D Y S L E X I A   A N D

C O G N I T I V E   F U N C T I O N

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A THESIS SUBMITTED
IN PARTIAL FULFILMENT OF
THE REQUIREMENTS FOR
THE DEGREE OF MASTER OF PHILOSOPHY (M. Phil.)

AWARDED BY THE
COUNCIL FOR NATIONAL ACADEMIC AWARDS

DEPARTMENT OF COMMUNICATION STUDIES
SHEFFIELD CITY POLYTECHNIC

IN COLLABORATION WITH THE
DYSLEXIA UNIT, GRENVILLE COLLEGE,
BIDEFORD

JUNE 1980

DECLARATION

I, Edwin James Watkins, being a candidate for the degree of M. Phil. as awarded by the C N A A declare that while registered as a candidate for the above degree I have not been a registered candidate for another award of the C N A A or a University. Secondly that none of the material contained in this thesis has been used in any other submission for any other award. Further, that the contents of this thesis are the sole work of the author except where an acknowledgement has been made for any assistance received.

Date 1st June 1980 signed

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DYSLEXIA AND COGNITIVE FUNCTION

ABSTRACT

The research undertaken investigates the difficulties that dyslexics have with reading and spelling, attempting to explain these from the standpoint of cognitive psychology, using an information processing paradigm. Evidence is produced to support the contention that dyslexics suffer from both a short-term memory deficit and a specific weakness in accessing deeper levels of processing. This manifests itself as a wider limitation in processing all forms of information. As a basis for research, neurological and psychological perspectives are examined and, from a study of observed symptoms, a classification and definition of dyslexia is offered. The precise differences between dyslexia and general reading retardation are discussed with specific reference to the significance of short-term memory deficits and by an analysis of the theoretical levels of processing. Haber and Hershenson's model of information processing is adopted as the frame of reference for the experimental investigation. This investigation considers the hypothesis that dyslexia is characterized by both a limited capacity in short-term memory, exhibited by reduced channel capacity and a limited access to deeper levels of processing. Three experiments are presented to test this hypothesis:

(1) An investigation into the performance of cross-lateral, dyslexic and control groups on a direct recall task using various forms of tachistoscopically presented information.

(2) An investigation into immediate recall of auditory signals of varying set size under direct recall conditions by three different age groups of dyslexic and control subjects.

(3) An investigation into spatial and temporal factors that influence dyslexic's performance on a memory task.

The results show that dyslexic's performance in all these tasks is inferior to that of matched controls. The hypothesis is therefore accepted. A model is presented that incorporates the initial hypothesis and is substantiated by considering current research literature. Finally the implications of these findings for teaching are considered.

DEDICATION

To my parents who gave me an enquiring nature and to my wife Christine and children, Rowena and Lucy, who gave me encouragement.

ACKNOWLEDGEMENTS

I acknowledge my debt to Dr Tim Wheeler, my thesis supervisor, who has encouraged me, by his example, to look further.

I am indebted to Asher Cashdan for his constructive advice and help during this research undertaking, particularly for his advice after reading the drafts of the manuscript.

I would like to thank the Headmaster of Grenville College, Bideford, D.C.Powell-Price, for his willingness for this research project to be undertaken and his consideration over the past three years. Thanks are also due to many pupils who co-operated so patiently.

I thank my many friends who have borne with me and finally I thank my typist, Margaret Kay, whose deciphering abilities are quite remarkable.

CONTENTS

PREFACE

The essential purpose of the research presented here is to look at the phenomena of dyslexia as presented from the many differing disciplines and to attempt to bring some semblance of logical ordering to the confusion that has existed. An attempt is made to clarify and evidence is produced to explain and accommodate this apparent confusion. The central frame of reference contained herein is that of the exogenous psychological model which has as its major construct an endogenous causality. This frame of reference is relatively new in that the first researchers adopting this perspective can be traced to the early 1970's.

Suggestion is made in this thesis that it is scientifically more reasonable and profitable to use verifiable psychological constructs in an attempt to impose order on what appears to be contradictory and confusing. One of the problems is that dyslexia has been considered by many to be mainly a phenomenon concerned solely with problems in the use of written language. In this thesis it is suggested that it is more profitable, in terms of understanding and remediation, to consider the dyslexic phenomenon as a problem which is manifested as a limitation in processing not just the written word but all forms of information regardless of modality.

It is outside the parameters of the research presented here to try to explain the problems of dyslexia from the biological, physiological or medical standpoint. Although the earliest research into dyslexia had indeed been undertaken from a medical and specifically opthalmic standpoint, it soon became obvious that neurological and psychological standpoints were more vitally important in the extension of an understanding of the concept of dyslexia. Consequently this research not only details the developement of awareness of the symptoms and syndromes of dyslexia and the ensuing classifications and definitions offered, but it explores the precise areas of short-term memory and levels of processing. The reason for studying this psychological area in particular arises from recent significant research. The theory that the dyslexic suffers from a deficit in short-term memory with consequent theoretically restricted access to increasing depth of processing levels is the basis for the three experimental investigations of this thesis.

As a working frame of reference various models of information processing are discussed and that of Haber and Hershenson is presented in detail. This model goes further than the others in offering an explanation of the complex processes involved in the concept of information processing. Detailed explanation of the model is a pre-requisite to full use being made of its structure. Consideration of the use of the model is thus given, as well as assumptions which impose a limitation on the model and which beg to be fully investigated. In the light of contemporary research evidence, a slightly modified model is offered to formulate working hypotheses which can be experimentally investigated. A full explanation of all the different stages and processes of the model is attempted.

Thus on ths basis of Haber and Hershenson's model the following experimental investigations are made:

(1) An investigation into the performance of cross-lateral, dyslexic and control groups on a direct recall task using various forms of tachistoscopically presented information.

(2) An investigation into immediate recall of auditory signals by dyslexic and control subjects.

(3) An investigation into spatial and temporal factors that influence dyslexics' performance on a memory task.

As a result of these three experimental investigations a new model is proposed. This is compatible with the contemporary research reviewed earlier in this thesis and goes further in explaining the main proposition that dyslexics suffer from a central short-term memory deficit.

From this model a number of important educational principles arise, specifically strategies of remediation which could aid the dyslexic to achieve his potential in a learning situation.

CHAPTER 1

CURRENT THEMES IN DYSLEXIA

CONTENTS

1A THE NEED FOR SELECTIVITY : NEUROLOGICAL AND PSYCHOLOGICAL PERSPECTIVES

Although the concept of dyslexia is only 100 years old there exists sizeable research literature dealing with everything from phenomenological to neuropsychological approaches, with every shade of consideration in between. It is not the intention of this chapter to duplicate the competent reviews already extant but, from this spectrum of viewpoints on dyslexia - neurological, psychological, educational, sociological - to select two for further study. These are the neurological and psychological perspectives for they seem to have the most relevant bearing and provide the necessary background for the experimental investigations of this thesis. These investigations are into the significance of short-term memory, levels of processing and the dyslexic's cognitive function. Indeed perhaps in these areas of cerebral function and the measurement of information processing the two perspectives profitably meet.

1B THE PROBLEM OF DEFINITION AND SOME PHENOMENA OBSERVED

One can perhaps best illustrate these two perspectives by looking at the definitions they have historically afforded and the phenomena observed at the time. Early research was grounded in the medical profession and was based almost exclusively on the neurological perspective. Hinshelwood, in a major opthalmic study in 1917 said the condition was:-

> "A congenital defect occurring in children with otherwise normal, undamaged brains, characterized by a disability in learning to read so great that it is manifestly due to a pathological condition and where the attempts to teach the child by ordinary methods have completely failed".

He focussed on the concept of congenital word blindness, his illiterate patient's difficulty being caused not by defective vision but by:-

> "a grave defect in the visual memory centre ...... even though the powers of sight, intellect and speech are intact".

Significantly, this observation contained the germ of the later psychological concept that the problem could be related to a defect in short term memory.

Later, researchers concentrated even more on the observable symptoms of the condition. Orton (1925), a psychiatrist and neurologist defined it thus:-

> "failure in recognition of a printed word even after it has been encountered many times".

He was the first to propose the concept that the characteristics of the dyslexic (ambilaterality, reversals, abnormal clumsiness, difficulty in understanding spoken language, transposition of letter order in written work) could be caused by:

> "ambiguous occipital dominance, physiological in nature, representing a faulty patterning of brain function".

His term was "Strephosymbolia" (twisting of symbols).

Other researchers of the same period, notably Bachman (1927) introduced the idea of a maturational lag as the cause of the problems. From 1930 onwards a growing interest in reading problems developed and it was perhaps at this period that the purely neurological perspective moved into the areas of educational and sociological development. The idea that "word blindness" was simply a problem of an "organic constitutional" condition lost ground. Critchley, a neurologist, writing in 1962 summed up the new directions of enquiries of the 1930's:-

> "Later still, the conception of a congenital word blindness became qualified by opinions of a different sort. What had hitherto been a medical province or responsibility now became invaded by sociologists and educational psychologists. Backwardness in reading became envisaged more as a problem in sociology than a medical issue".

In later years this movement away from the directly medical and neurological perspectives continued. The struggle to discover a definition which incorporated both the neurological problems and the educational challenge of the dyslexic child, remained. Critchley, writing now in 1968, suggested there was:-

> "A difficulty in learning to read, which is constitutional, often genetically determined and which is unassociated with general intellectual retardation, primary emotional instability, or gross physical defects."

In the same year the World Federation of Neurology presented this definition that dyslexia was:-

> "A language disorder in children, who despite conventional classroom experience, fail to attain language skills of reading, writing and spelling commensurate with their intellectual abilities".

Consequently, there had been over the years an extension of the original idea that dyslexia could be considered purely from the neurological perspective. A broader-based psychological perspective seemed to be emerging. In 1972, Klasen reminded us that:-

> "Dyslexia is not synonymous as claimed by many with congenital reading disability originally associated with lesions of the brain. We know today that lesions are by no means ascertainable in all cases. It is apparent that specific dyslexia is not always congenital".

Attention having been focussed on some observable symptoms of dyslexia, conflicting theories as to its cause perhaps prepared the way for the psychologist to study and measure the phenomenon. The symptoms will be discussed in finer detail later in this chapter. Suffice it to quote here, Margaret Newton, who in 1974, spoke of dyslexia:-

> "As a primary difficulty consequent upon the incompatibility between the written language system itself and the intrinsic, developmental skills of an individual's perceptual/motor system".

It was the psychological area of perception and information processing which particularly interested Miles (1973). His contribution to the understanding of dyslexia has been profound and will be discussed in the relevant subsequent sections of this thesis.

Interest in a psychological information processing paradigm rather than a neurological concept to describe dyslexia is currently increasing. It is with this psychological perspective in view that this present piece of research proceeds.

1B1 THE SIGNIFICANCE OF CEREBRAL DOMINANCE

Early neurological perspectives then, had concentrated on theories of structural brain defect or a maturational, functional lag. But interest had developed into the question of the controls operated by the cerebral hemispheres. Indeed the first experiment of this thesis (Chapter 4) considers the question of cross-laterality from an information processing perspective.

The significance of cerebral dominance had been grasped by, notably, Orton (1930's), whose theories suggested that incomplete cerebral dominance in the two hemispheres of the brain which serve the visual part of the language function caused a representational conflict when the dyslexic tried to build visual and auditory association simultaneously between letters and shapes. In normal subjects, only the dominant hemisphere was 'active'; in the dyslexic child 'engrams' might be formed in the associative tracts of both hemispheres but 'normally' those in the non-dominant hemisphere were usually employed. As these non-dominant 'engrams' were mirror-wise, should there be a lack of clear-cut dominance a confusion in orientation and sequence would occur - as indeed it did so frequently among the patients he observed. This area of research continued until the late 1960's.

Ingram and Reid (1956) cited a group of dyslexics who had lack of consistent laterality. Similarly De Hirsh, Jansky and Langford (1966) were leading exponents of the concept of maturational delay. Maturation, they considered, was determined by a variety of factor inherited patterns, e.g. biological growth, emotional, cultural and educational experience. Synder et al's (1967) Rossi's(1968) Goldberg's(1972) findings suggested that a maturational lag inhibited dyslexics' processing efficiency because the children were not developmentally ready to acquire the necessary sub-skills and skills pre-requisite to reading processes. Klasen (1972) considered that maturational delays were significant in 33.2 per cent of dyslexic reading and spelling problems.

Similarly Harris (1957) quoted a figure of 40 per cent compared to 18 per cent in his control group. He later observed (1961) that crossed dominance as well as delayed development of laterality occurred, up to the age of 9, far more frequently amongst slow than normal readers. It was concluded that cerebral maturity and dominance had a direct correlation. The majority of children pass through this normal stage and go on to full literacy, the dyslexic child was characterized by making errors of reversal and transposition for so long.

In the same period 1960-61 Ingram and Zangwill considered that the frequency of retarded speech development, poor or defective spatial perception and motor clumsiness were indications of defective cerebral maturation and ill-lateralization.

Zangwill (1960; 1961) offered three possible explanations for the reading difficulties of ill-lateralized children. viz:

1. "poorly developed laterality and reading retardation when occurring together may be the effect of an actual cerebral lesion"

2. "in the absence of neurological lateralizing signs, a genetic factor controlling handedness and cerebral dominance may be involved and associated slow maturation"

3. "those lacking strong and consistent lateral preferences are particularly vulnerable to stress such as that of minimal birth injury".

Critchley (1962) summed up what had become a controversial area.

> "recent studies tend to show that what is important for reading is not which hand or which eye is dominant, but rather whether or not the child has developed laterality and directionality".

Certainly the majority of researchers appeared to believe that there was at least an associative positive correlation between laterality and reading patterns yet the situation was by no means clear cut, "the causal nature of the relationship is far from being proven" Klasen (1972).

There were, for instance, many cross laterals who were not dyslexic. Similarly large scale surveys (Clarke 1970, Rutter (1970) had failed to find any significant relationship between left handedness or mixed handedness and reading retardation. There was no positive agreement as to how laterality as a general trait (if, indeed, it is general) or even handedness as a specific trait, should be determined, and as has been noted different tasks or tests can and do yield different results. Perhaps it is pertinent to cite Vernon (1957) who did not accept that incomplete lateralization and lack of maturation could plausibly explain reading failure. She could see no reason why only reading failure should occur and other cognitive factors be left unaffected; she expected some carry over to affect performance more generally, especially in language faculties, if the defect were due to maturation. Her doubts would seem to be worthy of further research and indeed the concept of a maturational lag is considered in the experimental undertaking of chapter five and six.

Never-the-less, there seemed sufficient research evidence to show that a relationship appeared to exist between cerebral dominance, lateralization and reading disability. The neurological,medical, psychological and educational perspectives may eventually meet - not, one hopes, at intangible infinity - but at some point where one might coherently explain the causes, and interpret the symptoms, of the phenomenon of dyslexia. The remainder of this introductory chapter will consider the psychological evidence or symptoms of the phenomenon.

1C CATEGORIZATION : SYMPTOMS AND SYNDROMES

Any deviation from normal functioning in behaviour is considered to be indicative of an underlying condition of physical or mental disorder or disturbance. This phenomena is defined as a symptom or an indication of a 'set' of symptoms.

1C1 THE CONCEPT OF SYNDROME

Any disagreement on the specific symptomatology of dyslexia is undoubtedly related to the absence of appropriate control groups to assess the extent to which presumed symptoms are unique. It follows that absolute agreement on the symptoms is related to what behavioural phenomena can be associated or correlated with the acceptable use of the term dyslexia, and this in turn is determined to a great extent by the very nature of the observations made by researchers in their studies. Their observations and findings are influenced by definition, classification and presumed aetiology of the dyslexia. (See Wheeler and Watkins 1978, 1979 for reviews.)

The major question arising from the above, a question incidentally that has been asked since the beginning of this century, is whether dyslexia has a unitary causative factor for a unitary phenomenon or whether it can be ascribed to a unitary causative factor which presents a grouping of discernible dyslexias, or whether a unitary or multiple dyslexia can be traced to a multiplicity of causal factors. Attempts to isolate a single factor responsible for reading problems have come to little avail (Robinson, 1946; Johnson, 1957). As Klasen (1972) remarked.

> "There are no indications that reading disability will ever be traced back to a single aetiological factor. The complexity of the reading process itself makes this most unlikely."

The causes and classification of specific dyslexia as a syndrome as opposed to a general retardation are discussed in the final section of this chapter. Meanwhile an examination of symptoms may lead one towards that end.

What are the recognisable "symptoms" of the dyslexic? Broadly speaking, in educational fields, dyslexia is observed as failure of the child to acquire a satisfactory level of reading, spelling and written work in spite of intellectual ability (in some cases a high degree of intelligence), normal and natural school experiences, emotional stability and socio-economic opportunity.

More precisely certain "deficits" make persistent appearances in the literature about the dyslexic child:

1C2 <u>AN INDEX OF DEFICITS</u>

1. <u>DIRECTIONAL CONFUSION (LEFT RIGHT)</u>

   Orton (1937); Rabinovitch, Drew, De Jong, Ingram and Withey (1954); Shepherd (1956); Zangwill (1960); Belmont and Birch (1965); Ginsburg and Hartwick (1971); Miles and Wheeler (1974).

2. HANDEDNESS AND CEREBRAL DOMINANCE (CROSSED DOMINANCE)

Hildreth (1950); Smith (1950); Bauer and Wepman (1955); Zangwill (1960); Branch et al (1964); Birch (1964); Annett (1967) and (1970); Antony (1969); Bϕ (1972); Belmont and Dunlop et al (1973). Newton (1970); Naidoo (1972); Klasen (1972); Bϕ (1972).

3. SPONTANEOUS WRITING AND SPELLING IMPAIRMENT

Orton (1928); Rabinovitch et al (1954); Zangwill (1962); Buchanan (1968); Bannatyne (1971); Miles (1974); Wheeler (1978).

4. VISUAL PERCEPTION DEFICIENCIES

Howes and Solomon (1957); Broadbent (1958); Lachman (1960); Benton (1962); Kinsbourne and Hartley (1968); Bakker and Satz et al (1970); Klasen (1972).

5. NEUROLOGICAL DYSFUNCTION

Orton (1928); Zangwill (1960); Naidoo (1972).

Rabinovitch (1968); Naidoo (1972); Sklar et al (1972); Francis Williams (1974).

6. MOTOR DYSFUNCTION

Orton (1928); Hildreth (1950); Penfield and Roberts (1959); Critchley (1962); Harris (1966); Goldberg (1968); Miles (1974); Newton (1974).

7. FINGER DIFFERENTIATION PROBLEMS

Hildreth (1950); Rabinovitch et al (1954); Kephart (1968); Naidoo (1961); Critchley (1964); Bannatyne (1968); Klasen (1972)

8. <u>WEAKNESS IN MEMORY STORAGE</u>

Sampson and Spong (1960); Alwitt (1963); Blank and Bridger (1966); Klatzky and Atkinson (1971); Allik and Siegel (1974); Miles (1974); Wheeler and Watkins (1977).

9. <u>FAMILIAL OR INHERITED DISABILITY (GENETIC FACTORS)</u>

Critchley (1962); Keeney (1968); Naidoo (1972); Francis Williams (1974).

10. <u>DELAYED MATURATION</u>

Bakker and Satz (1970); Vernon (1971); Naidoo (1972).

11. <u>MATERNAL AND NATAL FACTORS</u>

Kawi and Pasamanick (1959); Critchley (1962); De Hirsch et al (1966); Naidoo (1972); Newton (1974).

12. <u>LANGUAGE DELAYS</u>

Orton (1928); Orton (1937); Schonell (1942); Zangwill (1960); Gibson (1965); De Hirsch (1966); Moyle (1968); Klasen (1972); Miles (1974).

13. <u>SEX DIFFERENCES</u>

Donvan (1953); Bannatyne (1966); Money (1962); Prechtl (1962); Critchley (1964); Rabinovitch (1968); Bornstein and Sroka (1969); Klasen (1972); Newton (1977).

1C3 PSYCHOLOGICAL TAXONOMIES OF SYMPTOMS

As if confirming such an index the Word Blind Centre's Committee laid down certain working or functionally orientational criteria for the recognition of dyslexic children. They were:

Always Present

1. Reading and spelling considerably behind intelligence.
2. Inability to deal with symbols forming letters or words and weak retention of symbols.
3. Bizarre spelling.
4. Persistent reversal of letters.

Commonly Present

1. Crossed laterality.
2. Bizarre and cramped handwriting.
3. Difficulties with numbers similar to the difficulties with letters.
4. Weakness in copying diagrams.
5. Similar difficulties in other members of the family in the same or earlier generations.
6. Sometimes a secondary emotional disturbance showing itself in physical symptoms which recur frequently and lead to absence from school, which is then blamed for the reading difficulty.

Miles (1973) as has been noted was one of the first researchers to look specifically at dyslexia from a psychological information processing paradigm. While concurring with the symptoms detailed here he made specific reference to the dyslexic's deficit in short-term memory as a causal factor. The overall purpose of the research undertaken in this thesis is to define, using an information processing paradigm, the dyslexic's problems specifically in short-term memory and to present a model which can account for them.

1D SPECIFIC DYSLEXIA VERSUS GENERAL READING RETARDATION

Having examined some of the neurological and psychological perspectives and observed the symptoms of dyslexia - especially those most obvious to the educationalist - perhaps some indication has to be given of the essential difference between the concept of specific dyslexia and reading retardation. At worst the term dyslexia has been used as an imprecise "umbrella" description of all reading difficulty or even as a "convenient" impressive "label" to excuse a lack of intelligence in a child. Wepman (1962) was one researcher guilty of such a misuse of terminology viz:-

> "Dyslexia is used in the present paper to mean any or all degrees of reading impairment from nonreading to delays in the normal acquisition of reading of sufficient degree that the subject is considered a reading problem."

Obviously the researcher and teacher must not only dispel such ideas but observe and measure accurately the precise nature of this specific problem.

1D1 OBJECTIVE MEASURES OF THE DIFFERENCE BETWEEN DYSLEXIA AND READING RETARDATION

A simple "measure", as it were, of this difference is, that :-

> "Dyslexic children are characterized simply by making so many of these mistakes for so long" (Hagger 1968).

In other words one does not "grow out" of dyslexia - although the problem can be ameliorated by a structured educational process. Let us now consider some precise differences between the dyslexic child and the "retarded reader".

1, The dyslexic child will characteristically exhibit a discrepancy between full scale intelligence score and performance level in academic subjects - particularly within the skills of reading and spelling. This is not marked in the child suffering from general reading retardation who will in the main, have a low overall intelligence score (Clark 1970; Rutter et al 1970). The psychometric profile of the dyslexic child will be markedly 'saw-toothed' with particular weakness in the verbal scale. Coding and digit span will be areas of specific weakness and it is indeed rare for a dyslexic child to recall more than four reversed digits (even though the child's intelligence may be superior). They invariably gain better scores on performance items of the W.I.S.C, whereas the profile of the reading retardate is generally more even.

2, Attempts to employ normally accepted practices of teaching reading and spelling result in failure for the dyslexic child. This is because there are specific functional weaknesses which identify the dyslexic. Not only is there the major functional weakness of an I.Q/performance discrepancy mentioned above, but there is a lack of consistency in the error patterns of educational performance - while the reading retardates show a consistency in their mistakes, the dyslexic child shows a pattern of bizarre spelling and reading error.

3, Dyslexic children form a relatively homogeneous group exhibiting the functional patterns just mentioned. Reading retardates form a more heterogeneous group whose causal factors of reading difficulty include partial sight or hearing, educational sub-normality, maladjustment, organic brain damage, disrupted schooling, lack of adequate educational opportunity and other such factors. Herman (1959) makes the point that dyslexia is :-

> "a specific disorder of function and not merely the chance result of a series of external factors".

4, The problems of the dyslexic child seem to centre around a specific weakness in short-term memory - a weakness and difficulty in apparently gaining access to and from long-term memory. This whole area and the question of levels of processing will be investigated and discussed in ensuing chapters. Supporting evidence also came from the epidemological study of schoolchildren on the Isle-of-Wight which sought to ascertain if a pattern of reading difficulties could be identified. 2,334 nine and ten year old children were screened. Rutter et al were interested in three identifiable groups

1. children who were "intellectually retarded" (WISC score two standard deviations below the mean)

2. children "Backward in reading" (reading attainment 28 months below their chronological age regardless of IQ), and

3. children "specifically retarded in reading" (28 months or more below their expected reading level based on mental age on the Neale Analysis of Reading Ability). 86 (3.7%) were identified as being specifically retarded in reading; 155 children (6.6%) were identified as backward readers. Of this latter group, 76% were also specifically retarded in reading.

Rutter et al. stated that the "6.6% must be regarded as a minimal estimate of the reading retarded since 28 months is a severe degree of backwardness. From the control group it was found that 2% of the reading retarded children were missed by the group screening techniques. This would increase the incidence of specific reading retardation to a possible 5.7% and reading backwardness to 8.6%."

Perhaps significantly when the children with specific reading retardation were retested 2 years later, all were still reading below their chronological age levels. This finding is not surprising in the light of comments already made about the need for specialized remediation if these children are to make progress. Rutter et al - noted that with the general reading retarded groups their mathematical ability was also retarded along with other scholastic subjects. Yet those children identified as suffering from specific retardation in fact did considerably better both in mathematics and other school subjects. Indeed, the general consensus is that the dyslexic child suffers only from a specific reading and spelling retardation whereas the reading retarded group suffer from a general retardation.

As if confirming these findings then, the Tizard (1972); Bullock (1975) and Warnock (1978) reports all acknowledged the existence of a homogenous group of children who were identifiable by their specific reading disability and were often called dyslexic. Warnock stated

> "Although there are no agreed criteria for distinguishing those children with severe and long term difficulties in reading, writing and spelling from others who may require remedial teaching in these areas, there are nevertheless children whose disabilities are marked but whose general ability is at least average and for whom distinctive arrangements are necessary".

1D2 ACCEPTANCE OF DYSLEXIA

Encouragingly the Department of Employment takes seriously the concept of dyslexia to the extent that they issue a "Green card" stating that the prospective employee is suffering from dyslexia. It is a recognizable disability which is certifiable. The Medical School Officers Handbook devotes a whole chapter (1975, Chapter 10) to the phenomenon of dyslexia and gives valuable advice and guidance. The Open University was one of the first academic institutions officially to recognize and make provision for the dyslexic candidate. Today the majority of public examination boards accept and give special dispensation to dyslexic pupils who take CSE, 'O' and'A' level exams.

1D3 TERMINOLOGY

Perhaps the proponents and opponents of the term dyslexia and its many variants have themselves added to the difficulty in separating the specifically dyslexic child from the reading retardate. Cruickshank (1968) adequately sums this up:

> "If the child diagnosed as dyslexic in Philadelphia moved to Bucks County, ten miles north, he would be called a child with a language disorder. In Montgomery County, Maryland, a few miles south, he would be called a child with special or specific language problems. In Michigan, he would be called a child with perceptual disturbance. In California he would be called either a child with educational handicaps or neurologically handicapped child. In Florida and New York State, he would be called a brain injured child. In Colorado the child would be classified as having minimal brain dysfunction."

However, constructive useful attempts <u>have</u> been made to classify dyslexia as a specific entity and these must be considered.

1D4 CLASSIFICATION

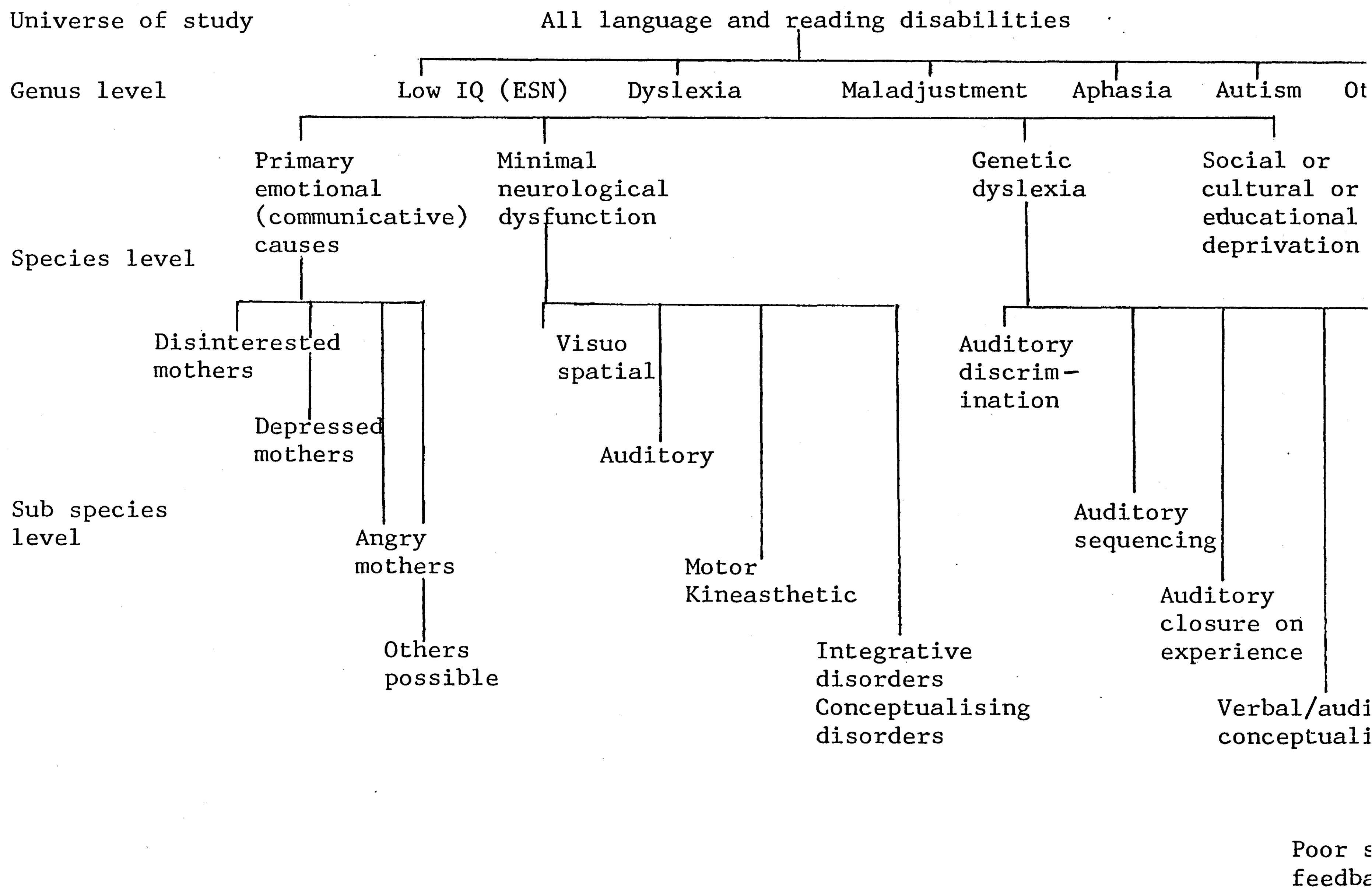
De Hirsch (1968) indicated the enormous complexity of starting on a classification system.

> "The overall performance of so called dyslexics seems to point to a profound and basic maturational deficit; a deficit so severe that one might speculate that it is rooted in a biological matrix and constitutes a type of cerebral dysfunction"

Yet other researchers have considered this viewpoint of organic disorder less important than the one which suggests a functional problem, i.e. lack of emotional readiness to read or a developmental lag (Stone and Church 1957). Useful classification of dyslexias and other types of dyslexia were produced by Keeney (1968). Goldberg (1968); Bannatyne (1971) and Klasen (1972) who all proposed the idea that there were types of dyslexia perhaps with separate causes.

Only Bannatyne's model is offered, possibly because it went further, in as much as it clearly differentiated the fundamental differences between the reading retardate and the dyslexic. Of course, it will be observed that the functional factors that go to make up the separate entities are not mutually exclusive, there is a point of overlap which is possibly one of the reasons for the continuing controversy about what criteria constitute the dyslexic subject as opposed to the reading retardate.

Bannatyne's Classification of Causes and Types of Dyslexia (Note : none of these categories is mutually exclusive)



More recently Naidoo (1972) in her work at the Word Blind Centre came to the conclusion that the "concepts of dyslexia under the specific headings of genetic factors, maturational lag, neurological dysfunction and cerebral dominance, need not be mutually exclusive."

Similarly Singleton (1976) felt that hypotheses about the causation of dyslexia fell more plausibly into four broad categories, viz:

1. Brain damage
2. Genetic factors
3. Defective lateralization
4. Developmental delay.

Again these categorizations were not mutually exclusive.

The aetiology may be divided into two major categories, endogenous and exogenous. Klasen (1972) proposed such a classification of causes and made comment that,

> "Our own classification cannot be completely or absolutely correct ... it is based on the assumption that specific dyslexia constitutes a multi-aetiological syndrome, according to causal relationships and frequency of occurrence."

Klasen's classification was as follows:

1. <u>Somatogenetic Dyslexia</u>

   a. Functional : neurological disorders in the organization or functioning of the central nervous system without evident organic or structural changes (EEG normal or only slightly and unspecifically changed).

b. Constitutional : inborn weakness without pathogenetic evidence, at least as far as today's diagnostic means allow determination.

c. Heredity : familial tendency towards reading and spelling disorders of various manifestations in the absence of other evident causes or pathological signs.

d. Maturational : delayed or arrested development of the nervous system, especially of its functions, often accompanied by psychological immaturity in various areas of growth (especially often observed among prematurely born children).

e. Traumatic : conclusively diagnosed traumata of the nervous system, organic changes, birth trauma, etc.

2. <u>Psychogenetic Dyslexia</u> : neurotic conflicts, defences or reactions, originating in inner psychic or social tensions.

3. <u>Sociogenetic Dyslexia</u> : caused by social milieu, family, school, culture or similar social institutions and the limitations they may impose.

Attempts to isolate single deficits or clusters of deficiency in cortical functioning sufficient to limit reading skills have in the main yielded little additional information (Ingram, 1960; Mattis 1975). Perhaps the main contribution of the type of research undertaken by such researchers is that it reinforces the idea that a language deficit is the most fundamental problem in dyslexia (Ingram and Mason 1965); Debray 1968; Doehring 1968; Ingram et al 1970; Rutter Tizard and Whitmore 1970).

One is again faced with a difficulty of definition. Is dyslexia a specific term that can be used to describe a homogeneous grouping of difficulties or is it an overall general term that can be used to describe a collection or group of symptoms? The attempts to classify dyslexia, though useful, were perhaps in some cases too gross, for instance Johnson and Myklebust's (1967) distinction between auditory and visual dyslexia. The Word Blind Centre in its 'in depth' study of dyslexia between 1967 and 1969 had the following to say:-

> "in view of suggestions made in recent years that there may be sub-groups or types of dyslexia characterized by different patterns of disability, an attempt was made by cluster analysis to distinguish such patterns and to relate them to the various possible aetiological factors".

Naidoo (1972) concluded that statistical analysis revealed a continuum rather than identifiable sub-types. She stated

> "The evidence from this study does not support the existence of clearly defined sub-types of dyslexia".

The search for a "Definitive description" continued then, with these two alternatives, viz:-

1. that dyslexia was not diagnosable as a clinical entity and probably did not exist as such,

2. that in place of the single condition previously hypothesized there were the dyslexias, a group of disorders centred on reading disability.

Such questions as the authenticity of the specific syndrome disappeared if the second and alternative hypothesis was accepted. Indeed there was much evidence to support the second alternative. Miles (1961, 1967) made comment "to justify the term 'dyslexia' a certain cluster of symptoms must be present together." It also opened avenues for research rather than dismissing considerable evidence, and thus provided the opportunity for specific remedial help. As Houghton (1967) claimed

> "utility in the remedial situation is the final criterion of all our theorizing".

1E THE SIGNIFICANCE OF SHORT-TERM MEMORY

The intention of this section is to present selected information on the dyslexics' specific problem with short-term memory and information processing within the framework of psychological functioning, and to provide an introduction to this area before referring the reader to a more detailed consideration of research in Chapter two, which looks particularly at short-term memory and related areas in some detail.

Bronner, as long ago as 1917 spoke of the weakness of the dyslexic's visual memory but it was not until the 1960's that interest in short-term memory as a possible fundamental explanation of dyslexia was posited by Vernon (1966) and Money (1962). Increasingly, as has already been mentioned in the preceding sections, research evidence confirmed that short-term memory and information processing deficits were to be found in children diagnosed as dyslexic. Indeed, initial research was instigated by Miles (1973) in this country and Stanley and Hall (1973) Stanley (1975) Stanley Kaplan and Hall (1975) in Australia. Until this time, attempts to find a single underlying factor which allowed the researcher to describe the dyslexic condition from a particular standpoint and which accommodated the numerous observable symptoms had come to no avail.

One of the justifiable criticisms of the antagonists was that the symptoms of the dyslexic child equally 'fitted' the retarded reader and therefore it was not valid to apply this term to an arbitary grouping of children who could equally well be classified as reading retardates. Perjoratives such as "a middle-class syndrome" emerged at this time and unfortunately, but understandably are still bandied around today despite the evidence (already enumerated) to substantiate the term dyslexia.

However, an accurate measure and definition of the dyslexic child's problems - and one which adequately accommodated the main symptoms - was finally offered by investigation into the specific limitation in short term memory exhibited by the dyslexic child. The thrust of this type of investigation (or information processing paradigm) was to separate accurately the dyslexic child from his non dyslexic counterpart - the reading retardate.

There is little doubt that the psychological information processing perspective offers a major contribution to the understanding and integration of the concept of dyslexia and it is towards these ends that the following chapters are dedicated.

1F <u>CONCLUSION</u>

In conclusion it seems apposite to quote Klasen (1972) who stated,

> "Nearly one hundred years of research have done nothing to diminish the significance of the phenomena of specific dyslexia"

yet it does seem that over the last two decades research has moved away from a search for specifics and central symptoms to a broader perspective - that of a multi symptomatology which accounts for a grouping of behavioural phenomena. It is towards these ends that this particular piece of research is undertaken, in an attempt to quantify observable phenomena, especially the dyslexic's difficulties of information processing because of a measurable deficit in short-term memory. These have been briefly mentioned here and will be more fully discussed and investigated in the rest of the thesis.

CHAPTER 2

A REVIEW OF READING AND SPELLING PROCESSES, WITH PARTICULAR REFERENCE TO INFORMATION PROCESSING, LEVELS OF PROCESSING AND DYSLEXIA.

CONTENTS

2A DYSLEXIA AND INFORMATION PROCESSING: LIMITATION IN SHORT-TERM MEMORY

The intention of this section is to consider specific evidence relating to short-term information processing and its relevance to dyslexia. The section will refer particularly to spelling and reading deficits, and to dyslexia seen as a deficit of any receptive pathway which channels afferent information via short-term memory. Increasing load and decreasing time will theoretically lead to a breakdown of information processing. Initially general evidence will be reviewed which makes assumptions that a weakness in short-term memory store is characteristic of the dyslexic and as such might be a specific manifestation.

Following this the concept of processing will be outlined in a chronological sequence with specific reference made to the particular areas of weakness from which the dyslexic suffers in this respect. This will be followed by consideration of the inherent skills needed both in spelling and reading from an information processing perspective and will investigate the factors determining the 'bits' or size of units being processed. The parameters of short-term information processing will be investigated. The differences in retention of order and information have implications for the whole concept of dyslexia, especially the specific difficulties that dyslexics have in sequencing both afferent and efferent information and the ordering of phonemes in spelling. Finally there will be a brief review of the area of research into short-term memory since the beginning of the 1960's.

Ever since the early 1960's interest has increasingly been shown in the model of short term information processing and its application to the understanding of the aetiology of dyslexia. Vernon (1960), Money (1966).

Various factors in the overall "syndrome" of dyslexia had led a number of researchers (Stanley and Hall, 1973; Miles and Wheeler 1974; Stanley 1975) to consider that short-term memory was "directly implicated". As mentioned in chapter one, since the beginning of this century several authorities in the field of dyslexia had indicated a number of characteristics which went to make up the dyslexic "syndrome", (Hinshelwood (1895), Morgan (1896), Orton (1928), MacMeeken (1939)). Among these regularly reported features was one of directional confusion. The children became muddled when they had to distinguish between left and right and particularly in finer, higher order skills like the repeating or spelling of polysyllabic words - they often left out part, or repeated syllables and in most cases they reproduced them in a muddled order.

Various aspects of research into cerebral dominance and information processing suggested a connection with reading ability, (Thomas, 1969; Fritzen, 1972; Haber, 1973).

Sperry (1968) thought it necessary for cerebral dominance to be established for information processing to proceed successfully in a sequential manner from the right to the left cerebral hemisphere. If Sperry was correct, the reading retardation associated with cross laterality would seem, therefore, to be associated with impaired sequential information processing. Other recent advances in research on short-term memory have supported, and added to Sperry's work. (Klatzky and Atkinson, 1971; Siegel and Allik, 1973; Allik and Siegel, 1974; Watkins and Wheeler, 1976; Wheeler, Watkins and McLaughlin, 1977).

Stanley and Hall (1973) tested dyslexics on a visual information storage task and concluded that the visual persistence of dyslexic children was greater. Yet Stanley (1975) concluded that dyslexics had a greater difficulty in transference from the visual information storage to short-term memory. Stanley, Kaplan and Poole (1975) showed that dyslexics had inferior short-term memory irrespective of presentation modality. However, in the previous experiment and a subsequent one, Stanley and Molloy (1975), using a different experimental paradigm found there was no significant difference between dyslexics and controls for brief visual information storage. The above finding would indicate that dyslexics have a limited capacity in short-term memory rather than visual persistence in visual information storage.

Miles and Wheeler (1974) suggested that the main feature of dyslexia was the inability to retain complex information over time and that problems over orientation, when they occured, were a manifestation of this more basic limitation. Their thesis was that the 'difficulty over orientation' associated with dyslexia should be seen as a particular manifestation of a more general limitation; the more general limitation was the inability to retain a complex 'load' of material over time. It seems reasonable if their thesis was correct, to vary the complexity of stimulus material and study the time-intervals over which such material can be recalled. This is the basis of the ensuing experiments.

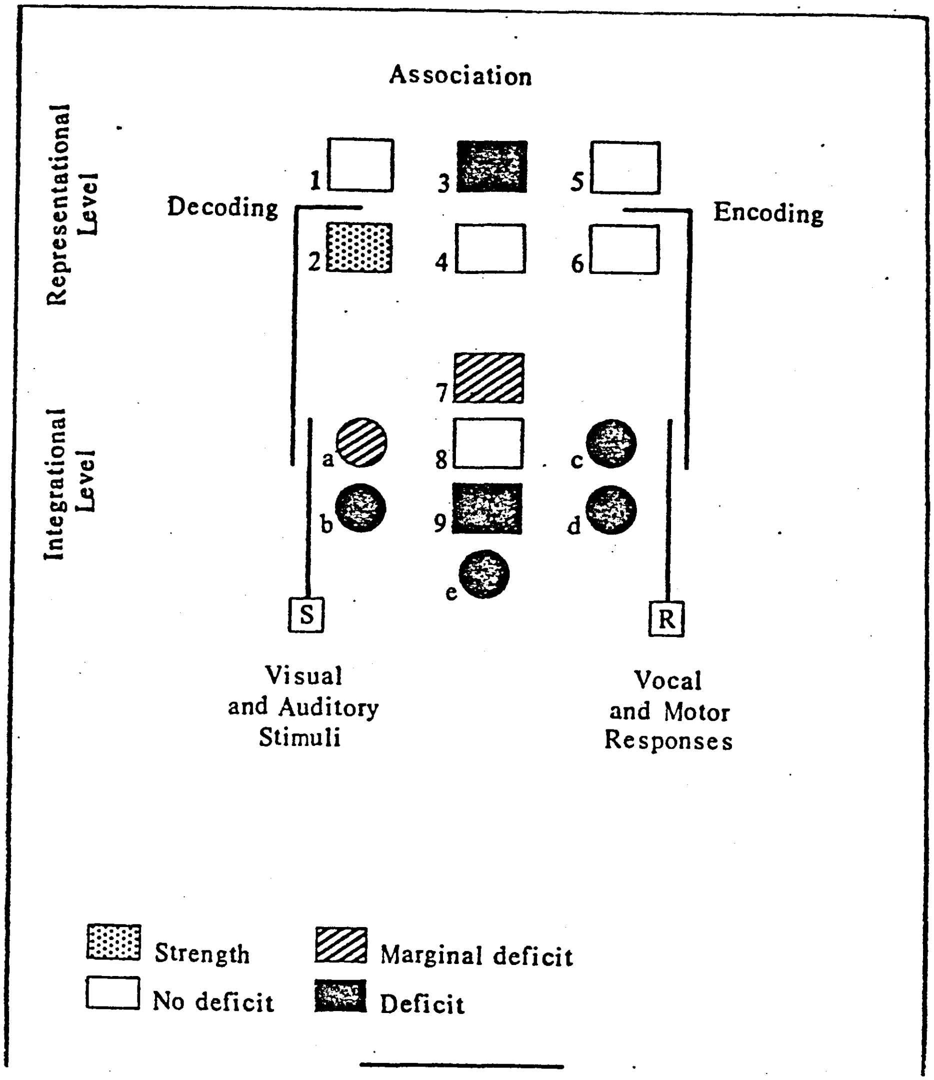
2B SHORT-TERM MEMORY AND PERCEPTUAL SPEED

McKeen (1885) showed that the perceptual span for familiar words in normal subjects was nearly as great as for single letters exposed for the same duration. Subjects were able to perceive up to as many as four times the number of letters if they were organized in a familiar word pattern rather than if they were arranged in an isolated or unfamiliar sequence. Similarly Dodge (1905) researched into high speed perception using a tachistoscope. He found that perception occurs in reading only during fixation periods, not in the saccadic jump from one fixation to another. It is "jumpy, irregular, spasmodic" but is a very accurate leap from one point to another. It is in this fashion that man normally samples his visual environment, gaining information about the world.

Saccades in reading normally proceed from left to right in a series of "jumps" across the page. Very little is seen during saccadic movement, information is picked up between saccades when the eye is still -during fixations. Very young normal children are able to read three letter words exposed for only 40 milli seconds, which is too fast for sequential eye movements to occur.

Rizzo (1939) and Lyle and Goyen (1962) found that there was a slower performance in perceptual speed with poor readers than with normal readers. They used a visual sequential memory task. Geschwind and Howes (1962) used a tachistoscope to look specifically at dyslexic difficulties. They used the Zipf measurement of vocabulary but held that the basic deficits of word blindness were clearly much more delimited than aphasia and that the deficit was suited to analysis with experimental methods that had been worked out for normal subjects. They compared the patients' inability to perceive written words with the perception of non-verbal visual stimuli. It appeared that in the case of the dyslexic subject the ability defined by McKeen was defective. They found that the subjects' inability to see words in contrast to letters was most marked, unlike the normal person's relative inability to see letters in contrast to words. Howes (1961) in a quantitative analysis looked at this 'Cattell' effect. He found that the duration threshold of a written word was in proportion to the frequency of the word in general linguistic usage.

Kass (1966) found that there was a relationship between difficulty in learning to read and performance on tests at the automatic level, including tests of perceptual speed, closure and visual memory. There was a difference between the automatic (integrational) and the representational (symbolic) levels for children who are retarded in reading. It is at the automatic level rather than the representational level that these children suffer. Kass found that in many cases children suffering at the automatic level scored high at the representational level (ability to interpret pictures). She considered that this might possibly be a compensational trait since the child will have had to rely on contextual clues from the pictures in books rather than the words.



KASS'S MODEL (1966)

FIGURE 16

REPRESENTATIONAL LEVEL

1 Auditory decoding
2 Visual
3 Auditory vocal association
4 Visual motor association
5 Vocal encoding
6 Motor encoding

INTEGRATIONAL LEVEL

7 Auditory vocal automatic
8 Auditory vocal sequential
9 Visual motor sequential
a Visual automatic (closure)
b Sound blending (Monroe)
c Mazes (WISC)
d Memory for designs (Graham Kendall)
e Perceptual speed (PMA)

Kass believed that there was a relationship between failure at the automatic level and reading disability. Failure at this level had more adverse effect on the child's performance. Possibly automatic ability was more related to reading disability than were symbolic or representational levels. Johnson (1967) looked at perceptual speed and orientation of letter forms. He found that if insufficient time were available for all stimuli to be organized, or if information decay from memory store occurred in an inverse sequence to that of acquisition, errors at different levels might occur, e.g. q for p or b or d for p. Further, if higher dimensions on the response hierarchy were to attract the bulk of cognitive effort, then orientation focus might suffer and reversals and sequential errors might occur.

Kinsbourne and Hartley (1968) formulated an attentional hypothesis invoking a lowly place for orientation on the response hierarchy. That is, given insufficient time children with reading problems have a tendency to rotate the form with reversals and other attendant orientation problems. They found that under experimental conditions errors were made in a manner suggestive of a successive primary decision process. Muller and Bakker (1968) investigated temporal order perception using colour codes. They found that at a stimulus presentation of 100 milli seconds, subjects with a poor level of reading attainment performed at a much lower level than normal readers.

Van Meel, Vlek and Bruijel (1968) in an experiment, presented slides tachistoscopically at 100 m secs to a group of mixed ability children. The task was to identify a particular pattern from a series of visually presented stimuli. The time factor was constant. Their findings suggested that as the complexity of a visual discrimination task increased so the performance of children with specific reading difficulties was comparatively more hampered. When only a few dimensions were involved performance was equal to or better than the normal children of comparative age, but they began to lag when the number of relevant dimensions were increased. It should be noted that the group was not matched for I.Q. level or laterality.

Alwitt (1963) researched decay of immediate memory for the visual presentation of digits among non-readers and readers. She cited many experiments as using successive rather than simultaneous presentation of visual stimuli (Hawkins, 1897; Rizzo, 1939). In her experiment children were presented tachistoscopically with cards containing a series of randomly selected digits. The reading retardates' scores were significantly different from those of the reading controls. Alwitt suggested that it was the underlying mechanism of immediate memory traces recall that caused the retardates to score lowly, furthermore because of insufficient attention to the whole stimulus, field elements of the stimuli would not reach the immediate memory processes.

It appears from her study that reading retardates might have a lower limit on the amount of material which they are capable of holding in immediate memory. Possibly the reading retardates had aphasial characteristics which resulted in difficulty in associating memory traces with verbal response elements which represented the trace.

Klatzky and Atkinson (1971) looked at specialization of the cerebral hemispheres in scanning for information in short-term memory. Their results supported the hypothesis that in a memory scan, letters and pictures are both spatially and verbally represented respectively and are processed in different cerebral hemispheres. Spatial comparison of letters was undertaken faster than verbal-acoustic comparison processes. Right hemisphere processing of letters appeared to be favoured, but lacked verbal capacity required to transform pictures of an object to the initial letter of its name. Picture stimulation appeared to be a left hemisphere function.

They put forward a model of processing, viz:

1. PROCESSING : naming picture and coding letter of its name.
2. COMPARISON of information.
3. Verbal response.
   DECISION

and held that the cerebral hemispheres acted as two information processing systems which optimized performance by specializing in different functions and, when capacity was limited, sharing the processing load.

Stanley (1976) looked at the processing of digits by children with specific reading disability. His sample consisted of 40 children aged between 8 years and 12 years 3 months, 20 control, 20 experiment. His findings were that the dyslexic group appeared to have difficulty:-

> "mainly with digits having curved features, making more errors with these digits and confusing them with other digits having curved features."

Further:-

> "that the error patterns for many dyslexics reflect confusions relating to curvature, for digits with curved features, is consistent with the notion that they are responding in terms of visual trace."

It should however be pointed out that Stanley used only single digits in his experiment. So his findings that the dyslexic group made more correct identifications than the control group is not really surprising in the light of

(a) his comments about visual trace

(b) the results of the piece of work undertaken by the writer using 3, 4, 5 and 7 digits, letters and symbols

(c) the findings of other researchers, that dyslexics are able to process limited amounts of information; it is only when the amount of information is increased that processing ability is impaired.

2C READING AND SPELLING : THE INTERRELATIONSHIP WITH SHORT TERM MEMORY

Towards the end of the previous chapter it was suggested that short-term memory was a significant factor differentiating the dyslexic from the reading retardate. This factor must now be analysed in more detail.

Short-term memory processes are, according to many researchers, a prerequisite for the acquisition of both reading and spelling skills (Werner, 1935; Miller, 1956; Coltheart, 1972; Gregg, 1975). Brief visual storage holds the initial visual impression or icon for approximately 250 m. sec (Haber 1973). Cognition takes place at this stage if the information is to be used, that is : recognition, decoding and possibly encoding occur. Information processing raises the question of how the information of the iconic trace is transformed into different forms of representation or codes, visual codes, auditorily represented linguistic codes, and semantic codes. From these processes man is able to see, to hear, and to understand the multi stimulation reaching his eyes. Obviously there are several stages or processes involved and because of this each stage or process must be stored or temporarily held so that further information-processing sequences can be undertaken. It is thought that memory does not play a rôle in perceptual matches when it is not needed to encode the name of the stimulus to make a perceptual meaningful match, but that if it was necessary for information about the stimulus to be stored in order to perform the match, then the perceiver would have to encode them and therefore to identify them. This of course is what happens in the perceptual matching of perceived letter groups in reading. What is suggested is that with linguistic material the perceiver extracts information from the iconic storage by coding, categorizing and attaching meaning to the shapes of patterns represented there. This is done sequentially, one at a time, and in a spatially left-to-right order. The perceiver uses all his knowledge of spelling patterns, word context and the like, to aid in categorizing and naming each unit. When the letters are in a familiar sequence the perceiver is able to make predictions about what the next word will be. The nearer the word approximates, the shorter the time needed before the word is named. If letter arrays are followed by an interpretation in the form of conflicting visual stimuli then only those letters already in the iconic storage will be available for naming. Any meaningful visual stimuli not processed will be irretrievably lost. If the duration of display is increased then more time is available for processing to take place.

Bearing this in mind, a question of how recognition takes place is considered at this juncture. The question is whether the process is based on analysis of line features of the individual letters, the individual letters, or syllables or the whole words. The skill of reading involves rapid sequential scanning of letters, groups of letters and words as the eye moves across and down the page. Possibly the reader uses a variety of recognition strategies or processes depending on the difficulty of the text. However, the advanced reader will acquire a high degree of skill in reading processes, making saccadic jumps and absorbing 'chunks' of information as he scans the whole rather than the parts.

Current conceptions of visual information processing (Haber, 1969; Neisser, 1967; Sperling 1963) imply that the information contained in a brief visual stimulus is represented in different forms at different times after stimulus offset. At first the visual image is retained in a high capacity, short lived storage, the 'icon' or visual information store (VIS). VIS decays rapidly, usually fading completely in less than 1,000 milli seconds. An encoding process transfers a smaller, more manageable amount of this information into the next stage of the memory system, which is called primary memory (Waugh and Norman, 1965) or short term memory (STM). Short term memory is more resistant to decay but of considerably more limited capacity. It is strengthened by rehearsal processes and lasts long enough to provide information for subsequent responding. From short-term memory information is transferred into long term memory (LTM), a more or less permanent store from which information can be retrieved. Learning to read involves all three stages of the process.

The major question posed in this piece of research is whether dyslexics suffer from a deficit in one of these processes. It is hypothesized that this is so particularly in the short-term memory stage.

In Haber and Hershenson's 1973 model (to be presented in Chapter 3) it will be observed that interaction occurs between all three stages, namely VIS, STM and LTM. This recognition process interacts with LTM in determining the best possible match between the physical features of the stimulus and a list of features corresponding to information held in long term memory. Perceptual units of the text have corresponding signs in long-term memory. According to the model each segment of information has its correspondent in long-term memory. A recognition process occurs which makes a choice using a match process or what has been termed the "best bet". This recognition process initiates a corresponding synthesis programme for the chosen sign and information then enters short-term memory.

Gibson, Pick, Osser and Hammond (1962) in an experiment investigating confusion errors of retarded readers showed how these errors could be utilized in recognition processes. They held that some letters have a confusion potential in that they have major features in common, e.g. b-d, p-q, a-o, n-u. In their experiment subjects were required to make same-different judgements of letter pairs simultaneously presented. They found that errors and reaction times increased in proportion to the number of features shared by the two different letters. Shallice and Warrington (1975) found that individual patients might exhibit a predominance of one or possibly two types of the above error. They considered that investigations of such patients could be informative about the properties of functional pathways, such as the grapheme phonemic route and the direct graphemic semantic encoding route. They pointed out that although semantic errors had been reported by a number of authors in the neurological literature, the syndrome they term 'deep dyslexia', where semantic errors were the cardinal feature and graphemic phonemic errors did not occur, was rare. These findings seem to concur with the model of information processing and levels of processing presented in the final chapter. It appears then that a multiplicity of strategies is involved in reading processes. The perceptual unit of the individual letter as the key to reading processes is not upheld. Research evidence also appears to indicate that word recognition is not dependent upon the correct unit recognition of individual letters.

Of these various strategies used in reading processes, it appears that skilled readers are able to hazard an 'educated guess' or to predict the next group of words to a considerable extent. The reason for this is not fully understood, but two possible reasons are considered here : (1) information is available via peripheral vision, that is, although saccadic focus is directed to one position on the page the reader can see other words which occur in peripheral vision. (2) contextual clues are used. The reader knows what has preceded and is able to guess what is coming on the basis of what has already occured. Peripheral vision may not play such a large part but rather it is the reader's ability to construct a prediction of what is to follow on the basis of having sufficient time and processing ability to think ahead.

Rabinovitch and Strassberg (1968) looked at the individual's syntactic abilities. They investigated whether syntactic structures facilitate recall in good readers and whether this effect exists in dyslexic children. They used a paired associated task equating two groups of good readers and dyslexics on their ability to associate words. A tape recorder was used to teach four sentences, composed of nonsense elements. Two sentences were syntactically structured; the other two were unstructured. Results confirmed that good readers learned the structured sentences more rapidly than the unstructured sentences. Dyslexics learned both sentences with equal 'facility' but took longer to do so. However, there was no difference between the good readers and the dyslexics' ability to retain the unstructured material. In their conclusion Rabinovitch and Strassberg held that the facilitation effect lies in the syntactic cues, implicit in the structured lists of which the dyslexics do not make use.

Vogel (1974) looked into syntactic abilities in oral language of twenty normal and twenty dyslexic children. Nine measures were used to assess syntactic abilities; none required reading or writing. It was found that the dyslexic group were significantly different from the normal children on seven of the nine measures. The normal group gained superior performance on all of the tests while the dyslexics were significantly deficient in oral syntax. At this juncture the theoretical concept of levels of processing must be considered.

2D THE THEORETICAL CONCEPT OF LEVELS OF PROCESSING

The final essential area to be considered is that of Levels of Processing. This must now be reviewed both as a background to the experimental chapters and as a basis for the final model presented in chapter seven of this thesis.

Dyslexic children have an apparent difficulty in accessing information from their language store. Earlier paradigms had presented the two process theory i.e. recognition and recall. Kintsch (1970) claimed that recall involved search and decision, recognition only involved the latter. McCormack (1972) claimed merely that the thresholds were different. This model was considered to be too flexible by Craik and Lockhart (1972) who stated:

> "For example whether or not recall is facilitated by the process of certain 'retrieval cues' may depend critically on the form of the item's initial encoding, and failure to recall might just as well be viewed as a consequence of inappropriate initial encoding as due to an inadequate retrieval cue".

They considered that many advocates of the two process theory use the term retrieval in a more restricted sense, but commented that "the exact nature of this restriction is far from clear". An attempt to define exactly the terms and concept of 'search' and 'retrieval' has been frequently presented analogously like 'locating a book in the library'. A mis-shelved book in the library requires much searching before location. This type of analogy relies heavily on the 'computer model' of information retrieval. Tulving and Pearlstone (1966) demonstrated the usefulness of this form of analysis. They considered the term 'availability' to refer to the existence of intact trace in memory store, and 'accessibility' to refer to the problem of locating it. Under this interpretation a 'retrieval cue' is seen as any thing that serves to locate the available, but hitherto inaccessible trace.

Questions emerge from such research. For example - does organization influence recognition; does recognition entail retrieval? Results have varied from study to study however. Mandler (1972) believed that it was safe to assume that recognition increased with the degree or organization. Lockhart, Craik and Jacoby (1976) considered it gratuitous to make inference that such results say any thing about retrieval processes in recognition. They advanced specific proposals to answer the question "does recognition entail retrieval?" They considered that recognition of an event depended on (1) "the depth of initial encoding", (2) "the similarity of presentations and test encodings" and considered the processing of a stimulus as a function on a theoretical continuum of analysing operations. First the physical and structural features of the stimulus were analysed, then the stimulus was subjected to progressively more elaborate and deeper semantic analysis. They considered that the memory trace was a by product of the analysing operations and the durability of the trace was a function of depth - holding that deeper initial processing yielded a longer lasting trace. They suggested that this "depth" might refer to two distinct changes in processing namely (1) 'dimensions' might be considered as hierarchical organizations proceeding from shallow, structural dimensions to deep, semantic dimensions. Semantic memory function was envisaged as interpreting incoming stimuli before deciding on relevant action. Processing was carried out until the dimension or 'domain' relevant to the task was reached. They considered that often this process would be automatic especially when encoding operations of familiar stimuli without involvement of consciousness. Consciousness could be established by directing attention to the relevant domain. They instanced an example of two levels: 'skimming' as opposed to reading the text for typing errors. (2) At any depth, the stimulus might be further analysed or elaborated by carrying out additional operations within one qualitatively coherent dimension. Each level of the analysis provided evidence to either confirm or reject the structural description of the hypothesised patterns at the next and slightly deeper level. Craik and Lockhart and Jacoby preferred the second descriptive analysis because it stressed the concept of structural descriptions being a product of expectancies and past learning as the products of the current stimulus input. Their views are in keeping with Norman (1968) and Treisman (1964).

Accordingly, implications for practice and repetition effects are raised. Practice would have the effect of making stimuli or stimulus response sequence more probable and would, Craik and Lockhart considered, cause highly practised encoding operations to be performed with minimum processing in each dimension. Further, with:-

> "extended practice it may even be possible to bypass a complete dimension".

An obvious example here is the dyslexic child who is forced to sound out letter sequences in an attempt to understand the written text, while the competent reader may well bypass the phonemic stage entirely (Hardyck and Petrinovich, 1970). They proceeded to question the validity of a processing sequence that moved from simple to complex in a rigid, non-flexible manner, suggesting that the depth of processing necessary to yield conscious perception of a spoken word might be less than that necessary to yield conscious perception of its constituent phonemes, even though evidence from shallower to deeper levels is typical of all practised skills. The example they gave was, in perception of a 'pointillist' painting we perceive the figures and objects contained therein faster than we perceive the constituent coloured dots;-

> "even though the deeper, more meaningful levels must depend on some analysis at shallower levels."

A further point they made, as did Tulving (1972), was the distinction between episodic and semantic memory. However they considered that "these two aspects of the perceptual/memory system are more closely interrelated than Tulving supposed". In their paradigm, semantic memory acts:-

> "as part of a pattern - recognition system whose function is to interpret incoming stimuli by means of complex analysing and encoding operation."

They considered that:-

> "the product of these operations is the memory trace, which forms the latest addition to episodic memory that part of the system comprising the temporally ordered collection of all encoded episodes and events".

In essence then:-

> "the deeper and more elaborately a stimulus is analysed by the perceptual system, the richer and more detailed will be the episodic memory trace".

Their subsequent modifications (1976) offered the idea that episodic memory has <u>no</u> inherent structure:-

> "but is envisaged as a rather structureless system which maintains the order in which episodes occur but does little else."

They did however accept that a literal record of temporal sequences might be available for a brief time immediately after occurence. Repetition of encoding operations evoked memory of the original event. Traces could be accepted in two ways, (1) by searching directly in semantic memory or (2) by scanning procedure through most recent episodic memory.

Recent studies (Hyde and Jenkins, 1969; Schulman, 1971; Craik, 1973; Evans and Jacoby, 1973; Gotz and Jacoby, 1974;) had shown that if a word was encoded in terms of its semantic features it would facilitate better and more accurate recall and recognition than if it were encoded in terms of the phonemic features; phonemic encoding was however better than structural encoding. They concluded "deeper, more semantic coding yielded a more durable trace." Similarly recent studies have indicated that items held in 'primary memory' were poorly retained under delayed recall tests (Craik, 1970: Craik and Watkins, 1973) unless a delayed test was anticipated. Accordingly Lockhart, Craik and Jacoby (1976) speculated that:-

> "processing which maximises long-term retention may actually be less than optimal for immediate or short term recall ... such encodings appear to be less efficient for immediate recall than shallower phonemic encoding".

Recognition demands varying depths of processing depending on various factors, namely the retention interval, similarity of surroundings and distinctiveness of the original episodic trace.

In relation to the above, Lockhart, Craik and Jacoby made the point about Word Frequency effects, stating that common words (like TABLE, DOG) were better recalled than rare words (like GIMLET, ATOLL). However in recognition this situation was reversed. Two factors were involved to explain this result. Common words were relatively easily encoded and the resultant episodic trace was not rich; rare words however demanded greater analysis and resulted in a richer trace. This observation will be discussed in chapter seven. Rare words according to them would result in nearly identical encodings on successive occasions and would give easier more distinct access, while common words may well lead to somewhat different encodings on successive occasions. An example of this will be observed in the experiments that follow where dyslexics require longer times to make accurate recall and make more errors on commonly occuring stimuli, e.g. colour, shapes and common elements.

However, in the light of more recent research, Lockhart, Craik and Jacoby retained the notion that retention in short-term memory was equivalent to continued activation of some part of the analysing structures and incorporated Jacoby's (1974) paradigm that stated that many short-term memory phenomena were attributed to the retrieval strategy used. In essence the notion of short-term memory mechanisms with a range of specific characteristics (limited capacity, acoustic coding, etc.) might be an over simplification. Waugh and Norman's (1965) probe digit techniques were examples of this mode of operation. Lockhart, Craik and Jacoby concluded:-

> "it still makes sense to distinguish 'short-term' from 'long-term' memory, but the characteristics of short-term retention will depend not only on material and task (which in turn will influence the depth of encoding) but also on the retrieval strategy utilized by the subject".

They spoke of two basic modes of retrieval for recognition, reconstruction and scanning and the two existed also for recall.

However, the results of several recent studies suggested that not all semantic analyses were equally beneficial to recall (Fraise and Kamman, 1974; Shulman, 1974). Saltz's (1976) 'cognitive space model' went some way in attempting to answer these questions. The model briefly was as follows:-

> "The existing cognitive structures can be conceived as an n-dimensional space, composed or attribute dimensions which can be loosely described as adjectival in nature (e.g. size, shape, movement). Many of these dimensions are grounded in perceptual aspects of concepts. Others are evaluative or judgmental (e.g. pleasant unpleasant) .... A concept is defined in this model as that region in the cognitive space determined by the intersection of attribute dimensions relevant to the concept. The structure of a concept in this cognitive space is an important factor in determining memory for a concept. A concept that is specified on very few dimensions, or that occupies a large region on a number of dimensions, is defined as being very diffusely specified in the space and therefore subject to a great deal of interference and rapid forgetting."

Saltz thought that the reason abstract concepts were forgotten quicker than concrete ones in free recall was due to the diffuse nature of abstract concepts and certainly this observation illuminates the dyslexics' problems of dealing with abstract material.

Saltz suggested that there is a direct correlation between the dimension and the extent of intersection - that is let us say in this instance, two independent dimensions in space. The more precisely the two dimensions are correlated the larger will be the region or area occupied in cognitive space, thus theoretically making recall or recognition more accurate. Deeper levels of processing involve placement of the concept named by the word on more relevant dimensions, leading to more precise specification of the concept region. This will involve specification or activation of more relevant attributes of a meaningful stimulus, thus increasing its likelihood of being recalled. However, it should be held in mind that not all semantic processing is equally beneficial for recall. Shulman (1974) found that processing a concept on an irrelevant semantic dimension had little effect on retention. He found that words used in incongruous queries (e.g. "Is a chapter slippery?") were recalled more poorly than words from congruous queries (e.g. "Is a twinge sudden?"). Shulman's finding was obviously compatible with Saltz's cognitive space paradigm, since the model assumed that semantic processing involved isolating the concept within the intersection of attributes that characterize it. Klein and Saltz (1976) questioned whether an increase in levels of processing at the semantic level meant that the subject had more categories in which to place words or any information load, thereby providing additional cues which might facilitate the retrieval process. From their research they questioned this concept and presented evidence that rating on two dimensions resulted in better recall than rating on one and concluded that their results were inconsistent with the position that dimensions are serving as cues to recall.

The concept of Levels of Processing has been challenged recently by two researchers Nelson (1977) and Eysenck (1978). Nelson in an empirical and theoretical critique of levels of processing presented his own evidence taken from three of his experiments. He cited various researchers in an attempt to make his point, namely the current view of depth of processing is not valid, ranging from as far back as Ebbinghaus (1885).

Surprisingly he made singular reference to Atkinson and Shiffrin's (1968) model of memory, mentioning that their model retained a structural emphasis. He highlighted the role of rehearsal processes in improving an item's memorability:-

> "For instance, an item might be in short-term memory state, such that rehearsal had the simultaneous rôle of maintaining the item in short-term memory and transferring (copying) the item into long-term memory state."

This process is, of course, far more complex.

Nelson went on to look at Craik and Lockhart's (1972) model of depth of processing, mentioning that little attention was paid to the structural or qualitative aspects of memory. His criticism of Craik and Lockhart's model is of course scientifically admissible but perhaps significantly he overlooked other researchers' models, i.e. Klein and Saltz (1976) cognitive space model which has been reviewed earlier.

Nelson forcibly questioned the problem of circularity inherent so he stated, in the model of Craik and Lockhart (1972):-

> "So far the only ordering for depth of processing has been circular, with the various kinds of processing being ordered in terms of their effect on memory."

He held that until falsification became possible, the principle was scientifically meaningless.

Eysenck (1978) also made this point:-

> "there are not suitable criteria available for indexing either the depth or the spread of encoding. Further more, encoding depth and spread appear to affect the retrieval component of recall, but are largely irrelevant to the determination of retrieval strategies and to the decision component involved in recall and recognition."

Lockhart and Craik made reply to this criticism:-

> "Our position is to concede immediately that circularity is inherent, at present, in the levels of processing approach, but to argue that the presence of circularity and the consequent lack of predictive power, by no means render the ideas scientifically valueless. Given our very sketchy knowledge of how cognitive processes operate, it seems to us that the two traditional goals of science - prediction and understanding (Toulmin 1961) - the latter should be strongly emphasized at present."

They went on to make the point that theorists are continually questing for cogent ways to conceptualize memory processes and that:-

> "in view of this uncertainty and lack of theoretical agreement, an idea is likely to be helpful to the extent that it brings a measure of coherence to the data and provides firm guidance on the kinds of relationships that are important to study, and on the kind of data that should be collected."

They quoted a number of eminent examples to illustrate their point viz : (a) the theory of evolution, (b) the concept of reinforcement, (c) the notion of schemata (Bartlett 1932), (d) cell assemblies and phase sequence (Hebb 1949):-

> "which are not predictive and non-verifiable, yet have been tremendously influential and helpful to subsequent workers. In a similar sense then we argue that the concept of 'depth of processing' is not a fixed entity to be tested experimentally - it would be missing the point entirely to set out to prove that 'levels of processing' is wrong - but is an attempt to represent the relationship between cognitive functions in a way that makes sense of the data and that can be modified as the data demand."

On the question of quantitative and qualitative differences they were indeed in complete agreement with Eysenck (1978) that:-

> "there is now substantial evidence however to support that statement that the effectiveness of a retrieval cue depends on the qualitative nature of the encoding (Tulving and Osler 1968; Tulving and Thomson 1973; Fisher and Craik 1977). Within the context of levels of processing then, the quantitative and qualitative aspects refer to two distinct levels of explanation, 'depth' differs from 'strength' in that depth does not refer to more of the same thing, but refers to quantitatively different encoding."

They considered that as particular sensory events became well learned and associated with the co-occurance of other events, with implications and outcomes, the encoded traces of such sensory events would gradually be transformed from shallow to deep representations in their terminology. Klein and Saltz (1976) held the same opinion. Indeed other researchers back this (Nelson, Wheeler, Borden and Brooks, 1974; Jacoby, 1974; Moscovitch and Craik, 1976).

It appears then that the concept of levels of processing is not without its critics, but then the structural models of memory were questioned and criticised when they first appeared. This is of course right and proper and has led on to tighter more critical explanations. Yet no one can deny that the overall models or concepts have proved most useful in the quest for explanation of memory structure. It is from this standpoint that subsequent chapters are directed in an attempt to relate contemporary models to the specific area of dyslexia and information processing. In the final chapter a model will be offered which combines both Haber and Hershenson's (1973) model of information processing, Craik and Lockhart's (1972/1976) model of levels of processing and Saltz's cognitive space model. This new model will go somewhat further to explain the dyslexics' specific information processing deficit.

PRESENTATION OF HABER AND HERSHENSON'S MODEL OF HUMAN INFORMATION PROCESSING IN RELATION TO EXPERIMENTAL INVESTIGATION AND DESIGN.

CONTENTS

3A INTENTION

Having decided that the series of investigations undertaken in the following experiments to be presented in this thesis would lie within the area of information processing and in particular short-term memory, it seemed essential to identify an adequate theoretical model from which to work. After some consideration it seemed clear that Haber and Hershenson's model would be the most appropriate for the purpose. This model offers a substantial advance on other contemporary ones in as much as it defines specific stages and processes. These stages are fundamental to the research undertaken in this thesis. Further, their modified model integrates cogently with the conceptual model of levels of processing advanced by Craik and Lockhart. From the models offered it has been necessary to consider the particular phenomena of the dyslexic and their specific problems. The explanation of these, given in chapter seven, returns specifically to the area of a short term memory deficit in reception access, capacity and store. As will be seen, the experimental chapters investigate this phenomenon and their results confirm the hypothesis, that dyslexics' difficulties in short term memory have a direct effect on access to deeper levels of processing. A new model is advanced to explain these observations.

The model of perception proposed by Haber and Hershenson, that of information processing, was formulated between the period 1971 - 1973. The model is presented with some minor adaptations and then an attempt is made to justify its selection on the basis of previous findings in the fields of perception, cognition and memory. In particular their model and its relevance to the research presented, namely, information processing by dyslexics, is elaborated, explained and justified as first consideration.

3B PRESENTATION OF HABER AND HERSHENSON'S MODEL OF HUMAN INFORMATION PROCESSING IN RELATION TO EXPERIMENTAL INVESTIGATION AND DESIGN

As Haber and Hershenson state,

> "The information processing approach to the study of perception did not arise as a reaction against other viewpoints. Rather, it was a reflection of new conceptualizations and methods applied to the study of perception and cognitive activities."

It is an apparent natural development of earlier models and is a result of some unresolved conflicts with older approaches, particularly those of Sperling (1963, 1967), Neisser (1967) and Atkinson and Shiffrin (1968), which were unable to satisfactorily explain phenomena which the earlier models had themselves created (Broadbent 1958). Haber and Hershenson are the first to admit that this model is not the definitive and perfect final model,

> "Research findings in the area of perceptual and cognitive functioning are changing the science so rapidly that any model is likely to need revision frequently."

As perceivers, we normally express what Haber and Hershenson describe as

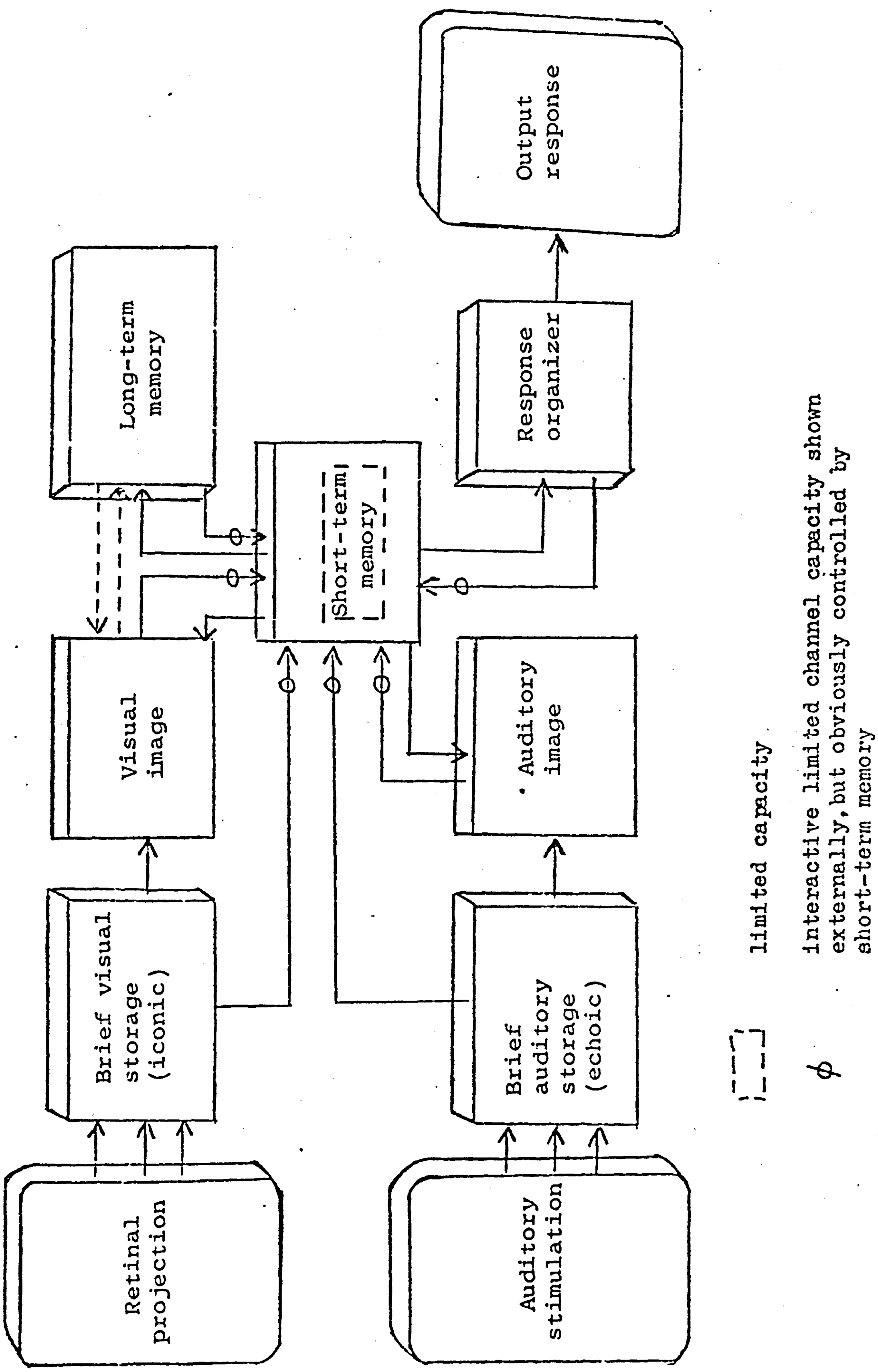
> "a naive realism when describing our perceptual experiences - we feel that what we see is a mirror of the stimulus. Moreover, this realism implies that seeing occurs automatically, immediately upon onset of stimulation, and that it terminates with the offset of stimulation."

They consider such assumptions are unwarranted. They of course make the assumption, as do all researchers who propose new models, that in each new model there must be, by its very nature, either explicit or implicit assumptions about the processes which they describe or explain.

The major assumption made by Haber and Hershenson's model of information processing, and one incidentally made by most other information processing models, is that perception is not an immediate outcome of stimulation, but is the result of processing over time. It follows that neither the perceiver's visual experience nor his overt responses are immediate results of stimulation. They are consequences of processes or of a sequence of processes which take a finite amount of time. Therefore in studying a complex perceptual task such as visual recognition, this time interval may be divided into a number of stages or processes corresponding to a series of transformations of the information in internal representations of the stimulus.

Their information processing approach assumes also that information theoretically may be deposited and retained at various stages in the processing model. They call this property of operation, storage or memory. They separate the different types of information on the basis of their relative durations and on the extent of their storage capacity, rather than the operations performed on the information whilst it is held in memory storage.

3 B1 HABER AND HERSHENSON'S (1973) MODEL WITH MINOR MODIFICATIONS



3B2 ASSUMPTIONS ABOUT THE MODEL

Their approach assumes that experimental operations can be devised to examine the contents of the representation of the stimulus information at every stage in the total process or sequence. Comparing the samples over time with the original stimulus projections provides evidence for inferences to be made concerning the nature of the processing involved. The total time from stimulus onset to the occurence of a response can be divided into intervals each separately characterized by a different operation. Each process can be assigned a duration during which its characteristic operation is performed.

3B3 INFORMATION LIMITATION

Limitation in the amount of information processed in a given time duration is assumed in the model. The size of this limitation can be determined empirically for each operation separately. At extremes or under certain circumstances the amount of information processed in a saccade is limited, while at the other extreme and under different circumstances the potential amount of information processed may be limitless (Luria, 1963). Capacity limitation usually, according to this model, leads to selectivity because not all information can be processed to the same degree within finite time allowances for such processing.

3B4 DESCRIPTION OF STORAGE OR MEMORY

Already discussed are a number of information processing models which have all in turn been proposed to account for various perceptual phenomena (Sperling, 1963, 1967; Neisser, 1967; Atkinson and Shiffrin, 1968; Posner, 1969 and Norman, 1970; Broadbent, 1958, 1971; Coltheart, 1972). It will be seen that Haber and Hershenson's model (1973) is a general theoretical model which incorporates many aspects from earlier models.

The model is divided into three parts, viz:

1. The luminance discontinuities of the light projected (stimulus) over the retinal surface at any instant in time which is directly measureable;
2. The overt observable reaction made by the perceiver (response) which is directly measureable;
3. The hypothetical constructs or non-observable processes (the nature of the process)which are the main part of the model.

According to Haber and Hershenson most models omit the first two parts, assuming that the distinction between observable and non-observable phenomena is somehow to be understood. Their model makes the explicit distinction between the retinal projection and immediate internal representation of the same; further it differentiates between the internal mental organization necessary to produce overt responses and the responses themselves.

It seems necessary at this stage to describe and define the various separate stages, storages, processes and channels implicit in the model because a number of what Haber and Hershenson term 'major departures' from previously held orthodoxies are considered, namely the notion of three types of memory, viz:

1. Very short-term
2. Short-term memory
3. Long-term memory.

These are modifed in the light of their theoretical model parameters, as is the relationship between the separate stages.

3B5 PROCESSES

They consider that the essence of the information processing model is that operations may be applied to information which transform it in various ways as it is used by the perceiver. Further they consider that information to be placed in store will require a process to put it there; they term it 'read-in' and one to take it out again 'read-out'. 'Read-in' and 'read-out' transfer information from one storage point to another and can treat information randomly, or arbitrarily, or according to some predetermined pattern of transfer. Such processes can involve loss of information in transmission. Coding processes may be involved in such transfer, and will serve to preserve parts of the information in a more efficient form. 'Read-out' process can be in the form of scanning, (a systematic procedure of going from one portion of an information field to the next and so on). When a field is scanned, each item is processed in turn, that is serially. Parallel processing is the processing of all items at once rather than one at a time.

3B6 ICONIC STORAGE

From the physical stimulus of light to the brief visual storage is a simultaneous parallel process. Neisser (1967) defined this visual information store as iconic storage. The content of the iconic store is related to the period of saccadic eye movement; the time for a sweep after reading a line of print is approximately 50 milli seconds. During the fixation time between saccades - a minimum of 250 milli seconds - the visual representation could be registered. When saccadic movements occur, the representation from the previous fixation is lost, due either to rapid decay during the eye fixation or to the interference or suppression of visual sensitivity during the movement. If stimulus exposure is less that 250 milli seconds then various mechanisms extend the impression to about 250 milli seconds; total fade has taken place soon after this.

This is compatible with the processes and terminology used by Sperling (1960) of visual information store and also that of Neisser (1967) relating to iconic store.

For perception to occur the perceiver has about 250 milli seconds to process the content of the initial visual representation so that the information can be transferred to either a more stable temporary store or permanent store.

3B7 VISUAL IMAGE

Visual information from brief visual storage is transferred into short-term memory. According to Haber and Hershenson

> "the sequence represents the encoding of visual information into conceptual or linguistic representations which may occur either in parallel with the construction of a visual image or in series with it."

The creation of a visual image occurs soon after the onset of visual stimulation; this visual image is correlated with the conscious awareness of the experience of perceiving. It is thought that, when the stimulus is letters, the visual form of the letters is scanned very rapidly in the iconic stage, so that they are initially coded into either letters or names. If the letters spell a familiar word, not all of them need be scanned separately - the word as a whole is coded, the sum rather than the parts. After this process the correct name of the word would be ready for storage in the short-term memory.

Haber and Hershenson hold that the visual image is correlated with the conscious awareness of the experience of perceiving and that this representation is integrated over time. Successive saccades introduce visual information which combine with previous ones to build up a whole or 'integrated' image (picture). Formation of the same is dependent on normal principles of perceptual organization. Duration of visual image is purely related to the correct visual fixation, the entire or 'whole' visual scene is perceived in the image which is held by rapidly changing fixations of the visual scene. Haber and Hershenson consider that the visual image is different from the specific contents of the brief visual storage, because, although it can be removed by a process of transfer and fade, the visual image can still persist especially if it is reinforced from short-term memory.

3B8 AUDITORY PROCESSING (ACOUSTIC CODE)

Haber and Hershenson's model deals with both visual and auditory processing as major initial stages. Accordingly auditory information causes a primary flow of information within their model which can be defined as a physiological process of a complex nature. However, certain basic components can be related directly to physical properties of the stimulus, e.g. amplitude or loudness.

There is a substantial amount of evidence that the short-term memory representation is in the form of an acoustic code. They consider the process of naming literally as an internal function quite distinct from visual processing. The perceiver might name internally the letters presented individually or as phonemes if they are ordered, before transfer from iconic storage to short-term memory. Again they hold that there might be a sequence of processing auditory stimuli where the acoustic signal is held briefly in what they term 'echoic' storage while the acoustic features are processed and encoded.

The duration of information in short-term memory is very much longer than 'iconic' storage, lasting minutes if rehearsal is used. Short-term memory is not a permanent store, but it is capable of holding auditory coded information, e.g. letters and word names, and it does have a time duration sufficient to retain information until it can be encoded and stored in long-term memory, or used in an immediate response.

Information is initially transformed in the auditory processing stage where information about the stimulus is coded in parallel processes. Simultaneous coding of a large number of auditory features into this brief auditory store is considered to be a fairly immediate process. This concept is compatible with processes and terminology used by Sperling (1963) of auditory information store, together with that of Neisser (1967).

Echoic storage is held to be related both to the attention and kind of information being presented. Dichotic listening tasks require a refractory period of approximately 100 milli seconds for the necessary phonemic coding to take place. Representations are lost either because of rapid decay of information, or suppression of auditory sensitivity on a fixed cyclical basis. It is considered that brief auditory storage is of such transient nature together with a comparatively small holding store that new information erases previous inputs of information. Like iconic memory, echoic memory has automatic persistence mechanisms. This means in effect that if exposure duration of the auditory field is less that 100 milli seconds the automatic persistence mechanism extends the duration of brief auditory echoic storage to 100 milli seconds. Naturally the quality of the representation deteriorates over this brief period and fades completely after the 100 milli seconds. For auditory perception to occur the perceiver must have approximately 100 milli seconds to respond; processing of the initial auditory stimulus takes place during this time and information has various potentials, viz transfer to a more stable temporary store, to permanent storage or to fade.

3B9 AUDITORY IMAGERY

From brief auditory storage information is directly transferred to short-term memory. Almost simultaneously with auditory stimulation, formation of an auditory image occurs. The auditory image, according to Haber and Hershenson, is correlated closely with the process of conscious awareness of the perception of sound. Integration of this representation occurs over time as continuous auditory processing and gradually builds up a 'picture' of the sounds, as in a word, or in a melody.

3B10 SHORT-TERM MEMORY

Short-term memory in their model receives incoming information from four sub-routes either directly from 1) brief visual store or 2) brief auditory storage or from an intermediary 3) visual or 4) auditory image stage. Visual and auditory information is encoded into linguistic or conceptual representation either in parallel with the construction of a visual or auditory image or in series with it. According to Haber and Hershenson there exists substantial evidence to suggest that representations are in the form of an acoustic code in short-term memory. Overwhelming evidence suggests that short-term memory is not a permanent store. However the duration of short-term memory does vary from researcher to researcher and is to some extent a theoretical problem with no totally accepted duration. If it is taken that the store is in the form of an auditory code, it follows that a storage time of sufficient duration to permit encoding into either long-term memory or an immediate response is needed. Rehearsal in short-term memory is held to be an essential feature.

3B11 LONG-TERM MEMORY

Long-term memory, as its name implies, has its persistence measured in decades. Theoretically the duration is permanent (Luria 1959). However Haber and Hershenson consider rather arbitrarily that it ranges from five minutes onwards. The contents of long-term memory are held to be in the form of images, letters or words. However they consider that the most likely explanation is in terms of semantic representations which contain meaningful structures (Baddeley, 1966; Shiffrin and Atkinson, 1969). Long-term memory recall is thought to be facilitated by manipulations which induce deeper and more elaborate processing.

3B12 OUTPUT PROCESSES

This process in the model deals with outputs from the perceptual information processing system. As such, any information decisions require motor programmes to operate before a response can be made. A spoken response needs motor action before articulatory apparatus can function. Written or pointing responses, or for that matter any behavioural parameters, require a motor programme before their responses are manifest. Accordingly this section in the model represents an infinite number of potential avenues for output from the system, all of which are organized in some way.

Haber and Hershenson's model does not provide direct outputs from any other components. They hold there can be none from the visual image representation as there is no way that one can see individual visual images. Also, no output is detailed from long-term memory because their model assumes, "that the contents of memory first have to be translated into words or actions." Iconic storage likewise has no output.

The overall organization of the motor programme takes a finite amount of time to choose the appropriate response to be generated. It is the culmination of the information processing process, and as such is particularly susceptible to failures in dealing with information at earlier stages.

3B13 OUTPUT RESPONSE

Output response is classified accordingly - verbal classification in the form of a spoken response, or manual classification in the form of either writing something down or pressing a button or the like. This can be as an unconscious autonomic response such as a psychogalvic response or changes in EEG patterns, or a conscious behavioural response.

3B14 INTERCONNECTIONS

Complex interconnections between the different processes give information about the action and its influence. Arrows in both directions indicate that information can flow in both directions and also that each process can influence the other.

Inputs to the iconic storage are shown in parallel. All the information about the luminance discontinuities that is extracted from the retina is assumed to arrive at the same time.

The two exits from iconic storage are assumed to be parallel and independent. Thus, there can be simultaneous naming of items represented in iconic storage along with a construction of their visual image representation. These are both information feature extraction processes. Haber and Hershenson contend that visual image construction always occurs but the naming may only occur if the requisite vocabulary is available. However, both of these processes are affected by the contents of short-term memory which is itself often influenced by long-term memory so that the two processes may be affected by the extraction processes.

The interconnections between the visual and short-term memory representations indicate that both affect the other interactively and that they both can be used to generate each other. Thus from a name, a visual image is generated even in the absence of concurrent visual stimulation.

Long-term memory is reciprocally connected to short-term memory. Thus the names of the components in the stimulus are stored more permanently either as literal names, or more commonly as ideas or concepts. To retrieve these concepts at a later time from long-term memory they have to be recoded or encoded as words again. However these will necessarily be in the form of paraphrases of the original coded information, since the original was not stored. Certain visual image representations are translated directly into long-term storage as concepts or ideas. Haber and Hershenson are undecided whether an image of stimulation can be generated directly from long-term memory or whether short-term memory relay is involved. For this reason a dotted line is used for this process in the model. At all stages they hold that substages can be fitted into the overall model.

The inputs to the echoic storage are shown in parallel. All of the incoming information about the differences in air pressure that are extracted from the cochlea is assumed by them to arrive at the same time. The two exits from echoic storage are assumed to be parallel and independent although the possibility that they are serial is not yet disproved.

3B15 ADVANTAGES OF HABER AND HERSHENSON'S INFORMATION PROCESSING MODEL

Haber and Hershenson's model makes a distinction between retinal projection and immediate internal representation of the same, as do they that of auditory 'echoic' representation. It also makes distinction at the external process, between internalized hierarchical mental organization necessary to produce alert responses and the fundamental basic responses themselves. The information processing model presented is characterized by its focus on how the information of the luminance discontinuities contained in the retinal projection is transformed into different forms of representations or codes, visual codes, auditorily represented linguistic codes, and semantic codes. This model has the advantage of avoiding the temptation of assuming that visual feature analysis is the first central representation of information. The model makes clear that several stages or processes are involved, and that in no sense can perceptual processing be considered immediate or instantaneous. Each process is stored or rehearsed so that information processing sequences can be subdivided into stages, stores and processes - each with its own sequences, time constants and interactions. Haber and Hershenson for this reason speak of a general model; this seems reasonable considering that any model based on current features may be modified and distorted by future findings. Prominence is given to visual image representation in this model It is a unique position in that previous models have not done so. What this means is that it enables the presented model of information processing to explain various processes, not just the processing of linguistic information (Posner and Keele 1970) but also the perception of scenes, objects and pictures.

Popper (1957) holds that,

> "Experiment presupposes measurements, and measurements presuppose theories."

Bearing this in mind Haber and Hershenson's model is employed as the central frame of reference in this investigation of the dyslexics' abilities to process both visual and auditory material, and as such has influenced the experiments undertaken. With this in mind it must be stated here that each experiment and findings should be able to stand on its own merits. In fact it is held that they do, irrespective of the adequacy of the model. The model serves to integrate the separate experiments and the findings into a workable understandable 'whole'.

It is important that one should work towards an integration of the parts, especially, as so often has happened in the past, individual parts have been left to stand on their own with the result that no direction or trend has been observed and a general amorphous collection of parts has resulted in wanderings and justifiable criticism of this state.

3B16 RATIONALE FOR USING HABER AND HERSHENSON'S INFORMATION PROCESSING MODEL IN THE STUDY OF DYSLEXIA

Research into information processing abilities of dyslexics is, as has been detailed, a relatively recent occurrence. Research has for some time been concerned with the interindividual abilities of dyslexic and control groups. What has been highlighted by this research is that many researchers have raised a plethora of both theoretical and working questions, but have in most cases failed to answer them; indeed there has been a distinct lack of activity in this area. One of the obvious reasons, it would appear, is that many researchers have failed to employ any theoretical intra-individual model or have used what can only be described as outdated and untenable models. Others have failed to offer any model. It appears then that in most cases little has been done towards positively attempting to answer questions raised or in providing a suitable working model, such as Haber and Hershenson's. This model does give an overall unified frame of reference with specific stages or processes which have implications in the study of dyslexia.

CHAPTER 4

AN INVESTIGATION INTO THE PERFORMANCE OF CROSS-LATERAL, DYSLEXIC AND CONTROL GROUPS ON A DIRECT RECALL TASK USING VARIOUS FORMS OF TACHISTOSCOPICALLY PRESENTED INFORMATION.*

CONTENTS

* A brief account of this experiment has been published:

Watkins, E.J. & Wheeler, T.J. (1978)
"Dyslexia, Laterality and Short Term information processing."
<u>Psychology and Psychiatry</u>.

4A INTRODUCTION

A number of recent reviews of research into reading and dyslexia have been sceptical about the validity of isolating a group of children who have reading problems, and calling them 'dyslexic'. (White, Dwyer and Lintz, 1973; Singleton, 1975/1976). Others consider that reading difficulty is just the extreme end of a normal distribution of reading ability. Numerous previous studies had shown that retardation in reading was related in some way to ill established cerebral dominance.

Others questioned whether isolated factors such as handedness and eyedness were, in fact, good predictors of reading ability. Belmont and Birch (1965), considered that there was no such relationship. This view conflicted with other findings because there were many reasons why children may fail to read; emotional disturbance, lack of early schooling or uncorrected hearing and sight difficulties, as well as different varieties of neurological dysfunction referred to in Chapter 1 (Bannatyne, 1971), and these reasons had not been clearly differentiated. The major problem with many of these studies was the lack of homogeneity of the groups of non readers investigated. The resulting inconsistency of findings was thus not surprising because there had been a fundamental error of categorization as the causes of reading retardation are diverse. Yet, if one takes a group of children who have been diagnosed as dyslexic, a homogeneous group is obtained in at least the respect that all have consistent difficulties in reading and other tasks.

Again, if one takes a group of children who have problems of cerebral dominance which have been precisely quantified, a homogeneous group appears for which one can predict reading failure with a high degree of accuracy in nearly all cases (Thomson, 1975). The relationships to be found between poor reading,crossed laterality and problems of short term memory have not been investigated. Chapters one and two showed that dyslexics have inferior performance on memory tasks when compared to controls.

In an attempt to explain, integrate and substantiate these findings it was proposed to undertake an experimental investigation involving all the relevant factors, namely, 1) some specific causes of reading failure such as dyslexia and laterality problems, and 2) the subject's ability to process specific forms of information utilising an information processing paradigm requiring both access and storage in short-term memory.

Children were used who had passed the age of the developmental establishment of cerebral dominance which is about 7 years (Lenneberg, 1964; Goldberg and Shiffman, 1972). The children were also selected within an IQ range 110-120 because at that level children of the age range chosen should have mastered the basic processes of reading (Hage and Stroud, 1959).

It was predicted that children with ill established cerebral dominance would require repeated access to short-term memory and consequently their performance on information processing tasks would be impaired. It was also predicted that the performance of dyslexics would be impaired as dyslexia has been shown to be explicable in terms of a limited capacity in short-term memory (Miles and Wheeeler, 1974). Further, that as a limitation in short term memory capacity is a more profound handicap than the need for repeated access to short term memory, it was predicted that the dyslexics' performance would be both quantitatively inferior and qualitatively different from that of the cross lateralized group (the other reading retarded group). It was also felt that there would be a significant difference in the performance of the cross lateral, dyslexic and control groups. This would apply equally to varying types of information and increasing set size.

If the above hypotheses were substantiated, then the use of the category dyslexia to describe a homogeneous group of children who suffer from specific reading problems as a manifestation of a wider limitation in processing all forms of information would be vindicated.

4B METHOD

4B1 SAMPLE

Subjects were obtained from a sample of two hundred and nine Junior School children from the south west sector of Sheffield.

The control group was selected on the bases of consistent laterality, absence of dyslexic symptoms and above average reading age. An experimental cross lateral group was selected. The children had been diagnosed as cross lateral on the basis of the Harris Test of Lateral Dominance (eyedness, handedness and footedness) together with ear dominance tests; and had obtained a score of zero using Thomson's criteria (Thomson, 1975). Another experimental group consisted of 10 dyslexic children. The children had been diagnosed as dyslexic on the basis of the Bangor Dyslexia Test and the Aston Index Standard.

2. The criteria used in their selection were:

(i) A reading and spelling age at least 2 years below the chronological age;

(ii) Performance at average or above average in other school subjects;

(iii) An intelligence quotient of average or above;

(iv) Absence of gross behavioural problems;

(v) Absence of organic disorders;

(vi) No long absences from school;

(vii) Characteristic bizarre spelling;

(viii) Special difficulties in tasks involving orientation and/or sequencing.

These criteria are consistent with those employed by current researchers (Stanley and Hall, 1973; Newton, 1974; Miles 1975; and Wheeler, 1977). The sample included a sub group of 118 cross laterals with retarded reading ages and

41 diagnosed dyslexics. Any child with hearing or sight problems was excluded from this study.

The entire group, control, cross lateral and dyslexic had normal school opportunities and continous uninterrupted educational facilities coming from a homogeneous socio economic background, i.e. their fathers came in class 4 or above on the Hall Jones Scale of Occupational Prestige for Males (Oppenheim, 1966).

4B2 SUBJECTS

Three groups of ten children were selected, without subject to subject matching, namely (1) non dyslexic and uni lateral (control) (2) cross-lateral and (3) dyslexic. Tables 4A, B and C demonstrate the similarities and differences which existed among the three groups. Table 4A gives a classification of their intellectual ability which was gained using the Raven's Standard Matrices, set A,B,C,D and E before the experiment and their scores were transformed and classified into appropriate groupings. The three groups were not significantly different on the non verbal intelligence test ($F = 1.13$; $df = 2,27$; $P = NS$).

Table 4B shows the classification of chronological ages. The control group of 10 children were between the ages of 8 years 4 months and 9 years 2 months (mean age = 8 years 10 months). The cross lateral group of 10 children were between the ages of 8 years 5 months and 9 years 2 months (mean age =

8 years 9 months). The dyslexic group of 10 children were between the ages of 8 years 0 months and 9 years 11 months (mean age = 9 years 1 month). The three groups were not significantly different for age ($F = .93$; $df = 2,27$; $P = NS$)

Table 4C shows the classification of reading ages worked out from the revised version of the Schonell Graded Word Reading Test. The control group had reading ages between 9 years 0 months and 11 years 9 months (mean reading age = 11 years 0.6 months). The cross lateral group was between the ages of 6 years 9 months and 9 years 11 months (mean reading age 9 years 0.7 months). The dyslexic group was between the ages of 5 years 4 months and 9 years 0 months (mean reading age of 6 years 9.6 months).

TABLE 4.A

CLASSIFICATION OF INTELLECTUAL ABILITY

I.Q.	DESCRIPTION	CROSS LATERAL		DYSLEXIC		CONTROL	
130+	Very superior	-		-		-	
120-129	Superior	1		2		1	
110-119	Bright Normal	9		8		9	
100-109	Average	-		-		-	
	TOTAL	10	100%	10	100%	10	100%

CROSS LATERAL GROUP IQ :	MEAN = 114.6 RANGE = 110-120	
DYSLEXIC GROUP IQ:	MEAN = 116.4 RANGE = 110-120	
CONTROL GROUP IQ:	MEAN = 115.5 RANGE = 110-120	
DYSLEXIC v CONTROL	U = 39.5	P = NS
DYSLEXIC v CROSS LATERAL	U = 36.5	P = NS
CROSS LATERAL v CONTROL	U = 49	P = NS

TABLE 4.B

CLASSIFICATION OF CHRONOLOGICAL AGES

YEARS & MONTHS		CROSS-LATERAL GROUP		DYSLEXIC GROUP		CONTROL GROUP	
8	8.5	2		2		1	
8.6	8.11	6		1		5	
9	9.5	2		1		4	
9.6	9.11	-		6		-	
TOTAL		10	100%	10	100%	10	100%

CROSS-LATERAL GROUP AGE : MEAN = 8 years 9 months
RANGE = 8 years 5 months to 9 years 2 months

DYSLEXIC GROUP AGE : MEAN = 9 years 1 month
RANGE = 8 years 0 months to 9 years 11 months

CONTROL GROUP AGE : MEAN = 8 years 10 months
RANGE = 8 years 4 months to 9 years 2 months

DYSLEXIC v CONTROL	U = 32	P = NS
DYSLEXIC v CROSS-LATERAL	U = 36	P = NS
CROSS-LATERAL v CONTROL	U = 44.5	P = NS

CLASSIFICATION OF READING AGES

YEARS & MONTHS		CROSS-LATERAL GROUP		DYSLEXIC GROUP		CONTROL GROUP	
5	5.5	1		2		-	
5.6	5.11	-		-		-	
6	6.5	-		1		-	
6.6	6.11	1		-		-	
7	7.5	4		4		-	
7.6	7.11	-		1		-	
8	8.5	-		-		1	
8.6	8.11	-		1		3	
9	9.5	2		1		1	
9.6	9.11	1		-		2	
10	10.5	-		-		3	
10.6	10.11	-		-		-	
11	11.5	-		-		-	
11.6	11.11	1		-		-	
TOTAL		10	100%	10	100%	10	100%

CROSS-LATERAL GROUP READING AGES : MEAN = 9 years 0.7 months
6 years 9 months to
9 years 11 months

DYSLEXIC GROUP READING AGES : MEAN = 6 years 9.6 months
RANGE = 5 years 4 months to
9 years 0 months

CONTROL GROUP READING AGES : MEAN = 11 years 0.6 months
RANGE = 9 years 0 months to
11 years 9 months

4B3 APPARATUS

Stimuli were presented in an Electronic Developments two field card tachistoscope. The cards were presented at a distance of 490 mm from the subject's eyes giving a subjective illumination at the eye of about 5 lux. A Behaviour Systems International Audio Generator Model 258 supplied a 4 KHZ supporting tone triggered by the start pulse generator and timer on the tachistoscope.

4B4 STIMULI

The stimuli consisted of 180 cards in 9 sets of 20 cards as follows: 3, 5 and 7 digits; 3, 5 and 7 letters; and 3, 4 and 5 symbols (square, triangle, cross, diamond and circle). The sequence of all stimuli was ordered from random number tables. The stimuli were all 10 mm high (Letraset didot 36 pt. Helvetica Medium).

4B5 EXPERIMENTAL DESIGN

A 3 (group) x 3 (form) x 3 (number) factor design, with repeated measures on second and third factors was employed. Each subject in all groups was presented tachistoscopically with all three categories of stimulus for the three different values of units. The order of presentation of the categories and values was randomised for each child. To avoid a differential fatigue effect, even though the order had been randomised, only one stimulus set was presented to a subject without rest. The average minimum time in m.sec for the subject to make a 100 per cent accurate verbal recall was obtained by the method of converging limits. A set of practice trials was given.

4B6 PROCEDURE

Children were tested individually and instructed to focus on the central black spot in the secondary field of the tachistoscope. The stimulus was presented centrally in the primary field. Their attentiveness was supported by a tone of 4 khz given 200 m.sec prior to the presentation of the stimulus. They were instructed to make an immediate verbal response after the termination of the stimulus presentation. They were told to guess if they were not sure exactly what stimulus had been presented.

4C RESULTS

The results and statistical analysis are presented in three sections - mean results and comparison between the three groups; an analysis of variance for the three factors; category of reading retardation, form and number; and finally, a consideration of the findings about the reading ability of the three groups.

TABLE 4.1

Table of Mean Exposure Times in m.sec for uni-laterality, cross-laterality and dyslexic groups, with three different forms, and three different numbers of units.

CONDITIONS			UNI-LATERAL (Time in m.sec)		CROSS-LATERAL (Time in m.sec)		DYSLEXIC (Time in m.sec)		MANN WHITNEY U TEST (Difference between grou					
			MEAN	S.E.	MEAN	S.E.	MEAN	S.E.	U	½ P	U	⅓ P	U	
A	DIGITS	3	5.2	2.8	10.5	4.7	41.5	21.4	34	N.S.	9	<.001	30	
		5	339	94.2	885.5	147.4	1524	369.1	12.5	<.01	4	<.001	12.5	<
		7	3210	475.4	7825	1145.1	28478.3	8301.2	12	<.01	0	<.001	6	<
B	LETTERS	3	3.0	0.21	58	22.9	96.9	46.5	6	<.001	0	<.001	16.5	<
		5	442	64.9	2660	489.7	6854	2804.4	1	<.001	0	<.001	13	<
		7	4830	713.4	10050	715.7	46460	12837.8	7	<.001	0	<.001	0	<
C	SYMBOLS	3	427.8	343.9	685.7	214.5	858.2	160.7	22	<.025	0	<.001	6	<
		4	1381.0	374.1	3508	969.7	4512.5	1005.7	26	<.05	1	<.001	16	<
		5	3680.0	959.5	6860	978.6	33363.3	10205.9	23	<.025	0	<.001	0	<

TABLE 4.2

Table of Mean Chronological and Mean Reading Ages for uni-lateral, cross-lateral and dyslexic groups.

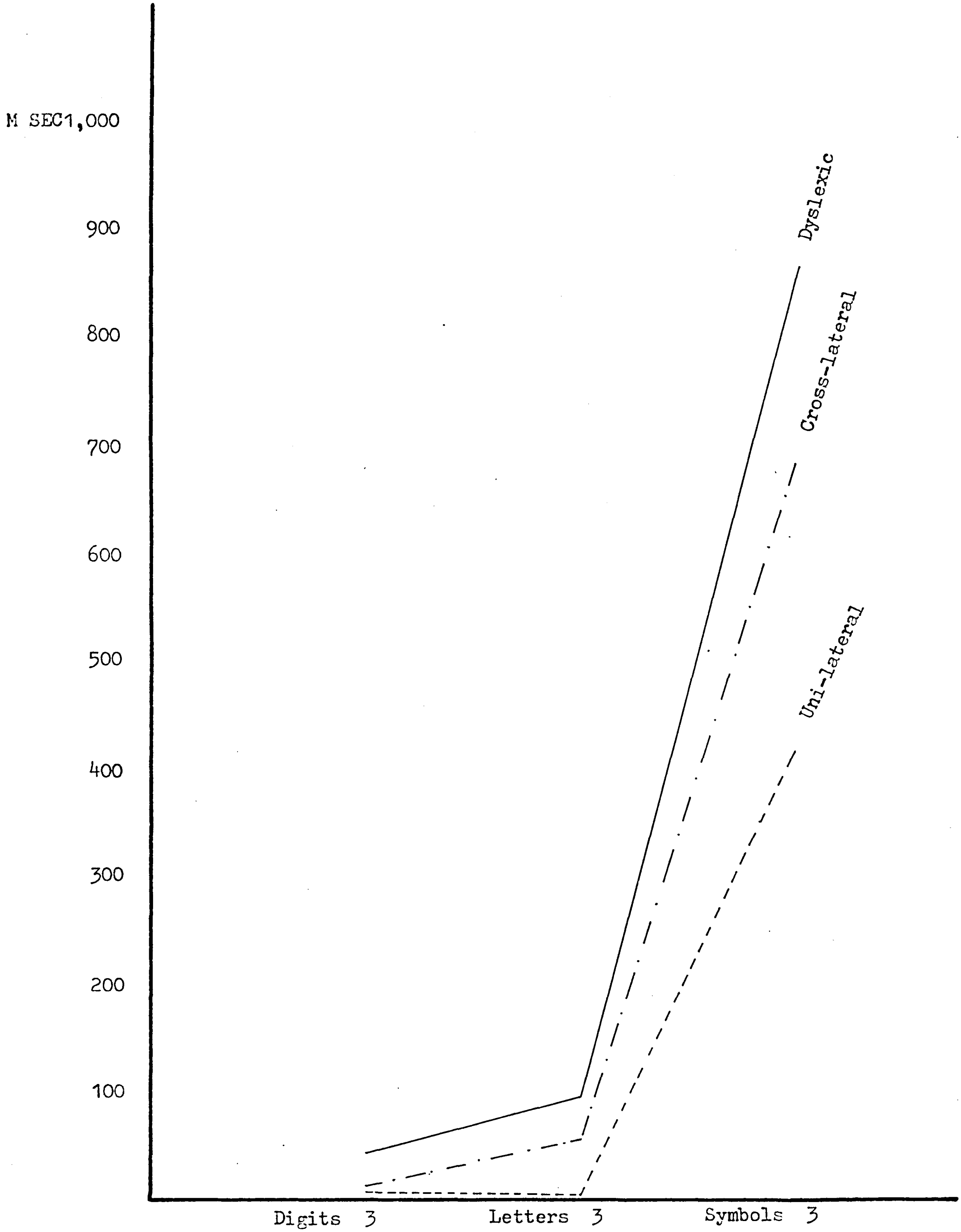
Group	Chronological Age and Standard Error (in yrs. mths)	Reading Age and Standard Error (in yrs. mths)	Difference (in mths)	Mann Whitney 'U' Test (between value: 'U' =	n1/n2 =	P =
Uni-lateral	8 yrs. 9.7 mths ($\pm$1.07 mths)	11 yrs. 0.6 mths ($\pm$4.62 mths)	26.9 ($\pm$4.76)	9	10/10	$<$.001
Cross-lateral	8 yrs. 8.8 mths ($\pm$1.08 mths)	9 yrs. 0.7 mths ($\pm$9.17 mths)	3.9 ($\pm$9.54)	41.5	10/10	N.S.
Dyslexic	9 yrs. 1.2 mths ($\pm$2.67 mths)	6 yrs. 9.6 mths ($\pm$6.05 mths)	-27.6 ($\pm$5.32)	1	10/10	$<$.001

TABLE 4.3

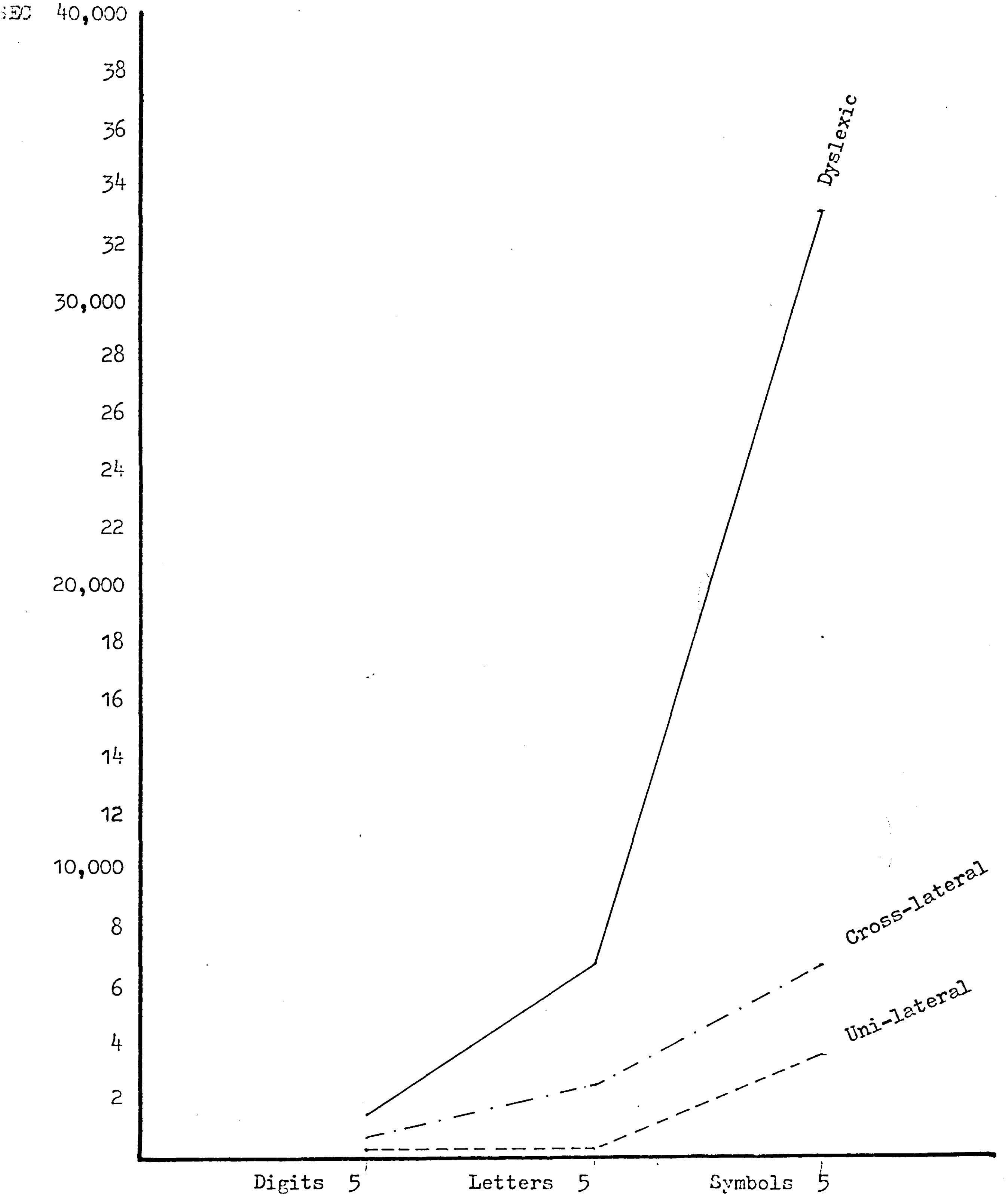
Table of comparison of difference in mean reading ages for uni-lateral, cross-lateral and dyslexic groups.

COMPARISON BETWEEN GROUPS	DIFFERENCE IN READING AGE (MONTHS)	MANN WHITNEY 'U' TEST (BETWEEN VALUES) 'U' =	n1/n2/n3 =	P =
Uni-lateral v Dyslexic	51.0	0	10/10	$<.001$
Cross Lateral v Dyslexic	27.1	3	10/10	$<.001$
Uni-lateral v Cross Lateral	23.9	22	10/10	$<.05$

Graph showing exposure times for three digits, three letters and three symbols for uni-lateral, cross lateral and dyslexic



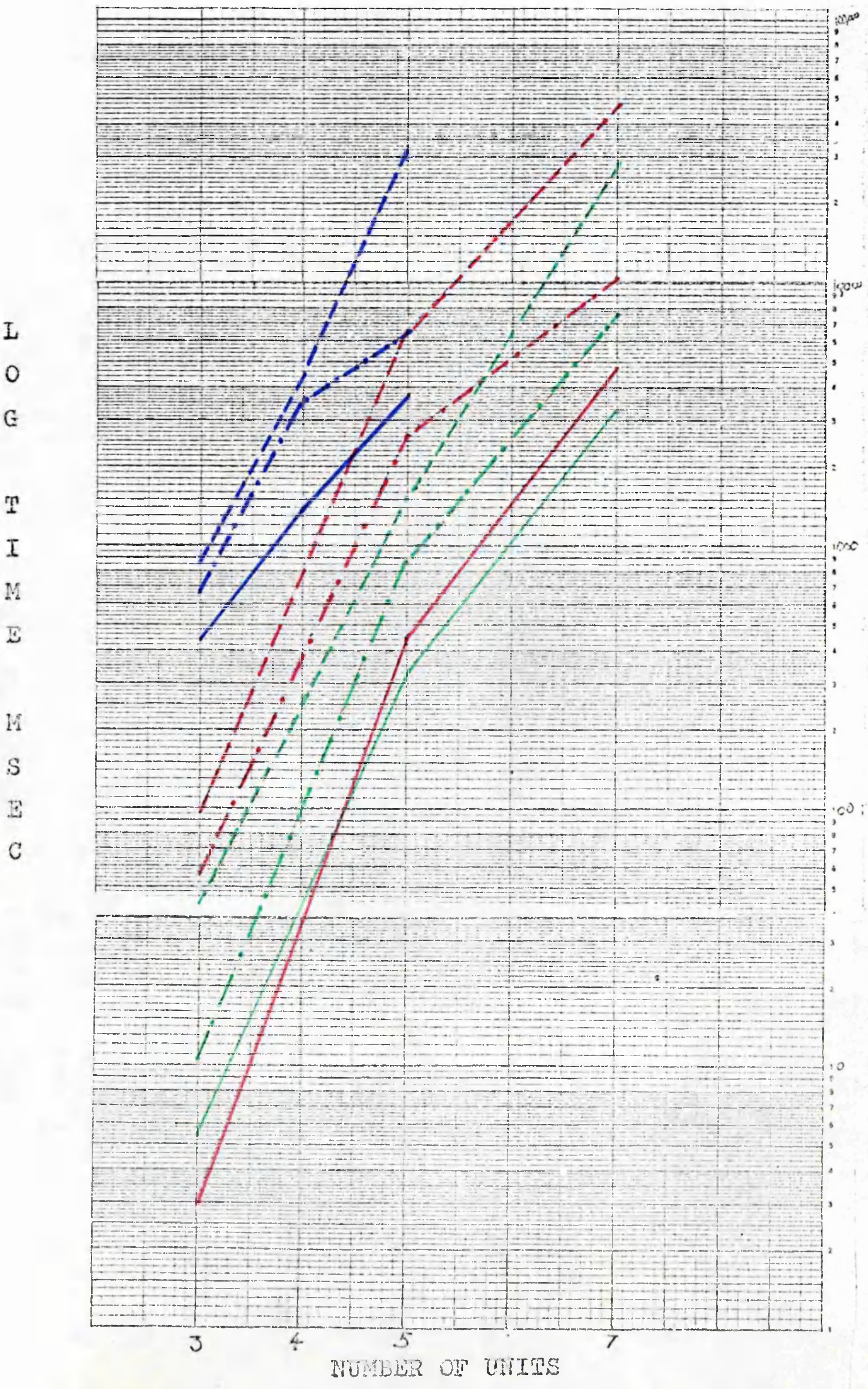
Graph showing exposure times for five digits, five letters and five symbols for uni-lateral, cross-lateral and dyslexic subjects



A graph of the performance of uni-lateral, cross-lateral and dyslexic groups on an information processing task involving three different forms of information with differing set sizes as indicated by the log of exposure time in Msec.

——— Uni-laterals; —.—.—Cross-laterals; - - - - -Dyslexics.

——— Digits; ——— Letters; ——— Symbols.



4C1 MEAN RESULTS

The overall performance of each group was progressively impaired as the information load was increased. Both dyslexic and cross-lateral groups took significantly longer to identify accurately the information presented. The dyslexic's performance was differentially worse and quantitatively different from that of the cross-lateral group. Each group appears as a separate entity.

4C2 STATISTICAL COMPARISON

There was no significant difference between the three groups for the smallest information load (3 digits). However, for all other information (digits 3 and 5, letters 3, 5 and 7, and symbols 3, 4 and 5) there was a significant difference.

4C3 THREE FACTOR ANALYSIS OF VARIANCE

A 3(group) x 3(form) x 2(number of units: 3 and 5 units only) factor analysis of variance with repeated measures on second and third factors yielded the following results:

(1) There was a significant difference in the performance of the groups. ($F = 19.67$; df = 2, 162; $P < .001$).

(2) The type of information presented was a significant factor for all groups. ($F = 15.13$; df = 2, 162; $P < .001$).

(3) The number of units of information presented was a significant factor for every type of information presented. ($F = 27.96$; df = 1, 162; $P < .001$).

(4) A second order interaction factor of type or form of information and number was significant. ($F = 13.98$; df = 2, 162; $P < .001$).

(5) A second order interaction factor of group and number of units was significant. ($F = 19.20$; df = 2, 162; $P < .001$).

(6) A second order interaction of group and form of information was significant. ($F = 10.78$; df = 4, 162; $P < .001$).

(7) The third order interaction factor of groups and form and number of units was also significant. ($F = 10.78$; df = 4, 162; $P < .001$).

4D DISCUSSION

Consider Table 4.1. The cross-lateral group took longer to process information than did the uni-lateral control group; however the dyslexic group took even longer to process information than did the cross-lateral group. Furthermore the difference between the groups became progressively larger as the number of units of information increased. The difference between the groups also increased markedly as the form of the information changed from relatively small set size to a larger set size (from digits - 10 alternatives, to letters - 26 alternatives, to symbols - theoretically limitless).

It will also be noticed that the dyslexic group had greatest difficulty with tasks involving high information loads, particularly with large numbers of complex forms of information, e.g. 7 letters. With tasks requiring less information load, e.g. smaller numbers of units and simpler forms, their performance tended more towards the control group, although they were still significantly worse than the control group. The cross-lateral group was not significantly different from either of the other two groups. In conclusion, all three groups were functionally separate as measured by their information processing ability. This fact would support the use of the term dyslexia in an attempt to distinguish differences between various groupings of children who are retarded in reading. It would also support the contention of Wheeler (1977) that dyslexia is associated with a general limitation in short-term memory.

With regard to Table 4.2, the positive analysis results for the three factors of group, type of information presented and number of units were obviously consistent with the hypothesis in the introduction. The second order interaction factor of information type and number of units was not surprising as the two combined gave the total amount of information presented. There was a differential second order effect observed for the groups for both form of information and number of units of information. The dyslexic group was the most severely affected; in addition, there was a significant third order effect observed for the groups produced by form and number of units of information. The dyslexics were dramatically inferior when attempting to process large numbers of symbols. There was thus clearly a measurable distinction between the three groups.

The disparity between chronological and reading age was interesting in that for children of above average intelligence balanced in every other respect, two groups, i.e. the uni-lateral and dyslexic group were significantly different from their chronological age (uni-lateral + 26.9 months and dyslexic - 27.6 months). Referring to Table 4.3, in addition to the three groups being separated quantitatively in their ability to process information, they were also distinct from one another in terms of reading age. The dyslexic group was significantly worse even though cross laterals were themselves significantly inferior to the uni lateral control group.

Haber's (1973) model of information processing has, as its central processing mechanism, short term memory as a common store for both visual and auditory information with a link to long term memory and response production.

A number of researchers have shown that information decoding is processed in a parallel manner in both cerebral hemispheres (Klatzky and Atkinson, 1971). However, information encoding is serially processed which requires information to be processed sequentially from right to left hemisphere. If cerebral dominance is ill established this sequential processing is impaired and manifests itself as a limitation in information processing, caused by the hypothetical need for repeated access into short term memory. This explains Birch and Belmont's (1965) findings that poor auditory/visual integration is related to failure in reading.

Many previous studies had made reference to the dyslexic's obvious problems with short term memory and had tried to explain their characteristic difficulties in terms of "poor memory" but as had been demonstrated previously other groups of retarded readers who were not dyslexic also had difficulties in short term memory and information processing. (Wheeler, Watkins and McLaughlin, 1977). This research demonstrates that dyslexics can be clearly differentiated from other groups of retarded readers because the cause of their problems appears to be specifically a limitation in capacity. However, the cross lateral's difficulties in short term memory are hypothesised to be caused by the inefficient need for repeated access, thereby producing a heavier load on short term memory. These limitations in capacity of short term memory and the need for repeated access appear to affect any kind of information processing task, not just reading. This research also presents a model to explain why children with dyslexia or ill established cerebral dominance have difficulties with reading and why these difficulties are nearly always associated with severe problems in spelling and writing tasks. The reason is that these tasks are all serially processed and require either a relatively large store or a fast process time in short - term memory. It also explains why the dyslexic's difficulties are more severe than those of the other retarded group. Thus, a group of dyslexics has been seen to be different both qualitatively and quantitatively from other groups of retarded readers in their ability to process information; the continued use of the category in investigating these problems can therefore continue to be justified.

In the light of the above findings it is possible to offer a functional definition for dyslexia as follows:

"Dyslexia is experienced by children of adequate intelligence, as a general language deficit which is a specific manifestation of a wider limitation in processing all forms of information in short term memory, be they visually, auditorally or tactilely presented. This wider limitation exhibits itself in tasks requiring the heaviest use of short term memory such as reading, but particularly spelling."

4E SUMMARY

The performance of 10 dyslexic children and 10 cross-lateral children was compared to a control group of 10 uni-lateral children on short-term information processing tasks using three types of units - digits, letters and symbols. The tasks consisted of presenting different numbers of units of information simultaneously by tachistoscopic exposure. Both the dyslexic and cross-lateral groups took significantly longer to identify accurately the information presented; their performance significantly deteriorated as the information load was increased from 3 to 5 units. The dyslexics' performance was differentially worse and qualitatively different from that of the cross-lateral group. The dyslexic group was also significantly inferior both to the uni-lateral control group and the cross-lateral group, which was itself significantly inferior to the control group. It is contended that the reading retardation associated with both groups is a specific manifestation of a general limitation in any kind of information processing.

The dyslexics' limitation would appear to be primarily associated with a limited capacity in short-term memory, whereas the cross-lateral groups is associated with the theoretical need for repeated access into short-term memory. Thus, dyslexia can be operationally distinguished from other forms of reading retardation.

CHAPTER 5

AN INVESTIGATION INTO IMMEDIATE RECALL OF AUDITORY SIGNALS OF VARYING SET SIZE UNDER DIRECT RECALL CONDITIONS BY THREE DIFFERENT AGE GROUPS OF DYSLEXIC AND CONTROL SUBJECTS.*

CONTENTS

* A brief account of this experiment has been published:

Watkins, E.J. & Wheeler, T.J. (1978) "Immediate recall of auditory signals by dyslexic and control subjects." IRCS Med. Sci., 6, 180.

5A INTRODUCTION

Among the differing approaches and interpretations outlined in preceding chapters, it had been suggested by some researchers that dyslexia was attributable to deficient, malfunctioning intersensory connections and was often associated with a 'maturational lag' or 'developmental delay'. Mention of developmental delays was consistently made in clinical observations. Vernon (1957), Zangwill (1960), and Critchley (1962) considered delayed maturation as a fundamental causative feature in the dyslexic's handicap. Stanley and Hall's (1973), findings supported the theory of a 'developmental lag' in the visual memory of dyslexics.

Recent research findings indicate that reading difficulties can be caused by sensory integration problems. Birch and Belmont (1964) found that retarded readers were "significantly less able integrators than normal readers." They suggested that the ability to treat visual and auditory patterned information as equivalent is one of the factors that differentiated good from poor readers. It should be noted however that the main criticism of Birch and Belmont's investigations has been the heterogeneous sample they used. In their particular study (1964) subjects were drawn from the total population of school children. The only criterion used was that the retarded readers were in the last decile of reading ability. Birch and Belmont and others then equated the sample as manifesting dyslexia and worked subjectively from that premise. This was of course completely untenable.

It has been noted that dyslexics had significant disorders in the ability to reproduce complex rhythms (Col and Lafaye, 1966). Similarly Zigmond (1966) investigated intersensory functioning in dyslexic children, and was particularly interested in intra inter modal deficiencies in his groups of subjects. Both normal and dyslexic readers were initially assessed using standardized tests and paired associate learning objectives. The groups were different on both measures of intra and inter modality processes and the dyslexics gained poorer scores than normal readers on all measures of auditory functioning and six out of seven intersensorysub tests. Findings indicated that auditory disabilies were more significant in dyslexic reading difficulties than either visual or intersensory deficits.

Now one of the main criticisms of the integration hypothesis was the discriminating effect of tasks which relied heavily on verbal components when poor readers were involved and which made it more difficult to make accurate assessment and predictions of the degree to which apparent integration deficits were caused by a more basic incompatibility of the auditory visual systems.

Corkin (1974) believed it was a more profitable exercise to look particularly at audio visual integration from the standpoint not of integrational aspects, but rather the serial ordering and memory processes which were involved. Calvet (1967) spoke of twenty five per cent of his subjects having integration disorders. He concluded that phonetic integration disorders were not sufficient to explain all dyslexias. However it did, as noted in Chapter one, focus attention on one of the aspects of a complex syndrome.

Spring and Capps (1974) presented a model attributing poor recall of dyslexic children to slow speech motor encoding. Their findings indicated that dyslexics named visually presented, non word stimuli more slowly than the controls.

Leong (1975), using dichotic auditory processing tasks, compared the efficiency of two groups, namely dyslexic and non dyslexic, matched for age, sex and non verbal ability in using pre instructed strategies to report dichotic materials. His results showed a significant difference between the groups when serial position scoring was used, irrespective of which ear or type of material used. He concluded that dyslexic children were inefficient in using strategies to process dichotic materials. Rudel's et al (1976) findings were similar but they held that the deficits were not attributable to specific modality dysfunction nor to a failure of intersensory integration, but were suggestive of a general encoding and retrieval deficit. His findings raise the question of a deficit in short term memory and related difficulty in gaining access to deeper levels of processing.

Bearing in mind the aforementioned information about 1) intersensory and integrational difficulties of the dyslexic and 2) the concept of a maturational lag, (which would, according to theory, differentially and progressively be ameliorated as the child develops), it was therefore decided to instigate an experiment using simple pure sound tones of very short duration. The target stimuli of 100-250 milli seconds duration were used to investigate auditory processing and maturational development of three distinct age groups of dyslexic children using a direct recall paradigm with varying set sizes. The following hypotheses were thus generated.

There might be a significant difference between the dyslexic and control groups on their performance on the tone recall task. There might be a significant difference in the performance on the tone recall tasks as the age of the groups increased. There might be a significant difference in the performance of the subjects on the tone recall task as the number of pulses in the stimuli increased.

5B METHOD

5B1 SAMPLE

Subjects were obtained from a sample of two hundred and eight children (originating from all parts of the British Isles) attending Grenville College, Bideford, North Devon, including a group of sixty three assessed dyslexics. Children with hearing deficits were excluded from this study.

The criteria used in the selection of the dyslexics were:

(a) a reading and spelling age of at least 2.5 years below normal as measured on the revised Schonell Graded Word Reading Test.

(b) performance at average or above in other school subjects.

(c) an intelligence quotient of average or above as measured on a non verbal intelligence test. (Raven's Matrices)

(d) absence of gross behavioural problems.

(e) absence of organic disorders.

(f) no long absences from school.

(g) characteristic bizarre spelling.

(h) particular difficulties in tasks involving orientation and/or sequencing.

The criteria used are consistent with those employed by other current researchers (Stanley and Hall, 1973; Newton, 1974; Miles, 1975; Thompson, 1976; Wheeler, 1977) and rule out extraneous factors such as mental deficiency, emotional problems, sense organ malfunctioning, frank brain damage, and lack of opportunity, as primary causal factors or reading retardation.

All the dyslexic subjects were receiving specialist help in the dyslexia unit but were still experiencing difficulties in both spelling and reading and were on average some two and a half years below what would be acceptable for their non-dyslexic peers of the same intellectual potential. The entire group both dyslexic and non dyslexic had normal school opportunities and had continous uninterrupted educational facilities coming from a homogeneous socio economic background, i.e. their father came in class 3 or above on the Hall Jones Scale of Occupational Prestige for Males (Oppenheim, 1966).

5B2 SUBJECTS

Two groups were selected, namely non dyslexic (control) and dyslexic. Three distinct sub groups of chronological age ranges were arrived at without subject to subject matching Tables 5.1 and 5.12 demonstrate the similarities and differences which exist among the three groups. Tables 5.1, 5.2 and 5.3 give a classification of their intellectual ability which was gained using the Raven's progressive Matrices. There was no significant difference between the three groups, and none differed too severely from an approximate upper normal distribution ($U = 34.5$; $P = NS$; $U = 49$; $P = NS$; $U = 43$; $P = NS$)

A comparison between chronological ages is shown in Tables 5.4, 5.5 and 5.6. Table 5.4 shows the mean chronological age for group A, dyslexic, which was 13 years 9 months, (range : 13 years 3 months - 14 years 2 months) and the mean for group A, control was 13 years 5 months, (range : 12 years 11 months - 14 years 2 months). There was a significant difference between the groups ($U = 16$; $P = < .05$).

Table 5.5 shows the mean chronological age for Group B, dyslexic which was 14 years 7 months, (range : 14 years 2 months – 15 years 4 months) and the mean for group B, control was 15 years 0 months, (range : 14 years 6 months – 15 years 7 months). There was no significant difference between the two groups (U = 27; P = NS).

Table 5.6 shows the mean chronological age for Group C, dyslexic which was 16 years 10 months, (range : 16 years 3 months – 17 years 10 months) and the mean for group C, control was 16 years 10 months, (range : 16 years 3 months – 17 years 7 months). There was no significant difference between the groups, and neither differed too severely from an approximate upper normal distribution. (U = 44.5; P = NS).

Tables 5.7, 5.8 and 5.9 show the classification of reading ages worked out from the revised version of the Schonell Graded Word Reading Test. Table 5.7 group A, dyslexic shows the mean reading age 12 years 1 month, (range : 10 years 9 months – 12 years 9 months) and for the control group the mean reading age of 14 years 8 months, (range : 14 years 2 months – 15 years 0 months). There was a significant difference between the groups. (U = 0; P $<$.001).

Table 5.8 group B, dyslexic shows the mean reading age 12 years 6 months, (range : 10 years 3 months – 13 years 9 months) and for the control group the mean reading age of 14 years 3 months, (range : 13 years 4 months – 15 years 0 months). There was a significant difference between the groups. (U = 7; P <.001).

Table 5.9 group C, dyslexic shows the mean reading age 12 years 8 months, (range : 9 years 8 months - 14 years 2 months) and for the control group the mean reading age of 14 years 8 months, (range : 14 years 6 months - 15 years 0 months). There is a significant difference between the groups. (U = 0; P <.001).

Tables 5.10, 5.11 and 5.12 show the classification of spelling ages worked out from the revised Schonell Spelling Test. Table 5.10 group A, dyslexic shows the mean spelling age 9 years 6 months, (range : 8 years 0 months - 11 years 1 month) and for the control group the mean spelling age of 13 years 8 months, (range : 12 years 6 months - 14 years 5 months). There was a significant difference between the groups (U = 0; P < .001). Table 5.11 group B, dyslexic shows the mean spelling age 10 years 8 months, (range 8 years 4 months - 12 years 8 months) and for the control group the mean spelling age of 13 years 0 months, (range : 11 years 7 months - 14 years 4 months). There was a significant difference between the groups. (U = 9; P <.001).

TABLE 5.1

Classification of Intellectual Ability

GROUP A

I.Q.	DESCRIPTION	DYSLEXIC		CONTROL	
130+	Very superior	0	0%	0	0%
120 - 129	Superior	1	10%	1	10%
110 - 119	Bright normal	4	40%	7	70%
100 - 109	Average	5	50%	2	20%
TOTAL		10	100%	10	100%

DYSLEXIC GROUP IQ : Mean = 113.25
Range= 100.125+

CONTROL GROUP IQ : Mean = 112.6
Range= 103 - 125+

U = 34.5; P = NS

TABLE 5.2

Classification of Intellectual Ability

GROUP B

I.Q.	DESCRIPTION	DYSLEXIC		CONTROL	
130+	Very superior	0	0%	0	0%
120 - 129	Superior	1	10%	0	0%
110 - 119	Bright normal	6	60%	8	80%
100 - 109	Average	3	30%	2	20%
TOTAL		10	100%	10	100%

DYSLEXIC GROUP IQ : Mean = 112.7
Range = 106 - 120

CONTROL GROUP IQ : Mean = 111.9
Range = 108 - 117

U = 49; P = NS

TABLE 5.3

Classification of Intellectual Ability

GROUP C

I.Q.	DESCRIPTION	DYSLEXIC		CONTROL	
130+	Very superior	0	0%	0	0%
120 - 129	Superior	4	40%	2	20%
110 - 119	Bright normal	5	50%	6	60%
100 - 109	Average	1	10%	2	20%
TOTAL		10	100%	10	100%

DYSLEXIC GROUP IQ : Mean = 118.4
Range = 100 - 125

CONTROL GROUP IQ : Mean = 114.9
Range = 106 - 125

U = 43; P = NS

TABLE 5.4

Classification of Chronological Ages

GROUP A

YEARS AND MONTHS	DYSLEXIC GROUP		CONTROL GROUP	
12.6 - 12.11	0	0%	2	20%
13 - 13.5	3	30%	4	40%
13.6 - 13.11	6	60%	3	30%
14 - 14.5	1	10%	1	10%
TOTAL	10	100%	10	100%

DYSLEXIC GROUP AGE : Mean = 13 years 9 months
Range = 13 years 3 months to 14 years 2 months

CONTROL GROUP AGE : Mean = 13 years 5 months
Range = 12 years 11 months to 14 years 2 months

U = 16; P = <.05

TABLE 5.5

Classification of Chronological Ages

GROUP B

YEARS AND MONTHS	DYSLEXIC GROUP		CONTROL GROUP	
14 - 14.5	4	40%	0	0%
14.6 - 14.11	2	20%	3	30%
15 - 15.5	4	40%	6	60%
15.6 - 15.11	0	0%	1	10%
TOTAL	10	100%	10	100%

DYSLEXIC GROUP AGE : Mean = 14 years 7 months
Range = 14 years 2 months to 15 years 4 months

CONTROL GROUP AGE : Mean = 15 years 0 months
Range = 14 years 6 months to 15 years 7 months

U = 27 P = NS

TABLE 5.6

Classification of Chronological Ages

GROUP C

YEARS AND MONTHS	DYSLEXIC GROUP		CONTROL GROUP	
16 16.5	2	20%	5	50%
16.6 - 16.11	5	50%	1	10%
17 17.5	2	20%	2	20%
17.6 - 17.11	1	10%	2	20%
TOTAL	10	100%	10	100%

DYSLEXIC GROUP AGE : Mean = 16 years 10 months
Range = 16 years 3 months to 17 years 10 months

CONTROL GROUP AGE : Mean = 16 years 10 months
Range = 16 years 3 months to 17 years 7 months

U = 44.5 P = NS

TABLE 5.7

Classification of Reading Ages

GROUP A

YEARS AND MONTHS	DYSLEXIC GROUP		CONTROL GROUP	
10.6 - 10.11	1	10%	0	0%
11 - 11.5	1	10%	0	0%
11.6 - 11.11	1	10%	0	0%
12 - 12.5	3	30%	0	0%
12.6 - 12.11	4	40%	0	0%
13 - 13.5	0	0%	0	0%
13.6 - 13.11	0	0%	0	0%
14 - 14.5	0	0%	1	10%
14.6 - 14.11	0	0%	5	50%
15 - 15+	0	0%	4	40%
TOTAL	10	100%	10	100%

DYSLEXIC GROUP READING AGE : Mean = 12 years 1 month
Range = 10 years 9 months
12 years 9 months

CONTROL GROUP READING AGE : Mean = 14 years 8 months
Range = 14 years 2 months to
15 years 0 months

$U = 0 \quad P < .001$

TABLE 5.8

Classification of Reading Ages

GROUP B

YEARS AND MONTHS			DYSLEXIC GROUP		CONTROL GROUP	
10	-	10.5	1	10%	0	0%
10.6	-	10.11	0	0%	0	0%
11	-	11.5	1	10%	0	0%
11.6	-	11.11	0	0%	0	0%
12	-	12.5	1	10%	0	0%
12.6	-	12.11	2	20%	0	0%
13	-	13.5	2	20%	1	10%
13.6	-	13.11	3	30%	2	20%
14	-	14.5	0	0%	3	30%
14.6	-	14.11	0	0%	3	30%
15			0	0%	1	10%
TOTAL			10	100%	10	100%

DYSLEXIC GROUP READING AGE : Mean = 12 years 6 months
Range = 10 years 3 months to 13 years 9 months

CONTROL GROUP READING AGE : Mean = 14 years 3 months
Range = 13 years 4 months to 15 years 0 months

$U = 7 \quad P < .001$

TABLE 5.9

Classification of Reading Ages

GROUP C

YEARS AND MONTHS			DYSLEXIC GROUP		CONTROL GROUP	
9.6	-	9.11	1	10%	0	0%
10	-	10.5	0	0%	0	0%
10.6	-	10.11	0	0%	0	0%
11	-	11.5	0	0%	0	0%
11.6	-	11.11	0	0%	0	0%
12	-	12.5	3	30%	0	0%
12.6	-	12.11	0	0%	0	0%
13	-	13.5	2	20%	0	0%
13.6	-	13.11	2	20%	0	0%
14	-	14.5	2	20%	0	0%
14.6	-	14.11	0	0%	5	50%
15			0	0%	5	50%
TOTAL			10	100%	10	100%

DYSLEXIC GROUP READING AGE : Mean = 12 years 8 months
Range = 9 years 8 months to 14 years 2 months

CONTROL GROUP READING AGE : Mean = 14 years 8 months
Range = 14 years 6 months to 15 years 0 months

U = 0 P $< .001$

TABLE 5.10

Classification of Spelling Ages

GROUP A

YEARS AND MONTHS			DYSLEXIC GROUP		CONTROL GROUP	
8	-	8.5	2	20%	0	0%
8.6	-	8.11	0	0%	0	0%
9	-	9.5	2	20%	0	0%
9.6	-	9.11	3	30%	0	0%
10	-	10.5	1	10%	0	0%
10.6	-	10.11	1	10%	0	0%
11	-	11.5	1	10%	0	0%
11.6	-	11.11	0	0%	0	0%
12	-	12.5	0	0%	0	0%
12.6	-	12.11	0	0%	1	10%
13	-	13.5	0	0%	1	10%
13.6	-	13.11	0	0%	4	40%
14	-	14.5	0	0%	4	40%
TOTAL			10	100%	10	100%

DYSLEXIC GROUP SPELLING AGE : Mean = 9 years 6 months
Range = 8 years 0 months to 11 years 1 month

CONTROL GROUP SPELLING AGE : Mean = 13 years 8 months
Range = 12 years 6 months to 14 years 5 months

$U = 0 \quad P < .001$

TABLE 5.11

Classification of Spelling Ages

GROUP B

YEARS AND MONTHS			DYSLEXIC GROUP		CONTROL GROUP	
8	-	8.5	1	10%	0	0%
8.6	-	8.11	0	0%	0	0%
9	-	9.5	1	10%	0	0%
9.6	-	9.11	0	0%	0	0%
10	-	10.5	1	10%	0	0%
10.6	-	10.11	0	0%	0	0%
11	-	11.5	2	20%	0	0%
11.6	-	11.11	2	20%	1	10%
12	-	12.5	2	20%	2	20%
12.6	-	12.11	1	10%	2	20%
13	-	13.5	0	0%	2	20%
13.6	-	13.11	0	0%	2	20%
14	-	14.5	0	0%	1	10%
TOTAL			10	100%	10	100%

DYSLEXIC GROUP SPELLING AGE : Mean = 10 years 8 months
Range = 8 years 4 months to 12 years 8 months

CONTROL GROUP SPELLING AGE : Mean = 13 years 0 months
Range = 11 years 7 months to 14 years 4 months

$U = 9 \quad P < .001$

TABLE 5.12

Classification of Spelling Ages

GROUP C

YEARS AND MONTHS			DYSLEXIC GROUP		CONTROL GROUP	
9	-	9.5	2	20%	0	0%
9.6	-	9.11	0	0%	0	0%
10	-	10.5	0	0%	0	0%
10.6	-	10.11	4	40%	0	0%
11	-	11.5	0	0%	0	0%
11.6	-	11.11	3	30%	0	0%
12	-	12.5	1	10%	0	0%
12.6	-	12.11	0	0%	1	10%
13	-	13.5	0	0%	1	10%
13.6	-	13.11	0	0%	2	20%
14	-	14.5	0	0%	5	50%
14.6	-	14.11	0	0%	1	10%
TOTAL			10	100%	10	100%

DYSLEXIC GROUP SPELLING AGE : Mean = 10 years 8 months
Range = 9 years 5 months to 12 years 4 months

CONTROL GROUP SPELLING AGE : Mean = 13 years 9 months
Range = 12 years 8 months to 14 years 8 months

$U = 0 \quad P < .001$

Table 5.12 group C, dyslexic shows the mean spelling age 10 years 8 months, (range : 9 years 5 months - 12 years 4 months) and for the control group the mean spelling age of 13 years 9 months, (range : 12 years 8 months - 14 years 8 months). There was a significant difference between the groups. ($U = 0$; $P < .001$).

5B3 APPARATUS

The apparatus consisted of an ITT KB cassette tape recorder with a pre-recorded stimulus tape, a Wye audio-generator and a purpose-built integrated circuit pulse timer. The subject listened to the stimuli through a pair of Sennheiser stereo headphones, connected with both headphones in parallel at a volume of approximately 85 db.

5B4 STIMULI

The stimuli used were five sets of sound pulses. The sets consisted of 3, 4, 5, 6 or 7 pulses. There were 8 test items in each set. The sound pulses were either short (100 m sec $\pm$ 2 m sec) or long (250 m sec $\pm$ 5 m sec) and were separated by an absence of signal for 200 m sec. They are shown in the stimulus figure. The interstimulus interval was 15 seconds enabling the subject to record his responses.

STIMULUS

The stimulus sets presented were as follows :

3 item stimulus set

.	.	.
-	-	-
-	.	-
-	-	.
.	-	-
-	.	.
.	-	.
.	.	-

4 item stimulus set

.	.	-	-
-	.	.	-
-	.	-	.
.	-	.	-
-	.	-	-
.	.	.	-
-	-	-	.
.	.	-	-

5 item stimulus set

-	.	-	.	-
-	.	.	.	-
-	.	-	-	.
.	.	-	.	.
.	-	-	.	.
-	.	-	-	-
.	-	.	-	.
.	-	-	.	-

6 item stimulus set

.	-	-	.	.	-
-	-	.	.	-	.
.	.	-	-	-	.
-	-	.	-	.	-
.	-	-	-	-	.
.	.	.	-	.	-
-	-	-	.	-	-
-	.	-	-	.	.

7 item stimulus set

.	.	-	.	-	.	-
-	.	-	-	-	.	-
.	.	.	.	-	.	.
.	-	-	.	-	.	.
-	-	.	-	.	-	-
-	-	-	.	-	.	.
.	-	-	.	-	.	.
-	.	.	-	.	.	.

5B5 EXPERIMENTAL DESIGN

A 2 (group) x 3 (age range) x 5 (number) factorial analysis of variance with repeated measures on second and third factors was employed. Each subject in each group heard all five sets of stimuli in the order shown. There was a sixty second delay between the presentation of each set. Subjects were required to respond immediately after the termination of the stimulus. A set of practice trials was given individually. The dependent variable was the number of correct identifications made. The criterion was hundred per cent accuracy in recording the stimulus set.

5B6 PROCEDURE

Each subject was tested individually. Each subject was informed that he would hear a series of short and long sound tones and that he was to write down exactly what he had heard immediately after cessation of the tones using a dot for a short tone and a dash for a long tone. The subject was allowed to change his response subsequently if he so desired by crossing out the complete sub-set and rewriting. The instructions given were as follows:

DIRECT INSTRUCTIONS

"You are about to hear some sounds in these headphones. Some will be short, like this (100 m sec) or long, like this (250 m sec). Be sure to listen carefully. I want you to write them down immediately they have finished. Use a dot for the short sound and a dash for the long sound, like this (long tone - short tone - long tone heard, and are written down as, dash - dot - dash).

Are you sure you understand all the instructions?"

A set of twenty practice trials was given. The twenty trial stimuli consisted of four each of 3, 4, 5, 6 and 7 items. (dots or dashes) After these trials the full experiment began, that is, eight each of 3, 4, 5, 6, and 7 item stimuli were presented with an interstimulus interval of sixty seconds, at a volume of 85 db.

The same set of instructions as those used in the practice trials was used. The presentation of the stimuli was in the same order for each subject.

5C RESULTS

The results are presented in three sections, viz:

1. The mean number of correct recordings for both groups.
2. Statistical comparisons.
3. Analysis of variance.

5C1 MEAN RESULTS

The overall performance of both control and dyslexic groups was increasingly impaired as the set size increased from three to seven items. However, the dyslexic's performance was markedly inferior to that of the control group for all age groups as increasing set size led to increasing impairment of performance. Dyslexic subjects were differentially affected by longer tone sequences and performance did not significantly change with increasing age.

5C2 STATISTICAL COMPARISONS

There was no significant difference for the two age groups 13.5 and 14.5 between dyslexic and control for the smallest set size (3). For all other set sizes (4, 5, 6 and 7) there was a significant difference both between the age groups (13.5, 14.5, 16.5) and the dyslexic and control subjects' performance.

5C3 ANALYSIS OF VARIANCE

A two (group) x 3 (age range) x 5 (number) factorial analysis of variance with repeated measures on second and third factors yielded the following results:

(1) There was a significant difference between the dyslexic and control groups for their performance on the tone recall test. ($F = 75.09$; df 1,270; $P = < .001$)

(2) There was no significant difference in the performance on the tone recall tasks between the different age groups. ($F = 83$; df 2,270; P = NS)

(3) The subject's performance on the tone recall task was increasingly impaired as the number of pulses in the stimulus increased. ($F = 289.08$; df 4,270; $P = < .001$)

(4) There was no significant second order interaction effect of group and the age of the subjects as indicated by differences in their performance. ($F = .64$; df 2,270; P = NS)

(5) Dyslexic subjects were differentially impaired by increasing stimulus length as measured by their performance on the tone recall task. ($F = 7.54$; df 4, 270; $P = <.001$)

(6) There was no significant second order interaction factor between the age of subject and increasing stimulus length as measured by performance on the recall task. ($F = .51$; df 8,270; P = NS)

(7) There was no significant third order interaction effect between group, age of the subject and increasing stimulus length as measured by performance on the recall task. ($F = .89$; df 8,270; P = NS)

TABLE 5.13

Table of Mean Number of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Subjects

GROUP A

	Dyslexic		Control	
Set Size	Mean	S.E.	Mean	S.E.
3	6.0	± 0.49	7.1	± 0.31
4	4.1	± 0.48	6.6	± 0.31
5	3.4	± 0.50	4.9	± 0.35
6	2.2	± 0.63	5.0	± 0.33
7	0.6	± 0.27	2.6	± 0.34

TABLE 5.14

Table of Mann Whitney U Tests performed to test the Difference between Mean Numbers, of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Group

GROUP A

Set Size	U	Age = 13.5 N1/N2	P
3	29.5	10/10	NS
4	7	10/10	< 0.001
5	21	10/10	< 0.025
6	11.5	10/10	< 0.001
7	8	10/10	< 0.001

GRAPH 5.1

Graph showing mean number of correct identifications of signals for varying set size for direct recall for dyslexic and control subjects (age 13.5)

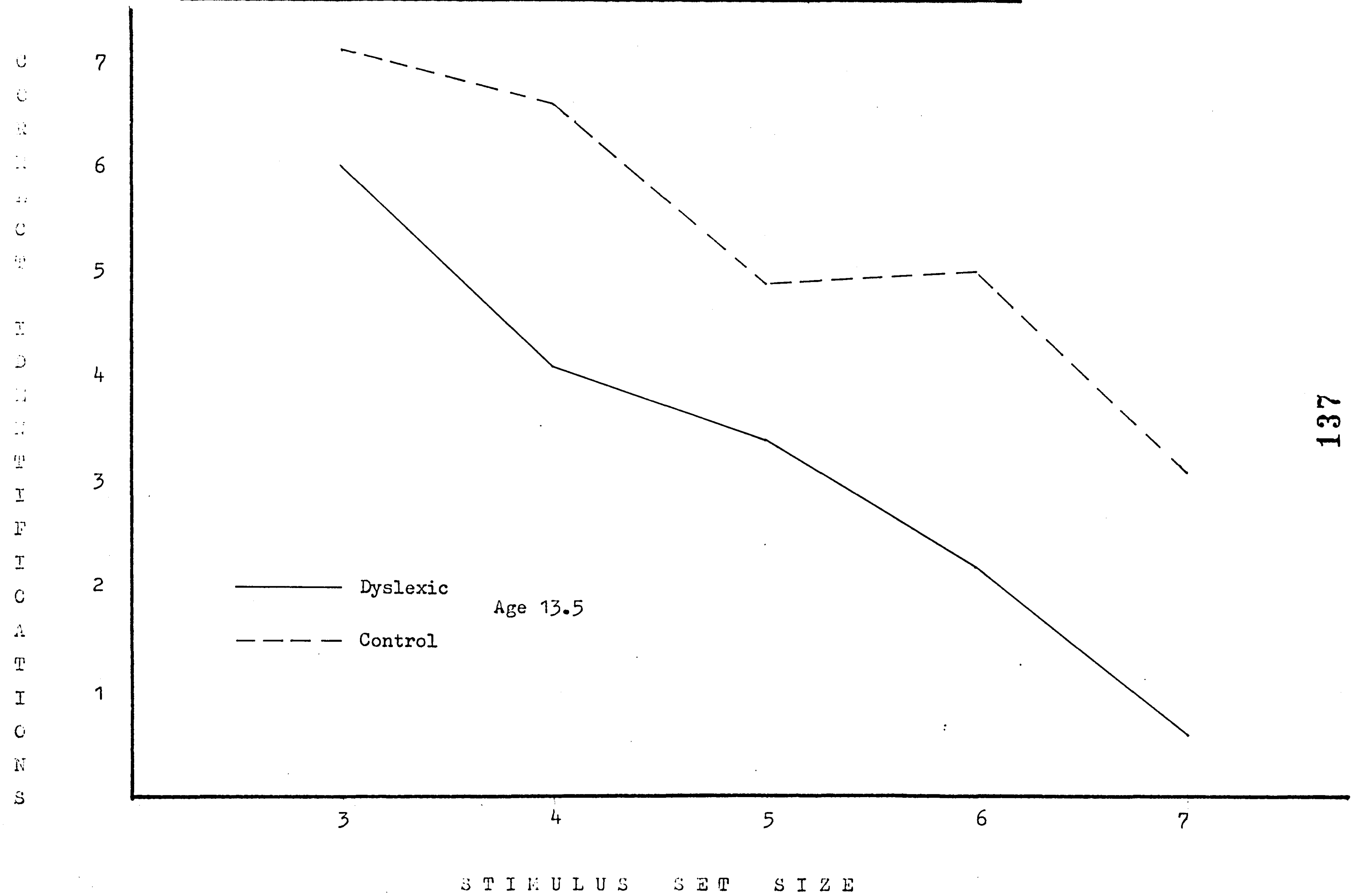


TABLE 5.15

Table of Mean Number of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Subjects

GROUP B

Set Size	Dyslexic Mean		Dyslexic S.E.	Control Mean		Control S.E.
3	6.2	±	0.66	7.7	±	0.15
4	4.4	±	0.48	6.8	±	0.42
5	3.1	±	0.50	6.1	±	0.41
6	2.9	±	0.48	6.0	±	0.30
7	1.0	±	0.30	4.8	±	0.36

TABLE 5.16

Table of Mann Whitney U Tests performed to test the Difference between Mean Numbers, of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Group

GROUP B

Set Size	U	Age = 14.5 N1/N2	P
3	29	10/10	NS
4	11	10/10	<0.01
5	7.5	10/10	<0.001
6	5.5	10/10	<0.001
7	0	10/10	<0.001

<u>GRAPH 5.2</u>

Graph showing mean number of correct identifications of signals for varying set size for direct recall for dyslexic and control subjects (age 14.5)

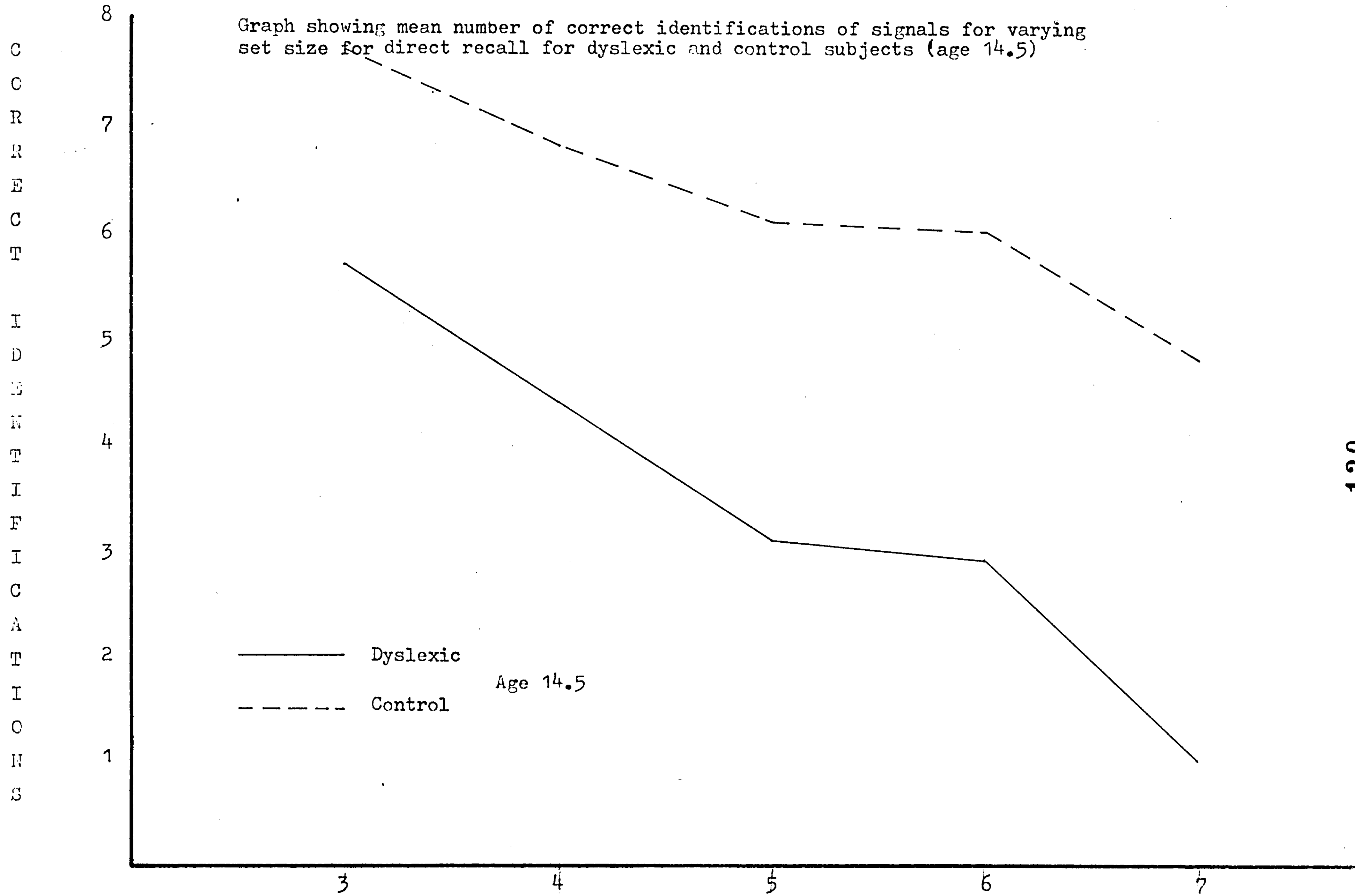


TABLE 5.17

Table of Mean Number of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Subjects

GROUP C

Set Size	Dyslexic Mean		Dyslexic S.E.	Control Mean		Control S.E.
3	5.0	±	0.67	7.7	±	0.15
4	4.8	±	0.57	7.1	±	0.28
5	3.3	±	0.70	5.4	±	0.43
6	2.9	±	0.62	5.6	±	0.37
7	0.9	±	0.35	3.6	±	0.54

TABLE 5.18

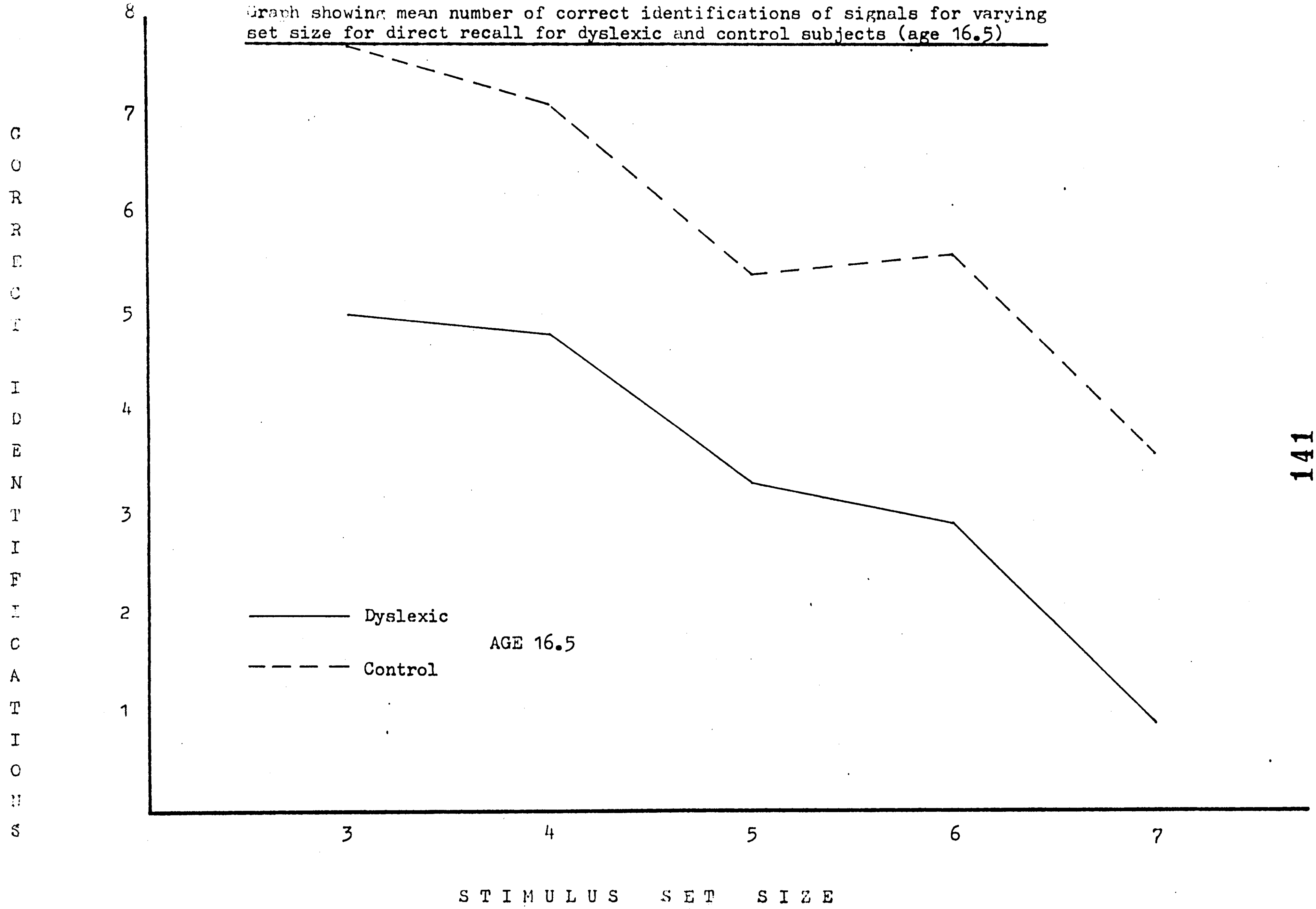
Table of Mann Whitney U Tests performed to test the Difference between Mean Numbers, of Correct Identifications of Signals for varying Set Size for Direct Recall for Dyslexic and Control Group

GROUP C

Set Size	U	Age = 16.5 N1/N2	P
3	4.5	10/10	$<$ 0.001
4	9	10/10	$<$ 0.001
5	21	10/10	$<$ 0.025
6	10.5	10/10	$<$ 0.01
7	8	10/10	$<$ 0.001

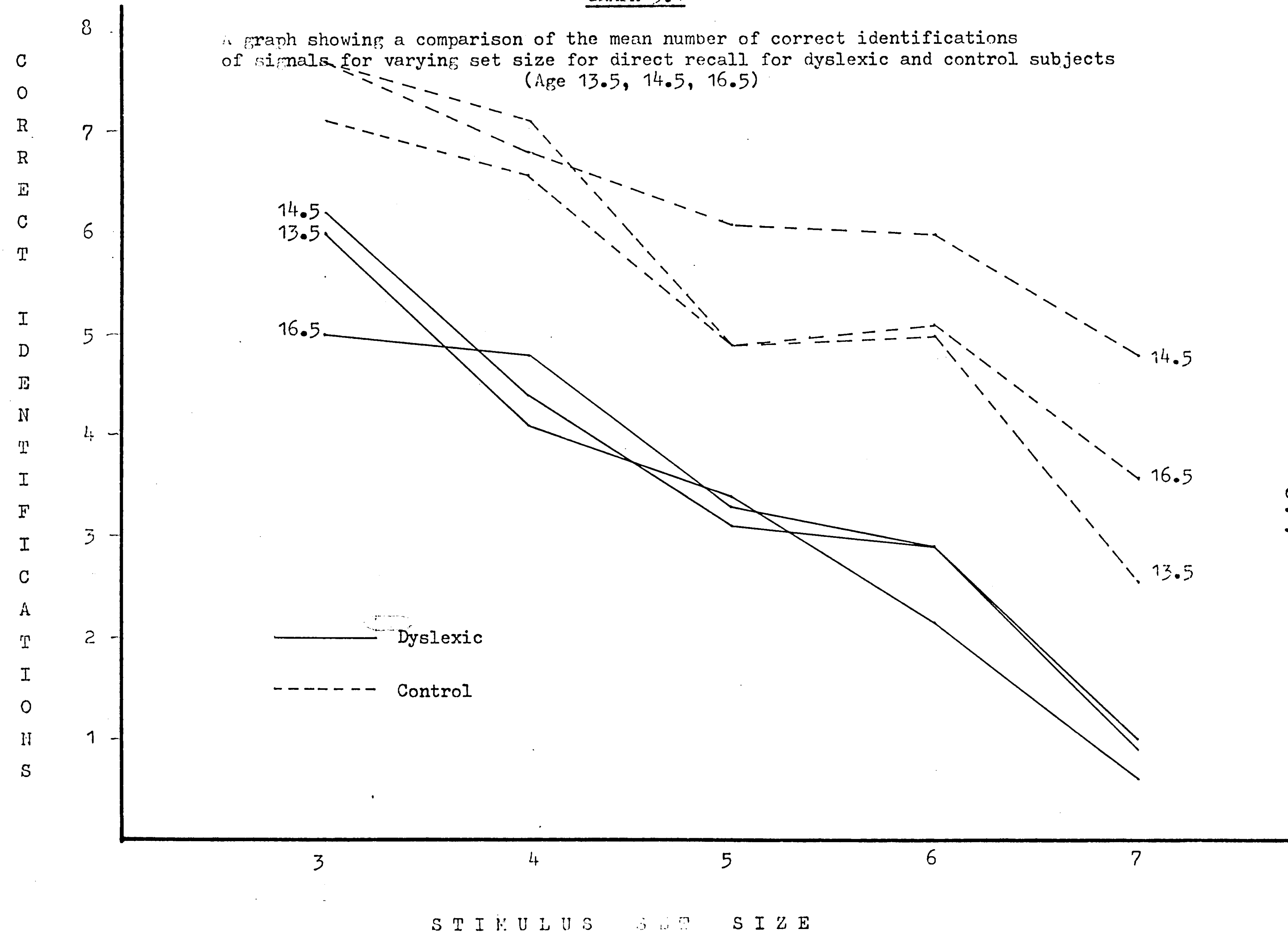
GRAPH 5.3

Graph showing mean number of correct identifications of signals for varying set size for direct recall for dyslexic and control subjects (age 16.5)



GRAPH 5.4

A graph showing a comparison of the mean number of correct identifications of signals for varying set size for direct recall for dyslexic and control subjects (Age 13.5, 14.5, 16.5)



5D DISCUSSION

Consider tables 1, 2 and 3. There was no significant difference between the three groups for intellectual ability, this was an important consideration because one is comparing groups of the same age. Tables 4, 5 and 6 show that the mean chronological age for each group was not significantly different. Tables 7, 8, 9, 10, 11 and 12 compare reading and spelling ages between the dyslexic and control groups. There was a significant difference between the dyslexic and control groups in reading and spelling ages for each of the different age ranges. This is important as the groups were therefore matched and balanced in these important aspects and were above average intelligence. However, increase in age produced a small improvement in reading and spelling, particularly for the dyslexic group. This was not surprising as the dyslexics were receiving specialized help. With regard to tables 13, 15 and 17, it will be observed that the dyslexics' performance on the recall task was inferior to that of the control group for all ages. Furthermore, the difference between the groups became progressively larger as the number of units (sound tones) increased. Dyslexics were differentially affected by larger set size of tone sequences and had the greatest difficulty with tasks involving the highest information loads. The dyslexics appeared to have less difficulty in processing smaller information loads. Their performance for three sound tones was not significantly different from that of the controls except at the age 16.5. Thus the two groups were functioning as quantitatively separate entities as measured by their ability on information processing tasks. Further, the concept of maturational lag in dyslexic groups advanced by many researchers was not substantiated by the results of this experiment. They supported the overall hypothesis that dyslexics were fundamentally less efficient information processors. This supported the contention of Wheeler (1977), Done and Miles (1978) and Thompson and Wilsher (1978) that dyslexia was associated with a general limitation in the dyslexics' short-term memory.

If one considers evaluation of the hypothesis and the data presented graphically, there was a significant difference between the dyslexic and control groups in their overall performance on the tone recall task (graph 4). This was in keeping with the concept that dyslexics function at a less efficient level than a matched control group. Reference to graphs 1, 2, 3 and 4 shows that there was a significant difference in the performance of the dyslexic and control groups on the tone recall task as the number of pulses in the stimulus increased. The two groups were distinctly different in their ability to handle increasing set size of tone pulses. Both groups' performance was increasingly impaired as information set size became heavier.

There was a significant second order interaction effect between group and increasing stimulus length, this was in keeping with general memory constraints. There was no significant second order interaction effect of groups and age, neither group exhibited a maturational increase in information handling. This fact added support to the hypothesis that there was no maturational increase of information handling potential. Both group's performance progressively suffered as tone set size increased. There was no dramatic fall off in the dyslexics' performance against that of control group at any of the three ages. Performance differed in an apparently systematic way, in as much as dyslexics appeared to be functioning at a less efficient level overall, even with a small information load (three set size). The 16.5 group had the largest difference in three tone performance.

Various points arose from the results. The performance of the dyslexic group suggested that they were less efficient processors of auditory information, further, that because of the experimental parameters there was little chance for verbal encoding to take place, as an immediate response was required. If one accepts that dyslexics have 1) a short term memory store deficit which affects and impairs their capacity to handle large or complex 'loads' of information, and 2) a difficulty in gaining access to deeper levels of processings (Craik and Lockhart, 1972; Klein and

Saltz, 1976), then sub-vocal verbal encoding was unlikely to take place within the time available before the response was made. Rather it seemed likely that the tone sequence was held in echoic storage. Response was made, in the case of the dyslexic child, without verbal encoding taking place. Thus within the short-term memory stage, various processes occured (1) auditory stimulation in the form of tone pattern - short and long, (these patterns were theoretically held in serial order,) (2) verbal encoding took place again in a theoretically sequential manner, (3) matching of the tone stimuli to verbal responses in a sequential manner before, (4) a motor response was made. These factors together with limited short-term memory facilities resulted in the dyslexic child attempting to make motor responses without the help of verbal encoding. In effect, the dyslexic child was at a disadvantage in two ways : (1) access to deeper levels of processing was limited because of a short-term memory deficit and (2) because of this limitation in access sequential encoding did not take place with the result that the dyslexics' response was measurably poorer than that of the non-dyslexic.

The results of this experiment tied in with Haber and Hershenson's (1973) information processing model and Rumelhart's (1977) schematic model of reading. Discussion of the rôle of the models is undertaken in the final chapter.

5E SUMMARY

The performance of 10 dyslexic and 10 matched control subjects on a task requiring auditory processing of information of varying set size under direct recall conditions at three distinct chronological ages, 13.5, 14.5 and 16.5 was examined to see if the concept of a maturational lag was appropriate to the dyslexics' difficulties in information processing. The results show that the dyslexic group's performance was significantly worse than that of the controls with every set size and was also differentially worse than that of the control group for the large set size. Age range however was not significant. Dyslexics were differentially affected by longer tone sequences. The results suggest that the concept of a maturational lag was inappropriate as the dyslexic's performance did not significantly change with age and the dyslexic's auditory short-term memory has obviously developed by the age of 13. The concept of dyslexia being characterized by a general limitation in short-term memory which manifests itself with an increasing information load, was substantiated.

CHAPTER 6

AN INVESTIGATION INTO SPATIAL AND TEMPORAL FACTORS THAT INFLUENCE DYSLEXICS' PERFORMANCE ON A MEMORY TASK.*

CONTENTS

* A brief account of this experiment has been published:

Watkins, E.J. & Wheeler, T.J. (1978)
"An investigation of spatial and temporal factors that influence dyslexics' performance on a memory task."

Research in Psychol. Psychiat.

6A INTRODUCTION

As stated in chapters one and two it had been postulated that dyslexia was associated with a fundamental limitation in both visual and auditory memory processes. (Money, 1962; Cruikshank, 1966; Goldberg 1972). Auditory processes have been examined in chapter 5; spatial and temporal factors must now be examined. Benton et al (1960) attempted to relate specific observations to a more general concept. In his researches he required the subject to remember both the form and the spatial attitude as well as the sequence of the stimuli. He spoke of impairment in visual perception and assumed that:-

> "this deficit is general in nature, i.e. it applied to the perception of nonlinguistic and nonsymbolic visual stimuli as well as symbolic material",

this was at odds with Orton's earlier observations which held that dyslexics' problems were specifically of a symbolic nature involving only writing and spelling. However, perhaps it was not surprising as it was known that perception was a cognitive process and not a task specific process. Certainly Orton's comments have not been substantiated by subsequent research findings.

Kintsh (1970) and Herriott (1974) believed that all visual information was not stored in the same way. They contended that rehearsal processes within memory store were used as a method of coding information and considered that the process was accompanied by transformation of the printed word into its spoken form. For instance, pictorial information which could not be easily coded into words was stored in a different form. Haber (1970) considered this question and agreed that when the memory processes for pictorial material were compared with the processes:-

> "by which words, numbers and other symbols were remembered, it became clear that the two systems were in all likelihood different".

Both systems processed material that was presented visually. Both were perceived when light stimulated the retina, generating impulses that were then coded, organised and sent to the brain. In the case of pictorial material, the image was received and stored permanently in pictorial form although the semantic aspect of some pictures might also allow a form of coding similar to that used for linguistic material. It is these aspects of the short-term memory,-specifically the cognitive processes and strategies used by dyslexics in a task-which requires both spatial and temporal skills.

Researches in this area indicated that dyslexics performed significantly worse on the Memory-for-Designs Test than a group of matched controls (Lyle 1968). Further research by Lyle and Goyen (1968) presented the theory that memory differences could possibly be explained by:-

> "assuming that dyslexics have some limitation in perceptual speed or channel capacity".

As outlined in chapter two, Stanley and Hall (1973) examined difference in performance between two groups (dyslexic and non-dyslexic) in their recall of letter arrays presented for varying time durations. Results showed significant differences in the level of performance as opposed to differences in the kind of visual information processing. They considered that their findings supported the hypothesis of a "developmental lag" in visual memory among dyslexics.

The question posed by these findings is whether their hypothesis also applied to non-alphabetic material e.g. pictorial information, symbols or shapes. According to Orton(1928), Rizzo (1939) it should not. It was surmised that when words and letters were used, one of the first steps was to transpose the stimulus from its visual form, to code the items and extract their meaning. Further, the collection of letters making up the printed word was not stored or recalled as a distinct image, but as words, and words were remembered as ideas. Such processes, described in Chapter 3 according to Haber and Hershenson (1973), appeared to consist of several definable steps.

Recent work - Watkins and Wheeler, (1976) Wheeler, Watkins and McLouglin, (1977); Watkins and Wheeler, (1978) suggested that dyslexia in children might be attributable to a general deficit in processing any form of information, especially sequentially, independent of the nature of the material presented. One of the questions arising from these findings, and one which provides considerable debate, is whether dyslexics processed information in a distinct and unique way or whether they differed from non-dyslexic children only in their capacity to handle and manipulate varying 'loads' of information.

Thomas (1969) tested the hypothesis that fluent readers used "immediate word identification" in reading processes whereas both "early readers" and dyslexics use "mediated word identification". Smith (1970) held that "early readers" formed "distinctive feature lists" of both words and letters, ie. they were initially concerned with the differences between both letters and words as opposed to fluent readers who were able to proceed to word identification and meaning in one step. If Smith's hypothesis were correct then the question was whether dyslexics used a paradigm of mediated word recognition. Certainly this would have gone some way towards explaining their difficulties of fluency in reading. If the dyslexic also had a specific weakness in short-term memory then it would also have explained why dyslexics had greatest difficulty in reading long unfamiliar words or ambiguous words. There were a number of questions to be answered. Firstly, whether dyslexia was characterized by a limitation in short-term memory which affected the processing of information or just the sequencing of that information? Secondly, was this short-term memory deficit related to the central difficulty in processing information at depth?

Now the major link in all these observations was the dyslexics' apparent memory deficit; specifically their lack of immediate short-term memory. Accordingly in this experiment the dyslexics' general processing efficiency is investigated from a hierarchical standpoint. The inter-relationships between memory in general, more specifically short-term memory, maturation and the concept of levels of processing are considered. It was hypothesized that the dyslexics would, because of their predicted short-term memory deficit, be less efficient at matching pairs of cards; that because this was related theoretically in some way to a developmental delay older groups would perform at a better level than the younger groups.

6B METHOD

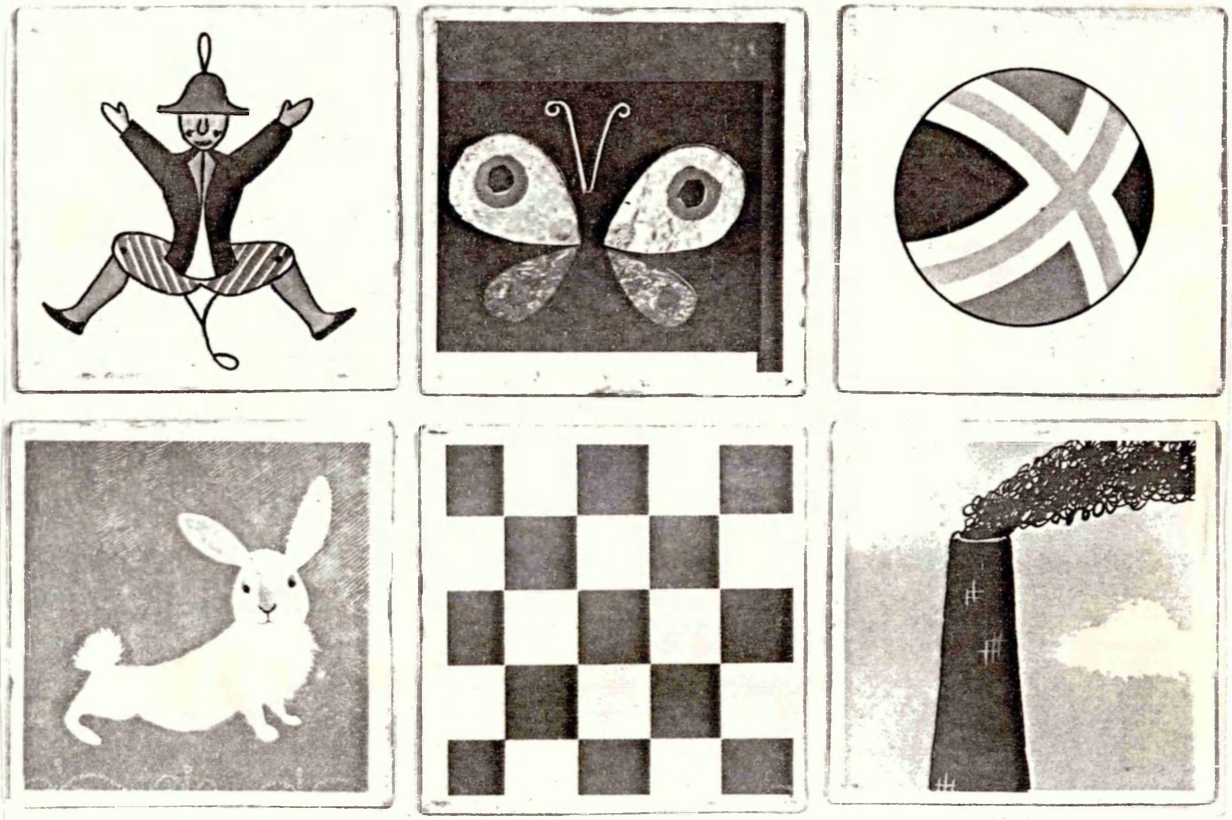
6B1 SAMPLE AND SUBJECTS

As the subjects used in this experiment were the same subjects that were used in the previous experiment, the reader is referred to section 5B1 on sampling and 5B2 on the nature of the subjects.

6B2 APPARATUS

The apparatus consisted of a set of Waddington's Memory Game cards. These are stiff cards 5 cm x 5 cm with a uniform blue backing and coloured graphical representations of concrete objects and arbitary patterns. The cards were placed face down in random order with no overlapping of cards on the table directly in frontof the subject so that easy access to all cards was available.

6B3 STIMULUS



6B4 EXPERIMENTAL DESIGN

A two (group) x 3 (age range) factorial analysis of variance with repeated measures on the second factor was undertaken using 5 different dependent variables (number correct, number incorrect, total, Hit-rate and mean number of incorrect exposures).

Cards were displayed face down in a randomized order to subjects who were required to turn over two cards, one at a time, in an attempt to match pairs. The two cards were either matched or returned face down to their original position before the next attempt was made. A time limit of 300 seconds was imposed. Scores of both correct and incorrect matchings were made.

6B5 PROCEDURE

Each subject was tested individually. Each subject was informed that the aim was to match as many pairs as possible in the five minutes available.

DIRECT INSTRUCTIONS

"Before you are 36 pairs of cards. You are required to turn over two cards, one at a time, thus ... The aim is to match as many pairs as possible. If the cards you have turned over do not match, turn them over face down thus ... to their original position. You see these two cards match, thus ... and these do not. When you have turned over a matched pair place them here (at the side, thus). You have five minutes to do this. Do you fully understand all the instructions?"

Subjects were given a practice trial consisting of one minute's duration using the complete set of cards. The same set of 'instructions' as those used in the practice trials was used. After this practice trial the experiment began using the complete set of cards.

6C <u>RESULTS</u>

The results are presented in three sections, viz:

A. A consideration of various factors based on means, total number of responses, hit-rates, incorrect exposures in the form of graphical representation.

   1. The mean number of correct identifications for both groups.

   2. The mean number of incorrect identifications for both groups.

   3. The total number of responses.

   4. The hit-rate for both groups.

   5. The mean number of incorrect exposures.

B./C. Statistical comparisons for (a) control - dyslexic (b) age ranges.

TABLE 6.1

Table of Performance of Dyslexic and Control Groups for differing Age Ranges (means ± SE)

Age = 13.5 years

Variables		U	P
No. wrong			
Dyslexic	64.4 ± 3.1	6.5	<0.001
Control	49.1 ± 2.5		
No. correct			
Dyslexic	12.7 ± 2.0	48.5	NS
Control	11.9 ± 1.7		
Total			
Dyslexic	77.1 ± 8.7	14.5	< 0.01
Control	61.0 ± 2.7		
Hit-Rate (%)			
Dyslexic	15.8 ± 1.9	41.5	NS
Control	19.4 ± 2.6		
Mean Exposures			
Dyslexic	6.60 ± 1.19	48.0	NS
Control	4.84 ± .61		

TABLE 6.2

Table of Performance of Dyslexic and Control Groups for differing Age Ranges (means ± SE)

Age = 14.5 years

Variables		U	P
No. wrong			
Dyslexic	117.4 ± 8.8	12	< 0.01
Control	72.4 ± 7.9		
No. correct			
Dyslexic	14.9 ± 2.1	17.5	< 0.01
Control	20.7 ± 2.7		
Total			
Dyslexic	132.3 ± 9.6		
Control	93.1 ± 9.0	16.5	< 0.01
Hit-Rate (%)			
Dyslexic	11.2 ± 1.4	6	< 0.001
Control	22.6 ± 2.4		
Mean Exposures			
Dyslexic	9.06 ± 1.11	10	< 0.01
Control	3.79 ± .41		

TABLE 6.3

Table of Performance of Dyslexic and Control Groups for differing Age Range (means ± SE)

Age = 16.5 years

Variables				
No. wrong				
Dyslexic	133.3	± 10.8	14	< 0.01
Control	94.1	± 6.7		
No. correct				
Dyslexic	17.2	± 1.4	28.5	NS
Control	21.4	± 2.2		
Total				
Dyslexic	150.5	± 10.4	21	< 0.025
Control	115.5	± 7.0		
Hit-Rate (%)				
Dyslexic	12.0	± 1.3	13	< 0.01
Control	18.8	± 1.8		
Mean Exposures				
Dyslexic	8.41	± 1.19	13	< 0.01
Control	3.79	± .92		

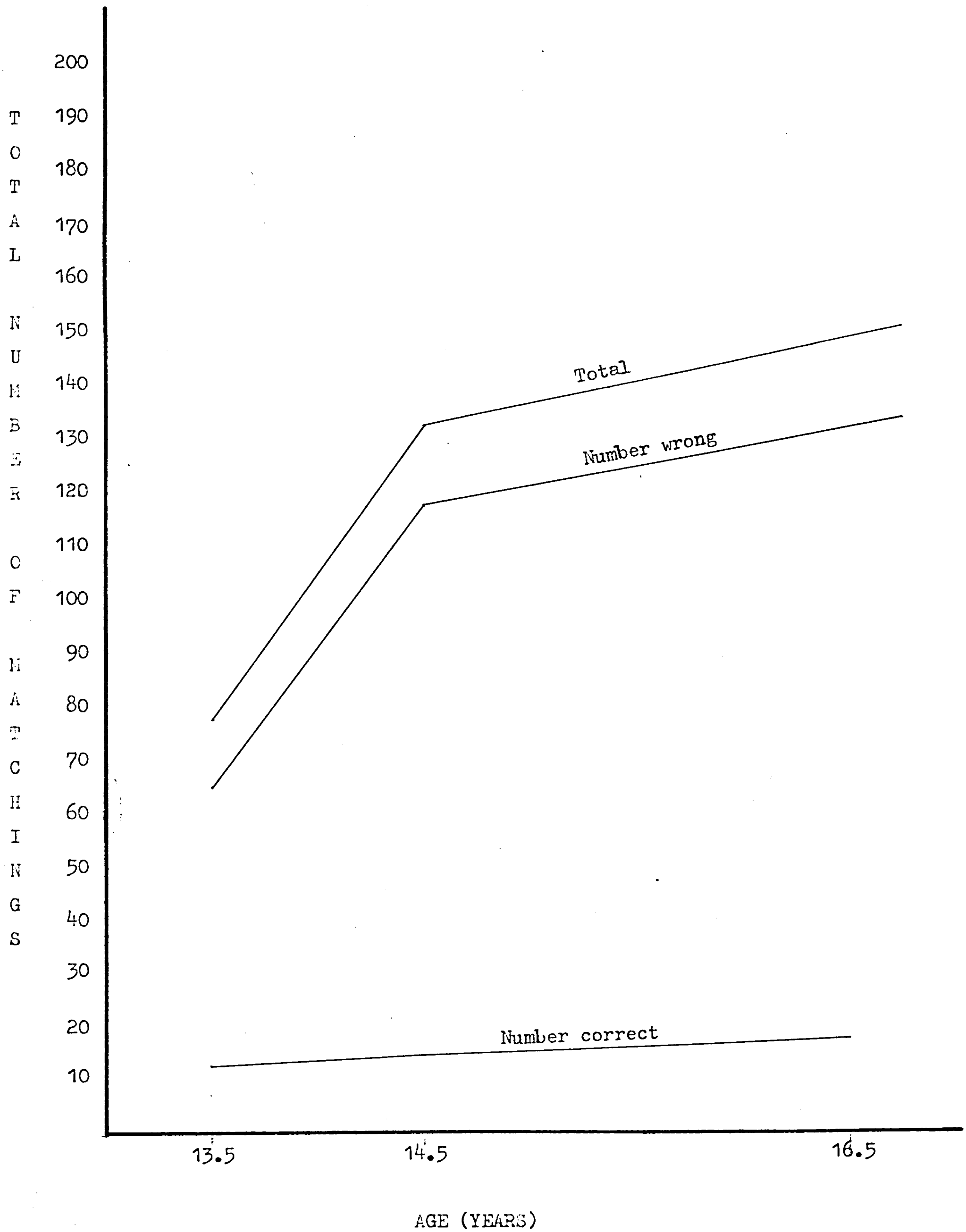
6C1 MEAN RESULTS

The control group performance was better than the dyslexic group for every age group as was their hit-rate (%). The controls needed fewer exposures per correct matching than the dyslexics.

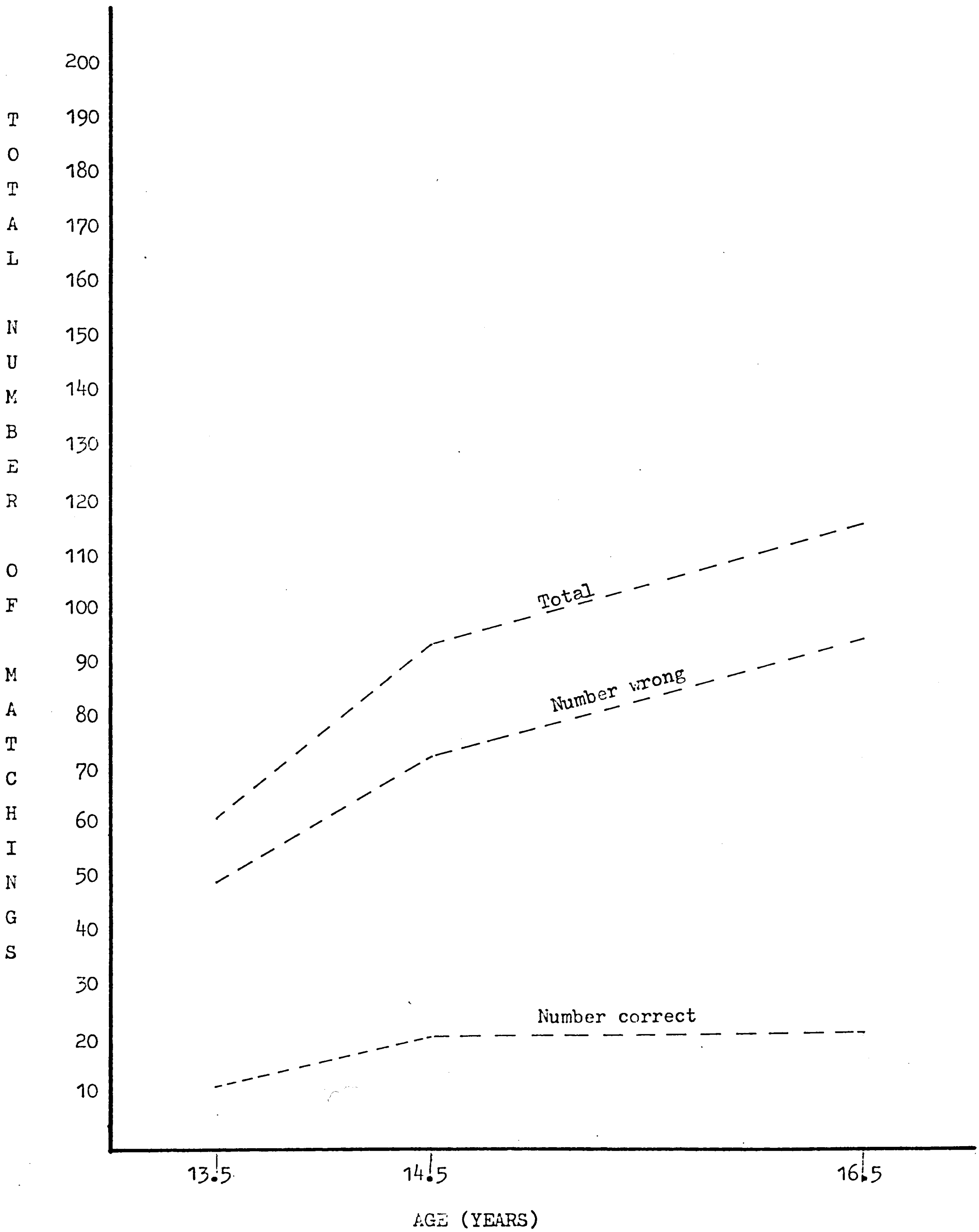
6C2 STATISTICAL COMPARISONS

There was no significant difference between the dyslexic and non-dyslexic subjects for the number of pairs correctly guessed. However age was a significant factor. Dyslexics made significantly more correct responses than controls. Younger subjects made significantly fewer incorrect responses than older groups. Control subjects were significantly more efficient than dyslexics as indicated by their higher hit-rate. In this respect age was not a significant factor.

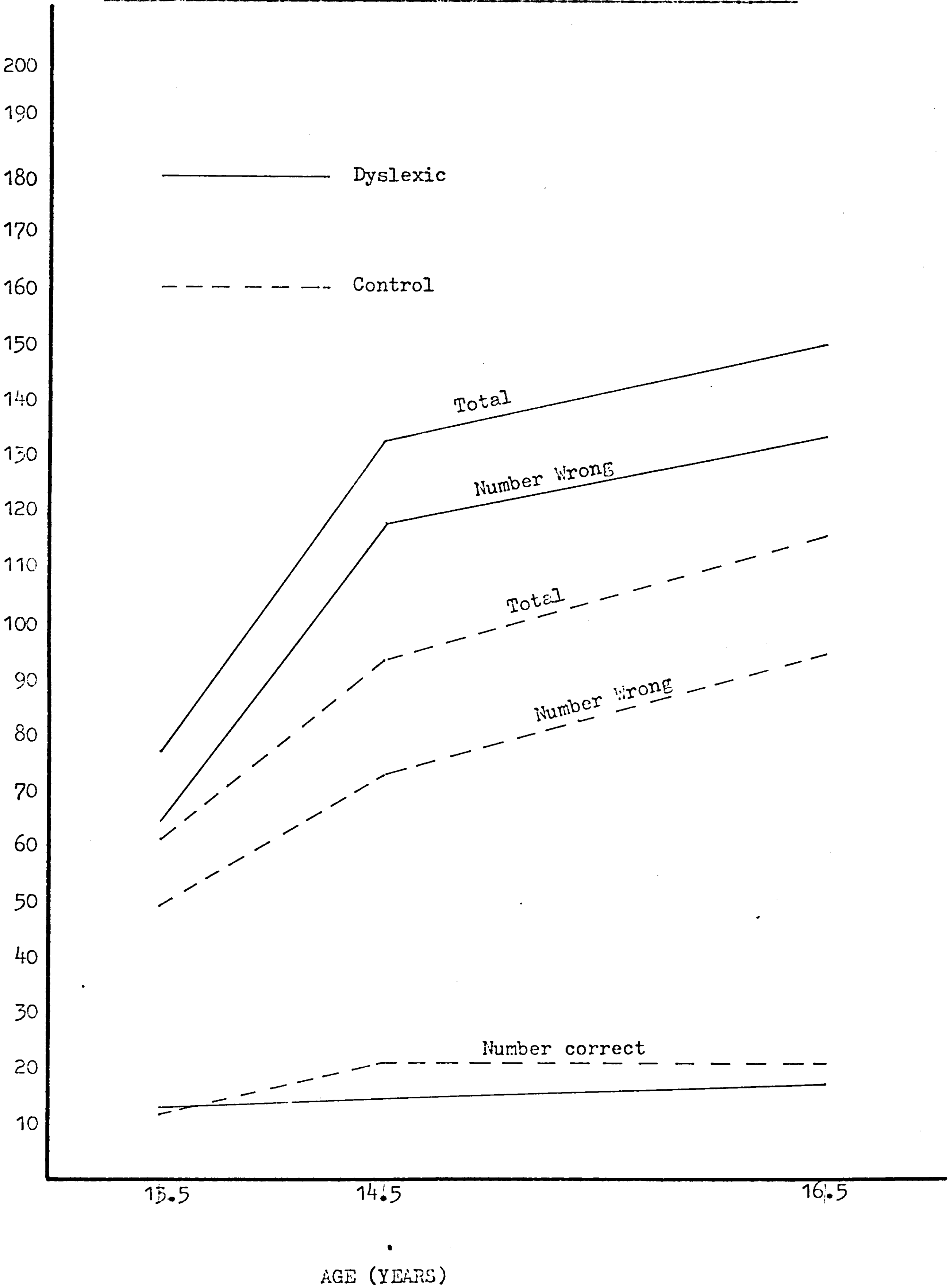
A graph showing number wrong, number correct and total number of attempts for the dyslexic group of differing age ranges



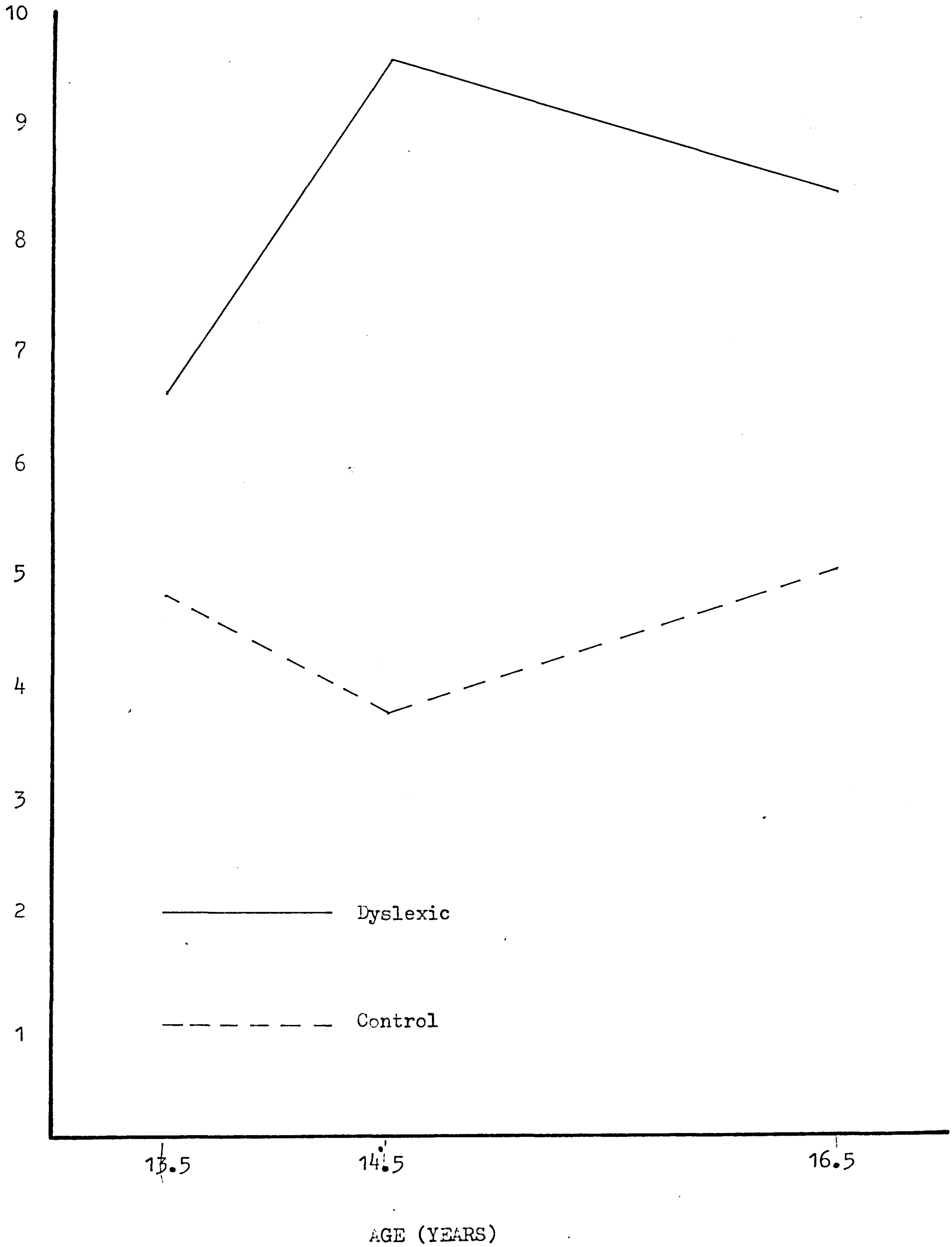
A graph showing number wrong, number correct and total number of attempts for the control group of differing age ranges



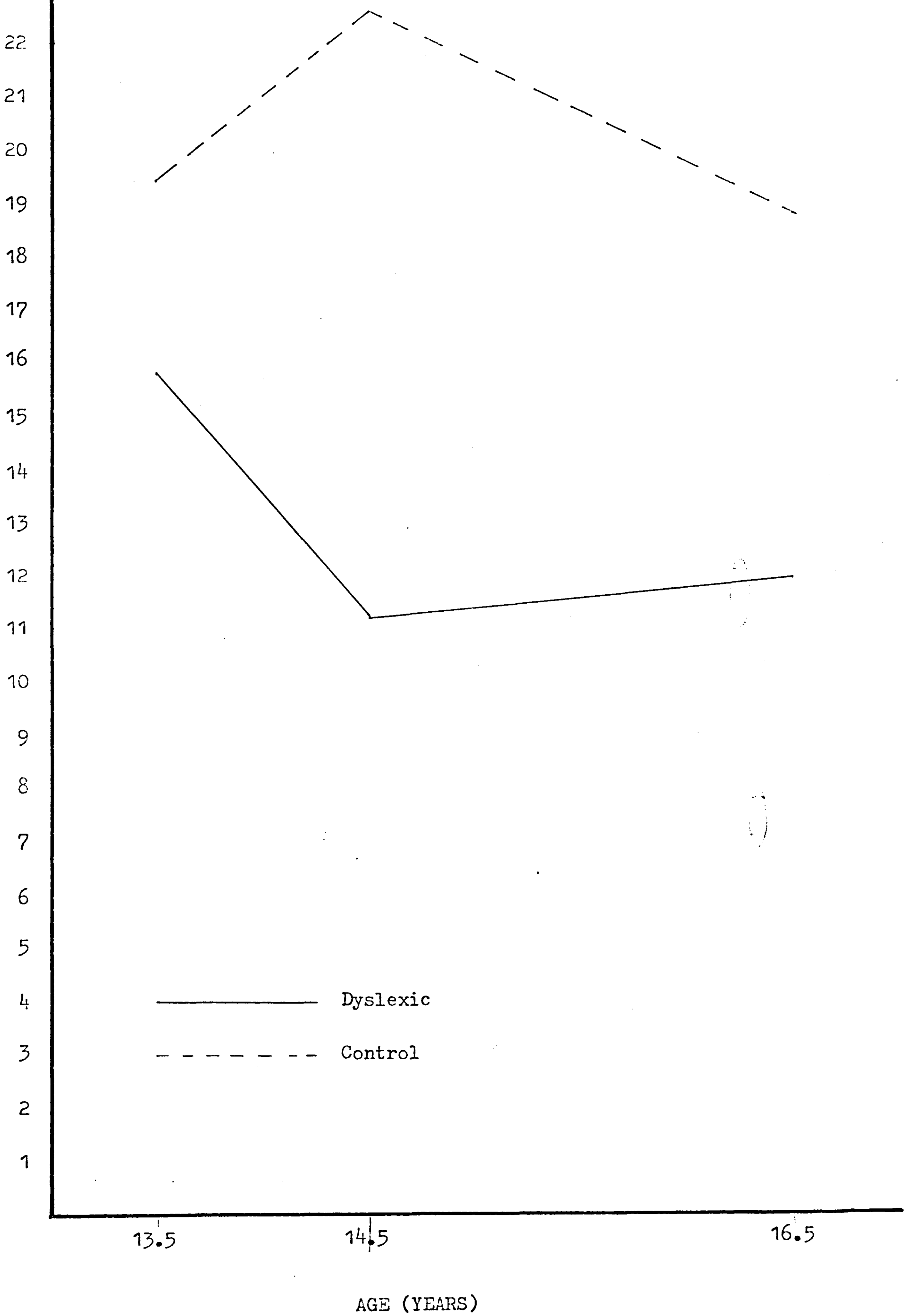
A Graph showing number wrong, number correct and total number of attempts for both the dyslexic and control groups for differing age range



A. Comparison between dyslexic and control groups of differing ages for the mean number of exposures for one correct response on the memory task



ages for percentage hit-rate on the memory test



6C3 THREE FACTOR ANALYSIS OF VARIANCE

A 2 (group) x 3 (age range) factorial analysis of variance with repeated measures for 5 dependent variables (number correct; number incorrect; total; hit-rate; and mean number of exposures) yielded the following results:

(1) There was no significant difference between the dyslexic and controls for the number of pairs correctly matched. ($F = .40$; df 1,54; P = NS).

(2) There was a significant increase in the mean number of correct identifications made as the age of the groups increased. ($F = 4.01$; df 2,54; $P = < 0.25$).

(3) There was no differential change in the number of pairs correctly matched for dyslexic subjects as opposed to control subjects as the age of the group increased. ($F = .50$; df 2,54; P = NS).

(4) The dyslexic group made significantly more incorrect matchings than the control group. ($F = 31.55$; df 1,54; $P = < .001$).

(5) Older age groups made significantly more incorrect matchings. ($F = 19.72$; df 2,54; $P = < .001$).

(6) There was no differential change in the number of incorrectly matched pairs for dyslexic subjects as opposed to control subjects as the age of the groups increased. ($F = 1.91$; df 2,54; P = NS).

(7) The dyslexic group made significantly more matchings than the control group. ($F = 19.65$; df 1,54; $P = <.001$).

(8) The older groups made significantly more matchings than younger groups. ($F = 19.79$; df 2,54; $P = <.001$).

(9) There was no differential change in the total number of matchings made by the dyslexic as opposed to control subjects as the age range increased. ($F = 1.57$; df 2,54; P = NS).

(10) Control groups had a significantly better hit-rate than the dyslexic groups. ($F = 7.43$; df 1,54; $P = <.01$).

(11) There was no significant change in the hit-rate as the age of the group increased. ($F = .39$; df 2,54; P = NS).

(12) There was no differential change in the hit-rate for the dyslexic as opposed to the control group as the age range increased. ($F = .83$; df 2,54; P = NS).

(13) The dyslexic group needed significantly more mean exposures per correct identification than did the control group. ($F = 19.96$; df 1,54; $P = <.001$).

(14) There was no significant change in the mean number of exposures per correct identification as the age of the groups increased. ($F = .57$; df 2,54; P = NS).

(15) There was no differential change in the mean number of exposures per correct identification for the dyslexic as opposed to the control group. ($F = 1.69$; df 2,54; P = NS).

6D DISCUSSION

With regard to tables 1, 2 and 3, there was no significant difference between the dyslexics and controls for the number of pairs correctly matched with the exception of the 14.5 group. There was a significant increase in the mean number of correct identifications made as the age of the groups increased. These results can be accounted for by the subjects' increased manual dexterity and the dyslexic's strategy of turning over a significantly larger number of cards as age increases. Older age groups made significantly more incorrect matchings and the dyslexic group as a whole made significantly more matchings than the control group.

These findings confounded the hypothesis advanced by many researchers (Vernon, 1970; Bakker and Satz, 1970; Naidoo, 1972), that dyslexics suffered from a maturational lag. However, the dyslexic group did make significantly more incorrect matchings than the control group. This was interesting in as much as it substantiated the overall hypothesis that dyslexics were fundamentally less efficient processors of all kinds of information. It will be observed that as the age of the groups increased and greater manual dexterity was facilitated, so the number of attempts increased. This increase was initially dramatic for the dyslexic group while the control groups increase was less so. The contention of Miles and Wheeler (1974), Wheeler, (1977), Ellis and Miles (1978) and Thompson and Wilsher (1978) that dyslexics suffered from a specific limitation in short-term memory was further supported by these results.

There was a significant difference between the dyslexic and control groups for the total number of attempts, furthermore as the age groups increased the total number of attempts made by the dyslexic group dramatically increased from 77.1 at 13.5 to 150.5 at 16.5 (a difference of 73.4 attempts), while for the control group the increase was from 61.0 at 13.5 to 115.5 at 16.5 (a difference of 54.5). The differences at each age group between the dyslexic and control subjects were progressively larger.

The control group had a significantly better hit-rate than the dyslexic group, however there was no significant change in the hit-rate as the age of the group increased. Furthermore there was no differential change in the hit-rate for the dyslexic as opposed to the control group. These findings are interesting when considered in conjunction with the total number of attempts. It will be observed that the increase in total number of attempts did not lead to a better hit-rate for the dyslexic group and this factor might be explained in terms of the dyslexic child's inefficient ability to use the information which he received. This added support to the short-term memory deficit hypothesis.

It will also be observed that the dyslexic group needed significantly more mean exposures per correct identification than did the control group and it is hypothesized that they were functioning at a less efficient level than the control group for all age groups. The dyslexic subjects' mean efficiency was 8.02 exposures per correct identification and the controls 4.55. This confirmed the hypothesis that dyslexics suffered from a smaller capacity in short-term memory store. The controls were able to store more 'bits' of information in memory. There was no significant change in the mean number of exposures per correct identification as the age of the group increased and there was no differential change in the mean number of exposures per correct identification for the dyslexics as opposed to the control group. Control subjects were significantly more efficient than dyslexics as indicated by their higher hit-rate.

The dyslexic subjects were able to overcome some of the effects of their limitation in short-term memory by working at a faster rate, thereby reducing the temporal load on short-term memory. However, as explained, this strategy did not enable them to obtain a better hit-rate or more correct matchings.

6E SUMMARY

The experiment was designed to investigate dyslexics' spatial information processing ability over a specific duration of time, 300 seconds; to ascertain whether there was a limitation in short-term memory and further whether there was a maturational lag which was associated with this limitation. Two groups of 30 children were selected, namely non-dyslexic (control) and dyslexic, comprising of three distinct age ranges, 13.5, 14.5 and 16.5 years. The task consisted of matching 36 pairs of cards displayed in a randomized order. There was no significant difference between the dyslexic and non-dyslexic subjects for the number of pairs correctly guessed. However, age was a significant factor, as subjects get oldertheir performance improved. Dyslexics made significantly more incorrect responses than controls. Younger subjects made significantly fewer incorrect responses than older groups. Control subjects were significantly more efficient than dyslexics as indicated by their higher hit-rate. Age was not a significant factor.

The concept of a maturational lag was not tenable since the performance of neither the dyslexic nor control group increased with age. The dyslexics were able to overcome some of the effects of this limitation in short-term memory by working at a faster rate thereby reducing the temporal load on short-term memory. However, using this strategy did not enable them to obtain a better hit-rate or more correct matchings. The results were compatible with the concept that dyslexia was characterized by a 'general limitation' in short-term memory which manifested itself with an increasing information load.

CHAPTER 7

A FINAL DISCUSSION OF THE EXPERIMENTAL PROGRAMME

CONTENTS

7A FINAL DISCUSSION - AN OVERVIEW

In chapter one, the complex literature relating to dyslexia available from differing academic disciplines was presented, reviewed and analysed. This included the setting of the concept of dyslexia in its historical perspective, defining the term, reviewing the terminology, symptomatology and producing an index of deficits. From this it will have been observed that within the area of dyslexia there is disagreement and an inherent confusion and misunderstanding of the terms used in the description of dyslexia. Chapter one reviewed the 'state of dyslexia' and acted as an appropriate frame of reference.

One of the conclusions of chapter one was that until the last decade, the various schools of thought were each isolated, in their own area of research with little communication between them. However during the last 10 years there appeared to have been a growing concensus of opinion on the nature of dyslexia. Even so, within this general area of agreement there were still areas where no consensus was forthcoming and doubt and disagreement were prevalent. One possible reason for this appeared to be that some of the complex processes involved in reception, perception, modality integration and the like were not at this time sufficiently understood. Another was that some forms of research had ignored relationships which obviously existed. The advantages of taking into account these relationships in the furtherance of our total cognisance of the concept of dyslexia would, it was contended, become obvious.

The central purpose of chapter two was to use the short-term memory model as a theoretical basis as well as a research tool to investigate and define dyslexia. It also reviewed the research evidence on short-term memory generally related to visual and auditory information processing. Selected evidence from the wealth of information available on the basic perceptual processes was presented and this served to define the parameters of this particular piece of research as well as placing it in its historical context. Certainly within this field of research, where essentially psychological structural mechanistic models had been used as a theoretical basis for research, there were problems. Many of these could be attributed to problems of operational definition and interpretation of data.

What first appeared as conflicting evidence was often the result of inadequate experimental design or where the definition was not clearly related to the theoretical model used. In many cases there had been heterogeneous subject grouping together with lack of control over fundamental factors, e.g. matching of subjects for age, sex, intelligence and social grouping. In some cases no model had been advanced to provide an experimental framework from which an interpretation could be made. Where short-term memory structural models were used well with cogent experimental design, results were in the main unified.

Chapter three presented Haber and Hershenson's model of human information processing in relationship to experimental investigation and design. The model was presented with some minor adaptions followed by justification for its use.

The paramount question to be asked in regard to Haber and Hershenson's information processing model was, firstly whether their model was tenable as a theoretical concept and, secondly did it provide a useful research tool which could be used to explain the results of the three experiments reported here? The answer to both of these questions in the light of this present research would appear to be positive. Their model contained and explained the criticisms levelled in chapter two and went further in accounting and accommodating for the specific phenomena contained in chapter one (Miles and Wheeler, 1974). Further, if one accepted Haber and Hershenson's model, one should theoretically be able to measure and demonstrate the difference between the dyslexic and non-dyslexic subject. Moreover, if the modelwere an instrument which had application for research into the dyslexics' memory processes it might well have implications for research in other areas as well, which required a very fine experimental definition of a number of related processes by differentiating reading retardates e.g. non-dyslexic, cross-lateral and dyslexic. The dyslexics could broadly be defined under the operational definition as poor or inadequate information processors, and the non-dyslexics as potentially good information processors. The cross-laterals, as will be observed, were a distinct measurable group on the continuum between non-dyslexic and the dyslexic groupings.

These measurable differences between the short-term memory functions of dyslexic and non-dyslexic subjects raised a number of questions which needed to be answered if a better understanding of the dyslexic's problems were to be obtained. This understanding could allow meaningful remediation to be undertaken as it would have as its basis, understanding of the underlying structure of the dyslexic's short-term memory deficit.

Chapter four investigated the performance of three distinct groups of children, namely dyslexic, cross-lateral and a control group, on short-term information processing tasks using three types of units. These were digits, letters and symbols which were presented simultaneously by tachistoscopic exposure. The purpose of this experiment was to establish 1) whether within the continuum of reading retardation it was operationally feasible to distinguish between two distinct groups of reading retardates and 2) to see whether, as predicted theoretically, there would be a differential effect on subjects' performance as information load increased. It was predicted that the dyslexic's limitation would primarily be associated with a limited capacity in short-term memory, whereas the cross-lateral group's deficit would be a result of the need for repeated access into short-term memory.

Processing speed was an important and delicate mechanism used in research into reading processes and it was only recently that processing speeds in dyslexics had been investigated (Denckla, 1972; Blank et al, 1975; Spring, 1976). Processing speed was a vital pre-requisite for reading efficiency and was of particular importance during two distinct phases involved in reading, viz: 1, primary decoding processes where there was a direct correlation between sequential ordering and the subjects' ability to retain information in short-term memory store, and 2, during the final stage of word integration. This process could be likened to "keeping track" on a rotating record; unless tracking could be maintained then misplacing occurred and the order of information flow was broken. In the reading process the reader must keep track and to do this he used various strategies, e.g. either active mental processes or as in the case of the inefficient reader a concrete means such as a finger.

As previously mentioned Katz and Deutsch (1963), Siegel and Allik (1973)&Stanley (1975) found that reaction time for reading retardates increased dramatically when modality changes were unexpectedly presented for both visual and auditory stimuli. Such findings could be explained and defined if 1, the theoretical concept of a capacity limitation in short-term memory was accepted for the dyslexic and 2, a problem of limited interactive input in modality ability is accepted for the cross-lateral subjects. Further, this presented a model to explain why dyslexics and cross laterals have a measurable difficulty in reading.

The results from this experiment were significant in that they offered an explanation for what is considered by some researchers to be a normal homogeneous grouping of 'reading retardates'. This research demonstrated that dyslexics could be clearly differentiated from other groups of retarded readers from within the normal distribution of reading retardates, because the cause of their problem is specifically a measurable limitation in information processing capacity. On the other hand, cross-laterals' difficulty in short-term memory would appear to be caused by need for repeated access because of inefficient cross-modal integration, creating a heavier load in short-term memory. It was surmised that such a limitation would affect any kind of information processing task, not just reading.

If the concept of a short-term memory deficit was acceptable then it followed that because of this active and measurable limitation the theoretical model of Levels of

Processing would be affected also in as much as the short-term memory deficit would inhibit or retard the subject's ability to gain swift and accurate access to deeper levels within the theoretical model advanced. It was considered by some researchers that dyslexics suffered from a specific limitation in the processes of reading and spelling and generally from a "General overall language deficit". Certainly the model of a short-term memory deficit went some way to account for and explain these observations.

Chapter five looked at the dyslexic's auditory processing abilities; specifically it investigated the immediate recall of auditory signals of varying set size under direct recall condition for three distinct age groups 13.5, 14.5 and 16.5. Two prime factors were investigated, namely the dyslexic's ability to process auditory information and whether their ability improved as a function of maturation, as predicted by various researchers. The findings indicated that the concept of dyslexia which included the idea of a general limitation in short-term memory was valid but that the concept of a maturational lag was inappropriate as the dyslexic's performance did not significantly change with age and that their auditory short-term memory had obviously developed by the age of 13. This finding concurred with Satz, Rardin and Ross's (1971) comments, which stated:-

"On this basis, the pattern of deficits within dyslexic groups should vary as a function of the age at which certain skills are undergoing primary development".

Because visual-motor skills were established ontogenetically earlier (ages 7 - 8), one might have expected to find this pattern of difficulty in the younger dyslexic child. Conversely, those functions which develop ontogenetically later (e.g. language and formal operations) might have been expected to occur in much older dyslexic children (ages 11 - 12) who were assumed to be maturationally delayed (Piaget and Inhelder, 1969).

The experimental design for this investigation was taken from Birch and Belmont (1964) and also employed Wheeler's (1977) paradigm. However, the main area of difference was that this experiment looked specifically at three different age groups to see if the phenomenon of maturational lag in the case of immediate auditory memory as opposed to a delayed recall paradigm used by Birch and Belmont and Wheeler was valid. Results indicated, as predicted, that the concept of a short-term memory deficit in dyslexics was indeed a valid one.

Chapter six was an experimental undertaking that combined visual/spatial and auditory information processing in an investigation of spatial and temporal factors that influenced dyslexics' performance on a memory task.

The concept of a maturational lag was looked at to see if it was in some way related. Further, the theoretical model of 'Levels of Processing' was investigated to see if it provided additional information which might increase understanding of the dyslexic's specific weakness in short-term memory.

Prior research had indicated that there existed a measurable difference in form perception between dyslexics and non-dyslexics. Stanley and Hall, (1973a,b) believed that these deficits were a result of a developmental lag, while others (Goldberg, 1972; Miles and Wheeler, 1974) believed that dyslexics suffered from weak visual imagery. Others considered that dyslexics had a difficulty in applying verbal labels to certain physical stimuli.

Do the theoretical 'Levels of Processing' constructs advanced by various researchers aid in the understanding of the concept of dyslexia? All of the above questions were looked at in this experiment. Essentially, the levels of processing model advanced by Craik and Lockhart (1972) held that as greater depth was reached on their theoretical continuum of analysing operations, so the stimulus was subjected to progressively more elaborate semantic analysis. Durability of the trace was a function of depth. Craik and Lockhart's model of levels of processing tied in extremely neatly with the model advanced by Haber and Hershenson in as much as if dyslexics were both theoretically, measurably and functionally different from other reading retardate groups - as well as having as their central problem a measurable deficit in short-term memory, then the various models of levels of processing contributed to our understanding of dyslexia.

The results from the experiments carried out in this thesis indicated a significant difference between dyslexic and non-dyslexic subjects in respect of their ability to handle increasing amounts of information presented via either visual, auditory or tactile modalities or in combination. This difference could be accounted for in terms of a specific measurable weakness in short-term memory. Dyslexics seemed to be inferior to controls on tasks involving active use of short-term memory and presented a distinct "entity/minority" at the extreme end of the reading retardation continuum (Rutter and Yule 1975). It had been shown that a gross impairment in short-term memory could be quantitatively related to impairment in both reading and spelling tasks. These symptoms together with many others were interesting in themselves but also served as predictive measures in our attempts to test whether the phenomena of dyslexia are compatible with the model advanced by Haber and Hershenson, i.e. that of a general structural model of memory.

7B TESTING HOW FAR THE PHENOMENA OF DYSLEXIA ARE COMPATIBLE WITH HABER AND HERSHENSON'S INFORMATION PROCESSING MODEL

In this section the index of deficits set out in chapter one will be presented again and an attempt will be made to account for these features in terms of a central deficit within short-term memory. Haber and Hershenson's model will be used as a theoretical basis to see how far the various deficits fall into clear groupings so that they may have a use as possible pointers to understanding of the phenomena of dyslexia.

7B1 DIRECTIONAL CONFUSION

The concept of directional confusion related to a processing difficulty in as much as for correct response to be made the subject had to make a mid-point cross over between the two cerebral hemispheres. If this task required an immediate perceptual motor response together with, as so often happens, a transference of left to right in relation to the subject's body in space and to the stimuli, then the increasing load within short-term memory would often lead to an incorrect response, e.g. a reversal. Often the dyslexic subject would have difficulty with the concept of up and down in many cases making complete inversions. The subject, because of increasing memory load and a specific limitation in short-term memory, would progressively suffer from 'overloading' within this store and this would lead to progressive fading of information from memory store and result in incorrect responses.

7B2 SPONTANEOUS WRITING AND SPELLING IMPAIRMENT

The efficient processing of arbitrary symbolic information called for a high level of internal neurological processing efficiency, both decoding and encoding within memory store made heavy demands on these processes. Specific skills were required, e.g. visual perception, visual sequential memory, auditory sequential memory. As had already been mentioned in chapter two the process involved required active and heavy use of short-term memory store - it has been shown in this research that the dyslexic is a measurably less efficient processor because of a quantifiable specific limitation in short-term memory capacity. It is suggested that this factor is the key to the dyslexic's problems of spontaneous writing and spelling impairment.

7B3 FINGER DIFFERENTIATION PROBLEM

Benton (1962) suggested that dyslexia was not a true language disorder and certainly his hypothesis was substantiated by the research undertaken in this thesis. Benton spoke of finger agnosia as being a manifestation of dyslexia. Many dyslexics had inordinate difficulty in naming the finger being stimulated in agnosia tests. This manifestation could be likened to a problem of information processing where in the case of the dyslexic subject new unfamiliar information was presented. It was a novel situation which required immediate response. The subject had received no prior rehearsal and information overload in all likelihood occurred because of this. The level of processing required is probably deeper and more ambiguous in as much as there was a very large choice factor which must be searched before a response is made.

7B4 VISUAL-PERCEPTUAL DEFICIENCIES

This deficit covered an enormous area of problems not exclusively dyslexic in nature. There was no doubt that visual-perceptual deficiencies occurred in the dyslexic subject but it was reasoned in this thesis that they were a specific manifestation of an underlying central deficit in both short-term memory and levels of processing. It could be argued of course that there was a certain circularity in this postulation rather like the "chicken and egg" syndrome. However, it was held in this research undertaking that the causal effect was the result of an underlying endogenous aetiology which manifested itself in an exogenous psychological construct, that of a central deficit in short-term memory.

7 B5 HANDEDNESS AND CEREBRAL DOMINANCE

It had been demonstrated in experiment 2 "Dyslexia, Laterality and Short-term Information Processing" that crossed-cerebral dominance imposed a measurable deficit in tasks that required theoretical active and heavy use of short-term memory. It should be firmly held in mind however that crossed laterality in itself was not dyslexia, as defined by Wheeler and Watkins (1978) but was a measurable entity within the continuum of reading retardation. The cross-lateral's problem appeared to be one of need for repeated access to short-term memory rather than as defined for the dyslexic subject, a specific deficit or size limitation within short-term memory store. Many subjects were, in addition to being measurably dyslexic,also cross-lateral. Cross-laterality or even more significantly confused laterality (Thomson, 1976) would exacerbate the fundamental deficit within short-term memory of the dyslexic subject.

7B6 WEAKNESS IN MEMORY STORAGE

Little need be said here as chapters 2, 3, 4, 5 and 6 make specific reference to this and more will be said later in presentation of a modified model of information processing which combines Haber and Hershenson's and Craik and Lockhart's theoretical models.

7B7 MATERNAL AND NATAL FACTORS

It was considered that damage to the central nervous system as a result of pre - peri or post natal trauma might affect the individual skills in tasks requiring symbolic processing of information. Fetal anoxia resulted in a lowered oxygen content to the brain. Those parts of the brain concerned with reading and spelling abilities were terminal end vessels and as such were the first to be affected by a lack of oxygen to the brain. Both reading and spelling are recently acquired skills in evolutionary terms requiring specific and active use of short-term memory. This factor together with the repeated mention made in dyslexia literature would indicate that there was a correlation between maternal and natal factors and a limitation in short-term memory capacity. It is obvious that short-term memory is a psychological construct and as such may be an exogenous manifestation of an underlying endogenous causation. As such it is used as a psychological cognition model to explain concurrently these studies.

7B8 MOTOR DYSFUNCTION

Klasen (1972) spoke of certain neurological signs. These might become manifest as awkwardness of movement, incoordination and lack of fine motor control and might be traced back to either structural or functional disorders or to delayed maturation of the central nervous system. Cohn (1961), Myklebust (1964), Whitsell (1967), Doyle (1962) and Klasen (1972) considered that up to 49.2 per cent of dyslexics exhibited motor dysfunction. Luckert (1966), Hunger-Kaindlertorfer (1960) spoke of the typical characteristic of dyslexia as poorly developed fine motor-muscle coordination. Kephart (1968) presented a very useful account of how the child's earliest learning is based on motoric experiences and development. Certainly the majority of researchers instanced motor dysfunction as being one of the symptoms in the phenomenon of dyslexia and this factor is confirmed by the writer's own clinical observations. Now, if motor dysfunction was seen as a theoretical point on a gradation of the whole continuum of brain damage resulting from numerous complex interactions, endogenous and exogenous in nature, then a possible link could be established between (a) a motor dysfunction and (b) a central deficit in short-term memory as they were both correlated to a measurable cerebral dysfunction.

7B9 DELAYED MATURATION

Delayed maturation was inextricably linked to delayed cerebral maturation. It was known that within this framework certain maturational milestones must be passed before acquisition of specific skills in a largely ordered sequential manner. Problems associated with delayed maturation would, it was observed, limit performance on certain tasks, especially those requiring a high level of competence in processing efficiency, e.g. reading and spelling. This measurable delay in maturational processes it was postulated, was linked with the dyslexic's problems of processing efficiency. Because of this, especially in younger children, the necessary cerebral maturational processes would be delayed, so inhibiting the pre-requisite structural internal processes which lead on in a sequential manner to accomplishment of higher level subskills. Short-term memory capacity deficiency would, it was postulated, be a result of either genetic, familial transference or result from cerebral trauma associated with pre, peri or post natal factors. The model proposed in this research accommodates these observations.

7B10 NEUROLOGICAL DYSFUNCTION

Neurological dysfunction was a result of either endogenous or exogenous factors and was well documented in research literature. The hypothesis in this research undertaking postulates directly that a neurological dysfunction is the causal agency for a deficit in short-term memory.

7B11 FAMILIAL OR INHERITED DISABILITY (GENETIC FACTORS)

Possible genetic relationships with dyslexia were tentatively suggested as long ago as 1917 (Hinshelwood). Evidence is advanced in chapter one to support this prediction. Certainly in the writer's clinical experience a familial relationship is supported. If one accepted genetic transference of dyslexia as an aetiological factor, and there was much evidence to support this, then many symptoms associated with dyslexia might well be, in some cases, determined by genetic factors. The theoretical concept of a central neurological deficit reflected as a specific deficit in short-term memory is central to the research undertaken here.

7B12 SEX DIFFERENCES

Evidence points to the fact that the incidence of dyslexia is more prevalent in males than females. Figures range from 3:1 to 10:1. This observation did nothing to either support or condemn the concept of a short-term memory deficit and little need be said other than males would appear to be more susceptible to both genetic transference and a propensity towards pre, peri and post natal trauma. Interestingly, there is no scientific evidence available to explain the predominance of male dyslexics. This is an area ready for research.

7B13 LANGUAGE DELAYS

For the full acquisition of fluency in language a high level order of skill was required. This process required both active decoding and encoding in a complex hierarchy of differential functioning. Language delays and fluency in written language were a result of many factors, but chiefly, underlying constitutional or functional problems which caused interference or confusion. A language delay might well reflect a maturational delay which in turn could be linked to an immaturity in processing efficiency. Certainly there was a correlation between the two. Further, if one accepted research evidence, it appeared that over 60 per cent of dyslexics suffered from a language delay reflected in a small vocabulary and difficulties with words, phrases and sentences theoretically requiring deeper levels of processing, (Craik and Lockhart, 1972).

It will have been observed that the index of deficits could be positively related to the model advanced, namely a specific weakness of information processing and by inference some weakness in accessing deep levels of memory.

It is contended that the index of deficits was a valid construct, one which attempted logically to index symptoms. Furthermore, the majority of deficits could be explained using as a central feature the above model. More will be said about this later.

7C Justification for the incorporation of a Levels of Processing paradigm

Earlier workers, had spoken of the dyslexics' weakness in memory and as a general overall concept it was viable. However, advances in both understanding and knowledge had necessitated more detailed models to account for the evidence produced, i.e. Haber and Hershenson's (1973) model of memory processes.

For the successful operation of reading and spelling a number of simultaneous operations were essential. If for any reason coordination among these functions was disrupted or the complex functional processes failed to act in unison then resulting performance was impeded. This impairment was theoretically on a progressive scale depending on the nature and severity of damage to underlying processes. It was observed by some researchers (Goldberg and Shiffman, 1972; Stanley, 1976) that some subjects had no problems with individual subskills, e.g. form and position, but in tests that required simultaneous use of a number of subskills performance was progressively affected. These observations were accounted for in the model presented here.

It was contended that progressive interference on a theoretical continuum leading to a breakdown in processing efficiency was a direct result of the need for increased loading of short-term memory together with access at increasingly deeper levels of processing. Heavier theoretical loading of short-term memory was a result of the need for the combining of different separate skills to produce a coherent 'whole'. With increasingly 'deeper levels' of processing there might well be a problem of conceptualization.

There would seem to have been a case for considering the wider implications of a general language deficit, resulting from a specific and measurable functional deficit in short-term memory and subsequently access to levels of processing.

Evidence is presented in this thesis indicating that the concept of a maturational lag was not viable for children over the age of thirteen. This was in keeping with other findings. Causes for a maturational lag were diverse, but the common factors associated were pre, peri or post natal in origin. Genetic familial transference was also a major factor according to various researchers Critchley (1964, 1978), Shiffmann (1971), Naidoo (1972).

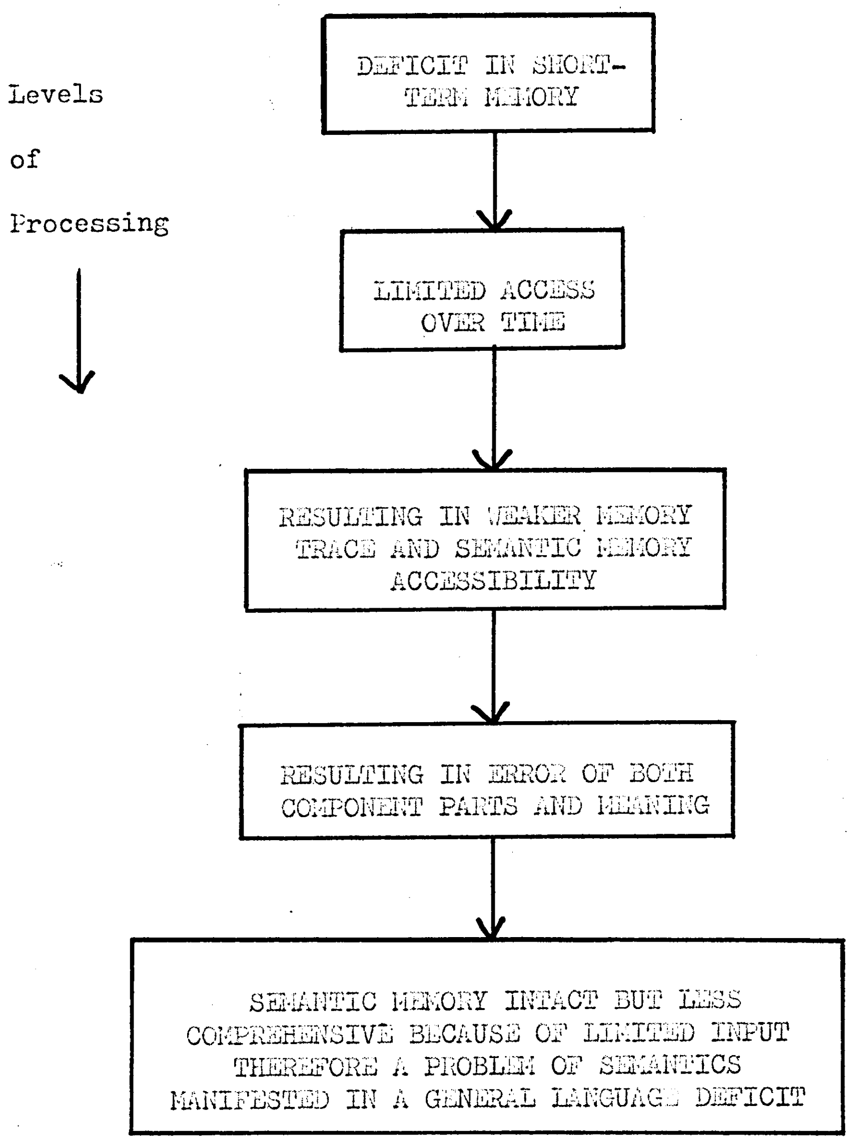
If it was accepted that a maturational lag was related to an individual's cerebral development and resulted in retardation of the acquisition of pre-requisite subskills, fundamental to the fluent processing of information, particularly thosewhich require a very high level of processing competence, then this maturational lag was, in the case of the research undertaken here, a potential hindrance until the age of 13. It followed, then, that for these children the processes of reading and spelling would be impaired depending on the severity of the lag and that the deficit would retard the child's progress for some time after cessation of the maturational lag. If as a comcomitant, an underlying deficit in short-term memory was considered as part of this maturational deficit - one incidentally that was not progressively ameliorated - then the results presented in the research here are substantiated.

Because of the dyslexic's weakness in short-term memory storage it also followed that there would be an associated difficulty in accessing increasing depths of memory (the theoretical model advanced by Craik and Lockhart). With increasing depth, tasks would be differentially affected, not only decoding but also encoding (hence the concept of a general language deficit). The word concept must have been mastered e.g. semantically for the individual word in isolation, then within a contextual setting while at the same time the individual letters of the word had to be 'pulled' from memory store in a sequential order for each word, while at the same time the sequential grouping of the words must have been held in short-term memory until the complete sentence was written. While this was going on the preceding and following words, component letters, component words and meanings must have been rehearsed in a continuous and rapid fashion as each letter, word, sentence and paragraph was constructed.

Paradoxically it seems that expectancy would facilitate initial encoding but it also had the effect of reducing the richness of memory trace and later effectiveness of the resultant memory trace. The question arose, whether the dyslexics' inability to master spelling was a by-product of this system, in as much as visual recognition and expectancy of stimuli in reading would reduce the trace in memory so that in encoding tasks for spelling there would be a fundamental weakness in memory trace. Certainly dyslexics in the main suffered from a poor visual memory and it was observed that for many there was a massive gap between reading and spelling levels. The link between expectancy and emotional involvement was worth considering. It was accepted that with increasing anxiety there was a progressive loss of optimal learning and functional levels. The dyslexic would often display considerable negative emotional responses in a 'learning' situation where in his experience failure was the likely outcome. In such a situation it was interesting to consider that the dyslexic would in a balanced chance situation gain a considerably greater number of errors than chance. This is an area which deserves study. It appeared that the dyslexic used both wrong cognitive styles and strategies in such a situation to the detriment of self esteem and self confidence.

A possible explanation for the dyslexic's many symptoms could be advanced, if the theoretical model of Haber and Hershenson (1973) was accepted, together with the concept of a short-term memory deficit, and the model of Craik and Lockhart (1972). Consider the postulation that fluency of access to deeper levels of processing was concomitant with a non-deficit in short-term memory. If there were a deficit in short-term memory then according to the hypothesis advanced here, semantic memory store would be theoretically less comprehensive than it would be otherwise. This was because of two fundamental factors, viz: (1) because of limited short-term memory, input to semantic memory would be less and (2) a short-term memory deficit would mean that access to semantic memory would be less efficient and precise. Semantic store, based theoretically at depth would be inhibited, such concepts as 'deeper', 'richer' or more semantic traces would not be applicable and would result in confusion and ambiguity leading to ambivalence of response.

The theoretical parameters were as follows on a hierarchical concept of levels:-



For tasks utilizing long-term memory there was not the same problem in as much as 'time' would appear to be the contolling factor and given time, access to semantic memory was facilitated. However, what was postulated was that there was a potential weakness in semantic memory which was manifested by dyslexics in their general language deficit and time alone would not always result in totally accurate recall. The weakness in semantic memory was caused by a continuous limitation in information access and processing.

The dyslexic's problems were analogous to that of the 'outspread hands'. Consider each finger 1 to 10 as a theoretical stage in a specific learning task. Whereas the non-dyslexic subject needed input and conceptualization at points 1, 4, 8 and so on; was able to make inference and transference between points 1 and 4 - and 4 and 8 without difficulty; was able to see relationships between 1 and 4 and 4 and 8 and 4 and 1 and 8 and 4 and 1 and 8 and so on in differing patterns, the dyslexic subject was unable to make any 'jumps'. There was positive need for 'infilling' and establishment of routes between each point, e.g. ($\bar{a}$) says ($\breve{a}$), ($\check{a}$) says ($\bar{a}$). This could be likened to spread of information at any theoretical level (rather like 'ripples' on a pond) while the concept of 'depth' was itself a different dimension equally in need of establishment of routes between successive levels. There was in effect a need for two dimensional reinforcement and establishment of routes and links for the dyslexic subject if amelioration of specific difficulties were to be attempted. At a superficial level Visual-Auditory Kinesthetic links were sensible ways of helping to establish these links which to the non-dyslexic child are often automatic.

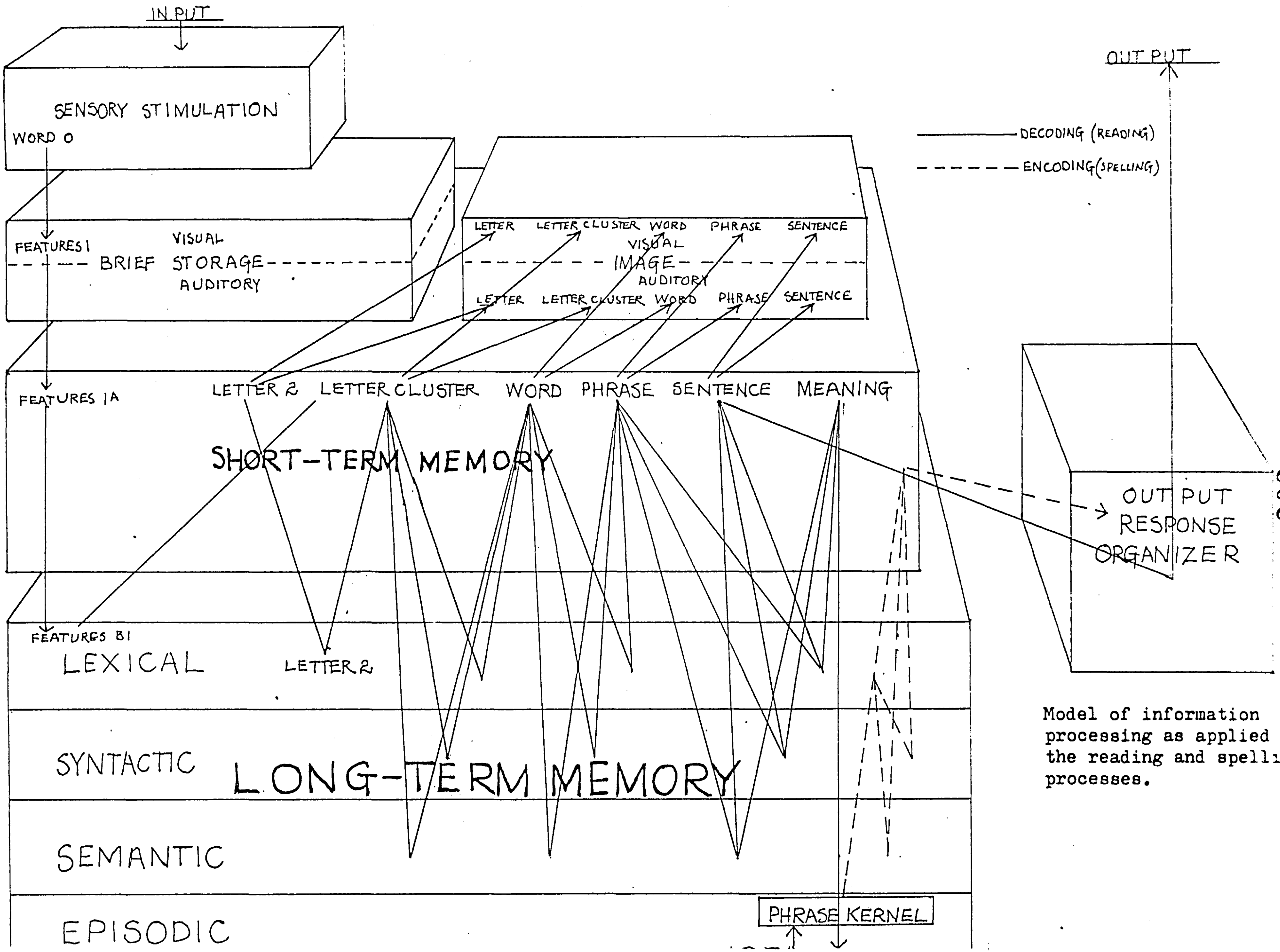
This phenomenon of the dyslexic child's need of 'infilling' linked perfectly with the concept of a problem in short-term memory and levels of processing within a psycho-neurological framework of reference. Because of the above deficits, cerebral integration and hierarchical levels of processing were differentially affected with the resultant measurable deficits in processing efficiency.

Reading and spelling were known to be active processes requiring dynamic processing. Various memory models had been presented, but Haber and Hershenson's model as outlined in chapter 3 and Wheeler's (1977) modified model would appear to go further in explaining the processes involved and certainly the predictive nature of their model appeared to substantiate this contention.

7C1 INITIAL COMMENTS ON PROPOSED MODEL

Before presentation of a modified model of information processing as applied to reading and spelling processes a number of points need to be clarified. The model results from three influences, namely (1) earlier research into short-term memory (2) researches presented here, and (3) the assimilation of the overview and discussion.

It is suggested that it is now possible to produce a more detailed model of information processing to account for memory processes than that of Haber and Hershenson's (1973) model. The theoretical model presented combines both Haber and Hershenson and Craik and Lockhart's models and sets out different levels with brief comments on each stage, this is followed by a short rationale. The model proposed provides a well developed framework within which the problems of the dyslexic child can be explained. Finally a definition of dyslexia is presented which incorporates research evidence contained in this thesis.



Model of information processing as applied to the reading and spelling processes.

7C3 SENSORY STIMULATION

Sensory stimulation within the model implies impingement of any modality receptor by afferent signals. Visual, auditory or tactile sensation produces a primary flow of information via complex electro-chemical actions in the receptor nerve cells. For visual inflow, stimulation of the retina by the projection of a given stimulus results in initial primary information potential of the complex nerve cells within the eye, which transforms the physical energy into an electro-chemical component. Certain basic features of the information relate directly to the physical properties of the stimulus, e.g. luminance, whereas others such as symbolic encoding do not. Similarly auditory stimulation is caused by activation of the cochlea by physical energy in the form of sound which is transmitted from the eardrum via several stages within the ear, which in return produces a basic primary inflow of information derived from complex electro-chemical actions. Again certain basic features of the information inflow relates directly to physical properties of the stimulus, e.g. amplitude or loudness whereas others do not, e.g. selective attention.

Tactile stimulation depends on two factors, (1) pressure, and (2) area of stimulation. Afferent information is transmitted via complex electro-chemical routes into the initial stage of sensory stimulation. Ignoring the complex nature of physiological process one can abstract a simplified psychological concept of information starting within the model.

7C4 BRIEF STORAGE

Information from the visual stimulation stage is transferred from primary physical input and a number of features from the stimulus are initially coded in a number of parallel processes. Simultaneous coding of a large number of visual features into brief store is an almost immediate process. Representation of the stimulus in brief visual store is visually coded at this stage. Content of brief visual storage is directly related to the frequency and duration of saccadic eye movements, a minimum of 250 milli seconds, (according to Haber and Hershenson) in which time, visual representation is registered. During each saccadic movement representations from previous fixations are lost due to either rapid decay during the period of eye fixation or the suppression of visual sensitivity during the movement. It is theorized that brief visual store is of such transient nature and has such a relatively small store, that any new fixation erases the previous saccadic input. For exposure duration in the visual field of less than 250 milli seconds, an automatic persistence mechanism extends the duration to 250 milli seconds. Quality of representation deteriorates over this time and has totally faded after 250 milli seconds.

For perception to occur the perceiver has approximately 250 milli seconds in which to process the content of the initial visual representation so that information can be transformed to a more stable temporary store.

Similarly brief auditory storage reacts in the same way, information is initially transferred in the auditory stimulation stage where a selected number of features about the stimulus are coded in a number of parallel processes. Simultaneous coding of a large number of auditory features into brief auditory store is an almost immediate process. Representation of the stimulus in brief, auditory store is coded auditorally. Content of brief auditory storage is related to the attention and kind of information being presented. Evidence from dichotic listening tasks indicates that a refractory period of approximately 100 milli seconds is necessary for phonetic coding to take place. Auditory representations are thus registered. Representations are lost from this stage either as a result of rapid decay or suppression of auditory sensitivity on a fixed cycle basis. It is also theorized that brief auditory store is of such a transient nature and has as such, a relatively small store, that new information erases previous information. Again, if exposure duration of the auditory field is less than 100 milli seconds, then an automatic persistence mechanism extends the duration of the brief auditory echoic storage to 100 milli seconds. Quality of such representations deteriorates over this time and has faded away after 100 milli seconds.

For perception to occur, the perceiver has about 100 milli seconds to process the content of the initial auditory representation so that the information can be transferred to either a more stable temporary store or a permanent store.

7C5 IMAGE

After or during the process of the construction of an image in short-term memory, either immediately or very rapidly after the construction of a representation in short-term memory, a visual, auditory or kinesthetic image is sometimes constructed. The importance of these images is that they serve as a foci for selective attention and also give a representation that is amenable to further scrutiny or modification.

7C6 SHORT-TERM MEMORY

Incoming information reaches short-term memory storage from two routes, namely Brief-Storage and Long-Term Memory. It is contended that incoming information is encoded into either conceptual or linguistic representations prior to construction of an image.

That short-term memory is not a permanent store is self evident, what is more problematic is the duration of storage in short-term memory and what happens to existing representations when additional information enters. Therefore information in short-term memory requires a storage duration which permits either encoding into long-term memory or an immediate response. The duration of information in short-term memory may obviously be extended by rehearsal. Constant rehearsal maintains the information until it can be transferred to long-term storage, or used and forgotten. The duration of the storage in short-term memory is considered to be in the region of a few seconds without rehearsal.

7C7 LONG-TERM MEMORY

Long-term memory is the longest lasting information store, with a storage duration which is theoretically permanent, but which for practical purposes is arbitrarily defined as longer than five minutes. According to the model proposed, long-term memory comprises four major sections which theoretically can each be subdivided indefinitely to account for interactive processes within each major section. The concept of levels of processing is central to the model; and particularly to investigation of long-term memory.

7C8 LEXICAL STORAGE

This part of long-term memory consists of rules which are used to combine and compare features which have been isolated at brief storage stage. Lexical storage is the first theoretical level within long-term memory and is considered to be a surface process.

7C9 SYNTACTIC STORAGE

By contrast, this level of long-term memory consists of rules for constructing and recognizing groups of letters. It may come into function either in grouping single letters into letter clusters or morphemes or in relating single words to each other within sentences.

7C10 SEMANTIC STORAGE

At the semantic level single words, word groups, phrases and sentences are analysed and the raw data in the form of linguistic code are related to meaning. The smallest unit of language is given meaning via a highly complex routing within the overall semantic store. Interpretation of component parts is facilitated at this stage. Context enables increasing accuracy to be given to incoming stimulus, cross reference takes place at ever increasing depths.

7C11 EPISODIC STORAGE

Episodic storage is theoretically situated at the deepest levels and encompasses groupings of events and acts as a store for factual information, concepts and events. Access to the lower levels is predicted by access through the more peripheral levels. For efficient use of this level active use is made of cross reference and access to prior formed random associations.

7C12 OUTPUT RESPONSE ORGANIZER

This part of the model is concerned with the output from the perceptual information process system. All information decisions require a motor programme to make them manifest responses. The organization of the motor programme again takes a finite amount of time to choose the appropriate response to be generated. It is the culmination of the information processing system, and as such is particularly susceptible to previous failure in dealing with information at earlier stages.

7C13 INTERCONNECTIONS

Incoming information is perceived as some form of physical stimulation. From this incoming stimulation certain key features are extracted in a parallel process, these features are stored for a longer duration in short-term memory where, on the basis of information from the lexical store they are perceived as a larger meaningful unit, such as a letter. Similarly in short-term memory these letters are remembered in their order and again, on the basis of information from the lexical store in long-term memory, they are organized and perceived as letter clusters or syllables. It is at this point that the representation in short-term memory is matched with information in the semantic store to see whether the letter cluster has a meaning. Similarly the syllable or letter clusters are grouped into words. By the same process words are blended into phrases and sentences whose meaning is stored in episodic memory or an output response is organized and executed. What has been described is a simple process of decoding written information (reading). There exists a theoretical relationship between the notion of time, interconnections and depth. Greater depth is achieved with increasing time.

The reverse process, encoding (spelling) starts off with an idea generated in episodic storage which has to proceed through the semantic, syntactic and lexical stages before arriving as some form of representation in short-term memory which is then organized as an output response. This encoding process relies heavily on an external feedback loop which enables the encoding process to be monitored by the decoding process which has just been described. The notion of stimulus duration and progressive fading from each stage is an important consideration in as much as the process can be subdivided. On the one hand there is the stimulus and on the other the time.

7C14 EXTERNAL FEEDBACK

For all encoding tasks external feedback is a necessary process as it allows monitoring of information being generated at each stage and level. On the model detailed here encoding processes are represented by a dotted line and appear at first glance to be a less complicated process. However, it is contended that for encoding to take place there must be external feedback of the information at each stage so that before a motor response is made encoding can be checked and modified if necessary. Time is a vital pre-requisite for both decoding and encoding processes and the notions of time and depth are inextricably linked in the model. Time allows access to increasingly deeper levels and with it comes greater potential for cross referencing.

It is suggested that dyslexics cannot utilize external feedback as efficiently as their non-dyslexic counterparts.

7CI5 EVALUATION OF THE MODEL

It is contended that this model is capable of giving a greater insight into the dyslexic's problems with reading and spelling and that it includes all modalities. In this respect it goes further towards understanding of the dyslexic's handicap. It accounts for visual, auditory and tactile channel input and as a result of this, enables the application of an educational concept of multisensory remediation to take place. The model incorporates the concept of levels of processing and certain parts of the information processing model used by Haber and Hershenson. Further, the model provides a well developed framework within which the problems of the dyslexic child can be explained. The central point is that of the dyslexic suffering from a limited channel capacity which is manifested in a poor short-term memory. It is contended that this is because of a lesser potential within that store than the non-dyslexic individual. Because of a limited short-term memory the dyslexic has difficulty in progressively accessing deeper levels of processing. It appears that limited channel capacity, specifically into and out of short-term memory, is the central causative factor. However, it can also be surmised that this initial lesser input-potential also affects all other levels, but is a major problem in short-term memory where highly efficient processing is essential, because a large number of operations have to be carried out over a very short time duration and 'time' is a 'critical factor'.

The dyslexic has a smaller input capacity because of a number of factors already enumerated in earlier sections. This affects every stage of the theoretical model in as much as each and every stage and level has a lesser total potential capacity available to deal with incoming stimuli. This is in essence the central weakness which faces the dyslexic. What does emerge from research evidence contained in this thesis is the vital part that short-term memory plays in allowing greater cognisance of the dyslexic's processing efficiency. It appears that even allowing for a lesser potential in the very first stages of the model, no major problems appear to result in progressive breakdown of processing efficiency. It is not until short-term memory store is accessed and has to handle progressively increasing amounts of information that the major problems occur. On the model advanced it will be noticed that a multitude of output and return routes is shown in short-term memory store. It is at this stage that dyslexics are unable to cope with both an increase in short-term memory loading and what amounts to a decrease in time available to manipulate, sort and order major increases of information. At this stage in an attempt to overcome increasing chaos, either strategies occur or progressive failure ensues. Strategies may include concrete aids such as the use of physical aids, e.g. fingers to aid in holding information or rehearsal by way of restating in an attempt to maintain an 'anchor point' while successive manipulations occur. If this is not executed then natural refining of information occurs by way of selection of pointers and information loss occurs. When this happens there is a reduced trace and access to increasingly deeper levels of processing is barred or inadequate for accurate recall to follow. Fading of memory trace occurs even with the additional aid of rehearsal if the memory loading is too great to cope within short-term memory. When this happens it is surmised that progressive memory fade results in errors ranging from marginal to severe.

7C16 DEFINITION

Arising from the research undertaken, a definition of dyslexia, taking into account the findings, is possible, viz: "Dyslexia is experienced by children of adequate intelligence, as a general language deficit which is a specific manifestation of a wider limitation in processing all forms of information in short-term memory, be they visually, auditorally or tactilely presented. This wider limitation exhibits itself in tasks requiring the heaviest use and access to short-term memory such as reading, but particularly spelling. This limitation can have a multiplicity of causes (e.g. genetic, or birth trauma) and observable effects (e.g. clumsiness, reversals and bizarre spelling). It may make sense in a number of circumstances to talk about subcategories of dyslexia, e.g. genetic dyslexia, traumatic dyslexia, visual or auditory dyslexia if it helps in the diagnosis, prognosis and most importantly remediation of the symptoms of this general limitation. The choice of these subcategories does not detract from the use of the term dyslexia to describe this general language deficit, as dyslexia is a polymorphous concept."

7D IMPLICATIONS FOR TEACHING DYSLEXICS

The research undertaking in this thesis was twofold; (1) to look in depth at the dyslexic's information processing abilities and to see to what extent some underlying central factor could account, contain and go further in explaining the multitudinal grouping of observable symptoms, and (2) to use the research findings in furtherance of understanding and to seek more efficient teaching methods and strategies.

For very young children in the process of acquiring the prerequisites of reading subskills it is observed that they make many 'dyslexic type' errors in their first attempts at reading and writing e.g. reversals, inversions, substitutions and omissions; they have poor directional sense and short-term memory facility is limited.

The ability to make finely differentiated choices from all modalities is observed to affect the young child. Initially gross motor activities together with gross visual and auditory responses are made. However, with both cerebral and physical maturation processes, what initially is confusion becomes clear. The child increasingly makes more sense of his immediate environment progressing through a number of well documented stages until he is ready to make what can only be termed the mammoth step from a world of concrete solid concepts to the once removed area of language. The child's ability to cope with abstractions is limited initially and this is observed especially when items to be held in short-term memory are of an abstract nature, once removed from concrete concepts, and are also ambiguous in form, orientation and position in space. Lenneberg (1964) considers that our acquisition of language is our 'first symbol system' and one which is gradually acquired during the child's natural development. Language must be mastered if communication at anything above a very basal level is to be attempted. Language enables the child to deal in increasingly richer abstractions and the use of the model of 'Levels of Processing' is implicit in this with a gradually increasing potential for both depth and spread as maturation progressively takes place.

A process twice removed from concrete concepts is that of the written word. Language is represented through a sophisticated system of arbitrary abstract symbols which are codified to form our written language.

In the maturational process of the acquisition of both reading and spelling development in the young child it is a normal and observable fact that, as the child's cerebral maturation takes place, so the various intricate subskills of the fluent processing of information needed in reading and writing are acquired. All children naturally pass through a phase when cerebral integrational facilities are immature and not fully established. At this stage the child's short-term memory facility along with other cerebral maturational dependent skills is limited.

The concept of a short-term memory deficit can be illustrated in as much as the young child has a weakness at this stage in holding large amounts of information, particularly if the information to be held in memory store is of an arbitrary symbolic nature. The four, five and six year old child, because of this normal initial limitation, makes many errors enumerated above. Because of immature cerebral processes, the child, in an attempt to accommodate information held in short-term memory uses, it is surmised, strategies which cause them to make mistakes. While trying to hold information, clarity and detail suffer because of memory fade and ambiguity of the symbol, i.e. 'b' becomes 'd' in as much as the child knows there is a straight line ' ' with a loop 'C'. It is observed that the child may make any combination of response, e.g. b, d, p, g, or q. These errors are made in the normal acquisition of reading and writing fluency. However, by the time the non-dyslexic child has reached the age of 7 or 8 years these responses have largely disappeared because continuing cerebral maturational processes have developed to the extent that an integrational hierarchy and short-term memory is established, an increasing fluency is facilitated.

The contention is, that for the dyslexic child, this cerebral maturation and the establishment of an integrated hierarchy is not facilitated. Further, this is centrally linked to a measurable deficit in short-term memory which is a pre-requisite for the fluent processing of information particularly arbitrary symbolic information and generally any information. This deficit in short-term memory is central and affects all modality reception of information so that for the dyslexic the problem is one of amount of information over time.

The non-dyslexic child goes through stages which produce effects exactly like the dyslexic child but the major difference is that for the dyslexic child the passage through this phase is never completed. The concept of a maturational lag is valid and is well documented in research literature. However, evidence presented in this piece of research suggests that by the age of 13 any maturational deficit which interferes with the fluent processing of information will remain.

From research evidence presented here and experience gained in teaching the dyslexic, a salient point arises, namely, the need for the teacher involved in the teaching of the dyslexic to have an understanding of the various processes which are needed by the potential reader. There is an inherent need for structure and logic, with infilling at each step so that the concept might be fully grasped. The teacher should be cognisant of the problems faced by dyslexics. There is need for individual concrete steps to be taught. For instance, where grapheme phoneme correspondence are linked and understood and where the component parts of the 'bricks' of language are made. Strategies can play an important part in the overall process of helping the dyslexic child. Because the dyslexic child has a limitation in short-term memory he is unable to handle increasingly large amounts of information in decreasing amounts of time. There is a problem of information load over time expressed thus:

$$\frac{\text{Increasing information load}}{\text{Decreasing time}}$$

The information should be 'chunked' e.g. listing for word learning will aid in this connection. For example, s-p-r-i-n-g is made up of six individual letters and implies the use of six 'bits' of information to be held in short-term memory store. By lumping 'spring' into two 'bits' it becomes a lesser load e.g. 'spr' - 'ing'.

The idea of information 'chunking' is not new, we have a number of such devices, e.g. mnemonics which can be used to good effect by the dyslexic. Perhaps the main point is that of lessening the loading in short-term memory. This can be attempted in a number of ways. The use of programmed learning, much in favour in the mid-sixties, now gathering dust in many educational spheres, is raised by the findings. The main object of programmes was to take the individual along a structured line of detailed, logical and sequential information so that at each stage the previous step was reinforced and used in furtherance of information. Each step was directly related to the previous and the following step. Information to be held in memory store was limited at each step, or seemingly so, and yet at the end of the programme a test was given to further reinforce learning. One of the criticisms of programmes was that they tended to be boring and one could not 'jump' places if one grasped a concept or point quickly. Such criticism may well be justified for the non-dyslexic child, but for the dyslexic 'Programmes' offer a way of gaining information in a highly relevant manner. Information 'loading' is kept to small 'bits', it is presented in a logical sequential manner and most importantly it reinforces each stage before moving to the next.

Similarly the use of all reception modalities is mooted. Because of a short-term memory deficit the dyslexic may well need greater 'information input', this means that because of the short-term memory deficit efficient use of one modality may not result in a sufficiently strong memory trace to counteract the rapid memory fade. It seems reasonable to use all reception modalities in an attempt to 'punch' information into that part of long-term memory which one is attempting to utilize in a highly efficient manner so that response from it is almost automatic. The use of the word 'punch' is important in that for the dyslexic child of secondary school age there is much to be attempted if amelioration of their difficulties is to be attempted. In this connection another piece of hardwear comes into its own in the teaching of the dyslexic. It is the Synchrofax Audio page which can be tailor made for the individual. It utilizes both visual and auditory modalities and use can be made of tactile modality if one so desires. In this way a strong input is generated. The programme runs for only four minutes, yet in that time many different items can be programmed. Further, the child can re-run any part of the programme to aid memory or to reinforce a point.

Often incorrect cognitive styles will have become ingrained. The child will have, if he/she has one at all, an ingrained cognitive trace of probably the incorrect spelling or word. Some "trigger," it may have a confused "look say" I.T.A. or phonetic approach as its basis, or in all likelihood a 'mix' will invariably produce an inaccurate spelling, written or oral response. To overcome this, a very strong trace must be used instead. Initially possibly greater confusion will result. However, this usually diminishes in due course as the new trace is 'punched' into memory store.

The use of all modalities to facilitate this is obvious. The central point is that information should be restricted to small logical sequential 'bits'. Flash cards are just such a principle to maintain a small information load.

Abstractions relating particularly to language are almost impossible for the dyslexic to master without a thorough understanding of the processes involved. It is vitally important for the dyslexic child to have an understanding of the reasoning involved in abstraction otherwise the mysteries of English are never unravelled. Dyslexics' patterns of learning appear to be irregular. In many cases they seem to have great difficulty in building on and establishing relationships on already learned data. These observations fit into the analogous model presented, that of outstretched fingers with infilling needed.

The size of the problem has been noted in chapter 1 and certainly there is no doubt that a problem does exist. The government's interest in adult literacy highlights the concern felt, but although the idea is laudable, the reality is that it is like 'bolting the stable door after the horse has fled'. The ideal and logical answer would appear to be to look for the child at risk in the infant and primary school. A progressive system of screening should be made available. Research evidence presented suggests that dyslexics are less efficient information processors. There is a positive correlation between processing efficiency and reading and spelling levels. A screening programme could be usefully constructed and would enable those children 'at risk' to be identified at an early age.

7E THE PROBLEM OF INTEGRATION

There appear to be a number of factors which cause problems of integration of information relating to research findings in the field of dyslexia, viz:

(a) disciplines with conflicting aims and status,

(b) other interested groups, i.e. administrators, politicians, advisers, teachers and parents,

(c) the child.

Outlined in chapter one was the fact that from differing standpoints and disciplines came an apparent confusion of views. Each viewpoint was from an area of acquired learning and this indubitably affected the perception, understanding and interpretation of the perceived phenomena. Data available from differing disciplines, for example, the medical, neurological, behavioural, sociological, educational and psychological all presented their own information related to that discipline. In the past each discipline had remained to a considerable extent isolated from the others in its communication of information and this situation had been used by the antagonists to great effect to confuse, mislead and hamper those individuals who sought a rounded, informed, total view.

The inherent problems of attempting a global, rational, integrated approach to dyslexia, a highly complex human phenomenon, was obvious and these difficulties had resulted in failure in the past. Until such time as the information presented by each discipline was integrated into a universally acceptable concept of dyslexia, one which superseded, contained and adequately accommodated all preceding definitions, the problem would remain. The antagonists would use the diversity which exists to confound the important search for clarity of definition. Tizard (1972) used this very diversity to dismiss the enormous amount of objective information. He dismissed dyslexia on the grounds of diversity.

The Warnock Report published in May 1978 spoke of integration of children with special educational needs and encouragingly related the dyslexic child to the whole field of special education with many other groups of children who had learning difficulties. Dyslexics were seen as part of a very much larger group of children with learning difficulties. Mary Warnock made specific reference to the assessment process. The process was not just one of assessing or measuring a disability, rather it should have given access to the education appropriate to the child's specific needs. The outdated system of statutory categories of handicap were abandoned in favour of specifying the actual needs of the individual child.

Mary Warnock's realistic view was that the required coherent teaching system did not exist and there was a need for appropriate teaching needs to be organized. She made reference to the need for a concerted effort to establish the 'dyslexic profile'. She advocated urgent priorities:-

> "One set of proposals demand instant action; (1) initial training of teachers, (2) in-service courses of a year's duration, (3) in-service training of a more specialized kind related to teaching children with special educational needs. Of course, unless these three aspects of training are all looked after, debates about the improvement of special educational needs will become so many idle words."

There had in the past been the situation where evidence in a logical objective manner had been presented only to be dismissed subjectively under the guise of empirical objectivity and the resultant misinterpretation of the concept for political ends.

7F FURTHER RESEARCH

Arising from the research undertaken in this thesis are a number of points which beg to be answered in further research.

1) There would appear to be need for longitudinal research to investigate further the parameters of the dyslexic's short-term memory deficit and limitation in accessing increasingly deeper levels of processing and to test whether the concept of a maturational lag is valid. Evidence suggests that there is a correlation between dyslexia and the concept of a maturational lag. This effect is substantiated by the experiments contained here and this appears to be a possible area for further research to clarify the matter. Certainly the area for detailed research suggests itself to be from the ages of 9 - 15 where learning skills are increasingly put to good use by children.

2) Further investigation of the proposed model of information processing to see whether it is able to explain adequately the full panoply of phenomena associated with dyslexia.

3) Investigation of long-term memory, specifically syntactic and semantic levels with specific reference to the concept of the dyslexic's general language deficit.

4) In an attempt to provide a method of screening for dyslexia, further research is needed, using information gained from researches into short-term memory. Could the use of a simplified tachistoscopic test using digits, letters and symbols aid in this direction?

5) There would appear to be a need for an extended programme of research to investigate strategies used by both non-dyslexics and dyslexics in an attempt to aid our understanding of strategies used so that we may further aid the child.

In retrospect, it would have been useful to have larger groupings of dyslexics and to have had two distinct groups for the auditory and memory experiment. However, this was not possible within the limits imposed by the available dyslexics to hand for investigation. Further, the apparent increase in manual dexterity as the subjects became older and the relationship of this to maturational processes needs to be further investigated.

Finally, closer links and better communications need to be established between those working in academic research institutions and those in educational fields so that research findings can aid in the understanding and remediation of the dyslexic child.

To have arrived at the end of this piece of research seems a contradiction in as much as the end of this thesis is really the beginning of further research in an attempt to answer the many questions that have been raised. In this respect the end is really the beginning.

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