. Moreover Hermann(1959) found complete concordance of dyslexia in 12 pairs of monozygotic twins as opposed to only 11 out of 33 pairs of dyzygotic twins, a finding endorsed by Bakwin(1973).

With regard to neuroanatomical studies of developmental dyslexia Hier, Le May, Rosenberg and Perlo(1978) in a study of 24 dyslexic children found that 42% had a larger parietoccipital lobe in the right as opposed to the left hemisphere. This was significantly greater than a 9% incidence in non-dyslexic right handers and a 27% incidence in non-dyslexic left-handers in the normal population. Moreover of the ten subjects with a larger right parietoccipital lobe 4 showed delayed speech compared to only one of the remaining 14 subjects. Such a finding suggests a neurological cause of developmental dyslexia in a region of the brain that is known ,from neurological examination of the acquired dyslexias , to be specifically involved in certain aspects of reading. However in the case of developmental dyslexia the neurological organization that makes normal spelling practically impossible is inherited rather than acquired by insult to the brain, as in acquired dyslexia, and such biological preprogramming is likely to be a permanent feature of these children.

Dennis and Kohn(1975) and Dennis and Whitaker(1976) showed that patients with early left or right hemispherectomy obtained comparable verbal IQ scores. However a more thorough assessment of language skills revealed that patients with only a right hemisphere showed more difficulty in acquiring word relationships and syntax than left hemispherectomized patients. Witleson(1977) in reviewing the evidence of neural plasticity in respect of language processing concluded that plasticity is limited. Thus early damage to some language areas of the brain may never be fully compensated by neural plasticity. One of the limiting factors is probably an innate biological preprogramming of the language areas, demonstrated by the findings of Geschwind and Levitsky(1968) and Witleson and Pallie(1973), who both found from post-mortem studies that in normal brains the left temporal lobe is significantly larger than the right temporal lobe.

If there is a constitutional origin of developmental dyslexia then the neurological defect which causes reading difficulty can be considered as the neurological defect in those subjects who have attained a reasonable level in reading but remain retarded in spelling. It is possible that a shift in reading strategy might allow the dyslexic child to use a different neural system to process visual orthographic information. Alternative reading strategies to phonological decoding have been proposed by Morton(1979),Marcel and Patterson(1976) and LaBerge and Samuels(1974) . Perhaps it is just such a change of strategy which allows the dyslexic child to attain a reasonable level of reading. This idea has been proposed by Seymour(1979)and Brown(1978). However it seems to be the case that there is no obvious alternative spelling strategy available to the dyslexic child which obviates the neurological defect . If there were alternative strategies for spelling then the incidence of improved spelling skills should be much higher. Instead for dyslexic children it is "inordinately if not impossible to improve their writing and spelling......"(Naidoo 1972). If this arguement is true then selecting dyslexic subjects on the grounds of writing and spelling disorders is more efficacious than on the grounds of reading retardation alone ,which selects out a specific subtype of dyslexic child.

1.1.6 Sub-Types of Dyslexia

Eisenberg commented ".....reading failure is the final common expression for more than one and probably multiple underlying causal factors ". Similarly Rutter(1978) reported ".....specific reading retardation is not a homogeneous condition and the question arises as to whether any finer subdivision is possible". If it is the case that there are a variety of developmental dyslexias, as proposed for the acquired dyslexias (Patterson(1981), Coltheart(1980),Marshall and Newcombe(1973), Shallice(1980)) then the attempt to find one root cause of developmental dyslexia must seem obsolete.

In attempts to separate out different sub-types psychological test batteries have been administered to large samples of developmental dyslexic subjects. With the aid of factor or cluster analyses it has been possible to identify subgroups which differ in terms of the cognitive skills that are impaired or unimpaired (Naidoo(1972);Mattis,French and Rapin(1975);Mattis(1978); Denckla (1975); Rutter(1969)).

Naidoo(1972) gave an extensive battery of tests to 98 boys retarded in reading and spelling. However cluster analysis failed to distinguish any subgroups. Instead there appeared to be a continuum with a predominance of boys having a family history of reading and spelling disorders at one end and at the other end boys without a family history but with signs of neurological dysfunction. Despite this failure of the cluster analysis to distinguish separate subgroups Naidoo nevertheless split the 98 subjects into 4 subgroups "....artificially but legitimately". Of those considered as "Genetic Dyslexics" i.e. having a family history , there appeared to be a subgroup characterized by speech and language delays and disorders, and another subgroup characterized by atypical patterns of cerebral laterality. Of the boys classified as "without a family history but with signs of neurological dysfunction" there were also two subgroups. One of these subgroups was characterized by a specific disability in reproducing, from memory, visual patterns with some degree of speech disorder, and the other subgroup had no clear characterization at all. However common to all four subgroups were abnormal difficulties with : 1.Phonic blending i.e.identifying a word from a sequence of phonemes and 2. Digit span and coding in the WISC IQ test.

Mattis, French and Rapin(1975) did successfully identify 3 independent dyslexic syndromes from a sample of 82 children classified as dyslexic. These 3 subgroups accounted for 90% of the cases studied, and are described as follows:

TYPE.1. Language Disorders.

Characterizations: Anomia plus either poor comprehension(i.e. a poor performance on the Token Test), or poor recitation (similar to Conduction Aphasia) or poor speech sound discrimination(i.e. poor at rhyming).

TYPE.2. Articulatory and Graphomotor Dyscoordination

Characterizations: Poor sound blending (i.e. low score on the ITPA sound blending test) and poor graphomotor coordination.

TYPE.3. Visual Perceptual Disorder

Characterizations: Verbal IQ > Performance IQ by more than ten points plus a Raven's Progressive Matrices IQ percentile score lessthan the equivalent derived from the Performance IQ. Also subjects are characterized by a below average visuo-perceptual memory as measured by the Benton Visual Retention Test.

Mattis(1978) in a later study of 293 children referred to a clinic identified 163 dyslexic subjects ranging in age from 8 to 14 years. Mattis(1978) could allocate 78%of these dyslexic children to one or other of his three subgroups in the proportions , 63% as Type.1., 10% as Type.2., and only 5% as Type.3. However unlike Naidoo(1972) who found that visuospatial difficulties were confined to a non-genetic neurological dysfunction group, Mattis(1978) reported that all 3 types of dyslexia were found in "genetical and secondary" dyslexic children.

Denckla(1975) identified 3 subtypes of developmental dyslexia which were very similar to those identified by Mattis et al.(1975). From a battery of tests given to 52 children diagnosed as dyslexic Denckla identified 28 children (54%) with a language disorder and predominant anomia, 6(12%) with articulatory and graphomotor dyscoordination syndrome and 2(4%) with a visuo-perceptual disorder syndrome. Denckla also identified 7 children (13%) who had a dysphonemic sequencing difficulty characterized by poor recall of a sequence of phonemes but with normal naming,comprehension and "speech-sound production". Also there were 5 children (10%) who were identified as having a "verbal memorization (learning) disorder" characterized by normal language skills except for poor sentence repetition and poor verbal pair-associate learning. However Denckla considered that this latter subgroup were probably less severe cases of the language disorder with anomia group, but due to the insensitivity of the test in older children these 7 subjects escaped the classification of anomia. Had Denckla used a test for speed of name retrieval(i.e. the Oldfield and Wingfield test (1965)) then these children might have had long name latencies suggestive of anomia(Oldfield and Wingfield 1965). A similar test should have been given to the 7 children characterized by their dysphonemic sequencing disability who also had a normal score on the naming test. Mattis(1978) recognized that these "dysphonemic children",from Denckla's study were similar to 16(10%) of the children in his own study that did not fall into one of his categories.

In the Doehring and Hoshko(1977) study 31 tests of "rapid reading skills" were given to 34 children with reading problems. These tests included 7 visuo-perceptual tests, 7 auditory-visual integration (i.e cross-modal matching) tests, 9 visuo-verbal translation tests (i.e. reading aloud letter, syllable and word sequencies) and 8 visual scanning tests (e.g underlining targets in a piece of prose). From the factor analysis performed on the response time data 3 groups were distinguished according to their loadings on 4 factors. These 3 groups were:

TYPE.1. Characterized by deficits in oral word and syllable reading reflecting a language disorder at a high linguistic level (i.e. at the level of comprehension).

TYPE.2. Characterized by deficits in cross-modal(i.e.auditory-visual) letter matching tests.

TYPE.3. Characterized by deficits in cross-modal matching of words and syllables, but not letters, reflecting a deficit in the analysis of higher verbal units due to poor phonetic perception and sequencing.

Thus Doehring and Hoshko's Type.1. and Type.3. are groups with primarily linguistic difficulties and Type.2. has an intersensory integration deficit. Intersensory integration deficits had previously been reported by Birch and Belmont(1964) in a specific group of retarded readers and later reported by Blank and Bridger(1966), who replicated the Birch et al. (1964) finding. However Blank et al.(1966) discovered that to do the cross-modal matching task all subjects verbally mediated the intersensory integration i.e.they would describe verbally the sequence presented in one modality and then find the sequence presented in the other modality which fitted the description. In the case of the group of retarded readers , Blank et al.(1966) found that subjects were describing sequences incorrectly and so concluded that all intersensory integration deficits reported in retarded readers were caused by inefficient language skills. Therefore in the Doehring and Hoshko (1977) study it would appear that all three subgroups of dyslexic simply reflect different degrees of linguistic impairment rather than discreet subgroups with qualitatively different impairments.

Of all these attempts to find subtypes of developmental dyslexia Rutter(1978) commented "Numerous investigations have indicated that dyslexic children can be subdivided into 3 groups: those with mainly language,mainly articulation, or mainly visuospatial problems. On the other hand , there has usually seemed to be appreciable overlap between groups and a sizeable proportion of children who do not fall into a definable category." Rutter's comment is endorsed in the summary of Naidoo(1972) where she states that there appeared to be a continuum with , at one end congenital dyslexia, characterized by speech or language disorders or atypical patterns of laterality, and at the other end secondary dyslexia (i.e. due to perinatal difficulties) with neurological dysfunction, difficulty in reproducing visual patterns from memory and, to a lesser extent, speech disorder.

Summary of the Studies on Subtypes of Dyslexia.

All of the reported studies find that the majority of developmental dyslexic children have a general linguistic impairment, apparently at the phonological level leading to problems with name finding, articulation, sound blending, recitation, and rhyming (Mattis et al.1975,Mattis 1978, Denckla 1975, Naidoo 1972). Most of the other attempts to find subgroups have repoted similar findings (Lyle 1971, Bannatyne 1974, Fuller and Friedrich 1975, Ingram 1964, Johnson and Myklebust 1967).

Visuo-perceptual difficulties are often reported to be minority cases (i.e 4% in the Denckla(1975) study and 5% in the Mattis(1978) study) and perhaps these result from brain damage early in life (Naidoo 1972) ,which if known a priori often pre-empts a diagnosis of dyslexia according to some criteria (e.g. Rabinovitch 1968).

Attempts at identifying distinct subgroups of developmental dyslexia have suffered from the problems of either large numbers of subjects who fall between subgroups or sample sizes of between 30-90 subjects which result in subgroups of as few as two subjects. Since individual differences are to be expected, groups containing such low numbers of subjects become rather meaningless. Naidoo(1972) on the other hand found subgroups of dyslexia but at different points on a continuum rather than at different places in a multidimensional space.

Finally sequencing disabilities are found in all the studies mentioned and in a number of different subgroups. To this extent Doehring(1968) concluded that dyslexia resulted from a disturbance of either verbal or visual sequential organization.

1.2.1 Reading and Language.

General Overview

It is commonly held that the reading processes and the processes subserving speech production and perception are often one and the same. Mattingly(1972) commented "Speaking and listening are primary linguistic activities; reading is a secondary and rather special sort of activity that relies critically upon the reader's awareness of these primary activities ". Fries(1962) wrote "Learning to read ......is not a process of learning new or other language signals than those the child has already learned. The language signals are all the same. The difference lies in the medium through which the physical stimuli make contact with his nervous system. In "talk" the physical stimuli of the language signals make their contact by means of sound waves received by the ear. In reading , the physical stimuli of the same language signals consist of graphic shapes that make their contact with his nervous system through light waves received by the eye. The process of learning to read is the process of transfer from the auditory signs for language signals, which the child has already learned, to the new visual signs for the same signals ."

Bloomfield(1955) considered there to be a control processing system which handled speech production and perception as inversely related processes of encoding and decoding respectively. He held the viewpoint that ,in reading, text was converted into units of speech sounds with either audible or "internal substitute movements"(p.103). Bloomfield considered these units of speech sound to be equivalent to phonemes.

More recently the studies have shown that experienced readers need not necessarilly convert graphemes to phonemes in order to comprehend a text. Thus Marshall and Newcombe (1973), Shallice and Warrington (1975),Patterson (1981) and Saffran and Marin (1977) have discovered two types of acquired dyslexia,namely "deep" and "phonological" dyslexias, in which patients are unable to decode print phonetically. In studies of normal adults it has been shown that experienced readers need not phonetically decode words in order to access word meanings directly from print (Hawkins, Reicher, Rogers and Peterson 1976). However visual processing (i.e. direct access to word meanings from print without phonetic decoding) is a sophisticated reading strategy that is learned only after a grapheme to phoneme route has been extensively used (La Berge and Samuels 1974). Similarly Bower(1970) pointed out "Reading can be, and for skilled readers often is, a visual process".

Hence in the case of developmental dyslexia where children are still learning to read, and where the subjects are unskilled readers, alternatives to the grapheme to phoneme route of reading are not likely to be used and are certainly not responsible for the well documented problems dyslexics have with letter naming (Calfee1977, Supramaniam and Audley, 1976) and phoneme recognition (Monroe 1932, Savin 1972). Accordingly pure visual processing of print is unlikely to cause the reading problems in children although it might be possible to teach these children to use a pure visual processing strategy rather than grapheme to phoneme decoding (Brown 1979; Seymour 1978).

1.2.2 Speech Processes and Reading.

There is considerable evidence which suggests that the reader recodes the visual input into an articulatory based "speech" code ,when he finds the text difficult to read.

A number of different techniques have been devised to investigate the involvement of articulation during reading. One such technique makes use of EMG recordings of muscle movements in the articulators (i.e. lips,tongue, larynx etc.). Edfeldt(1960) used needle electrodes implanted in muscle to measure articulatory muscle activity in student subjects reading either semantically difficult or simple passages as well as physically clear or blurred texts. Edfeldt's results indicated that the amount of electrical activity in , and therefore use of , speech musculature increased as texts became either more semantically difficult or more physically blurred.

Locke and Fehr(1970) required subjects to read silently two different groups of words. In group.1. there were no words which contained labial phonemes , whereas in group.2. a large proportion of words did contain labial phonemes. Locke et al. measured movement of the labial muscles during silent reading and found that there was a tendency for more labial muscle movement while reading the words from group.2. This result indicates the use of articulation during reading, and therefore infers the use of an articulatory decoding strategy.

Hardyck, Petrinovich and Ellesworth(1966) took 17 slow reading undergraduates and placed surface electrodes on their carotid cartilage. These electrodes were relayed to an audio-feedback apparatus such that whenever the electrodes picked up muscular movement a white noise was heard by the subjects, who had previously been instructed to perfect reading without the concomitant noise. After a short period of time all 17 subjects were able to read without articulatory movement. In a subsequent study Hardyck and Petrinovich(1970) used 18 students from a remedial English class and assessed the influence of difficulty of comprehension on subvocalization during reading. To test this, 3 conditions were used. In condition.1. subjects had surface electrodes placed on the larynx, chin, lips, and right forearm (the latter as a control measure of general muscle activity) which were not relayed to audio-feedback apparatus. In condition.2. the same arrangements of electrodes were used except the EMG signals were converted to auditory signals and subjects were instructed to suppress the auditory signals. In condition.3. the same set up was used as in the preceding condition.2. except that the forearm electrode was connected to the audio-feedback apparatus, thereby acting as a control condition for condition.2. The results of these experiments demonstrated that laryngeal,chin,and lip EMG'S responded more to text complexity (i.e. difficulty of comprehension) than the forearm EMG. This suggests that the more difficult a subject finds the text the greater the amount of subvocalization. In addition, when subjects suppressed the movement of their laryngeal muscles comprehension of the more difficult passages suffered. However this latter finding did not apply to the suppression of movement of the chin and lip muscles.

Another EMG study was carried out by McGuigan and Rodier(1968) who measured EMG activity at the forearm, chin and tip of the tongue during prose reading under three conditions. Condition.1. involved distractor prose being read to the subject whilst he read silently a different text. Condition.2. was similar to condition.1. except that the distractor prose was read backwards and was accordingly meaningless. Condition.3. was similar to the other two conditions except that white noise replaced the distractor prose. There was also a control condition with no external distraction. In the results their was an increase in the tongue and chin muscle activity during conditions.1. and 2. with respect to the control condition with no external noise. In other words it appeared that if external noise is structured then the silent reader indulges in increased articulation to focus attention on the reading task and minimize interference from the external message.

An alternative technique to EMG in the study of speech processes during reading is articulatory suppression (AS). The theory behind this technique maintains that if the articulators are fully occupied on an unrelated task then they cannot be used during concurrent reading. If articulation is neccessary during reading then performance must suffer. In practice AS involves the recitation of totally redundant verbal or non-verbal material. Murray(1967) and Conrad(1972) asked subjects to say "the" whilst reading a series of letters to be subsequently recalled. In both studies a reduced level of recall resulted from the AS condition than a control condition without AS . Murray reported a 50% reduction due to AS and Conrad(1972) reported a 33% reduction. Baddeley,Thompson and Buchanan(1975) obtained similar results when subjects read a list of words while concurrently performing an AS task. However these three experiments have examined the influence of AS on subsequent memory for names rather than on comprehension . Short term memory for names is known to involve a phonological store and articultory rehearsal (Wickelgren 1965a,b;Ellis 1979;Conrad 1959,1964,1965) which at the same time makes little demand on the comprehension process (Baddeley and Hitch 1974). Thus Pintner(1913) and Reed(1916) asked subjects to silently read a given text whilst counting allowed . Both authors reported that comprehension was unimpaired as a result of this concurrent AS.

There appear to be no studies done on developmental changes in the effect of AS on silent reading. However McGuigan,Keller and Stanton(1964) looked at muscle action potentials (MAP'S) in the chin and lip muscles in 6-11 year old children and in college students during silent reading. They found that MAP'S were significantly greater, indicating increased use of chin and lip muscles, during reading for both groups. McGuigan et al. obtained two baseline MAP levels, before and after reading against which MAP during reading was contrasted. Table.1.1 below shows residual MAP values when the baseline MAP is subtracted from the reading MAP.

	RESIDUAL (reading MAP-pre-reading MAP)	RESIDUAL (reading MAP-post-reading MAP)	CHRON AGE
EXPT.1.	2.5	not available	6-11
EXPT.2.	1.03	0.9	6-11
EXPT.3	0.3	0.3	college students

TABLE.1.1 Adaptation of McGuigan et al's (1964) MAP data.

In Table.1.1 the larger the residual MAP value the greater the increase in MAP during reading. So the difference between MAP during reading and the two baseline conditions is less in the student group than it is for the children. This suggests a reduction in articulation in more skilled readers. However, it is further complicated by the effect of text complexity on articulation (Hardyck et al.1970; Edfeldt 1960) since the adults might have been given a relatively easier text.

A third experimental procedure for assessing speech coding during reading was introduced by Corcorran(1966,1967). In this procedure (Corcoran 1966) subjects were asked to delete the letter "e" whenever it was located in a given text thereby encouraging the subjects to use a visual search strategy during reading. However ,in his sample of 20 naval ratings Corcorran (1966) found that the probability of missing out a silent "e" was significantly greater than missing out a pronounced "e". Thus in a text processing task which encouraged visual processing the acoustic image was scanned as well as the visual input giving a greater chance of detection for pronounced "e's". In a follow-up experiment Corcorran(1967) asked some naval ratings to perform the converse task of detecting omitted "e's" in a prepared text, a task akin to proof reading. From the results it appeared that undetected omissions were significantly more common for silent "e's". In other words the pronounced "e's" again had an advantage over the unpronounced "e's". Healy (1976) adopted Corcorran"s basic technique except that subjects were asked to detect the presence of "t's" in a text. Healy(1976) found that the "t" in "thy" was easier to detect than "t"in "the" which she interpretted as being due to "the" being processed by subjects as a whole unit whereas "thy" is less familiar and is therefore decoded into its component letters. These results of Healy's suggest that subjects can use whole word reading strategies which do not involve the break down of words into letters or phonemes. Such reading strategies have been included in the reading models of Morton(1979) and LaBerge and Samuels(1974).

In summary it appears that speech processes are frequently used in reading ,especially when the text is complex,or when print is unclear or when there is an external source of distraction. With regard to the reading strategies of children it would appear that by using a grapheme to phoneme reading strategy they will be using the speech processes to decode the print. In the case of dyslexic children the text will be difficult to decode and so one would expect that they will tend to adopt a speech based strategy as adults do with difficult texts (McGuigan and Rodier(1968); Hardyck and Petrinovich(1970); Edfeldt(1960)).

A different line of research which was intended to investigate the role of speech , or phonetic coding , in the acquisition of reading has looked at reading performance in deaf children.

1.2.3 Reading in Deaf Children.

The great difficulty deaf children have in learning to read strongly suggests that children must start to read by translating graphemes into phonemes. If it is the case that congenitally deaf children with normal intelligence and without neurological signs are retarded in reading and spelling then there is a strong case against a pure visual processing route (i.e accessing meaning directly from print) available to young children learning to read. If there were an alternative route to the grapheme to phoneme route then the peripherally deaf could learn to read by this alternative route and thereby reduce the incidence of illiteracy in the deaf.

The evidence for reading retardation in congenitally ,or pre-lingual , deaf children is irrefutable. In fact only very occasionally will a congenitally deaf child acquire reading skills. Vestberg Rasmussen(1973) ,referring to Danish children said, "We are forced to admit that we cannot teach deaf children to read." Conrad(1977) carried out an extensive survey on 41 special deaf schools in the UK and reported that according to Furth's(1966) criterion of illiteracy (i.e. reading comprehension age must be greater than ,or equal to, eleven years on leaving school) 75% of deaf schoolleavers with average intelligence were functionally illiterate and only 4% of all pre-lingually deafened children reached the criterion of "ability to understand complex subject matter". In concluding his study of these 15.5-16 year old deaf children Conrad commented on the limitations in their reading ability, "On the basis of a median reading age (for comprehension) about 9 years may , in fact , represent a theoretical limit." These findings of Conrad(1977) are difficult to dismiss on the grounds of a complex grapheme-phoneme correspondence in English, since Moore(1972) reported that in spite of a close phoneme-grapheme correspondence in the Russian language the Soviet Union found it neccessary to abandon strictly "oral" methods of teaching reading to the deaf,due to their lack of success.

Locke(1978) used Corcorran's letter deletion task (Corcorran 1966) with deaf and normal hearing children to see if deaf children decoded graphemes into phonemes during reading. Locke asked 11-16 year old deaf and 12-13 year old hearing children to delete pre-specified letters from a given text. Texts had been selected for the presence of three different letters ("c","g", and "h") which occured in a modal form (i.e. "g" as in "gap") and a non-modal form (i.e. "g" as in "rough"). To create as natural a situation as possible subjects were required to read for comprehension, which was tested afterwards with a comprehension test. As a result Locke discovered a very significant group(deaf vs. hearing) by letter type (modal vs. non-modal) interaction which was caused by the deaf children producing an equal proportion of errors on non-modal and modal forms, whereas the hearing children produced over twice as many errors on non-modal forms. "Modal" in Locke experiment is similar to "pronounced" in Corcorran's experiments (Corcorran 1966,1967) whereas non-modal is similar to "unpronounced". Locke concluded that normal hearing children decoded print into a phonetic form "in going for meaning" which deaf children did not.

The evidence from these studies of reading in deaf children indicate that the processes of speech production and reception are neccessary for learning to read. Deaf children obviously lack the use of the mechanisms of speech reception and due to the lack of auditory feedback have poorly developed speech production too. It seems to be the case that due to these difficulties alone so few deaf children learn to read properly.

1.2.4 Speech Processes in Reading and Spelling Disability.

There are numerous different areas of research which have , in the majority, found that specific reading and spelling disabilities result from inadequacies of certain speech processes.

A celebrated ethnological study of specific reading disability(SRD) was reported by Makita(1968), who was principally concerned with discovering the incidence of SRD in Japan compared to other countries. SRD in Makita's study was considered to occur in children with adequate intelligence, a normal history of schooling and without defective eyesight. Accordingly Makita carried out a survey of SRD in Japanese primary schools and found there to be a 0.98% incidence of SRD which compared with reported incidences of 10-20% in German schools, 22% in Austrian schools whilst Monroe(1932) reported a 12% incidence of SRD in American schools. Thus the incidence of SRD in Japan is some ten times lower than the average for Western countries.

In Japanese there are two orthographies, namely kana, which is a syllabery composed of Hiragana and Katakana, and kanji,which is an ideography. These two orthographies compare markedly with Western orthographies all of which are alphabetic. Makita(1968) noted the following differences between kana and the alphabetic languages: 1. In kana there are no symbols which stand in a mirror relationship to each other like "b" and "d", which is well known to be a stumbling block in beginning readers (e.g.Calfee, Chapman and Venezky 1970).

2. Kana is made up predominantly from 96 symbols, each representing a syllabic unit composed of a consonant plus a vowel. These kana syllables have invariant pronunciation compared with the changing sound of graphemes in English (e.g. compare the phonetic translation of the letter "a" in "pale","pane", and "pan").

3.This lack of invariance in English is also true of consonant pairs such as "th","gh", and "kn" . However consonant clusters do not occur in kana.

The results of Makita's survey also showed that the incidence of SRD for readers of kana decreases rapidly from grade.1. through grade.4. apparently fading away altogether.

With respect to kanji the problems children will go through in learning to read kanji are very different from those produced by an alphabetic orthography. For example the kanji vocabulary increases between grades and approaches a figure of about 1850 characters in daily use by adults, compared to the 26 in English. This presents the difficulty of vocabulary size even for normal children in advanced grades. Secondly, reading errors tend to be visuo-conceptual rather than mispronunciation errors. In other words children reading kanji might confuse the visually similar symbols representing "nail" and "needle" or those representing "left" and "right", whereas English reading children tend to mispronunciation e.g. "picnic" for "panic" or "floor" for "flour". Thirdly in kanji a single character usually has two or more pronunciations which are dissimilar in sound such as "me" and "gan" for the symbol 眼. The different pronunciations are determined by the context such that the "me" pronunciation means "eyedrop" but "gan" means "nearsightedness". Whereas in kanji the variants of the script-sound relationships are large in terms of pronunciation, but subtle in terms of meaning, the reverse is true in English.

Thus Makita suggests that alphabetic languages present a different set of problems to the beginning reader. He suggests that these problems arise principally from the complexity of grapheme-phoneme translation. However it is interesting to note that some alphabetic orthographies such as Finnish and Russian are almost perfectly regular and yet Gibson and Levin(1976) report , of Finnish , "......(it) is one of the most regular languages..... ....Each phoneme always has the same letter irrespective of its place in a word....Reading is not considered a problem in Finland; however, larger cities have reading clinics, and there are also a few full-time reading specialists who go from school to school. Obviously reading problems do exist in Finland despite the official "nonproblem" attitude"(p.525). Downing(1973) also reports that reading problems are known to occur in countries in which the writing system maps the language more directly than English. Thus alphabetic languages with grapheme-phoneme regularity still produce a significant number of specifically reading and spelling retarded children. In fact, there are few cross-cultural studies that compare orthographic complexity with incidence of reading and spelling disorders, and of these Gibson and Levin(1976) summarize, "......it is not clear to what extent the orthographies of languages affect the acquisition or level of reading achievement". Indeed, we know that complexity cannot be the only cause of difficulties in reading acquisition. Many children continue to have problems even when the words are carefully chosen to include only those which map the sound in a consistent way and are part of the child's active vocabulary (Savin 1972). Thus the invariance in the pronunciation of syllables in kana is not unique to Japanese and other non-alphabetic orthographies and cannot be used to explain the low incidence of reading and spelling disability in Japan. It therefore remains to investigate the different processes used to decode print in syllabic,ideographic and alphabetic languages .

1.2.5 Phonological Skills in Dyslexic Children.

Liberman,Shankweiler,Fischer and Carter(1974) examined the ability of pre- and beginning readers to segment auditorily presented words into their constituent phonemes or syllables. 4, 5 and 6 year old children were split into two groups at each age and they were asked to tap out either the number of phonemes (phoneme group) or syllables (syllable group) in an utterance. After a good deal of training the subjects were given a series of test trials with a criterion of six consecutively correct trials before the test was completed. From the results it was clear that at all three ages the number of children reaching criterion was significantly greater in the syllable group. In the four year old children none of the subjects reached the criterion for phoneme segmentation whereas 46% could segment by syllable. In fact phoneme segmentation did not appear until the age of five and even then only 17% of the children reached criterion in the phoneme group. However by the age of six 70% could segment into phonemes and 90% into syllables. There is therefore a sudden acquisition of phoneme segmentation skills between five and six in this study of American children. Liberman et al.(1974) considered that this sudden acquisition arose either from some developmental shift at this age or as a result of the onset of reading instruction. A follow up study was carried out by Liberman(1973) on these 6 year old children one year later when they were in grade.2. In a word recognition test every child in the top 33% of the second grade ,as opposed to only half of those in the bottom 33%, had been successful at phoneme segmentation one year earlier. A similar result was obtained by Bruce(1964) whose 5-7.5 year old subjects were given a word, asked to delete a given sound and pronounce the resulting word i.e. given /pot/ and asked to delete /t/ the subjects should respond /po/. Bruce(1964) found that 6 year old children were aware of the separate phoneme segments but correct phoneme deletion was not achieved until 7 years of age.

Fox and Routh(1980) compared normal, mildly retarded and severely retarded 6 year old readers on their abilities at segmentation of sentences into words, words into syllables or syllables into phonemes. They found that the severly retarded were worse in respect of syllable and phoneme segmentation compared with the normal children. The mildly retarded children were only worse than the normal children in phoneme segmentation. Thus conceptual analysis of a sentence(i.e. segmenting a sentence into words) was intact but accoustic analysis into either syllable or phoneme segments was impaired in the reading disabled children.

Wepman(1960) and Clark(1970) reported that the ability to discriminate between similar sounds e.g. /p/ and /b/ or /ae/ and /ə/ was poor in retarded readers although Shute and Graham(1977) and Naidoo(1972) obtained results to the contrary. However on a test of sound blending in which given a sequence of phonemes such as /b/-/ae/-/g/ the subject should reply "bag" Naidoo(1972) found that dyslexic children were significantly impaired relative to the control group. In addition a reading plus spelling retarded group was significantly worse than the spelling only retarded group. Naidoo(1972) commented that "whereas it is not until the age of 11 years that a majority of dyslexic boys show this ability(i.e. blending 4-5 sounds) , among the controls a majority can do so from the age of 8 years upwards." Similarly

Savin(1972) reported that 7 year old illiterate children were unable to analyse syllables into phonemes, were insensitive as to whether two syllables rhymed and could not say whether the two words "cat" and "cow" began with the same sound. Durrell and Murphy(1953) also reported that almost every child who came to their clinic with a reading achievement score below first grade had a marked inability at discriminating sounds in words. Durrell et al. even claimed that children with severe handicaps in phonemic analysis would seldom achieve a primer level in reading.However Rozin and Gleitman(1977) reported that children with poor auditory-verbal disrimination i.e gaining a low score on the Wepman Auditory Discrimination Test, need not have poor auditory perception per se. Instead they are probably unable to "focus" on sound in words. This was demonstrated by children who reported that "pat" and "bat" sounded the same but when asked to repeat each word after hearing it they would frequently make the correct distinction. Rozin et al(1977) concluded from this that "perceptual problems with sounds of speech thus cannot be assumed to play a major role in reading disability, except in rare individuals "(p.89).

Conrad(1977) obtained a linear regression when extent of congenital deafness (i.e minimal dB level for sound detection) was plotted against reading age at 15.5-16 years of age. Consequently it could be argued that these auditory-verbal difficulties of dyslexic children could result from some mild peripheral auditory impairment. However in the Naidoo(1972) study all children were screened for hearing loss and those with any hearing defects were eliminated from the study. Shute and Graham(1977) also reported from a study of dyslexic children that they did not show any general impairment on the Seashore Test of Musical Talents, a test of non-verbal auditory perception. Therefore it seems that a peripheral hearing loss explanation of dyslexia is untenable, which makes it neccessary to look at the next stage in the transition from sound wave to auditory perception. But without intrusive techniques this is a difficult task since there is a considerable theoretical difference between the processes of natural listenning and tests of auditory perception which demand subjects to detect the presence , or absense, of certain phonemes.

1.2.6 The Reality of Phonemes.

Liberman, Cooper, Shankweiler and Studdert-Kennedy(1967) artificially deleted the vowel sounds from a tape recording of the CV'S /di/ and /du/ leaving the phoneme /d/ intact and alone. However Liberman et al(1967) reported that these /d/ segments from separate vowel environments, "...........could hardly sound more different from each other. Furthermore, neither of them sounds like /d/ nor like speech of any sort ". Harris(1953) attempted to separate phonemes on pieces of tape and then recombine those from different phonetic environments only to produce unintelligible noise. Wung and Swertsen(1958) also found that the smallest possible unit of speech recombination was roughly half a syllable in length. Such findings led Liberman,Shankweiler, Liberman, Fowler, and Fischer(1977) to conclude that there was no accoustic criterion which marks out phonetic segments in words although every syllable does have a vocalic nucleus and therefore a distinct peak of acoustic energy(Fletcher 1929). Phonemes ,it appears, do not have an accoustic reality although they do have a psychological reality in the perception and production of speech. Thus psychological tests which call for the detection of phonemes demand the use of an unnatural cognitive process. Conscious analysis of the word into its components, especially phonemes, is not a practice that occurs in the natural use of spoken and perceived speech. However in reading such an analysis is essential. Liberman(1971) observed that in order to read the word "bag" the child must first of all process the three graphemes into their phonemes namely /b/, /ae/ and /g/ which as a concatenation produces the sound "buhaguh", which in turn is nothing like the correct pronunciation of "bag". Secondly, and at the same time, the child must realize that the word "bag" in his own lexicon is composed of the three phonemes before he can map "buhaguh" onto the word in his lexicon. The child's natural competence in speech production and perception are of no intrinsic use in this matter , since these latter phonetic processes are not available at the level of cosciousness. This is made abundantly clear when one considers that the minimal contrast of /ba/ and /pa/ is perceived by one month old children (Eimas, Siqueland, Jusczyk and Vigarito, 1971) yet even 6 year old children cannot discriminate the much greater phonetic contrasts between /b/, /a/ and /g/ in "bag" when asked to tap out the number of phonemes in the word (Liberman et al, 1974). Thus the linguistic phenomenon peculiar to reading, in contrast to speech, is that reading demands the breakdown of the external written word, as well as the internal analogue in the lexicon, into phonemes. It appears to be the cognitive processes that are used in the analysis of words into the component sounds and the subsequent synthesis of sounds into words, which underlies the difficulties of dyslexic children.

Although during normal discourse people are not aware of the procedures they use to analyse and synthesise speech there are occasions, especially during speech acquisition, when one has to make strategic phonetic adjustments to mispronunciations. For example, children frequently pronounce "dog" as "gog" but they can be taught to make the relevant correction. To make this correction the child must carry out a phonetic analysis of his utterance. But if dyslexic children have difficulty with phonetic analysis, as reported by Downing (1973), then it might be expected that not only will reading and spelling suffer but so too will the normal development of intelligible speech. In addition one would expect early articulatory defects. Just such problems have been reported to occur in developmental dyslexia (Naidoo, 1972).

This same conscious phonetic analysis is used occasionally in adults although it is rarely used in discourse. When subjects are asked to perceive and remember nonsense words they will analyse the word into its constituent phonemes which will, at recall , be concatenated to produce the response. However a string of phonemes held in memory is liable to suffer from inter-phoneme interference (Wickelgren 1965,1966) resulting in parts of the nonsense word being incorrectly recalled.

It could be argued that children who have great difficulty with phonetic analysis might not have impaired comprehension once a sufficient level of skill in phonetic analysis is achieved. However Perfetti and Hogaboam(1975) had groups of 8 and 10 year old children split up into those who performed well or badly on reading comprehension and vocabulary tests. The results showed that skills on these two "semantic" tasks were correlated with the phonetic reading performance of pseudo and rare words. Perfetti et al(1967) concluded that the level of performance on a low level skill was responsible for the differences that existed in comprehension and vocabulary. They hypothesised that the human system is limited in its attentional capacity such that the poorer reader is more occupied with processing graphemes into phonemes and therefore has less capacity for comprehension. Such a limited capacity reading model has been set out by La Berge and Samuels(1974) to explain the changing strategies during the development of reading and spelling.

1.3.1 Cognitive Models of Reading

General Overview

In cognitive psychology the tendency to create an organized framework has taken the form of constructing hypothetical systems which are referred to as models. Research into the psychology of reading should make reference to a theoretical model , or models , in order to make empirical predictions which can be tested and to update the model when new discoveries are made . Pertinent to this issue is the following quote from Farnham-Diggory(1975), "Available data refer only to pieces of reading models and say nothing about changes that could result from interactions among pieces. In fact most of the experiments used in evidence for the existence of certain memory stores make no reference to a general model of reading or information processing".

During reading , Gough(1972) argued, the reader's eyes begin focussing on a point just to the right of the beginning of the line and they remain at that fixation for some 250msecs (Tinker 1958). The eyes then sweep 1-4 degrees of visual angle , roughly 10-12 letter spaces, to the right and a new fixation will begin (Gough 1972). This process will continue uninterrupted for as long as normal reading continues. Reading is therefore not unlike a series of brief exposures each of which can be simulated with a tachistoscope or microcomputer. In this way factors relevant to reading can be studied one at a time in the psychology laboritory. Once a process in the visual information processing system can be operationally described it can then be considered as a unit in the processing system if factors influencing this process (i.e. the speed with which it processes the information) do not also influence other known processes in the same way. For example if the time taken to process information at one stage correlates with time taken at a separate stage then these two stages are in fact aspects of a single stage (Sternberg 1969). Bearing in mind Sternberg's law theoretical models of reading have been formulated which are made up of separate processes or stages linked together to form a serial information processing system.

Farnham-Diggory(1975) has pointed out that a limitation in a number of visual information processing models(e.g. Gough 1972, Haber and Hershenson 1973, Morton 1979) is that they "....say nothing about changes that could result from interactions among pieces" (Farnham-Diggory 1975). In other words models have a certain degree of concreteness in their structure which fails to allow for ,or explain, the changes that the system undergoes during development. However a flexible model that describes changing patterns of reading, or spelling behaviour, is neccessary for research into the development of reading and spelling. Such a model should be able to describe the initial reading strategy of grapheme to phoneme translation and the subsequent synthesis and blending of these phonemes to form whole words. Later on in development not only are words and phrases processed as whole units, rather than analysed into subunits (Reicher 1969, Wheeler 1970, Morton 1979), but also skilled readers can extract semantic information directly from the print without an initial phonetic decoding (Marcel and Patterson 1978, Allport 1977, Marshall and Newcombe 1973, Saffron and Marin 1977, Shallice and Warrington 1975).

The model which most successfully provides a framework to the process of strategy changes is the LaBerge and Samuels(1974) model. This model has its roots in the realization that to execute a complex skill, such as reading, it is neccessary to coordinate many component processes within a very short period of time. Now Perfetti and Hogeboam(1975) found that children who had impoverished grapheme to phoneme translation skills were also those who had impoverished comprehension and vocabulary which , they argued , was due to an extortionate amount of attention being diverted away from these tasks onto phonetic decoding. If each component process required attention then the execution of a complex skill would be impossible due to the limited capacity of attention (Broadbent 1958, Moray 1959, Treisman 1964). Accordingly LaBerge and Samuels (1974) have created a system in which it is possible for the component sub-skills to be executed either automatically or executively i.e.without, or with the aid of attention.

It has been frequently reported that words are processed differently from strings of letters. In the visual modality it has been noticed that the detection of letters embedded in a word is easier than the detection of a single letter by itself (Reicher 1969, Wheeler 1970) . This has given rise to the term " Word Superiority Effect " or WSE. The WSE also occurs in the auditory modality (Warren 1970, Warren and Obusck 1971, Warren and Sherman 1974). Warren (1970) and Warren et al. (1971,1974) found that subjects identified the presence of single phonemes which had been deleted from a word. For example when /s/ was deleted from "legislative" subjects reported that they actually heard the /s/, when actually they were presented with "legilative".

Juola,Schadler , Chabot and McCaughey (1970) reported that the WSE could be found in 8 year old children when word perception was compared to letter perception . Moreover Juola et al. found that the WSE for words was an all or nothing effect i.e. the magnitude of the WSE for "dog" over "ogd" or "gdo", does not increase as the child gets older. This would suggest that soon after a child can read a given word he need no longer opt for the grapheme to phoneme route since he can decode the word as a whole unit. The transition from grapheme-phoneme decoding to whole word processing can be explained by the LaBerge and Samuels(1974) model.

The logogen model of Morton(1979) was developed principally to integrate all the pieces of research which had demonstrated a WSE. Morton(1979 p.143) reported that "The big debate is the extent to which the grapheme-phoneme route is used in different tasks and under different procedural variations ......Even if we initially learn a particular word by using the phonic method one could easily envisage a learning process whereby we eventually recognize the same word purely visually." The logogen model ,despite its inability to describe the development of the WSE, coordinates processes involved in the perception of both orthography and speech (Morton 1979). However the grapheme to phoneme route and indeed all the subskills below the level of whole word processing are not covered by the logogen model.

Despite a number of different standpoints in the models of LaBerge and Samuels(1974) and Morton(1979) there are some areas of agreement. These similarities will be enlarged upon after the two models have been more thoroughly described.

1.3.2 The LaBerge and Samuels Model(1974).

A pictorial representation of the LaBerge and Samuels(1974) model , derived from Figure.7. of LaBerge and Samuels(1974), is presented in Figure.1.1. In this figure there are separate information processing stages drawn as separate boxes. Circles , whether filled or unfilled, represent coded units ("code" refers to those stimulus features represented in the memory trace, and "coding" refers to the process of translating to that representational form used in storage). Thus a circle in VM, for example , represents a memory trace made up of the visual features for letters or spelling patterns(e.g. "po" and "st"), whole words (e.g. post) or even word phrases (e.g. post office).

Feature detectors (Rumelheard 1970;Hubel and Wiesel 1959) initiate the coding of information by coding features such as lines,intersections, and curvatures from the pattern of light and dark falling on the retina.

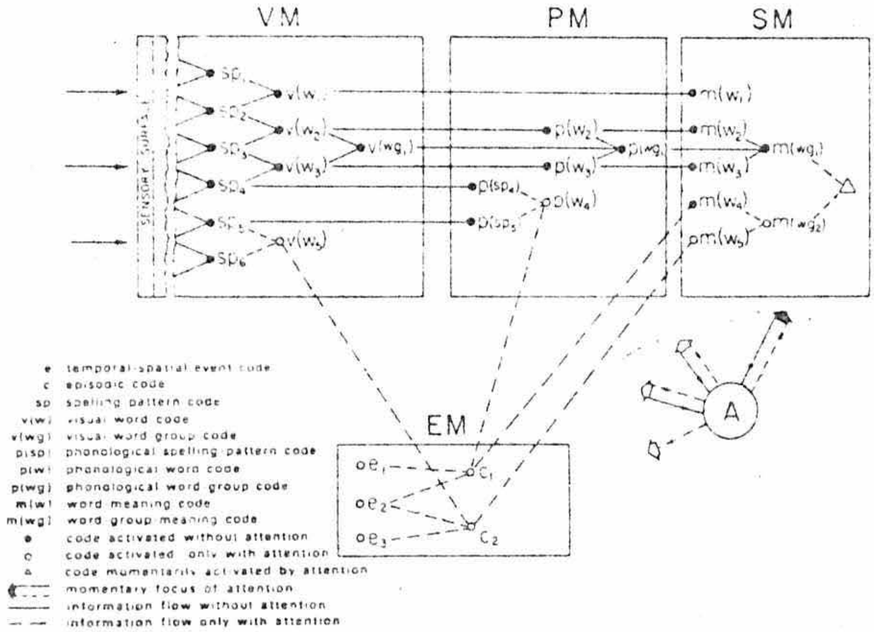


Figure 1.1 Representation of some of the many possible ways a visually presented word may be processed into meaning. The four major stages of processing shown here are visual memory (VM), phonological memory (PM), episodic memory (EM), and semantic memory (SM). Attention is momentarily focused on comprehension in SM, involving organization of meaning codes of two word-groups.

Several activated feature detectors converge at each node(i.e.a circle in the figure) in VM (suppose SPi). From the physiological process of summation the threshold will be reached where the node (SPi) will be activated. Once activated, higher order nodes in VM (e.g. V(W1-3)) or PM (e.g.P(SP4)) or SM (e.g. M(W1)), which are connected to SPi, will recieve information from SPi. For example if the VM nodes representing letters "p" and "o" are activated then information will be sent to either a VM spelling pattern node representing "po", or a VM node representing "post" , or a PM node representing /p/ or /ɔ/. Which one of these routes is used depends on the reading ability of the subject such that in beginning readers , who use a grapheme to phoneme route , activated VM nodes for graphemes will only transmit information to PM nodes for phonemes. In experienced readers this route is available but there are more efficient routes which are more commonly used whereby higher order nodes representing words or even phrases can be activated. Higher order VM and PM nodes , once activated, can transmit information directly to certain SM nodes which represent the denotative and connotative meanings in memory. Thus the visual information processing system consists of separate memory stores each with its own heirarchical infrastructure of nodes with links between nodes within or between the separate memory stores.

Activation of nodes can happen either automatically or only when attention is focussed on these nodes, depending on their status. Attention in the model is considered to be limited in capacity and selective in the same manner as Broadbent(1958), Moray(1959), Treisman(1964), and Deutsch and Deutsch(1963). In the case of a skilled reader , reading for comprehension , the processes of visual analysis, phonological coding and semantic coding cannot all be using up attentional capacity since comprehension of large amounts of text happens rapidly. Attention is being used optimally , probably at the semantic level combining meanings and associations in new ways to produce new understandings. This state of affairs leaves no extra attentional capacity available to attend to the accoustic or visual properties of the message , which are nevertheless critically involved in the accessing of the SM nodes . Thus visual and phonological structures will be "ignored" resulting in incomplete perceptions such as proof-readers error(Pillsbury,1897; Vernon,1929). These unattended nodes in VM and PM are thought to be activated automatically. However for a beginning reader activation of nodes at every stage demands attention and there is the minimum of automatization in the system. Thus young children have to attend to all the visual features in turn prior to identifying a letter. With practice scanning strategies are developed and only the non-redundant features are scanned, although this process of scanning itself initially demands a good deal of attentional capacity.

Evey time a set of visual features and a letter node in VM are activated contingently "...some trace of this organization between features and letter code is laid down"(La Berge and Samuels 1974 p.554) such that eventually activation of these distinctive features activates a unique letter node automatically(e.g. SP1-SP6 in the Figure 1.1). With considerable reading experience spelling patterns, words or even word phrases can be characterized by a set of distinctive features. Similarly each time a series of letter nodes and a spelling node in VM, or visual features and a word node in PM, are contingently activated then the direct link between the relevant nodes is further consolidated .

Any activated node in VM can act as a source of input to phonological memory (PM). Thus nodes in PM represent the phonological codes for letters, spelling patterns, or words. For the beginning reader the link between a node in VM and a node in PM is not direct and contingent activation demands attention to both nodes. Initially there is the need for external information to choose the appropriate node in PM. In this case information in episodic memory of past temporal and physical events facilitate the selection of the correct node in PM. For example attending to both an activated VM letter node for the letter "p" as well as the nodes in EM representing past memories such as the page in the reading book with a picture of Peter and the teacher repeatedly uttering the sound /p/ will activate the phonological node for /p/ in PM. With practice "......direct lines may be formed between visual and phonological nodes". Progress in grapheme-phoneme learning is customarily indicated by a reduced frequency of errors. However the speed of phonological decoding is still slow even after the error rate reaches zero and attention might still be neccessary for the access of the correct node in PM. For example Suppes et al.(1966), Shapiro(1968) and La Berge and Samuels(1974) have shown that the latency in paired associate recall tasks continues to decrease with practice well after error responses have been eliminated altogether. La Berge and Samuels(1974) used a set of familiar letters (b,d,p and q) and a set of unfamiliar symbols and assumed that overall latency of naming a letter was the sum of perceptual coding time,association time between name and percept, and response organization time. By teaching subjects perceptual matching the familiar and unfamiliar symbols were initially equated for perceptual coding time. Subjects were then given a paired associate learning task until they had learned names for the unfamiliar symbols. After day seven of the experiment the percentage of naming errors was equivalent for both sets of symbols but between days seven and twenty name latency for the unfamiliar symbols was reduced by 25% against a minimal reduction for the letters. They explained this sequence of changes by saying that initially name production demands attention , the use of mnemonics, and episodic memory. As learning progresses the mnemonics and episodic memories become redundant although attention is still important in selecting the correct node in PM. Gradually a direct link between the nodes in VM and PM will develop and the role of attention to create a link will be reduced until it is possible to activate the node in PM automatically from activation of the node in VM.

The LaBerge and Samuels model can be used to account for a variety of different reading strategies, or routes , from print to comprehension in skilled readers. For example there is the route, which shall be referred to as Route.1., wherein a VM node can automatically activate a SM node (e.g. V(W1) > M(W1) in Figure 1.1). This route is similar to that proposed by Marcel and Patterson (1978) and Allport(1977), who showed that in adults ,skilled at reading, the meaning of written words can be aroused although the subjects are unaware that the word has been seen. Also Saffron and Marin(1977), Shallice and Warrington(1975) and Marshall and Newcombe(1973) provided evidence for such a route from the reading errors of brain damaged patients who would produce semantically similar words which were unrelated phonetically to the original (e.g. "gnome" read as "pixie" and "tulip" read as "crocus"). In these patients word meanings can be accessed direct from the visual percept, but the phonetic form is inaccessible.

In Route.2. the SM node is automatically activated by the activation of a PM node, which in turn is automatically activated by a VM node (e.g. V(W2)>P(W2)>M(W2) in Figure 1.1). This is arguably the normal reading route in skilled readers (Conrad 1972; Edfeldt 1960; Novikora 1966 ; Hardyck and Petrinovich 1970). These authors report evidence for increased EMG activity of the articulatory muscles during normal silent reading in skilled readers.

1.3.3 THE LOGOGEN MODEL (MORTON 1977,1979).

The two principle features of the logogen model are the two processes called "logogen system " and "response buffer" (see Figure 1.2 below). The concept of a "logogen" was introduced by Morton(1964). A logogen is the interface between stimulus features and the "internal responses" of lexical and semantic access. Each word, or even each morpheme, is represented by a unique logogen . The logogen acts as a template which recieves inputs from the stimulus feature analysers (i.e. visual or auditory word analysis boxes in Figure 1.2) and directs the flow of information to specific structures in the cognitive system (Figure 1.2).

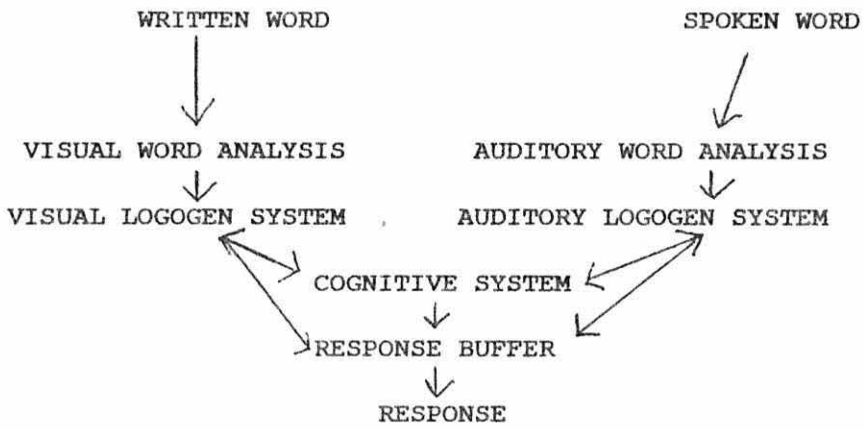


Figure 1.2 The Logogen Model (Morton 1977).

Morton(1977) described the cognitive system (see Figure 1.2) "as that part of the information processing system that subsumes all processing other than that specified in other parts of the model "(p.3.Morton 1977). When a stimulus is perceived the cognitive system produces information (e.g.word meanings) only after a logogen has been located which mirrors the set of visual features. However the cognitive system can also influence the "firing" threshold of logogens through processes such as expectancy and practice which reduce perceptual thresholds. Conversly during speech production ideas ,or the kernal(Chomsky 1964), for a speech act arise in the cognitive system and are transformed into a surface structure by the activation of relevant output logogens. What a "logogen" actually is in terms of a well described mechanism remains a mystery, indeed Morton has described his own model as "a useful expository device" in so far as it was designed to make sense of a large number of experimental findings. Hence the only way of understanding the usefulness of the logogen concept is by describing how the model accounts for the research findings in word perception, principally the word frequency effect and the effects of context.

Word Frequency Effect (WFE)

A relationship between word recognition thresholds and the frequency with which words occur in the language has been reported many times(e.g.Solomon and Howes1951; Howes and Solomon 1951; Oldfield and Wingfield 1965; Brown and Rubenstein 1961). It is generally found that perceptual thresholds are a linear function of log(word frequency).

The logogen model explains this phenomenon of the WFE at the level of the logogen itself. In the visual system information is transmitted initially from the feature detectors to the logogen system where an automatic matching process compares the set of features with "templates" held in a kind of filing system. When a suitable match has been found (i.e when the visual threshold has been reached) information is transmitted from the logogen system to the cognitive system with the neccessary details about the word's identity. Now these perceptual thresholds have a relatively fixed mean value due to the long term influence of stable variables such as word frequency, so that logogens of high frequency words will tend to fire before logogens of low frequency words (Morton 1979). However the firing threshold at a given moment in time varies widely due to the influences of information from the environment as well as internal infromation from the cognitive system both of which can bias the level of the threshold. Thus in an experimental setting new threshold values for logogens can be induced by varying simply the number of previous presentations (King-Ellis and Jenkins 1954; Shapiro 1968; La Berge and Samuels 1974). In the King-Ellis et al.(1954) task subjects read a nonsense word printed on each of a pack of cards. Words recurred on separate cards 20,15,5,2 times or just once. Subsequently the visual perception threshold values were measured for these words and it was found that the thresholds were linearly related to the log(number of recurrent presentations). Thus logogens can be thought of as units which assimilate relevant information from both outside and inside the system , and output information to other relevant parts of the system once a threshold has been reached. Now this threshold has a "base level", which is determined by the long term and stable influences such as word frequency, as well as a "local level" determined by immediate influences such as effects of context, expectancy and set. Carroll and White(1969) and Gilhooly and Logie(1980) have argued that the "base level" component of a logogen threshold is accounted for by age of word name acquisition. In experiments on name latency they found that age of acquisition accounted for a significantly higher portion of the latency variance than word frequency.

Effects of Context.

Miller, Heise and Lichten (1951) and O'Neill(1957) found that words embedded in noise and presented auditorilly were recognized more easily when presented in a sentence than in isolation. Tulving and Gold (1963) and Tulving , Mandler and Baumal (1964) found for the visual modality that the ease of word recognition varied according to the length, and so presumably the relevance, of a previous meaningful context. Thus relevant context in either the visual or auditory modalities reduced the recognition threshold for words. Morton (1979) considered that to recognize a word in isolation a certain amount of sensorial evidence must be received at the logogen before the threshold can be reached. In the presence of relevant context the cognitive system can pass on to the logogens cues for likely stimulus attributes which will make the detection of some physical features redundant. Thus the necessary amount of sensorial evidence can be reduced . Morton (1979) even considered that information received by a logogen carries no identity as to whether the source is an external or an internal source. This claim is supported by the anecdotal evidence from subjects that given a relevant context it is not only easier to provide the correct response but it is also easier to actually "see" or "hear" the physical properties of the stimulus. In addition Sternberg(1969) put forward the idea that if two variables influencing the information processing system produce an interaction effect then they must both be operating at the same level in the system. Just such an interaction was reported by Meyer, Schvaneveldt and Ruddy(1974) who found that the magnitude of the effect of context on word perception thresholds increased as stimulus legibility was reduced indicating an interaction between external and internal information.

In the cases of speech production and reading aloud the flow of information from the logogens is directed towards the articulatory system. So , instead of an activated logogen accessing a semantic address , it accesses a motor program for the articulation of the word. To coordinate a set of motor programs into a continuous speech act they are stored in sequence in a response buffer. Ellis(1979) has provided a more powerful role to the response buffer than previously given by Morton and so the term "response buffer" will be used to refer to the version in the Ellis(1979) model.

1.3.4 The Response Buffer.

This component in the Logogen model is really an extension of the previously described processes of Primary Memory(Waugh and Norman 1965), Working Memory(Baddeley and Hitch 1974), the execution and rehearsal of articulatory motor programs in the Sperling model (Sperling 1963), and the short term store (Atkinson and Shiffrin 1968), all of which have been attempts to describe a mechanism for the memory span phenomenon (Miller 1959; Norman 1970; Broadbent 1958). In essence memory span represents the maximum amount of information that can be recalled from a list of items given at a rapid rate. Usually between 4 and 9 items only can be remembered under these conditions although we can recall on demand thousands of events , names , faces , images of places , historical dates , references etc. The response buffer is the process that is responsible for the memory span phenomenon. During reading, or listening to speech, information received by the senses is stored in the response buffer for a short period of time to allow successful completion of the slower processes of semantic access and the chunking of word meanings. Some observations of the behaviour of readers have provided a strong case for the critical role of a short term store , or response buffer. For example it has been noticed that during reading the eyes are always fixated on words well ahead of the word that is currently being spoken (Levin and Kaplan 1970; Rayner and McConkie 1977; Morton 1964). Rayner and McConkie (1977) showed subjects a line of text on a VDU. The text was arranged into a continous horizontal string although the VDU acted like a cursor moving along the string from left to right with the speed of movement varying with the subjects reading speed. With this method it was possible to vary the viewing window size and see what the effects of reduced window had on reading speed. It is apparent that if the leftmost word on the VDU is the word currently vocalized then any words presented to the right of this word will be lying ahead of the voice. McConkie and Rayner(1977) found that if fewer than 10-11 letters appeared ahead of the voiced word then reading speed , and various measures of eye-movement, were affected. In addition McConkie et al. found that different sources of information were perceived at different locations. Thus letter and word shape information was being perceived 10-11 letters ahead of the voice although word length was being perceived some 15 letters ahead of the voice. Now,this information must be temporarilly stored if it is not going to be lost by the time the response is produced.

The study of reading errors has also provided strong evidence for the role of the response buffer during reading and speaking. Morton(1964) noticed that reading errors can occur which are anticipatory productions of a word, or part of a word. Morton(1964)gave the examples:

1. You know that you must go › You must know that you....

2. Hall could › call ..... hall could.

In both of the above examples words, or parts of words, have been produced well before they are due to be read. These words are most probably retained in an ordered sequence in some kind of short term buffer until they are produced in their correct textual location (Baddeley,Thomson and Buchanan 1975). Ellis(1979) related the findings of Rayner et al (1977), as well as those of Levin and Kaplan(1970) to these reading errors in suggesting that the words in the eye-voice span are stored as "a phonemic string of potential responses to be outputted in the appropriate order".(Ellis1979 p.162). From an analysis of word and letter transposition errors during reading Ellis (1979) concluded that the response buffer was capable of holding at least five or six words in serial order in a phonological code, although occasionally items in store become translocated leading to the sort of errors reported by Morton(1964). This estimate of response buffer capacity during reading is very similar to the reported size of memory span.

Ellis (1979) has also suggested that the response buffer serves a somewhat different role during reading for comprehension compared to reading aloud. Instead of storing a sequence of motor programs for speech acts the response buffer can retain a string of words temporarilly to allow the slower process of comprehension to take its course (Marshall 1977 p.152) in accessing word meanings and syntactical relationships from the semantic and episodic memory stores . Craik and Watkins(1973) referred to this latter process as "elaborative rehearsal". Once the current contents of the response buffer have been processed to a "deeper level" the buffer can be cleared and refilled with the next series of words. Gough (1972) reported evidence in support of just such a process operating during reading. In Gough's (Gough 1972) study subjects were asked to recall a five word sentence and five unrelated words. It was found that if the sentence was presented before the list of five unrelated words then overall recall was superior to the condition where the sentence was presented after the list of unrelated words. Gough interpretted this result as indicating that when the sentence is presented first it is quickly processed for meaning and then cleared from the response buffer. However , if the sentence is presented last it can be processed only at the cost of some items from the list. In this way the response buffer acts as a temporary store in the service of elaborative processes.

A third role of the response buffer during reading is exclusive to inexperienced readers who are unable to read for comprehension since most of their limited capacity attention is devoted to the phonological decoding of print. Thus when they are confronted with a word they cannot immediately recognise they will analyse the word into an ordered series of phonemes which are stored in the response buffer. Rehearsal of this sequence prevents the memory trace from decaying whilst the internal lexicon is searched for a whole word entry with similar phonological features. At the same time rehearsal helps to blend phonemes together, which is regarded as a critical process in phonic reading schemes (Gleitman and Rozin 1977; Liberman 1977). Therefore in the beginning reader the response buffer is used to store phonemes in a serial order during word analysis and during word synthesis(i.e. blending).

Morton(1970) pointed out that the response buffer plays a crucial role during speech production. Thus he commented, "The Response Buffer is seen as having the primary function of allowing the production of speech to be programmed efficiently". Similarly Ellis(1979) has pointed out that anticipatory lip rounding for the /u:/ in /stu:/ occurs during the pronunciation of /s/ and Liberman et al (1967) found that in speech the sound spectrogram for /d/ is variable and depends upon the following vowel context. Thus during speech a string of phonemes is stored in a sequential order prior to actual speech production.

The spoonerisms reported by Franklin(1973) closely resemble the reading errors reported by Morton(1964). For example:

You <u>b</u>etter stop for <u>g</u>as > You <u>g</u>etter stop for <u>b</u>ass

In this example the phoneme /g/ in "gas" must have been stored in the response buffer at the same time as the speaker intended to say "better". Thus serially ordered speech segments are prepared and stored before speaking commences. Morton(1964) and Ellis(1979) considered that if there is evidence for any phonological preplanning then some form of response buffer must be implicated which stores the serially ordered phonemes between speech preparation and speaking. In addition they regard this response buffer as the process responsible for not only speech and reading errors , but also memory span and eye-voice span.

During spelling the role of the response buffer is considerably greater than during reading. Gibson and Levin(1975) pointed out that during spelling from dictation , "the heard word........is decoded phoneme by phoneme , and recoded letter by letter , but recognized at the level of the whole word"(p.336). In this case two separate verbal strings, namely a phoneme string and a letter string have to be stored in the response buffer , as opposed to a single phoneme string during the reading of the same word. It is also likely that as reading develops "…..the child must abandon this early hypothesis, i.e.

regularity of individual grapheme-phoneme correspondences, and come eventually to interpret written symbols as corresponding to more abstract lexical spellings "(C.Chomsky 1970),i.e. reading whole words rather than phonemes.

In the Simon and Simon (1973) computer simulated spelling program a "phonetic generator" was used to generate a series of phoneme strings for a given spelling. These generated phoneme strings were then "scanned" by a "recognizer" which was linked to a "stored visual recognition store(SVRS)". The recognizer could then match the generated strings against stored representations and select out good matches from poor matches. The "phoneme generator" in this model can be considered as a complex system comprising the phonological system, the response buffer and the speech production systems. If there was an error somewhere in the "phoneme generator" then the spelling simulator would produce many spelling errors , although word recognition would remain an intact process since the recognizer and SVRS remain intact. In this case spelling would be poor but whole word reading would be unimpaired. Now, this simulation is a useful heuristic for research into dyslexia. It was mentioned earlier (p.15) that dyslexic children frequently improve their reading skills, possibly reaching an average reading age, although spelling remains resilient to improvement. This dissociation of reading and spelling occurs after considerable reading and spelling experience , at which point a well established logogen system could exist in which whole word recognition has replaced grapheme to phoneme decoding as the principal reading strategy. That spelling remains impaired implicates the "phoneme generator" as the locus for the dyslexics' problems. However spelling will always involve serial processing since only one letter can be written at a time.

1.3.5 Testable Predictions.

From these theoretical viewpoints mentioned above a number of predictions can be expressed which will be tested in the experiments to be described. The predictions which have been made are as follows:

1. Dyslexic children tend to make order errors during reading and spelling, of which the classical reversal "saw" > "was" is an exemplar. Morton(1964) and Ellis(1979) have implicated the response buffer as the locus of such order errors. This implies that dyslexic children are unable to use the response buffer efficiently.

2. It is frequently reported that dyslexic children confuse the months of the year, the days of the week and stages in arithmetic tables during recitation. Morton(1970) and Ellis(1979) considered that this kind of error is similar to a spoonerism in that both result from missequencing of items stored in the response buffer. This again implies that dyslexic symptoms arise at the level of the response buffer.

3. If the response buffer is experimentally pre-empted on a task in which dyslexic children are impaired then the performance level of the non-dyslexic controls will be reduced to the level of the dyslexic children.

Experiments 1 and 2 reported in this thesis were designed to test these predictions by comparing dyslexic and non-dyslexic children in tasks which critically vary the demands on the subjects response buffer.

CHAPTER 2

EXPERIMENT 1

INTRODUCTION

It has frequently been reported that dyslexic subjects are poor on visual memory span tasks (e.g. Rudishill, 1956; Rizzo, 1939). In such tasks it is generally held that subjects recode what they see into speech, i.e. an articulatory or phonetic code, in the case of letters (Conrad, 1963; Estes, 1973; Murray, 1967), digits (Baddeley, 1976) and pictures (Conrad, 1972). However, when there is no name or verbal associate for a visual form then articulatory recoding will not occur and the information is stored in a purely visual code (Phillips and Baddeley, 1971; Tversky, 1969; Posner, 1969; Coltheart, 1972). Nonsense shapes by definition have no meaning and therefore no name, although it is nearly impossible to obviate attempts at meaningful associations, and hence the use of articulatory coding, when presented with nonsense shapes (Bartlett, 1932; Grindley and Townsend, 1973; Van der Plas and Garvin, 1959). Pictures and digits on the other hand are familiar visual forms which possess names. If a subject is presented with a sequence of pictures then he will tend towards naming the pictures to remember the sequence of visual images. Thus Conrad (1972) found that errors in the immediate recall of picture series result from confusions of picture names rather than visual forms. However efficiency, or speed of naming covaries with memory span (Mackworth, 1963; Baddeley, Thomson and Buchanan, 1975), and it has been observed that pictures of familiar objects are slower to name than digits (Mackworth, 1963, 1966; Denckla and Rudel, 1974; Spring, 1976). Mackworth (1963) using adult subjects found that digits were named at a rate of 3.4 digits per second as opposed to 1.8 pictures per second for familiar objects. Spring (1976) found reading rates in 12 year old boys of 2.4 digits per second and 1.4 pictures per second.

Despite the critical role of naming speed on the size of the memory span (Mackworth, 1963; Baddeley et al, 1975), some symbolic information can be retained without implicit naming. Thus Kolers and Katzman (1966), Scarborough and Sternberg (1967) both reported unimpaired serial recall when six digit sequences were presented one at a time at a rate in excess of the rate of implicit speech. Sternberg (1967) also reported that by physically degrading a criterion test digit the speed of memory search is slowed when S. has to search a memorized set of digits for the presence/absence of the test digit. This latter result of Sternberg's strongly suggests that the representation of the test digit in memory retained the property of visual degradation.

In serial recall S's have to remember not only item identity but also item position or order. Wickelgren (1965), Conrad and Hull (1964), Baddeley (1966, 1967, 1970), Sperling (1963), Morton (1970), Ellis (1979) have presented evidence that the order of items is held in the response buffer as a string of phonemes or phoneme clusters. However, for visual presentations, item position can be retained in a visual code (Merikle et al, 1971; den Heyer and Barrett, 1971; Murray and Newman, 1973) although only two items, approximately, can be stored in short term memory in this way (Posner, 1969; Coltheart, 1972). Therefore when presented visually with a sequence of items some will be named and stored in the response buffer in an articulatory, or phonetic, code whereas other items will be stored in a separate visual short term memory store. Indeed it is possible that an item might be represented in both stores at any one time.

Although the number of named items stored in the response buffer varies with speed of naming it is considered that the number of items stored in visual short term memory is invariant of the type of item. Consequently by measuring memory span for digits, pictures and nonsense shapes it is expected that for digits a relatively larger number of items will be stored in the response buffer compared to pictures, although for both sets of items approximately two items will be stored in visual short term memory for a given sequence. For nonsense shapes the role of the response buffer will be minimized since few shapes will be named to the extent that it might not be used at all. In this way the role of the response buffer is allowed to vary systematically whereas the role of another short term memory, namely visual short term memory is held constant. By comparing dyslexic and non-dyslexic children on memory span for visually presented sequences of digits, pictures and nonsense shapes it will be possible to contrast the hypothesis of a response buffer deficit with a hypothesis of a general short term memory deficit in dyslexia.

METHOD

Subjects

18 male dyslexic subjects were individually matched with 18 male non-dyslexic subjects. Matching was carried out according to the following rules:

Rule 1. Within each matched pair (consisting of one dyslexic and one non-dyslexic subject) both subjects had similar chronological ages (CA), and similar IQ, as measured by Ravens Progressive Matrices Sets A,B,C,D,E (Raven, 1965).

Rule 2. The non-dyslexic member of each matched pair had a spelling age (SA), as measured by the Schonell Graded Word Spelling Test, similar to his CA and suited to his IQ. Thus non-dyslexic subjects of IQ 115 or above were required to have a SA not less than (CA-1) years and with an IQ of 101-114 the SA was not less than (CA-1.5) and with an IQ of 90-100 the SA was not less than (CA-2.0) years. In the case of the dyslexic subjects SA was related to IQ in the following manner. For dyslexic children with an IQ of 115 or above the SA had to be less than (CA-3.0) years and with an IQ between 100 and 114 the SA had to be less than (CA-3.5) and with an IQ between 85 and 99 the SA had to be less than (CA-4.0) years.

Each dyslexic subject had been previously given a clinical test at UCNW (Bangor) Dyslexia Unit and had been diagnosed as dyslexic according to the criteria: 1. Average or above average intelligence. 2. Retarded in both reading and spelling, with a positive indication of dyslexia on the UCNW Dyslexia Test. This test assesses left-right discrimination; the ability to recite polysyllablic words, arithmetical tables, months of the year, and sentences, all presented orally by the clinician; WISC digits forward and reversed; WISC arithmetical subtraction; crossed laterality; ability to appreciate rhyme.

Table 2.1 gives the mean CA, IQ and SA of both groups and Table 2.2 gives the ranges for both groups on the three measures.

Table 2.1

Means of Relevant Subject Parameters

Mean Scores

Group	N	CA	IQ	SA
Dyslexic	18	13.2	107	8.6
Non-Dyslexic	18	13.2	107	12.6

Table 2.2

Ranges of Subject Parameters

Ranges

Group	N	CA	IQ	SA
Dyslexic	18	11.2-15.0	92-140	6.7-10.4
Non-Dyslexic	18	11.3-15.7	91-130	10.0-14.4

Materials

Hardware

An Electronic Developments 2-Field tachistoscope was used for the experiment. The illumination of Field 1 (fixation cross) was held at 40 Lux and that for Field 2 (stimulus field) was held at 90 Lux. Exposure time of Field 1 was 1.5 seconds and for Field 2 was 2.0 seconds. Exposure times for both fields were set before the experiment and remained at these levels throughout the experiment.

Software

Stimulus Software

The stimuli were sequences of items printed onto 22 cms x 20 cms plain white cards. A stimulus sequence was constructed from only one item set for a single trial and the three item sets used were the ten digits (0-9 inclusive), ten drawings of familiar objects (bell, cup, chain, dog, glove, ladder, bucket, saw, tap, watch) and ten nonsense shapes. Stimulus sequences were of lengths varying from 3-7 items per sequence, with items being selected pseudorandomly from the set of ten without replacement. The restrictions on randomization were firstly that familiar sequences would not be included e.g. 456 or 123456, and secondly that consecutive trials had no single adjacent pair of items in common.

The pictures were chosen because they had acoustically dissimilar names and were visually dissimilar too. The Thorndike Lorge word frequencies, in parentheses, for the picture names were bell (A), cup (AA), chain (A), dog (AA), glove (43), ladder (19), bucket (16), saw (AA), tap (32), watch (AA) where the numbers denote that number of occurences per million words of text and(A) denotes >49 and (AA) denotes >99 occurences per million words of text. Each picture was taken from a children's reader and photographically reduced to an appropriate size from which tracing was made for consistent reproduction. The pictures were then transfered onto the white tachistoscope cards, with a spatial centre for the sequence occupying the same position on the tachistoscope screen as the immediately preceding fixation cross. Each picture was finally inked over with a Rotring Micronom pen with black ink.

The ten nonsense shapes were designed to maximize visual discrimination and at the same time minimize verbal recoding. This was achieved by designing unfamiliar shapes with minimal complexity and assymetry (Attneave, 1957; Vitz and Todd, 1971; Van der Plas and Garvin, 1959) in order to maximize discrimination (Etaugh, Graffam and Turton, 1973) and minimize verbal recoding (Clark, 1965). In order to increase the memory span it was decided to increase the number of dimensions inherent in the set of shapes (Miller, 1959; Garner, 1972). Further, since it has been known for a long time that even nonsense shapes can be associated with familiar meaningful objects (Van der Plas and Garvin, 1959; Bartlett, 1932) it was decided that each shape would be constructed along the three dimensions of contour, colour (black or white), and angle of inclination. Since the latter two dimensions in no way change the form of the object it was decided that of the ten shapes there would be five different contours such that for each shape there would be another shape with an identical contour, but differing along the other two dimensions (see Appendix A , Table A).

For the familiar pictures a blueprint of the ten pictures shapes was drawn from which a pencil tracing was made. This tracing could then be transferred onto cards and inked over with a Rotring Micronom pen. The centre of the sequence occupied the same position on the screen as the preceding fixation cross.

The average horizontal visual angels, subtended at the subjects eyes, during a trial are given below in Table2.3.

Table 2.3

The Average Visual Angle (Horizontal) subtended by the Stimuli

Item Set	No. Items per Sequence				
	3	4	5	6	7
Digits	2.2°	3.1°	4.2°	5.4°	6.9°
Pictures	10.3°	10.2°	12.3°	14.4°	16.2°
Nonsense shapes	5.1°	7.7°	10.2°	13.2°	15.6°

The average vertical visual angles, subtended at the subjects eyes, during a trial are given below in Table 2.4.

Table 2.4

The Average Visual Angle (Vertical) subtended by the Stimuli

Digits	0.9^{o}
Pictures	2.7^{o}
Nonsense Shapes	1.6^{o}

Examples of the pictures and nonsense shapes are given in Table A of Appendix A.

Response Software

3 response boards were constructed from thick white card. On each one the ten items were printed in two columns and five rows. The whole was covered in transparent acetate material. This was presented to the subject together with a felt tipped pen and a damp cloth. The subject was required to make his response by drawing a ring around each item in the correct serial order with no item being ringed twice in the same trial. After each trial the subject wiped all traces of the ink from the response board with the damp cloth.

Organization of Trials

Each block of trials was made up from sequences of one item set only. There were three blocks of trials. Within each of these blocks the initial five trials were considered as practice trials and not included in the recorded data. There was one practice trial for each length of sequence with the initial practice trial being the three item sequence and the fifth practice trial being the seven item sequence. There followed fifteen experimental trials within each block made up from three replications of each of the five sequence lengths. The order of presentation of these fifteen experimental trials was pseudo-randomized such that the restrictions placed on a pure random design were firstly, a particular length of sequence was presented no more than twice in succession and secondly there were as many of the longer sequences as there were shorter sequences in both the initial and final halves of each block of trials.

A Latin Square design was used to organize the presentation orders of the three blocks of trials. A matched pair of subjects was assigned at random to a particular presentation order at the beginning of the experimental session. There were three orders of presentation which are shown in Table 2.5.

Table 2.5

Three Orders of Presentation. Each matched pair of subjects was assigned to one of these orders

Order of Presentation	First Block	Second Block	Third Block
Order 1	Digits	Pictures	Nonsense Shapes
Order 2	Pictures	Nonsense Shapes	Digits
Order 3	Nonsense Shapes	Digits	Pictures

PROCEDURE

The subject was seated in front of the tachistoscope which was adjusted to a suitable height such that the subject could comfortably look into the viewing window. He was then given the following instructions:

"You are going to see a small cross in the middle of the screen which I want you to observe. This cross will be replaced by a sequence of digits/pictures/shapes (depending on the item set currently in use) varying in length from 3 up to 7 digits/pictures/

shapes. Each sequence will remain on the screen for only 2 seconds. As soon as the sequence disappears from your screen you must show me how well you can remember it by placing a ring around those items on the board, that made up the sequence, in their correct order. You must always remember that points will only be given if you remember the order correctly (E. then shows S. the standard card of a six item sequence, for the current item set,and demonstrates by first drawing a ring around each item in turn scanning from left to right). Do you understand what you must do? (If S. did not understand then another card was shown to S. and E. ran through the demonstration again). As soon as you have placed a ring around the last item use the cloth to wipe the board clean. This will show me that you have finished for that particular go."

The subject was then shown another tachistoscope card with a 6 item sequence printed on it and was told, "Now imagine you have seen this sequence on the screen and it has just disappeared. How do you show me that you can remember the correct order of the items in that sequence?"

When the subject had shown that he understood all the instructions he was told to look into the viewing window and watch the fixation cross when it appeared. Five practice trials were then given to the subject followed by the fifteen experimental trials. At the end of a block of trials the subject had a short rest for two minutes during which time the response board was changed to the item set of the next block of trials. The experimenter explained to the subject that the procedure was identical except for the change of item set and that if the subject found this one more difficult he was to guess if he could not remember all of the sequence. It was emphasised that the subject should only guess as a last resort. If the following block of trials adopted the familiar pictures as the item set then the experimenter asked the subject to name all the pictures on the response board prior to the first practice trial.

Immediately after the subject had responded to the final trial of the third block of trials the experimenter produced the nonsense shape response board and asked the subject, "Can you tell me how you remembered these shapes?"

If the subject gave an ambiguous answer he was then asked, "Did you find some names for any of the shapes, and did you use those names to help you remember the order of the shapes?"

If a negation was given by the subject he was asked, "Did you just try to keep a picture or photograph in your mind of the shapes in their correct place?" However, if the subject gave an affirmative answer he was duly asked, "Which of these shapes (E. shows S. the response board) did you use a name for, and what was the name you used?"

Experimental Design

The layout of this experiment represents a partially hierarchal design (Winer, 1971). In the current design matched pairs of subjects 1 through 6 were observed under Order 1; matched pairs of subjects 7 through 12 were observed under Order 2; matched pairs of subjects 13 through 18 were observed under Order 3. Matched pairs of subjects are therefore nested within the Order of Presentation factor (factor A). Each matched pair of subjects had two levels of the Group factor (factor B) i.e. dyslexic and non-dyslexic and each level of factor B was observed at all three levels of the Item Set factor (factor C) and at each level of the Length of Sequence factor (factor D). Replications (factor E) for each

Length of Sequence of each Item Set made up the fifth factor. This design is given as follows:

3 (Orders of Presentation) x 2 (Groups) x 3 (Item Sets) x 5 (Length of Sequence) x 3 (Replications)

There were repeated measures of factors B, C, D and E.

The current design differs from the usual design adopted in the research on dyslexia, where subjects are usually matched by groups and not by pairs. Group comparisons are made between the overall Group means in the latter design rather than between subject means within each matched pair of subjects. Group comparison within each matched pair of subjects offers a much tighter design because IQ can be controlled at the level of the subject rather than at the level of the group.

Scoring the Data

The work on errors in STM has created a consensus of opinion that these errors are primarily order, or transposition, errors (Bjork and Healy, 1974; Fuchs, 1969). Further, there are a number of researchers who have found that good and poor readers do not differ in their ability to recall the stimulus items per se, but they do differ in their ability to reproduce the correct serial order of the stimulus items (e.g. Bakker, 1972; Senf, 1969; Mason, Katz and Wicklund, 1975). It was therefore decided to score for order only, in which case an item was deemed correctly ordered if, in the response, it occupied the same serial position as in the stimulus.

RESULTS

A post hoc decision was made to split the data set into two separate data sets. One data set consisted of all the data collected for sequences of length 5, 6 and 7 items and the other data set consisted of all the data for sequences of length 3 and 4 items. This was desirable since there were obvious ceiling effects on digit sequences at the smaller sequence lengths. Table 2.6 below gives the average performance level in each group for 3 and 4 item sequences combined for each of the three item sets.

Table 2.6

	Digits	Pictures	Nonsense Shapes	Chance
Dyslexic	96.56%	55.3%	46%	29.15%
Non-Dyslexic	99.9%	78.3%	58.2%	
Difference	2.34%	23.0%	12.2%	

From Table 2.6 it is apparent that group differences are minimal in the case of the digit sequences, but this is due to a ceiling effect rather than an interaction between group membership and information processing skills.

Both data sets were analysed using an analysis of variance (ANOVA) for repeated measures designs with the aid of the Program BMDP2V on a CDC 7600 Computer at the University of London Computing Centre. The BMD series of programs have been given a favourable evaluation by Francis (1973). Further BMDP2V is a program for the analysis of variance for repeated measures that was based on Win er's (1971) statistical model for such designs. The same statistical design was used in the current experiment.

ANOVA.1 will be used to refer to the ANOVA for sequences of length 5, 6 and 7 items and ANOVA.2 will be used to refer to the ANOVA for sequences of length 3 and 4 items.

Table 2.7

ANOVA.1
Summary of Analysis of Variance

Source	SS	df	MS	F	One-Tail Probability
Group Totals					
A (Orders)	1506.99	2	753.5	0.90	0.426
Subj.w. group	12510.73	15	834.05		
C (Item Sets)	112607.63	2	56303.81	167.96	0.000
AC	5090.55	4	1272.64	3.80	0.013
C x Subj.w.group	10056.74	30	335.22		
D (Sequence Length)	186.62	2	93.31	0.51	0.606
AD	239.91	4	59.98	0.33	0.857
D x Subj.w.group	5495.66	30	183.19		
CD	1240.52	4	310.13	2.22	0.077
ACD	1025.5	8	128.19	0.92	0.508
CD x Subj.w.group	8378.4	60	139.64		
Group Differences					
B (Groups)	12530.92	1	12530.92	19.93	0.000
BA	42.79	2	21.40	0.03	0.967
B x Subj.w.group	9431.76	15	628.78		
BC	3578.60	2	1789.30	5.51	0.009
BAC	2115.21	4	528.80	1.63	0.193
BC x Subj.w.group	9750.56	30	325.02		
BD	113.78	2	56.89	0.37	0.696
BAD	707.81	4	176.95	1.14	0.357
BD x Subj.w.group	4656.16	30	155.21		
BCD	492.38	4	123.10	0.79	0.537
BACD	1837.84	8	229.73	1.47	0.186
BCD x Subj.w.group	9358.61	60	155.98		
Residual	87466.21	648	134.98		

Design and Results of ANOVA.1

The plan for ANOVA.1 may be considered as a 3 x 2 x 3 x 3 x 3 partially hierarchal design with repeated measures on all but the first factor.

The summary table for ANOVA.1 is given in Table 2.7 above. It has been set out such that the results of greatest interest, that is the group difference results, are separated from the results calculated across groups.

Group Totals

The main effect of factor C (item sets) was highly significant $F(2,30) = 167.96$, $p < 0.001$, but this was the only significant main effect using group totals.

There was also a significant first order interaction AC (Orders of Presentation x Item Set), $F(4, 30) = 3.8$, $p = .013$. There were no other significant interactions for group totals.

A breakdown of the significant main effect of factor C is given in Table 2.8.

Table 2.8

Average Score per Trial

Digits	Pictures	Nonsense Shapes
4.201	2.44	1.62

The increase in the performance level of subjects from nonsense shapes through pictures to digits was not unexpected in respect of Mackworth's (1963) findings. A Duncan Multiple Range test was used as a post hoc test of differences between means of the three item sets. There were three comparisons, namely digits versus pictures, digits versus nonsense shapes and pictures versus nonsense shapes. All three differences between means were greater than their respective least significant ranges at the one per cent level, indicating significant differences between all three means ($p < .01$). There was a significant order of presentation x item set interaction indicating the need to counterbalance the order of presentation due to warm up and fatigue effects. Table 2.9 gives a breakdown of this interaction.

Table 2.9

Mean score per trial for each item set in each Block of Trials

	Block 1	Block 2	Block 3
Digits	3.84	4.71	4.05
Pictures	2.49	2.56	2.27
Nonsense Shapes	1.77	1.26	1.79

From Table 2.9 it is clear that both digits and picture item sets are recalled most efficiently when presented as the second block of trials, although nonsense shapes behave in a converse way. This suggests that processing of nonsense shapes could be different from the processing of verbal material.

Group Differences

The main effect of factor B (Groups) was significant, $F_{(1, 15)} = 19.93$, $p < .001$ which was due to a superior recall of the non-dyslexic subjects (see Table 2.10).

Table 2.10

	Mean score per Trial
Dyslexic	2.41
Non-Dyslexic	3.11

No other main effect were significant.

There was a significant second order interaction BC (Groups x Item Sets), $F_{(2, 30)} = 5.51$, $p < 0.009$. Table 2.11 gives a breakdown of this interaction. From Table 2.11 it appears that the dyslexic group becomes increasingly differentiated from the non-dyslexic group as one moves from nonsense shapes through pictures to digits. This interaction was analysed using the general linear modelling program GLIM 3 and weighted contrasts. By giving a weight to each item set of unity or zero it was possible to analyse group differences at each level of the Item Sets factor separately. For example by assigning a weight of unity to digits and zero to both pictures and nonsense shapes then the Item Sets factor had only one level, namely digits. Having weighted out all but one level of the Item Sets factor, the Group factor could then be fitted to the linear model and tested for significance. This weighting procedure was carried out such that the difference between the two groups was tested at each level of the Item Sets factor.

The results of this weighted contrasts method, using the computer program GLIM 3, (the weightings are given in parentheses after each level of the Item Sets factor) are given below in Table 2.12.

Table 2.11

Item Sets (Mean Score per trial)

Group	Digits	Pictures	Nonsense Shapes
Dyslexic	3.60	2.10	1.53
Non-Dyslexic	4.81	2.78	1.75
Difference (d)	1.21	0.68	0.22

It is apparent from Table 2.12 that groups differ significantly when compared on digits and picture sequences, but they do not differ on nonsense shape sequences. The group differences arise from the dyslexic subjects obtaining lower scores (Table 2.11).

In order to test the null hypothesis (H_0 = group differences on digit sequences are similar to group differences on picture sequences) a separate analysis of variance (ANOVA 1a) was computed on the data for ANOVA 1 less the data for the nonsense shape sequences. H_0 will gain support if the Group x Item Set (df 1) interaction fails to reach significance ($p > .05$).

Table 2.12

One Way ANOVA of Item Sets x Group Interaction using Weighted Contrasts

Weighting of Item Sets	Error			Fit of Group Factor			F
	SS	df	MS	SS	df	MS	
D (1) P (0) NS (0)	265.9	17	15.64	293.12	1	293.12	18.73***
D (0) P (1) NS (0)	195.6	17	11.56	111.7	1	46.47	9.66***
D (0) P (0) NS (1)	165.6	17	9.74	14.81	1	14.81	1.52 NS

Significance levels
*** = $p < .001$; NS = Not Significant ($p > 0.10$)
D = Digits; P = Pictures; NS = Nonsense Shapes

Results of ANOVA 1a

Main Effects

The main effects of Group $F(1,15) = 27.182$ ($p < .001$) and Item Sets $F(1,15) = 111.88$ ($p < .001$) were both significant. The reason for these significant main effects has already been described in the results of ANOVA 1.

Interactions

The Group x Item Set interaction $F(1,15) = 4.399$ ($p = .053$) has reached a level of probability where the apparent change in group differences across the two item sets cannot be attributed to chance factors alone although the F ratio just fails to reach the criterion level to reject H_0. With reference to Table 2.11 it is clear this interaction is brought about by an increased group difference on digits relative to the picture sequences.

There was also a significant Item Set x Order interaction which has been described in the results of ANOVA 1. No other interactions reached significance.

Table 2.13

ANOVA.2
Summary of Analysis of Variance

Source	SS	df	NS	F	Tail Probability
Group Totals					
A (Orders)	1.7267	2	0.863	0.32	0.733
Subj.w.group	40.7639	15			
C (Item Sets)	28.009	1	28.009	28.3	0.00
AC	0.810	2	0.405	0.41	0.671
C x Subj.w.group	14.847	15	0.989		
D (sequence length)	2.370	1	2.370	2.82	0.114
AD	6.837	2	3.419	4.06	0.039
D x Subj.w.group	12.625	15	0.842		
CD	4.481	1	4.481	3.01	0.103
ACD	0.199	2	0.099	0.07	0.936
CD x Subj.w.group	22.319	15	1.488		
Group Differences					
B (Groups)	41.564	1	41.564	26.55	0.000
BA	6.116	2	3.057	1.95	0.176
B x Subj.w.group	23.486	15	1.566		
BC	4.083	1	4.083	1.27	0.277
BAC	1.792	2	0.896	0.28	0.760
BC x Subj.w.group	48.125	15	3.21		
BD	3.000	1	3.000	3.61	0.077
BAD	0.042	2	0.021	0.03	0.975
BD x Subj.w.group	12.458	15	0.830		
BCD	0.0	1	0.0	0.0	1.000
BACD	2.514	2	1.257	1.14	0.345
BCD x Subj.w.group	16.486	15	1.099		

Design and Results of ANOVA.2

The plan for ANOVA.2 may be considered as a 3 x 2 x 2 x 2 x 3 partially hierarchal factorial design with repeated measures on all but the first factor. The level of digits in the Item Sets factor was left out due to a ceiling effect.

The summary table for ANOVA.2 is given in Table 2.13. It has been set out in a similar way to Table 2.7 for ANOVA.1.

Group Totals

The main effect of factor C (Item Sets) was significant, $F\ (1,15) = 28.3,\ p < .001$. Table 2.14 below gives the mean score per trial for each level of the Item Sets factor and shows a similar outcome to the results from ANOVA.1 i.e. pictures are

Table 2.14

Item Set	Mean Score per Trial
Pictures	2.39
Nonsense Shapes	1.805

recalled better than Nonsense Shapes. No other main effects were significant.

There was a significant second order interaction AD (Orders of Presentation x Length of Sequence). The mean score per trial for each length of sequence for each Order of Presentation is given in Table 2.15 below.

Table 2.15

Length of Sequence	Order of Presentation		
	1	2	3
3 Items	1.972	1.977	2.11
4 Items	2.166	2.04	2.097
Difference (1)	0.194	0.063	0.013
Sum	4.138	4.017	4.207

It is clear that the influence of the Length of Sequence factor only occured during Order 1. In the other two Orders of Presentation there is very little difference between recall scores for the two levels of the Length of Sequence factor. During Order

1 the first block of trials consisted of digits, the second block consisted of pictures and the third block consisted of nonsense shapes.

Group Differences

The main effect of factor B (Groups) was significant, F (1,15) = 26.55, $p < .001$ indicating, as in ANOVA.1, that the non-dyslexic group had a better recall score than the dyslexic group (see Table 2.16).

Table 2.16

Group	Mean No. Items Correct
Dyslexic	1.852
Non-Dyslexic	2.345

There was a significant second order interaction BD (Groups x Length of Sequence) which is summarized in Table 2.17 below.

Table 2.17

	Length of Sequence (Mean No. Items Correct)	
Group	3	4
Dyslexic	1.94	1.72
Non-Dyslexic	2.24	2.45
Difference (d)	0.30	0.73

It is apparent from Table 2.17 that the interaction is due to a larger difference between the two groups on the 4 item sequences in comparison to the 3 item sequences.

There is here an important difference between the results of ANOVA.2 and ANOVA.1 with respect to the group difference results. In ANOVA.1 there was a significant Groups x Item Sets interaction which was not obtained in ANOVA.2. Referring to Table 2.6, for 3 and 4 item sequences, the trend of increased group differences for picture stimuli was consistant with the results of ANOVA.1. Despite the fact that group differences were nearly twice as large for picture stimuli (23% compared with 12% for nonsense shapes - see table 2.6) this failed to reach significance ($F = 1.27$, df 1, 15, $p = 0.277$).

Subjective Reports

After the final experimental trial, each subject was asked about his coding strategies (see Procedure section above). The answers from the subjects were classifed into one of four classes as follows:

Class Label	Nature of Answer	Example
A	Suggesting a Verbal Strategy	"There was one I called a lollipop".
B	Suggesting a Non-Verbal Strategy	"I just kept looking at the screen afterwards to remember the pattern."
C	Ambiguous Answer	"I tried to remember them."
D	A case of mis-understanding	Subject reiterates the experimental procedure

A breakdown of the subjective reports is given in Table 2.18 in terms of frequency counts in each group of the 4 classes of answer.

It is apparent from Table 2.18 that most replies to the initial question were ambiguous. Replies were generally of the form, "Well, I just looked at them", and "I just remembered them". However, the second question provided some more positive answers which included six affirmatives from the non-dyslexic subjects (i.e. implying that they used a verbal recoding strategy) and four affirmatives from the dyslexic subjects. The mean correct

Table 2.18

Strategies reported by subjects for remembering nonsense shapes

Q1 = "Can you tell me how you rembered these shapes?"

Q2 = "Did you find some names for any of the shapes etc?"

Q3 = "Did you just try to keep a picture or photograph in your mind of the shapes in their correct place?"

Number	Group	Class Label A	B	C	D
Q1	Dyslexic	1	4	11	2
	Non-Dyslexic	1	6	11	0
Q2 and Q3	Dyslexic	4	9	5	0
	Non-Dyslexic	6	10	2	0

scores per trial for the non-dyslexic and dyslexic verbal recoders are given below in Table 2.19.

Table 2.19

Mean Score Per Trial (Nonsense Shape Sequences)

	Length of Sequence: 3 & 4 items	5,6 & 7 items
Non-Dyslexic Recoders (n=6)	2.25	1.70
Remainder of Non-Dyslexic Grp (n=12)	2.03	1.959
Dyslexic Recoders (n=4)	1.58	1.67
Remainder of Dyslexic Grp (n=14)	1.595	1.476

From Table 2.19 there appears to be some group differences. These differences can be stated:

(1) Non-dyslexic verbal recoders perform better than the remainder of their group on the 3 and 4 item sequences (H_1).

(2) Non-dyslexic verbal recoders perform worse than the remainder of their group on the 5, 6 and 7 item sequences (H_2).

(3) Dyslexic verbal recoders perform as well as the remainder of their group on the 3 and 4 item sequences (H_3).

(4) Dyslexic verbal recoders perform better than the remainder of their group on the 5, 6 and 7 item sequences (H_4).

(5) Non-dyslexic verbal recoders perform better than dyslexic verbal recoders on 3 and 4 item sequences (H_5).

(6) Non-dyslexic verbal recoders perform better than dyslexic verbal recoders on 5, 6 and 7 item sequences (H_6).

The null hypotheses for H_1 - H_6 are tested with the Mann-Whitney U statistic for small samples.

HO_1 = Non-Dyslexic verbal recoders behave in a similar way to the remainder of their group for the 3 and 4 item sequences.

Mann Whitney $U = 25.5$ $N_1=6$ $N_2=12$ $p > 0.05$

HO_2 = Non-Dyslexic verbal recoders behave in a similar way to the remainder of their group for the 5, 6 and 7 item sequences.

Mann Whitney $U = 27$ $N_1=6$ $N_2=12$ $p > 0.05$

HO_3 = Dyslexic verbal recoders behave in a similar way to the remainder of their group on 3 and 4 item sequences.

Mann Whitney $U = 26.5$ $N_1=4$ $N_2=14$ $p > 0.05$

HO_4 = Dyslexic verbal recoders behave in a similar way to the remainder of their group on 5, 6 and 7 item sequences.

Mann Whitney $U = 27.5$ $N_1=4$ $N_2=14$ $p > 0.05$

HO_5 = Non-Dyslexic verbal recoders behave in a similar way to the Dyslexic verbal recoders on 3 and 4 item sequences.

Mann Whitney $U = 3$ $N_1=6$ $N_2=4$ $p < 0.05$

HO_6 = Non-Dyslexic verbal recoders behave in a similar way to the Dyslexic verbal recoders on 5, 6 and 7 item sequences.

Mann Whitney $U = 11.5$ $N_1=6$ $N_2=4$ $p > .05$

From these six hypotheses there is only one null hypothesis i.e. H_5 that can be rejected. In other words non-dyslexic verbal recoders outperform the dyslexic verbal recoders on the 3 and 4 nonsense shape sequences but not on the 5, 6 and 7 item sequences.

If verbal recoding strategies were adopted by more than the six non-dyslexic subjects, who admitted using such strategies, then this could indeed explain the significant group differences in ANOVA.2 and insignificant group differences in ANOVA.1 for the nonsense shape item set.

Discussion of Results

ANOVA.1 and 1a

The singularly most influential factor in ANOVA.1 was the Item Sets factor, which contributed 37.5% of the overall variance. The importance of item type on serial recall has been described by Mackworth (1963) for short term serial recall. Mackworth demonstrated for each of her subjects a strong correlation between naming speed and serial recall for brief simultaneous visual presentations. In particular digits were named fastest followed by letters, colours and finally geometric designs. Similarly Denckla and Rudel (1974) found that the naming speed of digits was always faster than the naming speed of letters or familiar objects even after just one year of schooling.

From ANOVA.1 dyslexic subjects were found to be significantly inferior to non-dyslexic subjects in the serial recall of digit and picture sequences although the two groups had similar levels of performance in the serial recall of nonsense shapes. Further, from ANOVA.1a the dyslexic subjects show a markedly larger departure from a normal performance level on digits compared with pictures.

It therefore appears that there is some process underlying the serial recall of both digits and pictures which is impaired in dyslexic subjects. This same process is operative to a greater extent during the processing of digits thereby increasing the dyslexic-non dyslexic performance gap. However it should be recalled that dyslexic subjects performed better on digits than on picture sequences as did the non-dyslexic subjects. Indeed, the relative increase in performance on digits relative to picture sequences is similar for both groups i.e. digits were recalled 1.71 times and 1.73 times as well as pictures for dyslexic and non-dyslexic subjects respectively. These values compare well with the relative reading rates of Spring (1976) who found digits were named 1.71 times as fast as familiar objects in twelve year old children and Mackworth (1963) who obtained a similar value of 1.89 with adult females as well as Denckla and Rudel (1974) who obtained the value of 2.09 for 10 - 11 year old children.

Baddeley and Hitch (1974) and Baddeley, Thomson and Buchanan (1975) have produced evidence suggesting that the underlying mechanism of memory span is not only predominantly verbal, but also time-based rather than item-based, as proposed by Miller (1959). Applying this model to the current experiment the following predictions can be made:

(1) Memory span will increase from nonsense shapes through pictures to digits.

(2) The ratio between two spans will be of the same order as

the ratio between the two reading or naming rates. Both predictions are realized in the results presented here.

It therefore appears from ANOVA.1 and 1a that dyslexic subjects have a difficulty in specifically remembering sequences of verbal items. Support is therefore given to the hypothesis of a specific response buffer deficit in dyslexia.

ANOVA.2

The main differences between the results from ANOVA.1 and ANOVA.2 are (1) A significant Group x Length of Sequence interaction in ANOVA.2 not found in ANOVA.1 (2) A lack of Group x Item Set interaction in ANOVA.2, that was found in ANOVA.1, despite a very significant overall difference on the Group factor. Thus, with short sequence lengths (3 or 4 items) the two groups are differentiated on both picture and nonsense shape sequences, and for longer sequence lengths group differentiation only appears ($p < 0.001$) for picture sequences and not at all for nonsense shape sequences ($p > 0.05$).

The characteristic influence of sequence length on serial order recall is similar for both the auditory and visual modalities (Mackworth, 1964, 1963). From Mackworth's studies serial recall performance reaches a peak at around 8 digits in the auditory modality (Mackworth, 1964) and 10 digits in the visual modality using a simultaneous presentation (Mackworth, 1963) and in the same study (Mackworth, 1963) serial recall for geometric shapes was maximal at the shortest sequence length of 5 items.

Derk's (1974) study of the length of sequence effect found that the amount of time needed to study a sequence of consonants was a power function of the number of consonants presented. Asking his subjects to rehearse overtly Derks further discovered that this increase in study time was due to an increase in the time subjects rehearsed each item. In other words as the length of sequence increases subjects need to rehearse each item for a longer period of time, the exact amount of rehearsal time needed being a power function of the number of items in the sequence.

In the current experiment on the short sequences of 3 and 4 items it is possible that non-dyslexic subjects could not only recode nonsense shapes verbally but could also rehearse the items satisfactorily. For the longer sequences not only was verbal recoding incomplete at stimulus offset, or more precisely after the iconic trace has faded (Sperling, 1963) but also rehearsal would have been hindered according to Derks' power law. Recall would be further impaired by the subject's continued encoding after stimulus offset whilst they could have been rehearsing. If, as postulated earlier the number of items held in a visual code remains constant across sequences of different lengths then the relative influence of rehearsal, with a fixed study time, will decrease for the shape sequences of longer lengths.

It is unreasonable to suppose that no use of verbal recoding existed during retention of the nonsense shape sequences. Indeed Bartlett (1932) found that in perceiving ambiguous material exposed for short intervals of time, observers characteristically made "effort after meaning", that is they tried to identify the shapes and patterns as representations of real objects. Others using nonsense shapes have also found this irrepressable "effort after meaning" (e.g. Grindley and Townsend, 1973; Van der Plas and Garvin, 1959). The subjective reports in the current experiment also indicate the use of verbal strategies in some subjects which were used to greater advantage by non-dyslexics than dyslexics for the 3 and 4 item sequences. Such an advantage would produce group differences for the shorter sequences and not for the longer sequences.

Although the Group x Item Set interaction failed to reach significance in ANOVA.2 the trend toward a larger group difference on pictures than on shapes, found from ANOVA.1, does occur for 3 and 4 item sequences (see Table 2.20).

Table 2.20

Correct serial recall scores for 3 and 4 item sequences combined for dyslexic and non-dyslexic subjects

Mean correct score per trial (3 and 4 item sequences)

	Pictures	Nonsense Shapes
Non-Dyslexic	2.74	2.036
Dyslexic	1.926	1.611
Group difference (d)	0.714	0.425

Taking the score on the nonsense shapes as a baseline then the non-dyslexic group improve their performance level by 34.6% as opposed to the dyslexic improvement of 19.55% on picture sequences.

Subjective Reports

The subjective reports given by the participants in this experiment have provided corroborative evidence to the objective data.

Only 22% of all dyslexic subjects and 33.3% of all non-dyslexic subjects provided clear evdience that they used names to help them remember the nonsense shape sequences. Of these verbal recoding subjects the non-dyslexic ones were more accurate than their dyslexic counterparts on the 3 and 4 item nonsense shape sequences and equivalent at the longer sequences.

Nisbett (1970) reported that there is "little or no direct introspective access to higher order cognitive processes." and ".... when people attempt to report on their cognitive processes, that is, on the processes mediating the effects of a stimulus on a response, they do not do so on the basis of any true introspection." It is possible therefore that subjects might not report the use of names although the verbal recoding process was in operation. Further, the questions presented to the subjects asked about the use of names, to which a negation does not pre-empt the use of verbal mediation without names, as reported by Blank and Bridger's (1965) subjects during the retention of non-verbal auditory sequences.

Group differences on the 3 and 4 nonsense shape sequences could be due to a more extensive use of verbal mediators than the subjective reports reveal, and, as Blank and Bridger (1965) have shown, children with reading disabilities are inaccurate at using verbal mediational strategies when presented with superficially meaningless sequences.

CONCLUSION

The results from ANOVA.1 provide negative support for a theory of dyslexia which implicates a general deficit in short term memory. Group differences were not significant for nonsense shapes but they were highly significant for digit sequences. This means that dyslexic subjects are not generally impaired at processing and storing information. Instead dyslexic subjects are selectively impaired on the processing and storage of verbal materials.

ANOVA.1 provides a good deal of support for a theory of dyslexia which implicates a specific deficit of the response buffer in short term memory. In the first instance both sets of verbal items, i.e. digits and pictures, elicited significant group differences whereas non-verbal items did not. Secondly it is assumed that the extent of verbal encoding in digit sequences is greater than in picture sequences (Mackworth, 1963; Spring and Capps, 1976) since speed of rehearsal and subvocal naming affects memory span (Baddeley, Thomson and Buchanan, 1975) although the span of the visual short term memory is constant across different item sets. Since group differences were significantly larger for digit than picture sequences this lends support to the theory. However the results from ANOVA.2 were not so clear cut since despite a significant overall group difference the Group x Item Set interaction failed to reach significance. From the subjective reports, the non-dyslexic verbal recoders (i.e. those reporting the use of naming for nonsense shapes) benefited more at the shorter sequences, i.e.(3 and 4 items) than at the longer sequences (i.e. 5, 6 and 7 items) from the use of verbal strategies. For dyslexic subjects the opposite trend prevailed. This observation in combination with Derks' (1974) findings would suggest that the use of verbal rehearsal will be more beneficial at the shorter sequence lengths for nonsense shapes. However, if dyslexic subjects have some linguistic disability then the use of verbal recoding will be of little advantage (Blank and Bridger, 1966).

CHAPTER 3

EXPERIMENT 2

INTRODUCTION

The main findings of Experiment 1 were as follows:

1) Digit span is greater than picture span, which is greater than nonsense shape span for both dyslexic and non-dyslexic subjects.
2) The extent of memory span deficits in dyslexic subjects varies significantly with the nature of the items constituting the span.

Interpretation of these findings was based on a model of short term memory (STM) which includes a response buffer that is time based and stores items in a speechlike code (Baddeley and Hitch, 1974; Baddeley, Thomson and Buchanan, 1975; Ellis, 1979), and it is a partial failure of this response buffer in dyslexic subjects that causes the reduced memory span.

There is a continuing debate on whether the speechlike code of the response buffer is auditory, articulatory, phonetic or phonological (Conrad, 1964; Wickelgren, 1965a, 1965b, 1966, 1969; Lev y, 1971; Peterson and Johnson, 1971; Hintzman, 1965; Ellis, 1979). However it is agreed that the main form of short term memory storage is speechlike although capacity is limited and retention over a period of time is only possible when the information is rehearsed i.e. recycled. Rehearsal has been termed a "control process" by Atkinson and Shiffrin (1968) who adopted a similar theory of rehearsal as proposed earlier by Broadbent (1958). They considered that information stored in a short term store is "read out" of the store one item at a time. When an item is "read out" of the store a space is vacated which is filled by "writing" that item back into the store, thereby recycling information which would otherwise have decayed (Baddeley, 1976). Broadbent (1958), Atkinson and Shiffrin (1968), Sperling (1963), Hintzman (1965), Baddeley (1976) and Morton (1970) are in common agreement that rehearsal involves the covert articulation of information in store, which effectively acts in the same way as the articulation of items during stimulus encoding. It would therefore be expected that by occupying the articulatory apparatus on an irrelevant task (e.g. reciting the alphabet, or repeatedly saying "The") the articulators are unavailable for the conversion of visual information into the speechlike code of the response buffer or rehearsing information already resident in the buffer. Thus Levy (1971), Peterson and Johnson (1971) and Baddeley, Thomson and Buchanan (1975) have used articulatory suppression (AS) to occupy the articulators of S's whilst they performed a concurrent immediate recall task. In each of these studies S's were presented (visually or auditorily) with sequences of letters or words and during the presentation they carried out a concurrent articulating suppression. Without exception the AS concurrent with visual stimulus presentations reduced memory span since AS ".... stops the transformation of a visual stimulus into a phonemic code" (Baddeley et al, 1975). However although AS affected recall of visual presentations it did not affect recall from auditory presentations (Levy, 1971; Peterson and Johnson, 1971; Baddeley et al, 1975) leading Baddeley et al (1975) to comment ".... the assumption is made that articulatory suppression does not prevent rehearsal, but simply inhibits the translation of visual material into a phonemic code". This latter comment of Baddeley et al rests on the assumption that information from any modality can be stored in the response buffer, in a speechlike code, where rehearsal takes place. If the effects of AS are modality specific then rehearsal, which is a common process for both auditory and visual presentations, must be uninfluenced by AS. This being the case then AS performed solely during a retention interval, and therefore after any stimulus recoding, will have little effect on memory span. A corollary of this argument is that rehearsal need not involve articulation. Levy (1971) proposed that rehearsal can occur at two different levels namely a central level where a central mechanism is responsible for rehearsal and at a peripheral level where kinaesthetic feedback from the peripheral articulatory apparatus acts as the mechanism of rehearsal. Now Baddeley et al, 1975 have not tested their assumption (viz. AS does not interfere with rehearsal) by employing a condition where AS occurs during the retention interval only.

Information processing models of Sperling (1963), La Berge and Samuels (1974) and Morton (1979) have indicated that lexical entries in long term memory (LTM) have to be accessed before the speechlike code can be set up in the response buffer, since the phonological features of a word are resident in a lexicon. Lexical access of phonological features is known to be impaired in dyslexic children. Denckla and Rudel (1976) found that dyslexic children are much slower at eliciting picture names on the Oldfield-Wingfield Test (Oldfield and Wingfield, 1965) for all levels of word frequency. Stirling (1978) found that dyslexic children have anomic difficulties such as being unable to remember the word "tooth" for the prong of a comb or "eye" for the hole in a needle. However, there is also a considerable body of evidence to suggest that dyslexic subjects have a disability at the response buffer stage of information processing, since although their item recall (i.e. lexical access) can be apparently unimpaired their retention of serial order may be poor (Mason, Katz and Wicklund, 1975). These are however two distinct events, namely the lexical access and recall of names and also the recall of the serial relationship that exists between these names when serial order formation is important. If indeed serial order memory is impaired in dyslexic subjects and leads to spelling errors such as "was" → "saw", "people" → "pepole" then one must investigate the processes responsible for retaining serial order information. Now, Conrad (1959) found that transpositions of order are the most common error in immediate recall and these transpositions occur nonrandomly between like sounding items. Bjork and Healy (1974) and Fuchs (1964) have argued that order information and item information are stored differently, perhaps separately, in short term memory since order errors vary with serial position and the distance between items (i.e. proximity), neither of which influence item errors (i.e. intrusions from outside rather than transpositions within a series).

In the Baddeley and Hitch (1974) model of short term memory a process called the articulatory loop (in effect equivalent to the response buffer) has the sole responsibility for the retention of serial order in memory span tasks. Baddeley et al (1975) also provided evidence that this articulatory loop is responsible for the word length effect (i.e. memory span is greater for shorter words) and the speed of articulation effect (i.e. large memory spans are composed of items which can be articulated rapidly). Now, if articulatory encoding of visual stimuli is prevented with AS then the word length effect is found to disappear altogether (Baddeley et al, 1975). Therefore AS during an immediate recall task pre-empts the articulatory loop. However AS concurrent with stimulus presentation could affect the articulatory loop indirectly by inhibiting lexical access of speechlike codes such that the articulatory loop would receive no information or by interfering with the storage of items once they have been "loaded" into the articulatory loop. Thus an experimental paradigm in which AS is used concurrently with stimulus presentation cannot be used to differentiate between the processes of stimulus encoding and rehearsal. However AS during a retention interval only will prevent articulatory maintenance rehearsal of information in the response buffer, but will not affect stimulus encoding since this act will be completed before AS commences.

Baddeley (1976), Ellis (1979) and Morton (1979) have argued that the response buffer (i.e. articulatory loop) is critically involved during reading and spelling as a temporary store which stores phonemes or words in their correct order prior to semantic analysis or a written response. Further, Baddeley (1976) has argued that in retarded readers the articulatory loop is defective and responsible for the excess of order errors and reduced digit span in dyslexic children.

Evidence in support of this view was presented in the previous experiment (Experiment 1) in which dyslexic subjects had a relatively poor memory span for verbal items only (e.g. digits and pictures). Sequences of items that could not be named, because they were nonsense shapes, produced similar levels of performance in dyslexic and non-dyslexic subjects. An alternative test of response buffer failure in dyslexic children would be a test of the effects of AS on between group (i.e. dyslexic vs non-dyslexic) digit span differences. If AS can be used to pre-empt the response buffer during rehearsal then under such conditions group differences should be minimized if the explanation for the group x item set interaction in Experiment 1 is correct. Consequently in the following experiment (Experiment 2) AS was used during the retention interval, and after stimulus presentation, to prevent rehearsal specifically but leave stimulus encoding to procede normally.

In addition to testing the hypothesis that dyslexic children have an inefficient response buffer this experiment will allow Baddeley et al's (1975) claim that AS does not affect rehearsal to be tested as well. Also Levy's (1971) claim that rehearsal could occur at two levels, one central and the other peripheral, can also be tested since AS will affect peripheral kinaesthetic feedback but will not affect a central rehearsal mechanism since AS is considered to be a completely automatic task and therefore makes no demands on any central attention mechanisms (La Berge and Samuels, 1976).

METHOD

Subjects

15 dyslexic and 15 non-dyslexic male subjects were included in the experiment. Dyslexic subjects had previously been interviewed at UCNW (Bangor) Dyslexia Unit on the same day and they had been classified as dyslexic. At the interview subjects were given the Ravens Progressive Matrices Test to measure their intelligence, the Schonell Reading Test and Schonell Spelling Test as well as the UCNW dyslexia test (see Experiment 1 for more details). After the dsylexic S's had completed the diagnostic tests they were asked to be subjects in this experiment. In addition to being "diagnosed" as dyslexic, dyslexic subjects conformed to the criteria relating spelling age (SA) to IQ adopted in Experiment 1 (see Experiment 1). The means and ranges for CA, IQ and SA are given below in Tables 3.1 snd 3.2 respectively.

Table 3.1

Mean CA, IQ and SA of subjects

	CA	IQ	SA
Dyslexic (n=15)	15.3	107	11.0
Non-Dyslexic (n=15)	15.2	106	14.0

Table 3.2

Ranges for CA, IQ and SA of subjects

	CA	IQ	SA
Dyslexic (n=15)	14.5-16.2	97-117	8.5-12.7
Non-Dyslexic (n=15)	14.7-15.8	96-125	13.7->14.7*

* The Schonell Spelling Test has an upper limit of 15 years and therefore some non-dyslexic subjects reached the upper limit before making the five consecutive errors necessary for terminating the test.

Procedure

Hardware

An Electronic Developments 2-Field tachistoscope was used with the illumination of field 1, which was used to present the fixation cross, set at 40 Lux and the illumination of field 2, used for stimulus presentations, set at 90 Lux. The tachistoscope was programmed such that when the start button was pressed the fixation cross was presented in the centre of the field of vision for 1.5 secs and followed immediately afterwards by the stimulus sequence with the spatial centre of the sequence occupying the same position in the field of vision as the preceding fixation cross. The stimulus sequence was presented for 2 secs and was followed by a dark post-stimulus field.

Software

Stimulus Software

A stimulus sequence was made up from seven Letraset digits arranged in a horizontal line on white cards measuring 20 cm x 22 cm. Only the digits 0, 1, 3, 4, 6, 8 and 9 were used to the exclusion of 2, 5 and 7 since it was decided to investigate serial order memory rather than item memory. By using the same seven digits throughout the need to identify the items included or excluded in a given trial was eliminated. The mean horizontal visual angle subtended by a digit sequence at the eyes was 6.9° and the average vertical visual angle was 0.9°. There were 35 separate stimulus sequences which were pre-arranged in a pseudo-random manner. The restrictions on pure randomization were (a) over the 35 trials each of the 7 digits appeared in each serial position five times (b) no digit appeared twice in the same sequence (c) no digit occupied the same serial position on successive trials (d) redundant digit sequences (e.g. 1234567 or 1239876) were not included (e) consecutive digit sequences were not obviously similar.

Response Software

Each of the seven Letraset digits (0, 1, 3, 4, 6, 8 and 9) were positioned centrally on a small piece of white card (1.25 cm x 1.25 cm) which was stuck onto a small piece of hard-board (1.25 cm x 1.25 cm x 0.1 cm). To avoid orientation errors during response, which might transform the 6 into a 9 and vice versa, each of the seven square tablets had one blackened edge which indicated its top edge.

Procedure

S's were seated at a table in front of the tachistoscope and given a pack of 20 plain white cards. E. initially sat opposite S. but to one side of the tachistoscope so that he could see and talk to S. S. was then instructed how to perform articulatory suppression. He was told to say "The" clearly and audibly at a rate of once a second whilst dealing a card onto the table at the same rate. S. was instructed to judge the rate by following the beat of a metronome. This continued until the last card had been placed on the table after which E. stopped the metronome. If E. considered that S. had learned to perform the AS correctly then S. was given the following instructions, otherwise the AS practice was repeated:

"In front of you is a piece of equipment with a viewing hole. Shortly I will ask you to look into the viewer and I will ask you whether you are ready. You will then see the dark screen replaced by an illuminated white screen with a small black cross in the middle which you must watch until it disappears. It will be replaced by a sequence of seven numbers which will remain on the screen for two seconds. Your job is to remember the order of the numbers. Now, as soon as these seven numbers disappear from the screen you must show me how well you can remember the order by arranging these seven tablets on the table in front of you in the same order. You will notice that one edge of each tablet is blackened. This edge is the top edge and it must always be the edge farthest away from you so that you don't confuse the number six with a number 9. Now, all seven of these numbers will appear in each and every sequence so when you come to arrange the tablets you must use all of them. And remember that your main objective is to remember the order correctly. Sometimes I will ask you to wait a short while between the numbers disappearing from the screen and you arranging the tablets. During this delay I want you to perform the task where you say "The" and deal the cards just as you have already learned, remembering to do it at the same rate. When the last card in your hand is laid on the table you stop saying "The" and you then arrange the tablets into the correct order. Now, to begin with I simply want you to arrange the tablets as soon as the numbers disappear from the screen without delay. Is everything understood?"

S. was given five practice trials. On the first trial

S. arranged the tablets immediately after stimulus offset. On the second, third and fourth practice trials recall was delayed for 5, 15 and 20 seconds respectively during which S. performed the AS task. Each of these time periods was judged approximately by giving S. 5, 15 or 20 cards respectively. On the fifth practice trial S. was given 20 cards but told to simply deal the cards as before without performing AS. This latter condition was regarded as a control condition of delayed recall without retroactive interference. Table 3.3 summarises the six conditions used in the experimental trials. It will be noticed that condition 3 was not included in the practice trials since practice on the other three AS conditions was considered to be adequate enough.

Table 3.3

Summary of the 6 Experimental Conditions

Condition 1	Immediate Recall				5 trials
Condition 2	5 secs	Delayed Recall	+ AS		5 trials
Condition 3	10 secs	Delayed Recall	+ AS		5 trials
Condition 4	15 secs	Delayed Recall	+ AS		5 trials
Condition 5	20 secs	Delayed Recall	+ AS		5 trials
Condition 6	20 secs	Delayed Recall	NO AS		5 trials

There were five trials per condition and five practice trials for each subject. For each condition all five trials were given consecutively in a single block. There were a total of 35 trials of which the 30 experimental trials were organized into six blocks of five trials. Three condition orderings were planned pre-experimentally in a Latin Square design to avoid practice and fatigue effects. The three orders of presentation are given below in table 3.4.

Table 3.4

Ordering of Conditions

	Conditions					
Order 1:	1	2	3	4	5	6
Order 2:	3	4	5	6	1	2
Order 3:	5	6	1	2	3	4

Five matched pairs of subjects (each pair consisted of one dyslexic subject and one non-dyslexic subject) were assigned to each of the orders of presentation at random.

Experimental Design and Data Analysis

This experiment was organized as a two factor experiment with six levels of the trials factor and two levels of the grouping factor. Similar to Experiment 1 the individual selection of non-dyslexic subjects to match with each dyslexic subject allowed for group comparisons within matched pairs. Therefore each matched pair was considered as a case with two levels of the grouping factor and six levels of trials (i.e. conditions) factor. Hence the experiment conforms to a two factor experiment with repeated measures on both factors (Winer, 1971).

Two systems of scoring were used to assess the ability of an S. to recall serial order. In the first system, called serial position scoring (SPS) a point was given for each digit recalled in its correct serial position, thus given the stimulus "123456" and recalling it, by arranging the tablets, as "563412" S. was given two points since 3 and 4 were recalled in their correct serial position. In the second scoring system, called adjacent pairs scoring (APS), a point was given for each pair of digits where one digit correctly followed another, thus in the above example the S. scored three points since 6 correctly followed 5, 4 correctly followed 3 and 2 correctly followed 1.

The two systems of scoring differ in the following ways:

1) SPS takes into consideration memory for absolute position, which is ignored by the APS system.
2) APS takes into consideration adjacency, or memory for relative position, which is ignored by SPS.

Although serial position has been the traditional scoring procedure for order memory (e.g. Mackworth, 1963; Conrad, 1972) adjacency or relative position has been considered in some experimental designs. For example Wickelgren (1965) told his S's the position of three items at the recall of a nine item sequence. Wickelgren (1965a) and more recently Wickelgren (1969a, b; 1967) and Estes (1972) considered that during serial recall each recalled item could act as a cue for the proceding, and the preceding, items such that by providing the three cue items in the Wickelgren (1965) experiment S's ".... will never get very far off in the cue items that they are using in recall". Evidence to support Wickelgren's model was reported by McNicol (1971) and Fuchs (1969) who found that inter-item transposition errors occured more frequently between adjacent items than between non-adjacent items. Therefore if an item j acts as a cue for a proceding item k and k acts as a cue for a proceding item m then j can act as a cue for m and m can act as a cue for k (Kausler, 1974). Thus the sequence jkm could be easily recalled as jmk.

RESULTS

The mean subject scores for SPS and APS systems for each condition and each group are given in tables 3.5 and 3.6.

Table 3.5

Serial Position Scoring (SPS) - Mean score per block of trials

(n=5 trials, maximum score = 35 per block)

Group	Condition					
	1	2	3	4	5	6
Dyslexic (n=15)	20.2	15.6	14.8	14.9	12.1	17.2
Non-Dyslexic (n=15)	28.33	18.7	18.5	17.9	18.8	25.5
Difference (d)	8.13	3.1	3.7	3.0	6.7	8.3
t-value	5.08	1.39	1.99	1.4	4.98	4.96
Level of significance	$p<.01$	$p>.05$	$p>.05$	$p>.05$	$p<.01$	$p<.01$

Table 3.6

Adjacent Pairs Scoring (APS) - Mean score per block of trials

(n=5 trials, maximum score = 30 per block)

Group	Condition					
	1	2	3	4	5	6
Dyslexic (n=15)	15.4	10.4	10.5	11.6	9.3	12.7
Non-Dyslexic (n=15)	22.5	11.7	12.3	12.9	11.7	20.1
Difference (d)	7.1	1.3	1.8	1.3	2.4	7.4
t-value	3.97	<1	1.14	<1	1.75	4.15
Level of significance	$p<.01$	$p>.05$	$p>.05$	$p>.05$	$p>.05$	$p<.01$

Data from each scoring system was analysed separately, with a 6 x 2 ANOVA for repeated measures on both factors. The program P2V from the BMDP (1977) series was used for the analysis since it is specially designed to cope with the multifactor repeated measures designs set out by Winer (1971). Thus two separate ANOVA's were computed namely ANOVA (SPS) and ANOVA (APS) for SPS and APS scoring systems respectively.

Results from ANOVA (SPS)

The full ANOVA table is set out in table 3.7 below.

Table 3.7

ANOVA for Serial Position Scores

Source	df	SS	MS	f	Prob.
Group	1	1296.05	1296.05	18.2	$p<.001$
Error	14	1563.31	71.2		
Conditions	5	1844.36	368.87	15.93	$p<.001$
Error	70	1620.88	23.15		
Conditions x Groups	5	274.18	54.84	3.09	$p<.025$
Error	70	1240.4	17.71		

The main effect of Group was significant, $F = 18.2$ df 1,14 ($p<.001$), which was caused by a generally superior performance in the non-dyslexic group (see table 3.8). The other main effect of conditions was also highly significant, $F = 15.93$ df 5,70 ($p<.001$).

Table 3.8

Mean Subject score for the 30 experimental trials (max = 210)

Dyslexic	94.8
Non-Dyslexic	127.7

The mean score for each condition is given in table 3.9 below.

Table 3.9

Mean Subject score for each of Conditions 1-6

Condition

1	2	3	4	5	6
24.3	17.2	16.7	16.4	15.8	21.6

In order to analyse the contrasts responsible for the conditions effect a Duncan Multiple Range Test was calculated between the means in accordance with Hick (1964). However the majority of the possible contrasts are of no interest, and therefore were not calculated. The questions of interest here are:
1) Does AS during a retention interval have any effect on recall?
2) Is there any general effect of the amount of AS on recall?
3) Is there any evidence of memory trace decay over an uninterrupted retention interval?

With regard to the first problem the mean of condition 6 (20 sec retention interval without AS) was contrasted with the smallest and largest means from the five AS conditions, namely conditions 5 and 2 respectively. Both contrasts were significantly different ($p<.01$) using the Duncan's test. Thus AS during rehearsal significantly impairs serial order memory.
In respect of the second problem one can observe in table 3.9 that as the amount of AS during the retention interval was increased so did recall scores fall. Thus condition 2 elicited the highest score in the AS conditions whereas condition 5 elicited the lowest score. However the contrast of these two

means (i.e. conditions 2 and 5) was insignificant ($p>.05$) on the Duncan's test. Therefore there is no effect on recall of increasing the amount of AS from five to twenty interpolated articulations. AS nevertheless impairs serial order memory and so it must be assumed that after only five interpolated articulations a significant amount of serial order memory is forgotten. Lastly, in respect of the third problem, the contrast between the means of condition 1 and 6 was calculated to see if there was any forgetting over a twenty second unfilled interval. This contrast was insignificant ($p>.05$) which indicates that there was no significant decay of serial order memory during the unfilled interval.

The Conditions x Groups interaction was significant, $F = 3.09$ df 5,70 ($p<.05$). Table 3.5 gives the mean scores broken down by groups and conditions. The between groups difference scores (d) were calculated as well as matched pairs t-tests between the two groups in each condition. These values are given at the bottom of table 3.5 together with levels of significance. Inspection of these values reveals that the performance of the two groups were significantly different ($p<.01$ in each case) for conditions 1, 6 and 5 (i.e. immediate recall, 20 secs unfilled delayed recall, and 20 secs delayed recall filled with AS) whereas the groups were not significantly different ($p>.05$) in conditions 2, 3 and 4 (i.e. the 5, 10 and 15 secs delayed recall filled with AS). Generally speaking the dyslexic and the non-dyslexic subjects produced similar performances in the conditions where S's had to perform AS, during the retention interval, although with the greatest amount of AS, namely twenty interpolated articulations, dyslexic subjects produced a significantly lower performance.

Results from ANOVA (APS)

The full ANOVA table is set out in table 3.10 below.

Table 3.10

ANOVA for Adjacent Pairs Scores

Source	df	SS	MS	f	Prob.
Group	1	590.42	590.42	9.83	<.001
Error	14	841.24	60.09		
Conditions	5	1840.47	368.09	18.16	<.001
Error	70	1419.2	20.27		
Group x Conditions	5	286.11	57.22	3.3	=.01
Error	70	1222.22	17.46		

The main effect of Group was significant, $F = 9.83$, df 1, 14 ($p<.001$) due to a higher level of performance in the non-dyslexic subjects (see table 3.11).

Table 3.11

Mean Subject Score for the 30 experimental trials (max = 180)

Dyslexic	69.9
Non-Dyslexic	91.2

The other main effect of Conditions was also significant, $F = 18.16$, df 5,70 ($p<.001$). Mean scores for each condition are given in table 3.12 below.

Table 3.12

Mean Subject Score for each of Conditions 1 - 6

Condition

1	2	3	4	5	6
18.95	11.05	11.4	12.3	10.5	16.4

In order to analyse the contrasts responsible for the Conditions effect a Duncan Multiple Range Test was calculated between certain means. Not all differences between condition means were tested for significance. Adopting the same procedure used in ANOVA (SPS) specific means were contrasted. In that analysis an attempt was made to find solutions to three problems. Attempts to find solutions to these same three problems will be made for the current analysis.

With regard to the problem of whether AS affected recall performance the mean of condition 6 was contrasted with the means of conditions 4 and 5, the largest and smallest means respectively from the AS conditions. Both contrasts were significant ($p<.05$, and $p<.01$ respectively). Thus AS significantly reduced recall performance in each of the AS conditions.

In respect of the second problem, whether there was a general effect of amount of AS on recall performance, a contrast was made between the means of condition 2 (smallest amount of AS) and condition 5 (largest amount of AS). This contrast failed to reach significance ($p>.05$) which means that there was no effect on recall of increasing the amount of AS from five to twenty interpolated articulations. Finally the third problem of the effect of retention interval per se on memory was calculated by contrasting the means of conditions 1 and 6. The contrast failed to reach significance ($p>.05$). Thus no memory decay could be observed over a twenty second unfilled retention interval.

The interaction of Conditions x Groups was significant, $F = 3.3$, df 5,70 ($p \doteq .01$). Table 3.6 presents mean scores broken down by groups and conditions. The between groups difference scores

(d) were calculated as well as match pairs t-tests between the two groups in each condition. These values are given at the bottom of table 3.6 together with levels of significance. Inspection of these values reveals that the two groups differed significantly in the immediate recall condition (condition 1) and in the delayed recall without AS (condition 6). In conditions 2 - 5, all of which included AS during retention, group differences failed to reach a level of significance ($p>.05$ in each case). This result is similar to that obtained in the analysis of serial position scores. However using APS there is a slightly more clear cut result since group performance levels differed in the two non-AS conditions but did not differ significantly in any of the four AS conditions (conditions 2 - 5).

Discussion of Results

Serial position scoring and adjacent pairs scoring produced similar results in this test of immediate and delayed serial recall. Both ANOVAS produced significant main effects as well as a significant interaction. The breakdowns of the main effects and two way interaction were also similar for the two methods of scoring. The only difference in the two analyses was the group difference in condition 5, the twenty second delayed recall with interpolated AS. Using the SPS scoring system groups were significantly different in this condition, however, using the APS scoring system group differences were not significant.

Analysis of the effect of conditions showed that there was no significant decay of the memory trace over a twenty second unfilled retention interval. This was true for both methods of scoring. However the digit span was significantly impaired as soon as S. began to fill the retention interval with articulatory suppression. Thus in a 5 sec retention interval, filled with AS, performance was reduced by 29% and 42% for SPS and APS respectively. However the effect of AS had been fully realised by five seconds since no further reduction in performance occurred despite a quadrupled increase in the amount of AS.

Group differences varied across conditions. In general dyslexic and non-dyslexic subjects had similar digit spans in the four AS conditions regardless of the method of scoring, however in the immediate recall and the unfilled delayed recall group differences were large.

CONCLUSION

The results of this experiment support Baddeley's (1976) argument that the excess of order errors in the spelling and reading of dyslexic subjects is due to a malfunction of the articulatory loop. When the articulatory loop in non-dyslexic subjects is incapacitated with articulatory suppression then order errors become as frequent as they were for dyslexic subjects under the same condition. However for these same subjects large group differences existed when the articulatory loop was free to function normally (i.e. when there was no AS).

Liberman et al (1977) have produced evidence which corroborates the results presented here. They used good and poor beginning readers and a test of serial order short term memory for phonetically similar and dissimilar strings of letters. From the results it was clear that in both groups the frequency of order errors was increased for strings of similar letters in both immediate and delayed recall conditions. However, although the two groups differed markedly in the two conditions for the recall of phonetically dissimilar letters this group difference was much smaller in the immediate recall condition and became non-existent in the delayed recall condition for sequences of phonetically similar letters. Liberman et al (1977) concluded that the good readers could use phonetic recoding strategies more efficiently than the poor readers but these strategies were of little value when the letters were phonetically confusable.

The view of Baddeley et al (1975) that AS does not prevent rehearsal was disproved by the results of the present experiment. All 4 AS conditions produced a significantly lower memory span than the delayed recall condition without AS. Even 5 interpolated articulations in a 5 second delay produced a significantly lower score than 20 seconds of delay without AS. Since stimulus encoding had been completed before the onset of AS it is clear that AS selectively interfered with rehearsal which prevents short term memory trace decay (Atkinson and Shiffrin, 1971; Sperling, 1963). This effect of AS on rehearsal indicates that the rehearsal process involves a peripheral kinaesthetic feedback rather than a central rehearsal mechanism (Levy, 1971) since reciting "The - The" is an automatic or em~~m~~issive (Peterson, 1969) act which occupies a minimum amount of central processor time (Baddeley et al, 1976) or attention (Mackworth, 1963; La Berge and Samuels, 1976) yet nevertheless fully occupies kinaesthetic feedback mechanisms of the articulatory system. Evidence in support of this view was presented by Craik and Lockhart (1972) and Craik and Watkins (1973) who showed that rehearsal in a memory span task will maintain the trace at a surface level in the information processing system, which would implicate peripheral mechanisms. On the other hand mental arithmetic which monopolizes working memory, but mainly involves the CPU (Hitch, 1978) is unaffected by AS (Peterson, 1969). Thus the results obtained in this experiment indicate that the inefficiency of the dyslexic subjects response buffer is seen at a peripheral level of articulation. However if the execution time of an event is slowed down at an early stage of processing then it is conceivable that slowed execution time will be apparent at a much later stage of processing.

In the Baddeley et al (1975) experiment they concluded that the articulatory loop's capacity was restricted by time rather than the amount of information or the number of events. They controlled for the speed of lexical access by equating words for word frequency. However Mackworth (1963) and Spring and Capps (1974) found that reading speed or naming speed covary with memory span. In these studies lexical access precedes articulation such that the time to encode each word into the articulatory loop is the sum of lexical access time and articulation time. However if lexical access times are a function of word frequency (Oldfield and Wingfield, 1965) or age of acquisition (Carroll and White, 1973) then it is probably true that articulation time is also a function of these measures of familiarity and experience such that lexical access time and articulation time covary. From the results of Experiment 1 it would be expected that a sequence of pictures, whose names are similar to a sequence of digits, will nevertheless be recalled less accurately than the sequence of digits. Thus the sequence of pictures "Cat-tree-shoe-knife-bun-door" will be recalled less accurately than the sequence of digits "eight-three-two-five-one-four" although the phonetic structure of the words is similar for the two types of word. This is probably due to the fact that digit names are "automatically" accessed from the lexicon whereas object names are not (Denckla and Rudel, 1974). Indeed Sampson and Spong (1962) showed that when conventional and unconventional digits were used as visual stimuli more of the conventional digits were recalled and they were also read faster. However the articulation times for these two sets of digits are obviously identical. It is therefore conceivable that the impaired, or slower, naming ability (i.e. lexical access) of these dyslexic subjects for objects and digits (Eakin and Douglas, 1971; Denckla and Rudel, 1974, 1976) is the cause of the reduced efficiency of the response buffer. Thus if in dyslexic subjects item sets A and B are named at rates x and 2x items per second respectively then memory span for B items will be twice as large as for A items. Now, if the non-dyslexic subjects have naming rates 2x and 4x items per sec respectively then dyslexic memory span for A items will be half as large as the non-dyslexic memory span for A items and equivalent to their memory span for B items.

CHAPTER 4

EXPERIMENT 3

INTRODUCTION

The relationship between reading and the ability to name visual objects has been reported by Jansky and de Hirsch (1972) and Calfee (1977). Jansky et al demonstrated that in kindergarten children picture naming was one of the best predictors of future reading ability. In a longitudinal study Jansky et al found that picture naming ability in kindergarten children correlated highly with reading achievement scores some four years later at the age of eight. The authors commented that ".... reading, like picture naming requires ready elicitaion of spoken equivalents".

Critchley (1970) placed developmental dyslexia within the "aphasiological context", noting that dyslexic children attending his clinic resembled adults considered to suffer from alexia with agraphia. Critchley (1970) commented that dyslexic children were "deemed to be mild examples of aphasic alexia". Similarly Benson and Geschwind (1969) noted that patients classed as alexic and agraphic usually manifested a mild anomic type of aphasia.

The results of Experiments 1 and 2 have suggested that dyslexic subjects have a problem in retaining serial order information of verbal items due to a fundamental disorder of naming. In Experiment 1 it was hypothesised that the poor performance of dyslexic subjects was caused by a slow naming rate of digit and pictures which acts to reduce memory span in a time based short term memory store (Baddeley and Hitch, 1974). It was therefore decided to select some dyslexic subjects and obtain reliable measures of name latency for different sets of items, namely digits, letters and pictures in each subject. A measure of serial recall ability will subsequently be obtained for each subject for visually presented sequences of items. Consequently an analysis of covariance can be calculated with name latency as the covariate and serial order recall score as the dependent variable to test whether name latency is a limiting factor of serial order memory. As yet there have been no studies in which the influence of name latency on serial order recall has been investigated within subjects although a number of studies have found that dyslexic children have long name latencies for pictures (Denckla and Rudel, 1976), slow naming speeds (Spring, 1976) and show bizarre naming in difficult naming tasks (Sterling, 1978).

A frequently used test to measure speed of lexical access is the Oldfield and Wingfield picture name latency test (Oldfield and Wingfield, 1964, 1965). Denckla and Rudel (1976) administered this test to three groups of children who had been assessed as dyslexic without neurological soft signs, non-dyslexic with minimal brain damage (MBD), and non-dyslexic normal children of average reading ability eight to ten years of age. From the results it was clear that in all three groups of children the picture name latency increased with the logarithm of word frequency as Oldfield et al (1964, 1965) had earlier reported in adults. For high frequency words both dyslexic and MBD children had larger name latencies than controls and for low frequency words only the dyslexic subjects had significantly lower latencies than the controls. Denckla et al also noted that the picture name latencies of the control children, even at eleven years of age, were larger than those of non-university adults, which they suggested must indicate that the longer a word has been established in the lexicon then the quicker it can be accessed. Additionaly Denckla et al claimed that the latencies of the dyslexic children paralleled those obtained by Newcombe, Oldfield, Ratcliff and Wingfield (1971) on the same test with dysphasic patients who had suffered left hemisphere lesions. Errors from the dysphasic adults and dyslexic children were ".... clearly related to the process of linguistic retrieval, since correct circumlocutions, pantomimal demonstrations, or associative paraphasic responses predominated" (Denckla and Rudel, 1976).

In Experiment 3a name latencies will be assessed for digits, letters and pictures. Group differences will be calculated for each item set and tested for significance. Subsequently the same subjects will be given a test of immediate serial order recall (Experiment 3b), similar to Experiment 1, which will use the same stimuli from Experiment 3a. The relationship between speed of lexical access and serial order recall can then be assessed. Two types of letters will be used in both experiments, namely accoustically similar and dissimilar letters. These were included as a further test of articulation deficits in dyslexia since accoustically similar letters reduce the effects of articulatory encoding in short term memory (Murray, 1968; Estes, 1973), and have been found to reduce dyslexic - non-dyslexic memory span differences (Liberman et al, 1977).

4.2.1 Experiment 3a - Method

Subjects

16 male dyslexic subjects were individually matched with 16

male non-dyslexic subjects. All subjects were administered the Ravens Progressive Matrices test for IQ, the Schonell graded spelling and reading tests, and all dyslexic subjects had been seen by an educational psychologist, who had certified them as dyslexic and they were attending a special school for such children. As was the case in Experiment 1 (see Experiment 1) subjects were selected according to criteria which related spelling age (SA) to IQ in both dyslexic and non-dyslexic samples. Additionally in the current experiment subject selection followed criteria relating reading age (RA) to IQ. The latter criterion with respect to non-dyslexic subjects was that RA should be the same as or greater than chronological age (CA) i.e. RA $\geqslant$ CA and for dyslexic subjects RA $<$ CA - 1.5 years for IQ $>$ 115, RA $<$ CA - 2.0 years for IQ = 101 to 114, RA $<$ CA - 2.5 years for IQ = 90 to 100. These criteria are summarized in tables 4.1 and 4.2 below for non-dyslexic and dyslexic subjects respectively.

Table 4.1

Criteria used in the selection of Non-Dyslexic Subjects

Subject IQ	Criteria for Spelling Age (SA) and Reading Age (RA)
$>$ 115	SA not less than (CA - 1 year), RA $\geqslant$ CA
101 - 114	SA not less than (CA - 1.5 years), RA $\geqslant$ CA
90 - 100	SA not less than (CA - 2.0 years), RA $\geqslant$ CA

Table 4.2

Criteria used in the selection of Dyslexic Subjects

Subject IQ	Criteria for Spelling Age (SA) and Reading Age (RA)
$>$ 115	SA $<$ (CA - 3.0 years), RA $<$ CA - 1.5 years
101 - 114	SA $<$ (CA - 3.0 years), RA $<$ CA - 2.0 years
90 - 100	SA $<$ (CA - 4.0 years), RA $<$ CA - 2.5 years

Tables 4.3 and 4.4.give means and ranges respectively for non-dyslexic and dyslexic subjects for the parameters CA, IQ, SA and RA.

Table 4.3

Mean scores for CA, IQ, SA and RA for Dyslexic and Non-Dyslexic subjects

Subject Group	Size	CA	IQ	SA	RA
Dyslexic	N=16	14.6	114.2	9.85	11.82
Non-Dyslexic	N=16	14.2	115.1	>13.6	>14.4

Table 4.4

Ranges for CA, IQ, SA and RA for Dyslexic and Non-Dyslexic subjects

Subject Group	Size	CA	IQ	SA	RA
Dyslexic	N=16	13.9-15.7	95-132	7.10-11.10	9.0-14.1
Non-Dyslexic	N=16	12.9-15.3	100-128	13.3->14.1	13.8->14.9

Non-dyslexic SA and RA scores in tables 4.3 and 4.4 are imprecise since the maximum possible score of 15 years was reached by some subjects before the criteria of ten consecutive errors was realized. Hence exact SA and RA scores for non-dyslexic subjects could not be estimated.

MATERIALS

Hardware

A microphone was wired up to an Electronic Developments voice key, which in turn was wired up to a millisecond timer. Timing was begun by a 5 volt pulse emitted from an Electronic

Developments 3-Field Tachitoscope. The starting pulse came at the same time as the stimulus field (Field 2) became illuminated. Timing was stopped by the closing of a switch controlled by the voice key connected to the microphone, such that the first sounds of the subjects voice detected by the microphone caused the switch to close and the timer to cease timing. The time, in milliseconds, elapsed between stimulus onset and the beginning of S's vocal response was given in a lighted display on the face of the timer. The microphone was attached to the underneath of the tachistoscope viewing hole and was therefore about one inch away from the subjects mouth. At the beginning of the experiment the voice key sensitivity bias was adjusted to avoid variations in Voice Onset Time (VOT). Abramson and Lister (1970) have shown that VOT i.e. the onset of vocal chord vibration varies across syllables such as "pa" and "ba" by some 100 msecs. Since a large number of stimuli began with a voiceless sound e.g. "two", "three", "four", "five", "six" and "seven" as opposed to the voiced sounds of "one", "eight", "nine" and "nought" it was essential that onset of voiceless sounds was detected as quickly as onset of voiced sounds. This was achieved by asking each subject to utter a protracted /s/ at a normal amplitude and adjusting the bias on the voice key until onset of the sound caused the voice key switch to close.

The illumination intensity of both Field 1 (fixation cross) and Field 2 (stimulus field) were kept at 90 lux thoughout the experiment. Field 1 was illuminated at all times except during the illumination of Field 2 which lasted for 3 seconds throughout.

Stimuli were printed onto cards which were changed by an

Electronic Developments Card Chagev immediately after simulus offset.

Stimulus Software

White cards measuring 10 cms x 15 cms had a single digit/ letter/picture printed centrally on the card such that this stimulus when illuminated on the tachistoscope screen occupied the same position as the previously illuminated fixation cross.

Four item sets (i.e. sets of stimuli) were constructed, each containing ten items. These were digits (0 - 9 inclusive), uppercase accoustically dissimilar letters (F, H, J, M, O, Q, R, U, Y, Z), uppercase accoustically similar letters (A, K, B, C, D, E, G, P, T, V) and pictures of familiar objects (bell, bucket, cup, chain, dog, glove, ladder, saw, tap and watch). Letraset was used for digit stimuli as well as the two types of letter stimuli and tracings of pictures, (previously used in Experiment 1 and described fully there) were used again to print a picture centrally on each card. The pencil imprint was inked over using a micronorm pen. There were two cards prepared for each stimulus item making 20 stimulus cards per item set. The visual angles subjected at the eye of the subject are given in table 4.5.

Table 4.5

Average Horizontal and Vertical Visual Angles subtended by the stimulus at the Subject's Eye

	Horiz.Viz.Angle	Vert.Vis.Angle
Digits	0.6^{o}	0.9^{o}
Letters	0.6^{o}	0.9^{o}
Pictures	2.9^{o}	2.7^{o}

Response Software

Subjects responded vocally and so no response software was needed.

Organization of Trials

Each subject was given a minimum of 80 trials in which the presentation of a stimulus and the vocal response constituted one trial. If a subject failed to respond or accidentally caused the voice key to respond prematurely then that stimulus card was relocated at the back of the stimulus cards, in the card changer, and presented again as the last stimulus. The 80 trials were split into four separate blocks of trials, one for each item set and subjects were warned at the beginning of each block that they were about to see digits/letters/pictures. There were two presentations of each stimulus for the purpose of increased experimental control, since second exposures have reduced response latencies (Carroll and White, 1973), which might influence group differences obtained from single presentations.

The 20 cards in each block of trials were thoroughly shuffled before being loaded into the card changer and were therefore randomly assorted without any restrictions. These four blocks of trials were ordered in a Latin Square as follows

Table 4.6

Latin Square design for Orders of Item Set Presentation

	Block Number			
Order	1	2	3	4
1	Digits	Dissim Letters	Pictures	Sim. Letters
2	Dissim Letters	Pictures	Sim Letters	Digits
3	Pictures	Sim Letters	Digits	Dissim Letters
4	Sim Letters	Digits	Dissim Letters	Pictures

Subjects from 4 matched pairs were assigned at random to each order, with the restriction that both subjects constituting a matched pair were assigned to the same order.

Procedure

Preparation of Subjects

Each S. was given the pack of 20 stimulus cards at the beginning of each trial block and told to turn over each card saying aloud the name of the stimulus printed on the face of the upturned card. This allowed a pre-experimental check on alternative names and correction thereof. Misnamings occurred for "nought" named as "zero" on eight occasions and "glove" named as "hand" on six occasions. However these errors were corrected before the experimental trials proper.

Experimental Procedure

After a successful preparation S. sat in front of the tachistoscope on an adjustable stool that could be raised or lowered until S's eye level was the same as the viewing hole of the tachistoscope. He was then asked to make a continuous/S/ sound at normal amplitude and the sensitivity bias of the voice key adjusted accordingly. The subject was then asked to make the sound /S/ once every five seconds approximately so that the sensitivity setting could be tested. When E. was satisfied that /S/ at normal amplitude was detected by the voice key he then read S. the following instructions: "The numbers/letters/ pictures you were using a few moments ago will now be shown on a screen which you will be able to see if you look into the viewing tube. You must watch the small cross which is now showing in the centre of the screen. Can you see it? I will shortly say

"Ready?" and you must reply either "Yes" or "No". After you have told me you are ready there will be a two second delay, and then the cross will be replaced by a number/letter/picture (depending on which item set had been used during subject preparation). The object of the exercise is to find out how quickly you can name the items without making any mistakes. Please try very hard to not say anything else apart from the correct name, that is, avoid saying things like "er" or "um" or "Whats its name" as this will be picked up by the microphone and recorded as a wrong answer. This also applies to coughs and heavy breathing or sighing. Remember, the important point is to give the name of the item as quickly as you can, with no additional noises. Is everything clear?"

On acknowledging that everything was understood E. asked S. if he was ready for the first trial and approximately two seconds after S's affirmative reply E. triggered the tachistoscope. This in turn triggered off the timer which ceased timing as soon as S. began his first utterance. The reading of response latency time on the face of the timer was then recorded and the time reset for the next trial. E. then asked S. if he was ready and the next trial began. Stimulus cards from failed trials were placed at the end of the remaining stimulus cards. A trial was judged a failure whenever a sound detected by the voice key preceded the subjects response.

At the end of each block of trials E. asked S. to move his chair to the right of the tachistoscope and gave him a face down deck of cards for the next block of trials. E. instructed S. to turn over the cards one at a time and say aloud the name of the stimulus item printed on the card as he had done earlier. Completion of this preparation was followed by the next block of 20 experimental trials.

All four blocks of trials were administered in succession in one of 4 orders, as described above, to which each matched pair was randomly assigned.

Experimental Design

Response latency times were measured as the time elapsed between stimulus onset and response onset. Latency times were recorded to the nearest millisecond.

This experiment represents a 3 factor (Group x Item Set x Familiarity) design with repeated measures on all 3 factors. As was the case in both Experiments 1 and 2 the tight matching of dyslexic and non-dyslexic subjects allowed for group comparisons within matched pairs. The group factor had 2 levels, namely dyslexic and non-dyslexic. The item set factor had 4 levels, namely digits, accoustically dissimilar letters, accoustically similar letters and pictures of familiar objects The familiarity factor had two levels, namely first exposure and second exposure, and was included as a factor to test for the presence of shorter response latencies on second exposures as reported by Carroll and White (1973) and expected from Morton's (1980) theory of pictogens which act as picture recognition devices akin to logogens for word recognition.

RESULTS

There were 80 response latency times recorded for each subject. These response latencies were the data set which was analysed using program P2V from the BMDP (1977) package. P2V is a program for repeated measures ANOVA and derived from Winer's (1971) model of such experimental designs.

The ANOVA may be considered as a 2 x 4 x 2 repeated measures factorial design with repeated measures on all factors.

The summary table of the ANOVA is given below in table 4.7.

Table 4.7

Summary of the Analysis of Variance for Experiment 3a data (ANOVA 3a)

Source	SS	df	MS	F	Probability
Group Totals					
I (Item Sets)	11439534.8	3	3813178.3	108.0	0.000
Error	1588379.7	45	35297.3		
F (Familiarity)	482708.4	1	482708.4	36.55	0.000
Error	198106.5	15	13207.1		
IF	504318.6	3	168106.2	14.42	0.000
Error	524607.5	45	11657.9		
Group Differences					
G (Groups)	6780184.4	1	6780184.4	11.05	0.005
Error	9205987.6	15	613732.5		
GI	98256.5	3	32752.2	0.620	0.605
Error	2375056.5	45	52779.0		
GF	121343.99	1	121343.99	6.796	0.020
Error	267810.07	15	17854.0		
GIF	274064.6	3	91354.9	8.47	0.000
Error	485247.1	45	10783.3		

Group Totals

The main effect of factor I (item sets) was highly significant, $F(3,45) = 108.0$, $p < .001$. Mean scores for all four item sets are presented in table 4.8.

Table 4.8

Mean Response Latency Times (MSecs) for the 4 Item Sets

	Digits	Dissimilar Letters	Similar Letters	Pictures
Latency Time (msecs)	530.54	564.54	539.99	696.72

The Duncan Multiple Range Test (Hick 1964) was used to make statistical comparisons between the means ordered from high to low. From this test there were significant differences ($p < .01$ in each case) between the mean latency for pictures and the mean latencies for digits, similar letters and dissimilar letters respectively i.e. response latency for picture stimuli was significantly larger than response latency for any of the other item sets. There were also significant differences between the mean latency times of dissimilar letters and digits ($p < .01$). No other contrasts were significant.

The main effect of factor F (familiarity) was also significant, $F\ (1,\ 15) = 36.549$, $p < .001$. Table 4.9 presents the mean latency times of the four item sets for first and second presentations and the difference (d) scores are latency difference times (msecs) between first and second presentations.

Table 4.9

Mean subject response latency times for each item set on first and second presentations and the latency time differences between presentations

	Digits	Dissimilar Letters	Similar Letters	Pictures
1st Presentation	534.13	567.32	551.18	734.09
2nd Presentation	526.95	561.76	528.8	659.35
Difference (d)	7.18	5.56	22.38	74.74

From table 4.9 above it is clear that second presentations lead to faster response latency times in all four item sets. However there was a second order interaction of I (item set) x F (familiarity), $F\ (3,45) = 14.42$, $p < .001$ i.e. the effect of factor F differed between levels of factor I. To analyse this interaction separate ANOVA's were computed for each level of factor I to test for the presence/absence of a significant effect of factor F. This was achieved using an interactive program for general linear modelling (GLIM3) mounted on the CDC6500 computer at Imperial College, London. With GLIM3 it was possible to use the original data set but, prior to removing the effects of factor F, three levels of I were given zero weighting thereby excluding that data from the analysis. This becomes tantamount to four 2 x 2 ANOVAs computed for each of the four levels of I. At the same time effects of G (group) and G x F were tested in each ANOVA, thereby allowing a meaningful analysis of the third order G x I x F interaction in the main ANOVA referred to as ANOVA 3a (see table 4.7). Table 4.10 gives summaries for ANOVAs 3b, 3c, 3d, 3e. In each case the effects of factor F and second order interaction GF only are included since analysing factor G is redundant because in ANOVA 3a group differences were significant overall, $F\ (1,15) = 11.05$ ($p < .001$) without there being any second order GI interaction, $F\ (3,45) = 0.62$ ($p = 0.605$) i.e. group differences do not vary across item sets.

From table 4.10 it is apparent that factor F (familiarity) was significant only when the item set was the picture stimuli, the effect being insignificant with respect to digits, dissimilar letters and similar letters.

Table 4.10

Separate ANOVA's for each level of the Item Sets Factor

No.	Item Set Included	Source of Variance	SS	df	MS	F ratio	Probability
ANOVA 3b	Digits	F (familiarity)	10000	1	10000	<1	>.05
		Error (F x Between Subj pairs)	202000	15	13000		
		GF (group x familiarity)	400	1	400	<1	>.05
		Error (GF x Between Subj pairs)	2020000	15	135000		
ANOVA 3c	Dissimilar Letters	F	500	1	500	<1	>.05
		Error	218000	15	14500		
		GF	50000	1	50000	<1	>.05
		Error	2180000	15	140000		
ANOVA 3d	Similar Letters	F	11000	1	11000	2.75	>.05
		Error	56000	15	4000		
		GF	110000	1	110000	2.95	p > .05
		Error	560000	15	36300		
ANOVA 3e	Pictures	F	880000	1	880000	62.86	<.001
		Error	210000	15	14000		
		GF	390000	1	39000	19.5	<.001
		Error	280000	15	20000		

Group Differences

The main effect of factor G (groups) was significant, $F (1,15) = 11.047$, $p < .005$ which was due to the larger response latencies of the dyslexic subjects overall (see table 4.11 below).

Table 4.11

Mean Response Latency Times (MSec) for Dyslexic and Non-Dyslexic Subjects

	Mean Latency Time (MSecs)
Dyslexic	634.4
Non-Dyslexic	531.5
Difference (d)	102.92

There was no second order interaction between group and item set factors indicating that response latency difference between groups was consistent over item sets. However, there was a significant second order GF (group x familiarity) interaction, $F (1,15) = 6.796$, $p = 0.02$. Table 4.12 gives a breakdown of this interaction.

Table 4.12

Effect of Familiarity on Response Latency Times (MSecs) between Dyslexic and Non-Dyslexic Subjects

	Mean Response Latencies	
	1st Presentation	2nd Presentation
Dyslexic	655.03	613.8
Non-Dyslexic	538.33	524.6
Difference (d)	116.7	89.2

It is clear from table 4.12 that response latency times for both groups are shorter in the second presentation condition but this latency reduction was greater for dyslexic subjects, thereby reducing group differences in the second presentation condition by 23.6%. However, the influence of familiarity on group differences varied across item sets since the third order interaction GIF was significant, $F = 8.47$, df 3,45, $p < .001$. The raw data relevant to this interaction are presented in table 4.13. To test for the effects of this interaction 4 separate ANOVAs were computed for each level of the item set factor

Table 4.13

Breakdown of the Group x Item Set x Familiarity interaction. Each cell presents the mean latency (msecs) for a subject.

Item Set

	Digits	Dissimilar Letters	Similar Letters	Pictures
1st Presentation				
Dyslexic	576.75	622.84	602.66	817.86
Non-Dyslexic	491.51	511.80	499.69	650.32
Difference (d_1)	85.24	111.04	102.97	167.54
2nd Presentation				
Dyslexic	572.01	617.17	571.81	694.20
Non-Dyslexic	481.89	506.35	485.80	624.499
Difference (d_2)	90.12	110.82	86.01	69.7
($d_1 - d_2$)	-4.88	0.22	16.87	97.84

separately and these are presented as ANOVA's 3b, 3c, 3d, and 3e in table 3.11. The relevant feature of each of these ANOVA's is the GF interaction which was significant for picture stimuli, $F = 19.5$, df 1,15, $p < .001$ and insignificant for digits, $F < 1$, df 1,15 ($p > .05$), dissimilar letters, $F < 1$, df 1,15 ($p > .05$) and similar letters $F = 2.95$, df 1,15 ($p > .05$). Thus the third order GIF interaction is due to a larger effect of familiarity in dyslexic subjects for picture stimuli only, otherwise the effect of familiarity was consistent between groups for digits, dissimilar letters and similar letters.

<u>Summary of Results</u>

Experiment 3a was a test of the speed of lexical access. When the response latency times were collapsed across the two groups it was found that mean response latency times for the familiar picture stimuli (see p. 81 in the report of Experiment 1 for Thorndike-Large word frequencies) were larger than for any of the other three item sets. However this response latency difference was significantly reduced in the case of second presentations. This practice effect was caused by "local" (i.e. during the course of the experiment) familiarity which has been reported in other experiments (King-Ellison et al, 1954; Neisser, 1954; Ross, Yarczower and Williams, 1956; Carroll and White, 1973). Now, Morton (1981) has introduced "pictogens" into the logogen model. Pictogens are devices which make a particular picture name available just as a logogen "makes a word available as a response" (Morton, 1979 p. 112). Therefore the effect of pre-exposure would be expected to reduce the visual threshold just as it does for words. However it is also interesting to note that the visual thresholds for digits and letter stimuli failed to respond to a previous exposure. It seems likely that lexical access to these stimuli is automatic (La Berge and Samuels, 1974; Denckla and Rudel, 1974) to the extent that increased exposure fails to reduce the response latency (Shapiro, 1968; La Berge and Samuels, 1974). However two other issues should be mentioned here. Firstly the response latency times for digits are significantly shorter than the response latencies for the dissimilar letters and secondly there is a tendency for the accoustically similar letters to respond to familiarity i.e. Mean latency for second presentations is 22.38 msecs shorter than the mean latency for first presentations compared with a difference of 5.56 msecs for the dissimilar letters. With regard to the first issue the response latency difference can be explained by the effect of set size (Hick, 1952) since there are a possible twenty six letters to select from as opposed to only ten digits. Although only ten dissimilar letters were used in the experiment Welford (1967) reported that subjective set size is more influential than the objective set size prepared artificially by the experimenter. This is endorsed by the finding of an influence (albeit non-significant, $F(1,15) = 2.75$, $p > .05$) of familiarity by reducing response latency at the second presentation for acoustically similar letters. It is hypothesised here that during the course of the experiment subjects realized that all letter names in this set ended in "ee" (i.e. "bee", "cee", "dee" etc.) which reduced the subjective set size by eliminating all letter names that did not end in "ee".

In respect of group differences the dyslexic subjects were on average some 102.92 msecs slower than their non-dyslexic matches and this difference was consistent over all four item sets. The only other between groups effect of interest was a three way interaction of Group x Item Set x Familiarity. This interaction resulted from a much greater effect of familiarity in dyslexic subjects for pictures. Thus the mean response latency for dyslexic subjects was reduced by some 123.66 msecs at second presentation as opposed to 26.82 msecs for non-dyslexic subjects.

These results appear to indicate that the dyslexic subject responds to pre-exposure more than the non-dyslexic subject in the case of "unautomated" lexical access, although name production of "automatized" (Denckla and Rudel, 1974) stimuli, and even pre-exposed stimuli is still significantly slower. It should also be mentioned that the dyslexic subjects produced a greater familiarity effect for acoustically similar letters than non-dyslexic subjects. However this trend was not significant ($F(1,15) = 2.95$, $p > .05$)

4.3.1 EXPERIMENT 3b

Subjects

The subjects from Experiment 3a were used for the current experiment. Details of the subject selection procedure can be found in the subjects section in Experiment 3a.

Materials

Hardware

An Electronic Developments 2-Field tachistoscope was used with illumination of Field 1 (Fixation Cross) set at 40 Lux and that for Field 2 (Stimulus Field) set at 90 Lux. Exposure time of Field 1 was 1.5 seconds and for Field 2 was 2.0 seconds. Exposure times for both fields were set before the experiment and remained at these levels throughout.

The card changer auxiliary was used to change the stimulus cards after each trial.

Software

The stimuli were 7 item sequences printed onto 15 cm x 10 cm plain white card. 5 item sets were used with each set made up of 10 items. These 5 sets were digits, the acoustically similar, and the acoustically dissimilar letters, and the pictures used previously in Experiment 3a as well as the ten nonsense shapes from Experiment 1. Stimulus sequences had a fixed length of 7 items with items selected pseudorandomly from the set of ten without replacement. The restrictions on randomization were firstly that familiar sequences would be exempted e.g. 1234567 and secondly that consecutive trials had no single adjacent pair of items in common.

Digit and letter sequences were made from Letraset stuck onto the white cards. The blueprints for both pictures and nonsense shapes used in Experiment 1 were photographically reduced in size from which tracings in pencil were made. These tracings were then printed onto the white card and inked over using a Rotring Micronorm pen with black ink.

The average visual angles, subtended at the subjects' eyes, during an experimental trial are given below in Tables 4.15 and 4.16.

Table 4.15

Mean Visual Angles (Horizontal) subtended by stimuli

Item Set	Horizontal Angle
Digits	6.9^{o}
Dissimilar Letters	7.7^{o}
Similar Letters	7.7^{o}
Pictures	15.3^{o}
Nonsense Shapes	13.8^{o}

Table 4.16

Mean Visual Angles (Vertical) subtended by stimuli

Item Set	Vertical Angle
Digits	0.11^{o}
Dissimilar Letters	0.11^{o}
Similar Letters	0.11^{o}
Pictures	0.28^{o}
Nonsense Shapes	0.20^{o}

Response Software

A motor response was used in the current experiment, similar to that used in Experiment 1. Five response boards were constructed from thick white card onto which were printed the ten items of a particular item set in two columns and five rows. The whole was covered in transparent acetate material. The response boards for digits, pictures and nonsense shapes had already been used in Experiment 1 previously (see Appendix A Table A for examples). The two new response boards for the two letter sets were similar to that for digits except for the replacement of digits by the relevant letters.

Subjects were presented with the relevant board for the forthcoming block of trials together with a felt tipped pen, filled with water soluble ink, and a damp cloth. The subjects were required to make their response by drawing a ring around each item in the correct serial order with no item being ringed twice in the same trial. After each trial the subject wiped all traces of the ink from the response board with the cloth.

Organisation of Trials

Each block of trials was made up exclusively from sequences of one item set only. There were five blocks of trials. Within each block the first three trials were considered as practice trials and not recorded. Ten experimental trials then followed.

A Latin Square design was used to organise the presentation order of the five blocks of trials. A matched pair of subjects was assigned randomly to a particular presentation order at the beginning of the experimental session. There were five orders of presentation which are shown in Table 4.17.

Table 4.17

Latin Square Matrix of Blocks of Trials

Order of Presentation	Block 1	Block 2	Block 3	Block 4	Block 5
1	Digs	DS Letts	S Letts	Pics	N Shapes
2	DS Letts	S Letts	Pics	N Shapes	Digs
3	S Letts	Pics	N Shapes	Digs	DS Letts
4	Pics	N Shapes	Digs	DS Letts	S Letts
5	N Shapes	Digs	DS Letts	S Letts	Pics

Digs = Digits
Pics = Pictures
DS Letts = Acoustically Dissimilar Letters
S Letts = Acoustically Similar Letters
N Shapes = Nonsense Shapes

Procedure

S. was seated in front of the tachistocope on an adjustable stool that could be raised and lowered to establish the most comfortable position for S. with the eye level corresponding to the level of the viewing tube. He was then given the following instructions:

"You are going to see a small cross in the middle of the screen which I want you to observe. This cross will be replaced by a sequence of 7 digits/letters/ pictures/nonsense shapes (depending on the item set currently in use). Each sequence will remain on the screen for only 2 seconds. As soon as the sequence disappears from your screen you must show me how well you can remember it by placing a ring around the correct items on the board, in their correct order. You must always remember that points will only be given if you remember the order correctly (E. then shows S. the standard card, of a 7 item sequence, for the current item set and demonstrates by first placing a ring around the left most stimulus item on the response board followed by the next six items in their left to right serial order). Do you understand what you must do? (If S. did not understand then another card was shown to S. and E. ran through the demonstration a second time). As soon as you have placed a ring around the last item use the cloth to wipe the board clean. This will show me that you have finished for that particular trial."

S. was then shown another stimulus card with a 7 item sequence printed on it and was told, "Now imagine you have seen this sequence on the screen and it has just disappeared. How do you show me that you can remember the correct order of the items in that sequence?"

When S. had shown that he understood all the instructions he was told to look into the viewing tube and watch the fixation cross when it appeared. Three practice trials were then given to S. followed by the ten experimental trials. At the end of a block of trials S. was told that the stimulus items had now been changed to the next item set and was given the relevant response board. E. explained to S. that the procedure was identical except for the change of item sets and that if he found this one more difficult he was to guess the order of the seven items. It was emphasised that the subject should only guess as a last resort. If the block of trials used either digits, letters or pictures then E. asked S. to name them prior to the first practice trial.

Experimental Design

The layout of this experiment represents a 2 x 5 factorial design with repeated measures on both factors. Factor G represents the two levels of the groups factor, namely dyslexic and non-dyslexic and is treated as a repeated measures factor since groups were matched by subject pairs such that each case represents the scores of both subjects within a particular matched pair. Factor I represents the five levels of the item sets factor. Both factors are fixed. The experiment is therefore designed as a two factor repeated measures design which will be analysed initially with an analysis of variance for such designs (Winer, 1971).

Adjustments for the effect of covariates is possible. There are four covariate measures corresponding to the four name latency estimates. Each 'criterion measure' (W iner, 1971, p. 752), corresponding to a score for a set of sequences for subject i, is paired with a single covariate, namely the mean name latency of subject i for that item set. The design is similar to case (2) of W iner (1971). There is of course no covariate measure for level 5 (nonsense shapes) of factor I since no name latency covariate exists and so any statistical model for the anlaysis of covariance will omit the data for this level.

Scoring the Data

In line with the rationale of Experiment 1 it was decided to score each sequence for order only. Thus each response was scored for serial position. With this method a point is awarded for each item recalled in its correct serial position. Further details of the scoring procedure are given in Experiment 1.

RESULTS

The number of items recalled in their correct serial position were summed across the ten experimental trials for each item set. Correspondingly for each subject there were 5 totals, one for each item set. Since a matched pair design had been adopted a case in the ANOVA included the scores from both members of the matched pair, which allowed a within matched pairs group analysis. Therefore factor G, with two levels, is the groups factor and factor I, with five levels, is the item sets factor. The full ANOVA table is presented in table 4.18.

Group Totals

The main effect of factor 1 (item sets) was highly significant, $F (4,60) = 65.34$ $(p < .001)$. The mean scores for all five item sets are presented in table 4.19. A Newman Keuls post hoc test for differences between means was calculated and the level of significance is given below each mean contrast. It is clear that there are significant differences between all such contrasts.

Table 4.18

Summary ANOVA for Experiment 3b data

Source	SS	df	MS	F	Prob
Group Totals					
I (Item Sets)	7111.9	4	1777.97	65.34	$p < .001$
Error	1632.7	60	27.21		
Group Differences					
G (Groups)	970.22	1	970.22	18.94	$p < .001$
Error	768.37	15	51.22		
GI (Groups x Item Sets)	839.77	4	209.94	8.80	$p < .001$
Error	1431.62	60	23.86		

Table 4.19

Mean serial recall score from ten trials (no. items in correct serial position)

	Digs		ADL		ASL		Pics		NS
	4.84		3.92		3.26		2.71		2.08
		d=.92		d=.66		d=.55		d=.63	
Newman Keuls Test		p<.01		p<.01		p<.01		p<.01	

Digs = Digits

ADL = Accoustically Dissimilar Letters

ASL = Accoustically Similar Letters

Pics = Pictures

NS = Nonsense Shapes

Group Differences

The main effect of factor G (groups) was significant, $F(1,15) = 18.94$ ($p < .001$) due to an overall superior performance of the non-dyslexic subjects. However there was a significant 2-way interaction between groups and item sets, $F(4,120) =$

8.80, $p < .001$ indicating that the group differences varied across the five item sets. Table 4.20 gives mean scores for each group on each of the five item sets.

Table 4.20

Mean serial recall score of each group from ten trials (max = 7.00)

	Digits	Dissimilar Letters	Similar Letters	Pictures	Nonsense Shapes
Non-Dyslexic (n = 15)	5.52	4.55	3.78	2.65	2.06
Dyslexic (n = 15)	4.14	3.28	2.75	2.78	2.10
difference (d)	1.38	1.27	1.03	-0.13	-0.04
Ratio Score (d/N-Dys)	.25	.28	.272	-.05	-0.02

To analyse this interaction separate ANOVA's were computed to test for group differences in each of the five item sets independently. With regard to these ANOVA's there was a significant group difference for the data from digit sequences, $F(1,15) = 18.06$, $p < .001$, as was the case for the accoustically dissimilar letters, $F(1,15) = 20.12$, $p < .001$ and the accoustically similar letters, $F(1,15) = 15.34$, $p < .001$. However in respect of picture and nonsense shape sequences the group differences were insignificant, $F(1,15) = 0.24$, $p > .05$ and $F(1,15) = .04$, $p > .05$ respectively. In addition a two way ANOVA was also calculated to compare the two groups on the two types of letters (i.e. a 2 x 2 ANOVA) to test for a group by letter type interaction. This interaction proved to be insignificant, $F(1,15) = 0.56$.

Summary of Results

The results of this experiment are similar to those of Experiment 1. Dyslexic subjects were distinguished from non-dyslexic subjects on serial recall for strongly verbal items, such as digits and letters. For nonsense shape sequences the finding in Experiment 1 of no group differences was replicated. However in Experiment 1 the groups were found to differ significantly on the recall of picture sequences, a result not replicated here. It was interesting to note that in Experiment 1 group differences were found for nonsense shapes only when the sequences were three or four items long, whereas no group differences were found for five, six and seven item sequences. It was suggested in the conclusion of Experiment 1 that for the longer nonsense shape sequences the role of verbal recoding is less than it is for the shorter sequences since the amount of articulation needed per item increases as a power function of the number of items presented (Derks, 1974). It is therefore possible that by increasing the length of picture sequence to seven items the role of articulation in serial order recall is reduced to a minimum thereby extinguishing the group difference. This argument is endorsed by the ratio scores in table 4.20 since the digits and letters have similar ratio scores as do the pictures and nonsense shapes, although the ratio scores for the digits and letters are very different from the ratio scores for the pictures and nonsense shapes. From Experiment 2 it is clear that digits are encoded verbally as must be the case for the letters in the current experiment, since there was a significant effect of accoustic similarity. Thus the picture sequences were probably encoded in the same way as the nonsense shape sequences, which at lengths of seven items involve little verbal encoding (see Experiment 1).

The Group x Letter-Type interaction was not significant. This result is in contrast to the findings of Liberman et al (1977) and suggests that the performance of dyslexic subjects during serial recall is hampered by the acoustic similarity of letters as much as it is in non-dyslexic subjects. It is doubtful that verbal encoding was minimized in the case of the accoustically similar letter sequences since they were recalled significantly better than picture and nonsense shape sequences. It is probably more likely that successful verbal rehearsal was made more difficult by the accoustic similarity and subjects would have to exert more effort to avoid transposing phonemes. This extra demand of attention to phonological features (La Berge and Samuels, 1974) would further limit the amount of attention available and thus cause a reduction in memory span. However the demands made on the subjects' phonological skills would be constant for the two types of letter since a "pay-off" will occur between amount of phonological effort and memory span. If the phonological encoding of dyslexic subjects is less precise, leading to more phonemic confusions, then by increasing the demands on the dyslexic subjects phonological skills one would expect a reduced memory span as one would expect for non-dyslexic subjects.

4.4.1 Speed of Lexical Access and Serial Recall Compared

In the Introduction to Experiment 3a it was suggested that the poor serial recall performance of dyslexic subjects could result from their slower lexical access. If this were true then a covariance analysis, with name latency as the covariate and serial recall performance as the dependent variable, could result in the elimination of group differences on serial recall. However, since the results of Experiment 3a and 3b have shown that dyslexic subjects are not only slower at lexical access but also less efficent in serial recall, it will probably be true that a regression of name latency on memory span scores will be significant if all the data ~~is~~ are used, although within each group this relationship may not exist. In other words if groups differ on two unrelated variables then a regression analysis using the data from both groups could provide a spurious relationship between the two variables. This issue has been examined mathematically by Lord (1969). Fairfield-Smith (1957) pointed out that in this type of design (i.e. two groups, and two dependent variables with groups differing on both variables) the regression model used to eliminate the association between the contaminating and independent variables is often incorrect. Therefore an analysis of covariance with data collapsed across both groups was not calculated since this could lead to a spurious regression model. Instead, for each group a regression of name latency versus serial recall score was calculated using mean group scores for digits, accoustically dissimilar letters and pictures (accoustically similar letters were omitted since the serial recall score was also affected during rehearsal by accoustic similarity). Subsequently within group regressions were calculated for each item set separately with the two measures for each subject representing one case.

Results of Regression Analyses

Figures 4.1, 4.2, 4.3 and 4.4 are graphical plots of group mean serial recall score on group mean name latency for the three item sets. Since there was a significant effect of familiarity on name latency (see table 4.7) separate graphs were plotted for first and second presentations. Thus figures 4.1 and 4.2 correspond to first and second presentations respectively for dyslexic subjects whereas figures 4.3 and 4.4 correspond to first and second presentations respectively for non-dyslexic subjects. The results from the regression analysis for each of these plots are given in table 4.21.

Table 4.21

Results of Regression Analysis-Group Name Latency for each item set regressed onto group serial recall score

Group		Reg Coeff(β)	S.E.	t-value	df	Prob
Dyslexic	1st Pres	-0.033	0.01798	-1.85	1	$p > .10$
	2nd Pres	-0.0747	0.023	-3.20	1	$.05 < p < .10$
Non-	1st Pres	-0.1155	0.026	-4.43	1	$.05 < p < .10$
Dyslexic	2nd Pres	-0.132	0.024	-5.54	1	$.05 < p < .10$

Due to the shape of the curves in Figures 4.1, 4.2, 4.3 and 4.4 $\log_{10}$ (latency) was subsequently calculated and regressed onto group serial recall score. The results of the subsequent regression analysis are given in table 4.22.

FIGURE 4.1

Dyslexic - First Presentation

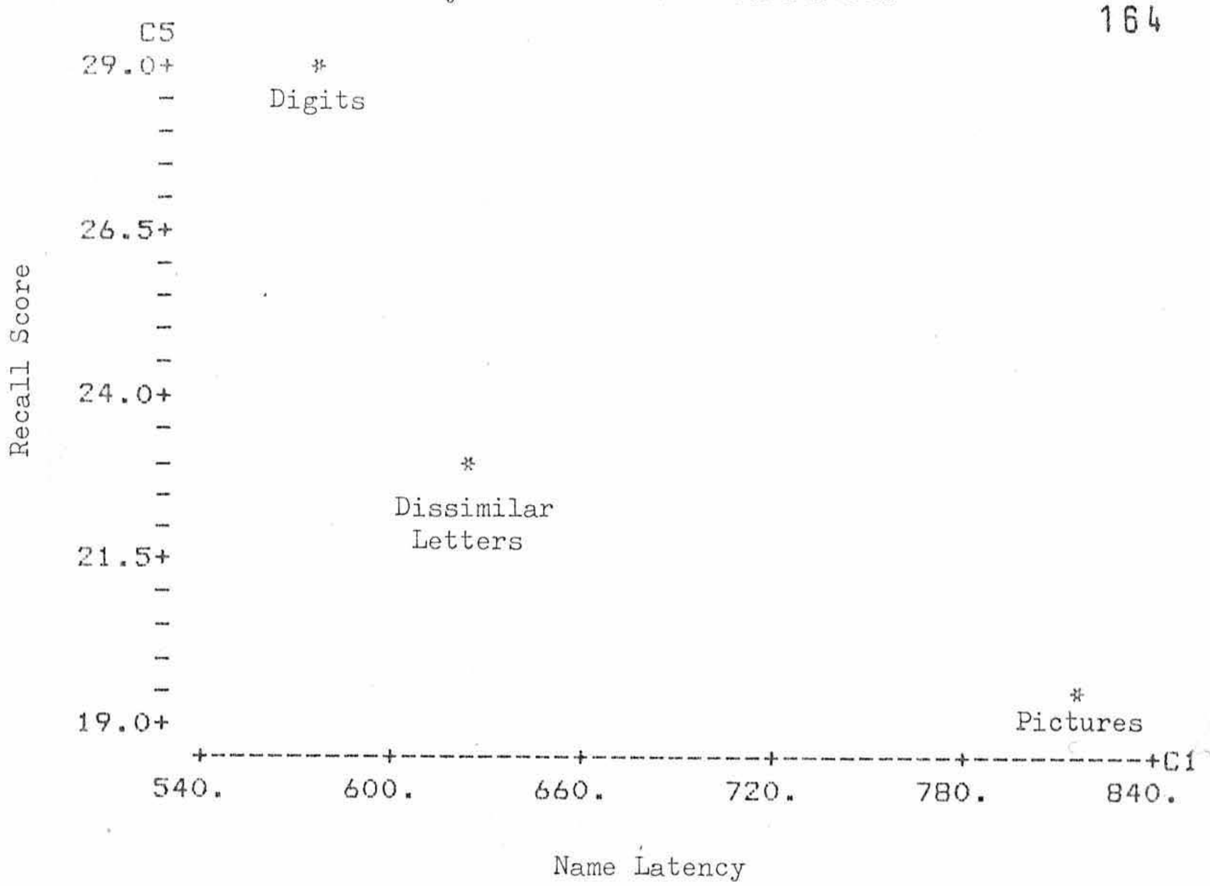


FIGURE 4.2

Dyslexic - Second Presentation

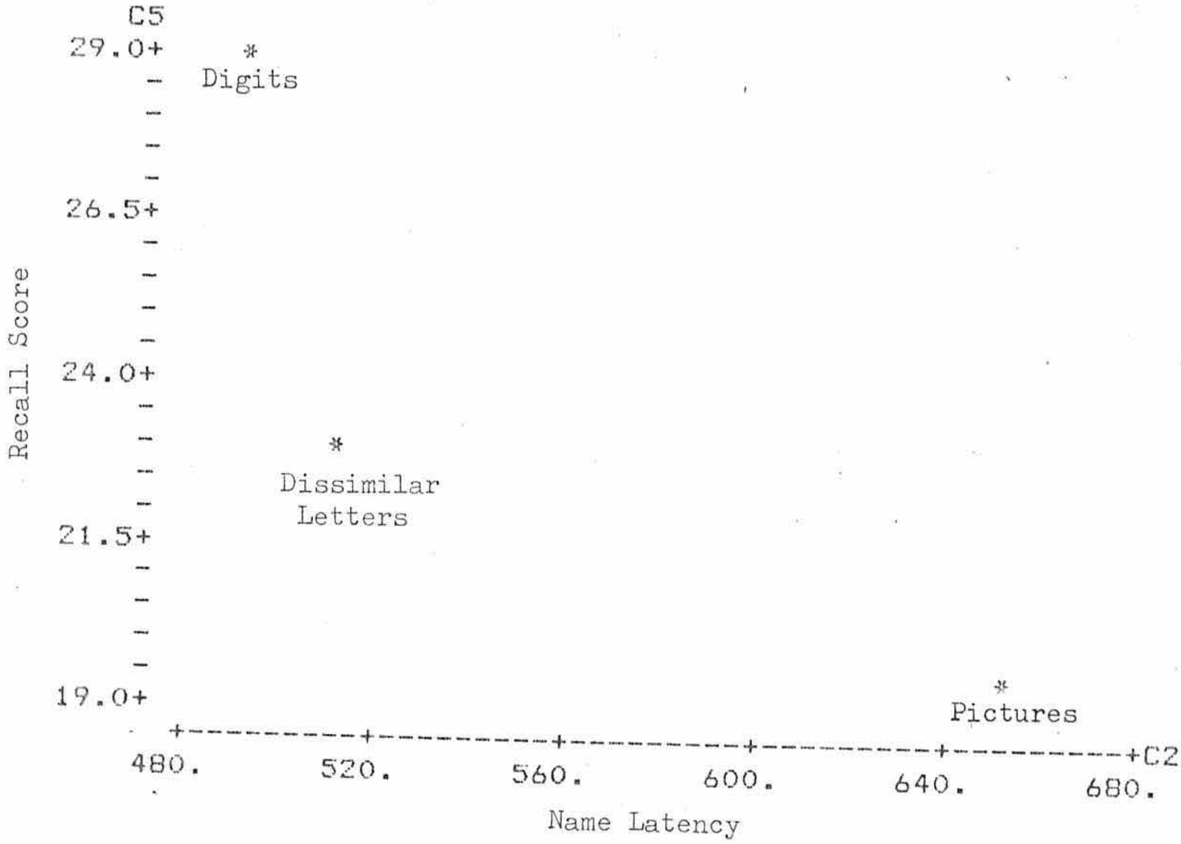


FIGURE 4.3

Non-Dyslexic First Presentation

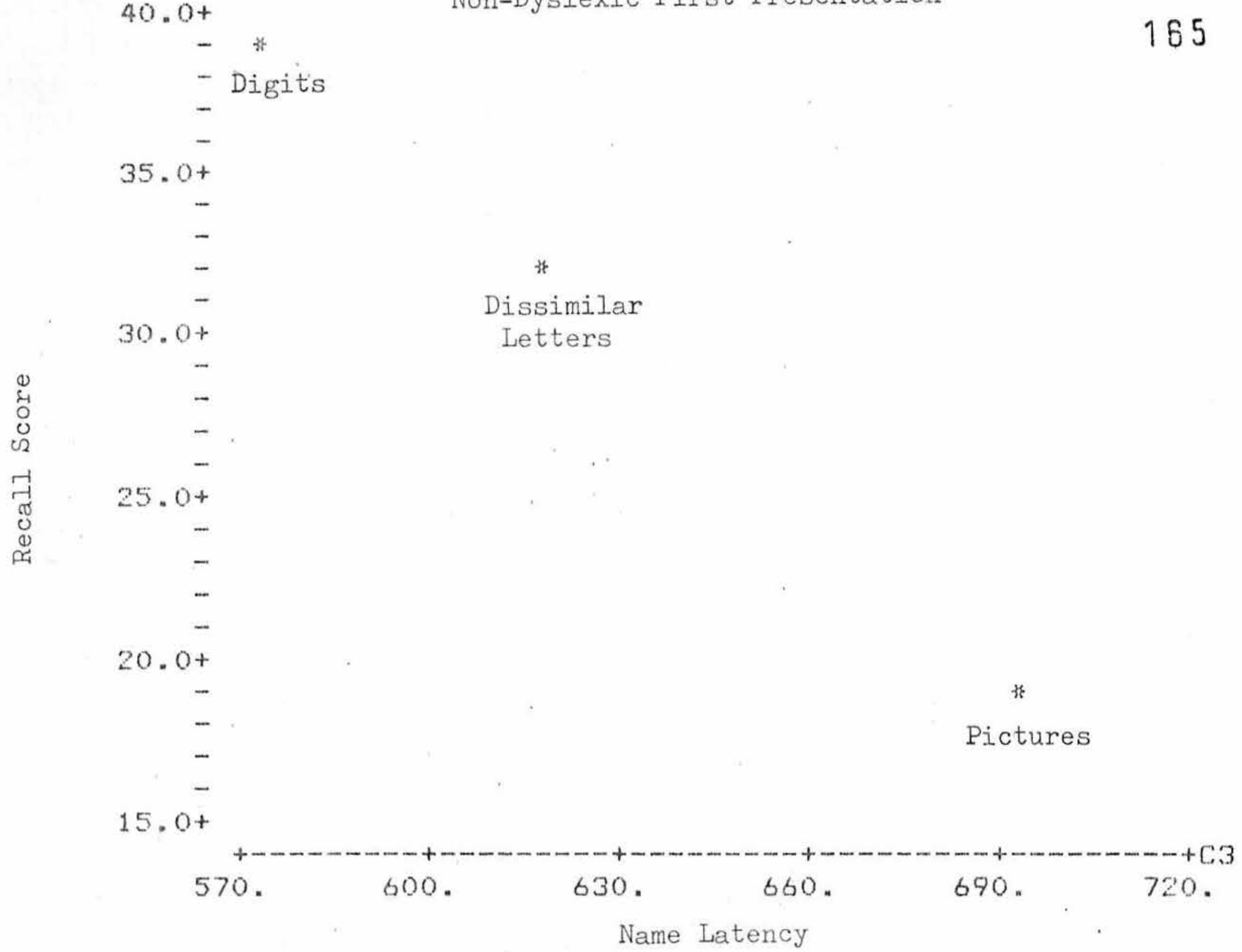


FIGURE 4.4

Non-Dyslexic Second Presentation

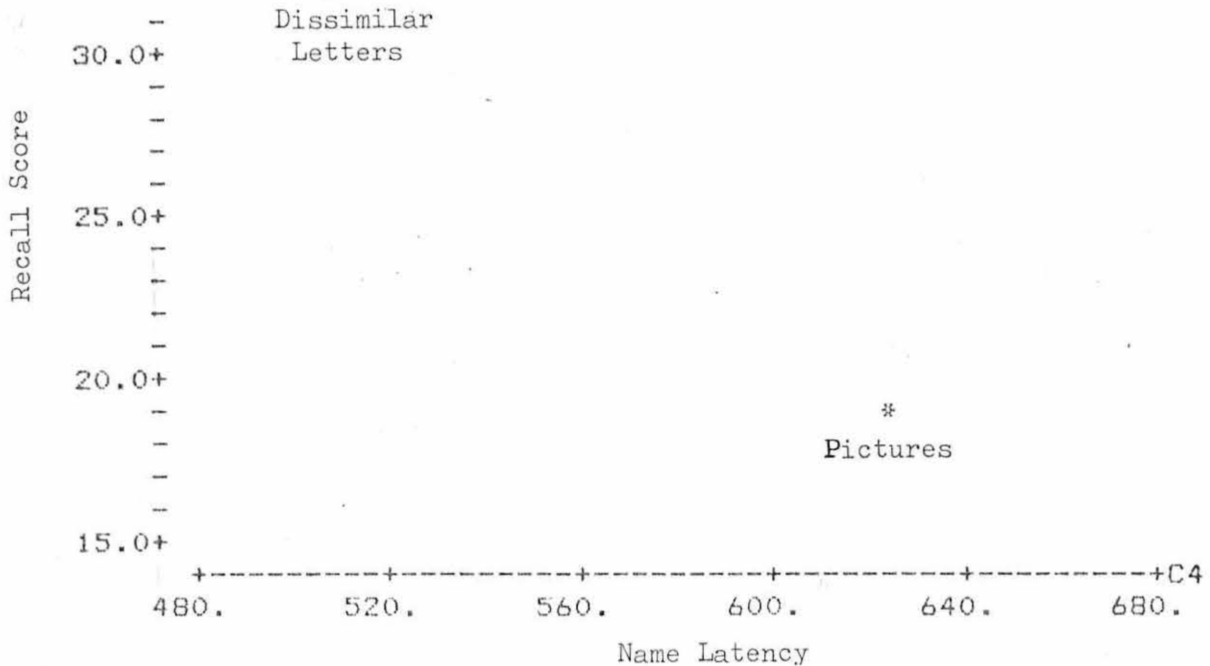


Table 4.22

Results of Regression Analysis. $\log_{10}$ (Latency) for each item set regressed onto group serial recall score

Group		Reg Coeff(β)	S.E.	t-value	df	Prob
Dyslexic	1st Pres	-0.0147	C.007	-1.99	1	$p>.10$
	2nd Pres	-0.0084	0.0024	-3.52	1	$.05<p<.10$
Non-	1st Pres	-0.0063	0.0013	-4.80	1	$.05<p<.10$
Dyslexic	2nd Pres	-0.004	0.00025	-6.25	1	$p<.05$

A better fit was realized when $\log_{10}$ (latency) was plotted against $\log_{10}$ (serial recall score). The results of these four regression analyses are presented in table 4.23.

Table 4.23

Results of Regression Analysis. $\log_{10}$ (Latency) for each item set regressed onto $\log_{10}$ (Serial Recall Score)

Group		Reg Coeff(β)	S.E.	t-value	df	Prob
Dyslexic	1st Pres	-0.9370	0.365	-2.29	1	$p>.10$
	2nd Pres	-0.4734	0.1071	-4.42	1	$p<.10$
Non-	1st Pres	-0.3944	0.0490	-8.06	1	$p<.05$
Dyslexic	2nd Pres	-0.360	0.0277	-13.02	1	$p<.025$

From table 4.23 it is clear that a $\log_{10}$ - $\log_{10}$ plot produces the best fit. Thus a $\log_{10}$ (latency) value is a good predictor of serial recall score, although the accuracy of prediction is greater in non-dyslexic subjects than it is in dyslexic subjects.

The relationship between name latency and serial recall was also investigated within subjects for each group. Since $\log_{10}$ transformations of the data produced the best fit for group mean data, it was decided that subject scores would be transformed in the same way. Subsequently for each group four regression analyses were computed, one for each item set, in which the y-variate represented the $\log_{10}$ (serial recall score) and the x-variate the $\log_{10}$ (latency). The results of these regression analyses are given in table 4.24.

Table 4.24

Regression Analysis within subjects. Log_{10} (subject serial recall score) regressed onto Log_{10} (subject name latency) for each item set

Digits

Group	Regression Coefficient	S.E.	t-value	df	Prob.
Dyslexic (n=16)	-.285	0.1868	-1.53	14	$.05<p<.10$
Non-Dyslexic (n=16)	+.054	0.162	0.34	14	$p>.10$

Accoustically Dissimilar Letters

Group	Regression Coefficient	S.E.	t-value	df	Prob.
Dyslexic (n=16)	-0.244	0.116	-2.11	14	$p<.05$
Non-Dyslexic (n=16)	-0.052	0.126	-0.41	14	$p>.10$

Accoustically Similar Letters

Group	Regression Coefficient	S.E.	t-value	df	Prob.
Dyslexic (n=16)	-0.235	0.1202	-1.95	14	$p<.05$
Non-Dyslexic (n=16)	0.001	0.133	0.01	14	$p>.10$

Pictures

Group	Regression Coefficient	S.E.	t-value	df	Prob.
Dyslexic (n=16)	-0.059	0.220	-0.27	14	$p>.10$
Non-Dyslexic (n=16)	-0.107	0.080	-1.35	14	$.05<p<.10$

It is clear from table 4.24 that for dyslexic subjects there is a significant regression of serial recall score on name latency for both types of letters. There is also a definite relationship between latency and serial recall for digits

($t = -1.53$, $df = 14$, $.05<p<p.10$) although there is no sign of a relationship for pictures. With respect to the non-dyslexic subjects there is no sign at all of a latency - serial recall relationship for either digits or letters although there is a definite trend towards such a relationship for the picture stimuli ($t = -1.35$, $df = 14$, $.05<p<.10$).

Discussion of Regression Analyses

It is obvious that if items are not retained in short term memory in some name code then factors affecting name coding and rehearsal will have little impression on memory span. Thus in Experiment 1 it was hypothesised that name coding is employed to a limited degree with nonsense shapes such that dyslexic subjects have similar spans as non-dyslexic subjects. In other tasks which do demand name coding then dyslexic subjects have smaller spans because name coding is less efficient and is the limiting factor of their performance. From the results of the within subjects serial recall on latency regression analyses it appears that generally the speed of lexical access, as measured by name latency, does influence serial recall performance in dyslexic subjects. However, no such relationship exists for non-dyslexic control subjects except for the picture stimuli.

From these results it could be argued that for highly "automated" lexical access (Denckla and Rudel, 1974; La Berge and Samuels, 1976) the speed of lexical access is not a limiting factor in serial recall performance. Thus digit and letter names can be accessed automatically by normal adolescent boys (Denckla and Rudel, 1974) which leads to a poor latency - serial recall correspondence for the non-dyslexic subjects in this experiment. However naming pictured objects is less automated (Denckla and Rudel, 1974), producing considerably longer lexical access times such that the importance of lexical access is increased as a limiting factor in serial recall. Indeed, in the non-dyslexic subjects the regression of $\log_{10}$ (group mean serial recall) on $\log_{10}$ (group mean latency) was highly significant ($t = -13.02$, df 1, $p < .025$ and $t = -8.06$, df 1, $p < .05$ for second and first presentations respectively see figures 4.3 and 4.4). Thus a strong relationship does exist between lexical access time and serial recall in non-dyslexic subjects across different types of stimuli. However, if individual variation of latency times is relatively small in automated lexical access then the variation that does exist will tend to become random variation or noise. The standard deviations for name latencies are given in table 4.25.

Table 4.25

Standard Deviations of Name Latencies for each Item set in each Group.

	Dyslexic	Non-Dyslexic
Digits	104.53	61.5
Dissimilar Letters	138.32	53.3
Similar Letters	114.47	55.4
Pictures	160.68	72.8

It is hypothesised here that when the standard deviation falls below seventy the individual latency differences are largely random fluctuations. Thus for non-dyslexic subjects the semblance of a latency-serial recall relationship should exist for pictures only and for dyslexic subjects this relationship should be observed for all four item sets. The results from seven out of the eight regression analyses support this hypothesis, the one exception being the picture stimuli in the dyslexic group. From table 4.25 it is clear that the standard deviation is highest in this cell, although mean lexical access times (i.e. name latencies) are the longest for this cell (see table 4.14). Since lexical access is slow (approximately 650 msecs per picture) few items will be held in a response buffer and the relative importance of the visual short term memory store will be increased. Therefore speed of lexical access will cease to become a limiting factor on serial recall (this argument has been explained fully in the introduction to Experiment 1).

4.4.2 SUMMARY

Speed of lexical access affects serial order recall performance. More items can be held in their correct order if their names can be accessed rapidly from the lexicon. In dyslexic subjects speed of lexical access is slowed down for very familiar as well as less familiar visual stimuli. In the case of digits and letters it appears from the results of this experiment that dyslexic subjects have failed to reach a level of automatic lexical access. This result is supported by the findings of Rudel, Denckla and Spalten (1976).

The failure to find a within subject relationship in the non-dyslexic subjects for digits and letters was considered to be due to a reduced importance of individual latency differences as predictors of serial recall performance. What individual differences did occur were considered to be largely random variation.

4.5.1 EXPERIMENT 3C

INTRODUCTION

The results of Experiment 3a indicated that the dyslexic subjects were slower at naming digits, letters and pictures than age and IQ matched non-dyslexic subjects. It was concluded at the end of this experiment that the dyslexic children appeared to have difficulty in accessing names from their internal lexicon. The relationship between reading and the ability to name visual objects has been already mentioned. Jansky and De Hirsch(1972) demonstrated that in kindergarten children picture naming was one of the best predictors of future reading ability. In a longitudinal follow up study Jansky et al(1972) found that picture naming ability of these kindergarten children correlated highly with reading achievement scores some four years later at the age of eight. The authors commented that "...reading, like picture naming , requires ready elicitation of spoken equivalents ".

From a clinical neurologist's viewpoint Critchley(1970) placed developemental dyslexia within the "aphasiological context", noting that dyslexic children attending his clinic resembled adults considered to suffer from alexia with agraphia. Critchley(1970) commented that dyslexic children were "deemed to be mild examples of aphasic alexia". Similarly Benson and Geschwind(1969) emphasised that although "alexia-with-agraphia" must by definition show greater disturbances of reading and writing than speech, patients usually manifest a mild anomic type of aphasia.

Carroll and White(1973) used a revised version of the Oldfield and Wingfield test to compare the relative importance of word frequency and age of word name acquisition as parameters involved in the organisation of the internal lexicon. Using the technique of multiple regression they concluded that the regression equation that best fitted the name latency data included only the age of word acquisition variables .The word frequency effect was completely explained by the very high correlation between that variable and age of name acquisition. As a consequence of this finding a number of other studies have since been carried out to examine the influence of age of name acquisition on lexical organization.Gilhooly and Gilhooly(1979) using a picture name latency measure found that name latencies in adults could be satisfactorily explained by age of name acquisition and "codability". This latter term they used as a measure of the variety of picture names given by the subjects tested. Thus pictures given the same name by all subjects tended to be named quicker than those which elicited a variety of different names. Gilhooly et al (1979) also found for anagram solving that earlier acquired words were more likely to be produced as solutions than later acquired words.Lachman(1973) and Butterfield and Butterfield(1977) have pointed out that "codability" or uncertainty correlates highly with age of acquisition. Butterfield et al(1977) commented that the greater the uniformity among adults about how to code a particular event then the younger the age at which children coded the event in an adult fashion. Moreover in respect of a particular event uniformity of name to describe the event increased with age . However despite the close relationship between age of acquisition and "codability" Lachman,Schaffer,and Hennrikus(1974)found that codability, age of acquisition and word frequency each contributed significantly to a unique portion of picture name latency variance, which has suggested a degree of independence of these parameters in the organization of the internal lexicon.

In view of the findings of Expt 3a in which children assessed as dyslexic had significantly longer picture name latencies it was decided to test for the influence of age of acquisition as opposed to word frequency as an influence on this group difference. To this end a revised version of the Oldfield and Wingfield test was constructed using a set of pictures for which age of name acquisition correlated minimally with word frequency. The age of acquisition norms were obtained from interviews (see below) with children from the age of 2.0 years old and upwards. This was considered neccessary since most age of acquisition norms are obtained from adult populations who subjectively estimate the age at which they acquired the names. Although these subjective values from Carroll et al's(1973) study correlated +0.847 with objective ratings obtained by Rinsland(1945), Dale(1948) and Dale and Eicholz(undated) they also correlated +0.703 with Kucera-Francis SFI word frequency values. Since the dissociation of age of acquisition and word frequency is to be examined in the current experiment even these high levels of correlation between objective and subjective ratings are not high enough. By obtaining objective measures it was possible to examine more thoroughly the relationship between age of acquisition and name latency in a population of dyslexic children for who digit,letter and picture name latencies had already been measured and found to be significantly longer than age matched controls.

METHOD

Subjects

16 dyslexic boys(mean C.A.=14.6) and 16 non-dyslexic boys(mean C.A.=14.2) were used in this experiment. All 32 subjects had been previously used in Experiments 3a and 3b. All the details on these subjects can be found in the subjects section of that experiment .

Materials

Hardware

The hardware used in this experiment is identical to that used in Experiment 3a. Therefore information about the hardware can be found in the hardware section of that experiment.

Stimulus Software

On each white card, measuring 10cms by 15 cms,there was drawn the picture of an object in black ink using a Micronorm mapping pen. There was a total of 69 such cards presented to each subject with a different pictured object on each card. The drawings were made by a qualified art teacher with 8 years of teaching experience , who was instructed to centre the picture at the centre of the card. The maximum visual angle subtended at the eye of a subject viewing the picture in the tachistoscope was ,in the horizontal plane , 6.2 degrees and , in the vertical plane , 5.4 degrees.

69 picture stimuli were used in this experiment. These are listed in Appendix B Table A along with age of acquisition (AOA1 and AOA2 , see below) and word frequency norms (SFI , see below). 58 of the 69 stimuli were selected from Table.1 of Carroll and White(1973). Stimuli were selected for inclusion if there was a greater than average discrepancy between Carroll et al's age of acquisition measure and the Kucera-Francis word frequency value. Normally a word with a high word frequency has a low value of AOA. The remaining 11 stimuli were selected from childrens' picture books. Although no age of acquisition values previously existed for these 11 stimuli estimates of these values were made from the age level of the reading book from which they were taken. The stimuli were chosen if either they appeared in an early reader together with a low K-F value or vice versa (i.e. high K-F value and only appearing in a more advanced reader). In this

way the criterion for selection was similar to that used for the other 58 stimuli.

Experimental Procedure

The procedure of Experiment 3a was adopted here. Subjects observed pictures displayed in a 3-field tachistoscope and responded by saying the name into a microphone relayed to a voice-key and millisecond timer. For a more thorough description of the procedure the reader is referred to the procedure of Experiment 3a.

All subjects were given the following instructions: "Do you remember viewing pictures inside this machine before?(all subjects did remember). Right,I now want to repeat that procedure in the same way with a different and somewhat larger set of pictures than we used before. Some of the picture names you will be familiar with but some you just might find a little bit more difficult. You will have to look in the viewing hole and watch the cross on the white screen. I will ask you whether you are ready and I want you to say "Yes" if this is so. There will follow a short delay of about a couple of seconds after which the cross will be replaced by the picture which you must name as quickly as possible. But please remember to avoid saying either the wrong name or things like "er" or "um" or "oh,yes" etc. Since the microphone is very sensitive and will pick it up very easily."

The set of 69 stimulus cards was then randomly arranged with a thorough shuffle and placed in the card holder of the tachistoscope, each card being presented once only to the subject.

In all other respects the procedure followed was the same as for Experiment 3a.

Word Frequency Data

Following the recommendation of Carroll(1970) all word frequency data used the norms of Kucera and Francis(1967)(K-F) which were converted to standard frequency index (SFI) scores using the formula SFI=10(LOG p+10) (Carroll 1970),where p is the word probability which is the K-F word frequency divided by the size of the K-F corpus of words. A frequency value of .001 was assigned to words not appearing in the k-f tables (i.e. having a frequency value of zero). This was necessary in order to obtain an SFI value for such words.

Age of Acquisition Data (AOA)

99 chidren between the ages of 2years 0 months and 6years 0 months were intervived by E. (the use of abreviated forms e.g.2.11 to represent 2 years and 11 months, will be used to express chronological ages). All children were shown the 69 pictures which were drawn on two large sheets of paper. E. pointed to each picture in turn and asked the subject what the picture was called. Pronunciation in some of the children, especially the youngest, was sometimes poor and

therefore had to be distinguished from poor knowledge of the name itself. E. was aware of the phonological rules used by children in mispronunciation and so he endevoured to accept well formed words which had been mispronounced and count as wrong words regarded as badly formed. For example shown a picture of a banana the response "bana" would be accepted as well formed but mispronounced since the subject had probably applied the week syllable rule (Salus and Salus 1974) although "Ba" would be regarded as a badly formed name since there is no well known phonological rule that accounts for the mispronunciation. Thus records of knowledge of picture names were obtained for each of these children. In order to establish AOA values children were first assigned to one of the following age categories (frequencies in parentheses): 2.0-2.5(n=7) 2.6-2.11(n=7) 3.0-3.5(n=17) 3.6-3.11(n=13) 4.0-4.5(n=17) 4.6-4.11(n=9) 5.0-5.5(n=22) 5.6-6.0(n=9).

The number of correct names for each picture were then calculated for each age category and the category in which 75% of children gave a correct name was recorded for each picture.

Two measures of AOA were subsequently derived. AOA1 simply represented the youngest age category at which the 75% criterion was met. AOA2 adopted the same procedure as AOA1 but additionally within each age category pictures were ranked according to the frequency of correct naming by children from the younger age categories. For example if two pictures , A and B, both met the 75% criterion in the second age category(2.6-2.11) but A was correctly named by 4 children and B by 1 child in the first age category(2.0-2.6) then A was given a lower rank than B indicating a lower age value . In this way each word received a rank between 1 and 65 inclusively. AOA2 was regarded as a fairer and more sensitive measure than AOA1 . Ranking within category1, the youngest age category, was decided upon the frequency of correct responses in this category as well as in categories 2 and 3.

4.5.3 Results

The recorded time between stimulus onset and response onset was regarded as the name latency time. Latencies were recorded to the nearest millisecond.

As a post hoc measure all data from four stimuli (reel, doorknob,anvil and xylophone) were not included in the subsequent analysis. This precaution was taken because, in the case of "reel" and "doorknob", a large number of dyslexic and non-dyslexic subjects gave alternative names (e.g. cotton reel or handle). In the cases of "anvil" and "xylophone" less than 50% of subjects knew the names. Consequently name latencies were recorded for 65 picture stimuli. This gave a maximum possible total of 2080 responses(32 subjects x 65 words). But 112 of these (5.4%) were excluded due to a different name being used (e.g. telescope for microscope) or due to some erroneous sound (e.g. a cough) producing an incorrect reading. The largest number of erroneous responses(n=8 or 25%) occured for "microscope" although within each group of subjects the highest error rate for the non-dyslexic group was produced by the "glove" and "feather" stimuli (n=5 or 31%) and in the dyslexic group by the "telescope" stimulus (n=5 or 31%). For the remaining 65 stimuli mean name latencies were calculated for each stimulus in each group with all incorrect responses omitted. Subsequent analysis was carried out on a DEC 20/60 computer using the MINITAB program (Ryan, Joiner and Ryan 1981) and GLIM3 .

Correlations between all parameters (mean latency, AOA1, AOA2, and SFI) were subsequently computed . These are presented in Table 4.30. below.

TABLE 4.30.
CORRELATION MATRIX OF PARAMETERS

		MEAN LATENCY		AOA1	AOA2	SFI
		DYS.	NON DYS.			
MEAN LATENCY	DYS	---	+0.764	+0.714	+0.717	-0.401
	NON DYS.		---	+0.674	+0.682	-0.306
AOA1				---	+0.983	-0.394
AOA2					---	-0.396
SFI						---

From Table 4.30. it can be seen that AOA1 and AOA2 are highly correlated (+0.983) and therefore any subsequent use of both variables in a regression analysis would not be necessary. Therefore AOA2 will be used as the measure of age of acquisition since it correlates marginally better than AOA1 with mean latency. Also, it was considered a fairer and more sensitive measure .

Two stepwise multiple regressions have been computed for each group. In the first multiple regression analysis (Table 4.31 and Table 4.33) the y-variate is the mean latency parameter and the x-variates are entered into the equation in the order AOA2 followed by SFI. In the second analysis the x-variates are entered in reverse order. In this way the first analysis allows one to estimate how much variance can be accounted for by the word frequency effect once AOA effects are removed. The second analysis allows the reverse to be estimated i.e. how much variance can be accounted for by AOA after the effect of SFI is removed. Together both analyses give an idea of the covariation and the unique variance of AOA and SFI.

The Anova tables for both of these regression analyses are given below in Tables 4.31. and 4.32 for the dyslexic subjects and in Tables 4.33 and 4.34 for the non dyslexic subjects. Regressions for each group separately were computed in order to test for any trend differences between groups.

TABLE 4.31

ANOVA FOR MULTIPLE REGRESSION ANALYSIS (Y-VARIATE=NAME LATENCY; X-VARIATES ENTERED IN THE GIVEN ORDER)- DYSLEXIC SUBJECTS.

DUE TO	DF	SS	MS	F	PROBABILITY
OVERALL REGRESSION	2	550879	275439.5	34.98	P<.001
AOA2	1	533503	533503	67.75	P<.001
SFI	1	17376	17376	2.2	NS
RESIDUAL	62	488230	7875		
TOTAL	64	1039109			

TABLE 4.32

DUE TO	DF	SS	MS	F	PROBABILITY
OVERALL REGRESSION	2	550879	275439.5	34.98	P<.001
SFI	1	167237	167237	21.24	P<.001
AOA2	1	383642	383642	48.72	P<.001
RESIDUAL	62	488230	7875		
TOTAL	64	1039109			

TABLE 4.33

ANOVA FOR MULTIPLE REGRESSION ANALYSIS (Y-VARIATE IS MEAN NAME LATENCY. THE X-VARIATES ARE ENTERED IN THE ORDER GIVEN) - NON DYSLEXIC SUBJECTS

DUE TO	DF	SS	MS	F	PROBABILITY
OVERALL REGRESSION	2	704069	352034.5	27.08	$P<.001$
AOA2	1	701557	701557	53.96	$P<.001$
SFI	1	2511	2511	.1	$P>.05$
RESIDUAL	62	806045	13000.7		
TOTAL	64	1510114			

TABLE 4.34

DUE TO	DF	SS	MS	F	PROBABILITY
OVERALL REGRESSION	2	704069	352034.5	27.08	$P<.001$
SFI	1	141437	141437	10.88	$P<.001$
AOA2	1	562631	562631	43.28	$P<.001$
RESIDUAL	62	806045	13000.7		
TOTAL	64	1510114			

In both of the multiple regression analyses where AOA effects are removed prior to the removal of word frequency effects (SFI) (i.e. Table 4.31 and Table 4.33) word frequency ceases to covary with latency. In other words AOA2 accounted for all of the variaion attributable to SFI. However the reverse was not true, since with the effect of SFI removed AOA2 still accounted for a significant proportion of the latency variance. Accordingly SFI will be omitted from subsequent regression equations. As a result the form of the regression equations for the dyslexic and non-dyslexic groups were:

Dyslexic group $Y = 672.8 + 4.84X$ (EQUATION 4.1)

Non-dyslexic group $Y = 605.7 + 5.55X$ (EQUATION 4.2)

(Y = name latency and X = AOA2)

A further regression analysis was computed to see if there were any significant group differences in respect of the regression of age of acquisition regressed onto name latency. To this end a group difference score (GDS) was calculated by subtracting the latency values of the dyslexic group from those of the non-dyslexic group for each of the 65 stimuli. Using GLIM3 on a DEC 20/60 computer AOA1 was regressed onto GDS (AOA1 was preferred to AOA2 because values of the regression coefficient and intercept can be more readily converted into real age values).

The regression equations for the two groups separately are:

Dyslexic group $Y = 661.6 + 34.9X$ (EQUATION 4.3)

Non-dyslexic group $Y = 594.6 + 39.66X$ (EQUATION 4.4)

(y-variate corresponds to "name latency" and the x-variate corresponds to "AOA1")

When AOA1 was regressed onto GDS the form of the regression equation was:

$$Y = 66.98 - 4.768X \qquad \text{(EQUATION 4.5)}$$

(The y-variate corresponds with "group latency difference" and the x-variate corresponds to "AOA1".)

The standard errors,and significance values for the two constants in this equation are given below in Table 4.35.

TABLE 4.35

NAME OF CONSTANT	VALUE	STANDARD ERROR	T-VALUE	DF	PROB.
Y-INTERCEPT	66.98	26.41	2.54	63	$P < .01$
REGRESSION COEFF.	-4.768	4.77	1	63	$P > .05$

With reference to Table 4.35. the y-axis intercept is significantly greater than zero. Since GDS was the value of dyslexic minus non-dyslexic mean latency values this result indicates that the y-axis intercept of the regression line for the dyslexic group is significantly greater than that for the non-dyslexic group. However the regression coefficients in the equations of the two groups (34.9 for the dyslexic group and 39.66 for the non-dyslexic group) did not differ significantly ($t=1, P>.05$, $df=63$).

From the regression analysis in Table 4.35 it appears that there is a constant latency difference between the dyslexic and the non-dyslexic groups to the order of 66.98msecs for all values of AOA1. Since name latency covaries with age of acquisition it is possible that a constant name latency difference of 66.98msecs between the two groups for any picture name indicates that the picture name was learned earlier by the non-dyslexic subjects, hence the shorter name latency value. By estimating a common regression coefficient for both groups it would be possible to estimate an age of acquisition gap between the two groups which will account for the 66.98msecs. between groups latency difference. Accordingly this was calculated by adding the mean latency scores of both groups which shall be called the combined mean latency (CML) and regressing AOA1 onto CML. The regression coefficient of the resulting equation can be regarded as an estimate of a common regression coefficient.

The regression equation for AOA1 regressed onto CML/2 was:

$$Y = 628.1 + 37.28X \qquad \text{(EQUATION 4.6)}$$

(the y-axis corresponds to CML/2 and the x-axis corresponds to AOA1)

By dividing the value of the y-axis intercept from Equation 4.5, i.e 66.98, by the common regression coefficient (i.e. 37.28) the age of acquisition gap between the two groups is calculated as 1.8 units of AOA1, or 10.8 months. In other words if pictures with AOA1 values of A were given to the group of dyslexic children and pictures with AOA1 values of (A+1.8) were given to the group of non dyslexic children then it would be expected that no group differences would be found in respect of name latency. This result of a 10.8 month lag in the dyslexic subjects acquisition of picture names could be accounted for if it assumed that the dyslexic subjects learned their first picture name some 10.8 months later, on average, than the non-dyslexic subjects.

4.5.2 Discussion of the Results.

The results from this experiment have shown that there exists a highly significant relationship between the age at which children first acquire names for pictured objects and the subsequent speed with which these objects can be named many years later. This influence of age of acquisition on picture name latency in adults has been reported before (Carroll and White 1973, Rochford and Williams 1962, Gilhooly and Gilhooly 1979). In addition age of acquisition was found to account for a far larger amount of the variance than word frequency and therefore could not be regarded as a pseudo word frequency effect. A similar finding was reported by Carroll et al. (1973).

Loftus and Suppes (1972), Lachman et al.(1974) and Lachman (1973) have argued that any variable which correlates with name access from the internal lexicon must provide information about the structural organization of the lexicon. Gilhooly(1979) more specifically argues that age of acquisition has a permanent influence on the "firing" threshold of logogens. As names are learned each name acquires a unique logogen in the logogen system (Morton 1979). In order to name a word or a picture a threshold of activity must be reached in the particular logogen before it "fires" and sends information to an output buffer or the cognitive system (Morton 1979). Gilhooly(1979) has suggested that age of acquisition has a permanent effect on the logogen's threshold.

Both the dyslexic and the non-dyslexic subjects displayed similar influences of age of acquisition on name latency. From the analysis of the group difference scores (GDS) both groups had similar regression coefficients. In other words as the age of acquisition value increased so did the name latency values of both groups increase by the same amount. However the intercept of the y-axis by the regression line of the dyslexic group was significantly higher than that for the non-dyslexic subjects. This was taken to indicate a delay in the onset of picture naming in the dyslexic children by 10.8 months on average.

Delayed speech development in dyslexic children has been reported by Ingram and Mason (1965), Debray(1968), Rutter, Tizard and Whitmore (1970) as well as Naidoo(1972). Naidoo (1972) reported that the mean age of onset of intelligible speech was 3.2 years for the group of reading with spelling retardation as opposed to 2.2 years for their control group. For the other group who manifested spelling retardation without reading retardation the figure was 2.9 years compared to 2.0 years in their age matched control group. The "onset lag times" for these two groups of retarded children were therefore 1.0 year and 10-11 months respectively. These two figures correspond very closely to the value obtained in the current experiment for the delay in onset of picture naming.

SUMMARY

By extrapolating the results of a series of regression analyses the longer picture name latencies found in the group of dyslexic subjects appeared to reflect a delay in the onset of picture naming , which in turn is probably related to the reported delay in speech development in dyslexic children. A very significant correlation between age of acquisition and name latency was found in the data reported here which compares well with the findings of Carroll et al(1973).The results also compared favourably with the findings of Denckla and Rudel (1976) who concluded that there was a common problem in both developmental dyslexic children and adult acquired dysphasic patients.

CHAPTER 5

EXPERIMENT 4

INTRODUCTION

The results of Experiments 1, 2 and 3 have demonstrated that dyslexic children are unable to use the response buffer, which stores verbal material, as efficiently as non-dyslexic children. From the results of Experiments 3a, 3b and 3c it appears that dyslexic children are slow at accessing names from the lexicon and it is this slowness which produces the poor serial recall. It therefore became necessary to find out why dyslexic children are slow at lexical access and in Experiment 3c it was found that delayed acquistion of names could produce the prolonged name latencies. Thus an early linguistic retardation could account for slow lexical access and poor memory span in adolescence, which in turn could account for the reading and spelling retardation in these children.

It remains to ask the nature of the linguistic processes that are impaired in young dyslexic children which cause the delayed acquisition of language. It is also necessary to find out how these impaired linguistic processes subsequently influence speed of lexical access and the efficiency of the response buffer at a later age. These two problems were investigated in Experiment 4.

Wickelgren (1965a,b) found that phonemes were more likely to be confused in STM if they shared a large number of phonetic features (i.e. distinctive features). To explain this Wickelgren suggested that the smallest unit of short term storage was the distinctive feature. Thus a phoneme is stored in STM as a set of distinctive features. Transposition errors arise from the transposition of distinctive features. Thus /p/$\rightarrow$/b/ ("$\rightarrow$" means "substituted by") involves the addition of the feature [+ voice], and /p/$\rightarrow$/d/ involves the changes of [+ voice] and [labial $\rightarrow$ dental].

Reanalysis of Wickelgren's (1965b) data shows that distinctive feature transpositions occur systematically rather than randomly. For example observation of tables VI and VII of Wickelgren (1965b) show that without exception devoicing a voiced consonant (i.e. /b/$\rightarrow$/p/) occurs more often than voicing an unvoiced consonant. The data for this particular case are presented in table 5.1

Table 5.1

Conditional probabilities[1] of consonant interchange taken from Tables VI and VII of Wickelgren 1965b

Nature of Voice transition

CP	/+ voice/$\rightarrow$/ - voice/		/- voice/$\rightarrow$/+ voice /	
	16 CS	23 CS	16 CS	23 CS
b-p	12.07	9.13	11.24	5.19
d-t	6.5	6.01	3.24	4.91
g-k	8.94	8.9	4.74	8.89
v-f	9.22	9.89	6.87	4.18
z-s	13.31	8.80	8.84	7.67

CP = Consonant Pair

CS = Consonant Study

(1) Conditional probability is calculated by dividing the total frequency of a particular transition by the total number of transitions for that phoneme and multiplying by 100.

This type of analysis employs the use of phonological rules. Thus in this particular example it appears that the rule $[+ \text{voice}] \rightarrow [- \text{voice}]$ occurs more frequently than the rule $[- \text{voice} \rightarrow [+ \text{voice}]$. Indeed Ellis (1979) noted that "when elements exchange in Spoonerisms they are, where necessary, accommodated to their new contexts" (P. 174). To explain this observation Ellis (1979) considered that some process was operative in the information processing system which applied phonological and co-articulatory rules, at a phonemic level, to the information stored in the response buffer.

Competence in phonology therefore appears to be related to the successful use of the response buffer. Subjects must not only code items by their distinctive features in the response buffer but also phonological processes are operative at this level to produce the systematic transitions in the data of Wickelgren (1965b) and the phonological correctness of Spoonerisms (Ellis, 1979; Wells, 1951; Boomer and Lever, 1968; Garrett, 1975). As a consequence it was decided to investigate the phonological competence of dyslexic children. If dyslexic children are phonologically less competent than non-dyslexic peers then one might expect the response buffer to be less efficient, the phonological coding of lexical items to be impaired and the acquisition of names to be delayed. To examine phonological skills a verbal pair associate learning (PAL) task was adopted whereby unfamiliar CVC trigrams are learned and associated with nonsense shapes, thereby becoming names. During PAL tasks there are considered to be two stages of learning (Underwood, Runquist and Schulz, 1959; Underwood and Shulz, 1960; Kausler, 1974). The first stage, called "response learning" involves learning a CVC i.e. learning the identity and correct order of the constituent phonemes. The second stage, called "associative learning", overlaps in time with response learning and involves the association or "hooking-up" of the stimulus with the response. Examination of the response learning errors might lead to a better understanding of the phonological skills of dyslexic and non-dyslexic children. In an attempt to make sense of the response learning errors (RLE's) a comparison was made with the phonological rules used by young children during language acquisition. There are a number of reasons for this approach. In the first instance phonological processes that are inadequate during the acquisition of names by dyslexic children might remain throughout life and impair response buffer operation. Secondly Vygotsky (1962) considered that thought was subvocal speech which developed from overt speech. Thus external speech gradually becomes internal speech. Flavell, Beach and Chinsky (1966) noticed that young children performing a serial order recall task rehearse overtly. As these children grow up there will be a transition from overt to covert rehearsal. Thus inefficient covert rehearsal might have been manifested overtly at a younger age.

Lenneberg (1960) pointed out that children recovering from aphasia showed profound regression to the earliest stages of speech acquisition in infancy, even babbling, and relived the path of development. Now, Critchley (1970) commented that dyslexic children were "deemed to be mild examples of aphasic alexia" and Benson and Geschwind (1969) noted the mild anomic characteristics of dyslexics were similar to those of aphasics. Therefore the phonology in dyslexic children might be retarded.

Experiments 4 and 5 were intended to have a similar format with the exception that Experiment 4 mainly taxed phonological skills and Experiment 5 visual memory and visual imagery. These two experiments will be compared in a variety of ways and should not therefore be considered independently. As the experimental design was rather complicated a brief layout of this design, which covers both experiments is given below in diagram 5.1

Diagram 5.1

A summarized layout of Experiments 4 and 5

Week 1

Part 1. Subjects are tested for their visual memory span of nonsense shape sequences.

Part 2. Subjects undergo a pair associate learning task in which they learn either verbal associates (Experiment 4) or visual associates (Experiment 5) to the set of visual stimuli used in Part 1.

Part 3. (This applies to Experiment 4 only)

(i) speed of naming was tested in which subjects had to provide the correct names for the stimuli used in part 2.

(ii) subjects are given a visual serial recall test in which they recall the sequence verbally.

There was no Part 3 in Experiment 5.

Week 2

Part 4. Subjects undergo a relearning test which is a repeat of the test in Part 2.

Part 5. Subjects in Experiment 4 are given the test in Part 3 (i) i.e. a naming speed test to encourage the use of names in dealing with the shapes. The subjects in Experiment 5 are taught to use a visual imaging mnemonic and dissuaded from using self generated names.

Part 6. Subjects are tested for their ability to remember a sequence of stimuli by generating name codes (Experiment 4) or visual images (Experiment 5).

Part 7. A repeat of the test in Part 1 to assess the relative influence of the two different learning tasks on STM followed by a test of serial order memory for visually presented sequences of digits.

METHOD

Subjects

12 dyslexic and 12 non-dyslexic subjects were selected. The dyslexic subjects were selected first, according to the criteria set out in Experiment 1. Thus all dyslexic subjects had been given a clinical test at UCNW (Bangor), Aston University or by a qualified educational psychologist. In addition all subjects had to conform to the criteria of Rule 2 and the matching of dyslexic and non-dyslexic subjects conformed to Rule 1 of Experiment 1. All subjects were male. The non-dyslexic subjects were selected from a pool of subjects who had been screened for IQ, SA and CA. From this pool of non-dyslexic subjects individuals were selected so as to match a

previously selected dyslexic subject. The experimenter was personally unaware of the identity of the non-dyslexic subjects since he had administered the IQ and spelling tests to groups of boys he had not met previously. It was therefore considered that the selection of non-dyslexic subjects was not biased by any personal knowledge.

The means and ranges for IQ, SA and CA are given in tables 5.2 and 5.3.

Table 5.2

Mean values for subject selection parameters

	IQ	SA	CA
Dyslexic (n=12)	115	10.38	14.1
Non-Dyslexic (n=12)	115	13.74	14.0

Table 5.3

Ranges for subject selection parameters

	IQ	SA	CA
Dyslexic (n=12)	100-140	7.9-11.6	13.3-15.9
Non-Dyslexic (n=12)	104-150	12.7-14.9	13.4-15.5

IQ was assessed by the Ravens Progressive Matrices Sets A, B, C, D and E (Raven, 1965) and SA was assessed using the Schonell Graded Spelling Test (Schonell, 1955).

PROCEDURES

Part 1

Method

Sequences of 4 or 5 nonsense shapes were presented tachistoscopically. After S. had been told the instructions he was given three practice trials followed by ten experimental trials. Each trial consisted of S. regarding a fixation cross, followed by a "Ready?" signal from E. Approximately one second after this signal a sequence of 4 or 5 nonsense shapes displaced the fixation cross and remained exposed for two seconds. At stimulus offset S. recalled the serial order using a non-verbal manual response (see Response Software).

Stimulus Software

Five nonsense shapes from a previous experiment (Experiment 1), in which naming was rarely reported, were used here. They are the five black shapes in table A of Appendix A. The stimuli were sequences of 4 or 5 shapes printed onto 22 cms x 22 cms plain white card. The sequences were selected pseudorandomly with the only restriction being that no sequence of three or more shapes be repeated in consecutive trials.

Initially a bluprint for the nonsense shapes was drawn from which a pencil tracing was made. This tracing could then be transferred onto the cards and inked over with a Rotring Micronom pen. The physical centre of the sequence was designed so as to occupy the same position on the tachistoscope screen as the preceding fixation cross. Average horizontal visual angles, subtended at the subject's eyes are given in table 5.4 below.

Table 5.4

Horizontal visual angles of sequences displayed in a tachistoscope

	No. items per sequence	
	4	5
Visual Angle	7.7°	10.2°

The average vertical visual angle was 1.6° at the subject's eyes.

Response Software

By using nonsense shape stimuli verbal recall was not viable. S's were therefore provided with five square tablets on which were printed the five shapes of the stimulus set. The top edge of each tablet was darkened and S. was instructed that this edge ran over the top of the shape thereby indicating correct orientation. Recall was performed by rearranging the tablets in the correct serial order immediately after stimulus offset.

Instructions

The following instructions were given to each S. at the beginning of Part 1 "If you look through the viewing hole you will see a small black cross, which I want you to observe. Shortly you will here me say "Ready?" to which you must reply "No" if you are not ready. Approximately one second after this signal the cross will be replaced by a sequence of 4 or 5 shapes. The shapes displayed are invariably those same shapes you will see on the tablets in front of you (E. indicates). Each sequence will remain on the screen for two seconds, and will then be replaced by the cross again. As soon as the shapes disappear from the screen you must show me that you can remember the correct order by selecting and rearranging these tablets. Remember that the darkened edge must remain uppermost since it covers the top of the shape. The first three trials will be practice to make sure you are doing it correctly. All right?"

Subjects were then given the three practice and ten experimental trials.

Part 2

Method

S. sat approximately 10' away from a white screen onto which a Carousel projector displayed slides of the five shapes previously used in Part 1. A projected slide had a white background with one black shape measuring 6" x 4" approximately, positioned on the left hand side of the screen. Slides were arranged in the projector in groups of three for each shape. Such a group will be referred to as a cycle. An example of a cycle is described below in diagram 5.2.

Diagram 5.2

Description of one cycle of the pair-associate learning task

	Slide 1		Slide 2		Slide 3
Nature of Slide	Slide of Shape X		Slide of Shape X		Blank Slide
Time Scale	4 sec	2 sec	4 sec	2 sec	4 sec
Purpose	Stimulus present-ation during which S. provides the response		Rein-force-ment trial where S. is provided with the correct response		Rest Period

From diagram 5.2 it can be seen that each shape was presented twice in succession, once as a stimulus to allow S. to respond and then as a reinforcement trial where stimulus and correct response were both provided. A tape recording (using an Akai 40000 DS MK-II tape recorder)in E's voice of the CVC trigram response was used during the reinforcement trial. Therefore during reinforcement S. passively observed the screen and listened to the tape recorded CVC associate. Stimulus presentation of a different shape followed two seconds after the rest period thereby starting a new cycle. Five such cycles occurred, one for each shape before any one cycle was repeated. The stimuli and their CVC associates are given below in table 5.5.

These CVC trigrams had association values of 25% or less according to the norms of Archer (1960).

Table 5.5

Stimuli used in Parts 1 - 5 and their CVC trigram associates used in Parts 2 - 5

Stimulus Shape					
CVC associate	"yad"	"wuc"	"fep"	"miv"	"gox"
Phonetic transcription of CVC	/jæd/	/wʌk/	/fep/	/mɪv/	/gɒks/

The cycles were arranged as follows:

CN:	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
SN:	yad	wuc	fep	miv	gox	fep	gox	wuc	yad	miv	wuc	gox	fep	yad	miv

CN = Cycle No.

SN = Shape Name

After cycle no. 15 the whole procedure was repeated, starting with cycle no. 1 and continued until S's vocal response was correct on two successive occasions for each shape. Thus a minimum of ten consecutively correct responses would terminate Part 2.

Instructions

The following instructions were given to S. at the beginning of Part 2, "The shapes you have already seen are now going to be used again. This time they will be projected onto the screen in front of you. Each shape has a name you will never have heard before, which does not occur in the English language. The object of the exercise is for you to learn the name for each shape.

The first slide on the screen will show one of the shapes by itself. This will then be followed by another slide showing the same shape and accompanied by its name produced from the tape recorder. A blank slide will follow during which you have a short break before another different shape appears on the screen.

I am now going to let you have a look at this procedure in operation, during which time you must familiarize yourself with the way the whole thing is organised. In addition you must try and remember the names. All right?" S. was then shown the procedure by E. for the first five cycles. E. provided the comments, "Here is a shape by itself" during each stimulus presentation and, "Here is the shape again ..... and that was its name" during the reinforcement trial, and, "This is a blank slide and serves as a rest interval". After this initiation E. gave the instruction, "We will now start again at the beginning and what you must do is remember the name correctly for each shape and tell it to me. Now, you must do that before the first slide changes and the tape recorder informs you of the correct name. In other words, when the first slide in the pair comes on the screen you must remember the name and tell it to me. We shall carry on until you have learned the name perfectly for each shape on every occasion. All right?" If S. had any problems these were duly answered and to help S. E. reminded S. during slide 1 that it was time to produce the name.

When the criterion of two successive correct trials for each shape was achieved Part 2 was terminated and Part 3 begun.

Part 3

Part 3(i) Method

On a piece of white card 7" x 5", each shape was printed five times (total = 25 shapes). These shapes were randomly assorted and set out into three lines (seven shapes per line) and one half line (four shapes). Each shape was spaced one inch apart as were the four lines. This card will be referred to as the "passage".

When S. was given this passage he was instructed, "Here is a passage of these shapes whose names you have just learnt. I want you, on the word "Go", to begin in the top left hand corner (E. indicates) and give me the name for each shape as you come to it moving along the line. When you reach the end of a line go to the beginning of the next line and carry on as before. All right?". E. then gave the word and started the timer simultaneously. Mistakes were not corrected by E. or pointed out to S.

Part 3(ii) Method

When the passage had been "read" completely S. was told that he would be shown sequences of shapes in the tachistoscope again and this time he was to recall using the names of the shapes. Each S. was given the following instructions, "At the beginning you saw sequences of shapes in the tachistoscope and remembered them by arranging the tablets in the correct order. You are now going to do this again, except instead of two second exposures I will give you more time, about nine seconds, and instead of using tablets you must say the names of the shapes in the correct order as soon as they have disappeared from the screen, but not before."

When S. indicated that the instructions had been understood E. presented him, tachistoscopically, with a sequence of four shapes exposed for 8 secs i.e. 2 secs per shape. The second sequence consisted of five shapes and was exposed for 10 secs (also 2 secs per shape). If S. recalled the names in correct order on either occasion then the exposure time was reduced by 25% i.e. 0.5 secs per shape, and E. presented another four followed by another five item sequence at these new exposure times (i.e. 6 and 7.5 seconds respectively).

Correct recall on at least one of these two sequences was followed by another 25% reduction in exposure time for two more sequences (i.e. a four and a five item sequence). This procedure was continued until at a given exposure time serial order recall was incorrect for both the four item and the five item sequences. The exposure time at this point was considered to mark the limit of perfect performance and concluded Part 3.

(One week later) Part 4

Method

The method used was the same as the method used in Part 2 above. However S. was not given the initial familiarization trials or lengthy instructions. Instead S. was asked if he could remember the procedure. Invariably S. did remember, but he was reminded that during the first slide he must recall the name before the slide changed and the tape recorder produced the name.

Part 5

S. was given the same test as in Part 3(i). That is he was presented with the passage and the instructions and his "reading" speed was timed.

Part 6

S. was given the same test as in Part 3(ii). The same nonsense shape sequences were used starting with initial tachistoscopic exposures of 8 secs (4 item sequence) and 10 secs (5 item sequence). Exposure times were gradually reduced until the limit of perfect performance was reached (see Part 3(ii)).

Part 7

A repeat of the test given in Part 1 followed by tachistoscopic presentations of 6 or 7 digit sequences. There were five trials for each length of digit sequence and the exposure time was held constant at 2 secs per sequence. S. recalled the serial order of the digits vocally.

RESULTS

The results of the current experiment shall be dealt with in separate sections. Section 1 will be used to report the results of the learning tasks i.e. Part 2 (PAL) and Part 4 (Repeat of PAL). Section 2 will be used to report the results of the serial order recall tasks i.e. Parts 1, 3(ii), 6 and 7, as well as the naming speed tasks i.e. Parts 3(i) and 5. Section 3 will be used to relate performance on the serial recall tasks with learning ability.

Section 1 - Results of PAL (Part 2) and Relearning (Part 4)

For each S. there was a record of each response given. These responses were initially categorized as either correct or incorrect responses. A response was deemed incorrect if the phonetic form of the response deviated from the original. Allowances were made for regional dialect by selecting subjects who did not have a strong regional dialect. In addition after completing the PAL task E. pronounced each CVC and asked S. to repeat it. Phonetic transcriptions were recorded and any obvious phonetic deviation due to dialect was taken into account when scoring the responses. Incorrect responses were separated into response learning errors (RLE's) and associative learning errors (ALE's) (Underwood et al, 1959; Underwood et al, 1960; Kausler, 1974). The rules for deciding whether an error was a RLE or an ALE were complicated. Three criteria were used in the selection of errors as RLE's. First if an erroneous response contained at least one correct phoneme then this error was regarded as a RLE since it demonstrated an incomplete learning of the CVC. Second if S. did not respond at all then this too was regarded as an RLE. Third if an error contained no phonemes in common with the CVC associate but did not resemble one of the other four CVC associates then this too was regarded as an RLE. An erroneous response was deemed to resemble one of the other CVC associates if they both shared two or more phonemes. Such an error was regarded as an ALE. The three types of RLE mentioned will be referred to as "near misses", "null responses" and "guesses" respectively.

Table 5.6 presents the mean number of incorrect responses (RLE + ALE), RLE's and ALE's for dyslexic and non-dyslexic subjects from Part 2 (PAL). Table A of Appendix C gives the frequency of each of these measures for each subject.

Table 5.6

Mean number of incorrect responses, RLE's and ALE's from Part 2 (PAL) of Experiment 4

	Incorrect Responses	RLE	ALE
Dyslexic (n=12)	39.7	35.0	4.7
Non-Dyslexic (n=12)	12.6	10.7	1.9

Matched pairs t-tests were calculated on each of the three measures of error in table 5.6 to test for group differences. In each case the dyslexic subjects made significantly more errors; for incorrect responses (RLE + ALE) ($t = 18.69$, df 11, $p < .005$), for RLE's ($t = 17.96$, df 11, $p < .005$) and for ALE's

($t = 6.017$, $p < .005$). From table A of Appendix C it can be seen that for RLE's there was a nearly complete dissociation of the two groups i.e. in eleven of the twelve matched pairs the dyslexic member made more RLE's. Group differences were less clearly marked for ALE's although they were highly significant ($t = 6.017$, $df = 11$, $p < .005$).

Analysis of RLE data

The frequency of occurrence of near misses, null responses and guesses, which together make up the RLE index, are given in table 5.7. Table B of Appendix C gives the frequency of each of these measures for each subject.

Table 5.7

Mean number of Near Misses, Null Responses and Guesses (the 3 composites of the RLE index)

	RLE	Near Misses	Null Response	Guess
Dyslexic (n=12)	35.0	24.9	4.9	5.2
Non-Dyslexic (n=12)	10.7	8.5	2.1	0.1

From the results of the RLE data it is clear that dyslexic children make many more phonological errors while learning simple CVC nonsense syllables. It should be remembered that a rote learning method was used in which the CVC was presented auditorilly and the response was given verbally. Therefore these RLE results give a very positive indication of severe phonological impairment in dyslexic children. Thus the language problems of dyslexic children during adolescence extend to the acquistion of names presented auditorilly. The deficit is not simply a difficulty in verbal encoding of visual stimuli.

Near Misses

Guesses do not readily lend themselves to phonological analysis since their relationship to the desired response is obscure. However analysis of near misses is possible. Phonetic transcriptions of near misses were initially analysed for serial position effects. Thus the error rate in near misses was recorded for each of the three segments in the CVC. The results of this analysis are given below in table 5.8. It should be noted that serial position 1 refers to initial consonant, serial position 2 refers to medial vowel, and serial position 3 refers to final consonant.

Table 5.8

Total No. of Near Misses and Percentage of Total No. Recorded at each Serial Position(1)

	Serial Position			
	1	2	3	sum
Dyslexic (n=12)	25 (6.6%)	205 (54.2%)	148 (39.1%)	378
Non-Dyslexic (n=12)	17 (15.6%)	49 (44.9%)	109 (40.4%)	109

(1) (N.B. total number of errors in table 5.8 do not tally with total number of near misses in table 5.7 since some near misses contained two errors)

Table C of Appendix C gives the frequency of errors at each serial position for each CVC. It is clear from table C of Appendix C that there is enormous fluctuation of error rates between different CVC's. Thus the medial vowel in /ʃep/ produced 11 errors in the dyslexic subjects and 0 errors in the non-dyslexic subjects compared with 78 and 28 errors respectively for the medial vowel in /wʌk/. The results in table C of Appendix C can be summarized as follows:

1. Initial consonant is recalled correctly more often than final consonant in each group and in nearly every CVC.

2. Group differences for the recall of the initial consonant are small and varied, the dyslexic subjects producing more errors in only three out of five CVC's.

3. Dyslexic subjects produce many more errors than non-dyslexic subjects on final consonants and medial vowels in each CVC.

4. Inspection of table 5.8 indicates that the error rate for serial position 2 is greater than for serial position 3. However, inspection of table C of Appendix C shows that this is probably due to the varying difficulty of the medial vowel since the trend is observed in only 3 out of 5 CVC's for dyslexic subjects and 2 out of 5 CVC's for the non-dyslexic subjects.

Phonetic transcriptions of near miss substitutions for the final consonant segment are presented in tables D.1-D.5 of Appendix C. The five final consonant targets were /d/ in "yad", /k/ in "wuc", /p/ in "fep", /v/ in "miv" and /ks/ in "gox" (/ks/ is a consonant blend). Errors in tables D.1-D.5 of Appendix C include consonant → consonant, consonant blend → consonant, consonant → consonant blend and omitted final consonant or consonant blend. Thus /d/ → /t/ in /jæd/ → /jæt/ occurred 20 times in the dyslexic group and never occurred in the non-dyslexic group. Similar tables have been constructed for initial consonant errors (see tables E.1-E.5 of Appendix C).

However due to the low error rate of initial consonants these will be examined no further.

The system of phonetic transcriptions for vowels given by O'Connor (1977) was used to categorize medial vowel errors in near misses. Since vowel pronunciation varies with regional dialect each subject had been specially chosen for his lack of regional dialect and additionally he was tested for his natural pronunciation of the CVC's after Part 2. The RP dialect (i.e. "Queen's English" or "BBC English") adopted by O'Connor (1977) as the standard dialect corresponds to the regional free dialect of the subjects in this experiment. Tables F.1-F.5 of Appendix C present phonetic transcriptions of medial vowel errors for each of the five target vowels (i.e. /æ/ in "yad", /ʌ/ in "wuc", /e/ in "fep", /I/ in "miv" and /ɒ/ in "gox"). Medial vowel errors in tables F.1-F.5 of Appendix C include vowel $\rightarrow$ vowel and vowel $\longrightarrow$ dipthong. Thus the dipthong /ɛə/ as in "pear" was produced 19 and 8 times respectively in the dyslexic and non-dyslexic subjects when recalling the medial vowel in "yad".

The phonetic transcriptions of consonant and vowel errors in tables D.1-F.5 of Appendix C are nothing more than a collection of observations since they are only the surface manifestations of the subjects' underlying phonological system. However the purpose of analysing near misses as phonetic transitions allows one to look for regularities amongst these transitions which could be described by a phonological rule. In the introduction to Experiment 4 it was suggested that there were grounds for comparing deviant phonology of dyslexic children with phonological rules used by young children during speech production. Now Ingram has produced a table of the more commonly reported phonological processes found in the speech of young children (Ingram 1976, p. 15). These phonological processes were derived from children's speech samples and it is believed by Stampe (1968, 1972) that the child's mental representation of adult speech is the source of the child's pronunciation and that these phonological processes operate upon this representation. A phonological rule therefore describes a phonological process which has acted on a learned phonological representation at the time of speech production.

Phonological Processes underlying phonetic errors

1. Final and Initial Consonant Errors

Recalling meaningless CVC trigrams and spontaneous speech production are different sources of speech sample. Accordingly there are rules included in table 2 of Ingram (1976) which are excluded here since they do not apply to the current speech sample. The excluded rules, with reasons for exclusion, are:

1. Rule 3. The deletion of unstressed syllables - CVC trigrams are monosyllables.

2. Rule 4. Reduplication - not applicable to monosyllables.

3. Rule 7. Nasalization of vowels which precede a nasal consonant - no final consonants had the feature [+ nasality].

4. Rule 8. Velar assimilation - no final velar consonant was preceded by an apical consonant.

5. Rule 10. Progressive vowel assimilation - CVC

trigrams have one vowel.

6. Rule 15. Gliding - no liquids were used in the 5 CVC's.

7. Rule 16. Vocalization - not applicable to monosyllables.

A revised version of table 2 (Ingram, 1976) is given below in table 5.9.

Ingram (1976) pointed out that many examples of speech error are not clear cut cases where one of these rules alone applies. Often more than one rule will apply. Ingram gives the example of "tick" → /gɪk/. The transition /t/ → /g/ can be explained by a combination of prevocalic voicing and velar

Table 5.9 (adapted from Ingram (1976))
Some Common Phonological Processes found in the speech of young children

Syllable structure processes

1. Deletion of final consonant - e.g. yad [jæ], fep [fe].
2. Reduction of clusters - the reduction of a consonant cluster to a single consonant e.g. gox [gɒk] or [gɒs].

Assimilatory processes

3. Prevocalic voicing of consonants - consonants tend to be voiced when preceding a vowel e.g. fep [vep].
4. Devoicing of final consonants, e.g. yad [jæt], miv [mɪf].
5. Labial Assimilation e.g. fep [mep].

Substitution processes

6. Stopping - fricatives and occasionally other sounds are replaced with a stop consonant e.g. fep [tep], miv [mɪt], gox [gɒkt].
7. Fronting of velars - velar consonants tend to be replaced with alveolar ones e.g. wuc [wʌt], gox [gɒts], gox [dɒks].
8. Fronting of palatals - palatals tend to be replaced by alveolars e.g. wuc [jʌk].
9. Denasalization - the replacement of a nasal consonant with an oral one e.g. miv [bɪv].
10. Vowel neutralization - the reduction of front and back vowels to central ones e.g. wuc [wek], yad [jɜːd].

assimilation (Rules 5 and 8 of Ingram, 1976). On these grounds it would have been possible to explain the guesses (the formal definition of a guess was given earlier on p. 206). For example "gox" $\longrightarrow$ /dʌt/ could be described by a combination of Rule 2 of table 5.9, /gɒks/ $\longrightarrow$ /gɒs/, followed by Rule 6 /gɒs/ $\longrightarrow$ /dɒs/, the Rule 5 /dɒs/ $\longrightarrow$ /dɒt/ and Rule 6 again /dɒt/ $\longrightarrow$ /dʌt/. However as an explanation this is cumbersome and depends upon the validity of using phonological rules to explain the simpler phonological changes in near misses. /dʌt/ after all might have been initially an associative error, i.e. /wʌk/, followed by phonological changes.

Table 5.10 presents the frequency of occurence of Ingram's rules in the generation of final consonant errors. The column labelled domain presents exemplars of the rule. For example Rule 1 in which the final consonant is deleted occurred on 29 occasions in the dyslexic group and on one occasion in the non-dyslexic group. From table 5.10 it can be observed that Ingram's rules explain a sizeable proportion of the corpus of final consonant near misses. 57.4% of dyslexic near misses and 63.6% of non-dyslexic near misses can be accounted for. However there remain a large number of errors which have yet to be explained, and it is therefore necessary to include some additional rules to explain these errors.

Phonological rules are essentially the tool of psycholinguists and are used to explain speech production errors. However in the psychological literature on learning and memory, errors are believed to reflect organizational processes of memory. In his

Table 5.10

Analysis of Phonological Rules used by subjects to produce Near Misses for the Final Consonant

Rule No.	Domain	Frequency of Occurence Dyslexic	Frequency of Occurence Non-Dyslexic
1	$\begin{bmatrix} d \\ K \\ P \\ V \\ KS \end{bmatrix} \rightarrow [\emptyset]$	29	1
2	$/KS/ \rightarrow \begin{bmatrix} K \\ S \end{bmatrix}$	5	0
4	$\begin{bmatrix} d \\ V \end{bmatrix} \rightarrow \begin{bmatrix} t \\ f \end{bmatrix}$	23	1
6	/V/ → stop consonant	3	5
7	$/K/ \rightarrow /t/$ $/KS/ \rightarrow /\genfrac{}{}{0pt}{}{ts}{ns}/$	20	20
Rule Combinations			
2 followed by 6	/KS/ → /K/ → /t/	4	1
5 followed by 4	/V/ → /g/ → /K/	1	0
	Sum Score	85	28
Total No. Final Consonant Near Misses		148	44
	% of Total explained	57.4	63.6

study of free recall organization Tulving (1968) suggested that organization of memory exists in two forms. One form occurs "when the output order of items is governed by semantic or phonetic relations among items", and the other when the output order is governed by the subject's own "prior, extra-experimental or intra-experimental acquaintance with the items constituting a list". Organized output of the first form is called clustering, and of the second form subjective organization. In addition, clustering may be further divided into two types, categorical and associative. Thus Bousfield and Sedgewick (1944) found that in freely emitting exemplars of the category "birds" subjects emitted responses in bursts. For example, there would be a burst of responding in which words like hawk, eagle and vulture were emitted in rapid succession, followed by a temporal gap, and then another burst in which words like chicken, turkey and duck were emitted consecutively. Bousfield and Cohen (1953) explained this categorical clustering by suggesting that phonetically or semantically related words are organized into superordinate systems. Activation of a single perceptual element may be sufficient to excite the superordinate system.

By analogy it might be considered that a subject's subjective organization will attempt to create a category of five items, namely the five CVC's. Since in the early stages of learning the associative strength between phonemes within a CVC string will be weak it is likely that associative interference (McGeoch, 1932; 1936; Melton and Irwin, 1940; Keppel and Underwood, 1962; McNeill, 1966; Wickelgren, 1969a, b; 1967; and Estes, 1972) could occur. In principle associative interference (AI) may occur if one item (R_1) in memory is similar to another item (R_2) such that circumstances leading to the recall of R_1 can also lead to the recall of R_2 instead (Young, 1955; Kausler, 1974). Thus during response production a subject who has recalled correctly the initial consonant and medial vowel of a CVC might erroneously recall a consonant from one of the other CVC's. The final consonant might be either one of the other nine consonants in the cluster or one of the other final consonants. However Nooteboom (1967, 1969), Boomer and Lever (1968) and MacKay (1970) have all observed that when phonemes exchange in a Spoonerism, the origin and target consonants or vowels tend strongly to have occupied the same positions in their respective syllables. Thus it is believed that serial position information is tagged to the phonemes or syllables of words in the lexicon. Indeed such tagging appeared in the current experiment since subjects found it relatively easy to recall the initial consonant but they experienced much greater difficulty with the final consonant. On this evidence it seems that a substitution error arising as a result of AI will retain position information. Thus a final consonant error can be considered to occur as a result of AI if the substituted consonant occurred as a final consonant in one of the other four CVC's. This will be referred to as the rule of AI. Table 5.11 is a revised version of table 5.10 since it includes the rule of AI in addition to childrens phonological rules. Since some errors can be explained by one of Ingram's phonological rules as well as the rule of AI it was decided that the rule of AI would be regarded as the over-riding process. Comparison of tables 5.10 and 5.11 however reveal that only 6 dyslexic errors (/KS/ $\rightarrow$ /K/ and /V/ $\rightarrow$ /d/) and one non-dyslexic error (/V/ $\rightarrow$ /d/) can be explained by AI or Ingrams phonological rules. This low rate indicates that the rule of AI accounts for a large number of errors that Ingrams phonological rules are unable to account for and vice versa. Thus 78.6% of dyslexic AI errors

<u>Table 5.11</u> (a revision of table 5.10)

A phonological description of final consonant errors, with a strict rule of associative interference as the over-riding process

Rule		Frequency Dyslexic	Non-Dyslexic
1	$\begin{bmatrix} d \\ K \\ P \\ V \\ KS \end{bmatrix} \longrightarrow \emptyset$	29	1
2	Reduction of clusters /KS/ ⟶ /S/	1	0
4	Devoicing final consonant $\begin{bmatrix} d \\ V \end{bmatrix} \rightarrow \begin{bmatrix} t \\ f \end{bmatrix}$	23	1
6	Stopping /V/ ⟶ Stop Consonant	1	4
7	Fronting of velars $\begin{bmatrix} K \\ KS \\ KS \end{bmatrix} \longrightarrow \begin{bmatrix} t \\ ts \\ ns \end{bmatrix}$	20	20
		74	26
12 Rule of AI	/KS/ ⟷ /K/	9	0
	/V/ ⟶ /d/	2	1
	/V/ ⟶ /K/	1	0
	/P/ ⟶ /PS/	1	0
	/d/ ⟷ /P/	5	0
	/d/ ⟷ /K/	6	0
	/K/ ⟷ /P/	1	4
	/KS/ ⟷ /d/	3	0
		28	5
Rule Combinations			
9 and 2	/KS/ ⟶ (/S/) ⟶ /z/	4	2
12 and 9	/d/ ⟶ (/P/) ⟶ /b/	2	0
"	/d/ ⟶ (/K/) ⟶ /g/	0	2
12 and 6	/p/ ⟶ (/K/) ⟶ /t/	1	0
	/KS/ ⟶ (/K/) ⟶ /t/	4	1
	/K/ ⟶ (/KS/) ⟶ /ts/	1	1
	/K/ ⟶ (/KS/) ⟶ /ps/	1	0
	/d/ ⟶ (/KS/) ⟶ /ts/	1	0
	/p/ ⟶ (/KS/) ⟶ /ts/	0	1
	Sum Score	115	38
Total No. Final Consonant Near Misses		148	44
	% of Total explained	77.7%	86.4

and 80% of non-dyslexic errors are not explained by Ingrams rules. Ingrams rules and the rule of AI together account for

77.7% of all dyslexic near misses and 86.4% of all non-dyslexic misses.

Group Differences

From table 5.11 it appears that the dyslexic subjects frequently deleted the final consonant, devoiced the final consonant and "alveolarized" final velar consonants, whereas non-dyslexic subjects rarely deleted or devoiced the final consonant but frequently "alveolarized" a final velar. In respect of associative interference between final consonants it appears that this occurred frequently in dyslexic subjects but rarely in non-dyslexic subjects.

Summary of Consonant Error Near Misses

General

1. Initial consonant errors were relatively rare whereas final consonant errors were common.

2. Phonological processes used by children during speech production could be used to explain 85 (57.4%) final consonant errors in dyslexic subjects and 28 (63.6%) final consonant errors in non-dyslexic subjects.

3. Associative interference accounted for 28 (19%) dyslexic and 5 (11.4%) non-dyslexic final consonant errors. Ingrams phonological rules together with AI accounted for 115 (77.6%) dyslexic and 38 (86.4%) non-dyslexic final consonant errors.

Group Differences

1. The influence of serial position was similar in both groups.

2. Group differences were small for initial consonants (n = 25 and n = 17 for dyslexic and non-dyslexic subjects respectively) although this might have been an artifact due to a ceiling effect.

3. Dyslexic subjects produced many more final consonant errors than non-dyslexic subjects (n = 148 and n = 44 respectively).

4. Dyslexic subjects showed a greater tendency towards a selective use of deletion and devoicing of the final consonant whereas fronting of velars occurred as frequently for non-dyslexic as for dyslexic subjects.

5. Associative interference was more common amongst dyslexic subjects (n = 27) than amongst non-dyslexic subjects (n = 5).

2. Medial Vowel Errors

The phonetic notation of O'Connor (1977) for the twenty-one vowel phonemes of RP (Received Pronunciation) has been adopted here to transcribe the near misses. Each of these vowels can be positioned in a two dimensional space representing the movement of the tongue during vowel pronunciation. The two dimensions of tongue articulation are 1) place of articulation (i.e. somewhere between the front and the back of the tongue. Centre refers to the midpoint of the tongue) and 2) openness of the vocal track (i.e. the amount the tongue is raised toward the palate. The terms close or high mean that the tongue is raised close to the palate whereas open or low means the tongue is far from the palate. Intermediate refers to a half closed - half open position). For example in RP pronunciation /i:/ in "beat" is a close front vowel, /uː/ in "boot" is a close back vowel, /æ/ in "bat" is an open front vowel and /aː/ in "calm" is an open, back vowel.

Ingram's phonological rules used by children was successful in describing a large number of consonant substitutions. Moreover Ingram (1976) has described only two rules used by children in mispronouncing vowels. These two rules are vowel neutralization and progressive vowel assimilation (Ingram, 1976 p. 15). The former rule refers to the reduction of vowels to a central vowel e.g. yad → /jɜːd/ and the latter rule to an assimilation of an unstressed vowel to a preceding stressed vowel. However progressive vowel assimilation is not relevant to the current data since only one vowel occurs in a CVC trigram. Now Salus and Salus (1974) included vowel lengthening before voiced segments as a frequently employed phonological rule used by young children. Thus the data of tables F.1-F.5 of Appendix C will be scanned for the use of vowel lengthening as well as vowel centralization. Now centralization of a vowel will be represented by a tendency to articulate both front and back vowels in the central region. Thus vowels like /ʌ/, /ɜː/ and /ə/ should occur frequently in place of the target front vowels such as /æ/ in "yad", /e/ in "fep", /I/ in "miv" and back vowels such as /ɒ/ in "gox". Further /ʌ/ in /wʌk/ should not be mispronounced as often as the other vowels since /ʌ/ is a central vowel already. Examination of tables F.1-F.5 of Appendix B reveals that /ʌ/, /ɜː/ and /ə/ are rarely produced as substitutions whereas /ʌ/ in /wʌk/ produced the largest number of substitutions for both dyslexic (n = 78) and non-dyslexic (n = 28) subjects. Indeed the substitution of /ɒ̆ / for /ʌ/ which occurred frequently is a process of decentralization. However it should be pointed out that the dipthongs /ɪə/ and /ɛə/ which were substituted for /æ/ in /jæd/ both terminate in a central tongue region. Now Judson and Weaver (1966) and O'Connor (1974) considered that the glides /j/ and /w/ are not distinct sounds but glides from one vowel to another. Thus /j/ results from an approaching glide from /I/ to another vowel, namely /æ/ in "yad" and /w/ results from a glide from /ʊ:/ to /ʌ/ in "wuc". Thus the dipthongs /ɪə/ and /ɛə/ in "yad" can be regarded as cases of vowel centralization. These two errors together account for 32 (15.6%) and 12 (24.5%) dyslexic and non-dyslexic errors respectively. However the transition of vowel ⟶ dipthong remains to be explained.

O'Connor (1977) considered that "Dipthongization and length are similar to each other in effect ..... one can see in English how sometimes dipthongization and sometimes length are used to carry the same contrast" (p. 220) and later "A dipthong .... is phonetically a vowel glide or a sequence of two vowel segments which functions as a single phoneme." (p. 220). Therefore the process of vowel ⟶ dipthong can be considered as a special case of vowel lengthening. The frequency of dipthongization of vowels in the five CVC's is presented in table 5.12 which is a summary of the data in tables F.1-F.5 of Appendix B.

One should be reminded that Salus et al (1974) reported that vowel lengthening by young children normally occurs before

Table 5.12

Frequency of Dipthongization of Medial Vowel

CVC

	Final Consonant Voiced		Final Consonant Not Voiced		
	yad	miv	wuc	fep	gox
Dyslexic	32	4	0	1	5
Non-Dyslexic	12	0	0	0	0

a voiced segment. From table 5.12 it will be observed that all non-dyslexic and most dyslexic cases of dipthongization did occur in the CVC's with a voiced final consonant. The six occurrences of dipthongization in the unvoiced final consonant CVC's were: fep → /fɛə/ as in "fair", wuc → /wɔək/, /wɔə/ as in "pour", and /wəʊv/, /wəʊd/, /wəʊg/ as in "toad". On 3 of these 6 occasions a voiced final consonant had been substituted and on only one occasion i.e. /wɔək/ was the proceeding consonant unvoiced. This data therefore adds further weight to the hypothesis that dipthongization is indeed a special case of vowel lengthening before a voiced final consonant.

Pure cases of vowel lengthening were /a:/ and /ɜ:/ in place of /æ/ in "yad" (n = 11, dyslexic and n = 2 non-dyslexic); /a:/, /ɔ:/ and /ʊ:/ in place of /ʌ/ in "wuc" (n = 3 dyslexic and n = 0 non-dyslexic); /a:/ and /i:/ in place of /e/ in "fep" (n = 2 dyslexic and n = 0 non-dyslexic); /ɜ:/, /a:/ in place of /I/ in "miv" (n = 7 dyslexic and n = 0 non-dyslexic); /ʊ:/ and /ɔ:/ in place of /ɒ/ in "gox" (n = 4 dyslexic and n = 0 non-dyslexic). Thus pure cases of vowel lengthening occurred on 27 (13.2%) and 2 (4.1%) occasions for dyslexic and non-dyslexic subjects. Of these, 18 dyslexic and both non-dyslexic cases occurred in the two CVC's with a following voiced consonant. Of the remaining 9 cases in the dyslexic group the erroneous responses were /wa:v/ (twice), and wu:k for "wuc"; /fi:n/ and /fa: / for "fep"; /gɔ:z/, /u:k/, /gu:t/ and /gu:ts/ for "gox". Thus in 5 of these 9 cases the voiceless final consonant had been either omitted or replaced by a voiced consonant.

In summary, pure vowel lengthening and diphthongization together accounted for 69 (33.7%) dyslexic and 14 (28.6%) non-dyslexic medial vowel near misses. Further dipthongization appears to be a special case of vowel lengthening.

Keller (1978) analysed vowel substitution errors in Brocas aphasics. One of Keller's findings was that vowels which are similar in articulation to the target vowel are much more likely to be used as substitutes than those which are dissimilar. To measure similarity Keller used five features from the Chomsky and Halle (1968) feature system with which targets and substitutions could be rated. For the current data the two dimensional system of O'Connor (1977) was used. On this vowel space the articulatory distance between target and substitute can be measured on the diagram with a ruler. However for dipthongs there is no fixed locus in the two dimensional space since the speaker changes the manner of articulation between the initial and the terminal vowel. Therefore two loci have been considered for dipthongs, namely the half way point in the vowel transition, and the terminal vowel. Tables G.1 and G.2

of Appendix C present, along a similar-dissimilar dimension, a rank ordering of all the vowels produced as substitutes. The frequency of occurence of each substitute has been calculated for each of the five target vowels. Table G.1 of Appendix C adopts the half-way stage of a vowel transition as the locus of dipthongs whereas Table G.2 adopts the terminal vowel as the locus of dipthongs. Cut-off points were then arbitrarily fixed separating the similar-dissimilar dimensions into three segments representing similar, intermediate and dissimilar substitute vowels. The number of substitutions falling into each of these three segments is presented below in tables 5.13 and 5.14 for each CVC. From these tables it is clear that the criterion locus of dipthongs barely

Table 5.13

The Articulatory Similarity of Vowel Substitutions (adopting the half way stage of vowel transition in dipthongs as the locus)

Target		Similar	Intermediate	Dissimilar
/æ/	Dyslexic	58	8	6
	Non-Dyslexic	13	0	3
/ʌ/	Dyslexic	75	1	2
	Non-Dyslexic	28	0	0
/e/	Dyslexic	3	1	7
	Non-Dyslexic	0	0	0
/ɪ/	Dyslexic	26	3	5
	Non-Dyslexic	3	0	0
/ɒ/	Dyslexic	4	5	1
	Non-Dyslexic	1	1	0
	(Dyslexic)	166 (81.0%)	19 (9.3%)	21 (10.2%)
	(Non-Dyslexic)	45 (91.9%)	1 (2%)	3 (6.1%)

affects the results. Thus 81 - 82% of dyslexic and 92% of non-dyslexic substitution errors were similar to the target compared

Table 5.14

The Articulatory Similarity of Vowel Substitutions adopting the terminal vowel in a vowel transition in dipthongs as the locus

Target	Group	Similar	Intermediate	Dissimilar
/ɑ/	Dyslexic	65	1	6
	Non-Dyslexic	13	1	2
/ʌ/	Dyslexic	75	2	1
	Non-Dyslexic	28	0	0
/e/	Dyslexic	2	2	7
	Non-Dyslexic	0	0	0
/ɪ/	Dyslexic	23	5	6
	Non-Dyslexic	3	0	0
/ɔ/	Dyslexic	2	6	2
	Non-Dyslexic	1	1	0
	(Dyslexic)	167 (81.5%)	16 (7.8%)	22 (10.7%)
	(Non-Dyslexic)	45 (91.9%)	2 (4%)	2 (4%)

with 10 - 11% of dyslexic and 4 - 6% of non-dyslexic errors which were dissimilar to the target.

It will be recalled that analysis of final consonant substitutions showed that 19% of dyslexic and 11.4% of non-dyslexic final consonant errors arose from associative interference between the other four CVC's. A similar analysis was therefore applied to vowel substitution errors. Table 5.15 shows the frequency with which a vowel from one of the other four CVC's was substituted for the target vowel. From this table it appears that 135 (66%) of dyslexic and 34 (69.4%) of non-dyslexic errors result from AI. In addition reference to table G.1 and table G.2 of Appendix C shows that 13 out of 24 (table G.1 of Appendix C) or 12 out of 24 (table G.2 of Appendix C) dissimilar vowel substitutions resulted from a transposition from another

Table 5.15

Frequency of Associative Interference in Medial Vowel Substitution Errors

Group	Frequency of AI (target vowel)					
	/æ/	/ʌ/	/e/	/I/	/ɒ/	Total
Dyslexic	28	75	8	23	1	135
Non-Dyslexic	2	28	0	3	1	34

CVC. Since there are 21 vowels and dipthongs in RP (O'Connor, 1977) the expected frequency of AI errors, by chance, in this category would be 4.6. Therefore the frequency of AI errors causing dissimilar vowel substitutions is well above chance.

In the introduction to Experiment 4 it was pointed out that Wickelgren (1965 a, b) failed to notice the directionality apparent in his data. In his data devoicing of voiced consonants occurred more frequently than envoicing of unvoiced consonants. It is therefore important to look for systematic shifts in the current data. Table 5.16 presents the observed AI vowel transpositions with the frequency of occurrence.

Table 5.16

Vowel Substitutions - Incidence of Associative Interference.

Target	Dyslexics	Non-Dyslexics
/æ/	/ɒ/(n=2),/e/(n=26)	/e/(n=1),/I/(n=1)
/ʌ/	/æ/(n=8),/e/(n=1),/ɒ/(n=66)	/æ/(n=1),/ɒ/(n=27)
/e/	/ɒ/(n=4),/I/(n=2),/ʌ/(n=2)	
/I/	/e/(n=20),/æ/(n=1),/ʌ/(n=1) /ɒ/(n=1)	/e/(n=3)
/ɒ/	/e/(n=1)	/ʌ/(n=1)
	= 135	= 34
	(Chance = 39)	(Chance = 9)

From table 5.16 it is clear that the frequent vowel substitutions of dyslexic phonemic transitions namely /æ/ ⟶ /e/ (n = 26), /ʌ/ ⟶ /æ/ (n = 8), /ʌ/ ⟶ /ɒ/ (n = 66) and /I/ ⟶ /e/ (n = 20) are not reflexive since /e/ ⟶ /æ/, /æ/ ⟶ /ʌ/ and /ɒ/ ⟶ /ʌ/ do not occur at all and /e/ ⟶ /I/ only occurs twice. Similarly for the non-dyslexic subjects /ʌ/ ⟶ /ɒ/ was recorded 27 times but the reverse /ɒ/ ⟶ /ʌ/ was recorded just once. Therefore a simple model of phonemic transposition between CVC's is not enough, since a rule of AI simply predicts that similar phonemes are more likely to be transposed than dissimilar ones. Since the frequency of /ʌ/ ⟶ /ɒ/ is some 93 times the frequency of /ɒ/ ⟶ /ʌ/ an additional phonological rule must be appended to a rulè of AI to account for this disequilibrium.

In pursuit of a phonological rule to append to the rule of AI that will predict any disequilibrium it seemed reasonable to investigate the role of the consonant environment. Now Wickelgren (1969 a, b) considered that neighbouring vowels or consonants influenced the phoneme transpositions observed at the response buffer level in memory span tests and during speech production. He put forward a context-sensitive, associative theory of speech production in which preplanned sequences of words are stored as sets of unordered "context-sensitive allophones" in which an allophone is a phoneme with one phoneme specified before and after it. Thus each phoneme acts as a cue to the preceeding and proceding phonemes. Moreover Derousne, Beauvois and Rantz (1977) investigated the influence of neighbouring phonemes on vowel substitutions in aphasia. Their "environmental influence theory" holds that a substitution of the form /ðə/ → /ði:/ for "the" is a fronting of the vowel arising from the frontal (alveolar) nature of the immediately preceeding consonant /ð/. A corollary of this environmental influence hypothesis is that when the place of articulation of the neighbouring consonants is similar to that of the vowel then either few vowel substitutions will occur or other factors will be exerting a stronger influence. Thus one would not expect a frontal vowel, for example, adjacent to two frontal consonants to be frequently replaced by a back vowel. Now in the case of /jæd/ (i.e. yad), /j/ and /d/ are palatal and dental consonants respectively (Compton, 1976) and /æ/ is a frontal vowel. Therefore vowel substitutions should be few and predominantly frontal vowels. Thus /e/ and /I/ should occur more frequently than /ʌ/ and /ɒ/ which is true of the dyslexic subjects (n = 26 for /e/ and /I/ substitutes against n = 2 for /ʌ/ and /ɒ/ substitutes) and non-dyslexic subjects (n = 2 for /e/ and /I/ against n = 0 for /ʌ/ and /ɒ/). For /WʌK/, /W/ involves the back of the tongue and /K/ is a velar consonant whereas /ʌ/ is a central vowel. Therefore it would be expected that /ʌ/ would be replaced frequently by a back vowel i.e. /ɒ/ should occur more frequently than /I/, /e/ or /æ/. This is true for dyslexic subjects (n = 66 for /ɒ/ against n = 9 for /I/, /e/ and /æ/ combined) and non-dyslexic subjects (n = 27 for /ɒ/ against n = 1 for /I/, /e/ and /æ/ combined). For /fep/, /f/ is a labial-dental and /p/ is a bilabial and

/e/ is a front vowel. Therefore vowel substitutions should be few and predominantly front vowels. So /I/ and /æ/ should occur more frequently than /ʌ/ or /ɒ/ which is not true for dyslexic subjects (n = 2 for /I/ and /æ/ against n = 6 for /ʌ/ and /ɒ/) and for non-dyslexic subjects no vowel substitutions were recorded. However the error rate was very low as predicted. In the case of /mɪv/, /m/ is a bilabial, /V/ is a labial-dental and /I/ is a front vowel. Therefore vowel substitutions should be few and tend to be the front vowels /e/ and /æ/ rather than the back vowel /ʌ/ and /ɒ/, which is true for the dyslexic subjects (n = 21 for /e/ and /æ/ combined against n = 2 for /ʌ/ and /ɒ/) and non-dyslexic subjects (n = 3 for /e/ and /æ/ against n = 0 for /ʌ/ and /ɒ/). Finally in the case of /gɒKS/, both /g/ and /K/ are velar consonants and /ɒ/ is a back vowel. Therefore vowel substitutions should be few and tend to be the central vowel /ʌ/ rather than the front vowels /I/, /e/ and /æ/. However /ʌ/ never occurred as a substitution in the dyslexic group and only once in the non-dyslexic group and /I/, /e/ and /æ/ occurred once in the dyslexic group and never in the non-dyslexic group. The paucity of errors is expected from the similar position of articulation of both consonants and vowel.

It should be remembered that the environmental influence hypothesis predicts that neighbouring consonants differing in place of articulation from the medial vowel will exert a systematic influence on the vowel. If however both the consonants and the vowel are articulated with a similar part of the tongue there will be no systematic influence on the vowel. Instead the systematic influence of the environment will be exerted after a vowel has been substituted. Thus rather than bring about the vowel substitution an influence will be exerted after the substitution. This distinction is important because it predicts that an environmental influence has been exerted by /W/ and /K/ in the case of /WʌK/ to bring about the frequent /ʌ/ → /ɒ/ substitution whereas no such influence was exerted by /g/ and /KS/ in the case of /ɒ/ since the consonants and the vowel are articulated with a similar part of the tongue. Therefore the frequent substitution of /ʌ/ → /ɒ/ is believed to result from three influences. First the glides /j/ and /W/ seem to encourage medial vowel errors perhaps due to the fact that a complex shifting from one vowel to another is demanded. Secondly /W/ and /K/ encourage the vowel to be articulated at the back of the tongue and thirdly AI brings about the specific selection of /ɒ/ rather than any other back vowel due to subjective organization of the five CVC's into a single category (Tulving, 1968).

Summary of Medial Vowel Misses

1. 205 medial vowel near misses were produced by the dyslexic subjects against 45 by the non-dyslexic subjects.

2. There was a very strong tendency for the substituted vowel to be similar in articulatory terms to the target vowel.

3. There was a strong tendency for the substituted vowel to be either a transposition from one of the other 4 CVC's (the rule of AI) or to be caused by a tendency to lengthen the vowel (the rule of vowel lengthening). The two rules did not

overlap at all for any medial vowel errors and in combination they accounted for 99.7% of dyslexic and 99.0% of non-dyslexic errors.

4. Associative interference does not work by itself since systematic vowel substitutions were observed. It seems likely that the environmental influence of neighbouring consonants made restrictions on the phonological domain of the medial vowel and the subject made a selection from one of the five available vowels. Alternatively associative interference between medial vowels made recall difficult and together with the environmental influence certain vowels, from similar consonant environments, were occasionally substituted.

5. Vowel centralization was observed on some occasions, namely dipthongs, but decentralization was more frequently observed. At best vowel centralization could be acting in combination with the rule of vowel lengthening but it rarely, if ever, occurred by itself.

Results of Relearning (Part 4)

Table 5.17 presents the mean number of incorrect responses (RLE + ALE), RLE's and ALE's for dyslexic and non-dyslexic subjects from Part 4 (Relearning).

Table 5.17

Mean no. Incorrect Responses, RLE's and ALE's from Part 4 (Relearning) of Experiment 4

	Incorrect Responses	RLE	ALE
Dyslexic (n=12)	6.33	4.75	1.58
Non-Dyslexic (n=12)	1.58	0.7	0.5

Table H of Appendix **C** gives the frequency of each of these measures for each subject.

Matched pairs t-tests were calculated on each of the three measures of error in table 5.17 to test for group differences. With regard to incorrect responses (RLE + ALE) there was a significant group difference, $t = 2.2$, df 11, $p < .05$. There was also a significant group difference with respect to RLE's, $t = 2.32$, df 11, $p < .05$. For both incorrect responses and RLE's the dyslexic group produced more errors. However for ALE's there was no significant group difference, $t = 1.85$, df = 11, $p > .05$. Due to the low error rate no further analysis was carried out on either the RLE or ALE data.

<u>Section 2</u> - Results of Serial Recall (Parts 1, 3 (ii), 6 and 7), and Naming Speed (Part 3 (i) and 5)

<u>Non-verbal Recall of Shape sequences</u> (Parts 1 and 7)

It will be recalled that in Parts 1 and 7 subjects were shown 4 or 5 item sequences in a tachistoscope which they subsequently recalled non-verbally. Part 1 can be considered as a pre-learning test of immediate serial order recall and the test in Part 7 can be considered as a post-learning test of immediate serial recall. In both parts performance was measured by counting the total number of tablets recalled in their correct serial position. For this purpose scores from both 4 and 5 item sequences were added together. As there were 5 trials at each sequence length a subject could obtain a maximum score of 45 points. The results are presented in table 5.18.

Table 5.18

Mean No. of Tablets recalled in the Correct Serial Position in Pre- and Post-Learning Serial Recall (Parts 1 and 7)

	Pre-Learning Part 1	Post-Learning Part 7	Difference
Dyslexic (n=12)	21.33	25.83	4.5
Non-Dyslexic (n=12)	25.6	33.08	7.48
Difference (d)	4.27	7.25	

A three way Groups x Treatments x Sequence Length repeated measures ANOVA (Weiner, 1972) was used to analyse these results. The overall group difference was significant, $F = 31.05$, df 1,11, $p < .01$, due to a superior performance by the non-dyslexic subjects. The treatment factor was also significant, $F = 56.31$, df 1, 11, $p < .01$. Observation of table 5.18 reveals that both dyslexic and non-dyselxic groups performed better in Part 7 (Post-Learning) than in Part 1 (Pre-Learning). The Groups x Treatments interaction was significant too, $F = 4.89$, df 1, 11 $p < .05$. Observation of table 5.18 reveals that the mean group difference in Part 1 was 4.27 and in Part 7 it was 7.25. The significant interaction can therefore be intepreted as the non-dyslexic subjects gaining more from the pair-associate learning experience than the dyslexic subjects.

Verbal Recall of Shape Sequences (Parts 3 (ii) and 6)

It will be recalled that in Parts 3 (ii) and 6 subjects were asked to verbally recall sequences of shapes presented in the tachistoscope. In both Parts 3 (ii) and 6 performance was measured as the exposure time at which the 4-item and the 5-item sequences were both incorrectly recalled. This method is generally known as the Method of Limits (Woodworth and Schlosberg, 1954). The mean exposure times recorded are given in table 5.19 (the values are the total exposure time divided by the number of shapes in the sequence).

Table 5.19

Mean Exposure Time per shape (Msecs) at which subjects were incorrect on both the 4-item and the 5-item trials

	Week 1 Part (3 ii)	Week 2 Part 6
Dyslexic (n=12)	699	692
Non-Dyslexic (n=12)	325	167

A three way Group x Treatments x Sequence Length repeated measures ANOVA was computed on the exposure threshold data. Since subjects were matched by pairs the Groups factor is treated in a similar way to that reported in Experiment 1 (see p. 87). The ANOVA gave a significant overall effect of the Groups factor, $F = 5.72$, df 1, 11, $p < .05$ due to a lower threshold for non-dyslexic subjects (see table 5.19). Both the Treatments factor, $F = 0.623$, df 1, 11, $p > .05$ and the Sequence Length factor, $F = 1.815$, df 1, 11, $p > .05$ were insignificant. There were no significant interactions despite the appearance of a generalised improvement in the non-dyslexic group between Week 1 and Week 2.

Verbal Recall of Digit Sequences (Part 7)

Immediately after the test of non-verbal serial recall of shape sequences in Part 7 subjects were asked to recall verbally digit sequences.

11 out of 12 non-dyslexic subjects recalled all of the six digit sequences perfectly. Therefore the data for six digit sequences in the non-dyslexic group will be disregarded. Group comparisons on the seven digit sequences were tested using a matched pairs t-test, which gave a very significant t-value, $t = 2.857$, df 11, $p < .01$. This group difference was caused by a higher performance in the non-dyslexic subjects.

Pearson product moment correlations were computed between seven digit recall scores and the other measures of serial order memory to assess the role of the response buffer in these latter tasks. The results are presented in table 5.20.

Table 5.20

Pearson Correlations between Digit Span and Serial Order Recall of Shape Sequences

	Digit Span (7-digit sequences)	
Part 1 (Pre-Learning Non-Verbal Shape Recall)	+0.350	$p<.05$
Part 7 (Post-Learning Non-Verbal Shape Recall)	+0.526	$p<.005$
Part 3(ii) (Week 1 Verbal Recall of Shapes)	-0.278	$p>.05$
Part 6 (Week 2 Verbal Recall of Shapes)	-0.445	$p<.01$
		df 22

From table 5.20 it is noticeable that digit span is correlated with non-verbal shape recall in both Part 1 (Pre-Learning) and Part 7 (Post-Learning). It was expected that familiarity with the shapes would encourage the development of spontaneous naming of the shapes. This was borne out by the larger correlation between digit span and shape recall in Week 2 (i.e. Part 7) than in Week 1 (i.e. Part 1). Familiarity with the learned names also affected the correlation between digit span and name recall. In Week 1 (i.e. Part 3(ii)) the performance of subjects was not significantly ($p > .05$) correlated with their digit span, however their performance in Week 2 (i.e. Part 6) was significantly correlated with their digit span ($p < .01$).

Reading Speed (Parts 3(i) and Part 5)

The time taken by subjects to read through the passage of shapes was recorded in Parts 3(i) and 5. In Part 3(i) many of the subjects produced long pauses whilst reading the passage, although Part 5 was relatively free of this problem and subjects read the passage quite fluently. Subsequently only the reading speeds from Part 5 have been used for statistical analysis. On this task there was a significant group difference, $t = 3.16$, df 11, $p < .005$ due to a slower reading speed in the dyslexic group.

Section 3 - Relationship between PAL and Serial Order Memory

The results of the digit span task in Part 7 were correlated with the results of the PAL task (Part 2). Five measures of PAL error were each correlated with the subjects digit span score on the seven digit sequences in both groups of subjects as well as a combined score from the six and seven digit sequences in the dyslexic group. It will be recalled that for six digit sequences a ceiling effect was discovered in the non-dyslexic subjects, which has lead to the elimination of this data from subsequent analyses. The five measures of PAL error were 1. Total error rate, 2. Total RLE rate, 3. ALE rate, 4. RLE errors caused by the action of phonologic rules (PR rate), 5. RLE errors caused by AI. Since dyslexic subjects produced a lower level of performance on both the digit span task and the PAL task it was decided to compare the relationship of digit span and PAL errors within groups. It is conceivable that dyslexic subjects perform at a lower level on a majority of quite different tasks, therefore combining the results of both groups might lead to spurious correlations between digit span performance and PAL error rates. The results of the correlation analysis are given in tables 5.21 and 5.22 for non-dyslexic and dyslexic subjects respectively.

Table 5.21

Correlations between Digit Span Score of Non-Dyslexic Subjects (Part 7) and five measures of PAL error for Final Consonant Errors (Part 2)

	Total Errors	Total RLE	ALE	PR Errors	AI Errors
Digit Span (7-item series)	-.482	-.317	-.511*	-.313	-.535*

* $p < .05$

Observation of table 5.21 reveals that in non-dyslexic subjects there is a tendency for digit span performance to be related to ALE and AI errors (the negative sign indicates that a high digit span score tends to be related to a low number of errors).

Table 5.22

Correlations between Digit Span Score of Dyslexic Subjects (Part 7) and five measures of PAL error for Final Consonant Errors (Part 2)

Digit Span	Total Errors	Total RLE	ALE	PR Errors	AI Errors
7-item Series	-.737•	-.590*	-.699•	-.475	-.547*
(6+7)-item Series	-.663•	-.494	-.733•	-.373	-.480

• $p < .01$

* $p < .05$

Observation of table 5.22 reveals that in the dyslexic subjects there is a tendency for digit span performance to be related to total error frequency, total RLE frequency, ALE frequency and AI error freqeuncy. The correlation with PR errors fails to reach significance for both measures of digit span ($.05 < p < .10$).

In summary, the correlation analysis reveals that a relationship exists between digit span and the frequency of ALE and AI errors in both groups. There is a less significant relationship between digit span and PR errors. The implication of these results is that a subject with a low digit span is likely to produce a high level of ALE and AI errors in a PAL task although his tendency to use phonological rules to transform a stored representation is unrelated to his digit span.

Discussion of Results

Results from the current experiment have been separated into three sections to deal separately with the PAL results, serial order memory results and, in the third section cross comparisons of PAL performance and serial order memory performance.

From the PAL tasks it was apparent that the dyslexic subjects had a severe handicap in initially learning the CVC responses. They tended to manufacture their own responses in so far as they frequently gave a response which was not one of the five CVC's included in the response set. Usually the initial consonant was correct and the source of error was either due to poor recall of the medial vowel or final consonant. The wide variation of error rates between CVC's, especially with regard to the medial vowel, indicates that there are important qualities of the component phonemes that make a CVC one which is easy to learn or one which is difficult to learn. Moreover it needs to be pointed out that an erroneous response can either result from a correct memory trace which is poorly recalled and produced, or an incorrect memory trace which is correctly produced.

As a heuristic the phonological rules used by children during speech production (Ingram, 1976; Stampe, 1972; Salus and Salus, 1974; Aitchison, 1980) proved useful in explaining some of the final consonant and medial vowel errors. Thus 57.4% of dyslexic and 63.6% non-dyslexic final consonant near misses and 33.7% of dyslexic and 28.6% of non-dyslexic medial vowel near misses could be explained by the use of the phonological rules adopted by children before the age of seven. These same errors could not be explained by associative interference. The implication is that these phonological processes which have been dormant for a number of years have been activated and used in this novel language acquisition situation which resembles initial language acquisition. Regression of this kind has been reported by Lenneberg (1960) in aphasic children. Karmiloff-Smith (1978) also considered that all rules of cognition are never completely lost during development, instead they "gather dust somewhere in the archives" and can be retrieved and used at a later point in time under peculiar or novel situations.

There were a large number of near misses that remained unexplained by these phonological rules. Since there were already in existence a large number of associative learning errors it seemed reasonable to look for associative interference errors amongst the unexplained near misses. It should be recalled that an associative learning error occured when one of the five CVC responses (e.g. R_2) was recalled incorrectly given stimulus S_1, when the correct response should have been R_1. Associative interference errors are considered to occur when one or two phonemes from a response (e.g. R_2) replace the phonemes in the correct response (R_1) that occupy the same serial positions. Thus the response still retains at least one correct phoneme. Associative learning errors and associative interference errors are considered to result from the operation of similar processes in the organization of the lexicon. Tulving (1974) considered that ".... if a stimulus in the retrieval environment renders possible or facilitates recall of the target word T, the retrieval information was appropriate to or compatible with the information contained in the episodic trace of T. Conversely, if a particular stimulus is ineffective in retrieving a particular trace, the conclusion follows that the appropriate relation was lacking" (Tulving, 1974; pp 778-779). Therefore an associative learning error arises when encoded visual stimulus (S_1) provides retrieval information appropriate to the information contained in the episodic trace of R_2. However CVC response units themselves are initially structures made up of S-R chains between adjacent phonemes.

The response learning theory of Underwood et al (Underwood, Runquist and Schutz, 1959; Underwood and Schulz, 1960) holds that for a nonsense syllable like JOQ the letter J is the initial response unit to the presented stimulus. The next S-R link in the chain is between the response produced stimulus from saying "J" and the next R unit of the syllable, the letter O. The final link is between the response-produced stimulus from saying "O" and the terminal R unit of the syllable, the letter Q. Eventually "JOQ" will become a complete unit and be recalled as a complete unit. Before this final stage is reached the same processes causing whole syllable associative learning errors can produce associative interference between phonemes. Thus the so-called associative interference errors arise when a phoneme P_1 provides retrieval information appropriate to the information contained in the episodic trace of the phoneme Px rather than the correct phoneme P_2. Therefore associative interference errors are phonemic associative learning errors and the previously termed associative learning errors are really syllabic associative learning errors.

It was found that medial vowel errors were usually phonetically similar to the target vowel. It is therefore proposed that subjects initially take some time to learn the set of phonemes that are used in the task. Each phoneme is initially stored as an imprecise memory trace and may even be indistinguishable from another stored phoneme. When the initial consonant (P_1) is recalled it acts as a cue for the retrieval of a particular medial vowel (P_2). However the trace of P_2 is not yet well formed such that a different medial vowel (P_3) is frequently recalled instead.

It is believed that in this novel learning situation, which approximates to language learning in young children, that before a CVC is recalled as unit it will be subjected to similar phonological processes observed in the speech of young children. These phonological processes will act upon the word when the phonological integrity of the word in the lexicon is ill formed. In addition before the medial vowel is well learned it will be susceptible to the environmental influence of the neighbouring consonants. It will be recalled that this influence was very strong during the acquisition of medial vowels resulting in the frequent transposition of medial vowels between CVC's.

Dyslexic subjects recorded significantly more PAL errors of all kinds. For example it was found that they produced significantly more associative learning errors for medial vowels and final consonants. Adopting the theory postulated above this is symptomatic of a difficulty in creating well-formed phonological entities in the lexicon. In the very earliest stages of learning the memory trace of the phonemes is less precise and so it takes longer to learn the set of composite phonemes. Similarly for dyslexic subjects it is believed that the higher incidence of whole syllable associative learning errors results from a similarly imprecise phonological description of the CVC syllable as a whole. In addition due to the presence of ill formed phonemes and syllables in their lexicon, dyslexic subjects will show a greater tendency for lexical output to be adjusted by phonological processes and be influenced by the consonant environment.

Items selected from the lexicon are "loaded" into the response buffer prior to speech production (Morton, 1979; Ellis, 1979). Now Wickelgren (1965a, b) and Conrad (1972) pointed out that as the phonological boundary between two items becomes less distinct then the greater the tendency for items in the response buffer to become transposed. Thus dyslexic subjects will access imprecise phonological descriptions from their lexicon in order to "load" the response buffer. Accordingly transposition errors will be greater in the dyslexic population resulting in a lower digit span, and poor serial order memory for the shapes once the names have been learned. This receives empirical support from the findings presented in section 3 of the results. There it was reported that the frequencies of associative learning errors and associative interference errors both correlated negatively with digit span in non-dyslexic and dyslexic subjects. That these correlations were significant in the dyslexic and non-dyslexic groups taken separately ($n = 12$ in each case) provides a strong indication that digit span and the frequency of phonemic and syllabic associative learning errors are strongly related, thus subjects with larger memory spans produce fewer errors and vice versa. In the case of associative learning errors the imprecise phonological descriptions of phonemes and syllables results in the frequent retrieval of the wrong phoneme or syllable. Similarly a number of imprecise phonological descriptions being rehearsed and stored in the response buffer are more likely to be transposed leading to a lower digit span.

Summary of Discussion

A theoretical view of the organization of the lexicon has been presented here. The theory holds that the CVC syllables are initially stored as a set of phonemes. Early in the task the phonological descriptions of these phonemes are crude and are therefore subject to adjustment during speech production through the operation of phonological processes. Gradually the phonemes become well formed and simultaneously the associations between phonemes within CVC's become established. Ultimately the CVC syllable exists as a complete phonological unit in the lexicon and can be accessed as a single unit when presented with the visual stimulus.

In dyslexic subjects it is held that the ability to form precise phonological descriptions of phonemes, syllables and words is impaired.

When the subject attempts to produce a novel vocal response, such as a CVC, phonological re-adjustments result from the operation of innate phonological processes on poorly described phonological entries. Thus some errors result from the operation of these processes on these poorly described phonological entries in the lexicon. In addition these phonological entries are likely to be confused during retrieval, resulting in both phonemic and syllabic associative learning errors. If a series of poorly described phonological entries are subsequently "loaded" into the response buffer then the chances of order errors is greatly increased since the phonological descriptions of items will be less distinct. Thus the efficiency of phonological organization in the lexicon is related to the efficiency of the response buffer in memory span tasks.

CHAPTER 6

EXPERIMENT 5

INTRODUCTION

Referring to the relationships between reading and listening, spelling and writing, Kolers (1979) said, "The principle query concerns the degree of the visual system's intelligence. One view is that the visual system's intelligence is so limited as to enable it only to acquire the printed words and hold them for that interval of time required by a language mechanism to translate them into a speech-based form. The codification and interpretation of the written signals then goes forward, so the argument has it, as it would for the more "natural" process of listening. An alternative view is that the visual system is capable of interpreting the visible marks in their own terms, or in what is sometimes referred to as a visual code. Does one recognize a chair by transforming its appearance into its name which is recognized, or can one recognize a chair from its appearance alone? Does one recognize a word by transforming its appearance into its implicitly sounded name which is recognized, or can one recognise a word from its appearance alone? The argument has gone on for a long time".

All the experiments carried out so far have established that the dyslexic child has difficulty with naming and memorizing names in their correct order. It remains to be seen whether the generation of visual images and their internal manipulation remains intact in the dyslexic child.

Bruner (1964) considered there to be three systems of processing information in human beings, namely enactive, iconic and symbolic systems. These three systems process information through action, imagery and language respectively. Bruner describes a seqeunce of images as standing for perceptual events just as a picture stands for an object. Indeed the relationship between visual imagery and visual perception has been commented on many times. Beech (1977) reported that when subjects are asked to visualize certain named objects then visualizing is quicker when object names are presented aurally rather than visually. Beech considered visual perception and visualization as competing processes, the former interfering with the latter. Similarly Brooks (1968) asked subjects to visualize an uppercase block F. Then starting at the bottom left hand corner subjects were asked to move clockwise around the corners of the F respectively and say "Yes" if the corner was either a top or bottom one, and "No" if it was neither. Subjects responded verbally or by pointing to an uppercase "Y" or "N" on a sheet of paper. Performance, Brooks found, was quicker using the verbal response, something Brooks attributes to a conflict between visual processes selecting "Y" or "N" and visualizing the block F. Paivio (1978) also reports a relationship between visual perception and visual imagery. He used the angular distance effect whereby the greater the angular distance between two angles the quicker ones response in noticing angular non identity. Paivio used three conditions; in condition 1 subjects were given two digital times (e.g. 3:22 and 7:55) and asked to imagine these times on a clockface and indicate which angle was the smaller; in condition 2 subjects were required to do the same as in condition 1 except one time was digital the other was presented on a clockface; and in condition 3 two clockfaces were presented, one set at 3:22 and the other at 7:55. The results showed that in all three conditions as the discrepancy between the two angles increased so reaction time decreased and since reaction times decreased from condition 3 through condition 2 to condition 1 Paivio concluded that visual imagery must be an analogue of visual perception. Further, as angular distance increased so did reaction time go down but this effect was much greater in condition 1 than in condition 2 which was in turn greater than in condition 3. However the relative effect was constant across the three conditions which only goes to support the idea of a common underlying processing mechanism. Sheehan (1966) and Shepherd (1978) have also demonstrated a functional correspondence between visual imagery and visual perception.

Visual imagery has been used to refer to different processing strategies. On the one hand, Millar (1972) and Mwanaluski (1974, 1976) have presented subjects with nonsense shapes and instructed them to "try and see these shapes in your heads", thereby requiring them to form an internal representation in a visual long term memory. Other techniques are more symbolic in nature and require subjects to generate visual images from spatially unrelated verbal cues such as Paivio (1971) who asked his subjects to generate images of a clockface from digital times, or Bugelski (1968) who asked subjects to create an image of a named object and juxtapose it with another image from a mnemonic.

In the experiment to be reported below, a form of symbolic imagery has been used where subjects presented with a stimulus have to create a spatially unrelated image. This transformation of information in the visual domain is analogous to the transformation of a printed word into its phonetic features. However both types of visual imagery (symbolic and representational) are functionally related to visual percpetion although visual symbolic imagery appears to have an extraordinarily large capacity (Bugelski, 1968; Ross and Lawrence, 1968). Also, in both cases it appears that subjects be they 3.8 years old (Millar, 1972) or adults (e.g. Bugelski, 1968) have an implicit knowledge of how to visualize objects since instructions are uncomplicated and usually of the form "I want you to see in your heads" (e.g. Millar, 1972; Mwanaluski, 1974, 1976) or simply "create an image of these objects" (e.g. Bugelski, 1968; Kosslyn, 1975). Despite the simplicity of these instructions subjects do appear to adopt the imaginal strategy demanded. Paivio's (1978) results confirm this as do Bugelski's (1968) who asked some subjects to use a "peg-word" mnemonic and others (the controls) to just "learn the words according to their serial position". The results showed a large difference between the imagery instructed group and the subjects using their normal strategy, the former turning in a better performance. In fact those instructed to use the imagery mnemonic reported "copious imagery" in contrast to the control subjects who had little to say by way of report on how they learned to remember items. At the same time Bugelski noted the strong avoidance of suggestion in the experimental subjects since if E. would ask "Was it red?" in reference to the subjects image, the subject would readily answer "No" and report some other colour, or no colour at all. Such a finding weakens any criticism of suggestion influencing subjective reports.

Even children can use imagery, albeit of a representational nature, when asked to do so. Millar (1972) used children aged between 3.8 to 4.7 years and asked one group (experimental subjects) to "see in their heads" nonsense shape stimuli. The task involved presenting the subject with a nonsense shape for two seconds, and them, after a delay of five seconds asking the subject to select which shape, out of an array of five, had been presented earlier. The control group were given no instructions on visualization. The results showed that not only did the experimental group perform significantly better but in both groups naming of shapes did not correlate with recognition scores. Mwanaluski (1974, 1976) using a similar methodology obtained similar results with children aged 6, 8 and 9 years.

In order to generate and use visual symbolic imagery it appears that familiarity with the to-be-imaged object is necessary. Mandler (1974) asked subjects to image a path through a maze and reported that an adult cannot form an image of the path until he has mastered and overpracticed the task by successive manipulation. It was only after frequent attempts at finding the path through the maze that subjects finally reported an image of the path had developed and that they were now using it.

An important attribute of visual imagery is the ability to combine a number of different images (e.g. a dog, a pavement, a policeman, etc.) into one unitized image. Having later recalled the unitized image the objects can then be recalled one-by-one. For example Bower (1969) asked subjects to either image two objects interacting in some way or separated in their imaginal space. Several such pairs were presented to each subject. A cued recall test resulted in superior recall of the interactive imagery group. Bower concluded that instructions to image objects per se have little effect and that the important component is the interactive relation between the imaged objects. Taylor, Josberger and Prentice (1970) came to a similar conclusion using 12 year old children. A concrete stimulus was either put into three separate images with each noun or subjects were asked to rote rehearse the nouns. The results showed that subjects using both imagery tasks recalled three times as much information as the rote rehearsal group and that recall was best under unitize-imagery conditions.

From the evidence presented above it seems feasable to ask adolescent subjects to use imagery strategies to remember information. In addition there are reasons for comparing dyslexic and non-dyslexic adolescent subjects in their abilities to use such strategies. One reason arises from research described earlier. In the previous chapter (Experiment 4) results indicated that dyslexic subjects have difficulty with information in a phonological form on a variety of tasks. However Experiment 4 did not prove that the problem was not caused by a more general limitation in information processing. Therefore a task involving non-verbal, visual information processing (i.e. visualziation and visual symbolic imagery) will be used to compare with the phonological encoding and immediate serial recall of Experiment 4. This will allow a comparison of information processing in the visual and phonological domains (or as Kolers referred to as "visual system" and "language mechanism").

Another reason for studying visual imagery in dyslexia arises from knowledge that phonological decoding of print may not be the only means of decoding print since: 1) orthographies do exist which are ideographic or pictographic (e.g. banji) and perhaps not dependent on phonological decoding, and 2) when phonological encoding is rendered impossible as in some acquired dyslexics, subjects can construct appropriate mental images directly from printed words and name the object imaged (Richardson, 1975).

In the following experiment an imagery mnemonic has been used of the kind referred to as the "method of loci" (Baddely, 1976) which involves familiarizing oneself with a sequence of locations and associating these with objects to be remembered. Accordingly subjects will be given instructions on how to use the mnemonic and how to visualize. Nonsense shapes (by definition nameless) will become familiar to the subjects and will be the to-be-imaged objects and the mnemonic instructions will encourage unitization of a number of shapes into a single composite image.

A summarized layout of Experiment 5 can be found in Diagram 5.1 on p. 191-192 of Experiment 4.

METHOD

Subjects

13 dyslexic and 13 non-dyslexic subjects were selected. Dyslexic subjects had all undergone a previous clinical assessment at UCNW (Bangor) Dyslexia Unit or at Dr. Margaret Newton's dyslexia assessment centre at Aston University. All subjects were male with average-above average intelligence (the range of IQ scores on the Ravens Progressive Matrices test (Raven, 1965) are given below in table 6.2). Apart from a clinical assessment dyslexic subjects had to conform to the criteria for retardation in both reading and spelling used in previous experiments (these criteria are set out on p. 79). Reading age was retarded on average by 2.4 years and spelling by 4.7 years although the permitted discrepancy between CA and RA or SA was systematically varied according to intelligence (see criteria on p. 79).

Non-dyslexic subjects were selected from a group of average - good spellers with normal reading skills. Each non-dyslexic subject was selected individually to match a dyslexic subject for CA and IQ, creating a matched pairs design. Other criteria for selection included that CA should not exceed RA by more than six months and SA by more than one year. Means and Ranges for IQ, CA, RA and SA are given for both dyslexic and non-dyslexic subjects in tables 6.1 and 6.2 below.

Limited by an upper limit of 15 years in both Schonell Graded Reading and Spelling Tests (1955) the observed discrepancies between CA and RA or SA, for non-dyslexics, are artifacts.

Table 6.1

Means of Parameters used in Subject Selection

	IQ	CA	RA	SA
Dyslexic (n=13)	112	14.7	12.3	10.0
Non-Dyslexic (n=13)	114	14.4	14.0	13.9

Table 6.2

Ranges for Parameters used in Subject Selection

	IQ	CA	RA	SA
Dyslexic (n=13)	103-130	13.0-16.4	11.1- 14.2	7.3- 12.8
Non-Dyslexic (n=13)	103-120	13.7-16.0	14.1->15.0	12.10->15.0

PROCEDURES

Part 1

Method

The method adopted was identical in all respects to the method adopted in Part 1 of Experiment 4 (see page 193-196 of Experiment 4).

Part 2 - Pair Associate Learning (PAL)

Method

On completion of Part 1 the subject was sat approximately 10' away from a white screen onto which a Carousel projector displayed slides of nonsense shapes. The first slide (stimulus presentation slide) had a white background with one black shape, measuring approximately 6" x 4", positioned on the left hand side of the screen. The second slide (reinforcement slide) presented two shapes, with the stimulus shape from slide 1 on the left and its pair associate on the right. The stimulus and pair-associate shapes are printed in table 6.3 below. This second slide acted as a reinforcement trial immediately after the subject had responded during the presentation of slide 1.

Slides were ordered into batches of three for each stimulus shape. Such batches will be referred to as cycles. An example of a cycle is described below in diagram 6.1.

<u>Diagram 6.1</u>

Diagrammatic representation of a cycle in the pair-associate learning task

Slide No.	1		2		3		4
Slide Description	Stimulus Shape 1		Stimulus Shape 1 & Pair-Associate Shape 1a		Blank Slide		Stimulus Shape 2
Time Scale	7 secs	2 secs	7 secs	2 secs	7 secs	2 secs	7 secs
Purpose	Stimulus presentation during which S. responds		Reinforcement trial. S. is shown the stimulus and response together		Rest		As for Slide 1 with a change of stimulus shape

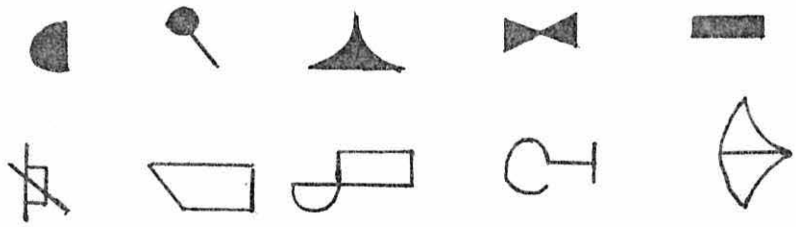
From diagram 6.1 above it is seen that during stimulus presentation the subject responded. The response was a drawing of the pair-associate shape on a special record sheet. A record sheet was a sheet of unlined A4 onto which a matrix of eighty 1" square boxes were printed. The matrix measured 8" x 10". During stimulus presentation the subject drew his first response in the top left hand box and the next response in the adjacent box on the same line. On completion of a line (i.e. eight responses) the experimenter folded the response sheet such that the completed top line was concealed underneath the sheet. Slide 2 presented the stimulus and its pair-associate together during which time the subject passively observed the screen. This acted as a reinforcement trial i.e. informing the subject of the correct response to the stimulus shape. Then, after a two second pause, a different stimulus shape was presented thereby starting a new cycle. Five such cycles occured, one for each shape, before any one cycle was repeated. The stimuli and their pair-associates are shown in Table 6.3.

Table 6.3

Stimuli used in Parts 1 - 5 and their pair-associate shapes

Stimulus Shape

Associate Shape
(taken from
Vellutino, 197)



A sequence of fifteen cycles was prepared. When the subject had completed these fifteen cycles without reaching criterion then the projector was reset to zero and the sequence began over again.

Instructions

The following instructions were given to each subject at the beginning of Part 2: "The shapes you used in the previous exercise are now going to be used again. You will remember that these shapes were shaded in, and so I shall refer to them as the shaded shapes. In this new exercise these shapes will be projected onto the screen in front of you. Each shaded shape has associated with it an unshaded or blank shape. The object of the exercise is for you to learn to draw the blank shapes from memory whenever I show you the shaded shapes, but you must learn which particular blank shape goes with which shaded shape. Now, the first slide on the screen will be a shaded shape by itself. This will be followed by a slide showing the same shape paired with a blank shape. After this slide the screen will remain bare for a short time before a different shaded shape appears by itself."

"I am now going to show you this procedure in operation, during which time you must familiarize yourself with the procedure. In addition, you must try and remember the blank shapes you will see and which shaded shape they go with. All right?" S. was then shown the procedure by E. for the first five cycles with E. providing the comments, "Here is a shaded shape by itself" during stimulus presentation and, "Here is the shaded shape along with its blank shape" during the reinforcement trial and "Here is the bare screen which serves as a rest period".

After this initiation E. continued, "We will now start again and what you must do is remember the blank shape which goes with the shaded shape and draw it in this first box here

(E. indicates to top left box in the matrix). Your drawing must be complete before the first slide changes and the second slide appears showing you the correct blank shape. It is also very important for your drawings to be accurate. To be correct no part of the blank shape can remain undrawn and no parts can be added. Any lines or curves which are too short or too long will render your drawing wrong. O.K.? And we shall carry on until you have learnt to draw the correct blank shapes accurately". S. was then asked if he had any problems which were summarily answered. S. was also reminded during slides 1 and 4 that it was time to draw the correct blank shape in the adjacent box on the record sheet.

When the criterion of ten consecutively correct responses (i.e. two correct responses per shape) were recorded PAL was terminated and S. was asked the following questions: Q1: "How did you remember which blank shape went with each of these shaded shape?" (E. then indicated each of the 5 shaded shapes in turn); Q2: "Did you use names at all to help you?; Q3: "Did you see a picture of the blank shape in your mind first before you drew it?"

After these questions Part 2 was terminated.

Part 3

This part was not included in Experiment 5.

Part 4 (one week after Parts 1 & 2) - Relearning the PAL task

Procedure

Part 4 was intended as a relearning task in which the sequence of events performed in Part 2 was repeated. However,

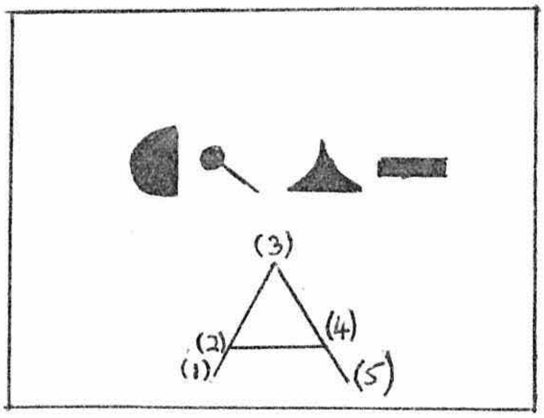
S. was not given the initial familiarization trials and detailed instructions as these were deemed unnecessary. Instead he was asked if he could remember the procedure from the previous week. Without exception each S. did remember the procedure, but they were nevertheless reminded to respond during the first slide and complete their drawing before the second slide, which showed the correct response, was projected. Once again a criterion of ten consecutively correct responses was adopted. When the criterion was met S's moved onto Part 5.

Part 5 - The Imagery Tasks

On completion of Part 4 E. reproduced the five tablets used in Part 1. In turn each tablet (with a shaded shape printed on it) was placed in front of S. whereupon E. asked S. "You have just learned to draw a particular blank shape whenever you see this shape I want you now to see a picture in your mind of the blank shape that goes with this shaded shape, avoiding the use of names at all costs. Can you do that?" Then, after the fifth shape, "Did you use any names at all?" And if S. responded affirmatively then E. replied "Well, you must try your hardest not to use names but see a picture in your mind instead."

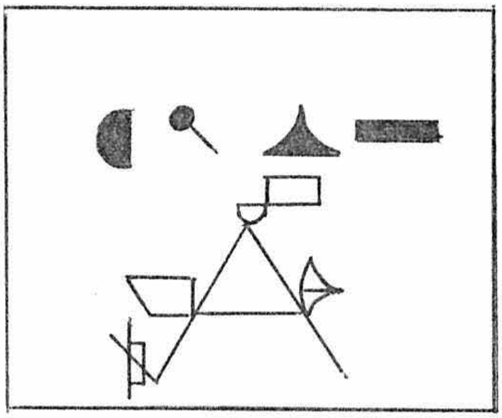
Imagery Initiation

S. was now shown a white card on which was printed 4 or 5 shaded shapes in a horizontal sequence. Each shape measured approximately 0.5" x 0.5" and a 4-item sequence measured 2.8" horizontally and a 5-item sequence 3.5". Directly beneath the middle of the sequence there was printed an uppercase "A" measuring 3" vertically and horizontally (at the base). A typical card is presented in diagram 6.2. S. was also given



6.2 a

Typical card presented to S. during Imagery Initiation, and prior to S's response (Nos. in parentheses were not drawn on the card and act as reference points)



6.2 b

Typical completed response on the "A" beneath the horizontal stimulus array

Diagram 6.2

Imagery initiation apparatus before and after S's response. Five and four item sequences were both used. This diagram represents a four item sequence

a pencil and the following instructions, "I want you to see a picture in your mind of the blank shape that goes with this first shaded shape (E. indicates to item 1 of the sequence). Can you do that? Right, now draw that blank shape attached to the base of the capital "A" here" (E. points to position 1, in diagram 6.2a). When S. responded successfully E. repeated the procedure pointing to the second shape and position 2 on the "A" and so on until the sequence was completed. Each S. was given eight of these cards in which half were 4-item and the other half 5-item sequences.

Imagery Training

Cards presented to S. during imagery training were similar to the cards used in the imagery initiation stage. Subjects were also given a booklet with a 3" by 3" uppercase "A" printed on each sheet. Instead of S. drawing his response on the "A" beneath the sequence he now drew on the "A" in the response booklet. Each subject was then given the following instructions, "I want you now to perform a similar exercise. This time I want you to look at the first shaded shape and see in your mind the blank shape that goes with it. Now see, in your mind, a picture of the capital "A" with that blank shape pinned onto it at this point (E. points to position 1). Have you done that? (When S. affirmed this E. continued.) Now do the same for the second shape and attach the blank shape to the A, in your mind, at this point (E. points to position 2). Successful? Now do the same for the third shape and pin it to the top of the A in your mind. When you have done that stop and see a single picture in your mind of the capital A with the three blank shapes pinned on in their respective positions. Have you done that? (E. continues only after S. affirms this) Now convert the fourth shape into its blank shape and again in your mind pin it onto the "A" here (E. points to position 4). When complete do the same for the fifth shape pinning it onto the capital "A" here (E. points to position 5 and waits for a few seconds before continuing). Have you done that? Good, now imagine the capital A with all 5 blank shapes pinned onto it, in their correct positions, as one whole picture. When finished say "Now"." When S. said "Now"

E. covered over the sequence of shaded shapes and asked S. to draw the blank shapes onto the uppercase A in the booklet, in their correct positions.

To summarize the imagery instructions: Stage 1. Imaging independantly the first three blank shapes pinned onto the uppercase "A". Stage 2. Imaging a unitized picture of these shapes pinned onto the "A". Stage 3. Imaging independantly shapes 4 and 5 pinned onto the "A". Stage 4. Imaging a unitized picture of these 4 / 5 shapes pinned onto the "A".

When S. had drawn the shapes onto the "A" he was warned that he must remember the rules and follow them precisely, neither omitting any stages or using names. He was then given six practice trials and asked to describe, after the second and sixth trial, the procedure he used. If any one stage of the mnemonic had been omitted then E. reminded S. of the procedure and asked him to make sure this stage was included.

Part 6

Imagery Test

On completion of imagery training S. was reseated in front of the tachistoscope and given the following instructions, "I want you to use the procedure (i.e. mnemonic) you've just learnt, except this time you will see the sequence of shaded shapes on the screen in the tachistoscope. So you must look through the viewer, I will then say "Ready" after which you will observe the sequence on the screen. You then follow the procedure for creating pictures of the outline shapes in your mind until you have completed the final stage. In other words until you can see in your mind a single picture of the capital A with all five outline shapes pinned on in their respective positions. When you have done that say "Now", and I shall remove the sequence from the screen and you will draw the shapes onto the "A" in the booklet as before. Any questions?" If S. had any questions these were answered. S. was then given ten trials, five at each sequence length, which were arranged alternately. The dependent variable was the image generation time between stimulus onset and S. saying "Now". S. was also asked the following three questions after the third, sixth and final trials:

Q1: "Tell me in your own words how you remembered the order of those shapes"

Q2: "Did you have any difficulty with following the instructions I gave you?"

Q3: "Did you use any names at all?"

Part 7

Method

The method adopted was identical in all respects to the method adopted in Part 7 of Experiment 4 (see pages 204-5 of Experiment 4).

Results

The results of the current experiment shall be dealt with in separate sections. Section 1 will be used to report the results of the learning tasks i.e. Part 2 (PAL) and Part 4 (Repeat of PAL). Section 2 will be used to report the results of the serial order recall tasks i.e. Parts 1, 6 and 7 as well as the imaging task i.e. Part 5. Section 3 will be used to relate performance on the serial recall tasks with visual-visual pair associate learning skills. Section 4 will describe the subjective reports of cognitive strategies adopted by subjects during the PAL task and the image generation task.

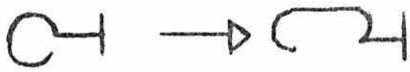
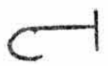
Section 1 - Results of PAL (Part 2) and Relearning (Part 4)

Method of Scoring Responses

Responses in the PAL task were scored using criteria set out by Benton (1963) in the manual for the Revised Visual Retention Test. Benton describes in the manual the following types of error:

1) Reversal - when a whole shape is rotated such as 
 or  (the "  " should be read as "is drawin in response as").

2) Ommissions and Additions - when a distinct part or segment is left out or added such as 
or  .

3) Distortions and Perseverations - poor drawings are nearly always distortions, often with perseveration. Therefore this type of error was only scored when a misdrawing was so severe as to suggest an addition e.g. 
or perhaps suggest an omission e.g. .

4) Misplacement - when a distinct part or segment is moved to a different part of the shape such as 

The category of "size errors" used by Benton was not relevant here since S's perceived 6" x 4" projections and so reduction of size was necessary during response. Three additional error types were included to suit the different constraints on behaviour in a PAL task as opposed to a visual retention task. These were as follows:

5) Unidentifiable Drawing - the criteria were

a) where the nature of the error cannot be specified e.g.

 .

b) where more than one type of error has occurred e.g. .

6) Abstention - when S. fails to make any response.

7) Associative Error - S. draws a blank shape correctly, but it is not the correct pair associate for the particular shaded shape. Table 6.4 below gives a breakdown of error frequencies.

Table 6.4

Mean frequences of Different Types of PAL error recorded in Part 2

	Group			
Error Type	Dyslexic (n=13)	Non-Dyslexic (n=13)	t-value	Prob.
Reversals	1.62	0.77	1.45	>.05
Om~~m~~issions and Additions	1.62	1.92	<1	>.05
Distortions and Perseverations	0.46	0.77	<1	>.05
Misplacement	0.46	0.77	<1	>.05
Unidentifiable	1.08	2.31	1.0	>.05
Abstention	4.54	2.92	1.26	>.05
Associative	2.23	1.92	<1	>.05
Total Errors	12.15	11.46	<1	>.05

From table 6.4 it can be seen that matched pairs t-tests were computed between groups for each error type as well as total error scores. These tests proved to be insignificant for each error type and also for total error scores ($t < 1$, $p > .05$, df 12). The null hypothesis of no differences between the groups cannot therefore be rejected for either separate error types or total error scores.

Relearning - Part 4

Subjects responses were analysed using the rules described in Part 2. Since the frequency of errors was so low a breakdown of responses into error types was omitted. Mean total error scores for dyslexic subjects was 1.3 and for non-dyslexic subjects it was 2.0. A matched pairs t-test computed for the difference between groups was not significant, $t = 1.2$, $p > .05$, df 12. Hence the null hypothesis of no group differences cannot be rejected.

Section 2 - Serial Order Recall (Parts 1, 3, 6 and 7) and Imagery Skills

Non-Verbal Recall of Shape Sequences (Parts 1 and 7)

The immediate serial recall tasks of Parts 1 and 7 were scored with regard to serial order. In the case of 4 item sequences S. initially selected 4, out of the 5 possible shapes, and then arranged them in the correct order. In the case of 5 item sequences S. re-arranged all the tablets in front of him. For each tablet placed in its correct serial position S. was awarded one point, giving a maximum score of 45. There were five trials at each sequence length. Results are presented in table 6.5.

A three way Groups x Treatments x Sequence Length repeated measures ANOVA (Winer, 1972) was used to analyse the data. The

Table 6.5

Mean No. of Tablets recalled in the Correct Serial Position in Pre- and Post-Learning Serial Recall (Parts 1 and 7)

	Pre-Learning Part 1	Post-Learning Part 7	Difference
Dyslexic (n=13)	23.61	27.92	4.31
Non-Dyslexic (n=13)	24.92	27.46	2.4
Difference (d)	1.31	0.46	

Treatments factor refers to the pretest-posttest comparison. Repeated measures occurred on all three factors since the strict matched pairs procedure necessitated group comparisons within pairs.

The main effect of Group (Dyslexic vs Non-Dyslexic) was not significant, $F < 1$, df 1,12, $p > .05$. However the main effect of Treatments was significant, $F = 13.74$, df 1,12 ($p < .01$). By inspection of table 6.5 for mean subject scores over ten trials it is clear that recall scores in Part 6 (Post-test) were higher than those in Part 1 (Pre-test). The other main effect of sequence length was insignificant, $F = 3.79$, df 1,13, $p > .05$.

There were no significant interactions. It is noteworthy that the Group x Treatment interaction did not even approach significance, $F < 1$, df 1, 13, $p > .10$ indicating that the effect of PAL on serial recall of shapes was similar in both groups.

Imagery Test - Part 6

Performance was measured by a) Time to generate images

b) Recall accuracy. The time between stimulus onset and the moment S. said "Now" was considered to be the image generation time. Recall accuracy was measured by the frequency of perfectly recalled images, thus if any one blank shape was drawn in the incorrect position on the "A" then this response was deemed incorrect and excluded from the image generation time data. The mean image generation times and the mean number of incorrect trials are presented in table 6.6 below.

Table 6.6

Mean Image Generation Time for Correct Trials and Recall Accuracy (No. incorrect trials, max = 10)

	Image Generation Time		Recall Accuracy (no. incorrect trials)
	4 Items	5 Items	
Dyslexic (n=13)	36.8	44.2	2.08
Non-Dyslexic (n=13)	59.52	70.53	1.08

Image Generation Time data and Image Recall (Part 6)

Image Generation Time

A two way Group x Sequence Length ANOVA was computed on an ICL 2980 computer using the program P2V from the BMDP series (1977). There were repeated measures on both sequence length and Group factors, the latter due to the matched pairs design which demanded within pair group comparisons.

The main effect of Group was significant, $F = 12.53$, df 1,12 ($p < .01$). From table 6.6 it is clear that mean times to generate images were shorter for the dyslexic subjects for both sequence lengths. Therefore the significant main effect of Group is due to quicker execution of the imagery mnemonic instructions by the dyslexic subjects. The other main effect of sequence length was also significant, $F = 9.85$, df 1,12. Inspection of table 6.6 above shows that for both dyslexic and non-dyslexic subjects the time to generate images was greater for the 5-item than for the 4-item sequences. This latter result was to be expected because a 5-item sequence demands the image generation of one extra shape.

The interaction of Group and Sequence Length was insignificant, $F < 1$, df 1,12 ($p > .05$). The full ANOVA table is given below in table 6.7.

Table 6.7

ANOVA table for Time to Generate Image Data. There are repeated measures on both factors

Effect	SS	MS	df	F	Probability
Group	8040	8040	1	12.53	$< .01$
Error	7697	641.4	12		
Sequence Length	1190	1190	1	9.85	$< .01$
Error	1450	120.8	12		
Group x Sequence Length	30	30	1	<1	$> .05$
Error	1245	103.7	12		

Recall Accuracy

Data for the total number of incorrect trials (out of the ten presented) are also included in table 6.6 above. Dyslexic subjects made errors of recall in 27 out of 130 trials as opposed to 14 errors made by non-dyslexic subjects. A matched pairs t-test was computed on the incorrect trials data to test for between group differences. The obtained t-value was insignificant, $t = 1.515$, $p > .05$, df 12 (two-tailed test) and so the null hypothesis of no group differences cannot be rejected.

Verbal Recall of Digit Sequences (Part 7)

The method of scoring has been described in Part 7 of Experiment 4 (see p. 234).

Correct recall scores for 6, 7 and (6 + 7) digit sequences are given below in table 6.8.

Table 6.8

Total number of Digits recalled in the Correct Serial Position for five trials of 6-item and 7-item sequences

	Sequence Length		
Group	6-Item (max=30)	7-Item (max=35)	Combined (6+7) (max=65)
Dyslexic (n=13)	24.6	19.15	43.8
Non-Dyslexic (n=13)	29.0	21.4	50.4
	$t=4.23$ $p<.01$	$t=1.18$ $p>.05$	$t=2.87$ $p<.05$

Matched pair t-tests were computed for 6, 7 and (6 + 7) digit sequences to test for group differences. In respect of 6 and (6 + 7) digit sequences t-values were 4.23, df 12 ($p < .01$) and 2.87, df 12 ($p < .05$) both of which are significant. The null hypothesis of no group differences must be rejected in favour of the hypothesis which predicts that there are group differences. In both cases the group difference is due to a higher correct score by the non-dyslexic subjects. However in respect of 7 digit sequences the t-value was 1.18, df 12,

($p > .05$) which is not significant and so the null hypothesis predicting no group differences cannot be rejected.

Pearson product moment correlations were computed between 6, 7 and the combined (6 + 7) digit recall scores and the other measures of serial order memory to assess the role of the response buffer in these latter tasks. The results are presented in table 6.9.

Table 6.9

Pearson correlations between Digit Span and Serial Order Recall of Shape Sequences

	Digit Span		
	6-Items	7-Items	(6+7)-Items
Part 1 (Pre-Learning Non-Verbal Shape Recall)	0.273^{NS}	0.370*	0.373*
Part 7 (Post-Learning Non-Verbal Shape Recall)	0.143^{NS}	0.101^{NS}	0.139^{NS}

* $p < .05$ df 24
NS = $p > .05$, df 24

From table 6.9 it is noticeable that digit span for 7-item and the combined (6 + 7) item sequences correlated with pre-learning serial recall of shape sequences. It should be recalled that this result was also found in Experiment 4 and therefore suggests that to some extent the verbal response buffer is used in recalling sequences of nonsense shapes. However, unlike the results of Experiment 4 it was found that familiarity with the shapes, as a result of PAL, did not encourage the development of spontaneous naming of shapes. It will be recalled that in Experiment 4 the correlation of digit span was greater with the post- then with the pre-learning non-verbal shape recall. Here the correlation between digit span and post-learning shape recall is not significant.

Pearson product moment correlations were also computed between 6, 7 and the combined (6 + 7) digit recall scores and image generation times. Image generation times were taken as the mean time to generate an image of a shape. This was calculated by taking the mean image generation time for 4-item sequences and dividing it by 4, and combining it with the mean image generation time for 5-item sequences and dividing it by 5. Correlations were also computed between digit span and image recall accuracy. The results are presented below in table 6.10.

Table 6.10

Correlations between Digit Span Scores, Image Generation Time and Image Recall Accuracy

Digit Span	Image Generation Time	Image Recall Accuracy
6 digits	.117	-0.468*
7 digits	-.048	-0.499*
(6+7) combined	.033	-0.556*

* $p < .01$

Observation of table 6.10 reveals that image generation time does not correlate with digit span whereas image recall does correlate significantly with digit span. Thus subjects who obtain a high digit span score are more accurate at recalling the order of shapes from the generated image, and vice versa.

Section 3 - Relationship Between PAL and Serial Order Memory

Pearson correlation coefficients were computed between the total number of PAL errors and digit span scores across all 26 subjects (table 6.11) and within each group separately (table 6.12).

Table 6.11

Correlation between Digit Span and Total No. of PAL errors

Digit Span	Total No. Errors
6 digits	-0.156^{NS}
7 digits	-0.199^{NS}
(6 + 7) combined	-0.206^{NS}

NS = $p > .05$ df = 24

Table 6.12

Within Group Correlations between Digit Span and Total No. of PAL Errors

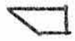
	Dyslexic (n=13) Total No. Errors	Non-Dyslexic (n=13) Total No. Errors
6 digits	$-.204^{NS}$	$-^{+}$
7 digits	$-.321^{NS}$	$-.006^{NS}$
(6 + 7) combined	$-.291^{NS}$	$.007^{NS}$

+ - not calculated due to a ceiling effect
NS = $p > .05$ df = 24

It can be seen from tables 6.11 and 6.12 that there is no correlation between digit span scores and performance on the PAL task (Part 2).

Section 4 - Subjective Reports

PAL task - Part 2

The questions subjects were asked taxed their knowledge of their learning strategies and whether naming or visualization was involved. From inspection of the protocols it was clear that many subjects were able to report the strategies used for each shape although rarely did one general strategy suffice for all five shapes (see table 6.13). Thus S1 (dyslexic) reported that three shaded shapes aroused meaningful images such as a football field and a goal mouth, a coathanger and a hook and the Sidney Opera House, which then acted as mediators from stimulus to response. For the remaining two shapes S1 detected a feature common to both stimulus and response (e.g. the diagonal line in  and ) which acted as the mediator.

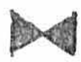
Strategies reported by all 26 subjects were limited to verbal mediation (e.g. S6 (non-dyslexic) who named  as "hook" which lead to the response "  "), creating a meaningful image as a mediator, detection of a common feature in the stimulus and in the response or visualize the response shape first or visualizing all five response shapes and selecting the most suitable. However subjects frequently reported neither the use of names nor visualization nor the use of a cognitive strategy, indicating some automatic access of the response (e.g. S10 (non-dyslexic) who said that the stimulus just "sparked" of the response). Table 6.13 presents the frequences of strategies. The strategy or automatic process for each S-R pair was assessed from subject protocols giving 65 S-R pairs per group (5 S-R pairs for each of 13 subjects). In table 6.13 each of these 65 S-R pairs has been given a category allocation.

Table 6.13

Frequences of Learning Strategies reported by S's in PAL

Type of Strategy Adopted

Group	Name Medi-ation	Meaning-ful Image	Detection of Common Feature	Visuali-zation of one Shape	Visuali-zing all 5 Shapes	Auto-matic
N-Dys	12	5	16	11	8	13
Dys	3	9	25	8	0	20

Imagery Test - Part 4

Subjects were asked on three occasions to report how they remembered the order of the shapes, whether they experienced difficulty with the mnemonic, and whether names were used. Inspection of the protocols indicates that subjects were in general using the mnemonic although some stages were omitted and some difficulty encountered. Table 6.14 below gives the frequencies of subjects reporting: 1) use of names 2) using the complete mnemonic 3) and 4) use of the mnemonic less stages 2 and 4 respectively 5) the need to close the eyes to generate an image 6) experiencing difficulty in using the mnemonic.

Table 6.14

Analysis of Strategies used by subjects in the ten imagery test trials

	Non-Dyslexic	Dyslexic
Names used	No(11) Yes(2)	No(12) Yes(1)
Complete Mnemonic Used	7	10
Complete Mnemonic less stage 2	6	0
Complete Mnemonic less stage 4	1	3
Closed Eyes	4	3
Difficulty with Mnemonic	5	3

Discussion of Results

General

The experiments described above included a non-verbal, visual pair associate learning task, pre- and post-learning serial recall tasks to assess the influence of the learning, and a visual imagery task. All these tasks were designed to minimize linguistic information processing and maximize utilisation of the visual short and long term memories.

It cannot be assumed that using nonsense shapes pre-empts linguistic processing of visual information. As Vernon points out "Many experiments have demonstrated the tendency to perceive shapes which are not obviously pictorial as representations of real objects" (Vernon, 1970 p.61). However, even meaningful material can be processed visually if subjects are asked to use an imagery mnemonic (e.g. Bugelski, 1968a, b). Hence by using nonsense shapes and instructions to visualize or use an imagery mnemonic, it was considered that linguistic processing would be minimized. This was indeed supported by the results of the tests as well as subjective reports from the participants.

In the PAL task all subjects were questioned on how they remembered the S-R associations. Linguistic mediation was reportedly used 11.5% of the time although non-dyslexic subjects were more prone to using this strategy than dyslexic subjects. Non-verbal strategies were numerous and included a) Meaningful image mediation b) Detection of a common feature c) visualization of one response shape d) visualization of all 5 response shapes. These four strategies together were reportedly used

63% of the time, whereas automatic access of the response without recourse to names, images or cognitive strategies occurred 25.4% of the time. Strategies a, b and d were volunteered by the subjects and not suggested by E. as perhaps linguistic mediation or visualizing the response shape might have been. These strategies accounted for 48.5% of S-R mediations, which indicates the low level of suggestion amongst these subjective reports.

The minimal involvement of linguistic processes in this PAL task is also suggested by the lack of correlation between measures of PAL performance and digit span. This contrasts markedly with a similar correlation in Experiment 4. It will be recalled that in this latter experiment S's learnt names (CVC nonsense syllables) for nonsense shapes in the PAL task. Under these distinctly verbal conditions digit span scores correlated with total error scores, as well as associative learning errors. This result is not surprising in view of contemporary theory which suggests that the verbal response buffer is critically involved in speech production (e.g. Morton, 1968, 1970). However in the PAL procedure reported in this chapter identical methods and materials were used except non-verbal drawing replaced verbal recall, thereby removing the work of a verbal response buffer.

There were no significant group differences in respect of PAL performance, in contrast to the very large group differences in the visual-verbal PAL task of Experiment 4. Dyslexic and non-dyslexic subjects did not differ in respect of the total number of errors or in respect of types of error although reversal errors (i.e. mirror images) tended to be more frequent in the dyslexic group.

In respect of Parts 1 and 6, the pre- and post-learning tests of immediate serial recall, group differences were insignificant. It was not unsurprising to find that performance levels in Part 6 (post-test) were significantly higher than in Part 1 (pre-test) due to familiarization accruing from the PAL task. Despite this, group differences in the post-test still remained insignificant as did the group by treatment interaction which indicates that dyslexic and non-dyslexic subjects had benefitted equally from the PAL task. It would seem likely that the familiarization afforded by the PAL task had little to do with learning verbal labels as mentioned above. Correlations between digit span and "shape span" support this view with respect to Part 6 since digit span scores failed to correlate with "shape span" scores for either group of subjects. However in Part 1 (pre-test) it seemed that subjects were using the verbal response buffer to some extent since digit span did correlate with "shape span" scores. This result was also found in Experiment 4.

During the imagery task subjects were repeatedly questioned about the manner in which they were going about the task. If there was an indication of the use of names or omission of any stage of the mnemonic then S's were reinstructed. Such strict monitoring has not been observed before (for example Bugelski, 1968a, Bugelski et al, 1968, Millar, 1972, Mwanaluski, 1974, 1976; Paivio, 1978). But, since the method of loci was unusual it was necessary to keep a regular check to make sure subjects did not lapse into a verbal strategy. Additionally there is evidence that the visual imagery task did not involve the services of the verbal response buffer since correlations between time to generate images and digit span scores were insignificant. Therefore linguistic encoding and verbal rehearsal were not involved during the image generation task.

Baddeley (1976) and Pylyshyn (1973) dispute that imagery is an analogue or an internalization of visual perception. However the majority of research using imagery mnemonics or instructions to visualize have controlled for alternative strategies (e.g. Millar, 1972; Mwanaluski, 1974, 1976; Bugelski et al, 1968) or used selective interference (e.g. Brooks, 1968; Beech, 1977) to indicate strongly that visual imagery is an analogue of visual perception. This is also borne out directly by the experiments of Paivio (1978).

The self paced rate of image generation was 12.05 seconds per shape and 14.88 seconds per shape for dyslexic and non-dyslexic subjects respectively (these times are averages taken from 4 and 5 item data combined). This involved both the generation of a visual image from a printed shape and fitting the image into a "unitized image" (Paivio, 1971). Imagery tasks demanding image generation and unitization have been used by Bugelski (1968) during which 8 seconds per item was needed and also Bugelski et al (1968) where 8.11 seconds per item was needed. In the latter experiment, which was subject paced, image generation times varied from 2 seconds to 20+ seconds. In the current experiment image generation times varied from 5.3 seconds up to 31.6 seconds per item. In consideration of the fact that meaningless, unfamiliar shapes were used here which demand a longer processing time (in linguistic processing anyway cf. Oldfield and Wingfield, 1965) the means and range of image generation times compare quite favourably with those of Bugelski et al (1968).

The analysis of subjective reports indicated that 8 subjects out of the 26 reported an overall difficulty with using the imagery mnemonic although no-one denied using it. Two non-dyslexic subjects and one dyslexic subject said they had used verbal mediation or naming to some extent, although these strategies were not reported consistently over all ten trials. This means that 12 out of 13 dyslexic and 11 out of 13 non-dyslexic subjects when asked whether they had used names denied the fact. If their denials resulted from suggestion i.e. wanting to appear to conform to the instructions then one would not expcet S's to report missing out stages of the imagery mnemonic. It will be recalled that emphasis in the mnemonic instructions was laid upon adhering to each and every stage of the mnemonic as well as avoidance of naming. However 7 non-dyslexic and 6 dyslexic subjects admitted at some stage that they had omitted stage 2 or stage 4 (sometimes both) of the mnemonic during which a unitized image was created of 3, 4 or 5 shapes pegged onto the image of "A". In other words if suggestion prevented S's from admitting to verbal strategies then one would expect a low level of admitted deviations from the rules of the mnemonic.

The results of Experiment 4 indicated that if subjects are required to learn names for and verbally process the very same nonsense shapes then very significant group differences arise in respect of ease of learning and speed of processing. That is, dyslexic subjects are slower verbal processors than non-dyslexic subjects. However, in the current experiment group differences are reversed, under visual, non-verbal processing non-dyslexic subjects are slower than dyslexic subjects. This reversal suggests that two different methods of processing are being adopted which depend upon the experimental method used.

Group Differences

Dyslexic subjects were, on average, retarded by some 4.7 (2.4) years with respect to spelling (reading). The non-dyslexic subjects had an average discrepancy of 5 (4) months between CA and SA (RA), although this was partly due to the limitation of the Schonell tests which only measure spelling and reading ages up to 15 years. In regard of intelligence and chronological age group differences were negligible.

In spite of this group difference both groups performed similarly on the non-verbal, visual PAL task and on the pre- and post-test immediate serial recall tasks. In using an imagery mnemonic dyslexic subjects were significantly quicker at generating images than their non-dyslexic counterparts although there was an insignificant tendency for dyslexic subjects to be less accurate at recalling the image.

There are three possible reasons why the dyslexic subjects were quicker image generators than their non-dyslexic counterparts. Firstly it is possible that the relative difficulty dyslexic subjects have in verbally encoding visual information (see Experiment 1) causes them to rely more on pure visual strategies to access semantic information stored in LTM. Richardson (1975), Saffron and Marin (1977) and Shallice and Warrington (1975) have suggested acquired dyslexics with grossly impaired phonetic skills can access semantic information directly from print. Morton's (1979) work indicates that normal adult readers do not necessarily decode print phonetically prior to semantic access. Morton's (1979) model indicates that access to the meaning and associations of a printed word can happen through a purely visual system, or an analogoue of visual perception via processors called visual logogens. Further Hardyck and Petrinovich (1970) showed that covert articulation (and therefore inner speech) is not used by skilled readers unless the text is complex, indicating that verbal decoding can be avoided. A second possible reason for superior imagery skills in dyslexics could be an artifact due to the speed-accuracy trade-off phenomenon (Pachella, 1971). In brief this phenomena takes the form of reduced performance accuracy when speed of performance is encouraged and vice versa. Accordingly quicker generation of images could result in a less precise image which leads to more errors at recall. Pachella (1971) reviewing the use of response latency as a measure of covert behaviour pointed out that in some cases small changes of performance accuracy can make large effects upon reaction time. However in the current experiment it is assumed that subjects have established a clear unified image since they were asked to indicate when they had a clear image in mind. Unless the dyslexics criterion for image clarity is lower than that for the non-dyslexics, recall errors could arise elsewhere i.e. from memory trace decay or interference during response. Since visuo-spatial inspection is the only way of monitoring the correctness of the response then interference with a visuo-spatial image will occur during response (Brooks, 1968; Beech, 1977). Alternatively it is possible that the verbal response buffer is used during recall but not during image generation. This latter view is supproted by the highly significant correlation between digit span and image recall wheras no correlation was found between digit span and image generation speed.

A third reason is the possibility that non-dyslexic subjects find it more difficult to suppress verbal strategies at the expense of time to generate images. Suppression of verbal strategies would demand attention which would cause conscious processing to cease elsewhere in the system until attention can be regained (La Berge and Samuels, 1974). To assess this criticism an experiment must include a proviso that if verbal strategies could not be suppressed then they should be used. However group differences in respect of reported name strategies were not found in the current experiment - only two non-dyslexic and one dyslexic subjects reported the use of a verbal or naming strategy.

Finally, inspection of table A of Appendix D (image times and recall errors) shows that two dyslexic subjects (S7 and S8) produced 36% of all dyslexic errors in the imagery task. The occasionally freak result would have the effect of producing the insignificant t-value ($t = 1.515$, $p > .10$, df 12) although dyslexic errors are nearly twice non-dyslexic errors. Mattis (1978) and Denckla (1975) have pointed out that dyslexic subjects with visuo-spatial problems account for one in twenty dyslexics. If this is correct then the sample of dyslexic subjects used here could have included subjects with such difficulties. At the same time these subjects would be expected to perform poorly during visuo-spatial PAL and in the immediate serial recall of shapes. However, inspection of table B of Appendix D will show that with respect to the PAL task S8's performance was better than even the majority of non-dyslexic subjects and although S7's performance was poor, two dyslexic and two non-dyslexic S's were even worse. It is the same story for the immediate serial recall of shapes where S8 performed above average and S7 marginally below average. Therefore this line of reasoning is untenable.

In summary, it appears that dyslexic subjects are quicker at generating visual images than their non-dyslexic counterparts. This indicates that the visual route to semantic and association areas (Morton, 1979; Patterson and Marcel, 1979; Allport, 1977) is intact in developmental dyslexic children. It is also possible that greater dependence upon this route due to a faulty phonological route could result in quicker visual information processing. However, the superiority of the dyslexic subject in speed of image generation is tempered by the less accurate image recall.

CHAPTER 7

CONCLUSION

7.1.1 Overall Summary of Results

There have been a number of studies which have reported that developmental dyslexic children have difficulty with naming. Calfee (1977) reported that dyslexic children have difficulty in learning letter names and that the extent of this difficulty correlates positively with reading three years later. Stirling (1978) reported that dyslexic boys suffer from linguistic uncertainty, mispronunciation and the wrong use of words, and Blank and Bridger (1966) reported that dyslexic boys provide inaccurate verbal descriptions of morse code. A possible locus for the language disability could be at the phonetic level since dyslexic boys have a great difficulty in segmenting words into phonemes (Liberman et al, 1974; Fox and Routh, 1980) although the ability to cope with syllables is less impaired (Liberman et al, 1974).

The experiments described in this thesis are not simply mutually supportive. Instead they form a developmental trend with the later experiments following on from the results of earlier experiments. This design has been used to narrow the possible causes of dyslexia from a variety of different verbal deficits to a more circumscribed phonetic disability. In so doing a link has been made between the clinical features of dyslexia and an impaired phonetic development. This impairment is believed to present difficulties for the dyslexic child from the earliest stages of phonetic development.

In Experiment 1 it was found that dyslexic subjects had a shortened memory span for verbal items only. In addition, items which could be named rapidly (e.g. digits) caused a greater memory span discrepancy between the two groups than items which were named relatively slowly (e.g. pictures). However this result is dependent upon the method of stimulus presentation since with short sequences of 3 or 4 items the memory span discrepancy between the two groups was observed with nonsense shape materials. From subjective reports this latter finding was considered to be due to the spontaneous naming of nonsense shapes at presentation. It was argued that the number of shapes named in long (> 4 items) sequences was probably reduced (Derk, 1974) and subsequently did not facilitate memory span. That subjects can spontaneously name nonsense shapes has been reported elsewhere (Grindley and Townsend, 1973; Van der Plas and Garvin, 1959; Vernon, 1970).

The conclusions of Experiment 1 were confirmed by the results of Experiment 2 where it was found that when rehearsal was prevented the memory span discrepancy between dyslexic and normal subjects was reduced. It was stressed that the design of the experiment allowed normal stimulus encoding but interfered with storage (i.e. rehearsal) and perhaps retrieval from the short term memory response buffer. However it was claimed that this result did not of necessity show that it was the method of rehearsal or retrieval that was impaired in dyslexic children. Rather it was hypothesised that the faster naming of items (i.e. lexical access) in non-dyslexic subjects gave them an advantage over dyslexic subjects. However in the delayed recall paradigm used in Experiment 2 items had to be rehearsed during the interval. Preventing rehearsal with articulatory suppression thereby removed the advantage gained by faster lexical access. This hypothesis was tested in Experiments 3a and 3b.

The results of Experiments 3a and 3b showed that dyslexic subjects do not only have smaller memory spans for digits, letters and pictures but also they are slower at accessing the names from their lexicon. It was claimed that speed of lexical access is integrally related to memory span. Within the dyslexic group speed of lexical access covaried with memory span for digits and letters indicating that the dyslexic subjects with the smallest memory spans also tended to be the slowest at lexical access and vice versa. This relationship was not found in the non-dyslexic subjects except for picture stimuli. The reasons given for this were that non-dyslexic subjects are able to access "automatically" digit and letter names such that any individual differences are largely random, although individual differences for the speed of lexical access of picture names are meaningful since these names are not "automatically" accessed. In the dyslexic group, it was suggested that digit and letter names are not "automatically" accessed such that individual differences in speed of lexical access are meaningful rather than random. Thus the conclusion to Experiments 3a and 3b was that poor memory span in dyslexic subjects is due to slower articulation which in turn is due to slower lexical access.

In Experiment 3c the same subjects, from Experiments 3a and 3b, were given a revised version of the Oldfiedl and Wingfield (1965) name latency task. Regression analysis applied to the name latency data showed that an objective measure of age of acquisition accounted for the between item name latency differences much better than word frequency. Moreover the non-dyslexic - dyslexic name latency difference was accounted for if the dyslexic subjects on average acquired the picture names some 10.8 months after the non-dyslexic subjects. Loftus and Suppes (1972), Lachman et al (1974) and Lachman (1973) argued that a variable which correlates with lexical access, such as age of acquisition, must provide information about the structural organization of the lexicon. Now it is held that the difficulties which dyslexic children have with letter naming (Calfee, 1977) as well as reading, spelling and picture naming are probably all related at the same level of lexical organization. The most probable level is the level of phonetic organization of lexical entries. If phonetic structures are poorly formed in the lexicon of dyslexic subjects then all naming skills would be imapired. This would account for the clinical observations of delayed language acquisition (Naidoo, 1972; Ingram and Mason, 1965; Debray, 1968; Rutter, Tizzard and Whitmore, 1970), inaccurate verbal descriptions of morse code (Blank and Bridger, 1966), linguistic uncertainty, mispronunciation and wrong use of words (Stirling, 1978), inability to segment words into phonemes (Liberman et al, 1974; Wepman, 1960; Clark, 1970; Naidoo, 1972; Savin, 1972; Durrell et al, 1953; Fox and Routh, 1980) and impoverished knowledge about phonetic structuring in words (Downing, 1973).

The ability to create phonetic structures in the lexicon was tested in Experiment 4 with a paired associate learning task in which subjects learned nonsense words and associated them with nonsesnse shapes. The results of this experiment showed that dyslexic subjects have great difficulty in learning nonsense names as well as associating these names with a visual symbol. The errors produced during the learning task were in part explained by the excessive use by dyslexic subjects of vestigial phonological rules that adjust the phonetic structure of lexical entries during speech production. In addition dyslexic subjects showed a greater tendency to transpose phonemes between CVC responses which suggests that the associations between phonemes within a CVC was loosened in these subjects. A similar level of organization is, of course, apparent in non-dyslexic children at an earlier stage of learning. However with dyslexic children the level of well consolidated phonetic entries is never reached. Indeed it is believed here that the inability to segment words into phonemes and the impoverished knowledge of phonetic structuring in words suggest that the description of individual phonemes is impoverished in all phonetically based processes of the dyslexic information processing system. Thus the conclusions of Experiments 1 and 2 in which the response buffer (Morton, 1977; Ellis, 1979) was found to be inefficient must be elaborated. An efficient response buffer needs accurate and well defined descriptions of phonemes and phonetic structures (e.g. of words, phrases and sentences). Phonetic items which have similar descriptions (e.g. /b/ and /p/) are frequently transposed in memory span tests (Wickelgren, 1965a, b). In dyslexic children lexical entries have ill-defined phonetic descriptions such that locating a specific entry is slow, or inaccurate, and the output from the lexicon into the response buffer is also ill-formed. Therefore the response buffer actually receives ill-formed phonetic entries which leads to an increased tendency to order errors due to inter item transposition, shown in Experiments 1, 2 and 3b.

Experiment 5 was originally intended as a control study to Experiment 4. Whereas Experiment 4 involved learning verbal labels and subsequently the use of these labels in verbal serial order memory tasks Experiment 5 involved learning visual labels and the subsequent use of these visual labels in visual serial order memory tasks. To achieve this end imagery was encouraged and verbalization discouraged in all subjects in Experiment 5. From the results there was a strong indication that subjects used non-verbal strategies which involved the mental manipulation of visual symbols and also tended not to use verbal strategies. Since the dyslexic and control subjects did not differ in the speed of learning and dyslexic subjects were quicker at generating subjective images there is a strong case for claiming that most subjects were indeed using non-verbal strategies. These results are also important in so far as they indicate that dyslexic subjects do not have a general information processing impairment. Instead, any stage of processing that demands the formation of phonetic structures (e.g. during subvocal speech, logical mentation or perhaps organizing any sequential response) slows down the processing rate in dyslexic subjects since the phonetic structures are difficult to access (or prone to misaccess) from the lexicon and are confusable with other phonetic structures.

7.2.1 The Locus of the Phonetic Impairment

The lexicon contains facts concerning the pronunciation of each item, the syntactic form class(es) of the item, semantic relations among items and special rules to which the item is subject before response production. The lexicon must be accessed for speaking, for listening, for reading, for writing and for making linguistic judgements.

Each of these activities requires either different methods of retrieving information from a single lexicon (Morton, 1970; Ellis, 1979) or different lexicons with each specifically designed to serve the special needs of a given activity. However, this latter hypothesis is less efficient at explaining the importance of phonetic skills for the development of reading skills (Kavanagh and Mattingly, 1972), as well as the phonetic basis for many spelling errors in adults and spelling intuitions in pre-literate children (Read, 1971). Thus it is believed by most researchers that there is only one lexicon that holds all the information.

Klatt (1982) has argued that there is a dominant lexicon which is used for speaking and represents words in terms of sequences of phonemes (rather than in terms of syllables or distinctive features). This lexicon could be used in the analysis-by-synthesis mode during speech perception (Stevens, 1972) and is probably used during reading and writing. In addition there is a seondary lexicon, used for the perception of familiar words, which is a special accoustically based lexical hypothesis module. In the production of speech the semantic or syntactic word forms become represented in terms of component phonetic distinctive features. Subsequent to producing sequences of phonemes these sequences are stored in the response buffer. Prior to, or during, the execution of the articulatory motor programs held in the response buffer a rule system is set into operation. In normal discourse rules are brought into operation to provide lexical stress patterns, fill in redundant entries in the motor program, elaborate or modify the stress pattern, and change feature values as a function of phonetic context and stress. The rule system also provides rules which change the binary phonetic features into phonetic scales appropriate for interfacing with the speech production apparatus and erase phoneme boundaries. It is this rule system which, in the PAL task of Experiment 4, produced and executed the vestigial phonological rules that had previously been used during language acquisition, as well as the co-articulation rule which adjusted vowels to their consonant environment.

Malapropisms have proved to be a useful source of evidence concerning the organization of lexical entries (Fay and Cutler, 1977; Hockett, 1967). Fay et al, 1977 and Hockett, 1967 have argued that the lexicon must be ordered according to both semantic and phonetic similarity within semantic categories. Klatt (1982) reported an analysis of malapropisms and discovered that similarity between initial phonetic segments has a greater influence than any other segment. Accordingly he argued that the lexicon is arranged in the form of a tree in which all words that share initial segments are grouped together until they diverge in terms of segmental composition. During speech perception, of unfamiliar words, such a structure facilitates lexical search since phonetically near neighbours are grouped together within semantic categories. Alternatively, Klatt argues, this phonetic organization within semantic categories could facilitate phonological rule application during speech production. Applying this latter theory to the results of Experiment 4 it is possible that when the phonetic organization within a semantic or syntactic category, arising from secondary organization (Tulving, 1968), is ill-formed there is a tendency for certain phonological rules to operate on the lexical entries. These phonological rules are normally dormant but remain available and can be activated in novel, or abnormal situations (Karmiloff-Smith, 1978). Thus young children, and the subjects in Experiment 4 have, initially, ill-formed phonetic structures due to the novelty of the words. In dyslexic children the phonological rules are used more often since they are in the abnormal situation of having ill-formed phonetic structures.

The mispronunciation, linguistic uncertainity and wrong use of words reported by Stirling (1978) indicates that the phonetic tree structures within semantic categories are less well developed in dyslexic children. In addition the continuity between error reduction and reaction time reduction in learning reported by La Berge and Samuels (1974) and Shapiro (1968) would also suggest, as a result of slower naming (Experiments 3a and 3c), that these phonetic tree structures are less well developed in dyslexic children.

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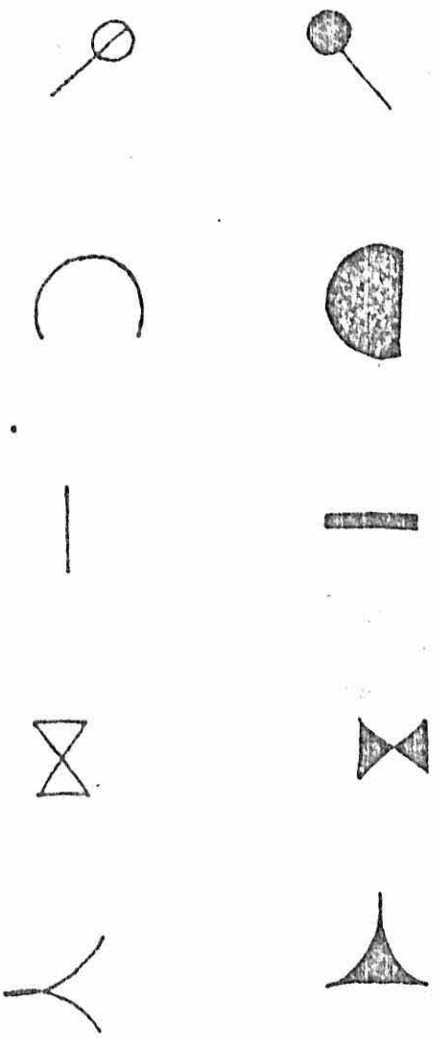
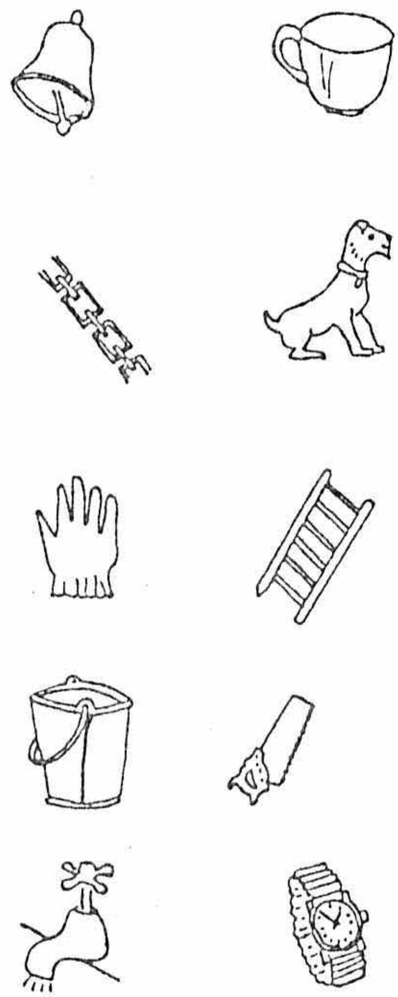
APPENDIX A

Table A

Nonsense Shape Stimuli



Picture Stimuli



APPENDIX B

Table A

AoA1, AoA2 and Kucera Francis word frequency counts (counts/million) for the 65 pictures used in Experiment 3c

	K-F count	AoA1	AoA2
airplane	11	1	6
anchor	15	8	61
apple	9	3	20.5
arrow	14	8	54
axe	6	8	52
bagpipes	1	9	63
basket	17	6	40
bed	127	3	14
bicycle	5	1	1.5
book	193	3	20.5
bus	34	1	1.5
butterfly	2	3	24
cactus	0	9	65
cake	13	5	37
carrot	1	4	31
chair	66	1	6
cigarette	25	8	59
clock	20	2	9
comb	6	4	28
cup	45	2	10.5
dice	14	7	47
drum	11	4	32
ear	29	7	46
elephant	7	1	4
eye	122	4	35
fan	18	8	58
feather	6	7	45
fish	35	1	3
fork	14	3	15
giraffe	0	4	27
glove	9	4	25

Table A continued

	K-F Count	AOA 1	AOA 2
hammer	9	4	33
horseshoe	0	8	50
hosepipe	9	8	51
key	88	3	18
kite	1	5	38
knife	76	3	16.5
leaf	12	7	44
lion	17	3	23
microscope	8	9	64
mousetrap	0	8	57
nail	6	8	55
octopus	1	8	60
penguin	0	4	30
piano	38	5	39
ring	47	5	35
scissors	1	3	22
screw	21	8	49
shoe	14	1	8
snail	1	6	41
snake	44	4	29
spoon	6	2	12
tap	18	2	10.5
telephone	76	1	6
telescope	4	9	62
tent	20	7	43
toaster	0	8	53
toothbrush	6	5	36
tortoise	3	4	26
tree	59	3	18.5
typewriter	10	7	47
umbrella	8	3	19
whale	0	9	55
windmill	1	6	42
window	119	3	13

APPENDIX C

Table A

Breakdown of PAL Learning Errors into the 3 subtypes of error for each subject pair (Experiment 4)

Subject Pair	Total Errors		Response Learning Errors		Associative Learning Errors	
	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic
1	54	14	47	14	7	0
2	21	12	20	7	1	5
3	24	6	24	4	0	2
4	50	19	34	16	16	3
5	57	15	49	15	88	0
6	39	21	33	16	6	5
7	63	3	62	2	1	1
8	44	6	44	5	0	1
9	26	13	25	11	1	2
10	10	10	10	10	0	0
11	44	19	35	19	9	0
12	44	13	37	9	7	4
Σ	476	151	420	128	56	23
$\bar{x}$	39.67	12.58	35.0	10.67	4.67	1.92

APPENDIX C

Table B

Frequencies of Total Errors, Response Learning Errors (RLE) and Associative Learning Errors (ALE) for each subject pair (Experiment 4)

Subj Pair	Total Response Learning Errors		Near Misses		No Responses		Guesses	
	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic
1	47	14	35	13	0	0	12	1
2	20	7	19	7	1	0	0	0
3	24	4	21	4	0	0	3	0
4	34	16	19	13	2	3	13	0
5	49	15	35	4	7	11	7	0
6	33	16	25	11	4	5	4	0
7	62	2	50	1	9	1	3	0
8	44	5	29	5	10	0	5	0
9	25	11	18	10	3	1	4	0
10	10	10	7	10	2	0	1	0
11	35	19	21	15	13	4	1	0
12	37	9	20	9	8	0	9	0
Σx	420	128	299	102	59	25	62	1
$\bar{x}$	35.0	10.67	24.92	8.5	4.92	2.08	5.17	.08

APPENDIX C

Table C

Frequences of Near Miss Errors at each serial position for each CVC (Experiment 4)

Group	Serial Position	/jæd/	/wʌk/	/fep/	/mɪv/	/gɒks/	Total
		CVC					
Dyslexic	1 (initial consonant)	2	1	10	3	9	25
	2 (medial vowel)	72	78	11	34	10	205
	3 (final	40	31	28	19	29	148
		= 114	110	49	56	48	378
Non-Dyslexic	1	1	1	11	1	3	17
	2	16	28	0	3	2	49
	3	2	13	9	7	13	44
		= 19	42	20	11	18	109

(N.B. Total no. errors in this table does not tally with the near miss total in table A of Appendix C since some entries in this latter table contained errors in more than one serial position)

APPENDIX C

Tables D.1 - D.5

Phonetic Transcriptions of Near Miss Errors for the final consonant in each of the five CVC Responses

Table D.1

Target /d/ in /jɑːd/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/t/	20	0
/K/	6	0
/p/	4	0
/ø/	4	0
/b/	2	0
/ts/	1	0
/KS/	1	0
/ns/	2	0
/s/	0	0
/g/	0	2
	= 40	= 2

Table D.2

Target /K/ in /WAK/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/ø/	8	1
/t/	7	10
/KS/	5	0
/ts/	1	1
/ps/	1	0
/g/	3	0
/ft/	3	0
/v/	1	1
/p/	1	0
/ng/	1	0
	= 31	= 13

Table D.3

Target /p/ in /fep/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/b/	11	2
/ø/	6	0
/pt/	2	2
/m/	2	0
/n/	2	0
/t/	1	0
/d/	1	0
/ps/	1	0
/f/	1	0
/ft/	1	0
/K/	0	4
/ts/	0	1
	= 28	= 9

Table D.4

Target /v/ in /mIv/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/ø/	10	1
/f/	3	1
/d/	2	1
/K/	1	0
/g/	1	0
/vd/	1	0
/ft/	1	0
/b/	0	4
	= 19	= 7

(N.B. /ø/ denotes ommission of final consonant)

APPENDIX C

Table D.5

Target /KS/ in /gɒks/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/ts/	11	9
/K/	4	0
/t/	4	1
/d/	2	0
/z/	4	2
/s/	1	0
/ns/	1	0
/n/	1	0
/ø/	1	0
	= 31	= 13

APPENDIX C

Tables E.1 - E.5

Phonetic Transcriptions of Near Miss Errors for the Initial Consonant in each of the Five CVC Responses

Table E.1

Target /j/ in /jæd/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/m/	1	0
/ø/	1	0
/d/	0	1
	= 2	= 1

Table E.2

Target /W/ in /wʌk/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/j/	1	0
/ø/	0	1
	= 1	= 1

Table E.3

Target /f/ in /fep/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/s/	2	8
/m/	1	2
/ø/	2	0
/fl/	4	0
/n/	1	0
/j/	0	1
	= 10	= 11

Table E.4

Target /m/ in /mIv/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/n/	3	0
/f/	0	1
	= 3	= 1

Table E.5

Target /g/ in /gɒks/

Error	Frequency: Dyslexic	Frequency: Non-Dyslexic
/j/	1	0
/k/	5	2
/gv/	2	0
/ø/	1	1
	= 9	= 3

APPENDIX C

Tables F.1 - F.5

Phonetic Transcriptions of Near Miss Errors for the Medial Vowel in each of the Five CVC Responses

Table F.1

Target /æ/ in /jæd/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/e/	26	1
/ɛə/	19	8
/ɪə/	13	4
/a:/	4	2
/ɜ:/	7	0
/ɒ/	2	0
/I/	0	1
/ɔI/	1	0
	= 72	= 16

Table F.2

Target /ʌ/ in /wʌk/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/ɒ/	66	27
/æ/	8	1
/a:/	1	0
/e/	1	0
/u:/	1	0
/ɔ:/	1	0
	= 78	= 28

Table F.3

Target /e/ in /fep/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/ɒ/	4	0
/I/	2	0
/ʌ/	2	0
/ɛə/	1	0
/a:/	1	0
/i:/	1	0
	= 11	= 0

Table F.4

Target /I/ in /mIv/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/e/	20	3
/ɜ:/	4	0
/a:/	3	0
/eɪ/	2	0
/æ/	1	0
/ɒ/	1	0
/ʌ/	1	0
/aɪ/	1	0
/ɛə/	1	0
	= 34	= 3

Table F.5

Target /ɒ/ in /gɒks/

Error	Frequency Dyslexic	Frequency Non-Dyslexic
/ʊ:/	3	1
/əʊ/	3	0
/ɔə/	1	0
/ɔɪ/	1	0
/ɔ:/	1	0
/e/	1	0
/ʌ/	0	1
	= 10	= 2

APPENDIX C

Table G.1

Analysis of Phonetic Similarity/Dissimilarity of Medial Vowel Substitutions using the Mid Points of the Vowel Transition in Dipthongs as the Vowel Locus on O'Connors (1977) 2-Dimensional Vowel Space

	Similar															Dissimilar
Target /æ/ :	ɛə	ʌ	aɪ	e	ɪə	əʊ	ɜː	ɔɪ	ɔə	eɪ	ɪ	iː	aː	ɔː	ɒ	uː
Dyslexic:	19	0	0	26	13	0	7	1	0	0	0	0	4	0	2	0
Non-Dyslexic:	8	0	0	1	4	0	0	0	0	0	1	0	2	0	0	0
Target /ʌ/ :	aː	ɛə	ɒ	aɪ	æ	ɜː	ɪə	əʊ	ɔː	ɔɪ	ɔe	e	eɪ	ɪ	iː	uː
Dyslexic:	1	0	66	0	8	0	0	0	1	0	0	1	0	0	0	1
Non-Dyslexic:	0	0	27	0	1	0	0	0	0	0	0	0	0	0	0	0
Target /e/ :	eɪ	ɪ	ɪə	æ	iː	ɛə	aɪ	ɜː	əʊ	ɔɪ	ʌ	ɔː	ɔɪ	uː	aː	ɒ
Dyslexic:	0	2	0	0	1	1	0	0	0	0	2	0	0	0	1	4
Non-Dyslexic:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Target /ɪ/ :	iː	eɪ	ɪə	e	ɜː	ɔɪ	əʊ	ɛə	aɪ	æ	uː	ʌ	ɔe	ɔː	aː	ɒ
Dyslexic:	0	2	0	20	4	0	0	1	1	1	0	1	0	0	3	1
Non-Dyslexic:	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0	0
Target /ɒ/ :	aː	ʌ	ɔː	əʊ	æ	ɛə	ɔe	ɔɪ	ɜː	uː	ɪə	e	aɪ	eɪ	ɪ	iː
Dyslexic:	0	0	1	3	0	0	1	1	0	3	0	1	0	0	0	0
Non-Dyslexic:	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
(Dyslexic)	20	4	67	49	26	1	8	3	2	4	2	3	4	0	6	6
(Non-Dyslexic)	8	1	27	44	55	0	0	0	0	1	1	0	2	0	0	0

Dyslexic	166 (81.0%)	18 (9.0%)	21 (10.2%)
Non-Dyslexic	45 (91.9%)	1 (2%)	3 (6.1%)

APPENDIX C

Table G.2

Analysis of Phonetic Similarity/Dissimilarity of Medial Vowel Substitutions using the Terminus of the Vowel Transition in a Dipthong as the Vowel Locus on O'Connors (1977) 2-Dimensional Vowel Space

	Similar															Dissimilar
Target /æ/ :	ɛə	ʌ	e	ɜ:	ɔə	ɪə	aɪ	ɔɪ	ɪ	eɪ	əʊ	i:	a:	ɔ:	ɒ	u:
Dyslexic:	19	0	26	7	13	0	0	1	0	0	0	0	4	0	2	0
Non-Dyslexic:	8	0	1	0	4	0	0	0	1	0	0	0	2	0	0	0
Target /ʌ/ :	ɛə	a:	ɒ	æ	ɔə	ɪə	ɜ:	ɔ:	e	əʊ	aɪ	ɔɪ	eɪ	ɪ	i:	u:
Dyslexic:	0	1	66	8	0	0	0	1	1	0	0	0	0	0	0	1
Non-Dyslexic:	0	0	27	1	0	0	0	0	0	0	0	0	0	0	0	0
Target /e/ :	eɪ	ɔɪ	aɪ	ɪ	æ	i:	ɜ:	ɔə	ɪə	ɛə	ʌ	əʊ	ɔ:	a:	ɒ	u:
Dyslexic:	0	0	0	2	0	1	0	0	0	1	2	0	0	1	4	0
Non-Dyslexic:	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Target /ɪ/ :	eɪ	ɔɪ	aɪ	i:	e	ɜ:	ɪə	eʊ	eə	ɔə	æ	u:	ʌ	ɔ:	a:	ɒ
Dyslexic:	2	0	1	0	20	4	0	0	1	0	1	0	1	0	3	1
Non-Dyslexic:	0	0	0	0	3	0	0	0	0	0	0	0	0	0	0	0
Target /ɒ/ :	a:	ʌ	ɔ:	ɔə	eə	əʊ	ɪə	ɜ:	æ	u:	e	aɪ	ɔɪ	ɪ	eɪ	i:
Dyslexic:	0	0	1	1	0	3	0	0	0	3	1	0	1	0	0	0
Non-Dyslexic:	0	1	0	0	0	0	0	0	0	1	0	0	0	0	0	0
(Dyslexic)	21	1	94	18	33	8	1	2	2	4	4	0	6	1	9	2
(Non-Dyslexic)	8	1	28	1	7	0	0	0	1	1	0	0	2	0	0	0

Dyslexic	167 (81.5%)	16 (7.8%)	22 (10.7%)
Non-Dyslexic	45 (91.9%)	2 (4%)	2 (4%)

APPENDIX C

Table H

Total No. of errors (RLE + ALE), Response Learning Errors (RLE) and Associative Learning Errors in the Re-Learning Task of Experiment 4

Subject Pair	Total No Errors		RLE's		ALE's	
	Dys	Non-Dys	Dys	Non-Dys	Dys	Non-Dys
1	4	0	3	0	1	0
2	4	5	3	0	1	0
3	4	3	4	2	0	1
4	6	5	1	3	5	2
5	9	0	8	0	1	0
6	6	0	6	0	0	0
7	10	0	8	0	2	0
8	5	0	5	0	0	0
9	0	4	0	3	0	1
10	0	0	0	0	0	0
11	11	0	8	0	3	0
12	17	2	11	0	6	2
	$\bar{X}$=6.33	1.58	4.75	0.7	1.58	0.5

Dys = Dyslexic

Non-Dys = Non-Dyslexic

APPENDIX D

Table A

Mean Image generation time (secs/item) and the frequency of Image Recall errors (max = 10) for Dyslexic and Non-Dyslexic subjects in Experiment 5

Subject Pair	Mean Image Generation Time		No. of Recall errors	
	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic
1	6.2	7.3	1	0
2	10.7	10.35	1	1
3	8.6	13.4	1	0
4	12.5	31.7	2	2
5	8.3	17.9	0	1
6	9.4	11.4	1	3
7	11.1	12.9	5	0
8	13.2	18.0	5	0
9	9.1	15.7	4	1
10	5.9	9.8	1	0
11	11.9	11.0	1	4
12	7.3	22.3	2	0
13	5.3	12.0	3	2
	$\overline{X}$ = 9.2	14.88	2.1	1.1

APPENDIX D

Table B

No. of Errors produced by each subject in the PAL task of Experiment 5

Subject Pair	Dyslexic	Non-Dyslexic
1	3	9
2	12	6
3	9	11
4	6	18
5	1	7
6	8	12
7	17	5
8	6	9
9	25	11
10	35	29
11	15	15
12	11	11
13	10	6
	$\bar{X}$ = 12.15	11.46

APPENDIX D

Table C

Serial Recall Scores of Shape sequences in the Pre-Learning Test (Part 1) and the Post-Learning Test (Part 7) of Experiment 5

Subject Pair	Pre-Learning Score		Post-Learning Score	
	Dyslexic	Non-Dyslexic	Dyslexic	Non-Dyslexic
1	23	32	26	32
2	27	22	27	23
3	25	39	24	43
4	20	26	19	25
5	30	26	35	32
6	26	22	24	25
7	18	26	30	29
8	26	16	36	24
9	18	19	25	26
10	25	26	35	19
11	21	26	27	30
12	24	23	34	26
13	24	21	21	23
$\bar{X}$	23.6	24.9	27.9	27.5