The early identification of dyslexia

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Summary

The objective of this study was to develop a screening test to identify children at risk for dyslexia at four or five years of age. A battery of tests, based on recent theoretical developments in dyslexia research, and including measures such as tests of IQ, phonological and motor skills, and reaction time, was administered to 91 children (including a small group with dyslexic parents or siblings) at the age of four and five years. Subjects were followed up at 6.6 and 7 years, and a group of dyslexic children were identified. Following analysis of differences in the performance of dyslexic and non-dyslexic subjects, a number of measures of phonological skills, fine motor skills and memory were combined to form the Screening Predictive Index (SPI). It was found that early identification of dyslexia was possible at moderate levels, however limitations in the selection of outcome groups may have reduced accuracy of prediction. In addition, slow learners were found to have performed similarly to the dyslexics on the SPI and therefore, to increase the accuracy of prediction, a further set of tests were combined into an annex to the SPI - the Screening Predictive Index (II). Background information was also studied. Theoretical issues concerning the early manifestations of dyslexia and the relationship of dyslexia to other forms of poor reading were examined. The findings of the study supported the existence of deficits in phonological skills in young children with dyslexia, and also difficulties with fine motor skills. However, no clear support for any of the existing theories of dyslexia was found. Further evidence of measures that distinguish dyslexics from slow learners, such as tests of cerebellar function, may be required for the accurate early identification of dyslexia.

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Chapter 1

Introduction

Preview to the chapter

There can be no doubt that significant advances have been made in the field of dyslexia research over the last ten years. However, although we are almost certainly moving towards a complete explanation of this controversial disorder, it has not yet been achieved.

The study described in this thesis has attempted to contribute to our existing knowledge about dyslexia on both a practical and a theoretical level. The major goal of the study was to devise a method of identifying children with dyslexia at a relatively young age (4 or 5 years), before they have chance to encounter repeated failure to develop written language skills. Current methods of diagnosis of dyslexia have tended to be implemented only when no other explanation for the child's failure to learn to read and spell can be accepted, often around the age of ten or eleven years. Evidence has revealed a range of negative outcomes following diagnosis at this late stage.

However, before one can begin to design a test which can be used to identify young children at risk for dyslexia, there has to be an understanding of the nature of the condition to be predicted. Therefore this introductory chapter presents a review of the concept of dyslexia and what is known or believed about it at this point in time. This review focuses on a number of main issues: the relationship of dyslexia to other forms of poor and normal reading and current theoretical explanations for the disorder.

Much of what is known about dyslexia today can be viewed in a historical context, and indeed this chapter begins with a brief outline of the early discoveries of the disorder over one hundred years ago. Coming to the present day, the concept of dyslexia is then discussed with respect to important but controversial issues such as definition, terminology, characteristics, incidence and subtypes. This is followed by a review of the major theoretical explanations of dyslexia and the recent research which has contributed to them. Recent genetic and neurological discoveries are discussed along with cognitive accounts of dyslexia such as the phonological deficit hypothesis, temporal processing deficits and the dyslexic automatisation deficit hypothesis.

This chapter, therefore, attempts to set a theoretical background for dyslexia against which to interpret the design and outcomes of the present study. In the following chapter, practical issues in dyslexia are considered, as current approaches to diagnosis and remediation are outlined. Limitations in these approches are discussed and detailed information regarding the specific issue of early identification of dyslexia is presented.

1. Reading and dyslexia

The acquisition of written language skills is a goal that is seen as attainable for many children across the world. Access to education allows the child to develop the skills necessary to read and spell so that they are able to seek and write about a wealth of information during their school years and beyond. Pumfrey and Reason (1991) point out that "Literacy and numeracy are amplifiers of human abilities ... They matter because they facilitate communication and the control that we have over our environments" (p. 3). The importance of written language skills cannot be underestimated as they are often viewed as an indicator of a child's general abilities in all areas. Bryant and Bradley (1985a) observe that "Of all the things that children have to learn when they get to school reading and writing are the most basic, the most central and the most essential" (p.1).

Exactly how children learn to read is still a controversial issue and a number of theories continue to develop (see, for example, Adams 1990; Frith, 1985; Goswami and Bryant, 1990; Goswami and Mead, 1992). However, experience shows that many children are skilled readers by the age of around seven years, often regardless of the amount or type of language teaching they have received. In light of this it is surprising, therefore that "Despite well over 100 years of compulsory education in the United Kingdom, we have failed to achieve the "universal literacy" so optimistically planned in the 1870 Education Act." (Thomson, 1991, p1). For some children who experience difficulty in learning to read, their problems are not unexpected, as such children may have problems with general intellectual functioning as expressed by low scores on standardised IQ measures and difficulties with all aspects of the educational curriculum. For other children, however, the failure to learn to read and spell may be a great deal more surprising as they are found to be intelligent, motivated and alert, and performing well in other aspects of their schoolwork. A number of different terms have been used to describe these two groups who collectively can be referred to as "poor readers". Children whose general level of intellectual functioning is lower than average are often referred to as "slow learners" in contrast to children whose written language difficulties exist in the presence of average or above average general abilities who may be referred to as "dyslexic" or as having "Specific Learning Difficulties".

Bryant and Bradley (1985a) suggest that the problem of poor readers poses two major questions: how to help the children who have already been identified as poor readers and how to prevent problems arising in the first place?

A relatively large body of research has been devoted to studying children who have been diagnosed as dyslexic, yet relatively little has been done regarding *prevention* of the problems associated with dyslexia. However, the focus of this thesis is the second of the two questions. The reported study has investigated the prevention of children's reading problems on the basis of prediction of future reading performance. The specific goal of such an undertaking is the early identification of *poor* readers, particularly those with dyslexia. However, this is not an easy task, it is a task which is fraught with theoretical and methodological problems, many of which will be discussed in this and the following chapter.

Accurate prediction and early identification of reading difficulties such as dyslexia needs to be based on a thorough understanding of the various issues involved. The first of these issues is an understanding of the disorder itself. However, as the opening sentence of this chapter indicates, a comprehensive and unanimously accepted account of the disorder has not yet been formulated. Therefore instead of this chapter simply explaining what dyslexia is and what it is caused by, the various lines of evidence that have contributed to our present understanding of the disorder are outlined, as it is on the basis of this information that the reported study was designed. Much of our understanding of the nature of dyslexia has come from information recently obtained, however, the findings of those who first stumbled upon the disorder have also provided important contributions to our knowledge. It is to the initial discovery of dyslexia that we now turn, as the origins of the concept are reviewed.

1.1 The historical context of dyslexia

1.1.1 Early discoveries about brain injury and aphasia

The historical context of what has come to be known as "dyslexia" is a medical one. By the mid-Nineteenth Century it had been established that brain injury could result in disorders of thought and speech - a phenomenon referred to as "aphasia". Developments in early knowledge of the brain, such as those by Broca (1861) encouraged speculation regarding brain function and the effects of neurological damage or disorder (Miles and Miles, 1990). A number of accounts of difficulties with language following head injury were written during the late nineteenth and early twentieth century, one of the first being that of Kussmaul, a German Physician, in 1877 (Thomson, 1991). Kussmaul wrote about a specific form of aphasia resulting in the loss of the ability to read which he referred to as "word blindness". This disorder referred not to a literal lack of facility with the senses, but to a more subtle perceptive difficulty: "He saw the text, but did not understand it" (cited in Miles and Miles, 1990, p. 3) Berlin, in 1887 was the first to refer to this disorder by the name "dyslexia".

1.1.2 Congenital Word Blindness

Following the establishment of forms of aphasia or word blindness as a consequence of brain injury, further evidence pointed to the possibility of a congenital form of the disorder. In 1895, James Hinshelwood, a Glasgow eye surgeon wrote a note to the Lancet on the subject of word blindness and visual and memory in adult aphasics (Pumfrey and Reason, 1991). This prompted Pringle Morgan, an attending physician to a preparatory school in the south of England, to write in the British Medical Journal of a 14 year old boy, Percy. The article was entitled "A Case of Congenital Word Blindness" and the observations made of Percy by Pringle Morgan strike a chord with those who are familiar with dyslexia today.

> "Percy F...has always been a bright and intelligent boy, quick at games, and in no way inferior to others of his age. His great difficulty has been - and is now - his inability to learn to read. This inability is so remarkable, and so pronounced, that I have no doubt it is due to some congenital defect.....In spite of....laborious and persistent training, he can only with difficulty spell words of one syllable."
>
> (Morgan, 1896, quoted in Miles and Miles, 1990, p 4))

Percy was found to make spelling errors such as "soojock" for "subject" and "seasow" for "seashore". He even made a mistake in spelling his own name, writing "Precy" for "Percy". At the same time, James Kerr, Medical Officer of Health for the City of Bradford made the same discovery as Pringle Morgan, although independently of him, as he described the existence in local schools of pupils who appeared to show "congenital word blindness". James Hinshelwood also wrote extensively on the subject from 1900 onwards. In 1917 he referred to the disorder as:

> "a congenital defect occurring in children with otherwise normal and undamaged brains characterised by a difficulty in learning to read so great that it is manifestly due to a pathological condition and where attempts to teach the child by ordinary methods have completely failed." (p. 40)

He also observed that this defect could be hereditary and was found more commonly in males than females.

1.1.3 The work of Samuel Orton

During the 1920's, an American neurologist, Samuel Orton proposed that understanding of the congenital disorder could be assisted by the study of acquired neurological conditions. He rejected the term "congenital word blindness" in favour of "strephosymbolia" (literally meaning "twisting of symbols") as he said "there is no true blindness for words" more a "tendency to distorted order in the recall of letters shown in the attempts of these children to read a word or to spell it." (Orton, 1937, p 71)

Orton hypothesised that for some children reading difficulties were the symptom of a failure of one of the hemispheres to become the dominant control centre for speech, language and motor functions (Orton, 1925, 1937). His ideas focused largely on the "reversals" (letters, words) observed in speech and written language in such children. Orton's experience with over 1000 dyslexic children led him to devise flexible guidelines for intervention, which have been incorporated into modern remedial programmes. Following his death in 1948, Orton's significant contribution to dyslexia was marked by the foundation of the "Orton (Dyslexia) Society" in the USA, a charitable organisation concerned with the promotion and research of dyslexia.

1.2 Contemporary approaches to dyslexia

The above review of the discovery of dyslexia highlights an important point regarding the concept of dyslexia: the relationship between developmental and acquired forms of the disorder. It is perhaps important at this stage to clarify that it is developmental dyslexia rather than the acquired condition that is the focus of this thesis. As the work described above suggests, acquired dyslexia can be conceptualised as difficulties with written language skills as a result of head injury or neurological disease, in individuals with no previous difficulties. Developmental dyslexia on the other hand is found in children who have not suffered major head injury or brain trauma, but nonetheless display problems with reading and spelling (as well as a range of other difficulties). Research regarding acquired dyslexia has been related to the developmental condition (e.g. Castles and Coltheart, 1993).

The concept of (developmental) dyslexia now attracts the attention of practitioners and researchers from many different fields including psychology, education, genetics and neurology. However, despite considerable inquiry into the disorder over the last hundred years, the term "dyslexia" is still one which is steeped in controversy. One of the reasons for this is that despite the original conceptualisation of dyslexia as a reading and spelling disorder (and its diagnosis usually made on the basis of these difficulties), evidence indicates that dyslexia can take many forms. Indeed, Fawcett and Nicolson (1994a) have pointed out that the syndrome of dyslexia "manifests itself in many different ways, to the extent that, whatever a researcher's domain of interest, a dyslexic child will obligingly demonstrate interesting and unusual performance in that domain" (p. xiv).

One outcome of the considerable variety of difficulties observed in the dyslexic child is a failure to establish a universally accepted definition of the disorder, and lack of agreement regarding its relationship to other forms of (poor) reading. Linked to this is a problem of terminology, with disagreement about what this wide-ranging group of difficulties should be called. Attention will be given to this particular issue first.

1.2.1 What's in a name?

Decisions about the use of a particular name reflect researchers feelings about issues such as characteristics and etiology as well as the relation of the disorder to other forms of poor reading. It was seen in the first section of this chapter that names such as "word blindness" and "strephosymbolia" were used by pioneers of dyslexia many years ago. Since that time, a number of terms have been used to describe the disorder. These include, "dyslexia", "specific developmental dyslexia", "specific reading retardation", "specific reading difficulties" and "specific learning difficulties". It can be seen that a number of these terms preserve the concept of reading, or difficulty with words, whereas the term "specific learning difficulties" allows consideration of a wider range of problems. This latter term was advocated by Tansley & Pankhurst (1981) in a report for the DES and was found by Pumfrey & Reason (1991) to be the term preferred by teachers and educational psychologists in the UK. The British Dyslexia Association on the other hand, prefer use of the term "dyslexia". The labelling of a condition is not a trivial issue, for a number of reasons. Implicit in terminology are beliefs about characteristics and, from an educational-legal perspective, assumptions about provision of special services for those receiving such a label.

Miles and Miles (1990) highlight the problem of terminology and note that although those in the field use many of the terms outlined above to describe broadly similar individuals, it is not just a case of "interchangeable synonyms" (p. viii) as the children referred to may vary from one another in subtle or not so subtle ways. In reference to this thesis, the lack of agreement on appropriate terminology is extremely relevant. This is for two reasons: firstly, one of the key issues which will be addressed in this predictive study is the relationship of developmental dyslexia to other forms of poor reading, and accurate terminology is therefore needed to establish exactly who these children are. Secondly, in the following chapter a range of early identification studies will be reviewed. Such studies have one thing in common - they are attempting to predict later academic performance of children based on tests administered at some early stage. The academic skill in which most studies are interested is reading, however, a number of different terms have been used to describe the children that the studies are attempting to identify. These range from "learning disabled" to "reading disabled" to "dyslexic". In some cases such terms refer to the traditionally accepted view of unexpected reading problems, whereas in others, any child with poor reading is included.

This issue of terminology and what it stands for is an important one in this thesis and will be returned to at a number of points. However, it should be noted that the general policy of this thesis is to use the term "dyslexia" to refer to the disorder under investigation (unless work cited uses alternative terminology) and to discuss it in relation to other forms of poor reading (slow learners or "garden variety" poor readers) and normal reading. The definition of such terms is outlined below, along with the controversies that currently exist regarding the relationship between these three forms of reading ability.

1.2.2 Definition of Dyslexia

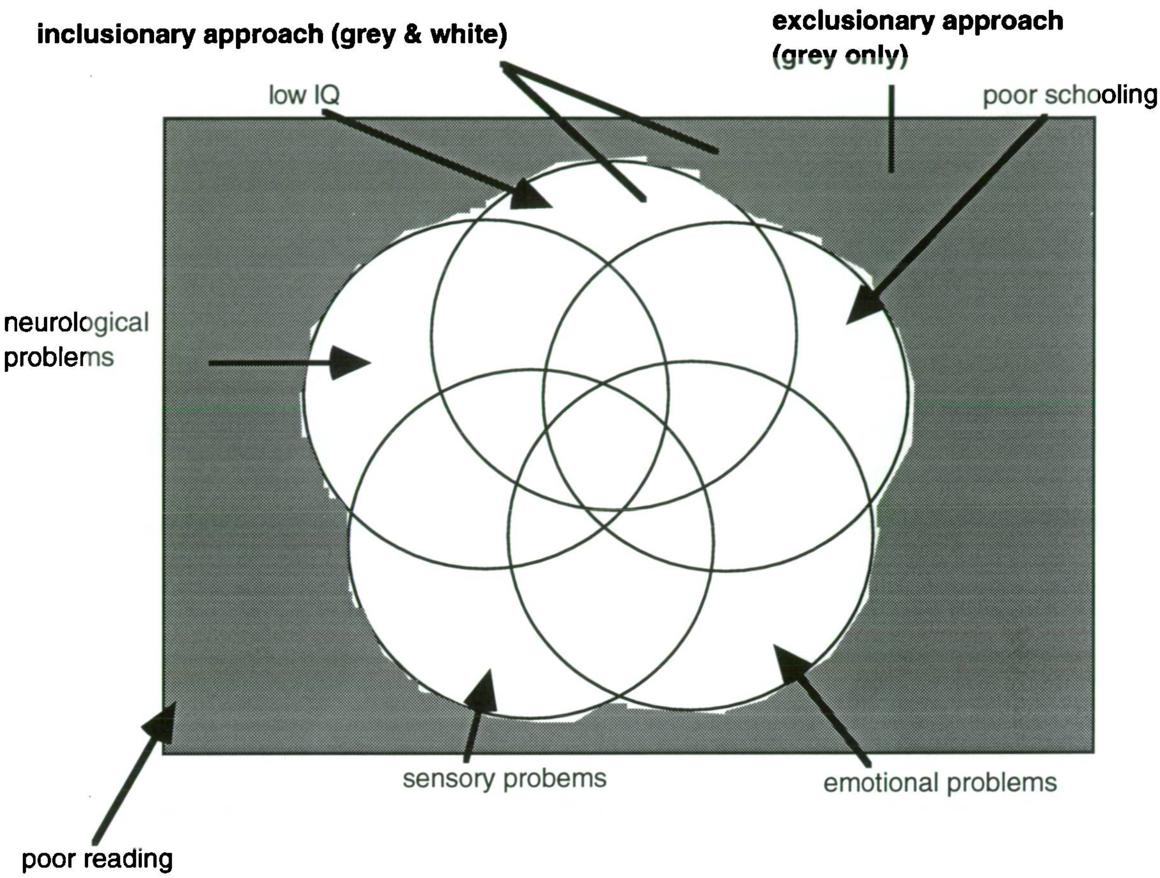
Simple interpretations of the term "dyslexia" could be "faulty reading" or "unexpected reading difficulties". The word can literally be translated as "dys" - difficulty and "lexicos" - pertaining to words (Brewster-Clark, 1988). However, as a psycho-educational concept, the definition of dyslexia has far reaching consequences for the diagnosis of individuals with the disorder. It is for this reason that a number of definitions have developed, not only to assist with understanding of what dyslexia actually is, but more as a sort of checklist for use in diagnosis and provision of educational services.

Brewster-Clarke (ibid) has observed that "a unanimously acceptable definition for dyslexia has not yet been formulated" (p. 17), however, a number of definitions are more widely used than others. One definition which has formed the basis for many subsequent formulations of dyslexia is that of Critchley and Critchley (1978). It states that:

> "Developmental dyslexia is a learning disability which initially shows itself by difficulty in learning to read, and later by erratic spelling and lack of facility in manipulating written as opposed to spoken words. The condition is cognitive in essence, and usually genetically determined. It is not due to intellectual inadequacy or to lack of sociocultural opportunity, or to emotional factors, or to any known structural brain deficit. It probably represents a specific maturational deficit, which tends to lessen as the child gets older, and is capable of considerable improvement especially when appropriate remedial help is afforded at the earliest opportunity." (p. 149)

This definition is a good example of an "exclusionary" definition of dyslexia - an individual is assumed to suffer from dyslexia if the observed written language difficulties cannot be explained by other factors such as poor schooling or low IQ. Such a definition also indicates that a child who has lower intelligence or emotional problems is unlikely to be viewed as dyslexic. "Inclusionary" definitions consider dyslexia to be poor reading regardless of factors such as low IQ, neurological problems and emotional problems. Figure 1.1 illustrates the difference between exclusionary and inclusionary definitions of dyslexia.

Figure 1.1 Exclusionary and inclusionary definitions of dyslexia (Just and Carpenter, 1986)



More recently, attempts have been made to define dyslexia on the basis of positive markers of the disorder, rather than exclusionary criteria. Such definitions would be required to list the features of dyslexia which were present and observable in the individual. In the last decade the catalogue of "symptoms" of dyslexia other than faulty reading has grown, and T.R. Miles (1982) for example, formulated The Bangor Dyslexia Test based on dyslexia indicators that can be assessed as being present or absent in an individual. These include difficulties in pronouncing polysyllabic words, problems with mental arithmetic, with rhyming, and difficulties saying the months of the year, in forward and reverse order. A constructive approach to defining dyslexia needs to take into account unexpected reading difficulties, but is also able to look for short term memory, sequencing and phonological problems which have been observed in a large proportion of dyslexics. The importance of establishing positive markers of dyslexia, particularly those that are unrelated to reading and spelling is vital in answering queries about whether dyslexia may also be found in children with low IQ and other exclusionary circumstances.

The purpose for which a definition is to be used will often influence the particular details of that definition. The British Dyslexia Association (BDA), a charitable organisation concerned with the promotion and understanding of dyslexia has the following definition for the disorder:

> "a specific deficit in learning, constitutional in origin, in one or more of reading, spelling and written language which may be accompanied by difficulty in number work. It is particularly related to mastering and using written language (alphabetic, numerical and musical notation) although often affecting oral language to some degree"
>
> (BDA, 1989)

Such a definition helps to establish some of the broad range of difficulties that an individual with dyslexia may experience. Other agencies such as educationalists require a "working definition" of dyslexia that specifies a relatively concrete set of criteria by which to judge whether a person can be confidently diagnosed as dyslexic or not. Such definitions are usually of the "exclusionary" type and often make reference to a discrepancy between an individuals performance in reading and spelling and performance on standardised IQ tests or chronological age (for example, one commonly used definition characterises dyslexia as reading and spelling performance which is eighteen months to two years behind what is expected based on chronological age and IQ, in the presence of an overall IQ score of ninety or above). Such definitions are referred to as "discrepancy definitions" and are often the basis for decisions regarding special educational provision. However, more will be said about methods of diagnosing dyslexia in the following chapter.

1.2.3 Issues in the definition of dyslexia

Debates regarding how best to define dyslexia continue, with certain key issues forming the basis for disagreements. Two major issues are: the role of IQ in defining dyslexia, and the validity of considering dyslexia as being either qualitatively or quantitatively different from other forms of (poor) reading (referred to as the "question of the continuum" by Bryant, 1985). These two issues are connected.

1.2.3.1 The role of IQ in the definition of dyslexia

Since its initial discovery, dyslexia has been viewed as a disorder characterised by a discrepancy between the general ability or potential of an individual and their performance in written language skills. This discrepancy has been operationalised by the use of IQ tests and standardised tests of reading and spelling. However, recently, a number of researchers have questioned the role of IQ in the definition of dyslexia and challenged the view that poor reading children with high and low IQ scores represent distinct groups. Two key figures in this issue are Stanovich (1988, 1989, 1994) and Siegel (1988, 1989, 1992).

Presenting the case against the use of IQ scores in defining dyslexia, Siegel (1989) claims that there are a number of major reasons for rejecting their use. Firstly, IQ tests such as the WISC-R, she claims, do not measure "potential" but abilities such as expressive language skills, memory, fine motor abilities and specific factual knowledge. Such tests are not independent of reading as they measure skills which are also used in reading. In addition, Siegel argues that a number of children with low IQ's *do* learn to read, which implies that those children with low IQ's who do not learn to read "are genuinely reading disabled and do not fail to read because of low IQ scores" (p. 472). Finally, Siegel presents evidence that poor reading children with low and high IQ's do not differ in terms of, for example, their profiles of performance on the WISC-R (Smith et al, 1977), but do differ in terms of deficits in phonological processing (Stanovich, 1988) which are proposed to be independent of IQ. Therefore Siegel advocates that IQ tests should not be used in the definition of dyslexia or reading disabilities, and instead detailed analyses of specific skills and information processing abilities would be more useful. Further work (Siegel, 1992) has supported this argument by revealing no differences in the performance of dyslexic children with low and high IQ's in terms of reading, spelling, phonological processing and a number of language and memory tasks, with both groups scoring less well than non-dyslexics.

B.A. Shaywitz et al. (1992) have provided evidence in support of this view of reading disability, also finding no differences in performance on a range of measures between discrepancy (D) and low achieving (L) defined reading disabled children, except those attributable to differences in the IQ of the two groups. They argue that the use of discrepancy scores fails to account for two important points with respect to reading disabilities: the correlation that exists between IQ scores and reading ability; and the regression towards the mean often found in reading disability. The implication of the above points is that the IQ scores of many reading disabled children are often depressed as a consequence of their reading difficulties with the IQ score not being great enough for the child to be eligible for use of the term "reading disabled" using discrepancy criteria. It can be seen therefore that the use of two measures that are related to each other can result in children who should be considered as dyslexic being diagnosed as slow learners.

Another strong advocate of the rejection of the role of IQ in the definition of dyslexia is Stanovich (e.g. 1989). Stanovich believes that "At their best, IQ test scores are gross measures of current cognitive functioning" (p. 487) and criticises the notion of the "locked potential" of a child that is prevented from expression by the reading disability. Stanovich has argued that a comparison of the performance of children on tests of reading and listening comprehension may provide a better basis for defining reading disabilities. Swanson (1989) proposes that the major basis for defining dyslexia should be differences in phonological processing ability, not IQ scores.

However, there are those who continue to advocate the use of the IQ concept in the definition of dyslexia. Torgesen (1989) supports the use of IQ test scores in the definition of dyslexia or reading disabilities and argues that IQ measures are necessary to provide evidence that the academic differences (such as phonological processing and rule learning difficulties) between the contrast groups are not primarily the result of differences in general learning ability. Lyon (1989) proposes that it is not the discrepancy definition of dyslexia that is at fault but the way in which is operationalised using standardised tests.

It can be seen therefore that the issue of the relevance of intelligence as measured using IQ tests to the conceptualisation of dyslexia is far from resolved. However, the role of IQ in the definition of dyslexia represents one aspect of a much deeper issue regarding the relationship of the condition to other forms of reading ability. This issue is currently the subject of much debate in the dyslexia community and is outlined below.

1.2.3.2 The relationship of dyslexia to other forms of poor and normal reading

It has long been considered that dyslexia represents a specific syndrome that is distinct from other forms of poor reading (e.g. Critchley, 1970). This may be due in part to the unexpected nature of the observed reading difficulties and attempts to relate developmental dyslexia to the acquired form of the disorder. Research which has been carried out investigating aspects of dyslexia has tended to specifically investigated those individuals fitting the standard exclusionary criteria for the disorder, i.e. individuals with "pure dyslexia".

A number of researchers have proposed grounds upon which dyslexics can be distinguished from other poor readers. One such distinction was made by Gough and Tunmer (1986) who identified two main constituents of the reading process: decoding and comprehension, upon which they based their categorisation of poor readers. Dyslexics, they argued could be distinguished from "garden variety" poor readers in that dyslexics had difficulties with decoding but not comprehension, whereas "garden variety" poor readers had difficulties with both decoding and comprehension.

For a great number of years the distinction between dyslexics, normal readers and poor readers with low IQ scores (referred to as "garden variety" poor readers, backward readers or slow learners) was observed in theoretical and practical approaches to dyslexia. It has been assumed that dyslexia but not backward reading is characterised by a range of particular symptoms, a specific neurological deficit and a response to particular forms of intervention. However, more recently a number of researchers have challenged the traditional view of the relationship between dyslexia and other forms of poor reading with the implication that the only difference between them is the one used to differentiate the groups: intellectual ability.

Stanovich (1994) has provided a critical review of a number of beliefs regarding dyslexia which seem to have been held since its discovery. Central to his critique is the notion that the term "dyslexia" carries with it many "empirically unverified connotations and assumptions" (p. 574). Early observations of the disorder in bright children has led, he argues, to an unquestionable notion of dyslexia as a condition found only in children of a certain intelligence level and qualitatively distinct from other forms of poor reading. He believes that evidence such as that cited in the previous section challenges this idea.

Evidence that dyslexia constituted a recognisable condition different from other forms of poor reading was initially provided by Rutter and Yule (1975) who proposed that it could be viewed as a "hump" in the lower tail of a normal distribution of poor reading. However, this view has been challenged by van der Wissel and Zegers (1985) who have highlighted methodological critisisms of the study which call into question Rutter and Yule's finding. S.E. Shaywitz et al. (1992) propose that the reading measures used in the study imposed a ceiling on the performance of the children, skewing scores and giving the appearance of a "hump" due to an over-representation of poor readers at the expense of good readers.

Shaywitz and colleagues (ibid) investigated the distribution and temporal stability of dyslexia and found that "dyslexia occurs along a continuum that blends imperceptibly with normal reading ability" (p. 148). The condition was also found not to be stable over time, showing a predictable year to year variability. Stanovich concluded in his 1994 review that "the research literature provides no support for the notion that we need a scientific concept of dyslexia separate from other more neutral, theoretical terms such as reading disabled, poor reader, less skilled, etc." (p. 587). This view has also been supported by Perfetti (1986) who believes that the differences between dyslexics and other less skilled readers maybe largely quantitative rather than qualitative.

However, Badian (1994) amongst others (e.g. Horn and O'Donnell, 1984; Jorm et al., 1986), has found differences in the performance of dyslexics and "garden variety" poor readers and proposed that the "findings suggest that there are valid grounds for believing that dyslexia is a separate entity from garden variety poor reading" (p. 45). She found that although both groups of poor readers had poor phonological awareness and non-word reading, only dyslexic subjects had difficulties with automatic visual recognition and phonological coding of graphic stimuli. In addition, Aaron (1987) and Aaron et al. (1988) have proposed that dyslexia is different from other forms of reading disability. Their argument is similar to that of Gough and Tunmer in that they consider the key difference between the two groups to be that dyslexics have a specific difficulty with decoding skills whereas other poor readers' difficuties are caused by generalised cognitive deficits. Wolf and Obregon (1992) have found evidence to suggest that one of the deficits associated with dyslexia - word retrieval problems - may differentiate dyslexics and garden variety poor readers. They suggest that there is "a tendency toward more pronounced naming problems in more globally, severely impaired readers and more ambiguous naming deficits in dyslexic readers" (p. 243).

There is no definitive outcome of this debate at the present time. It is fully acknowledged that there may or may not be valid grounds for distinguishing dyslexia from other forms of poor reading, and indeed an attempt has been made in the study to investigate the nature of such differences in very young children. However, it is only possible to test the value of a distintion between poor readers with low and high IQ's (dyslexics and slow learners) if the distinction is maintained for the purposes of the study. Therefore, it is perhaps important to reiterate that the definition of dyslexia used in this thesis is based on traditional exclusionary views of the disorder as a specific deficit in otherwise bright children.

1.2.4. Characteristics of dyslexia

As the quotation from Fawcett and Nicolson (1994a) earlier in this chapter indicates (see page 7), the various characteristics or symptoms associated with dyslexia are wide ranging and considerable in number. Two major methods of establishing such characteristics are clinical observation and carefully designed experimentation. Clinical observation of dyslexia by practitioners and researchers has served to provide useful lists of features found to be common to individuals with the disorder. For example, a systematic review of the signs and symptoms of dyslexia carried out by Wheeler and Watkins (1979) found that the following features were common to over twenty descriptive accounts of the disorder.

- directional confusion
- writing and spelling impairment
- finger differentiation problems
- visual perception deficiencies
- handedness and central dominance abnormalities
- weakness in memory storage
- maternal and natal factors
- motor dysfunctions
- delayed maturation
- delayed speech development
- neurological dysfunctions
- familial or inherited disability
- sex differences
- language delays

One problem of lists such as this is the degree of specificity of the features listed. Many of the above features could be found in a number of different disorders and therefore may not help our understanding of dyslexia. A more recent review of the manifestations of dyslexia is provided by Brewster-Clark (1988). She lists decoding problems such as an inability to decode unfamiliar words, incomplete mastery of letter-sound correspondences, difficulty in grasping the alphabetic principle and learning the phonetic code, breaking down and blending component parts of words, sound sequencing errors, letter-sound confusions, reversals or transpositions; word recognition problems; inefficient use of context and reading comprehension problems; spelling problems and handwriting problems, as features of dyslexia.

Single case studies of developmental dyslexia have been presented by a number of researchers (e.g. Snowling, 1987; Thomson, 1991) providing a more detailed characterisation of the disorder as experienced by the individual. For example Chasty (1985) describes a seven year old boy of superior intelligence who suffers from motor clumsiness, writes from the left hand side of the page after beginning at the right, has poor pencil control, makes letter shapes the wrong way round and is unsure about spacing on the page. This description reveals some of the range of difficulties that a dyslexic individual may face. Case studies like these serve to "bring to life" the issues which are being addressed in dyslexia by focusing on how the condition can affect a particular child. However, clinical observations have limitations in the sense that they may create misrepresentations of the condition. Two important issues in which observations of characteristics have since been questioned are the incidence of left handedness in dyslexia and increased prevalence of the disorder in males. These recent findings will be dealt with in greater detail later in the chapter when incidence of the disorder is discussed.

A more systematic way of establishing the characteristics of dyslexia is to carry out a series of clearly defined experiments with dyslexic and non-dyslexic individuals and compare performance of the groups on the tests. The introduction of the "reading age match" design for comparing the performance of dyslexics not only with children of the same chronological age, but with younger children of the same reading level has helped to establish which differences in performance are genuinely attributable to dyslexia and those which may only be the result of lack of reading experience. Research of this type has contributed considerable information regarding, for example, the phonological deficits found in many dyslexics, rapid naming problems and speed of processing difficulties (e.g. Bruck, 1992; Denckla & Rudel, 1976; Tallal et al., 1985; Wolf and Obregon, 1992).

In terms of educational practice, definitions of dyslexia need to be easily operationalised and are often based on observations of the behaviour and characteristics of dyslexic children within the school system. Pumfrey & Reason (1991) provide a characterisation of dyslexia that was based on a policy statement on specific learning difficulties (dyslexia) originally provided by a large South of England County and later adopted by a number of other different Local Education Authorities. The statement suggests that children with specific learning difficulties (dyslexia) have one or more of the following:

- extreme and persisting difficulty in learning to read, write and spell in children who otherwise appear able and well motivated, who have not suffered from protracted ill-health, or from unfavourable environmental conditions.

- extreme and persisting difficulty in remembering and dealing with sequences, such as the letters in written or printed words, or the sound of oral words, or the sequence of words in a sentence.

- similar difficulties with sequences of numbers or with arithmetical operations.

- problems with the recognition or retention of patterns, particularly where the factors of sequence, direction or orientation are important.

- spelling errors which are particularly bizarre, unusual or distorted, and which may be wholly inconsistent and irregular or marked by systematic errors, with letter sequence (such as reversals) or which had high levels of skill that represent consistently phonic versions of words whose correct spelling is regular.

- reading errors that are characterised by the persistence of frequent omissions and tabulations of words and parts of words, hesitations and repeated amendments.

- writing that continues to be very much slower than average or to be marked by extreme irregularity of layout and presentation, or very unusual letter formation.

- a wide, often growing gap between the child's level of "conceptual" understanding, or the sophistication of his/her oral language and his/her level of performance in "technical" skills such as reading, writing, spelling, drawing, interpreting maps and diagrams, or dealing with mathematical skills involving place value or directional or sequential aspects and processes.

- the persistence of difficulties of this kind despite remedial help.

In recent years more emphasis has been given to broadening the range of characteristics of dyslexia to include not just the written language problems that are manifested but also the difficulties found with motor skills, sequencing, rapid processing of information and organisation. Symptoms which have been considered to be incidental are now recognised by many as important constituents of the dyslexia syndrome, and perhaps more importantly, require explanation as much as the language disorders. Therefore, in establishing a detailed account of the characteristics of dyslexia, researchers are set the task of attempting to discover the underlying etiology of a condition that can produce such a range of symptoms. It is also necessary to establish which, if any of these characteristics are specific to dyslexia and which may also be found in readers of other ability levels.

One way in which researchers have attempted to make sense of the range of characteristics of dyslexia and the manner in which they have been observed to cluster together in individuals, is to propose subtypes of the disorder. Evidence for and against subtypes of dyslexia is discussed below.

1.2.5. Subtypes of dyslexia

A number of approaches have been taken to subtyping dyslexia. These include approaches based on clinical observation of dyslexics and approaches involving classification of individuals in terms of performance on administered tests, often using cluster analytic techniques (Newby, Recht and Caldwell, 1993; Newman, Wright and Fields, 1989). There have also been attempts to relate subtypes of developmental dyslexia to different forms of acquired dyslexia (Castles and Coltheart, 1993).

One of the early attempts at subtyping was that of Johnson and Myklebust (1967) who proposed that individuals with dyslexia could be divided into two broad subtypes: auditory and visual dyslexics. Auditory dyslexics, it was argued, have difficulties in the discrimination of speech sounds, sound blending, naming and auditory sequencing. Visual dyslexics, on the other hand, have problems with visual perception and visual discrimination, in activities such as scanning from left to right, and recognising letter clusters.

An alternative model of subtypes was proposed by Boder (1973) and was based on an analysis of the reading and spelling errors made by dyslexics. She found that the largest subgroup (63%) of dyslexics were the "dysphonetic" or auditory dyslexics experiencing difficulties with letter-sound integration and learning phonetically. Dysphonetic children learned words holistically, and relied largely on a sight vocabulary for reading and spelling activities. The second group identified (9%) were the "dyseidetic" or visual dyslexics who, it was found, could read and spell phonetically but experienced difficulty in building up sight words and perceiving words as visual wholes. A group with a mixture of both auditory and visual difficulties accounted for 22% of the total group and a further 6% remained undetermined.

Further evidence for subtypes has been provided by Thomson (1982) who found that three groups of dyslexics could be identified using the British Ability Scales (Elliot, 1983). Similarly to the models outlined above, he proposed that dyslexics could be subdivided into auditory-linguistic, visuo-spatial and mixed groups.

Like many aspects of dyslexia, the issue of subtyping is a controversial one, with some believing firmly in the existence of subtypes and others remaining more sceptical. The models of subtypes described here are just an example of those that have been proposed. Evidence regarding the models has not always been supportive, for example, van der Bos (1984) found no evidence to support Boder's typology in terms of differences in visual and auditory memory of children in the three proposed groups. Issues in this debate also include whether subtypes merely reflect a continuum of dyslexia in terms of varying degrees of severity of the condition, and if such subtypes exist, what are the implications for assessment and teaching of individuals with differing types of dyslexia. Like many aspects of the dyslexia debate, evidence for and against the issue of subtypes still continues to develop. For the purpose of this study, it is important to bear in mind the concept of subtypes as a possibility with respect to the identification and prediction of dyslexia in young children.

1.2.6. Incidence

Estimating the incidence of dyslexia in the population requires adoption of a particular definition of the disorder and therefore proposed estimates vary considerably as a result of the different definitions used. Yule, Rutter, Berger and Thompson (1974), for example, proposed an incidence of dyslexia in the population of around 3.5-6%, whereas Satz et al. (1978) claimed that as many as 15% of the population could be found to be dyslexic. One major difficulty in establishing the incidence of dyslexia is deciding what criteria to use to define the group and therefore what cut-off to employ to distinguish dyslexics from non-dyslexics. Such a cut-off might be a discrepancy between reading age and chronological age of at least 2 years, so that all children who are less than 2 years behind in their reading would not be included in the group referred to as dyslexic. However, Thomson (1991) has pointed out that such a fixed criterion can cause problems as the number of individuals who will be 2 years retarded in reading increases with the age of the individual, so that 1% of six year olds will be reading at 2 years below their chronological age, whereas 25% of nineteen year olds will be this retarded. Thomson also notes that considering incidence in practical terms, in a class of twenty-five children we can expect at least two to be dyslexic.

Taking into account the issues of definition and relationship to other forms of poor reading outlined above, it is clear that the incidence of dyslexia may range from smaller numbers if cases of "pure dyslexia" are reported, to quite considerable numbers if we include all children reading below a certain level (i.e. grouping dyslexics and slow learners together).

Two other issues regarding incidence levels and dyslexia are worth mentioning. For many years the incidence of dyslexia was considered to be greater in males than females with ratios of 2:1 to 5:1 proposed (e.g. Critchley, 1970; Finnuci and Childs, 1981). However, such figures have recently been challenged and have been attributed to a referral or ascertainment bias in clinic or school identified dyslexic populations (Guerin et al., 1993; Shaywitz et al., 1990). When considering non-school referred populations of dyslexics, Guerin and colleagues found that "across all levels and types of dyslexia, the male: female ratio was 1:1.2 ." (p. 350). Similarly, the greater incidence of left handedness in dyslexia has also been challenged (Miles and Miles, 1990) although evidence for and against the idea appears contradictory (e.g. Geshwind and Behan, 1984; Naidoo, 1972), and it is perhaps mixed handedness or cross-laterality that is more common in the disorder. More evidence regarding handedness and dyslexia is presented with respect to neurological explanations of the disorder in the following section.

1.3 Theoretical developments in dyslexia

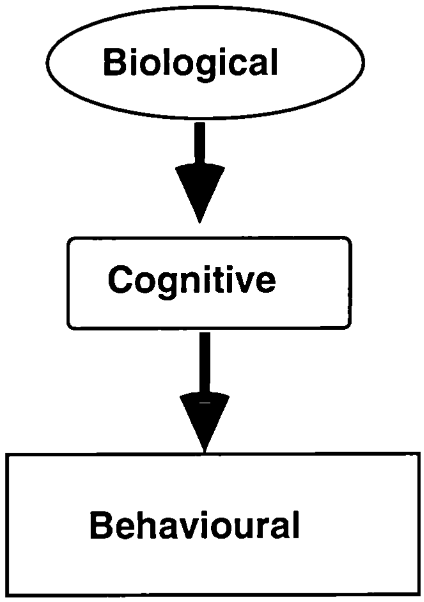
The concept of dyslexia developed in a largely medical context with parallels made between the acquired and developmental forms of the disorder to aid initial understanding. In addition, early conceptualisations of dyslexia referred to visual difficulties with terms such as "word blindness" emphasising visual aspects of the disorder. Such a visual approach to dyslexia (e.g. Orton, 1925) continued until the 1970's when Vellutino (1979, 1987) proposed that dyslexic deficits were not just in visual processing but, perhaps more importantly, also in the processing of language. Since that time many researchers have worked largely within a language-based approach to develop a theoretical understanding of dyslexia.

In the last ten years, a number of interesting theories of dyslexia have continued to develop based on the increasing information we have about the disorder, however there is as yet no one agreed explanation. For this reason this section of the chapter presents a kind of "work in progress" review, outlining the major contributions to our understanding of dyslexia at the present time. However, before discussing what has been discovered regarding dyslexia, I will briefly outline a framework for interpreting the various evidence to be presented.

1.3.1 Frameworks for investigating the etiology of dyslexia

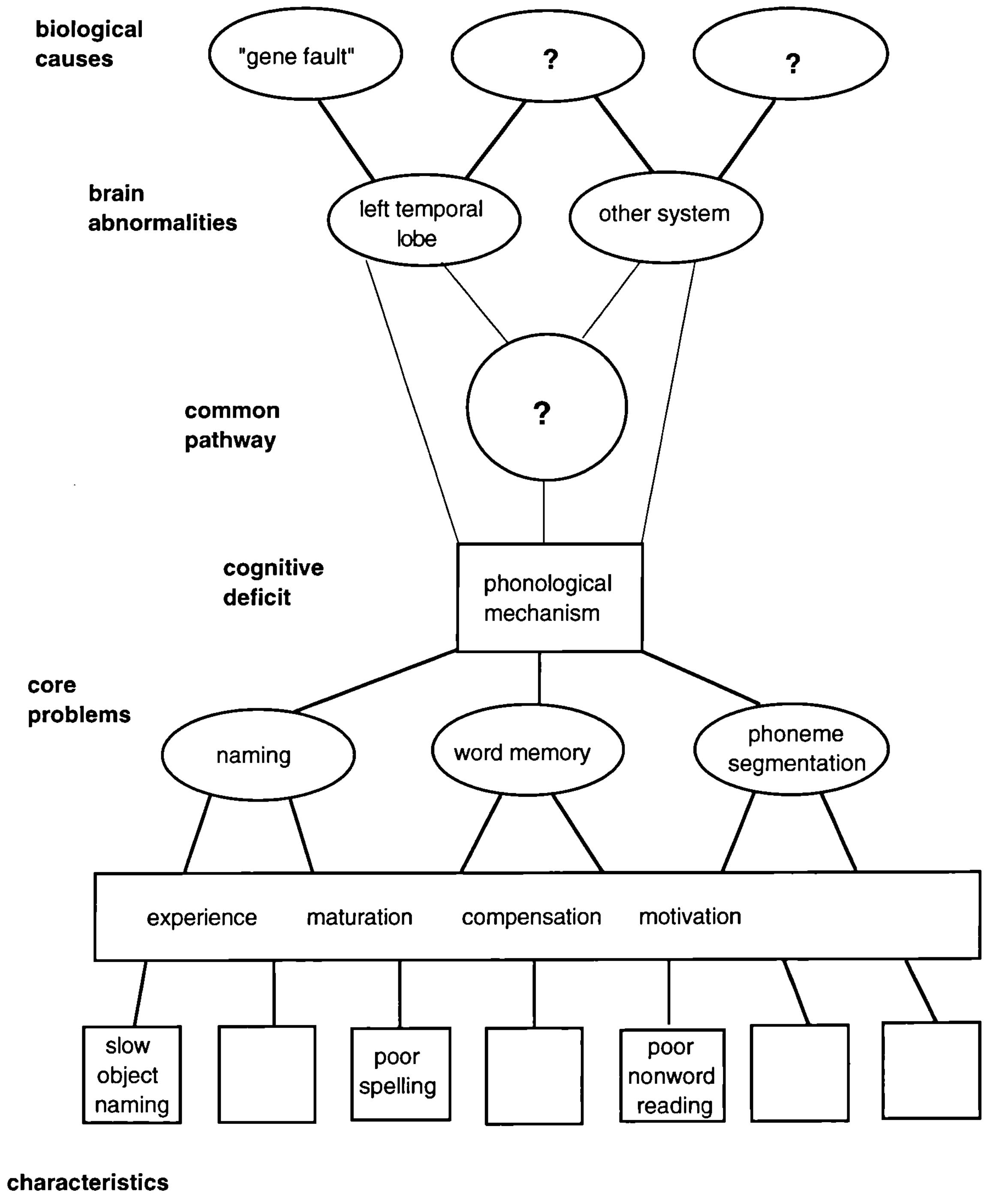
Frith (1992) and Morton and Frith (1994) have proposed a model or framework which can be used to aid our understanding of disorders such as dyslexia. Very simply, the model suggests that the biological causes and behavioural manifestations of a disorder are linked by some form of cognitive deficit (see figure 1.2 below). Thus dyslexia can be understood on three basic levels: biological, cognitive and behavioural.

Figure 1.2 A simplified model of the three levels explanation of developmental disorder (adapted from Morton and Frith, 1994)



The above diagram is, of course, an oversimplification of the possible relationships between biology, cognitive mechanisms and behaviour, in that there is almost certainly *not* a one-to-one mapping of the three levels of explanation. Frith (1992) has expanded the levels of explanation framework with respect to dyslexia and proposed the following model which, for illustrative purposes, represents one of the leading explanations of dyslexia at the present time - the phonological deficit hypothesis.

Figure 1.3 A Model of Dyslexia (Frith, 1992)



This more complicated model divides biology into two levels of explanation, illustrated here by a top level consisting of such factors as genetic influences which then leads to possible forms of brain abnormality. The model indicates a possible common pathway for the numerous potential biological influences that may be at work, leading to some form of cognitive deficit (in this case hypothesised as a phonological deficit). The cognitive deficit results in a number of core problems with behavioural manifestations or characteristics (which would, of course, be modified or exacerbated by intrinsic variables such as maturation and motivation).

The many empty cells in the above model indicate the current state of speculation regarding the mechanisms of dyslexia. It is not my aim to argue for the validity of such a model in itself, rather the model is presented here for the purpose of illustrating the differing contributions to the theoretical understanding of dyslexia which are presently available, and more importantly, how they may come together to provide a full explanation of the disorder on all levels.

In discussing the search for a theoretical understanding of dyslexia evidence from a number of sources is presented. Firstly, biological evidence regarding genetic and neurological advances in our understanding of dyslexia is discussed providing a picture of the possible structural bases for the disorder. This is followed by a review of the major cognitive psychological advances of the last ten years and the explanations of dyslexia which have stemmed from these, particularly the phonological deficit hypothesis, temporal processing and visual deficit explanations and the more recent dyslexic automatisation deficit. The value of such contributions to our understanding of the many manifestations of dyslexia is assessed.

1.3.2 Genes and dyslexia

At the beginning of this chapter is was noted that Hinshelwood made the observation in 1917 that congenital word blindness was hereditary, an observation which has been carefully investigated in the following years. Indeed, it was the hereditary nature of the condition that led Critchley (1970) to argue for the specificity of dyslexia compared to other forms of poor reading.

Studies of the genetic basis of dyslexia have yielded interesting results indicating that hereditary factors play a role in at least some forms of the disorder. For example, using monozygotic and dizygotic twins, concordance rates of up to 100% have been found in some studies (LaBuda and DeFries, 1988). Hallgren (1950) was the first to establish the mechanisms by which such a hereditary factor might operate. In a pedigree study of 112 families where children had dyslexic problems he examined the number of families with one or both affected parents and using Mendelian analysis and proposed that genetic transmission took place via a dominant gene that was autosomal. Subsequent studies, such as that by Finucci et al. (1976), however, found that there was no single clear cut mode of inheritance and that reading difficulties were heterogeneous. It has been proposed that where there is dyslexia in a family genes found on chromosome 15 may be implicated (Smith et al., 1983).

A number of recent studies have used a technique of linkage analysis to examine the role of genes in dyslexia. This statistical method tests whether two genes segregate together in a non-random fashion and therefore indicates whether they are located close together on the same chromosome. On the basis of this Pennington and Smith (1988) have been able to quantify degrees of familial risk for dyslexia. They have found that the risk of sons of affected fathers having dyslexia was 40%, with 35% of sons of affected mothers at risk. This is a five to seven fold increase in risk in comparison to sons of unaffected parents. The situation is similar although not so extreme for daughters of affected parents who have a 17-18% risk of being dyslexic, although this represents a ten to twelve times greater number than daughters of unaffected parents. The message is clear that having one or more affected parents dramatically increases the chance of a child being born with dyslexia.

DeFries and colleagues (1987) have hypothesised on the basis of evidence from their studies that around 30% of the cognitive phenotype (the cognitive and behavioural manifestations) in reading are attributable to heritable factors. In addition, Pennington and Smith (ibid) propose that although there may be genetically different forms of dyslexia it is a deficit in phonological coding in reading that is the common heritable aspect of the phenotype. Evidence suggests that orthographic coding, on the other hand, is not heritable.

Genetic studies of dyslexia reveal that in some cases at least there is a heritable component to the disorder, and speculation continues as to what this component could be. Although it is unlikely that there will ever be established a "gene for dyslexia" research is coming closer to identifying possible chromosome sites that may be implicated. However, there is a possibility that genetic factors may not account for all cases of dyslexia, with some perhaps resulting from neurological damage at a very early stage of life. There may be an interaction between genetic and environmental factors such that a propensity to dyslexia may be accompanied by some form of environmental influence. It is as yet, too soon to be sure about this particular biological aspect of dyslexia. In the following section, the evidence regarding neurological factors in dyslexia is reviewed. It is hoped that in the future the relationship between genes and brain biology with respect to dyslexic difficulties will become apparent.

1.3.3 Neurological evidence in dyslexia

Early speculation about possible neurological deficits in dyslexia focused on such issues as unresolved hemispheric laterality (e.g. Orton, 1937). However, more recent neurological evidence now indicates that the pattern of deficit in dyslexia may be much more subtle, complicated and widespread then was first imagined. In this section, the findings of neuroanatomical and neurophysiological studies of dyslexia are presented along with consideration of how they may assist our understanding of the causes of the disorder. Neurological evidence is presented in a number of broad sections representing particular techniques used for study and/or structures and processes studied.

(a) Neuroanatomical studies and the planum temporale

Post mortem studies of a small number of dyslexic brains led Galaburda and colleagues (1985) to recognise symmetry of a structure of the brain which in non-dyslexics is found to be asymmetrical. This structure, the planum temporale (PT) is a gross anatomical structure in the Sylvian fissure of the brain, a cortical area containing neuronal systems for higher-order auditory association (Larsen et al., 1990). The researchers also identified a number of ectopias and dysplasias - misplaced cells in the cortex of the dyslexic brains. Symmetry of the planum temporale was found to be due to the structure being larger in the right hemisphere rather than smaller in the left, and this was hypothesised to be due to reduced cell death during foetal development, leaving an excessive number of neurons surviving in the right planum. Galaburda (1993a) proposed that such excess neurons may form anomalous connections therefore resulting in a miswiring of the brain of the dyslexic. Animal models have revealed that symmetry of the PT happens when there is excessive generation of neurons and changes in the pattern of interhemispheric connectivity (Rosen et al., 1991).

Since this original work, a number of studies have been carried out to investigate the validity of the symmetry of this brain structure in dyslexia. Many studies have now used modern imaging techniques such as MRI (magnetic resonance imaging) to allow in vivo investigation of dyslexic brains. For example, Larsen and colleagues (1990) used MRI to examine the size and symmetry of the brains of dyslexic and control subjects. They found a high frequency of planum symmetry among dyslexics (70%) compared to only 30% symmetry in control subjects.

However, the implications of such findings are as yet unclear, although there is some speculation of the role of the PT in phonological processing. Larsen et al. found that all subjects with pure phonological deficits in reading had symmetrical PT, although Galaburda (1993b) has proposed that symmetry of planum temporale is not sufficient for dyslexia. That is, the other malformations such as microgyria and ectopic nests around the peri-Sylvian cortex may also contribute to the disorder by distorting neural networks associated with linguistic processes. Additional evidence of the role of the PT has been provided by Flowers and colleagues (Flowers, 1993) who in an MRI study found that there was a negative correlation between the size of the planum temporale and performance on tasks of serial naming and rote verbal memory.

(b) Studies of the corpus callosum

Studies of the size of the corpus callosum in dyslexic and non-dyslexic brains have also been carried out using magnetic resonance imaging techniques (Hynd et al., 1995; Larsen, Hoien and Odegaard, 1992). The corpus callosum (CC) is a major communicator between the right and left hemispheres. It has been hypothesised that one part of the CC, the splenium may be involved in efficient word processing (Larsen et al., 1992). However, findings have been inconsistent. Duara and colleagues, for example found an increase in the size of the CC in dyslexic brains. Larsen et al., on the other hand, found no gross differences in size of the total corpus callosum or splenium between dyslexics and controls, and no abnormalities in the size of the structure in subgroups of dyslexia related to gender, linguistic deficiencies or symmetry or asymmetry of the planum temporale. However, they point out that the neural function of fibretracts in the CC may be impaired despite the normal cross-sectional size.

The most recent study of this structure, by Hynd and his colleagues, found that the anterior region of the CC of interest (the genu) was significantly smaller in dyslexic children compared to controls. In addition, significant correlations were found between the region of interest measurements for the genu and splenium and reading achievement. The researchers concluded that subtle neurodevelopmental variation in the morphology of the corpus callosum may be associated with the difficulties dyslexic children experience in reading and tasks involving interhemispheric transfer.

(c) Studies of the magnocellular systems

Although there has been a general rejection of the role of visual deficits in dyslexia, recent findings regarding cerebral structures connected with rapid processing of visual and auditory information have reintroduced the possibility of visual deficits in dyslexia. Stein (1994a), Galaburda and Livingstone (1993) and Galaburda, Menard and Rosen (1994) have all reported evidence of a magnocellular deficit in dyslexia.

Stein proposed that dyslexia can be characterised by an impairment in phonemic segmentation and an impairment in sequencing small visual symbols. Both of these deficits are related to the nervous system's ability to time sensory events precisely: a magnocellular cell type is involved in this and may be impaired in dyslexia. Stein has found that dyslexics have lowered flicker and motion sensitivity, and they also have disordered layers of the magnocellular layers of the lateral geniculate nucleus (LGN). Reduced sensitivity to changes in frequency and amplitude of sounds and therefore impaired discrimination of speech sounds has also been found in many dyslexics. In other words, Stein proposes that dyslexics experience difficulty in segmenting rapid streams of visual and auditory information. Magnocellular impairments in dyslexia may contribute to reading problems by destabilising occularmotor control and producing a mild deficiency in the ability to use temporal transients to discriminate sounds. This neurological evidence suggests that the dyslexic deficit may be at the level of perceptual processing (of rapid auditory and visual stimuli) (Galaburda and Livingstone, 1993).

Focusing on structural differences in auditory anatomy (the medial geniculate nucleus), Galaburda, Menard and Rosen (1994) found that in dyslexics, but not controls, the left side of the MGN contained neurons that were significantly smaller than the right neurons. In addition, compared to controls there were more smaller neurons and fewer large neurons in the left MGN of the dyslexic brains. Galaburda and his colleagues have concluded that this evidence is consistent with reported behavioural findings of a left hemisphere based phonological deficit in dyslexia.

Anderson, Brown and Tallal (1993) have reviewed the evidence for a basic (perceptual) processing deficit in individuals with dyslexia. They found that neuroanatomical evidence such as that outlined above, along with neurophysiological and behavioural evidence, suggests a temporal processing deficit with problems in responding to rapidly (but not slowly) presented stimuli across all modalities. The finding of selective abnormalities of cells in the lateral and medial geniculate nuclei of the thalamus is consistent with Tallal's earlier finding that children with developmental communicative disorders such as dyslexia are severely and selectively impaired in integrating transient sensory and motor information that converges in the nervous system very quickly.

(d) Event related potential studies

A number of studies have identified different patterns of brain activity in dyslexics compared to controls by studying event-related potentials to both visual and auditory stimuli. For example, Taylor and Keenan (1990) recorded event-related potentials (ERP's) from dyslexic and control subjects in three visual reading related tasks: a non-alphabetic condition, an alphabetic condition and a lexical decision task. They found that aspects of the brain activity response, the N2 and P3 components were longer in latency and the P3 had a lower amplitude in dyslexics compared to control subjects. They concluded that the dyslexic children required more time to process the visual information across tasks and also appeared to have a different developmental pattern in their ERP's from that of non-dyslexics.

Ackerman, Dykman and Ogelsby also carried out a visual event-related potential study using a rhyming decision task. They found that the major anomalous feature of the dyslexic groups ERP waveform was a pronounced late positive peak (P500) which followed an attenuated N450 peak. They have proposed that this suggests non-automatic visual cognitive processing of rhyme in dyslexic individuals. Neville, Coffey, Holcomb and Tallal (1993) found that an early component of the visual ERP was reduced in amplitude in children with reading disability and language impaired children. They found that multiple aspects of brain activity were affected, heterogeneously across the sample of children.

Looking specifically at auditory event-related potentials, Erez and Pratt (1992) and Fawcett at al. (1993) have also found differences between dyslexics and controls in terms of brain activity. Erez and Pratt recorded ERP's to verbal and non-verbal stimuli while children performed an "oddball" target detection task. They found that the P3 peak amplitude was significantly attenuated in dyslexic children compared to non-dyslexics in response to verbal but *not* non-verbal stimuli. However, P3 apex latencies were longer and apex amplitudes larger in response to non-verbal rather than verbal stimuli. The most striking finding reported by the researchers was that the P3 apex orientation pointed in an upward-posterior direction with a slight tilt to the left in normal readers but to the *right* in the dyslexic children. They have proposed that this may reflect differences in brain structures involved in processing verbal and non-verbal stimuli. Fawcett et al. (1993) also used an "oddball" paradigm for presentation of auditory tones and using ERP's found that the dyslexics showed a temporal processing speed deficit compared to controls in P300 latency, in a selective choice reaction task. The data have been interpreted to show that the dyslexic deficit is not attributable to motor response selection or execution but instead appears to be linked to the need to make discriminations between stimuli. Fawcett et al present this as evidence that dyslexic children have a deficit in response categorisation even for non-linguistic stimuli.

(e) Dyslexia, handedness and immune disorders

Following early speculation concerning the relationship between dyslexia, cerebral lateralisation and immune disorders (e.g. Geshwind and Behan, 1984) a number of studies have attempted to investigate this link. Brunswick and Rippon (1994) studied cerebral lateralisation and reading ability in dyslexic and control children using ERP's. They found that the actual performance of the two groups varied on a phonemic awareness task, but not on a dichotic listening task. However, the ERP's of the groups varied on *both* tasks with the normal readers producing significantly greater N100 amplitudes in the left temporal region during dichotic listening compared to the dyslexics, who displayed approximately equivalent levels of amplitude bilaterally. They also found that the dyslexics were significantly less right handed than the controls, and that ERP lateralisation indices and hand preference scores were significantly related to phonemic awareness performance.

Tonnessen and colleagues (1993) investigated the relationship between dyslexia and handedness and immune disorders. They found that bivariate analyses highlighted a significant association between handedness and dyslexia and a significant, but weak association between handedness and immune disorders. However, no significant relationship was found between dyslexia and immune disorders. The authors conclude that the findings do lend support to hypotheses of links between dyslexia, handedness and immune disorders. Further support has been provided for this link with the development of an animal model for dyslexia: the New Zealand Black Mouse, which has been found to have immune disorders, cortical malformations and disorders of learning. (Galaburda, 1993a, 1993b; Sherman et al., 1987)

(f) The cerebellum

A very recent line of enquiry regarding neurological deficits in dyslexia has been taken up by Nicolson, Fawcett and Dean (1994). They have proposed evidence to suggest that the cerebellum is involved in dyslexia. The cerebellum has traditionally been considered a motor area of the brain and was not thought to be involved in linguistic or cognitive skill. However, recent research has suggested that the cerebellum is activated during cognitive enterprises such as word processing and working memory, and that damage to the cerebellum can result in problems in rapid attention shifting between modalities, impaired motor learning and error detection, and difficulties with judging time intervals. On the basis of such evidence Leiner et al. (1989) have proposed that the cerebellum is involved in cognitive learning, motor learning and particularly in the acquisition of "language dexterity".

Nicolson and colleagues argue that in addition to their language related difficulties, dyslexic children have problems with motor skill, balance, automatisation and speeded performance (these deficits will be dealt with in more detail in later discussion of cognitive psychological theories of dyslexia). To investigate the possible role of the cerebellum in these deficits, the researchers used a task which has been developed as a sensitive index of cerebellar function: time estimation, with dyslexic and non-dyslexic children. They compared the performance of the two groups on this task and a control task of loudness estimation (for which there would be no cerebellar involvement). Nicolson and colleagues found that the dyslexics showed a deficit in time but not loudness estimation. The authors conclude that such findings suggest that "for some reason the cerebellum cannot fully support the acquisition of skill in dyslexic children" (p. 8) and this provides a possible explanation for the wide ranging characteristics of dyslexia.

(g) Other neurological research in dyslexia

Other aspects of neurological structure or process have been investigated with respect to dyslexia. For example, Levin (1990) proposed possible frontal lobe deficits in dyslexia and evidence from Brain Electrical Activity Mapping (BEAM) studies also reveals abnormalities in the structure and process of the frontal lobes in dyslexic subjects (Duffy et al., 1980). Levin has hypothesised that deficient strategy formulation and execution in dyslexics may result from such primary frontal lobe dysfunction.

Duffy and McAnulty (1990) have provided neurological evidence in support of the notion that dyslexia is different from other forms of reading disability by suggesting that the brain electrical activity differs between the two groups. In addition, they have located subtypes within the dyslexic group, manifesting different forms of the disorder (anomic, dysphonemic and global) and differing electrophysiologically from one another. They note that these differences may be due more to compensatory strategies developed by the dyslexics than primary pathological changes associated with the deficit.

Functional neuroimaging (PET and cerebral blood flow (rCBF)) studies have also provided further information regarding the possible neurological basis for dyslexia. This technique is able to establish patterns of cortical activation elicited by cognitive tasks. For example, Rumsey and colleagues (1992) used oxygen 15 PET to measure rCBF in dyslexic and control subjects at rest and during a rhyme detection and an auditory tone detection task. They found that normal readers, but not dyslexics, activated the left temporopareital cortex near the angular gyrus during rhyme detection but both groups responded similarly to the tone detection. Dyslexics tended to activate a more anterior temporal region during rhyme detection, possibly representing compensatory activity. Flowers (1993) found using rCBF profiles that on tasks related to the so called "core language deficits" in dyslexia, there is a significant relationship between left temporal and parietal flow and dyslexia. In a previous study (1991) Flowers and colleagues had found evidence to suggest that the left temporal component was associated with phonological and orthographic skill, whereas the left parietal component was associated with comprehension.

1.3.4 Summary of the evidence for biological factors in dyslexia

Casual observation of the incidence of dyslexia in families tends to suggest a hereditary mechanism at work and this idea has been supported by detailed empirical studies of the role of genes in the disorder. The evidence reviewed above certainly suggests that for some forms of dyslexia at least, a genetic component may be important. Exactly how such a mechanism causes the varying difficulties that are part of the dyslexia syndrome can only be speculated. However, like many aspects of dyslexia research, progress in establishing the genetic basis for dyslexia in the last decade has been considerable.

In terms of neurological findings, a major difficulty lies in relating structural or process deficits in the brain to normal structure and function. There is still such a great deal that is not yet known about the role of the brain in certain tasks so that it is far from clear what an observed deficit might mean. However, knowledge regarding the functions of the brain is growing as is the wealth of evidence regarding neurological aspects of dyslexia. Galaburda (1993a) has proposed that with the development of better theories of language and reading and better methods for assessing the structure and function of living human brains and determining genetic transmission, cognitive neuroscience and neurology have been able to make a significant contribution to our understanding of dyslexia. The findings outlined above indicate that dyslexia is accompanied in most cases by fundamental changes in brain anatomy and physiology, many of which can be attributed to prenatal development. Galaburda believes that the evidence suggests that dyslexia may be closely related to factors that influence cerebral dominance and the development of the immune system. He suggests that one of the core characteristics in dyslexia, the language deficit may result from early perceptual anomalies that interfere with the establishment of normal cognitive-linguistic structure in the brain.

Duffy and colleagues (1980) believe that one day quantitative neurophysiology may offer for learning disabilities (such as dyslexia) what the clinical EEG has provided in the diagnosis of epilepsy, and Flynn and Deering (1989) have hypothesised that dyslexic children with different kinds of reading disorders may one day be differentiated using brain maps. They speculate that "quantitative neurophysiology may provide a marker for the early identification of dyslexic children" (p. 407).

Evidence of neurological and genetic deficits in dyslexia provides important information regarding the underlying biology of the disorder. Such information may aid our understanding of what dyslexia actually is and how it relates to other forms of poor reading. Having considered evidence regarding the biological basis of dyslexia, it is now important to examine how such structural deficits may link with the behavioural manifestations of the disorder. In terms of Frith's (1992) model, this requires identification of a cognitive deficit. The following section outlines a number of key contributions to the development of our understanding of the cognitive basis of dyslexia over the last decade.

1.3.5 Cognitive-psychological explanations of dyslexia

1.3.5.1 Phonological Deficit Hypothesis

The phonological deficit hypothesis has become the dominant cognitive explanation for dyslexia over the last fifteen years. It represents a shift of focus from viewing dyslexia as a visual disorder (i.e. word blindness) to a language disorder. Almost all those involved in dyslexia research and practice now agree that one of the core problems in dyslexia is a deficit in skills linked to phonological processing. Phonological processing can be thought of as "operations by which stimuli are interpreted in terms of the speech sounds involved" (Miles and Miles, 1990, p. 65).

The phonological deficit explanation for dyslexia was originally developed by Liberman and colleagues. The researchers challenged the visual view of dyslexia which had stressed that reversals of words and letters by dyslexics were the result of visual errors, by illustrating that some reversal of consonants such as p, d and b, that have a similar appearance were not as common as had been claimed, and that reversal errors in general accounted for a small proportion of the errors made (Liberman et al., 1971). Further studies by Liberman and colleagues (1974) pursued the notion that it is the sounds of words and letters that cause problems for poor readers by comparing readers of different ability levels on a task which required them to tap out the number of syllables or phonemes in a set of one, two and three syllable words. The important finding here was that it was much easier for children of all ages to segment words into syllables, but only the older children (first grade) were able to successfully segment words into phonemes.

There have been a number of major outcomes of the important discoveries of Liberman and colleagues with respect to the development of the phonological deficit hypothesis. The first of these is attempts by researchers to understand the role of phonological skills in the normal development of reading. The second has been a wealth of studies investigating aspects of phonological skills and the performance of dyslexics on tasks measuring these skills. A third outcome has been to consider other deficits in dyslexia and to relate them to a deficiency in phonological awareness or phonological coding. These issues are discussed in more detail below, as the evidence for a phonological deficit in dyslexia is considered.

In assessing the phonological awareness skills of dyslexic and normal children, a number of tasks have been used. These include tasks such as that described above where the number of phonemes in a word is tapped out by the child, tasks which require the adding and subtracting of phonemes, blending tasks, and "Pig Latin" tasks. A Pig Latin task was used by Olson et al. (1989) to compare the performance of dyslexics and reading age matched non-dyslexics. This involved the initial phoneme of a word being moved to the end of the word with -ay added on to this (e.g. pig - igpay). Olson and colleagues found that the dyslexic readers performed poorly on this task compared to the controls. Results such as this have indicated that dyslexic children do have a difficulty with phoneme awareness (i.e. awareness of words as sequences of discrete phonemes) and these difficulties are not just a consequence of the children's lower reading level.

There is general consensus that performance on a number of phonological tasks is predictive of later reading performance. Evidence for this comes from a number of sources, an important one being the studies of rhyming by Bradley and Bryant (1978, 1983) and Bryant and Bradley (1985b). Taking a large sample of 4 and 5 year old children they presented an "odd one out" task whereby subjects were presented with three or four spoken words and asked to indicate which was the odd one out. In the first condition, all but one of the words had the same last sound, that is they rhymed with one another (e.g. bun, gun, sun), with the word to be identified differing in its last sound (e.g. hut). In another condition, the target word had a middle sound that was different (e.g. lot, cot, pot, hat), and in the final condition it was the initial phoneme that was different (e.g. ham, tap, had, hat). The researchers found that performance on this test was significantly related to performance in reading four years later, taking into account differences in IQ. They were also able to illustrate that training in phonological skills allowed a group of poor readers to overcome some of their difficulties with reading. Maclean, Bryant and Bradley (1987) have demonstrated that three year old children's knowledge of nursery rhymes is related to later reading performance.

There are many studies carried out during the last ten years that have demonstrated that children who are poor readers lack facility with the phonological aspects of language, that dyslexics tend to perform worse that controls on such tasks, and that explicit instruction in phonological skills leads to improved reading performance. However, a number of other difficulties have been found in dyslexia which, although not directly relating to phonological awareness of language, have been included in the phonological deficit domain. These include both short and long term memory deficits, verbal repetition difficulties and naming difficulties.

Both casual observation and empirical evidence suggest that dyslexics have difficulties with remembering information. Inefficiencies in short term memory have often been illustrated using digit span tests (e.g. WISC-R) where a child is required to listen to an accurately repeat a series of numbers. Rugel (1974), for example, found that even when compared to normal readers of the same overall IQ, poor readers tend to have lower scores on digit span tasks. That phonological skills are used in such a task has been illustrated (e.g. Conrad, 1964) by the finding that it is more difficult to remember lists of letters that sound similar to one another (the phonological confusability effect), and by anecdotal reports of using "inner speech" in order to remember lists of items. The idea that dyslexics' short term memory difficulties could be attributed to problems in using phonological codes was supported by a reduced phonological confusability effect in dyslexia (e.g. Shankweiler et al., 1979). However, when compared to reading age matched controls, dyslexics were found to perform similarly (Holligan and Johnston, 1988) suggesting that dyslexics do make use of phonological codes in short term memory, but are less efficient in doing so. In addition, like phonological awareness, short term memory skills have been found to be related to later reading performance (Jorm et al., 1984).

The performance of dyslexics on measures of long term memory has also been investigated and evidence suggests that less use is made of phonological coding in long term memory. Bauer and Emhert (1984) found that dyslexics showed a reduced primacy effect which suggests that they are less efficient at transferring information into long term memory, although difficulties cannot simply be attributed to failure to use rehearsal as a memory strategy (Byrne and Shea, 1979). Rack (1985) investigated the possibility that when encoding information into memory dyslexics may attend to different properties of stimuli and encode stimuli in a different manner. Results of this study suggested that dyslexics did not make use of a phonological code for storing information in memory, but instead relied more on visual memory codes than normal readers.

Dyslexics have been found to have difficulties with spoonerisms (e.g. par cark) and repetition of single (particularly polysyllablic) words, which has led to a proposed dyslexic deficit in verbal repetition. This deficit has been tested using a number of methods often using nonsense words. Nonword repetition has been considered to be an important feature in the explanation of dyslexic failure (Hulme and Snowling, 1990) as " it requires that unfamiliar spoken words must be segmented prior to the compilation of a motor program for production" (Snowling, 1991, p. 65). Snowling et al. (1988) carried out a study which compared the performance of dyslexics and reading age matched controls on a nonword repetition task with a background noise manipulation. It was found that although both groups were equally affected by the noise, the performance of the dyslexics was worse than controls. The researchers concluded that dyslexics' problems lay with the processes of speech-segmentation. Nonword repetition tasks have also been used by Gathercole and Baddeley (1989) who proposed that the tasks are primarily measures of short term memory and as such, good predictors of vocabulary acquisition. A number of studies have also provided evidence that dyslexic children have developmental difficulties with speech perception that may interfere with phonological processing (e.g. Reed, 1989). Such evidence suggests that dyslexic children seem to have a problem with the perception of brief auditory cues (Snowling, 1991) and this may, of course, contribute to difficulties in the repetition of nonsense words.

It has been noted that dyslexics often have difficulty with finding the names for objects and empirical evidence appears to support this observation. Naming an item requires the retrieval of phonological information from long term memory. An early study of naming was carried out by Denckla and Rudel (1976) in which learning disabled children were compared with controls in terms of their ability to rapidly name a series of items (Rapid Automatised Naming - "RAN"). They found that errors made by the learning disabled children often took the form of circumlocutions rather than purely incorrect responses. Other studies have found that dyslexics have difficulty with naming (e.g. Catts, 1991; Fawcett and Nicolson, 1994c; Felton and Brown, 1989; Wolf, 1984, 1986,1991; Wolf, Bally and Morris, 1985; Wolf and Goodglass, 1986; Wolf and Obregon, 1992 and Wolf and Segal, 1992) and that performance on such tests correlates well with later reading ability, even when receptive vocabulary is controlled (Katz, 1986). However, although performance of dyslexics on naming tasks is poor compared to controls of the same age, it has been found to be comparable to reading age matched controls (Snowling, et al., 1988).

Evidence for a phonological deficit in dyslexia has also been gained from studies of the written language performance of dyslexics (i.e. reading and spelling). Measures such as lexical decision tasks, tests of written rhyme and the pronunciation and spelling of regular and irregular words have confirmed the difficulties that dyslexic children have with phonological awareness and phonological coding. Olson et al. (1989) for example, found that dyslexic readers performed poorly in a phonological condition of a word reading test compared to reading age controls, however dyslexics performed better than controls in a visual recognition condition. This suggests that they were relying to a greater extent on visual rather than phonological processes in the reading task. Studies also suggest that dyslexics have greater problems with nonword reading compared to non-dyslexics, highlighting their difficulties with phonological decoding skills (Stanovich, 1994).

Rack (1994) states that " it is quite clear that phonological skills play a central role in the majority of dyslexics' difficulties" (p. 30). The evidence presented above supports this assertion. However, the origins of such a deficit are as yet unknown although biological evidence regarding genetic and structural deficits relating to phonological skills has been proposed. Snowling (1991) has pointed out that although we have learned a great deal about the nature of dyslexia from the study of phonological deficits, "they are incapable of explaining the deficits of all dyslexic children" (p. 72). Indeed it now seems to be the case that phonological deficits may not be able to explain the range of deficits seen in an individual dyslexic child, as evidence suggests that "dyslexic children suffer problems in skills quite independent of phonological processing" (Nicolson and Fawcett, 1995, p. 2). The following section outlines some of the limitations of the phonological deficit hypothesis as a satisfactory explanation of dyslexia.

1.3.5.2 Limitations of the phonological deficit hypothesis

Fawcett and Nicolson (1994a) have highlighted a number of limitations of the phonological deficit account of dyslexia. The first of these limitations is that there is clear evidence of deficits in the performance of dyslexics on tasks unrelated to overt or covert phonological skills. Clinical observation and empirical evaluation of dyslexia suggests that as well as language problems, characteristics such as forgetfulness, distractibility and clumsiness tend to be found in the disorder. For example, Augur (1985) found that dyslexic children tended to have problems with motor skills (such as clumsiness, difficulties in hopping and skipping, clapping a rhythm and throwing and catching a ball) and attention (for example, carrying out several instruction at the same time, distractibility, rapid tiring under continuous load) in addition to difficulties related to reading. Haslum (1989) also found that children with dyslexia showed evidence of difficulties with motor skills at an early age, demonstrated in tests of catching a ball and walking backwards.

Nicolson and Fawcett (ibid) also highlight that there is no evidence to suggest that phonological deficits distinguish dyslexics from other poor readers. Phonological deficits appear to be found across the range of poor readers from dyslexics to slow learners. If one is considering dyslexia as being qualitatively different from other forms of poor reading, the phonological deficit hypothesis is not specific enough an explanation for the dyslexic syndrome. Additionally, in terms of specificity, the phonological deficit hypothesis runs the risk of premature specificity, that is, it is making specific assertions about the nature of dyslexia and its causes before fully establishing the range of symptoms to be explained. One such example of this is the evidence that dyslexic deficits are found in the visual as well as phonological domain, an area of research which has recently gained a renewal in popularity (particularly due to neurological findings outlined in the above section). It can be seen therefore that the phonological deficit hypothesis appears to fall short as an attempt at a comprehensive explanation of dyslexia. Visual explanations for dyslexia are considered in the following section.

1.3.5.3 Visual explanations of dyslexia

Following rejection of early visual explanations of dyslexia, the phonological deficit approach brought the study of dyslexia firmly into the domain of language. However, extensive work by a number of researchers has now clearly demonstrated that dyslexics and non-dyslexics do differ in terms of visual processing (e.g. Lovegrove, 1994). For example, Stein (1994b) has proposed the existence of visual deficits in dyslexia caused by unstable visual perceptions, possibly due to unstable visuomotor control.

One way in which visual deficits have been recently investigated is within a framework of spatial frequency analysis. Evidence has been found to suggest that dyslexics differ from controls in terms of the functioning of the transient visual system (a motion detecting system which transmits information about stimulus change and general shape). In addition, the role of the transient system in higher level perceptual tasks has been investigated (Williams and LeCluyse, 1990) and it has been found that dyslexics manifest difficulties on a significant number of such tasks. Neurological evidence for structural and process differences in the magnocellular layers of the lateral geniculate nucleus also provides evidence for a visual processing deficit in dyslexia.

Lovegrove (ibid) has attempted to consider how the findings outlined above may be related to other deficits in dyslexia. In a factor analysis study of dyslexics and controls (Lovegrove et al., 1988) it was found that nonsense word skills loaded on the same factor as measures of transient processing, implying that there is some relation between the two processing areas. It has been hypothesised that the observed deficits may be related, in light of an apparent dyslexic deficit in processing rapidly presented stimuli in all sensory modalities. In this respect visual explanations of dyslexia are strongly related to temporal processing deficit explanations, which are outlined in the following section

1.3.5.4 Temporal processing deficit explanations of dyslexia

Considering the evidence presented above for deficits in the processing of rapidly presented stimuli and neurological abnormalities associated with the fast processing, temporal processing speed deficits have been proposed as an explanation of the characteristics of dyslexia. Fawcett and Nicolson (1994b) note that "one of the more striking features of the performance profile for dyslexic children is an impairment in speed in almost any skill" (p. 158).

Tallal et al. (1993) have linked the abnormalities in the magnocellular system to problems with rapidly changing auditory events, such as processing rapidly changing speech signals (e.g. initial consonants in words). This deficit is able to explain difficulties with phonological discrimination, and a similar deficit in the visual system ia able to account for the visual deficits outlined above. Further evidence for reduced speed of processing in dyslexia comes from for example, Denckla and Rudel's (1976) findings of dyslexic's difficulties with the "rapid automatised naming" (RAN) task outlined in section 1.3.5.1, and from Bowers and Wolf (1993). Dyslexic children have been found to have particular difficulties in producing the names of successive linguistic and non-linguistic stimuli in speeded conditions. Wolf (1991) also presents evidence of speed of processing deficits in naming and found a relationship between speed deficit and severity of reading impairment some years later. Fawcett and Nicolson (1994b) have found that dyslexics have reduced speed of lexical access and slower choice (but not simple) reaction time performance.

It can be seen therefore that experimental and neurological evidence for a processing speed deficit in dyslexia is strong. In addition such an explanation is able, unlike the phonological deficit hypothesis, to deal with the evidence regarding both visual and language deficits in dyslexia. However, Nicolson and Fawcett (1995) have criticised the processing speed deficit theory of dyslexia as being too specific to be a credible explanation of the range of characteristics associated with dyslexia.

1.3.5.5 The Dyslexic Automatisation Deficit

Nicolson and Fawcett (1995) have criticised the phonological deficit and temporal processing deficit theories of dyslexia as being too specific, in that they are not able to account for the whole range of deficits found in dyslexia. They propose two linked hypotheses as a potential explanation of the causes of dyslexia: the Dyslexic Automatisation Deficit (DAD) and the Conscious Compensation hypothesis (CC). The DAD hypothesis states that "dyslexic children have unusual difficulty in automatizing any skill, whether motor or cognitive" and that "dyslexic children are normally able to overcome their automatisation deficit by means of conscious compensation that is, by trying harder and/or by using strategies to minimise or mask the deficit" (p. 4). Evidence for the theory was first provided when it was found that in dual task conditions (when attention was consciously directed away from the task in question, by introducing a secondary task) or when wearing a blindfold (preventing conscious monitoring without the complications of the demands of the secondary task), dyslexic children were much worse at balancing, a task completely unrelated to reading (Nicolson and Fawcett, 1990; Fawcett and Nicolson, 1992, 1994b). Peformance on this task without distraction was similar for dyslexics and non-dyslexic subjects. This test of gross motor skills was chosen as it was assumed to be simple and highly practised, yet results indicated that when prevented from consciously monitoring their balance, the dyslexic subjects experienced considerable difficulties compared to non-dyslexic controls.

Nicolson and Fawcett (1995) have found that dyslexics experience difficulties on a wide range of "primitive" skills, i.e. "basic skills that form the building blocks for more complex skills in each domain" (p. 6), such as phonological skills, working memory abilities, processing speed and motor skills, with the sole exception of simple reactions. They have proposed that such deficits lend significant support to the DAD explanation of dyslexia, whilst calling into question other theories of the disorder. They go on to argue that reading is a skill in which automatisation is very important as many component subprocesses have to be blended together to achieve the overall goal of decoding and comprehending the text. Compared to other less complex skills, reading requires a great deal of conscious compensation on the part of the dyslexic and therefore may provide more problems than other tasks. The authors propose that the discrepant profile of difficulties found in dyslexia arises as a result of differential automatisation and conscious compensation requirements, allowing dyslexics to perform much better in some areas than others. Further evidence in support of this explanation of dyslexia has come from the authors' initial studies of the role of the cerebellum in dyslexia (see section 1.3.3 above). This structure of the brain has been linked with the automatisation of motor skill and procedural learning, and deficits in cerebellar functioning have been found in children with dyslexia (Nicolson, Fawcett and Dean, 1994).

However, Nicolson and Fawcett (1995) acknowledge that there are limitations of the DAD/CC hypothesis as it is "merely a description, rather than a fully specified theory in itself" (p. 13). They have considered the possibility that the dyslexic deficit is possibly due to difficulties in "subsymbolic" learning (the automatic methods by which connections are strengthened in the process of skill learning). In addition, the authors acknowledge that DAD does not fully explain the pattern of deficits that they have found in dyslexia (that is, no difficulties with simple reaction speed, poor initial performance on tasks involving choice reactions but improvement at a normal rate, poor phonological skills and difficulties with motor skill that diminish with practice). Nicolson and Fawcett therefore view the DAD/CC hypothesis as a "reasonable description of the symptoms, but not a complete explanation of the cause of dyslexia" (p16).

1.3.6 Evaluation of the theoretical contributions to dyslexia

This section of the chapter has attempted to provide a review of the evidence that is currently available and the explanations that have been proposed for the cause of dyslexia. Biological evidence informs us that dyslexia is a condition which almost certainly results from some form of genetic, neuroanatomical and neurophysiological basis. Behavioural evidence indicates a wide range of manifestations of the disorder in the domains of language, vision, speed of processing and motor skills. A number of possible cognitive explanations have been proposed, none of which, as has been seen, represents a complete explanation of dyslexia. Therefore like the earlier sections of this chapter discussing definition issues, this section must also be concluded with comments to the effect that this is an area of debate and no clear answer regarding the cause of dyslexia exists.

However, the important point to be noted here is that very significant progress has been made towards the identification of the underlying etiology of dyslexia during the last decade, possibly more so than ever before during the century. The enormous amount of research activity in the field of dyslexia has meant that ever more increasingly sophisticated descriptions of the disorder are being formulated. Proposed explanations are coming closer and closer to being able to account for the various characteristics of the disorder. In this respect, the theoretical background for carrying out practical studies of dyslexia such as the one described in this thesis is much more conducive than a decade ago.

To conclude this section on the theoretical aspects of dyslexia, is can be seen that evidence suggests that there is a hereditary component in at least some cases of dyslexia. The neurological manifestations of the disorder appear to be located in a number of anatomical structures and pathways such as the planum temporale, the corpus callosum, the cerebellum and the magnocellular pathways of the medial and lateral geniculate nuclei. Many of these sites are directly related to language functions, but others to vision and motor skills. It may be the case that variations in neuroanatomical and neurophysiological basis may produce different forms of the disorder. At the cognitive level, a number of theories have been proposed. The phonological deficit explanation continues to dominate the dyslexia field, although, limitations of the theory have been found. Visual and speed of processing explanations have aspects in common, stemming from proposals regarding the rapid processing of stimuli. Finally, the dyslexic automatisation deficit provides a broader explanation of the many manifestations of dyslexia, but is best seen only as a descriptive account of the disorder.

1.4 Summary of the chapter

In carrying out a study investigating the early identification of dyslexia, a number of important issues need to be considered. Firstly, it would be helpful to have a clear definition of the disorder to be predicted. However, this chapter has outlined some of the reasons why a universally agreed definition of dyslexia has not yet been found. In addition, one would ideally like to know what the cause of the disorder is so that appropriate measures for identification can be selected to measure aspects of the causal mechanisms. This is not possible at the present time, so on what theoretical basis should such a study be carried out? Instead of basing prediction of dyslexia upon one chosen approach to the disorder, this study has attempted to take account of the various theoretical approaches and issues outlined in this chapter.

The purpose of designing an early screening test for dyslexia is to improve on current methods for identification of the disorder. These methods have been found to have a number of limitations which mean that they are costly both in financial and human terms. However, it is important to be aware of existing approaches to diagnosis when considering design of an early screening test. Therefore, the following chapter begins with an outline of the practical issues in dyslexia - diagnosis and remediation and the limitations that have been found. The case for early screening is made. This is followed by a review of the early screening concept and issues related to early screening research. Existing approaches to early identification are then evaluated.

Chapter 2

The Early Identification of Dyslexia

Preview to the chapter

Current approaches to the diagnosis of dyslexia have been found to have a number of limitations. One major limitation is the minimum age at which diagnosis can be attempted, which, using traditional methods (IQ and written language measures), is usually around seven years of age. However, in many cases diagnosis does not occur until a child is much older, if at all. The negative outcomes of late diagnosis, or failure to identify a child as dyslexic can be stated in academic, emotional and behavioural, as well as financial terms. For these reasons, early screening for dyslexia may provide a better approach to identification of children with the disorder than these existing methods.

The concept of early screening to identify children who may be at-risk for learning problems in school is one which takes influence from a number of different areas of psychological and education research. In considering early screening, one must be aware of the approaches that currently exist for identifying the learning difficulty in older children plus the theoretical and practical issues which influence a screening process involving younger children. The integration of information from a number of different sources provides the best basis for understanding and carrying out a screening programme. A theoretical basis to a screening programme is vital. The researcher must have a good understanding of the disorder to be identified, plus an appreciation of the "normal" path of development of skills in children of the age to be screened. There must be an awareness of problems or particular characteristics that may have been found to exist in children who go on to develop learning difficulties. Equally importantly, the researcher must be aware of the extent to which such screening is actually effective in identifying the very children it is designed to pick out and that it does provide an improvement on existing methods of identification and diagnosis. Screening is not an end in itself - to be of any use it has to be thought of as the first stage in a process of providing better and more timely help for children with learning difficulties.

The idea of early screening for learning difficulties is not a new one - screening studies have been carried out since at least 1935 (e.g. Monroe). A great number of researchers have recognised the value of early identification of children at-risk for academic failure, and there has been considerable interest in creating a test able to accurately and reliably predict those children that would later be found to be underachieving in one or more areas of the academic curriculum.

Scarborough (1991a) has asked the question: "How do dyslexic children differ early in life, before they have been taught anything about reading and writing? (p. 1). In this chapter, information from a number of sources is brought together in an attempt to answer this question and to provide a background to the current study.

In the first section of the chapter the existing methods for identification and remediation of dyslexia are presented, along with a review of some of the limitations of these methods. Following this, the case for early screening is presented and a number of important issues regarding early identification are discussed. These issues include: the importance of understanding the nature of normal development (of reading), evidence regarding possible precursors of dyslexia, recent ideas about the relationship of early spoken language disorders to reading difficulties, and the challenges inherent in assessing children of preschool age. This is followed by an outline of number of important technical issues in early screening such as the notion of screening versus diagnosis, the efficacy of screening (false positives and negatives) and labelling.

The chapter continues with a review of existing early screening studies, beginning with early attempts such as Monroe (1935) and studies from the 1970's in the USA and Britain. More recent studies (1980's) are then reviewed in terms of their measures, subjects and predictive success with an evaluation of the contribution of the studies to our understanding of the early manifestations of dyslexia. Early screening is not without its critics and a number of the limitations of existing early identification studies are discussed. However, recent developments to overcome such limitations are also outlined. The present study has attempted to address the above practical and theoretical issues by seeking to design a new and better test to identify children with reading difficulties before they have begun to learn to read. Of particular interest is the specific identification of children with dyslexia as distinct from other poor readers. The rationale for this study and the method by which it was carried out are described in the following chapter.

2.1 Practical issues in dyslexia: Diagnosis and remediation

When parents or teachers become aware that a child is not making the progress in reading and spelling that would be expected, attempts will be made to account for this lack of progress. It may be considered that the child is not very bright, and therefore it is not so surprising that he or she is having difficulties developing these complicated skills. It may be the case that the child has the ability to read and spell, but is just not motivated to learn to do this. However, it may also be the case that despite adequate motivation and good performance in other school subjects, the child does not develop the ability to read and spell well. In these circumstances, parents or teachers may begin to suspect that the child has dyslexic difficulties and refer him/her for assessment by an educational psychologist or other dyslexia specialist.

Thomson (1991) has proposed that the assessment of dyslexia has three main functions: to come to some kind of "diagnosis", to delineate specific difficulties, and to plan remediation. Approaches to diagnosis will be considered first.

2.1.1 The diagnosis of dyslexia

The aim of an assessment is to determine whether a child has difficulties that can validly be attributed to dyslexia. Identifying a child as dyslexic implies that he or she is not slow learning, although as Chapter 1 indicates, the usefulness of this distinction is currently being called into question. Despite theoretical debate, however, diagnoses have to be made. One approach to diagnosis is based on the exclusionary definitions of dyslexia outlined in the previous chapter. This involves establishing a reading difficulty and then ruling out any background factors which may have caused the difficulty. Such background factors may include sensory problems such as poor vision or hearing, behavioural or emotional difficulties, lack of access to education (for example, as a result of repeated hospitalisations), medical problems (such as epilepsy or hormonal deficiencies) and generally low intellectual functioning. A second approach to diagnosis involves the search for positive indicators of the disorder based on established characteristics of dyslexia. One example of this approach is the Bangor Dyslexia Test (Miles, 1982) which is described in more detail below.

2.1.2 The process of assessment

A number of professionals may be involved in the process of assessing for dyslexia including teachers, doctors and psychologists. Children may be referred for assessment following concern from parents or teachers about difficulties with learning to read and spell. One aspect of the diagnostic process has tended to mean that assessment is not possible before the age of seven years. This is the fact that often reading is only considered sufficiently poor enough to warrant referral for assessment if it is one-and-a-half to two years below the chronological age of the child. Standardised measures of reading do not measure a reading age of below five years, hence it would only be around the age of seven that such difficulties would be detectable. Consequently, very few children are referred for assessment before this age, and many are not assessed until much older. Thomson (1991) has noted that children are often referred for assessment around the age of nine to eleven years, after a number of years of school attendance.

(a) Assessment of general ability

During assessment, a number of measures of a child's performance may be obtained. One instrument that is often used in the diagnostic procedure is an intelligence test. Thomson (ibid) has proposed that the "appropriate assessment of intelligence is one of the most crucial factors in the diagnosis of dyslexia" (p. 143) for a number of reasons. Firstly, it provides a measure of the intellectual level of the child so that low intelligence can be ruled out as a cause of the written language failure. In the case of dyslexia, operationalising the concept of low intelligence often means distinguishing between those children whose full scale IQ score falls above and below 90. Therefore, using an IQ test in the diagnosis of dyslexia provides one of the key criteria on which the condition is often diagnosed: an IQ score of 90 or above. In addition, administration of an intelligence test allows examination of the actual relationship between the child's IQ, chronological age and written language attainments. Therefore an IQ score can be used in the diagnosis of dyslexia in one of two ways. It can be taken as an exclusionary factor by consideration of whether it is above or below the critical figure chosen by practitioners to distinguish dyslexics from slow learners (often a score of 90). A full scale IQ score can also be used in a regression index for reading as compared to IQ. Using this method, reading performance is judged to be poor if is significantly below the level predicted for the child based on chronological age and IQ. In this way, children with higher IQ's can still be found to have reading difficulties despite having average reading performance, due to the fact that this performance is low in the context of the age and IQ.

Intelligence test scores have been proposed to be able to provide diagnostic profiles for the identification of dyslexia, and such profiles can also be of use in establishing cognitive strengths and weaknesses for remediation purposes. One commonly used intelligence test is the Wechsler Intelligence Scale for Children (WISC) (Wechsler, e.g. 1976, 1992). Aspects of this test have been found to be particularly useful in the diagnosis of dyslexia. A number of studies, for example, have reported that dyslexic children tend to obtain lower verbal IQ scores on the test in comparison to their performance IQ scores (e.g. Belmont and Birch, 1966). In addition, many studies have also found that dyslexics' performance on four of the subtests of the WISC tend to be considerably poorer than other subtest scores. These subtests are information, arithmetic, digit span and coding, and the performance profile is often referred to as the "ACID" profile. A more recently developed intelligence test, the British Ability Scales (Elliot, 1983) has also been used with dyslexic children and it has been found that dyslexics score significantly less well on six of the subtests: speed of information processing, immediate and delayed visual recall, recall of digits, basic arithmetic and word reading (Thomson, 1991).

It can be seen therefore that intelligence tests can play a central role in the diagnosis of dyslexia by generating overall IQ scores, and discrepancies between performance and verbal IQ and between the ACID subtests and other subtest scores, as evidence in favour of a diagnosis of dyslexia. However, Siegel's (1989) arguments against their use raise important points about the validity of IQ scores as a measure of potential ability. One important practical point to note with respect to administration of IQ scales is that such scores can only provide a "snapshot" view of a child's abilities in a possibly stressful assessment situation. Such scores may not, therefore, be an accurate representation of what the child is capable of. This criticism is also relevant to other standardised measures which will be discussed below.

(b) Assessment of reading and spelling

In addition to a standardised measure of intelligence, standardised reading and spelling tests may be administered during the assessment for dyslexia. Single word tests of reading such as the Schonell Graded Word Reading Test (Schonell, 1951) and the test of Word Reading from the British Ability Scales (1983) provide an indication of the individual's ability to decode a number of increasing difficult words, and measures of speed and accuracy of reading can be obtained. Standardised reading age scores can be obtained using accuracy scores. Other reading tests such as the Neale Analysis of reading (Neale, 1966), provide an indication of the speed and accuracy of *contextual* reading using short passages that increase in difficulty. As well as reading accuracy and reading rate ages, reading comprehension performance can be measured. Single word spelling tests such as the British Ability Scales Spelling Scale (Elliot, 1992) may also be administered during the assessment and these provide accuracy based spelling age scores.

As indicated above, a discrepancy of at least eighteen months between the reading age of the child and the reading level that would be expected based on chronological age alone, or chronological age and full scale IQ is usually required for a diagnosis of dyslexia. Spelling performance is often found to be worse than reading performance in many dyslexics (Thomson, 1991). In addition to accuracy scores, error analysis may be used in the assessment of dyslexia to establish patterns of difficulty with reading and spelling. In all cases, the use of one off diagnostic instruments such as these requires caution in the interpretation of results.

(c) The Bangor Dyslexia Test

Specially designed diagnostic instruments such as the Bangor Dyslexia Test (Miles, 1982) can also be used in the identification of dyslexia. The test is a form of screening test that can be used by teachers and other practitioners to quickly and easily pick out children with dyslexia (from the age of about eight years). This test includes ten indicators:

- left-right (body parts)
- repeating polysyllabic words
- subtraction
- tables
- months forward
- months reversed
- digits forward
- digits reversed
- b and d confusion
- familial incidence

Assessment using the test involves noting whether the child scores as dyslexia positive or dyslexia negative on each item, depending on performance. A significant number of dyslexic positive items provides evidence in favour of a diagnosis of dyslexia. Support for this measure comes from Miles (1993) who found that in a sample of 9 to 12 year olds, dyslexics had a mean of 5.14 dyslexia positive items compared to only 2.24 for controls.

(d) The Aston Index

The Aston Index (Newton and Thomson, 1982) is also an instrument that may be used in the diagnosis of dyslexia. A two level screening device, the test enables assessment of a range of skills linked to the development of literacy which can be administered at the age of six years or older. Like the Bangor Test, the advantage of such a measure is that it attempts to specify positive indicators of dyslexia and test for them. Such indicators reduce the need to rely solely on discrepancy formulations of dyslexia based on standardised IQ and reading measures.

(e) Other information which may be obtained during assessment

The measures outlined above are just a number of the different methods of assessment that may be used in the diagnosis of dyslexia. Other information may be obtained during the assessment, such as measures of listening compared to reading comprehension and samples of free writing by the child. The child and his or her parents may be interviewed to determine whether possible background factors such as lack of school attendance, emotional problems or medical difficulties may be contributing to the written language problems. Information regarding developmental milestones such as talking and walking may be obtained in order to provide as complete a picture as possible of the child.

Following assessment for dyslexia, a diagnosis is provided for the child depending on their performance on the measures given. A diagnosis may indicate that the child is dyslexic or slow learning, or perhaps may just indicate that he or she experiences some difficulties of a dyslexic nature without being able to endorse a definitive diagnosis of the disorder. Although perhaps providing some reassurance that an individual is not "just stupid", a diagnosis of dyslexia is useless if no help is provided as a consequence of the assessment. In terms of current educational practice in the UK, following the 1981 Education Act, children diagnosed as dyslexic are deemed to have "special educational needs" and a "statement" of such needs is drawn up by those involved in the assessment procedure. This indicates the extent of the "special educational provision" that is required by the child (Pumfrey and Reason, 1991).

2.1.3 Intervention and remediation for dyslexia

Although it is almost certain that if you are born dyslexic, you die dyslexic, it is not the case that the difficulties that are experienced as part of the disorder cannot be overcome to a large extent. However, as in the case of methods of diagnosis, methods of intervention for dyslexia suffer from being based on an as yet incomplete understanding of the disorder. Nonetheless, researchers and practitioners have been working over a considerable number of years to develop effective methods for overcoming the difficulties experienced by many dyslexics.

A number of teaching programmes have been designed for teaching dyslexic children. These include the Alpha to Omega programme (Hornsby and Shear, 1976), the Bangor Dyslexia Teaching System (Miles, 1992) and the Gillingham/Stillman programme (e.g. Gillingham and Stillman, 1969). Programmes such as these use structured teaching methods and multi-sensory approaches to assist the development of written language skills of the dyslexic. Many of the programmes use explicit teaching of phonics and begin with basic letter sounds building up to more complex combinations. Multi-sensory teaching, as the name suggests, emphasises the interrelationship between the auditory, visual and kinesthetic (tactile) modalities in the development of language skills and is based on the work of Orton (1937). One of the benefits of a multi-sensory approach is that is allows presentation of the same material in different forms, overcoming interest and motivation problems when the same information has to be presented many times over.

There are a number of ways in which a dyslexic child may receive remedial help. For many children, their statement of special needs indicates that extra teaching should be provided by a visiting educational psychologist, remedial teacher or a specially trained teacher within the school. Children with very severe difficulties may attend special schools for dyslexic children. Remedial help can also be obtained from private teachers and from organisations such as the Dyslexia Institute. In many cases the form of the remedial given will be similar to that in the programmes listed above.

2.1.4 Limitations of current approaches to the diagnosis of dyslexia

There are a number of important limitations of the current approaches to the diagnosis and remediation of dyslexia. One of the most important of these is that such approaches are based on an incomplete and possibly faulty understanding of the disorder. In light of the fact that discrepancy definitions of dyslexia based on IQ scores have been so heavily criticised in recent years (e.g. Siegel, 1989; Stanovich, 1994) the theoretical basis of the measures used to diagnose the disorder has become undermined. It is almost certainly the case that there are children with low IQ, emotional and behavioural problems and other background factors that would normally exclude a diagnosis of dyslexia, who suffer from the disorder. However, methods of diagnosing such children are not readily available and therefore they may not be receiving the help that they need to function within the education system. At present, diagnostic procedures distinguish between dyslexic and slow learning children, and different forms of help may be provided for children in the two groups. The validity of such differentiation in provision is as yet unknown and requires further investigation.

The second major limitation of the current approach to identifying dyslexia is the relatively late age at which it is possible for an assessment to be carried out. A child of seven years in the UK will have been attending school for at least two years. The development of his or her written language skills is the key that unlocks the rest of the academic curriculum. If these skills do not develop, the child very quickly begins to be denied access to all sorts of information that his or her classmates are experiencing. Learning to read and spell are not ends in themselves, they are a means to an end, that is, the ability to communicate and to receive information from the written word. Any child who is not making progress in written language skill development will begin to experience difficulties with a whole range of activities as soon as they enter primary school. By the age of seven, the child will have been experiencing these difficulties on a daily basis for two years.

And yet, although seven is the earliest age at which a diagnosis may be attempted, evidence indicates that it is usually later than this that a child is referred for assessment. A number of children may be referred following entry to senior school (around the age of eleven years) as the increased demands of the curriculum expose the child's lack of ability with basic written language. Late diagnosis of dyslexia can be seen to have three possible negative outcomes:

- academic difficulties
- emotional difficulties
- behavioural difficulties

That a child who is not able to read or spell well will have academic difficulties is obvious, for the reasons outlined above. From the very beginning of the child's school career, information is provided using the written word, either on the blackboard or in text books. A child with dyslexia runs the risk of not being able to develop his or her academic skills outside of reading and although perhaps bright, will not make progress in the rest of the curriculum. The longer such difficulties are left unidentified, the further behind the child will become.

It is not hard to see therefore, how the secondary reactions to dyslexia - emotional and behavioural difficulties, develop in such circumstances. Thomson (1991) has noted that "the child is vulnerable in his academic work, but also in social, emotional and personality growth" (p. 21). Thomson quotes the case of "David" as an illustration of the emotional correlates of dyslexia:

> "David was 15 years old when he was referred, a physically mature boy who had been suspended from school for threatening the head teacher and generally being disruptive. David was of very superior intelligence, with a reading age of about 12 years, but spelling around the 7 $^{1}/_{2}$ year level with great difficulty in written expression. He was rather sullen and aggressive at first, but soon revealed a warm and pleasant personality with a tremendous verbal fluency and wide interests. David had given up school as a waste of time .... School reports from previous years indicated that he contributed considerably in classroom discussions, but written work and homework were very poor. He was reported to be lazy. More recently, however, David was making himself very popular with his class-mates by joking and fooling around in class, and at home was associating with a group of youths who had been involved with the juvenile courts" (p. 21).

This case clearly illustrates the dangers of not diagnosing dyslexia at an earlier stage. A circular situation appears to exist in that as the child begins to fail, he is not as willing to do the work and is viewed as lazy. If the teacher believes the child to be lazy then poor written language work will not be unexpected. However, the perceived laziness and other behavioural problems are actually a reaction to the child's inability to succeed with the development of reading and spelling rather than the cause of it. Thomson quotes another case of a child, "John" (ten years old) who was found to be anxious and withdrawn, and verged on tears when asked to do anything relating to written language. It was reported that he often cried at school, frequently claimed to be "ill" on school mornings, and had begun to wet the bed. Socially John had become isolated from his peers and was not able to participate in normal classroom activities, instead having to deal with "remedial work" which he found almost impossible. Unlike David, who had turned his frustration outwards and had begun "acting out" in the face of his dyslexic problems, John had turned inwards and become a very sad little boy.

The danger of such late diagnosis for David is particularly clear when one realises that at the age of fifteen, his time of compulsory school attendance is short and in the light of his disillusionment with education, he may well decide to leave school at the first opportunity. If this is the case, the chance of providing help to overcome some of David's difficulties will almost certainly be lost, and he may become one of many illiterate school leavers who find employment opportunities limited. Thomson (1991) has pointed out that non-diagnosed dyslexia can result in extreme outcomes such as breakdowns and psychiatric referral, or criminal and antisocial behaviour resulting in imprisonment (there is a high incidence of illiteracy in penal establishments).

The limitations of the present system for recognising and diagnosing dyslexia are clear: current methods of diagnosis mean that there is a limit on how early a child can be assessed for dyslexia, imposing at least two years of failure and frustration on the dyslexic child before anything can be done. In addition, because of the nature of the education system and the conceptualisation of dyslexia as unexpected reading difficulties, many dyslexics can simply slip through unnoticed and undiagnosed, leaving school with very few if any literacy skills at all, often finding themselves unemployable.

There is no doubt that the situation requires some improvement to prevent bright and well motivated dyslexic children from losing heart and switching off to the education system altogether. It is clear that diagnosis of dyslexia at as early an age as possible would be beneficial to prevent children experiencing the repeated failure of not learning to read. It would also be advantageous if all children were investigated for *risk of dyslexia*, so that there were no danger of children "slipping through the net". Such improvements to the present system of diagnosis seem extensive, however, they could potentially be achieved with the use of a simple screening test for dyslexia which could be administered to all children before or at school entry.

This study has attempted to design such a test for use with four and five year old children. Although the test itself must be simple, the theoretical considerations for such an undertaking are far from this. Having examined the current research concerning dyslexia in the previous chapter, the following sections provide a detailed analysis of issues relating directly to early screening and how they can be related to dyslexia.

2.2 Issues in the early identification of dyslexia

2.2.1 The case for screening for dyslexia

In the previous section it was observed that children who suffer from dyslexia often experience behavioural and emotional problems as well as academic difficulties as a result of their learning problem. Much evidence seems to suggest that these problems become more pronounced the longer they remain untreated. Catts (1991) has noted that:

> "For many reading disabled children ..... diagnosis comes only after considerable academic failure. Because these children are not identified until nine or ten years of age, many of them have struggled with learning to read for several years. This struggle often leads to poor motivation and negative attitudes towards reading as well as more serious socioemotional problems." (p. 1)

Butler (1979) has also observed that "children with learning problems which are not diagnosed and treated at an early stage in their school careers are likely to develop severe learning disability with associated emotional and behavioural disturbances." (p. 263) In addition, higher rates of delinquency and dropping out of school have been observed in children with such learning disabilities (Brown, 1978; Gordon, 1993).

The academic difficulties of the dyslexic child are often observed to become proportionally worse as the child gets older, a phenomenon that Stanovich (1986) has called the "Matthew Effect". Based on the idea of the rich getting richer and the poor becoming poorer, this effect can be seen in terms of those children who have reading skills being able to develop their reading and academic skills to a greater extent than the child with reading difficulties, and the gap between the two becoming greater over time. Such a finding obviously lends weight to the argument that children with dyslexia should be identified and given appropriate remediation as early as possible.

Other evidence which strongly supports use of early screening with dyslexic children comes from Strag (1972) who reports that the prognosis for those diagnosed as dyslexic varies considerably depending on the age at which diagnosis is made. Strag found that the proportion of children who could be brought up to the normal level of classroom work on the basis of diagnosis in the first two grades of school (ages 7 and 8) was 82%, but this figure dropped dramatically to 46% for children in grade 3, and by grades five to seven only 10-15% of the children were able to be remediated to grade levels. Satz and Fletcher (1988) are among a number of researchers who have also proposed that early identification and intervention results in more favourable outcomes for children in the long term.

The case for early screening can be made in financial as well as human terms. A simple screening test that is quick and straightforward to administer to all children of a certain age could allow those who may experience later failure to be given help in the early school classroom. Remedial help could be of a form that did not differ significantly from methods used in regular classrooms with young children. For example, Augur (1985) has noted that "teaching methods found to be most useful with the dyslexic child .... are also appropriate for small children receiving their first instruction in reading, writing and spelling" (p. 159). By this Augur implies that the structured multisensory teaching techniques that have proved to be very productive when used with dyslexic children would not be harmful in any way for normal children, and adapting the curriculum in this way for all children would provide the possibility of intervention for the young child without the use of outside specialist personnel. This possibility contrasts strongly with the situation often found at the present time where children who are not diagnosed as dyslexic until a later age often have difficulties which are very resistant to remedial help, and may have to be visited by educational psychologists or special needs teachers which can put a great strain on Local Education Authority budgets. For a number of dyslexic children, lessons outside of the school at, for example, a local Dyslexia Institute or even placement in a "special" school for dyslexics may be required to overcome the difficulties which the child is experiencing. Therefore, as Butler (1979) points out "A screening system at school entry would enable the subset of children who seem likely to be backward readers to be given anticipatory remediation during the period when reading is not yet established" (p. 272). An additional benefit of early identification is that it is able to take advantage of the plasticity of the young nervous system and therefore remedial efforts may be more effective at this early age (Satz et al., 1976).

There are other advantages of early screening which also relate to the provision of remedial services for dyslexic and learning disabled children. One such advantage is that gaining detailed information regarding the profile of performance of individual children with learning difficulties on tests such as those used in screening batteries provides a better basis for designing suitable remediation programmes. Awareness of the particular strengths and weaknesses of the child allows for a method of teaching which teaches to the strengths in order to overcome weaknesses. Differences in the performance profiles of poor reading children may provide evidence to support the distinction between dyslexics and slow learners, or the existence of subtypes of dyslexia.

In addition to the practical information that early screening can provide, information from dyslexic children as young as two years of age (e.g. Scarborough, 1991a) and upwards may provide evidence regarding the causes of dyslexia and aid our theoretical understanding of the disorder. As we saw in Chapter 1, research to date has yet to discover the true nature of dyslexia and the mechanisms responsible for it. However, the value of identifying differences between dyslexic and non-dyslexic children at an age before reading has been tried (and failed) is considerable, as this may provide information about the causes of the disorder.

2.2.2 Early screening and children's development

Although the intuitive value of early screening for learning disorders such as dyslexia is great and the benefits which it may bring may be considerable, the issues underlying early screening are complex, making it a far from straightforward undertaking. One important issue which researchers must address is a knowledge and understanding of the developmental processes of young children and the "normal range" of variation in the acquisition of cognitive skills. The National Joint Council on Learning Disabilities (1986) have made this important point:

> "Normal development is characterised by broad ranges of individual and group differences, as well as by variability in rates and patterns of maturation. During the preschool years, this variability is marked. For some children marked discrepancies in abilities are temporary and are resolved during the course of development and within the context of experimental interaction. For other children, marked discrepancies persist within and among one of more domains of function, necessitating referral for systematic assessment and appropriate intervention." (p. 158)

The challenge for early identification researchers is to obtain an adequate enough understanding of the processes of development in the domain in which they are attempting to predict disabilities. Only then will children whose path of development deviates sufficiently from the range of normal variation be identifiable.

The issue of whether dyslexia differs from other forms of normal or disabled reading in a qualitative or quantitative way has some impact on this understanding. If researchers believe that dyslexia does differ in a qualitative way from other forms of reading then the goal of the researcher is to establish these differences and examine how they are manifested in children who have yet to experience formal reading instruction. If, on the other hand, it is believed that dyslexia differs quantitatively from "garden variety" poor or normal reading, the importance of establishing the "normal" processes of reading acquisition is critical and poor reading maybe understood in terms of delays or deviation in the normal processes of learning to read. As the nature of the difference between dyslexia and other reading performance is not yet resolved, the following section provides a brief outline of some current theories of the development of reading skills. This does have some significance for even those who argue in favour of qualitative differences, in that evidence seems to be mounting to suggest that the best way of approaching remediation for dyslexia is to provide training in those skills which have been proposed as constituents of the reading development process, such as phonological skills.

2.2.3 Children's acquisition of reading skills

The development of reading skill may appear to be a simple process for most children, yet the actual stages and mechanisms involved in this development are not fully understood. For many years, primary school teachers have been using either "phonics" or "whole language" approaches or some combination of the two to instruct young children to read and spell, although the theoretical basis of such approaches was not completely established. However, reading research has progressed significantly over the last decade and Goswami (1990) has noted that the discovery that "there is a strong link between a child's phonological awareness and his or her progress in reading has been one of the most consistent results in research into reading development in recent years" (p. 301). In some cases, evidence regarding processes of reading development has come about as a consequence of investigations of dyslexia and its relationship to normal reading development (Adams and Bruck, 1993).

A number of models of reading development have been proposed. One example is that of Frith (1985). Frith outlined a three stage model of reading. In the first stage, the "logographic stage", the child identifies a small number of familiar words as whole shapes, purely on the basis of association. Salient graphic features are often used as cues in this recognition process (e.g. recognising the word "yellow" on the basis of the two "tall sticks" in the middle of it). Following this, in the "alphabetic stage" the child begins to understand that words are made up of letters which represent sounds. At this point the child's reading and spelling ability takes off, as increased flexibility is possible on the basis of combining and recombining the components of words. In the final stage of reading development, the "orthographic stage", words are recognised rapidly as visual units and attention is shifted away from basic decoding of print to an understanding of its meaning. Marsh, Friedman, Welch and Desberg (1981) have proposed a similar four stage model with the child moving from the first stage of "glance and guess" to sophisticated guessing, then to the acquisition of simple grapheme-phoneme correspondences and finally, to skilled reading.

Within the stage of phonemic development advocated by the two models, there has been further speculation regarding the exact process of development of phonological awareness. For example, some researchers believe that phonological awareness is a crucial precursor to reading (e.g. Bryant and Bradley, 1985b), while others believe that such skills develop as a result of learning to read (e.g. Morais, 1987). Evidence suggests that prereading children have good awareness of large sublexical units such as the syllable and the onset-rime but poor awareness of the smaller unit of the phoneme (Bruck, 1992) and that phoneme awareness is most influenced by the introduction of literacy instruction. Research by Goswami and colleagues (e.g. Goswami, 1990; Goswami and Mead, 1992) and Bruck and Treiman (1992) has further indicated that children use a process of analogy when learning to read and spell unfamiliar words, with different aspects of phonological awareness related to different kinds of analogies (e.g. onset-rime awareness is related to end analogies whereas beginning analogies are related to higher level phonological skills).

In conjunction with the development of phonological skills, children must also develop orthographic skills and the ability to derive meaning from print. Learning to read is a very complicated skill and the speed and relative ease with which most children acquire this skill is almost mystifying. A thorough review of this subject is beyond the scope of this chapter, however accounts by, for example, Adams (1990) provide a much more comprehensive study of the development of reading. Nonetheless, models such as those outlined above provide some indication of the possible mechanisms involved in the development of literacy skills, and the failure to develop such skills.

2.2.4 Precursors of Dyslexia?

Before it is possible to consider devising a screening test to identify children at-risk for dyslexia, it is important to have some idea of what a young dyslexic child might look like. That is to say, what might be observably different about the dyslexic child before they have begun to receive formal reading instruction? One of the most comprehensive listings of anecdotal evidence from parents of dyslexic children comes from Augur (1985, 1990). She has noted that parents of dyslexic children often report that they felt that something "wasn't quite right" about the child, but could not work out what the problem was. The following list outlines some of the characteristics which Augur found to be reported of young dyslexic children (age 3 to 5 years).

- History of dyslexia in the family
- Later than others in the family to speak, but a quick "thinker" and "doer"
- The use of substitute words
- Jumbled words, excessive spoonerisms or difficulty pronouncing multisyllabic words
- Inability to remember the label for known objects
- Appears accident prone: tripping, falling and bumping into things
- Mislabelling, e.g. "lampshade" for "lamp post"
- A lisp and/or possible history of slow speech development
- Aptitude and preference for constructional/technical things e.g. bricks, puzzles, buttons on the video or TV, computer keyboards
- Enjoys being read to but shows no interest in words
- Difficulty understanding prepositions connected with direction: confuses "down" with "up"
- Difficulty in fastening coat, shoelaces and tie
- Difficulty hopping, skipping or clapping a simple rhythm
- Difficulty throwing, catching and kicking a ball
- Undetermined hand preference
- Difficulty in remembering the days of the week in order, uncertainty about "yesterday" and "tomorrow"

Augur stresses that although some of these characteristics will be found in all children, including those without learning difficulties of any kind, it is the intensity with which the characteristics are displayed that may be cause for concern. A child who displays a considerable number of the characteristics above to a greater intensity is more likely to be at-risk for later difficulties. The British Dyslexia Association in a booklet entitled "Dyslexia Early Identification", have also outlined a number of signs that parents and professionals might look out for in a young child before or at school entry. These include: a delay in speech and language, a marked difficulty in copying shapes with a pencil or with bricks, difficulties with sequencing or remembering the order of simple instructions, clumsiness and poor coordination in gross and fine motor skills, delay in the establishment of laterality, distractibility, family history of reading problems, problems with buttons and bows, and problems with writing his or her name or copy letter shapes.

Augur's survey and the BDA booklet provide considerable insight into the possible early signs of dyslexia, nevertheless, the information is only anecdotal and suffers from the possibility that it may be coloured by what the parents know about their children now, i.e. that they are dyslexic. Evidence is growing, however, from scientific studies that have been carried out with young children with dyslexia, regarding possible precursors of the disorder.

As part of the British Births Cohort Study, Haslum (1989) studied the records of a group of children taking part in the study who had been diagnosed as dyslexic at the age of ten years. Information for each child had been collected at birth, five years and ten years of age and Haslum was able to look back at the records of the children and to establish if there were any differences between the dyslexics and the non-dyslexic children at each age. Haslum found that the dyslexic children differed from the non-dyslexics on six of the measures taken in the study. These differences varied for males and females. It was found that both males and females could be differentiated from non-dyslexics at five years of age on the basis of failure on a "catch-a-ball" test, but that male dyslexics also failed a "walking backwards" test, tended to have mothers with lower educational qualifications, and a difference in father's attitude to the child. Female dyslexics, on the other hand, tended to have fathers with lower educational qualifications and siblings with reading problems. The findings of this study raise the issue of whether there are sex differences in the constitution or manifestation of dyslexia and whether the precursors of the disorder may vary with the sex of the child (see also Badian, 1990a). Haslum concluded from the above findings that "there is a link between motor difficulty and dyslexia ...[and] .. the link maybe stronger for boys than for girls." (p. 627)

Melekian (1990) undertook a detailed study of the family characteristics of dyslexic children and found a number of factors that might be indicative of a child at-risk for the disorder. Like Haslum, Melekian found that low educational qualifications of the mother was a characteristic found in a significant number of the dyslexic children studied. It was also found that the majority of the children with dyslexia came from large sibships with three or more children, revealing a relationship between birth order and dyslexia. Approximately two thirds of the dyslexics studied were located in the second half of their sibship (see also Badian, 1984a). In addition, Melekian found that socio-economic status did have some influence on the development and aggravation of dyslexia, particularly in severe cases of the disorder.

There is some evidence to suggest that the month of birth and climatic temperature at the time of birth may be significantly associated with dyslexia (Badian, 1984; Livingston et al., 1993) and could therefore contribute to the prediction of the disorder. Early summer births (May, June and July) accounted for between 24% and 70% of the 585 cases of dyslexia examined by Livingston and colleagues. Badian found that monthly temperature at the time of birth was associated with dyslexia, with five times more children with reading disorders born in the hotter (summer) months. Livingston et al.. have hypothesised that the relationship between month of birth and dyslexia could actually be due to increased levels of viral infection during the *second trimester* of pregnancy, rather than mechanisms directly relating to factors at the time of birth. This hypothesis lends itself to the research findings of Galaburda et al. (1985) regarding the role of neuronal migration in the cause of dyslexia (see Chapter 1). Neuronal migration has been found to proceed at an accelerated rate during the second trimester of foetal development which is particularly interesting in light of the abnormalities of neuronal distribution found in studies of the cortex of a number of dyslexics. However, in the UK, children born in summer months do not enter school until two terms after children born in the autumn and therefore other reasons, such as differences in exposure to reading instruction, may also influence these findings.

Researchers have found a number of phonological processes to be good predictors of later reading ability and as such may be seen as precursors of dyslexia. These processes particularly include phonological awareness (e.g. sound categorisation), phonological coding in working memory (e.g. digit span) and phonological coding in lexical access (e.g. naming) (Felton, 1992). These possible precursors of dyslexia are considered below.

(a) Phonological awareness and later reading ability

The relationship between phonological awareness and later reading ability has received a great deal of attention (Singleton, 1988), particularly in the last two decades. For example, Wallach and Wallach (1976) noted that analytic and synthetic phoneme awareness has been shown to be predictive of early and later reading achievement in a number of studies. Further evidence to support this link has been provided by Lundberg, Olofsson and Wall (1980) and Fox and Routh (1983). More recently, Mann (1993) found that between 30% and 40% of the variance in first grade reading could be predicted by two tests of phoneme awareness (phoneme segmentation and invented spelling) and Ball and Blachman (1991) found that phoneme awareness instruction significantly improved the reading and spelling performance of a group of kindergarten children.

One of the most important findings in the search for phonological predictors of dyslexia has been that of Peter Bryant, Lynette Bradley and colleagues regarding the role of difficulties with rhyme as a precursor to later reading problems. As outlined in Chapter 1, in their study in 1983, Bradley and Bryant gave an "odd-one-out" rhyming task to a group of 403 four- and five-year-olds. The children were required to say which word was the "odd-one-out" of a list of three words such as "lot, cot, hat, pot". The researchers found that a child's performance in this task was an important predictor of how well she or he had learned to read and spell up to four years later, and moreover, training in these skills improved the performance of poor readers. In addition, Bryant, Bradley, Maclean and Crossland (1990) found that knowledge of rhymes and success in learning to read and spell were strongly related (see also Bryant, MacLean and Bradley, 1990).

To summarise, four major aspects of phonological awareness have been reported to have some relationship with later reading ability and therefore, may be early indicators of reading disability (Catts, 1991). These are:

- detecting words that rhyme or begin with the same sounds
- counting the number of phonemes or syllables in a word
- pronouncing a word after deleting an initial or final segment
- comparing the length of spoken words

(b) Phonological coding in working memory and later reading ability

Measures of verbal short term memory in kindergarten (such as digit span) have been found to be predictive of reading ability in first grade (Mann and Liberman, 1984). Difficulties with this task seem to be the result of phonological processing deficits, particularly problems in the use of phonological codes to maintain verbal information in memory (Wagner and Torgesen, 1987). Another aspect of this form of phonological difficulty which has been found to be related to later reading performance is the pronunciation of new, unusual or complex words (Catts, 1989). These phonological measures may also, therefore, be considered to be precursors of reading disability.

(c) Phonological coding in lexical access and later reading ability

Research has indicated that children at risk for reading problems often have difficulties retrieving phonological information from memory (Wolf, 1984). Such children frequently have word finding difficulties and may be described as "dysnomic".

Children with dyslexia have been found to have difficulties with tests such as the Boston Naming Test, which requires them to name a number of relatively common objects. Wolf has proposed that these difficulties are due to problems in retrieving the sound codes or names of the objects from memory. In addition, Denckla and Rudel's work with their test of Rapid Automatised Naming (RAN) has indicated that children with reading difficulties tend to show slower performance on this task. Difficulties with naming in kindergarten have been found to be good predictors of later reading performance (Catts, 1991; Felton and Brown, 1989; Wolf, 1984, 1986, Wolf, Bally and Morris, 1985; Wolf and Obregon, 1992; Wolf and Segal, 1992). Such naming difficulties have been linked to problems with a precise timing mechanism in dyslexia that may inhibit the ability of some dyslexics to achieve rapid processing (Wolf, 1991; Wolf and Obregon, 1992).

The role of such phonological skills in the prediction of reading difficulties is an important one and is also featured later in the chapter, when a number of existing predictive studies are reviewed. In addition to these difficulties, it has also been noted that in many cases, the early manifestations of a reading disability are difficulties in oral language (Catts, 1991b; Godfrey et al., 1981). Although research into spoken language disorders has been carried out for many years, it is only relatively recently that specific links have been made between spoken and written language difficulties. One important outcome of this is that difficulties with spoken language may serve as a valuable indicator for learning difficulties such as dyslexia. Recent research in the field of spoken language disorders is therefore briefly reviewed below.

2.2.5 Spoken Language Disorders and Reading

Evidence suggesting that children with preschool spoken language disorders constitute a high risk group for later academic and language difficulties has increased over the last fifteen years. Many children with language problems also have reading problems (Menyuk et al., 1991) and although the exact nature of the relationships between oral language and reading has yet to be fully described, one outcome of such a description would be that predictions and interventions could be made. Menyuk and her colleagues, for example, found that early language measures of metalinguistic abilities were the best predictors of later reading problems, but that different metalinguistic abilities were the best predictors for children with differing levels of reading difficulty.

Further evidence that children with spoken language disorders may be at risk for reading difficulties is provided by Aram and Nation (1980) who found that 40% of the language disordered children that they studied were not attending regular classrooms four and five years later, and Catts (1991b) has also proposed that in many cases the early manifestations of a reading disability are difficulties in oral language. Scarborough (1990, 1991b), in detailed longitudinal studies of children's early spoken language, found that children with reading disorders performed at significantly low levels on a measure of receptive language processing at ages three and four, producing syntactically less complex sentences and having a shorter mean length of utterance (MLU) than non-reading disordered children. Bishop and Adams (1990) also found that MLU at age 4.6-5.6 was the best predictor of reading and spelling abilities at age 8.6 years.

A number of researchers have actually carried out early identification predictive studies with children with oral language disorders such as Specific Language Impairment (SLI) (Bishop and Adams, 1990; Stark et al., 1984) and Early Language Delay (ELD) (Scarborough and Dobrich, 1990) and found that such children often developed reading problems in greater proportions than children without oral language difficulties. Bishop and Adams found that children with early phonology disorders alone tended not to be at-risk for reading disability, but that children with semantic-syntactic impairments did often develop reading problems. Stark and colleagues found that children with SLI aged four to eight years followed over four years did acquire language skills over time, but at a slower rate than normal children. They found that ninety percent of the LI children showed some degree of reading disability at follow-up with three of the "remediated" LI children also found to be reading disabled. Katz, Curtiss and Tallal (1992) have proposed that SLI and dyslexia, although differing in a number of respects, may have some degree of overlap, in that dyslexic deficits have been found to be broader than just reading, and many children with SLI have later reading problems. In addition, both groups of children, have been found to have deficits in perceptual and motor development, particularly in processing rapid sequential information (Wolff, Michel and Ovrut, 1990).

Evidence also exists to indicate that some of these oral language difficulties persist beyond preschool age in individuals with reading difficulties. Godfrey and colleagues (1981) have found subtle deficits in the phoneme analysis of spoken as well as written language in dyslexic children which suggest an inconsistency in the dyslexics phonetic classification of phonetic cues.

Butler (1988) has speculated in light of evidence that dyslexia and dysphasia have been found to be consistently linked on whether the two might represent a single developmental disability affecting specific processing constraints or perhaps specific aspects of the language learning system at different ages. In addition, Lewis (1992) found that some developmental speech and language disorders aggregate in families and demonstrated a familial concentration of dyslexia and learning disabilities in families of children with phonology disorders. On this basis, Lewis has also speculated on a possible verbal trait deficit which is part genetic and responsible for both phonology disorder and dyslexia.

It is clear therefore that the link between spoken and written language disorders may be important in the search for early markers of dyslexia. The consistent finding that at least some of the children with oral language problems go on to develop written language difficulties implies that such problems are either a cause or an early symptom of the dyslexic deficit. Whether it is cause or symptom remains to be established, however, what is clear is that spoken language difficulties can provide a useful early risk indicator for dyslexia. Along with the other evidence regarding early characteristics of dyslexia from anecdotal and experimental sources, this information can assist in the selection of tests for screening batteries. However, choosing tests to be incorporated in a screening programme must also take into account the characteristics of the population to which it is to be administered. There is no point in chosing highly predictive tests for the screening process if they are not suitable for the group to which they will be administered. The following section discusses some issues which need to be considered with respect to the subjects of the screening assessment: the preschoolers.

2.2.6 Issues in the Assessment of Preschool Children

One implication of the early screening concept is that children should be assessed for potential learning difficulties at early an age as possible. This is for two main reasons, firstly to make sure that help can be provided as early as possible for those who need it, and secondly, many researchers believe it is better to screen children before formal reading instruction has begun to avoid confounding the performance of the children on screening tests by such reading experience (Bryant, Maclean and Bradley, 1990). The majority of screening tests that are reviewed in this chapter have involved children of six years of age or younger at the time of testing, and more importantly perhaps, not yet attending conventional school classrooms. Assessing preschoolers can provide researchers with challenges which need to be overcome if the results of assessment are going to be meaningful.

Lidz (1983) notes a number of issues to be considered when assessing preschoolers and makes the following points:

> "Preschoolers can be very difficult to assess. They often do not have well-developed verbal expressive skills, are frequently still struggling with separation issues, do not sit with rapt attention at a table for an hour or more, and, more often than not, are not very concerned with compliance in order to please the examiner" (p. 17)

She also reminds us that the researcher must have the capacity to be flexible in the assessment situation, have a large repertoire of approaches from which to select, and be capable of capitalising on the situation with a particular child at a particular time. Lidz stresses the need for an appreciation of the developmental variability of children of preschool age and points out that behaviours which may be diagnostic of disorders at later ages may be normal for children of a younger age, such as motor skill difficulties and errors on particular tests. In addition, Santos de Barona (1992) notes that "development and learning in preschool-aged children often occurs at an uneven and unpredictable rate, being absent one day but readily apparent the next." (p. 244) Such variability between and within particular children during the assessment period must be taken into account .

One major difficulty inherent in testing very young children is ensuring that failure on a test or test item is due to the child's inability to correctly respond and not to limitations in the receptive and expressive language capacities of the child. Researchers must make sure that test instructions are given in such a way that they are made meaningful to the child, and rephrasing of instructions may be necessary if the researcher is in any doubt about the child's understanding. Quiet or shy children may know the answers to questions asked of them, but are either unwilling or unable to communicate them effectively to the assessor.

Many researchers have recognised the value of designing tests so that they resemble the sort of games and activities that children might normally carry out at nursery school. Tests need to be quick to administer so that results are not affected by the short attention span of the young child. A number of test scores have been found to be unstable when administered to very young children due to the particular challenges that testing this age group presents. Spitz (1986) (in Haring et al., 1992) has found that IQ scores are generally unstable for children before the age of six years.

Bearing this information in mind, the screening of preschool children is possible and can provide important practical and theoretical information about learning difficulties such as dyslexia. However, the limitations of information gained from very young children needs to be taken into account when the outcomes of screening are considered. Information which may be unstable cannot be used to make concrete diagnoses regarding the future academic potential of a particular child. Issues regarding use of these measures for screening verses diagnosis, establishing the efficacy of early screening and the advantages and disadvantages of labelling a child on the basis of a preschool screening battery are considered below.

2.2.7 Screening vs. Diagnosis

When designing and carrying out a screening programme for learning difficulties, researchers must consider carefully what is the aim of the screening process. Satz and Fletcher (1988) have made the important point that "screening should not be confused with diagnosis" (p. 825). Limitations of the screening process, such as those that result from the difficulties of testing preschoolers, make it impractical to make a *definitive diagnosis* of a learning disorder based on a battery of tests administered at four years of age. Satz and Fletcher note that:

> ".. a screening procedure should be a quick, efficient method that permits evaluation of each child. It does not provide a diagnosis but rather functions as a system designating the children who are at greater risk for subsequent difficulties. These children may require diagnostic evaluations." (p. 825)

Viewed in this way, screening for dyslexia and other learning difficulties provides an early warning system that alerts our attention to children who may be at-risk for later academic difficulty. Children who are identified by a screening test can be observed more closely by teachers and parents and referred for subsequent more detailed assessment by an educational psychologist, if needed. Only then can movement towards a "diagnosis" be made.

Satz and Fletcher point out that "true screening is rapid and cost effective and does not require professional interpretation." (p825). Ideally, this should be the case. The aim for most researchers is to create a screening test which can be administered and scored by teachers or other school personnel. The benefits of involving teachers in the screening process are considerable. For example, a much more detailed picture of the child in terms of classroom behaviour and other background factors would be possible, and such a system could help those children for whom teachers may be tempted to wait and see if things "sort themselves out" later on. Further investigation and early intervention can be initiated for these children as soon as screening has been completed.

2.2.8 Measuring the efficacy of early screening: valid and false positive and negatives

Before an early screening test can usefully pick out children for further investigation and appropriate intervention, its potential for accurate identification must be evaluated. Many existing screening efforts have tended to report the level of correlation of predictive and criterion measures as an indication of the efficacy of the screening test. Items with high correlations (e.g. above .6) are considered as good predictors. However, it is generally acknowledged that it is much easier to predict later good performance than later poor performance (the usual aim of the test) (e.g. Felton, 1992). Therefore further measures of the efficacy of a screening battery are required.

It is vital that a screening test is designed to effectively identify the children that it has been designed to identify (i.e. dyslexic, learning disabled) and that it does not inaccurately identify children who are later found to be performing normally. To check that this is the case, an evaluation model for early screening can be used to provide a comparison of the predicted and the actual identification outcomes. Mercer, Algozzine, and Triffiletti (1979) have outlined a prediction-performance comparison matrix for establishing the general utility of screening instruments which is shown in figure 2.1 below.

Figure 2.1 Prediction-performance comparison matrix (Mercer et al., 1979)

		performance	
		poor	**good**
prediction	**poor**	predicted poor performed poor **(valid positive)**	predicted poor performed good **(false positive)**
	good	predicted good performed poor **(false negative)**	predicted good performed good **(valid negative)**

The matrix indicates the various possible outcomes of a screening programme. Each child screened will have been predicted to be either performing well or poorly at follow-up, and the actual performance at follow-up is also noted. However, not all children perform as predicted, with some identified as at risk for difficulties but in fact performing normally at follow-up (false positives) and others not having been predicted as having problems, but nonetheless experiencing difficulties at later testing (false negatives). Children who are performing as predicted at follow-up are referred to as valid positives and negatives.

There are two levels of evaluation possible with such a matrix: a horizontal evaluation and a vertical evaluation. Horizontal evaluation compares observed values with prediction levels and provides the percentage of correct and incorrect outcomes for the screening test. For example, the overall hit rate can be calculated by comparing the number of valid outcomes by the total outcomes, and similarly the "miss" rate can be obtained by comparing the number of false outcomes to the total number of outcomes. Vertical evaluation is important as it compares the observed values with actual performance for the screening measure in terms of the number of false negatives.

The notion of false and valid positives and negatives is critical in early screening for learning difficulties. If the levels of false positives and negatives is too large the battery is not achieving what it was designed to achieve, with too many good readers identified as at risk, and perhaps more importantly, too many poor readers identified as normal, and therefore not receiving extra help. The ability of a screening test to accurately measure a set of abilities and then correctly identify those children who are at risk for learning disabilities is essential if educational decisions are to based on such a test. For this reason, the distinction between screening and diagnosis made in section 2.2.7 above needs to be re-emphasised. This is particularly true when we consider the possibility of labelling children as a result of a screening test. The issue of labelling is discussed in the following section.

2.2.9 Labelling

One of the most controversial issues in early screening is that of labelling. The limitations of early screening in terms of the difficulty of obtaining accurate measures from preschool children and the possibility of mis-identifying children following screening have been noted above. Such limitations require researchers and practitioners to exercise caution when labelling those children who pass and fail screening procedures. Haring and colleagues (1992) have appealed to those involved in early identification to be wary of a number of issues concerning labelling, particularly the relationship between learning disabilities and general low achievement, the dangers of labelling and low expectations, and the efficacy of different forms of intervention for children with learning problems. They comment that "it seems educationally unnecessary to label children in order for them to receive appropriate educational services" (p. 165) with the implication that children who are low achieving (slow learning) or learning disabled may benefit from similar interventions.

Haring et al. have identified possible positive and negative outcomes of labelling. On the positive side, labelling enhances the opportunity for the provision of funding for groups of individuals with recognised difficulties and makes it easier for professionals to communicate with one another about such groups. However, labelling can also have negative effects by lowering the expectations of teachers providing remedial services, and may result in a focusing on the weaknesses rather than the strengths of the individual. Foster, Schmidt and Sabatino (1976) (in Mercer et al. 1979) have demonstrated that the "learning disabilities" label generates negative expectations when compared to those labelled as "normal". This may be particularly dangerous for a child who despite reading and spelling problems, functions well in other areas of the curriculum. Expectations for such a child may be generally reduced on the basis of labelling as learning disabled or dyslexic.

Mercer and colleagues (1979) argue that problems result when the negative effects of a label outweigh the positive effects of intervention based on early identification. Labelling may be particularly harmful in the case of children who may have been misdiagnosed. This is particularly true for a child for whom overall expectations are lowered or for whom provision of help means being removed from the normal school curriculum. However, very importantly, Singleton (1992) has pointed out that screening tests for dyslexia do not seek to label a preschool child as dyslexic, but to *avoid* the child being wrongly labelled as lazy or immature in the future. It is surely better that a child is noted to be at risk for dyslexia early on and given some extra learning support rather than written off as stupid or unmotivated later in his or her school career.

The interpretation of the results of early screening, therefore, does need to be considered carefully and researchers and practitioners need to be aware of the dangers of attaching labels to children following performance on a screening test. In addition, it has to be remembered that merely labelling a child following screening and then not taking steps to provide intervention is a worthless activity, and any label attached to a child under these circumstances is pointless (apart from the possible residual effects based on the knowledge that the child is not "just stupid"). Screening can and should provide the first stage in the identification and remediation of children with dyslexia and other forms of learning difficulty. It is hoped that identification of a child as at risk for learning disabilities such as dyslexia is followed by intervention based on the particular needs of the child.

2.2.10 Summary of the issues in the early identification of dyslexia

This chapter has so far presented a number of issues concerning the early identification of dyslexia and other learning difficulties. Firstly, the issue of why one should consider screening in the first place is discussed in terms of the negative outcomes that have been noted as a result of present approaches to identifying and diagnosing dyslexia. Leaving diagnosis until the age of seven or above, or failing to identify the condition altogether can have very devastating effects on a bright and potentially able child. Early screening is able to overcome some of these negative outcomes by providing an indication of those children who may be at risk for dyslexia before they have repeatedly experienced failure in the classroom and therefore providing help at the earliest opportunity. Help provided early on is generally found to be much more effective than later remedial efforts.

However, a number of points which need to be kept in mind when attempting to screen for dyslexia are also discussed here. The first of these is an appreciation of the normal paths of development of reading skills and the normal variation found within this development. In this case, some appreciation of the normal development of reading may be necessary. The early screening researcher must also be aware of the particular qualities of the population to be screened, in this case preschool children, and the limitations that they may impose of the screening process. The role of the screening process as *screening* and not definitive diagnosis is emphasised, with the implication that the process is the first stage of identification, which may be followed by more detailed investigation. Methods for determining the efficacy of the screening process are outlined including the notion of false positives and negatives. Finally, in the light of the limitations of screening, the issue of labelling is addressed.

Bearing these issues in mind, the following section of the chapter presents a review of a number of major studies which have attempted to design, implement and evaluate screening procedures for the identification of children with academic difficulties, beginning with some pioneering early studies and then moving to a wider review of some more recent work.

2.3 The development of screening for dyslexia and other learning difficulties

2.3.1 Early attempts at screening

(a) Monroe (1935)

The idea of attempting to identify children who will experience later problems in learning to read is not a new one. One of the first major studies that investigated the possibility of predicting failure in beginning reading was that of Marion Monroe in 1935. In this very early study, Monroe encountered and examined a number of the important issues which still effect early screening researchers to the present day. She raised the important point that:

> "One of the difficulties in the way of successful prediction of reading disabilities is the complexity of the problem. No one proponent cause has been found which can be used as a criterion for prediction" (p. 7)

She also noted that many conditions such as sensory, intellectual and constitutional defects, emotional and environmental factors, and teaching techniques have been associated with reading disabilities, with combinations of factors more likely to bring about failure than a single cause. She also pointed out, however, that it was possible to find good readers who possess such traits and this therefore lowered the predictive value of such measures.

Monroe and her colleagues devised a series of aptitude tests to measure many different abilities on the basis of the assumption that reading is a complicated intellectual process and that a number of tests would be more predictive than any one test alone. The tests were designed to be administered to six year olds individually and in groups. There were six types of aptitude test: visual tests, auditory tests, motor tests, articulation tests, language tests and laterality tests. The tests that were given are outlined in table 2.1 below.

Table 2.1 Tests administered at six years of age in the Monroe (1935) prediction study

Visual tests	**Recognition of orientation**	Visual recognition of a target from a target and distracter figure.
	Ocular-motor control and attention	The ability to follow a twisted line
	Visual memory for forms	Child required to draw four designs after viewing them for 10 seconds
Auditory tests	**Word discrimination**	Child required to circle the correct written pronunciation of a word spoken by the examiner
	Sound blending	Examiner says sounds in a word and child required to circle correct corresponding picture
	Auditory memory	Child repeats 5-6 line story after examiner has read it
Motor tests	**Speed**	Child required to place a dot in centre of as many small circles as fast as possible
	Steadiness	Joining a series of dots to make a continuous line
	Writing	Write or print name
Articulation tests	**Reproduction**	Child repeats series of words increasing in complexity
	Speed	Child required to repeat word or phrase as quickly as possible
Language tests	**Vocabulary**	Identification of words illustrated by pictures
	Classification	Naming as many items as possible in a particular category (e.g. animals)
	Sentence length	Child asked to tell a story about a picture - measure of number of words in longest sentence
Laterality tests	**Laterality**	Measures of hand, eye and foot preference.

Monroe and her colleagues administered the tests to 434 children in the primary grades and standardised the scores by computing percentiles. The predictive value of the tests was determined by calculation of correlation coefficients between percentile scores on the aptitude tests and grade scores on reading tests that were administered later in the year to 85 of the children. The researchers found the highest correlation between reading achievement and the total percentile score for *all* the aptitude tests ($r = .75$). In terms of single measures, auditory and visual tests were the most predictive (.66 and .60 respectively), followed by intelligence, articulation, language and motor tests. Monroe was able to determine from the results of the study that all the children who scored in the 80th percentile or above on the predictive battery became good readers, whereas all children who scored below the 20th percentile were found to be poor readers later in the year. Therefore good accurate predictions about reading outcome could be based on this test.

The success of Monroe's study in attempting to establish tests predictive of later reading performance has paved the way for many other screening studies. However, in addition to recognising the advantages of predictive testing Monroe also noted that such tests "do not .. take the place of careful diagnostic study of individual difficulties" (p. 13) and concluded that:

> "The reading aptitude tests are presented as a tool for thoughtful teachers, to direct them to certain difficulties of their pupils which they might otherwise neglect, and to enable them to meet these difficulties intelligently at an early stage in the child's learning process." (p. 14)

The contribution that this early study has made to our current approaches to early screening for learning difficulties is considerable, and the insights of Monroe are still important today. Following the publication of this study, a number of other predictive batteries were designed and tested by researchers such as Simon (1952), Inizan (1966), Hirst (1969) and Feldman and Hilton (1971) (cited in Jansky and de Hirsch, 1972) with varying degrees of success. However, a major contribution to the field of prediction of reading difficulties was made by Jeanette Jansky and Katrina de Hirsch in 1972, when they produced a comprehensive assessment of the state of early screening research and presented their own screening test. Their work is briefly described in the following section.

(b) The work of Jansky and de Hirsch (1972)

In "Preventing Reading Failure" (1972) Jansky, de Hirsch and colleagues provided a review of the current approaches to early identification of reading problems and, based on this, outlined their own contribution to early screening methods. As part of this review, de Hirsch and Feldman presented the various existing methods of identifying reading failure. These were:

- single predictor variables (e.g. age, IQ, socioeconomic status, neurological status)
- combinations of variables (e.g. reading readiness tests, predictive tests batteries)
- teacher assessments

The authors reviewed some important issues regarding prediction which are worth outlining here. Firstly, the authors raise the question of what exactly is being predicted and for whom? They question whether there is perhaps a need for different predictors for different levels of reading or subgroups of readers. Secondly, they consider to what extent the quantification of assessment leads to neglect of parameters important for prediction. Thirdly, the authors raise the issue of the possible complex interactions among single predictor variables (for example, children may compensate for a deficit in one area by utilising a strength in another, such as use of visual rather than phonological memory in reading). Aspects of prediction such as these need to be carefully considered. Another important point is made based on the work of Thomas et al. (1963). That is, it is important to bear in mind that a predictive model utilises a set of initial findings to anticipate the nature of an eventual state, and therefore underlying the concept of prediction are two assumptions: that development is largely a consistent process and that individuals for whom predictions are made will continue in "expected environments". Clearly these are all important issues which any early screening attempt must consider if accurate outcomes are to be obtained.

In the following section of their work, Jeanette Jansky provides an outline of the authors' "new plan for prediction". Their screening test was designed to be administered to children in the spring of their kindergarten year to predict reading performance after two years of schooling. It was based on a pilot study by de Hirsch, Jansky and colleagues which administered 37 different measures to 53 kindergarten children. The best predictive tests were combined with a number of other measures to form the "Predictive Index". These tests are outlined in table 2.2 below:

Table 2.2 The Jansky and de Hirsch (1972) Predictive Index

Pencil Use
Name Writing
Bender Motor Gestalt Test
Minnesota Percepto Diagnostic Test
Trapped Patterns
Sentence Memory (from the Stanford-Binet Intelligence Scale)
Wepman Auditory Discrimination Test
Boston Speech Sound Discrimination Test
Roswell-Chall Auditory Blending Test
Oral Language Level
Number of Words Used in Story Telling
Category Names
Picture Naming
Letter Naming
Horst Nonsense Word Matching Test
Word Matching Subtests of the Gates (1937) Reading Readiness Test
Matching by Configuration (based on Gates)
Recognition of Words Previously Taught
Spelling Two Words Previously Taught

It is interesting to note that some of the tests which constitute the Jansky and de Hirsch battery are very similar to those that Monroe used almost forty years before.

The Predictive Index was administered to 401 children of age 5 years and ten months, and later reading performance was determined using a variety of oral and silent reading and spelling tests in second grade. Using stepwise multiple linear regression techniques, the researchers found that the best predictors of later reading were: letter naming, picture naming, Gates word matching, Bender Motor Gestalt, Binet sentence memory and word recognition, together correctly identifying 77% of the children who were found to be failing in reading in second grade. The correlation of these measures with later reading performance was .69. All of the best predictors apart from word recognition were combined by the researchers to form the "Screening Index". Interpretation of the predictive value of the tests revealed that measures of ability to cope with adult grammatical units and the ability to retrieve stored verbal symbols contributed successfully to the identification of children with reading problems, providing insights into the processes underlying reading development success and failure.

Following description of the development of their Screening Index, the authors emphasise the important issue that screening is not an end in itself by providing an outline of procedures for following up screening with diagnostic assessment, allowing a careful description of the child's strengths and weaknesses in order to provide appropriate intervention. They make the point that this intervention is obviously the goal of any screening procedure and the more closely it matches the needs of the child, the more successful it is likely to be.

The contribution of Jansky and de Hirsch to the field of early screening has been important in that it brought together and evaluated a number of approaches to early identification which had been developing over the preceding years, and in the light of these, developed their own fairly successful Screening Index. This index has also been incorporated into more recent screening tests designed by other researchers (e.g. the Kindergarten Screening Battery, Belkin and Sugar, 1985).

The work of both Jansky and de Hirsch and Monroe was carried out in the USA where a great deal of early screening research has been done. However, interest in early identification also developed in other countries, where differing attitudes to learning disabilities and schooling in general has resulted in some different approaches to early screening. Particularly relevant to the present study is the development of attitudes and practical approaches to early screening in the UK. Therefore, the last of the early studies reviewed here is a study which was carried out by a number of educational researchers and practitioners in the UK and was known as the Priorsfield Project.

(c) The Priorsfield Project (1976)

The Priorsfield Project Symposium in 1976 brought together researchers and practitioners in the UK who were interested in the early identification of educationally "at risk" children. A number of reports considering both theoretical and practical issues in early screening were presented, in the light of the growing popularity of early identification at the time. In his introduction to the symposium, Wedell (1976) noted the apparently ad hoc way in which such early identification procedures had developed in the UK, and compared the concept of educational screening with screening in medicine and the establishment of "at risk" registers. Following this, Gulliford (1976) and Schroots (1976) present reviews of some of the theoretical issues concerning early screening such as: why should we identify early? The meaning of terms such as "early" and "identification", and what follows identification? Some of the points they raised are considered here.

Gulliford noted that attitudes towards early identification in the UK stemmed largely from the notion of "readiness":

> "present attitudes towards the early identification of handicapping conditions owes to theoretical developments and to research in the post war period - the realisation of the importance of early experiences and learning ... for the development of intelligence, language and for general readiness for the tasks of learning in school." (p. 11)

In considering the possibility of identifying children who although performing normally in some areas of learning have low performance in other areas, Gulliford notes that one of the attractions of a systematic procedure for identifying children "at risk of educational failure" is that it allows a rational method for noting which children require early remedial help. Procedures in place at the time of writing already facilitated the identification of a number of difficulties that interfere with the normal educational development of children, such as sensory problems (hearing and visual impairment), severe physical abnormalities (such as cerebral palsy), severe mental handicap (e.g. Down's syndrome), severe speech and language disorders, emotional and behavioural disorders and environmental disadvantage, but it was likely that other measures would be required to detect more subtle difficulties. Gulliford outlined a number of reasons why identification should be carried out early:

- early educational help and parental guidance is a first positive step towards minimising the handicap

- some handicaps are missed at earlier medical screening

- teachers may be reluctant to refer a child of 5 or 6 ("give him a chance and see what he can do") because of a lack of provision or uncertainty about the severity of the problem ("am I making a fuss?") or not liking the idea of the child being removed to a special class or school

- identification procedures can be viewed as an epidemiological survey, and as such, an essential basis for provision

- it promotes interdisciplinary cooperation and coordination

- it promotes the development of appropriate teaching procedures

In considering the notion of "early", the author makes the point that there may be some problems with identifying children at preschool age, such as actually finding the children in the first place. For example, not all children of this age attend nursery, playgroup or child health centres. Schroots (1976) adds to this the problems linked to the attention and cooperation of young children and the rapid developmental changes that occur at this stage, concluding that five years is the best age to attempt early screening. One important factor influencing how early screening is attempted is the issue of what "at risk" characteristics are being identified, and at what age can these be reliably observed and assessed. These are all important issues which need to be thought out when selecting the population to be screened. In considering what is meant by "identification", a two stage process is advocated: screening followed by assessment and diagnosis.

In the light of the theoretical reviews of early screening provided by the Priorsfield Symposium, Wolfendale (1976) reports a screening study carried out in Croydon in the Southeast of England. This study began in the early 1970's when Wolfendale and Bryans attempted to develop a screening instrument for reading failure. Some of the considerations for the test were:

- the need to include items appropriate to 5 year old general development in the main areas of functioning, particularly those that pertain to learning and reading

- inclusion of items which research to date had suggested to be linked with requisites for all early reading progress and later appearing associated reading skills

- the need to include items which specifically tap early appearing individual cognitive and learning styles which could yield additional information regarding strategies and task persistence

- the need to balance the advantages of brevity and explicitness with the possible disadvantages of the battery not being sensitive enough

Wolfendale and Bryans designed the screening battery as a series of nineteen checklist items for which a teacher was able to mark a yes or no answer for the child. The items were organised in four sections:

(i) speech and communication (language)
(ii) perceptual - motor skills (such as visual discrimination, scanning)

(iii) emotional - social (such as withdrawal, aggression, teacher dependence)
(iv) response to learning situations

On the basis of a pilot study, the authors found that a child could be considered to be at risk if he or she obtained six or more "no" scores on the test. Positive results with the screening measure led to its introduction into Croydon schools in 1973, where teachers were given training in use of the test and further developments were made to the procedures over the next two years.

It is clear from the Priorsfield Project that genuine efforts were being made over twenty years ago in this country, to develop early screening for reading failure in schools. However, progress towards such a goal faltered to some extent following this project, and a number of major criticisms of early screening were proposed (e.g. Lindsay and Wedell, 1982). These criticisms will be dealt with in detail later in the chapter when the limitations of early screening are considered. At this point, it is important to note that some of the major insights and considerations that are still valid in early screening today were developed as early as 1935, with subsequent investigations further testing and refining these ideas. The second part of this section of the chapter moves to a wider review of a number of more recent early screening studies that were carried out mainly in the United States, during the late 1970's and 1980's, (British contributions to this area of research have been very sparse during the last fifteen years). These studies are evaluated in terms of their contributions to the development of successful early screening.

2.3.2 Recent screening studies

A great number of early screening studies were carried out during the late 1970's and 1980's. The majority of these studies attempted to predict academic outcomes particularly for low achieving children or children with learning disabilities. In most cases this has meant the identification of future failing readers, as "children with deficits in basic reading skills have always accounted for a major proportion of those identified as learning disabled in our educational system" (Felton, 1992, p. 212). The major approach to the early identification of learning difficulties has been to administer some form of predictive battery to children early on, usually before the age of about six years and then to follow this some time later with a set of criterion measures to establish the academic outcome status of the child. In many cases, selection of items for a screening battery reflects the theoretical bias of the researcher to the subject of reading development and reading disability (de Hirsch and Feldman, 1972). However, lack of consensus in both of these areas has made for some variation in the nature of existing screening tests.

In reviewing early screening studies here, the aim is to provide a sense of what has been learned from existing studies in terms of theoretical and practical knowledge about potential predictors and methodology for carrying out screening procedures. It is impossible to provide a detailed review of all of the studies which have been carried out over the last fifteen to twenty years, so a limited number of major contributions have been selected for discussion. In addition to this, a summary list of thirty-five screening studies that have been reviewed for this thesis can be found in Appendix 1. This summary provides brief details of the investigations in terms of the subject populations studied, the predictive tests administered, criterion measures and the best predictors that were found in each study. The present review begins with some general observations from recent early screening studies.

The format for early screening studies has not changed a great deal since Monroe's early study, although predictive tests and statistical analyses have become a little more sophisticated over time in the quest for improved accuracy of prediction. Some of the screening batteries that have been developed and used by their authors in a number of studies have been given titles, such as:

- Sheppard School Entry Screening Test (SSEST) (Sheppard, 1972)
- Spotlight for Literacy: Early reading screener (Sheppard, 1979)
- The Predictive Index (de Hirsch and Jansky)
- Kindergarten Screening Battery (KSB) (Belkin and Sugar, 1985)
- SEARCH (Silver and Hagin, 1981)
- Florida Kindergarten Screening Battery (Satz and Fletcher, 1982)

The theoretical basis of such screening batteries has been varied. For example, the "Spotlight for Literacy" screener was based on the assumption that "the complex process of reading particularly involves linguistic, perceptual and sensory skills, so it is composed of items assessing visual, auditory, and kinesthetic perception, memory and language" (Sheppard and Sheppard, 1983, p. 165). The "Kindergarten Screening Battery", developed by Belkin and Sugar, used the Jansky Predictive Screening Index as its basis and aimed to assess kindergarteners' proficiency in five areas to determine later academic performance. These areas were: personal and general information, reading readiness, receptive and expressive language skills, perceptual motor skills, and the ability to learn new information. Silver and Hagin, on the other hand, developed "SEARCH" on the notion that antecedents for learning failure are delays in the acquisition of spatial and temporal information, and therefore their battery is composed of tests that assess a child's visual and auditory performance, body image and a range of perceptual modalities.

The theoretical basis of various screening batteries can also be seen to reflect the current state of knowledge and opinion regarding the development of reading skills and the nature of learning disability, at the time of the study. Although there is a lack of *complete* consensus as far as these issues are concerned, the number of aspects on which there is beginning to be agreement is increasing as time goes on. For example, the role of phonological skills in the normal development of reading is now widely acknowledged (Spector, 1992) and many screening studies have placed emphasis on measures of phonological ability in their batteries. The review of studies in Appendix 1 reveals that in many cases some of the most predictive items from recent studies have been measures of phonological skills.

The predictive ability of early screening batteries has been varied, and no screening test has so far been 100% accurate in predicting reading outcomes (Jansky et al., 1989). The right combination of measures to identify exactly those children who would benefit most from early screening (i.e. children with learning disabilities), has not yet been found. However, a comprehensive examination of the findings of the existing screening studies provides evidence of predictors which might be of use in identifying such children. One researcher who has been involved in early screening for the last two decades is Nathlie Badian. Some of the outcomes of her research are outlined below.

The studies of Nathlie Badian (1982, 1984a, 1984b, 1986, 1988a, 1988b, 1990; Badian et al., 1990) have provided a great deal of information about the early identification of learning disabilities such as dyslexia. Beginning some years ago, Badian attempted to design a screening test for use within a small school system to determine which children would later be good and poor readers. On the basis of earlier work, Badian devised the "Holbrook Screening Battery" (HSB), a series of tests to be administered before kindergarten to predict later reading performance. This battery formed the basis of many of the Badian studies and the tests which make up the HSB are outlined below:

Table 2.3 The Holbrook Screening Battery (Badian, 1975)

WPPSI Information
WPPSI Sentences
ITPA Auditory Association
Prepositions (Gesell et al., 1940)
Verbal expression (tell picture about story: articulation, syntax, content)
Counting
Colours (name 8 colours)
Letters (name 13 upper case letters)
Shapes (name 5 geometric shapes)
Draw-a-person (Koppitz, 1968)
Name writing
Copy forms (copy 5 geometric forms)
Pencil use
Cutting
Gross motor (walk: backwards, on tiptoe, along straight line; stand on 1 foot; skip)

In one of the first studies reported, Badian (1982) administered the HSB to 129 pre-kindergarten children of mean age 4.9 years. Follow-up criterion testing was carried out at three time periods, when children were in grades 1.7, 2.7 and 3.7. The criterion measure used was the Total Reading score of the Stanford Achievement Test (SAT) which includes Word Study Skills, Reading Comprehension, and for grades 1 and 2, a word recognition section. Badian used a number of statistical procedures to examine the relationship between the HSB and later reading performance. The first of these involved correlation of the screening measures with the reading scores for each grade. This revealed that in each grade, five measures were strongly correlated with later reading: WPPSI Information, Counting, Letters, Name writing and WPPSI sentences. Some differences were found when correlations were computed separately for males and females, for example, Shapes was a much better predictor for boys than for girls. Badian also used Stepwise Regression Analyses to indicate the most effective combination of variables for prediction, and the five tests listed above were found to provide the strongest combination. Factor Analysis of the whole HSB revealed three main factors: I. Verbal, II. Visual-Verbal, and III. Visual-Motor. The five strongest predictors were found to load on the verbal or visual-verbal factors.

However, correlation is not a powerful method of evaluating the efficacy of a screening battery which is designed to identify individual failing readers - a large proportion of the correlation is often accounted for in the relative ease of identifying good readers (de Hirsch and Felman, 1972). In order to predict which children will be later found to be experiencing reading difficulties, the researcher must establish an at-risk cut off score at the time of screening. Badian used a cut-off of a total HSB score of more than a standard deviation below the mean of the group and found that this correctly identified 92% of the poor readers four years after screening. In addition, only one false negative and nine false positives were found.

The success of this study in revealing that combinations of measures can be used to identify children who will later be found to be failing in reading has been followed by studies in which Badian has attempted to improve prediction by considering other information in addition to scores on the HSB. For example Badian (1986) collected information using a parent questionnaire to assist with prediction. This provided data on family constellation, birth and medical history, developmental milestones, family history of learning problems and behavioural characteristics of the child. She also obtained ratings of the child's speech intelligibility, attention and activity and information regarding handedness, attendance in a special preschool and any special help received.

Analysis of the predictive ability of such a range of measures with a group of kindergarten boys highlighted some of the complexities of undertaking a screening programme. Badian found that although some of the measures correlated well with later reading performance, and a number of poor readers were successfully identified, 33 children were found to be false positives or negatives. On this basis Badian made a more thorough investigation of the individual profiles of the children for whom prediction was incorrect and found that different combinations of factors appeared to influence for example, responses to special teaching and ability to catch up over time. For example, for the false positives, she found that success in reading was more likely if the child "was first-born, did not have a speech delay or serious articulation problems, had a relative strength in visual-motor tasks and .[was].. born in a more favourable month" (p. 267). In addition, children with a history of birth complications were found to lag behind in development for several years but eventually catch up. In considering the children who were incorrectly identified as good readers Badian proposed that:

> "It is from the false negatives, with their average to superior intelligence, that most of the cases of specific reading disability or dyslexia were likely to be drawn." (p. 268)

One of the great problems for early screening researchers is that a battery like the HSB is almost certain to correlate with intelligence and therefore children with higher intelligence scores may not be picked up as at-risk. Badian found that the false negatives were a very variable group. However, by applying four sets of criteria based on the profiles of the children at screening, four groups were differentiated. Interestingly, Badian proposed that the characteristics of the four groups were consistent with the subtyping classifications proposed for dyslexia, and her findings certainly support the notion of heterogeneity of the condition, even at pre-kindergarten levels. In a later study, Badian and colleagues used a range of measures including neuropsychological/cognitive tests and neurological measures to predict dyslexia in six year old boys. Overall, Badian's studies have indicated that at an early age children at-risk for reading disabilities differ from non-reading disabled children in a number of ways and that these differences may vary with sex. The following table presents a summary of her findings.

Table 2.4 A summary of predictors of reading disability from Badian's studies.

WPPSI Information
WPPSI Sentences
Counting
Letters
Name writing
Colours
Family position (later born)
Temperature at time of birth (hotter)
Family history of learning disabilities
Possible birth history complications
Possible speech delay
Tests of symbol memory
Tests of rapid naming
Finger localisation
Letter sounds
Test behaviour
Visual and auditory evoked-potentials

Like Badian, Scarborough (1989) has also investigated the predictive quality of a set of measures administered before school entry (see Appendix 1). However, on the basis of evidence for a genetic mechanism in reading disability, Scarborough specifically selected a sample of children with a reported familial incidence of reading problems as part of the group of five year olds receiving the predictive battery. In addition, at follow-up testing at grade 2, children were identified as falling into one of three groups: reading disabled, low achieving and normal. Scarborough used analysis of variance to examine differences between the three groups on the preschool measures and found that the reading disabled children scored at lower levels than the normals on one of the tests administered, the SAT Sounds and Letters test (8 letter identification items, 16 letter-sound correspondence items and 20 phonological awareness items). In addition, the low achievers scored worse on the Boston Naming Test than the normals. Prediction of reading disability and low achievement from familial reading problems was found to be very accurate. Overall, using familial risk and measures of early verbal skills, Scarborough was able to accurately predict 79% to 82% of reading outcomes.

The evidence from the studies outlined so far therefore indicates that prediction is possible and that certain factors such as early language skills and familial incidence can provide useful information about the later academic performance of a child, and moreover, differences may be found not only between normal and poor readers, but between generally low achieving and specifically reading disabled individuals (see also Jorm et al., 1986). In fact Horn and O'Donnell (1984) have criticised some early screening researchers on the basis that "confusion exists in the literature because some researchers equate the prediction of low achievement with the prediction of learning disability" (p. 1107). Although this is a far from straightforward issue in the light of current debates regarding the relationship of reading disability or dyslexia to more general reading problems, the implication for early screening is that a test which does not make this distinction may just identify children who, although poor readers, are actually performing at a level commensurate with their overall abilities. The implications of this are as yet unclear, but the possibility of such children requiring different forms of intervention from specifically reading disabled children cannot be ruled out. Certainly, any differences that are found between reading disabled and low achieving children before formal reading instruction has begun may help in resolving this issue. It must be noted, however, that despite the differences in performance of the two groups, Scarborough was not able to accurately *predict* membership of the two groups on the basis of the predictive measures used.

In addition to the contributions made by Scarborough outlined above, further important information has also been provided by later studies (e.g. Scarborough, 1990; Scarborough and Dobrich, 1990; Scarborough, 1991a, 1991b) regarding the characteristics of children as young as 24 months old and their later reading performance. For example, in a longitudinal study of four children with Early Language Delay (ELD) Scarborough and Dobrich found that the ELD children had poorer measures of spoken language than control subjects, and although these were apparently at normal levels by the end of preschool, three out of the four children were found to have reading disability at grade 2. In another study, Scarborough (1990) found that children who later developed reading disabilities were deficient in the length, syntactic complexity, and pronunciation accuracy of their spoken language at 30 months, but did not have difficulties with lexical or speech discrimination skills. By the age of three years, these same children exhibited deficits in receptive vocabulary and object naming, and by 5 years, they had problems with phonemic awareness, object naming and letter sound knowledge. On the basis of this study Scarborough concluded that:

> "the picture that emerges from research on the precursors of dyslexia is one of a child who not only has difficulty with reading and language during the school years but who typically experiences problems with preschool literacy skills during the late preschool period; exhibits vocabulary deficiencies, poor rhyme recitation skills, and phonemic awareness deficits from the age of three or four years; and produces shorter, syntactically simpler sentences and less accurate pronunciations of words than other 2-year olds" (p. 1738).

The studies of Badian and Scarborough are just examples of the early screening research that has been carried out in recent years, however, their findings are notable and their influence on the present study is strong. Other recent early screening studies that are worthy of mention here are those of Butler et al. (1982, 1985), Jorm et al. (1986), Kelly and Peverly (1991), Lundberg, Olofsson and Wall (1980), Morrison and Mantzicopoulos (e.g 1990) and Sheppard and Sheppard (1983), although many more studies actually exist and are unfortunately beyond the scope of this review. The findings of two very recent studies screening studies (Catts, 1993; Felton, 1992) are, however, briefly mentioned here.

Based on the findings of previous studies by researchers such as Share et al. (1984), Lundberg and colleagues (1980), Mann (1984) and Badian (e.g. 1988), Rebecca Felton's (1992) predictive study included measures of phonological awareness (such as rhyme), phonological coding in lexical access (e.g. naming) and coding in working memory (word string memory test) as well as other measures (e.g. IQ, finger localisation) to predict the later reading performance of a group of kindergarten children. Felton found that when IQ was partialled out, the best predictors of grade 3 reading were rapid naming of letters, beginning sound discrimination and tests of auditory conceptualisation. A combination of two measures of phonological awareness and one measure of coding in lexical access was able to correctly identify all of the poor readers and 89% of the good readers in the study. Catts (1993) similarly gave measures of phonological awareness (deletion task and blending task), rapid naming and other measures to a group of kindergarten children, but in this study children with speech language impairments were included in the sample under investigation. Catts' findings highlight an important point in the prediction of reading, that is that the same measures may not have the same predictive value across the whole development of reading. For example, Catts found that although phonological awareness accounted for most of the variance in reading as measured by word recognition, other standardised measures of expressive and receptive language accounted more for reading comprehension. In the development of reading, emphasis moves from decoding to comprehension over time, and both aspects are vital to the total reading experience.

The above review, although limited, provides an indication of some of the major recent contributions to the field of early screening. The following table provides a summary of the measures that have been found to be successful in the prediction of learning and reading disabilities across a wide range of studies reviewed for this chapter.

Table 2.5 Measures found to be predictive in screening studies

WPPSI Sentences, Information subtests
Name writing
Naming colours, letters, pictures
Position in family
Temperature at time of birth
Rapid Automatized Naming
Finger localisation
Auditory Comprehension
Frostig Developmental Test of Visual Perception
Slosson Intelligence Test / general ability / IQ
Grammatic closure
Phonological awareness: phoneme segmentation, blending, reversal
Syllable segmentation
Language measures: receptive / expressive
Psycholinguistic measures
Spatial/form perception
Figure drawing
Test behaviour
Family history of learning disabilities
Motor skills: catching a ball, walking backwards
Lateral dominance
Gates Word matching Test
Bender Motor Gestalt Test
Sentence / word string memory
Alphabet recitation
Mean length of utterance (MLU) (30-48 months)
Knowledge of sound-letter correspondences

In addition to this list of predictive measures, evidence of tests used and found to be predictive also comes from a number of meta-analyses that have been carried out on existing screening tests. Two examples of meta-analysis studies are those carried out by Horn and Packard (1985) and Tramontana, Hopper and Selzer (1988). The findings of these studies are briefly considered.

Horn and Packard used quantitative procedures to combine the significance levels and effect sizes of 58 different early identification studies published up to 1984. They found that the predictor variables used in the studies fell into six main categories:

(a) Language variables

(i) Written expressive language - such as measures of ability to write name or the alphabet.

(ii) Oral expressive language - e.g. pronunciation tests, saying the alphabet, telling a story.

(iii) Receptive language - tasks that assess the child's ability to understand language such as the PPVT.

(b) Sensory variables

(i) Figure drawing - tasks that require the child to copy or produce a written shape or pattern.

(ii) Auditory-perceptual measures - tests that assess the child's ability to discriminate between similar sounding word or sound patterns.

(iii) Visual-perceptual measures - such as tests that require the child to pick out a target figure that matches a referent from a group of other figures.

(iv) Sensory integration measures - tests that require a child to integrate two sensory modalities.

(c) Behavioural-Emotional variables

(i) Measures of attention / distractibility and impulse control.

(ii) Measures of externalising behaviour problems.

(iii) Measures of internalising behaviour problems

(iv) Self help / social skills

(d) "Soft" Neurological variables

(i) Fine motor skills

(ii) Gross motor skills

(iii) Cerebral dominance / handedness

(e) IQ Measures
(f) Teacher Ratings

In a review of more than 70 predictive studies reported between 1973 and 1986, Tramontana and colleagues (1988) identified seven categories of predictors including measures of academic skills or academic readiness, IQ tests, measures of specific cognitive abilities (e.g. expressive or receptive language), measures of perceptual and fine motor skills, measures of gross motor skills, assessments of behavioural or emotional functioning and demographic variables. All measures apart from gross motor skills were found to have some predictive success in the studies.

Horn and Packard found that across the 58 studies they examined, the variables with the greatest predictive relation to later school achievement were ratings of attention/distractibility, internalising behaviour problems, language variables and tests of general cognitive functioning. They noted that some of the sensory integration and soft neurological variables which were thought to underlie reading disabilities, such as cerebral dominance, did not show a strong relationship with later performance. They propose two reasons why this might have been the case. The first reason is that the criterion measures of reading that were used were too heterogeneous (there are a number of different processes which underlie recognition and comprehension of text), and the second is that the group of children to be identified was too heterogeneous, and perhaps restricting identification to just reading disabled or low achieving children may make for more successful prediction. I would like to add a third possible reason for the lack of predictive ability of tests thought to be important in reading disability, which is that these assumptions may have been flawed. The theoretical basis of reading disability is not fully understood even now, ten years on from Horn and O'Donnell's review and it is likely that the basis of many of the screening batteries reviewed would now be considered incorrect, especially in the light of recent major advances in our understanding of dyslexia and reading disability.

Therefore, while it can be seen that much can be gained from the examination of predictive tests used in past studies, it is likely that variations in the conceptualisation of reading disability over time may mean that the theoretical basis for such batteries is questionable. This is an important point with respect to the fact that no existing battery has even been found to correctly identify all the good and poor readers in a study sample. However, it is one of a number of limitations of existing screening efforts which will be discussed in more detail in the following section.

2.3.3 Evaluation of existing screening studies

Despite the apparent usefulness of early screening for learning disabilities such as dyslexia, some researchers have not been supportive of the concept. Mantzicopoulos and colleagues (1992) have noted that "early screening practices are surrounded by controversy and confusion" (p. 574). Many of the criticisms stem from limitations in the screening efforts attempted to date. In this section, a number of these limitations are addressed, and existing screening studies are evaluated in terms of their contribution to the development of successful early screening.

A critical examination of the effectiveness of screening measures designed to identify educationally at risk children was carried out by Lindsay and Wedell in 1982. The authors highlighted important points such as the fact that evidence of a correlation between predictive measures and later performance does not necessarily imply causation. In addition, they point out that evidence of a relationship between predictive measures and outcomes for a population does not necessarily mean that such measures will correctly classify individuals. It is generally acknowledged that good readers are much easier to predict than poor readers and in many cases it is the good readers that contribute most to the high correlations found between measures. The contribution of information from medical sources in screening studies has also been examined with the conclusion that it is of dubious usefulness as a predictor of psychoeducational difficulties. Screening batteries based on a number of predictive (cognitive) tests such as those reviewed in this chapter are criticised for their lack of reliability and predictive validity, and the use of teacher rating scales such as the Infant Rating Scale (Lindsay, 1979) is advocated as a better alternative. A further limitation of such predictive batteries is the high levels of false predictions that are found in many studies. These are often children who pass the screening test but are later found to be performing poorly. On the basis of this review, Lindsay and Wedell concluded that:

> "It is apparent ... that there are major problems in the early identification of learning difficulties." (p. 215)

Other researchers have also been critical of existing approaches to the early identification of learning disabilities. Mercer, Algozzine and Triffiletti (1979) list the disadvantages of early identifications as:

- unreliability of the test instrument for certain groups (for example severe difficulties are easier to predict than mild or moderate difficulties)

• developmental and maturational differences are more varied early in life (is a child failing a screening test at risk, or simply immature?)

• labelling of children, particularly those who may have been misdiagnosed, and lowered expectations.

However, they do make the point that most of the disadvantages of early screening relate to the effects of *mis*diagnosis. A more recent evaluation of early identification carried out by Satz and Fletcher (1988) has provided a detailed review of some of the major issues involved. Satz and Fletcher make the point that screening studies do not seem to have improved as a result of the criticisms of them. They go on to point out some of the major issues for consideration and improvement in such studies. These include:

(a) The need for a theoretical basis for the test

(b) Consideration of an appropriate design for the study:
  (i) a longitudinal prospective design should be used
  (ii) the follow-up interval should be relatively long as it cannot be assumed that reading and learning disabilities will be expressed in all children at the same time
  (iii) there should be no confounding between the screening test and the criterion outcome variables

(c) Sample selection - this should be relatively large to protect against attrition and to provide a reasonable representation for the population addressed

(d) Test validity and utility - the test should measure what it is designed to measure and should be brief, cost effective and useful.

Unlike Lindsay and Wedell, their conclusion is somewhat more positive:

> "despite major concerns ... we feel that early screening is a viable process"
> (p 828)

Other researchers such as Lewis (1985), Haring et al. (1992), Fedoruk and Norman (1991) and Carran and Scott (1992) have also provided criticisms of early screening. For example, Lewis points out a paradox in the evaluation of screening procedures in the fact that such evaluation is often confounded by intervention that may have taken place for the child. However, it would obviously be "unethical to identify a group of children as needing help but then to deliberately withhold this" (p. 134). Haring and colleagues consider the implications of the efficacy of early screening for what follows it, that is, possible labelling and intervention. They also raise the issue of the relationship of learning disabilities to general low achievement and question the ability (or in fact the need) of screening tests to select items to distinguish between them. One major obstacle for early identification noted by Catts (1991a) and already discussed here is the lack of agreed definition or conceptualisation of reading disability or dyslexia.

The entire longitudinal concept which forms the basis of early screening is challenged by Carran and Scott, who believe that it is rife with methodological problems and lacking in scope when used for the early identification of at risk children. They note that a screening programme should operate on the assumption that the symptoms of the disability can be detected and measured, although this is not the case in many published studies, and most do not have a theoretical foundation for identification or intervention. The establishment of cut-off scores for both the screening and criterion measures is also a problematic issue. The authors note that "often this score is an arbitrary value that has been adjusted to achieve the best results in predictive accuracy" (p. 199). That is, researchers can manipulate screening cut-off scores in the light of the outcome status of subjects to make sure that they account for all the children who are found to be either learning disabled or normal at follow-up.

Although not completely, reading performance is related to general intelligence. Jorm and colleagues (1986) have criticised a number of screening tests for their over reliance on the use of measures of general intelligence and the predictive power which is gained from the use of such tests. For example, inspection of the review of studies in Appendix 1 reveals that many early identification measures utilise subtests of or even entire intelligence tests as part of their predictive measures. This is a particularly difficult problem for the identification of those children whose reading difficulties cannot be predicted from their overall intelligence - the dyslexics. As Badian noted above, these are the children who, in such a battery, are likely to constitute most of the false negatives.

A further criticism of early screening tests is that the goal of the prediction, the identification of children with learning or reading disabilities may be much more difficult than first thought as a result of possible heterogeneity of the disorders. For example, in the case of dyslexia, speculation about subtypes may mean that it is not one profile of performance that needs to be identified by the screening test, but several, reflecting the constellations of difficulties in each subtype.

The limitations of early screening studies can be considered on two levels: theoretical limitations such as those outlined above (e.g. lack of a coherent theory to underlie selection of test items and cut-off scores); and practical limitations. These include issues which need to be taken into account when implementing a screening programme into a school system (which should, of course, be the eventual aim of an early screening study). Singleton (1992), has examined a number of these practical issues, including selection of appropriate personnel for administration of the screening battery, effective administration and financial resourcing. He noted that although educational psychologists seem appropriate agents for administration of screening procedures, they are generally already overstretched in their existing responsibilities and it would not be practical for them to also carry out and interpret the results of an early screening programme. For teachers, time is also an issue, and extensive training would need to be given in the administration and interpretation of the screening tests. Administrative issues such as when, where and how the tests would be given also need to be considered. The financial cost of such a huge undertaking is very likely to be substantial.

To summarise then, although there is no doubt that early identification of learning difficulties is a good idea in principle, in reality there are a number of important limitations of current screening practices. Theoretical problems such as the lack of complete understanding of the condition to be predicted, insufficient follow-up intervals, use of statistics that are not powerful enough for the true evaluation of the battery, and the high levels of false positives and negatives in many studies can be coupled with practical issues regarding funding and use of appropriate personnel, to question the true usefulness of such an undertaking.

However, some recent studies have attempted to overcome some of the limitations outlined here both on a theoretical and a practical level. One of the key proposals regarding this has been to place early screening within the context of a two-stage system for detecting learning difficulties, therefore reducing the need to rely solely on the battery as a predictor of children at risk (e.g. Lindsay and Wedell, 1982; Badian, 1986). On this basis a quick and simple screening instrument may be administered to all children. The cut-off scores for at risk on such an instrument can be set at levels so as to be slightly over-inclusive, with all children failing the screening test investigated by a second more detailed set of measures. The benefits of such a two filter system are wide ranging and improve on both theoretical and practical aspects of existing tests.

For example, the need to distinguish learning disabled and low achieving children may not be necessary at the first stage of screening. In addition, professional personnel would not be required to carry out lengthy screening with *all* children, as this could be done by less specialised testers and then followed up at stage two by specially trained teachers or educational psychologists.

Other suggestions for methods of improving early screening have included the use of teacher ratings (e.g Feshbach at al, 1977; Lewis, 1985; Lindsay and Wedell, 1982; Mercer at al, 1979). For example, a number of rating scales have been devised to identify children at risk for learning difficulties instead of using batteries of cognitive or other tests. Some success has been found with these scales, for example, Feshbach and colleagues found that the "Student Rating Scale" was as good as a predictive battery in identifying at risk children and was more economical to deliver and more descriptive of the child's classroom competencies. Dynamic as opposed to static assessment of children's abilities to predict later reading performance has also been advocated (Spector, 1992). However, Fedoruk and Norman (1991) are also critical of this method of assessing young children as they found that "teachers vary considerably in the way they rank descriptors and that these variations may be a factor in the predictive inaccuracy of kindergarten screening" (p. 258). DeFries and Baker (1983) considered the value of incorporating parental data into methods of assessing children's later reading performance and found that such information could be very informative.

Practical issues in the administration of screening measures may be partly overcome with the use of computers in early identification programmes (Singleton, 1992). Computers can reduce the time demands on early screening personnel by presenting tests to children in a standardised format, possibly controlled largely by the child. Facilities now available can be used to administer tests using spoken stimuli, words and pictures, and can record the performance of the child. This frees the administrator to either leave the child to themselves with the test, or to watch the way that the child carries the task out, rather than being taken up completely with administration and scoring. Computers can provide accuracy of measurement that is far superior than existing methods, such as use of a stopwatch. They offer precision, objectivity and flexibility and are efficient and economical to use.

Therefore it can be seen that the concept of early screening can be improved to overcome some of the criticisms that have been levelled at it. Theoretical improvements and the introduction of new technology offer the way forward to allow early screening to be the useful and feasible process that was originally envisaged to be.

2.4 Summary of the chapter

This chapter has explored the concept of early identification of dyslexia by first focusing on the existing methods of diagnosis of dyslexia. The limitations of these methods in terms of the late stage at which most diagnoses are made and the possible negative outcomes are outlined. One method of improving methods of identification and remediation of dyslexia is to design a screening test to be administered to all children before or at school entry to allow children at risk from the disorder to be picked out. Early help can then be made available for these children. However, a number of important issues need to be considered when designing a screening test for dyslexia such as possible precursors of the disorder, the range of normal variability of development and prediction efficacy.

The chapter also provides a review of a number of pioneering and more recent screening studies and evaluates the contribution of these studies in terms of predictive test measures and methodology. Limitations that have been identified in these studies are addressed and some more recent approaches for overcoming screening problems are presented, such as the use of computer technology for test administration.

Taking into account the research that has been reviewed regarding dyslexia and early screening, the next chapter presents the rationale and method of the current study. The contributions of the studies outlined above have been important in considering new, improved methods for screening for dyslexia. The objectives of the study are set out and the procedures by which the study was carried out are described.

Chapter 3
Method

Preview to the chapter

Based on an thorough review of research regarding dyslexia and early screening, this study has attempted to investigate the early identification of dyslexia in four and five year old children. This chapter begins by outlining the rationale for the study and the specific objectives that are investigated. The study has been carried out longitudinally - as one large study rather than a series of separate studies. For this reason, the chapter continues with a brief overview of the whole project, followed by an outline of general features of the method by which the study was carried out. The remainder of the chapter consists of a detailed description of the subjects and tests involved at each stage of the study.

3.1 New approaches to screening for dyslexia: Considerations of the present study

As indicated at the end of the previous chapter, existing screening studies have made some important contributions in terms of theoretical and methodological approaches to the early identification of children at risk for learning difficulties. Although limitations have been found with such studies, a number of important developments mean that early screening has again become a worthwhile endeavour. Progress in a number of areas has meant that early identification of learning disabilities could possibly be more accurate than ever before. The major factors responsible for this are: recent theoretical developments in our understanding of dyslexia, improvements in early screening methodology and test selection, and the introduction of new technologies into the screening process.

In order to improve on existing screening studies a new screening study needs to take into account the better theoretical basis for dyslexia that is now available, in the selection of a fuller range of tests for the battery. One promising line of recent research that may be valuable in the selection of better tests for dyslexia prediction is that of Nicolson and Fawcett (1995). The researchers found a whole range of deficits in "primitive skills" in dyslexic children of eight years of age. It is possible therefore that children three and four years younger may also show these deficits and that these tests would be useful predictors of the disorder. A new screening study should employ recent technical developments in computer hardware and software to aid test administration and scoring. In addition, a new study for early identification of dyslexia is able to utilise a wide range of methodological approaches that have been found to be successful, such as the inclusion of children with a family history of dyslexia into the study. All these factors have been important in the present study, the theoretical and practical considerations for which are described below.

3.1.1 Objectives of the study

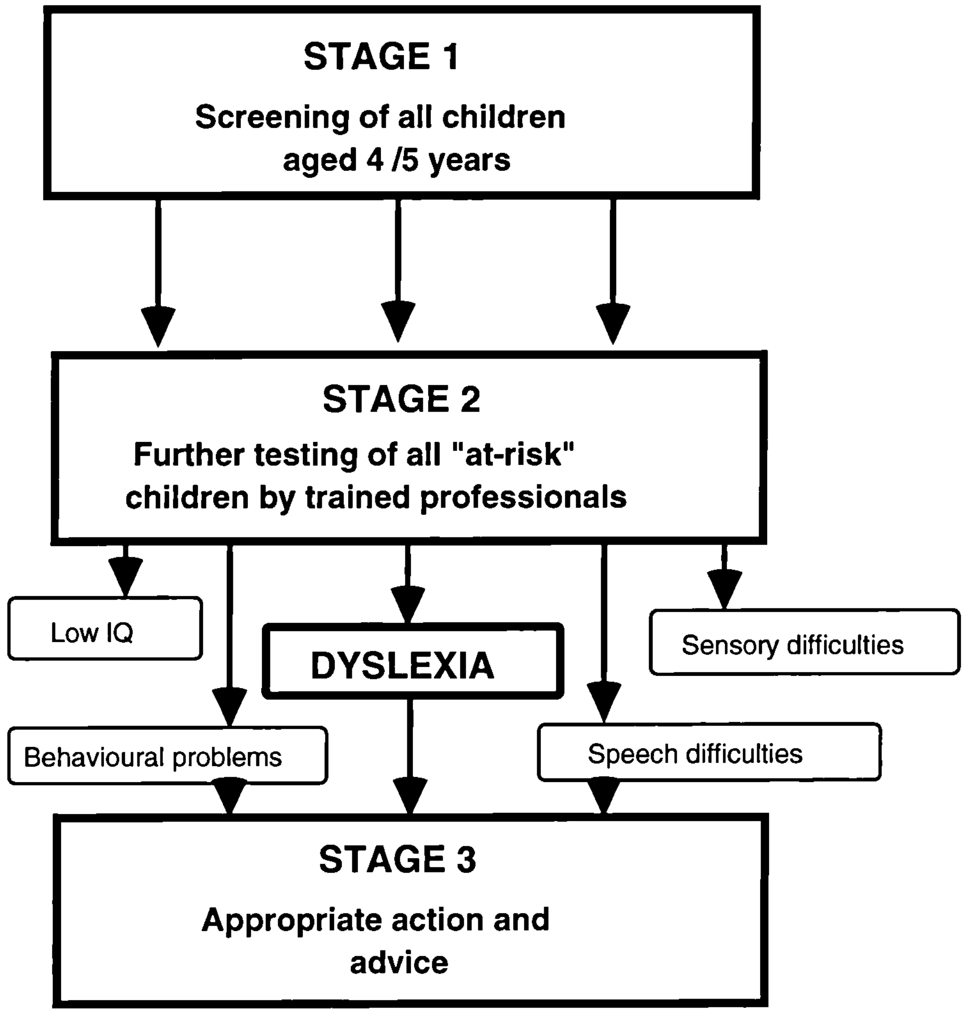
On a very simple level, the objective of the present study is to identify dyslexic children at preschool age. However, there are actually four main objectives of the study, one practical and three theoretical.

3.1.1.1 Practical Objectives

(a) The early identification of dyslexia

The practical aim of the investigation was to develop a test that is able to identify dyslexic children much earlier than is possible using existing methods. Instead of waiting until children show evidence of failing to acquire reading and spelling skills before assessing for dyslexia, the test is intended to be administered to *all* children before or at school entry. As advocated by researchers such as Satz and Fletcher, the test is designed to be the first stage of a process of screening for dyslexia. This process should be quick and simple to administer and cost effective, with straightforward guidelines for interpretation. The diagram in Figure 2.2 below provides an indication of the screening system as a whole. It is proposed that an early screening test for dyslexia should be administered to all children at the age of four or five years, before or at primary school entry. This test should give a quick indication of the children in the school year or class that may be at risk for dyslexia. These children are then in a position to be referred for more detailed testing by an educational psychologist or specially trained teacher and monitored closely during primary school. In this way, a child does not have to be definitively diagnosed and labelled as dyslexic at the age of five years, but at the same time, is in a position to receive specially designed remedial help and to be prevented from falling behind in his or her academic progress.

Figure 3.1 Multi-stage screening system for the early identification of dyslexia and other learning difficulties



The present study focuses on the first stage of this screening process and attempts to combine a set of measures to predict children at risk for dyslexia. The battery is based on an analysis of current theoretical explanations of dyslexia, the predictive success of existing tests, and recent research regarding the development of reading. The study was carried out by investigating the ability of large set of measures administered at four and five years of age to distinguish between children later found to be good and poor readers, and dyslexics, slow learners and normal readers. The tests found to be best able to distinguish the groups, and also having strong relationships with later reading ability are then selected to form a screening predictive index for dyslexia. The ability of the screening index to accurately identify children with dyslexia and the utility of the test for use with teachers in primary schools is examined.

3.1.1.2 Theoretical Objectives

(a) Establishment of early manifestations of dyslexia

By developing a set of measures that are able to identify very young children with dyslexia it should be possible to consider what the early manifestations of the disorder might be (e.g. spoken language difficulties). This has implications for providing a theoretical basis for early screening and early remedial provision, and our understanding of the disorder in general.

(b) Investigation of the relationship of dyslexia to other poor reading

Current debates regarding the relationship of dyslexia to other forms of poor reading have enormous implications for the diagnosis, and therefore prediction, of dyslexia. Traditionally, dyslexia has been viewed as a distinct entity that can be distinguished from slow learning or "garden variety" poor reading. However, questions regarding the concept of dyslexia as anything other than just a form of poor reading need to be answered if such children are to be reliably identified and given appropriate help. This issue is important to this study in two ways. The first is that an investigation of whether dyslexics and slow learners differ on measures administered before they have started to learn to read may provide some evidence of whether the two groups do differ in more than just their IQ levels. The second is that if there is a valid difference between these two groups, the different predictors that are required to identify them need to be established. It is hoped that this study can provide useful information with regard to both of these issues.

(c) Evidence to contribute to our current understanding of dyslexia.

The final theoretical objective of the study is the more general objective of attempting to discover information that can further our understanding of the nature and cause of dyslexia. As some of the measures selected for the screening test have been based on the major theoretical approaches to dyslexia, it is hoped that support may be found for one or other of the competing explanations. In addition, issues such as incidence and the existence of subtypes of dyslexia are also considered.

3.1.2 The population to be screened

It is the case that the larger the sample used in any investigation, the better the results obtained. This is particularly true in the case of a study like the present one as in any sample of the general population we would only expect a relatively small proportion of subjects to be dyslexic. This actual proportion is unknown, but as the evidence outlined in Chapter 1 indicates, is likely to be between 3.5% and 15% of the population. Therefore, in taking a group of children at an age before dyslexia is evident and administering a screening test for the condition, the sample of children has to be large enough to ensure that at least some of the children are likely to be dyslexic. However, there is a way of increasing the possibility of finding dyslexics in a group of young children. This can be done by including in the population sample a group of children with a family history of dyslexia (Scarborough, 1989). Genetic evidence indicates that boys with one or more dyslexic parents are five to seven times more likely to be dyslexic than sons of unaffected parents, and girls are ten to twelve times more likely to be affected (Pennington and Smith, 1988). Therefore the population screened in the present study is composed of two groups: a general population sample and a group of children who have one or more relatives with dyslexia.

3.1.3 The screening battery

The screening battery compiled for use in the present study was designed to reflect current theoretical approaches to dyslexia, with the inclusion of some tests from previous studies that had been found to have predicted value. The predictive battery was composed of a range of different tests which were grouped according to the types of skills that they measured. The skill areas were as follows:

- General ability
- Motor skills
- Phonological skills
- Reaction time
- Laterality
- Speed of processing
- Verbal labelling
- Rhythm

Within each skill area, one or more tests were administered, however, some of the tests could have been placed in more than one skill category. This is particularly true of the first skill area, general ability, in which a standardised intelligence test was able to generate an overall measure of IQ and individual subtests also provided measures of memory, motor skills and other abilities. A number of the tests that were incorporated into the screening battery were published standardised psychometric tests, some were adaptations of tests from previous studies and others were designed especially for the study. Tests were administer in either "pencil and paper" format or using an Apple Macintosh microcomputer (particularly tests of phonological skills). The actual method of administration of the measures is described in detail in the following sections (see pages 124 to 155), however, the rationale for chosing each of the individual tests is briefly outlined here. From the large number of potentially predictive tests administered to the children at age four and five years it was intended that the tests best able to distinguish the reading outcome groups should be incorporated into the final screening instrument.

(a) Tests of General Ability

(i) The British Picture Vocabulary Scale - As a British adaptation of the Peabody Picture Vocabulary Test-Revised (PPVT-R), the British Picture Vocabulary Scale (BPVS) (Dunn, Dunn, and Whetton, 1982) was designed to measure a subject's receptive (hearing) vocabulary. Vocabulary has been found to be one of the most important contributors to measures of intelligence (Elliot, 1983) and the best single index of school success (Dale and Reichert, 1957) (in Dunn et al., 1982). The BPVS was, therefore, administered to subjects in this study as a measure of their "general ability".

(ii) The British Ability Scales - The British Ability Scales (Elliot, 1983) consists of twenty-three scales measuring a wide range of cognitive abilities. For the purposes of this study, only a subset of these scales were used, in line with recommendations from the test's author regarding age range suitability. Elliot has noted that "As well as enabling global IQ figures to be calculated, the B.A.S. also enables profiles of cognitive strengths and weaknesses to be obtained and evaluated". The B.A.S. was administered to subjects in this study for three main reasons:

- to gain an overall "IQ" score for each child

- to obtain standardised scores on a number of tests measuring abilities considered to be important in the early identification of dyslexia

• to establish a profile of performance across the range of tests which could be examined for inconsistencies

Ten subtests of the British Ability Scales were administered to subjects in the predictive phases of the project. The tests are listed below along with a brief outline of what they were designed to measure. As indicated above, the nature of many of the subtests meant that performance of the subjects on them was interesting in its own right, as well as part of a measure of their general ability.

• **Block design** - this test is designed to specifically measure spatial ability but performance on the test has also been found to be highly related to overall IQ scores (Elliot, 1983).

• **Copying** - the Copying subtest is one of three tests of the British Ability Scales measuring "perceptual matching ability". Elliot has noted that "The development of copying skills has a place of some importance in the educational curriculum for young children, having implications for the development of writing skills and for the development of perceptual matching skills" (1983, Manual 1, p. 42) As well as being a component of general intellectual ability, "copying of designs appears to require both the ability to perceive similarities between a standard figure and the figure which is being drawn, together with some motor ability" (p. 43). Research has indicated that copying is a skill which may be particularly problematic for children with dyslexia. A number of accounts have noted that dyslexic children have difficulty copying information from the classroom blackboard (e.g. Miles and Miles, 1990).

• **Matching letter-like forms** - The second of the tests of perceptual matching, Matching Letter-Like Forms has been found to be "highly relevant to the development of visual discrimination skills in young children which is in turn relevant to their acquisition of reading and writing skills" (Elliot, 1983, Manual 1, p. 43).

• **Verbal-Tactile Matching** - this test was designed to investigate children's ability to integrate information from more than one sensory modality and was based on the work of Birch and colleagues (e.g Birch and Belmont, 1964). It is a complex task, requiring verbal comprehension and retention of verbal instructions, tactual discrimination and the ability to integrate information from the verbal and tactual modalities.

• **Recall of Digits** - this is a test of immediate auditory recall and is based on the approach to digit span used in the Illinois Test of Psycholinguistic Abilities (i.e. digits presented at the rate of two per second and only repeated forwards). Much research has indicated this test to be problematic for dyslexics due to problems with phonological coding in working memory (see Chapter 1).

• **Visual Recognition** - this test of visual memory involves the recall of a series of stimuli presented visually to the child. However, verbal encoding strategies are possible for some items and may assist with recall. Low scores on this test can be due to poor short term visual recognition, but can also be due to general visual perceptual problems or inattention.

• **Basic Number Skills** - this test focuses on the concepts and skills which lead to a basic competence in arithmetical computation, such as matching and classifying (by qualitative attributes and by number), one to one correspondence, comparison of sets, ordinal aspects of number, knowledge of number names and numerals, counting and awareness of number patterns and the ability to count in tens.

• **Naming Vocabulary** - this is a scale which assesses the spoken vocabulary of young children and is a measure of expressive language ability. The test requires the child to recall an item from long term memory and performance is dependent on the ability to do this effectively, and sufficient vocabulary development.

• **Verbal Comprehension** - this scale assesses the child's receptive language comprehension abilities.

• **Verbal Fluency** - this test attempts to provide a measure of the child's "creativity", and children who score well on this scale are likely to be quick thinking and have good general verbal abilities, particularly vocabulary development. However, performance may also be negatively affected by shyness or anxiety.

(b) Tests of Motor Skills

These tests were included in the screening battery to investigate potential motor skills deficits in very young dyslexics as suggested by the work of Augur (1985, 1990), Haslum (1989), the Dyslexic Automaticity Deficit hypothesis (Nicolson and Fawcett, e.g. 1990, see Chapter 1) and the possible role of the cerebellum in dyslexia. Two tests were designed to measure fine motor skills with another assessing gross motor skills, and it was proposed that children with dyslexia would show slower or less accurate performance on these tests.

(i) Pegboard Task - this test was designed to measure a child's fine motor skill ability under time pressures and was influenced by the pegboard studies of Annett (e.g. Annett, 1970).

(ii) Beads Task - this test was designed by the experimenter and was also a test of fine motor skills in speeded conditions.

(iii) Blindfold Balance - based on the 1992 study by Fawcett and Nicolson, the ability of the children to maintain a balanced position for a designated time period was investigated. The original balance studies were carried out with teenage subjects and therefore the design of the task was modified to suit the younger age of the present subjects. Therefore, instead of balancing on a beam, or on one foot, the subjects were simply required to balance on the floor with two feet together, and one foot in front of the other. As an alternative to the dual task paradigm of the original study (Nicolson and Fawcett, 1990), the blindfold technique of the 1992 Fawcett and Nicolson study was used to distract children's conscious attention away from the task of balancing. It was proposed that as in the case of older children, young dyslexic children would also exhibit difficulties with maintaining a balanced position, particularly when conscious attention to the task was prevented.

(c) Tests of Phonological Skills

(i) Phonological Discrimination Task - this test was based on an experiment by Bishop (1985) and involved the presentation of 20 spoken stimuli each accompanied by a small picture, using an Apple Macintosh SE/30 microcomputer with automatic computerised hypermedia format. The experiment was designed to investigate the ability of the child to discriminate the beginning sounds of words by presenting 10 real and 10 nonsense words and asking the child to indicate if the each of the words that they had heard was the right word for the picture that was shown. Nonsense words were created by exchanging the first letter of each of the real words, for example: "dog" - "rog", and for presentation of both of these words, the picture of the dog would be shown. This test was adapted from Bishop's original test by reducing the number of stimuli that were involved and also substituting lower age of acquisition, more frequent words for the original stimuli to make the test more appropriate for younger children. The advantages of computer presentation for this type of test included standardisation of presentation (all stimuli were recorded using SoundEdit software and presented in human voice), flexibility, and automatic recording of performance in terms of accuracy and time to respond. This ensured that all children received the task in identical format and left the experimenter free to observe the approach of the child to the task.

(ii) Nonword Repetition - This test, designed by Gathercole and Baddeley (1990) was also presented using the computer set up outlined above. Thirty of the original 40 stimuli were used, which were nonsense words of one, two and three syllables (10 words each) that also varied in complexity (the presence or absence of consonant clusters). This test is a measure of the ability to correctly perceive, remember and pronounce a series of unfamiliar words and has been established as a good test of phonological working memory.

(iii) Lexical Access - this test was designed to measure the ability of the child to make lexical decisions under timed conditions. It involved the presentation of 40 stimuli: 20 words and 20 nonsense words (created by altering the first consonant of each of the real words) using the Apple Macintosh computer and software as before, with the addition of a MacRecorder to measure voice onset latency for each response. The test required the child to be able to perceive the sounds in the word presented and then establish if the stimulus was an actual word or not. The test was adapted from a version used with older children by using more frequent, lower age of acquisition words that were more appropriate for the young subjects.

(iv) Rhyming Task - this test, which is actually a test of rhyming *and* alliteration skills, was adapted from the test designed by Bradley and Bryant in 1983. Instead of using the original "odd one out" format for presentation, which was felt to place significant demands on short term memory (see also Mann, 1993) as well as tapping those skills associated with rhyming and phonological skills, the present test was designed as a rhyming pairs task. This meant that for each trial in the three conditions, the child was presented with two, instead of three or four words and asked to indicate if the pair rhymed or if they did not rhyme. Like the above tests, this test was presented to subjects using a Hypercard program with an Apple Macintosh SE/30 microcomputer with stimuli presented in recorded human speech.

(v) Articulation Rate - A link between articulation rate and memory span has been found by Baddeley, Thomson and Buchanan (1975) and further evidence suggests the possibility of cognitive deficits in reading disabled children being attributable to deficits in working memory due to motor deficit in articulation speed (Nicolson, Fawcett and Baddeley, undated). This test of articulation rate is simply designed to measure the speed of articulation for six familiar words (two each of one, two and three syllables). The test employs computer technology to enhance accuracy of measurement, in the form of an Apple Macintosh computer with SoundEdit software and MacRecorder.

(vi) Phonological Segmentation Task - This test was adapted from the Auditory Analysis Test (AAT) devised by Rosner and Simon (1971) to measure phonological skill in the form of ability to delete syllables and phonemes from common words. The authors found that the test was able to provide a systematic method of assessing "the degree to which a child learned to sort, order, and synthesise the perceptual elements of auditory information" (p. 46) and was found to be strongly related to later reading performance (correlations of .53 to .84) However, as a relatively difficult test, requiring quite advanced levels of phonological skill this was administered to subjects in the second predictive phase only.

For all of the above tests with a phonological and short term memory component, it was hypothesised that the dyslexic subjects would perform slower and less accurately than the non-dyslexic subjects.

(d) Tests of Reaction Time

(i) Naming Game - this test was designed to measure the naming speed and accuracy of the subjects. As well as being a test of reaction time, it was also designed to address the issue of whether dyslexics experience difficulties in generating verbal labels for familiar items, particularly under time pressures. However, unlike the RAN test used in many naming investigations, the Naming Game was designed with discrete trials, rather than as a continuous naming task. It was presented to subjects using an Apple Macintosh LCII microcomputer using a program designed in Hypercard. A MacRecorder was also used. It was proposed that dyslexic children would perform at lower levels than non-dyslexics on this task, in terms of both speed and accuracy.

(e) Tests of Speed of Processing

(i) Visual Search Task - this test was designed to measure subjects' speed of finding a target figure from a background of visual noise, and as such was considered to be a test of visual processing speed. The work of Tallal and colleagues (e.g. 1993), and findings from neurophysiological studies have suggested possible perceptual processing deficits in dyslexia. It was proposed that such deficits might be evident in the sample of children later found to be dyslexic in this study.

(f) Tests of Laterality

(i) Laterality - in light of the continuing debate regarding the role of laterality in dyslexia, a test to determine the preferred hand, foot, eye, and ear of the child was given. This test was adapted from that used in the Aston Index (Newton and Thomson, 1982) to be more suitable for younger children: the key change being the substitution of bead threading for the threading needle item (in the interests of safety). The possibility of children with dyslexia having a greater degree of unresolved laterality at preschool age was considered.

(g) Tests of Verbal Labelling

(i) Prepositions - It has been noted by many of those involved with dyslexia that the one of the characteristics of the condition is a lack of proficiency in decisions regarding directions such as "left" and "right" (e.g Miles, 1993). In fact, anecdotal evidence from Augur (1990) indicates that very young dyslexic children may have difficulties with more basic prepositions such as "up" and "down". Therefore this task, based on the test devised by Gesell and colleagues in 1940, required the child to place an object (a ball) in a number of positions involving a box, as instructed using prepositions such as "in", "out", "up" and "down". It was hypothesised that dyslexic children would have difficulties with this task.

(h) Tests of Rhythm

(i) Clapping - this simple test was designed to measure the ability of subjects to repeat a rhythm which was clapped to them by the experimenter. It was based on the finding that dyslexic children have difficulty in maintaining the correct tempo and rhythm in their language, reading, writing and skilled actions (Katz et al., 1992) plus anecdotal information regarding rhythm problems in older dyslexics (Stirling, 1991, personal communication). The possibility of dyslexic children being less able to correctly repeat the clapped rhythm was considered.

3.1.3.1 Background Information: The Screening Questionnaire and Teacher Interviews

In addition to the tests of cognitive and motor skills used in early screening batteries, collection of background data have also proved to be a useful aid to prediction (e.g. Badian, 1990). In the present study it was hoped to obtain some background information regarding the subjects. This was attempted in two ways: informal interviews with nursery school teachers, and the administration of a questionnaire for parents. However, the success of both of these methods was limited for a number of reasons such as lack of access to parents and teachers. The purpose of obtaining background information was to establish a number of factors which could assist with the prediction of dyslexia. For example, informal interviews with the teachers or nursery nurses at the children's nursery schools were designed to obtain information such as: the child's temperament and social skills, their motivation to learn, attention levels, referral for investigation of sensory disabilities or speech problems, and home and family factors which might affect current or future performance.

The Questionnaire for parents was developed to investigate three main areas of the child's background: current aspects of the child's functioning and developmental milestones; health history from birth to the time of administration of the questionnaire (approximately 5 years); and birth history. A copy of the questionnaire can be found in Appendix 2.

A comprehensive collection of this information for all subjects was not possible, and methods of improving the acquisition of such data are currently under investigation. Questionnaires were not returned for many of the subjects, and not all children were tested in their nursery, making access to teachers for interviewing very difficult. However, some background data does exist and where possible, information additional to that gained from the screening test is reported for those children who have been found to exhibit later reading problems.

3.1.4 The design of the study

As advocated by Satz and Fletcher (1988) the present study took the form of a longitudinal prospective design. Two phases of predictive testing were administered followed by two phase criterion testing. A gap of approximately two years separated the administration of initial predictive measures and the first set of criterion tests. Overall general predictions made regarding the performance of dyslexics and non-dyslexics on the screening measures were investigated in a number of ways. Initially, as in many of the studies reported in the previous chapter, correlation was used to establish the strength of the relationship of between predictive tests and later reading measures. However, bearing in mind the limitations of such methods of analysis, the differences in performance of the various reading outcome groups were investigated using analysis of variance (see also Scarborough, 1989), and also effect size analysis (e.g. Cohen, 1969). Other methods of analysis used by early screening researchers have included for example, multiple regression analysis, factor analysis and discriminant function analysis. These forms of examination of the data were explored in the present study, but it was found that the data were not suitable for such analyses.

Based on these findings, the ability of the screening test to accurately predict the dyslexic and other poor reading (slow learning) children was investigated using a predictive index based on the incidence of scores of more than one standard deviation below the overall mean on a small number of selected tests (see Badian, 1986). On this basis, overall hit rates and incorrect predictions are calculated, and additional background and anecdotal information considered. Therefore the particular design of the study allows the investigation of prediction at two time points, the establishment of later reading outcome status and diagnostic status (dyslexic, slow learning or other), consideration of both the preschool profile of performance of dyslexics and slow learners, and examination of the ability of the screening battery to correctly predict the later academic status of a group of preschool children.

3.2 Overview of the study

Data for the study were collected in four major phases over the course of three and a half years. Two main groups of nursery school age subjects were involved: a general population sample and a "siblings" group. The subjects were selected to be approximately four and a half years of age at the beginning of the study, although there was variation in the ages of some children. The two groups were each followed over a period of approximately three years from four to seven years of age.

The first two phases of the study consisted of the "predictive" phases in which tests which were thought to have predictive value for dyslexia were administered to the children. The second two phases involved administration of tests to determine the reading, spelling and intellectual status of the children. This allowed children to be placed firstly into groups of good and poor readers (phase 3), and secondly following a more detailed assessment to be identified as either dyslexic, slow learners or "normals" (phase 4). The first three phases of testing were administered according to the timetable illustrated in the following table.

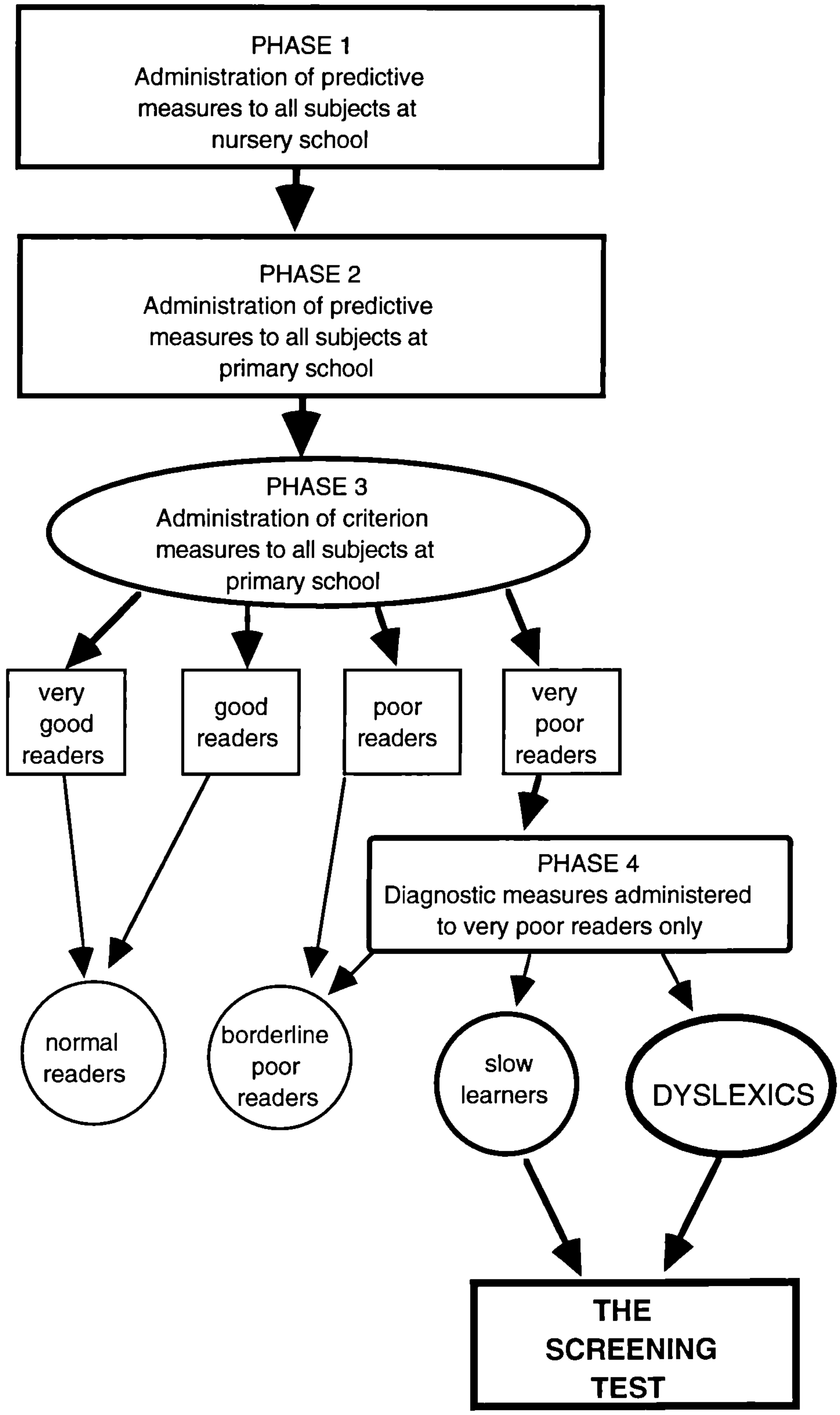
Table 3.1 Timetable for administration of Phases 1, 2 and 3 of the study

Phase 1	Subjects attending their penultimate or final term of nursery school
Phase 2	Subjects attending Primary School, usually for at least two school terms.
Phase 3	Children attending Primary School for at least one school year.

Only children who were identified as the poorest readers in the third phase of testing were included in the fourth phase of testing. In all but a couple of cases this final phase took place when children were at least seven years of age and had been attending school for approximately two years. This was carried out to establish which of the poor readers could be considered as dyslexic and which were "slow learners".

On the basis of categorisation of the children as either being dyslexic, slow learners or normal readers, performance on the tests administered in phases 1 and 2 has been analysed to establish which tests may be useful in the early identification of dyslexia. Figure 3.2 presents a summary of the longitudinal study in diagrammatic form, showing phases of predictive testing, criterion testing and the groups of children identified in the study.

Figure 3.2 Diagram to illustrate the four phases of the longitudinal study



3.3 General features of the study

In view of the longitudinal design of the study, a number of features of the project remained the same throughout, while others varied over the four phases of the study. The following section presents a review of the key aspects of the method which were relevant to all phases of the study, in terms of subjects, materials and design. In section 3.4, however, the particular features of each phase of the project are presented in detail, including the ages and other characteristics of subjects, and the materials and procedures for administration of the tests, plus informal observations of the performance of subjects on each of the tests.

(a) Subjects

Overall, the number of subjects initially recruited to the project totalled over one hundred and thirty. However, the total number of subjects who were available for testing in all of the first three phases of the project was ninety one.

Two main groups of subjects were involved in the study:

(i) The General Population sample

The largest of the two groups of subjects was the "general population" sample. This group of children was selected to represent "typical" children of the age group studied (approximately four and a half years old). They were selected from a number of nursery schools in the Sheffield area in an attempt to account for a representative cross-section of the population of the city. The subjects were all white, and English was the first language for all who took part. The children were recruited to the study by contacting local nursery schools willing to be involved, establishing children who fitted the criteria for the project, and then contacting the parents of the children to request consent for their participation in the study over the three year period. Only children for whom full consent was given were included in the study. At the outset of the study this group consisted of one hundred subjects. However, over the period of study the number of children from this group participating in all phases was reduced to 71. This was due to a number of factors including children moving away from the city, children who were consistently unavailable for testing and some children who were uncontactable following their movement from nursery to primary school. A preliminary examination of the subjects indicates that the characteristics of those children who left the study did not differ significantly from those who were available for all phases.

(ii) The "Siblings" group

The second, smaller group of subjects was referred to as the "siblings" group as each child in this group had at least one family member with dyslexia. In some cases this was an older sibling, although in others, it was a parent. Subjects in this group were recruited to the study using a number of methods. Some already had dyslexic brothers or sisters who were taking part in dyslexia research the University, others were contacted through local dyslexia groups or the Dyslexia Institute. Some subjects responded to posters, or to information on local radio and in the local press. At the beginning of the study the number of subjects in this group was 30. The number of "siblings" available for all phases of the study, however, was 20. Again, there is no reason to believe that the "siblings" subjects who did not complete the project differed in any way from those who did.

(b) Testing materials

During each of the four phases of the study, a large number of measures were taken for each subject. Some of the tests administered were standardised tests which had specially designed test materials provided (such as the British Picture Vocabulary Scale), others involved materials which were constructed by the experimenter for the study. A number of the tests were administered using Apple Macintosh computers and software. The specific materials required for the administration of tests is discussed in more detail below when each test is individually described.

(c) Design

The study was carried out according to a longitudinal prospective design. This involved administration of a number of predictive measures at the outset of the study, and the follow-up of all subjects after a designated period for administration of criterion measures, to establish subjects' outcome status. All subjects received all tests in the first three phases of the study. Performance in phase 3 determined whether a subject was administered tests in phase 4.

(d) Procedure

The procedure for administration of tests during the study varied depending on the particular phase of the study in question. Therefore information about the procedures used in the study is presented in detail in the rest of the chapter. Each of the four phases of the study is outlined in detail in terms of subject details and test procedures.

3.4 The study: A detailed description of method and procedures

3.4.1 Phase 1

3.4.1.1 Subjects

Following the recruitment of subjects in both groups to the study and the return of completed consent forms from parents, the subjects were either visited at their nursery school or attended appointments at the Psychology Department with parents. A period of familiarisation was allowed for each child to enable them to become comfortable with the experimenter before any testing began. This was particularly important for those children who were in the unfamiliar surroundings of the Psychology Department, where testing took place in a quiet experimental room or in the experimenter's office. Children who were tested in a nursery school were taken individually to a quiet room such as the staff room, so that the testing session could be as quiet and free from distractions as possible.

When the experimenter was sure that the child was as at ease with the testing situation, the first tests were administered. In order to assure that maximum concentration was given to the task by the child, tests were administered in a number of five to ten minute sessions. It was found that during this first phase the majority of children were unable to give attention to a task for longer than this.

The mean ages (with standard deviations) and age ranges of subjects during this phase are presented in the table below:

Table 3.2 The mean ages (with standard deviations and ranges) of subjects at Phase 1

Group	Mean age	SD	Range
General population	4.7 years (55.35 m)	2.98 months	4.0 - 5.3 years
Siblings	5.6 years (66.9m)	11.82 months	4.1 - 7.5 years
All subjects	4.9 years (57.87 m)	7.72 months	4.0 - 7.5 years

As can be seen from the above table, some of the subjects in the siblings group were older than those in the general population group. This was due to the difficulty in recruiting subjects to this group using the strict criteria employed (that the child should have a parent or sibling who was dyslexic) and who also matched exactly the age of the general population group. Therefore the range of ages of the siblings was wider than that of the general population group, as it was decided to include the older subjects in the siblings group to maintain sufficient numbers. However, as the results of many of the tests administered were standardised, this made little difference to the outcome of the study.

3.4.1.2 Test measures

Overall, considering each of the subtests of the British Ability Scales as a separate test, twenty four tests were administered during Phase 1. The majority of these tests were relatively quick to administer and score. Each of the tests was chosen specifically to tap a particular area of the child's skill which was considered to have some significance in the early identification of dyslexia (see section 3.1 above for a full review). Table 3.3 presents a list of the Phase 1 tests and the particular skill area that each test was designed to measure. It is important to note that this allocation of tests to skills is only a simplistic outline, as many of the tests were measuring more than one particular aspect of the child's cognitive skills. The apparatus for each of the tests and procedure for administration is described below together with informal observations of test performance that were made during administration.

Table 3.3 Tests administered in Phase 1

Skill	Test
General ability	British Picture Vocabulary Scale (Long Form)
	British Ability Scales (Long Form)
	Copying
	Verbal Comprehension
	Naming Vocabulary
	Verbal Fluency
	Basic Number Skills
	Recall Digits
	Visual Recognition
	Block Design
	Matching Letter-Like Forms
	Verbal Tactile Matching
Motor skill	Pegboard Task
	Beads Task
	Blindfold Balance
Phonological skills	Phonological Discrimination Task
	Nonword Repetition
	Lexical Access
	Rhyming Task
	Articulation Rate
Reaction time	Naming Game
Speed of processing	Visual Search Task
Laterality	Laterality Test
Verbal labelling	Prepositions Task
Rhythm	Clapping

(a) Tests of general ability

(i) The British Picture Vocabulary Scale

The "Long Form" of the British Picture Vocabulary Scale (BPVS) was administered using the apparatus provided for the test: a booklet, on each page of which were four pictures, and a score sheet on which to record the child's responses. When the child's attention had been directed to the first page of the booklet, the experimenter told the child that she was going to say a word, and that the child should point to the picture of the word that had been said. For example, the experimenter might say the word "man" and the child chose from a selection of four pictures of a man, a dog, a hand and a drum, and point to the correct picture. After six practice trials during which the child was familiarised with the experimental procedure, the test began and each of the child's responses was noted on the score sheet. Discontinuation criteria (six errors in eight consecutive items) were employed and testing ended when these criteria had been reached.

The BPVS yielded four scores for the child: a raw score, a standardised score equivalent, a percentile rank and an age equivalent. Thus a subject's "vocabulary age" and their relative performance compared to other children of their age was obtained.

Informal Observations

The B.P.V.S. was designed specifically to be given to subjects whose expressive language may be limited and in this case, some of the children did benefit from being able to indicate the correct answer without a verbal response as they were often a little shy. However, over the course of this first test, many of them began to relax and to respond to many of the pictures with personal anecdotes, and to generally become more verbal in their dealings with the experimenter.

The straightforward nature of the test, and use of the practice trials meant few problems regarding the child's understanding of what was required of them. Consequently, results of this test were viewed as an accurate representation of the subjects' receptive vocabulary. However, children from lower SES nursery schools did not seem to perform as well on this test, and this was hypothesised to be due to a restricted access to vocabulary compared to the children from more middle class homes. Therefore, the limitations of interpreting this measure in terms of general ability were noted.

(ii) The British Ability Scales (B.A.S.)

Ten subtests of the British Ability Scales were administered to subjects during the first phase of the project (in accordance with recommendations regarding age and test suitability). These are described below. For each test, three scores were obtained: a raw score, a standard score and a centile score (only centiles were used in analysis of results). Examples of items from the tests can be found in Appendix 3.1.

- **Block design (Level)**

The apparatus for the test consisted of nine black and yellow cubes, a booklet of designs and a stopwatch. Subject's were required to construct two-dimensional patterns as shown in the booklet of designs using the three-dimensional blocks (see Appendix p. 23 for examples). Designs became more complex as the test proceeded, initially involving only two of the wooden cubes, then four and finally all of the cubes. Performance on each item was recorded on the score sheet provided. For each design, a maximum time limit existed, beyond which the performance was scored as zero. A correct placing of the blocks within the time limit earned a score of one. In this and other subtests of the British Ability Scales, discontinuation rules allowed the test to be stopped after a number of successive incorrect answers, but nevertheless, to be scored as if all items had been given. In most cases the discontinuation rule for this test was employed so that the subjects were not required to repeatedly encounter failure and frustration on this difficult task.

Informal Observations

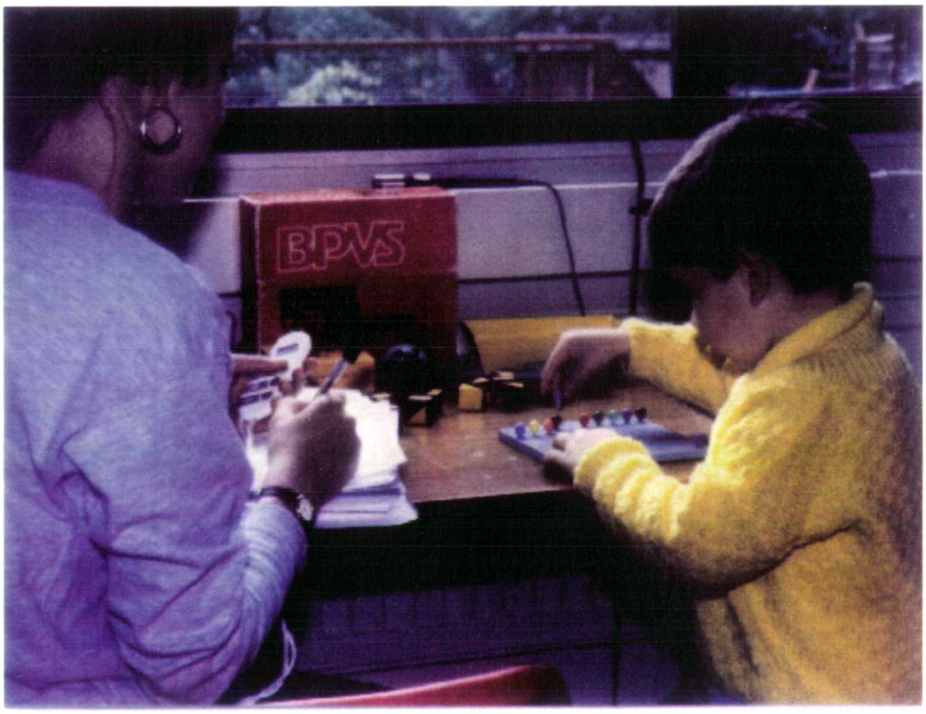
This test proved to be particularly difficult for many of the subjects, with some unable to complete more than the first of the designs presented. A number of children were unable to complete any of the designs correctly. Although the test was allegedly suitable for children of the age range tested, it appeared too difficult for the great majority of subjects, and the children did not seem particularly confident about what was required of them, or how to approach the task. Scores on this test were generally low during Phase 1.

- **Copying**

Administration of this test required a booklet of designs, sheets of A5 blank paper and a pencil. The child was presented with the first page of the booklet of designs and asked to copy the shape presented (see appendix p.22 for examples). Care was taken to ensure that the child knew what the word "copy" meant, and also the need to make their drawing *exactly* the same as the one in the booklet. The shapes increased in complexity from very simple figures such as a circle or line, to letter shapes and complex geometric figures. Following the scoring criteria outlined in B.A.S. Manual 3, a score of one was given for each design that fell within acceptable bounds of accuracy.

The Block design subtest of the British Ability Scales

The Pegboard task



Informal Observations

Subjects generally responded well to the demands of this test and were able to accurately copy at least the first few shapes presented. It was very interesting to observe the approaches that the children were able to take to the task and the various factors which appeared to influence performance. In the youngest or most immature children, many of the errors were due to poor pencil control: the child's grip of the pencil was not steady enough to form the shape required. For some of the other children, errors began to be made when he or she was required to copy a pattern with a *number* of shapes in it. Many of the children seemed to fail to realise that they needed to count the number of shapes to copy before drawing their own version. More advanced children actually stopped and counted the shapes out loud and then counted their own as they drew them. Occasionally though, a child's counting ability let them down with this strategy! In addition to this, a number of shapes appeared to create a general difficulty for all children of a certain age due to their specific nature. The triangle was a good example of this, as many of the subjects drew two of the sides of the shape and then failed to calculate the slope of the final line in order for it to join with the starting point. The result of this was that many of the triangles drawn tended to have four sides, or one rounded side.

- **Matching letter like forms**

Using the booklet of patterns provided with the test, subjects were asked to chose from a selection of one identical figure and five transformations (reversal, 180° rotation, 180° rotational and reversal, 45° rotation and 315° rotation), the item which matched the target figure (see appendix p. 25 for an example). To establish that the instructions of the test had been understood, the child was initially presented with the first of three training pages of the booklet and asked to point to the one of the six shapes presented in the bottom page of the booklet which matched that on the top page. If the child answered *incorrectly* on these training items, he or she was guided to the correct answer by the experimenter. In the following items, however, the child was asked to select the matching shape without any help from the experimenter. For each of the test items, the child's response was noted on the score sheet and the number of correct responses calculated.

Informal Observations

The children did often seem to require some guidance in the training items, but by the time they had moved on to the test proper, most seemed to be aware of what was required of them. However, even though reminded to choose carefully after considering all possible matches, some children did seem to make a number of hasty judgements, quickly selecting the figure that looked *something* like the target figure without checking to see if it was an exact match. It was therefore noted that although some children did genuinely have a difficulty in distinguishing between the shapes in various rotations, some also performed relatively poorly due to lack of concentration and impetuous responses.

- **Verbal-tactile matching**

The materials for this test are contained in two cotton bags, each with a tape which goes around the child's neck allowing the bag to fall in front of the child so that both hands can be put inside it. In this way, the child is able to feel what is inside the bag without being able to see inside it. The materials consisted of small object such as cubes, sticks, pieces of foam, balls, stones and string. In the first part of this test, the child was required to identify the items in one bag on the basis of descriptions given by the experimenter such as "find something soft and not round" (a piece of foam). In the second part of the test, the child placed his or hand into the other bag and attempted to find a series of named objects such as a rubber ball or a piece of leather. In all cases objects were returned to the bag after identification. A score of one was given for each item correctly identified. If a child produced an incorrect item from the bag or did not produce an item before 45 seconds had elapsed, a score of zero was given for that item.

Informal Observations

This test was difficult for some of the children. Some had problems with understanding the terms that were used to describe the items (e.g. "softest round thing"), and some did not know what items were (e.g. leather). Other children experienced difficulties due to impulsivity - they did not wait to find the correct item before removing it from the bag - they just pulled out the first thing that came to hand. This was despite repeated instructions from the experimenter to wait until they were sure they had the right thing before taking it out of the bag. In these cases, therefore, a score of zero was recorded, although, it was not necessarily the case that the child did not know what the item was.

Many of the children did perform quite successfully on this test, however, and did not have any problems with understanding the instructions for it.

- **Recall of digits**

No materials were required for this test apart from a list of numbers visible to the experimenter only. The test involved the experimenter reading a list of numbers and then asking the child to repeat the numbers back in exactly the same order. Numbers were read out at a rate of two per second. The number of digits in the lists increased as the test proceeded, from two digits to nine. Five different sets of digits of each length were presented, and discontinuation rules allowed testing to be finished when all five items in a block of numbers had been failed. A score of one was recorded for each correctly repeated list of digits.

Informal Observations

The performance of the children on this test was relatively good and there seemed to be few problems with children not understanding task instructions. On the whole performance appeared to closely reflect ability, except perhaps in a few cases where inattention and distractibility meant that lists of digits did not appear to have been listened to very closely.

- **Visual recognition**

The items in this test consisted of series of visual stimuli: pictures and non-representational designs, contained within a booklet. The test was presented to the child by opening the booklet at the first item and encouraging the child to look at the picture on the page (for example, a toy dog). A five second time limit was placed on this. Following this, the next page of the booklet was shown. This contained an array of drawings within which the original object was embedded (e.g. a toy dog and a toy cat). The child was required to identify the original picture that he or she had seen on the previous page (see appendix p. 24 for an example). Stimulus items increased in difficulty as a result of an increase in number of items to be remembered, semantic similarity, and degree of abstractness. One point was awarded for each set of stimuli correctly recognised.

Informal Observations

It has been noted (Elliot, 1983) that it is possible to use verbal encoding strategies on the early items in this test, and indeed many children did seem to do that. However, it was interesting to note that their appreciation of the task did not appear to be sophisticated enough to take into account the semantic similarity of many of the items (e.g. a boat was embedded in a page of other types of boats and submarines). In addition to remembering pictures of objects as a result of naming them, some children tried to make sense of the abstract pictures and attach verbal labels to these also. It appeared to be the more mature and able children who used this strategy in general, however, some children may have used verbal labels without explicitly articulating them. Nevertheless, performance on this test was relatively good for many children whether purely visual or visual and verbal strategies were used.

- **Basic number skills**

The materials for this test included a booklet of pictures and a set of twelve green plastic cubes. The test required the child to use skills related to number to answer a series of questions based around the booklet of pictures. Items began with questions concerning classification of pictures and then moved to simple arithmetical concepts and operations. For example, an early item on the test required the child to match a series of ladders of three different lengths to three houses of different heights. Later items required the child to identify the largest and the smallest numbers from a set of five digits on the page and to count the green cubes. A score of one was given for each correct item in the test.

Informal Observations

Performance on this test varied a great deal, from a good understanding of number to almost no understanding of any aspects of the test. Children did not seem to encounter major problems due to lack of comprehension of test instructions - failure appeared to be due to lack of facility with numerical information.

- **Naming vocabulary**

Materials required for this test included a booklet of pictures and a number of objects found in the experimental room (chair, window, box, paper). For each item the experimenter pointed to the object or picture and asked the child "what is this?". If the child produced an acceptable answer (as defined in BAS Manual 3), a score of one was awarded. Unacceptable responses (e.g. saying "shape" for circle) were scored as zero.

Informal Observations

Children performed reasonably well in this task, although two observations were noted from the performance of some children. The first was that children from lower SES homes tended to score at lower levels, possibly due to a more limited vocabulary and knowledge of objects. The second observation was that some children (including a couple from the "siblings" group) tended to produce circumlocutions instead of the one word answer required. An example of this was found with one child, who, for the item "robin" gave an answer of "it begins with Robin Hood", and for switch said: "it begins with a light". It appeared that the child knew what the items were but had difficulties in retrieving the verbal label for them.

- **Verbal comprehension**

A number of items were involved in the administration of this test. These included a large photograph of a teddy bear, a small box containing small toy objects (horse, pencil, watch, button, car, soldier, dog, cat), and a wooden tray with inset items such as a house, tree and a little boy. For each of the items the examiner asked the child a question to measure the child's comprehension of language. For example, for the picture of the bear, the experimenter asked questions such as "show me teddy's mouth" and "show me teddy's arms". With the box of small toys instructions such as "give me the car" and "put the button on the car" were given, and with the inset tray, instructions became more complex such as "give me the van and the car at the same time". Like other subtests of the BAS, a score of one was give for each correct response.

Informal Observations

This test is designed to be given to very young children (two and a half to five years) and as a consequence very few of the subjects experienced difficulties with it. Occasionally, however, a small number of children found the later items, where more than one instruction was given at the same time, difficult.

• **Verbal fluency**

This test was administered after the child had become acquainted with the experimenter and was therefore relatively relaxed in the testing situation (in line with advice from BAS Manual 3). The first two items from the test were administered based on the young age of the children. The test involved asking the child to tell the experimenter the names of as many things to eat as he or she could in a thirty second time limit. This was followed by the child producing the names of as many animals as possible, again in a time limit of thirty seconds. For each new item produced, a score of one was given. The total scores for the two parts of the test were then rescaled according to the instructions given in BAS Manual 3 (p. 175).

Informal Observations

The number of items that were produced by the children in each of the two categories varied quite considerably. Children with wider vocabularies and better concentration abilities seemed to score much better on this test. Some subjects could not produce many items at all, and tended to keep repeating the same couple of responses.

(b) Tests of motor skill

(i) Pegboard task

The first of the tests of motor skills was designed to measure the child's speed of fine motor skill. The test involved a plastic board (approximately 10cm x 10cm) with ten lines of ten holes in it. This pegboard was of the kind often found in nursery schools (where the children are usually encouraged to make patterns using small coloured pegs placed in the holes of the board). For the purposes of this task, only ten pegs were used and these were placed in a straight line at the top of the board, on a table in front of the child. The task was demonstrated to the child by the experimenter and it was made clear that the child should move the line of pegs to the next-but-one line of the board as fast as they could, moving the pegs with one hand, one at a time. The experimenter then told the child when to begin moving the pegs and the time taken to move them was recorded using a stopwatch. This was repeated four more times. The five time scores were noted on a score sheet.

Informal Observations

It was observed that some of the children did have difficulties with this task, particularly during the first or second trial, although most had mastered what was required of them by later trials. In the majority of cases, subjects visibly improved in their speed and efficiency of moving the pegs over the course of the five trials. Some children were notably slower than others and had a greater tendency to lose their grip of individual pegs, which often resulted in the pegs being dropped on the floor. If this happened a number of times during a particular trial, the trial was discounted from the final score.

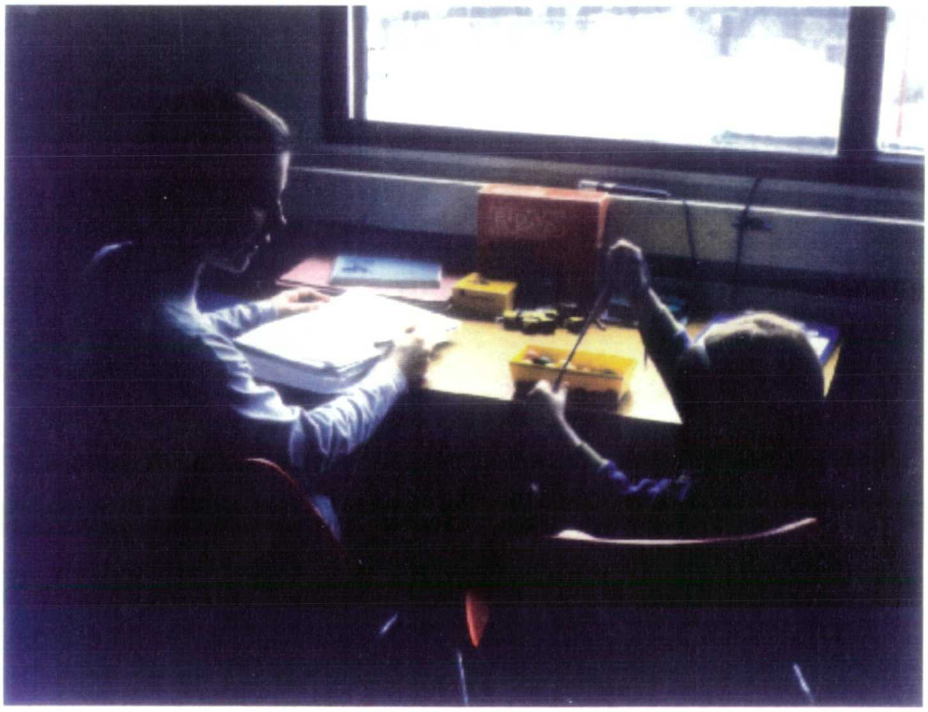
(ii) Beads task

Like the Pegboard Task, the Beads Task was also designed as a test of the child's fine motor skill functioning. The child was presented with a box of wooden beads and a coloured bootlace on which to thread as many as possible in one minute. Such items are also commonly found in many nursery schools and were familiar to the subjects. The bootlace and beads were placed on the table in front of the child and the child was asked to try to thread as many beads on to the lace as possible in the time given. The stopwatch was started as the child was instructed to begin the task and the number of beads on the string after one minute was counted. One point was awarded for each bead on the string, with half a point for a bead that was in the process of being threaded as the time limit was reached.

Informal Observations

As in the case of the Pegboard Task, children were already familiar with the materials used in this test. It was possible that there were slight sex differences in this familiarity, however, as the female subjects may have been encouraged to, or desired to thread beads at home or nursery school more than males. However, this did not seem to effect performance to any degree and the majority of subjects understood well, and carried out efficiently, what was required of them. As in the case of the Pegboard Task, some of the children did not appear to have a very sophisticated grip of the beads or the bootlace, and beads and string were sometimes dropped on the floor.

The Beads task



(iii) Blindfold balance

This test was a modification of the test designed by Fawcett and Nicolson (1992) to determine ability to maintain a balanced position over a set time period (see section 3.1 above). The test was modified by simplifying the balancing that the child was required to carry out (balancing on the floor rather than using a beam). The Blindfold Balance test had with four conditions. The first two conditions did not require that the child's eyes be covered. The child was first simply asked to stand with both feet together and arms held out at the sides for a period of 30 seconds. During this time, the experimenter filmed the child using a video camera and measured the time that she or he held this position using a stopwatch. Secondly, the child was asked to stand with one foot in front of the other so that the heel of one foot was placed at the toes of the other (the romberg condition). Occasionally the experimenter was required to demonstrate this position to the child. The child was again asked to hold this position with arms outstretched to the side for a period of 30 seconds and this was video recorded.

For the second two conditions of the Blindfold Balance test, the child's eyes were covered using a specially made blindfold. The child was shown the blindfold before it was placed on in order to reassure them, and it was explained that the experimenter just wanted to make sure they could not see anything (and that this was easier than keeping their eyes shut). Once the child was happy to have the blindfold on, and it was checked that they could not see anything, he or she was placed into the two balancing positions described above, and performance again filmed.

The performance of subjects on this task was rated using a system judging the number and severity of wobbles made with the arms and the legs. Using an Apple Macintosh SE/30 computer and a Hypercard program specifically designed for the analysis of the Blindfold Balance video recordings (Nicolson, 1993), an experimenter who had not been present during the filming of the children's performance scored the extent to which each child wobbled in each condition. This produced a score for each child in each of the four conditions indicating the extent of the problems they experienced in balancing.

Informal Observations

Possibly the most significant observation regarding the young children's performance on this test was their general inability to persevere with balancing for the full 30 second period. Some subjects did grasp the need to try to stay in the required position until the experimenter told them they could move, however many of the children tended to move around, especially after they had made their first "wobble". Such children then found it difficult to adopt the balancing position for the rest of the time period. This was particularly noticeable in the blindfold condition, where some subjects pulled off the blindfold before timing was complete. All this was in spite of the experimenter making every effort to demonstrate to subjects what was required of them for the task. For some subjects, the blindfold did cause some concern, and served to unsettle some of even the most confident children. Generally, it was observed that for children of such a young age, psychologically and logistically, this was a difficult task to carry out.

(c) Tests of phonological skills

(i) Phonological discrimination task

This task was designed to measure the child's ability to discriminate phonemes in simple words. The test was presented using an Apple Macintosh SE/30 microcomputer and a program developed using the Apple Hypercard environment. As in most cases this was the first of the computer presented tests that were administered, it was presented to the child only after he or she had been allowed to become familiar with the concept of a "talking computer". This was important as some of the children seemed to be quite frightened and intimidated by the sounds that the computer made. It was also important to point out to the child that the computer was often "silly" and tended to make mistakes and get things wrong.

The child was positioned with the computer screen on a table in front of them so that they could clearly see and hear the stimuli presented. The Phonological Discrimination Task program spoke its instructions to the child using synthesised speech, but this was not always very clear and it was often required for the experimenter to clarify the nature of the test to the child. The child was told that there would be a small picture displayed on the screen in front of them and that the computer would say the name of the picture out loud. It was explained that, although on some occasions the computer would say the name properly, sometimes it would say it wrong (i.e. produce a morphologically valid nonsense word). The child was asked to tell the experimenter if the computer had said the word correctly, by saying "yes" or if it had said it incorrectly, by responding "no". As soon as the child responded the experimenter clicked the computer mouse and then indicated to the computer program whether the response had been a "yes" or "no".

Before the test proper began, the child was given two practice trials to check that they had understood what they were required to do. Once the experimenter was satisfied that the child was ready to begin the test, the first stimuli picture was displayed. The stimuli presented to the child were all highly frequent, low age of acquisition, concrete words, such as "dog" and "hat". The computer program was designed to produce ten correct and ten incorrect words over the twenty trials of the test. Nonsense words were generated by replacing the first letter of the correct word with another letter (e.g. "dog" - "rog"). A full list of stimuli for this test can be found in Appendix 3.2

During presentation of the test, the program was designed in such a way that the child's responses were automatically noted, and a score in terms of the percentage of "hits" (real words correctly identified) and "correct rejections" (of nonwords) and the time taken for the child to respond to each of the stimuli, was recorded. A maximum score of 20 was possible for this test.

Informal Observations

Although this tended to be the first of the tests using the Apple Macintosh computers that the children encountered, they seemed to grasp the instructions of the test quickly and performed very successfully. Occasionally, children with poor attention skills and high levels of distractibility did experience some difficulties with the test as they were not always able to maintain their attention to the visual and spoken stimuli. However, the majority of children appeared to respond correctly to most of the test items.

(ii) Nonword repetition

Like the Phonological Discrimination Task, Nonword Repetition was presented using a Hypercard program on an Apple Macintosh SE/30 computer. This test required the child to listen to a nonsense word spoken by the computer (in recorded human speech) and to repeat it as accurately as possible to the experimenter. Each word was listened to twice before the response was made. The test consisted of a total of thirty words, ten of one syllable (such as "sep" or "fot"), ten of two syllable (e.g. "vannow" or "prindle") and ten of three syllables (such as "skitticult" or "bannifer"). A full list of stimuli can be found in Appendix 3.2.

After the child had been presented with a word twice, he or she was asked to repeat it. If the child so wished, the experimenter could click on the computer mouse and the word be presented again. Once the child had made an attempt at repeating the word, the experimenter clicked the computer mouse to indicate if the response was correct. If it was not correct, the experimenter typed into the computer program what the child had actually said. In this way, as the test proceeded, the program recorded the number of words of that the child repeated correctly, and the child's responses for those that were incorrect. Scores out of a possible 30 were noted for each child.

Informal Observations

The majority of subjects were able to understand the instructions for this test adequately and carry out the task with relatively few difficulties. Children with speech problems, such as lisps or poor articulation, however, did sometimes found repeating the nonsense words difficult. In addition to this, responses from such children were also more difficult to score as correct or incorrect due to the lack of clarity of their speech.

(iii) Lexical access test

Like the Phonological Discrimination Task, this test involved the child being presented with a series of 20 words plus 20 morphologically valid nonwords (words with one consonant altered) by the computer, in recorded human speech. (See appendix 3.2 for a list of stimuli used). For this test, however, there was no visual stimulus for each auditory stimulus. As each word was presented, the child was required to decide as quickly as possible, if the word was a real word or not, and to respond by saying either "yes" (for a word such as "leg") or "no" (for a nonsense word such as "feg"). A"MacRecorder" was placed in front of the child to record the voice onset time for each response. This allowed an accurate record to be made of the time taken by the child to decide if what he or she had heard was a real or a nonsense word, plus the number of each type of word that were correctly identified. Scores obtained by the subjects (maximum score 40) were recorded automatically by the computer.

Informal Observations

Some of the children did appear to experience problems with this task, and at times such problems became compounded by the use of the MacRecorder. Despite having been clearly instructed to answer only "yes" or "no" following presentation a stimulus, some subjects found themselves just repeating the word that they had heard. This response was detected by the MacRecorder and therefore a response latency based on the repetition was recorded. This meant that the particular trial in question was ignored and the trial repeated at a later stage of the test. In addition, it was not only the child's inappropriate answers that caused incorrect response latencies to be noted by the MacRecorder - occasionally background noise from the nursery school (such as a door slamming) was loud enough for the computer to think that a response had been made by the child. Again, such trials had to be repeated. In addition, the test took quite a time to administer, and for some of the children, it appeared to outlast their concentration spans.

(iv) Rhyming task

This test, which is actually a test of rhyming and alliteration skills, was adapted from the test designed by Bradley and Bryant in 1983. Instead of using the original "odd one out" format for presentation, the present test was designed as a rhyming pairs task. This meant that for each trial in the three conditions, the child was presented with two, instead of three words and asked to indicate if the pair rhymed (by responding "yes") or if they did not rhyme (by responding "no"). The test was presented to subjects using a Hypercard program with an Apple Macintosh SE/30 microcomputer. As in the other computer based tests, pairs of words were presented in recorded human speech. After the child had responded to each item, the experimenter used the computer mouse to indicate if the response had been a "yes" or "no".

There were three conditions of the test: last sound different (eg cat, hat; leg, hen), middle sound different (eg cot, pot; map, cup) and first sound different (i.e. alliteration) (eg hat, ham; kick, fill). After explanation of the test procedure (including discussion with the child about rhyming words) and administration of two practice trials, the child was presented with the first of the ten pairs of words in condition one. This procedure was then repeated with condition two, where it was made clear to the child that it would be the middle sound that would be the same or different. Finally, before the third condition of the test, the experimenter played an "I-spy" game with the child to establish the idea of words beginning with the same sound. When the experimenter was happy that the child had some grasp of this idea, the final "alliteration" condition of the test was presented. For each condition, a subjects' performance out of a possible score of 10 was noted. See Appendix 3.2 for a list of the stimuli used in the test.

Informal Observations

The actual instructions for the task did not seem to cause any problems for the majority of children, although the rhyme detection skills required to carry out the task did seem to be lacking in many of the subjects. It was interesting to note that even though some children were able to come up with a rhyming word before the test began, they seemed completely unable to distinguish whether the pairs of words rhymed or not during the test. Consequently, some of the subjects merely answered "yes" or "no" to all the items, regardless of whether rhyme was present.

The final condition of the test appeared to be the most difficult condition for many subjects. The ability to detect that two words begin with the same letter seemed to be a skill that only the most advanced children had any grasp of. In many cases, although clearly told otherwise, children still attempted to search for rhyme in this condition.

(v) Articulation rate

This test was designed to measure the speed of articulation of the subjects. This was done using an Apple Macintosh SE/30 microcomputer, "SoundEdit" software and a MacRecorder. Each child was required to say six words, each word being said a number of times over as fast as they could, into the MacRecorder which was placed on the table in front of them. The six words were of one syllable (pig, bus), two syllables (monkey, rocket) and three syllables (butterfly, elephant) and were words with which the children were likely to be familiar. Using the SoundEdit software, the speed of articulation (time taken for the child to say each of the test words five times) was noted by the experimenter.

Informal Observations

One of the most noticeable features of this task was the fun that the children had in carrying it out. This was derived from their being asked to say words such as "pig" over and over again, and the fact that in determining the time taken to say the word five times, the experimenter was required to play back to the child the recording of their voice. In the majority of cases this test was carried out without any problems at all. The occasional difficulty was encountered with children with articulation and speech problems, for whom the lack of clarity of their performance made interpretation of the words spoken problematic.

(d) Tests of reaction time

(i) Naming game

This test was designed to measure the naming speed and accuracy of the subjects during this first phase of the study. As well as being a test of reaction time, it was also designed to address the issue of whether dyslexics experience difficulties in generating verbal labels for familiar items, particularly under time pressures. However, unlike the RAN test used in many naming investigations, the Naming Game was designed with discrete trials, rather than as a continuous naming task. It was presented to subjects using an Apple Macintosh LCII microcomputer using a program designed in Hypercard. A MacRecorder was also used.

The Naming Game consisted of four conditions:

- picture naming: the child was required to name as quickly as possible as series or twelve pictures of familiar objects (e.g. cat, dog, tree, table)

- colour naming: six common colours (red, blue, green yellow, black and white)

- naming of numbers: eight numbers (1, 2, 3, 4, 5, 6, 7, 8) presented in random order in bold helvetica font.

- letter naming: eight lowercase letters were presented in random order (a, b, c, d, o, w, s, t) in bold helvetica font.

Each condition was presented in unpaced, single trial format. For each condition, the item required to be named was presented on the computer screen and the child asked to call out the name of the item as fast as they could. Before the actual test began, the test procedure was explained to the child, and the 12 picture objects from the first condition presented with their names spoken in synthesised speech by the computer. This was to ensure that the children were familiar with the names of all the pictures. Once the experimenter was satisfied that the subject understood the instructions of the test, items in the first condition were presented. After the child had responded by saying the name of the object, the next picture was presented following an interval of 1 to 1.5 seconds. In the second condition, six colours were presented, in the third condition eight numbers, and in the final condition, eight lowercase letters. A full list of the stimuli for this test can be found in Appendix 3.3. If the child answered correctly, the next item was displayed, however, if the response was incorrect, the experimenter recorded on the computer program the incorrect response given. In this way, scores for the test included the number of items correctly named in each condition, the time taken (in seconds) to name each item plus any incorrect responses given for the test items.

Informal Observations

Using a MacRecorder for this test occasionally resulted in the kind of problems encountered in the Lexical Access Test - sounds other than the required item name activated a response latency (such as irrelevant comments by the child and noise from the nursery school). It was possible to overcome this by repeating the trial later in the test, although, this did mean that the child had already seen the stimulus before it was presented again. This may have influenced the time taken to name the item on second presentation.

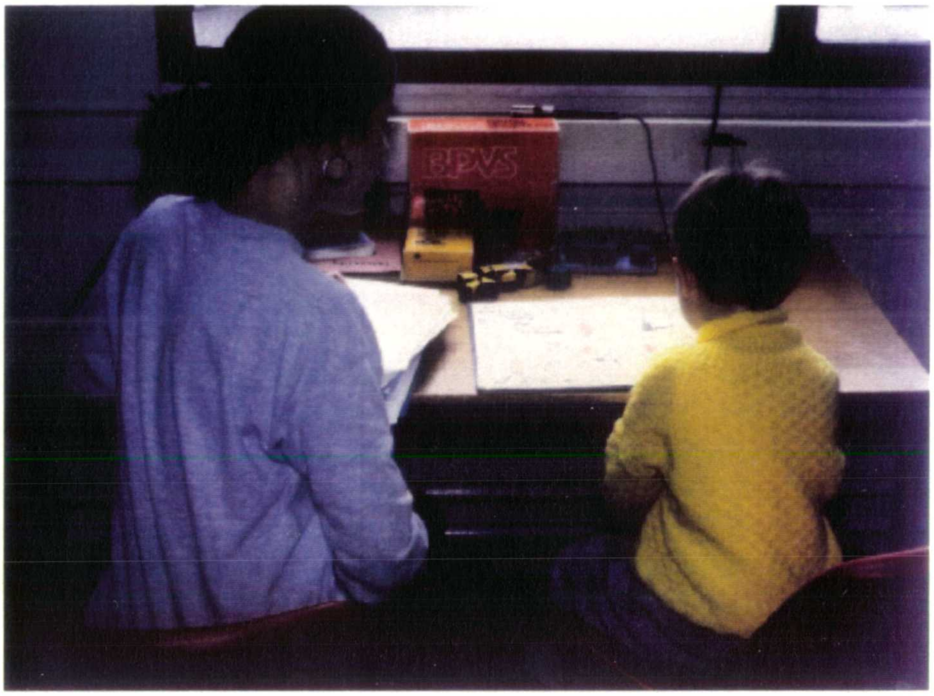
(e) Tests of speed of processing

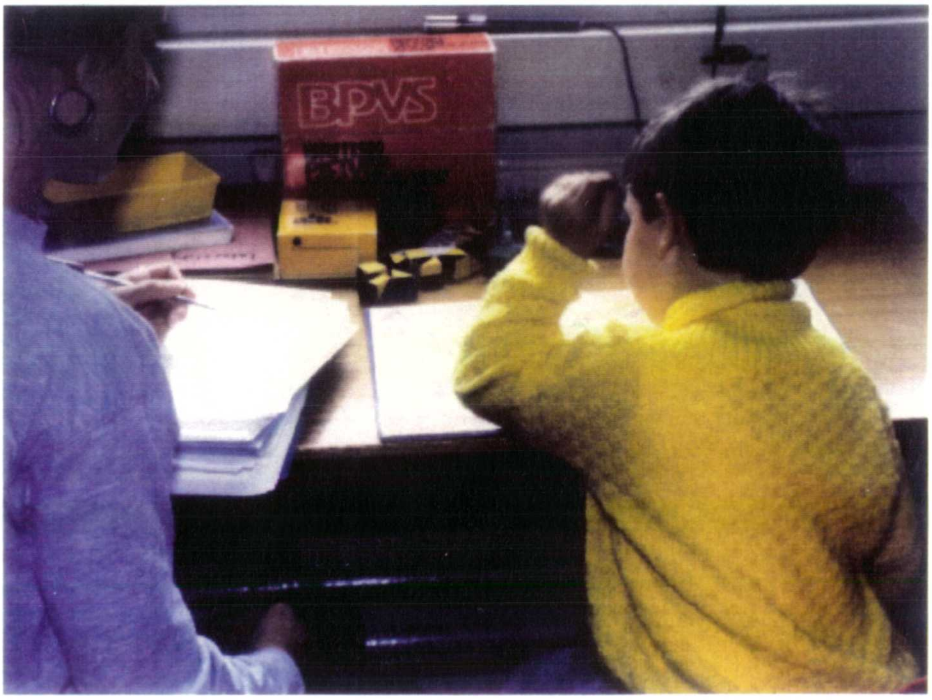
(i) Visual search task

This test was designed to measure subjects' speed of finding a target figure from a background of visual noise. This was done using a children's book - the "Round the World Picture Word Book" (Carol Watson, David Mostyn and Betty Root, 1980) and a stop watch. The book was placed in front of the child and the first page was opened. The child was shown a small picture of the target figure (a small cartoon dog) to ensure that she or he had a good idea of what was to be looked for. The features of the dog (his yellow coat with black spots) were emphasised to the child. Following this, the book was opened at the first of the thirteen test pages (see Appendix 3.4 for an example). Each of the pages was a cartoon drawing of a scene (such as a carnival or a jungle) with a great deal of detail included. The target figure varied in size in the thirteen test pages, and in the extent to which it was easy or difficult to find.

Once familiarised with the target, the child was asked to find the dog on each page of the book as fast as possible. The time taken to find the dog was timed using the stop watch. Timing continued until ninety seconds had passed, by which time it was found that if a child had not identified the target, they were completely unable to do so. For each page of the test, the experimenter noted on a score sheet if the target had been found, and the time taken (in minutes) to locate it. Two overall scores were obtained for the test: the total number of targets correctly found within 90 seconds, and the mean time to find the targets across the whole test.

The Visual Search task





Informal Observations

The instructions for this test were understood quickly and easily by the children, although this did not always mean that they found the task easy. Some of the children took a great deal of time in locating the target, and in many cases ran out of time and had to be shown where the dog was by the experimenter. There seemed to be at least two ways in which the children approached the task. Some of the (particularly younger) children searched the page in a very unsystematic way, their eye gaze moving from one side of the page to the other, often looking at an area already searched. Other children, however, seemed to adopt a very systematic method of searching for the target, moving their gaze slowly around or across the page, often also using their finger to guide their search. On the whole, children who used the latter strategy seemed to perform best on this task. Some of the children did not score well at all on this task as they did not seem to maintain their concentration long enough to complete a thorough search.

(f) Tests of laterality

(i) Laterality test

This test was adapted from that used in the Aston Index (Newton and Thomson, 1982) to be more suitable for younger children: the key change being the substitution of bead threading for the threading needle item (in the interests of safety). This meant that the ten items of the test were, for laterality of hand: writing, cutting with scissors, unscrewing a lid from a jar, dealing cards, throwing a ball, threading beads; for foot laterality: kicking a ball; for eye laterality: looking through a cardboard tube, and binocular test hole; and for ear laterality: listening to a watch with the preferred ear. Each of the items was performed twice, and the experimenter noted on a score sheet which side the task was performed with on each of the two occasions. The number of left and right responses was recorded.

Informal Observations

This was a very simple and straightforward task for the children to carry out. Very few problems were encountered. It was particularly interesting, however, to note a small number of children who *did not* show a preferred hand or eye on a number of the test items and were observed to use one side for the first trial of an item and the other side for the second.

(g) Tests of verbal labelling

(i) Prepositions task

This test required the child to place an object (a ball) in a number of positions as instructed using prepositions. The subject sat in front of a small cardboard box and the ball was placed in the his or her hand. The child was then asked to move the ball - firstly to put the ball "up", then to put the ball "down". The child was then asked to put the ball "in" and "out" of the box, "in front" and "behind" the box, "under" and "above" the box, "on" the chair, and "next to" the box. Each of the child's responses on the ten items was noted on appropriate score sheet, providing a score out of ten for the task.

Informal Observations

A significant number of subjects had very little difficulty with this task, scoring full marks for all items. Those that did experience difficulties tended to confuse the concepts of "in front" and "behind". Consequently there was not a great deal of variation in performance on this task, which was perhaps due to it being more suitable for children of a slightly younger age.

(h) Tests of rhythm

(i) Clapping

This simple test was designed to measure the ability of subjects to repeat a rhythm which was clapped to them by the experimenter. Five different rhythms were presented, each one clapped a number of times before the child was asked to clap the rhythm themselves. The complexity of the rhythm increased across the five trials. For each trial the experimenter noted whether the child was able to accurately clap the required rhythm or not, producing a score out of five for the test.

Informal Observations

Performance on this short test varied a great deal, with some children being able to accurately repeat most or all of the five clapped rhythms, but other having great problems with the task. These difficulties appeared to stem both from perception and production difficulties. In some cases children did not seem to be able to hear or remember the rhythm to be clapped, while in others lack of motor proficiency appeared to effect performance.

3.4.1.3 Overall comments: Phase 1 method and procedures

On the whole, administration of tests in Phase 1 of the project was relatively straightforward and did not result in any major problems in data collection. Problems that were encountered tended to result from two sources. The first source of test administration difficulty was a consequence of the young age of the subjects. Problems with inattention and distractibility were sometimes combined with a lack of understanding of test instructions. The second source of problems of test administration tended to stem from technical issues such as use of computer equipment for presentation of stimuli and recording of responses. However, it was considered that in most cases, the performance of the subjects on the test measures was a relatively good indicator of their skills in the eight areas tested.

3.4.2 Phase 2

3.4.2.1 Subjects

The second phase of predictive tests was administered to the subjects when the majority of them had been attending primary school for one or two school terms. The mean ages (with standard deviations) and age ranges of subjects during this phase are presented in the table below:

Table 3.4 The mean ages (with standard deviations and ranges) of subjects at Phase 2

Group	Mean age	SD	Range
General population	5.10 years (70.28 m)	3.92 months	5.3 - 6.9 years
Siblings	6.7 years (79.55m)	11.57 months	4.7 - 9.3 years
All subjects	6.0 years (72.32 m)	7.42 months	4.7 - 9.3 years

As can be seen from the above table, there are variations in ages of the subjects, particularly in the siblings group. In some cases the variations in age of subjects in Phase 1 was compounded in this second phase of testing due to difficulties in contacting subjects to arrange appointments for testing. In the case of the youngest child (aged 4.7) it was felt that it was better to administer tests to her at this young age to ensure that data were collected at relatively similar intervals for all subjects. As in Phase 1, a number of tests administered in Phase 2 were standardised and therefore variations in ages are taken into account when scores are calculated.

By the time Phase 2 began, subjects from the three nursery schools had moved to a number of primary schools in the local area, and for the majority of subjects, visits were made to the schools in order to collect data for this phase of testing. Testing was carried out in 15 to 30 minute sessions depending on the concentration levels of the child. Children were, on the whole, able to co-operate in the testing situation to a much greater extent in Phase 2. This appeared to be due to their experience of the requirements of a school classroom (such as sitting at a desk, following instructions and concentrating on tasks given by the teacher).

Children who were tested at school were taken individually to a quiet room (such as the library or staff room) away from the rest of the class so that maximum concentration could be given to the tests at all times. Subjects who were not available for testing in their school visited the Psychology Department with their parents and tests were carried out in a quiet office or experimental room. For all subjects, time was taken at the outset of the first testing session to re-acquaint children with the experimenter and put them at their ease.

3.4.2.2 Test measures

Some of the tests administered in Phase 1 were re-administered in Phase 2, with the addition of a small number of new tests. The purpose of administering a second phase of predictive tests was to establish a number of important points regarding the early identification of dyslexia. Firstly, it was felt that some of the tests administered in Phase 1 might have not been as sensitive to differential performance of the children due to the very young age of the subjects. The mean age of all subjects had increased by approximately 1.3 months since administration of the first phase of tests and it was believed that those tests on which children appeared to have significant difficulties would now become relatively easier. In the light of this, greater discrepancies between those scoring well and those scoring poorly (due to e.g. dyslexic difficulties) on such tests should become apparent. Secondly, it is possible that young children with dyslexia may not only start off with poorer scores on the measures given, but that the developmental progress of their performance may also be slower than their non-dyslexic peers, increasing the discrepancy between scores in the second phase of testing. Administration of a selection of those tests used in Phase 1 also allowed monitoring of development in the major skills areas which were considered to be important in the prediction and early identification of dyslexia.

In total, eleven tests were administered to subjects in this phase (see table 3.5 below). Ten of the tests were predictive, and one, the British Ability Scales Word Reading Test, was administered as an early measure of reading abilities.

Table 3.5 Tests administered in Phase 2

Skill	Test
General ability	British Picture Vocabulary Scale (Short Form)
	British Ability Scales Block Design subtest
	British Ability Scales Recall of Digits subtest
Motor skills	Pegboard Task
	Beads Task
Phonological skills	Nonword Repetition
	Rhyming Task
	Lexical Access
	Phonological Segmentation Task
Reaction time	Naming Game
***Reading**	British Ability Scales Word Reading

The procedure for administration of the tests is outlined below. Only those tests that were administered for the first time, or for which there were substantial differences in administrative procedure are discussed in great detail. For all other tests, refer to Phase 1 method and procedures above. Informal observations for each test are also provided.

(a) Tests of general ability

(i) British Picture Vocabulary Scales (Short Form)

It was decided that as a measure of general ability, the British Picture Vocabulary Scale should be included in the group of tests re-administered in Phase 2. However, as the Long Form of the test had been given to the children less than 18 months before, only the Short Form of the test was administered in this phase. This form of the test was designed to measure the child's receptive vocabulary abilities in exactly the same way as the Long Form of the test, the only difference being the number of items which the child was asked to respond to. This version of the test was significantly quicker to administer than the Long Form. Scores were calculated for each child as in Phase 1, providing a raw score, standard score, percentile rank and vocabulary age equivalent.

Informal Observations

As would be expected, the major observation regarding performance on this test was an increase in the receptive vocabulary of the children since testing in Phase 1. The range of performance, however, appeared to remain similar across subjects.

(ii) British Ability Scales: Block design and Recall of digits subtests

Two subtests of the British Ability Scales were administered to the children in Phase 2: block design and recall of digits. These two tests were chosen to be re-administered at this stage for a number of reasons. The block design test has been shown to be a good measure of general ability, and also a test on which dyslexics have been considered by some researchers, to score better than the population as a whole. The recall of digits subtest is a test of short term sequential memory and as such, it is regarded as a test on which dyslexics usually score relatively badly. It was predicted that dyslexic subjects would perform differentially on the two tests, scoring well on the block design test, but poorly on the recall of digits test.

Informal Observations

Subjects' performance on the two tests showed considerable improvement since the initial administration of the tests. For the block design test, children were able complete many more of the designs than they had been able to in Phase 1. Scores on the recall of digits test were also greater at this stage for the majority of subjects.

(b) Tests of motor skills

(i) Pegboard task and Beads task

Both the Pegboard Task and the Beads Task were re-administered to the children in Phase 2 of the study. For each test, the materials were exactly the same as those used in Phase 1, only the procedure was altered at the stage. For both tests, three trials were given - for the pegboard task, the pegs were moved three times, and for the beads task, the child was asked to thread the beads onto the bootlace on three occasions. A mean (and median) score for each task was calculated in terms of time taken to move the pegs and the number of beads threaded.

Informal Observations

Subjects performance on both tasks appeared to have improved since Phase 1, in terms of the speed and accuracy of the motor movements involved. This meant that on the whole, pegs were moved faster and beads were threaded at a quicker pace than when the tests were initially administered.

(c) Tests of phonological skills

(i) Nonword repetition, Rhyming task and Lexical access

The three tests of phonological skills re-administered to the subjects in the second phase of predictive testing were Nonword Repetition, Rhyming Task and Lexical Access. The Phonological Discrimination Task was not re-administered in Phase 2, as it appeared that most subjects were already scoring at ceiling level on this test in the previous phase. All of these tests were presented using the same procedures as outlined in Phase 1. Results for each test were automatically recorded as part of the test program on the Apple Macintosh computer.

Informal Observations

For all tests administered using the Apple Macintosh computers, the children now seemed a lot more comfortable in their use, and this tended to mean that many of the problems encountered in test administration in Phase 1 were now overcome. Particularly, subjects tended to have better attention and concentration abilities, and to be able to complete tests without interruptions and invalid responses.

(ii) Phonological segmentation task

The Phonological Segmentation Task was administered to subjects in Phase 2 only. As a relatively difficult test, requiring quite advanced levels of phonological skill, it was found to be too difficult for even the most advanced subjects to carry out in Phase 1, and so children were only tested with this measure once they had been attending school for some time. The procedure for administration of this test involved the experimenter asking the child to say the first test item word (e.g. "cowboy") to which the child replied "cowboy". Then the experimenter asked the child to say "cowboy" again but without "boy". The child then either answered correctly by saying "cow", or gave an incorrect answer. The items in this test increased in difficulty as the test proceeded, beginning with deletion of syllables from the end and beginning of words (as illustrated above), followed by deletion of phonemes from the beginning and end of the target words (e.g. removing the "m" from "meat" producing "eat") and finally, deleting phonemes from phoneme clusters (e.g. removing "c" from "clap"). Fifteen items were presented to the subjects in total. Performance was noted on a score sheet and scores were recorded as the number of correct responses to the fifteen test items. See Appendix 3.2 for the stimuli used in this test.

Informal Observations

On the whole, subjects did seem to understand what was required of them for this test, however, there were obvious differences between those children who had the phonological sophistication to carry it out, and those who did not. Some children were not able to segment words into phonemes, no matter how hard they tried. It did seem, however, that the children had more success in correctly responding to items that required removing a final phoneme, as in many cases this was done by saying the word but stopping before it had all been said. This approach was not possible for words where the initial phoneme had to be segmented, as this required the child to decide what the word should sound like before beginning to say it. Overall, although most children were accurately able to segment a word into syllables, manipulation of phonemes proved very difficulty for many.

(d) Tests of reaction time

(i) Naming game

The Naming Game was re-administered in Phase 2 to measure the same abilities as were tested in Phase 1, although more attention was directed at speed rather than accuracy of performance, as it was anticipated that the majority of subjects would now be able to accurately name all of the pictures, colours, number and letters presented in the test. The Naming Game was administered according to the procedures outlined in Phase 1, and scores and naming latencies were automatically recorded using the Apple Macintosh computer.

Informal Observations

As was predicted, the majority of children were now able to correctly name the pictures, colours and numbers presented in this test, however, some did still have problems with letters, particularly "b" and "d". These two commonly confused letters were often substituted for one another, and also, in a small number of cases, "c" was referred to as "s".

(e) Tests of reading

(i) British Ability Scales Word Reading (Test A)

Unlike the other predictive tests in this phase, the British Ability Scales Word Reading subtest was administered as a criterion measure, in order to establish an initial measure of the subject's early reading skills. As part of the British Ability Scales, the word reading subtest provided a standardised score based on the child's ability to read a number of individual words presented on a card. The test consisted of 90 words printed on a card in bold black font, which decreased in size as the reading difficulty of words increased (see Appendix 3.5). The child was required to read each word, moving across the page, until s/he had failed to read ten successive words. The number of words correctly read was counted and on the basis of this a T-score, percentile and reading age were calculated using the appropriate table of norms for the British Ability Scales (BAS Manual 4).

Informal Observations

All subjects had by this stage, begun to be formally instructed in reading, and it was hoped that this measure would provide some idea of how subjects were responding to this instruction. However, it was noted that some subjects had yet to get to grips with the business of reading, and that despite instruction, many subjects were not able to correctly read one word of the test. However, some children scored very highly indeed on this test, and such cases it was assumed that parental imput prior to, and since starting primary school was providing children with a head start in reading.

3.4.2.3 Overall comments: Phase 2 method and procedures

Administration of Phase 2 measures was generally much more straightforward than administration of the first set of predictive measures. This was due to factors such as the older age of the subjects, their experience with compliance with the conventions of the school classroom, and a greater interest in taking part in such tasks. That is, by this time children seemed to quite like the idea of "working" rather than seeing it as an unwanted distraction from their play. Logistical problems did still persist to a certain extent due, in many cases to compromised testing situations within schools. However, the collection of measures in Phase 2 was generally regarded as successful.

3.4.3 Phase 3

3.4.3.1 Subjects

Phase 3 of the study was administered to subjects when they had been attending primary school for at least one year. The main purpose of this first phase of criterion tests was to establish the intellectual and reading ability of all the subjects. Testing was carried out at a time when children had been exposed to the formal instruction of the school curriculum for a long enough period to allow differences in performance to be reliably measured and distinguished.

The following table provides an indication of the mean ages (with standard deviations) and age ranges of subjects during this phase:

Table 3.6 The mean ages (with standard deviations and ranges) of subjects at Phase 3

Group	Mean age	SD	Range
General population	6.5 years (77.55 m)	5.20 months	5.3 - 6.9 years
Siblings	7.2 years (86.3m)	13.57 months	4.7 - 9.3 years
All subjects	6.7 years (79.47 m)	8.56 months	4.7 - 9.3 years

3.2.3.2 Test measures

During this phase, two main types of test were administered to measure the children's abilities in two areas: tests of general intellectual ability; and tests of written language (reading and spelling) skill. Performance in these two areas was measured to provide an initial indication of those subjects showing the traditionally recognised discrepancy between general ability and written language skills, that is, the pattern of performance found in the majority of dyslexics. A test of mathematical ability was also administered to establish if some subjects performed at significantly greater levels in mathematical ability as compared to their written language abilities. The table below indicates the tests administered in Phase 3.

Table 3.7 Tests administered in Phase 3

Skill	Test
General ability	British Ability Scales (Short Form)
	Matrices
	Similarities
	Naming Vocabulary
	Recall of Digits
	Block Design
Mathematical skills	British Ability Scales Basic Number Skills
Reading skills	British Ability Scales Word Reading
	Schonell Test of Single Word Reading
	Neale Analysis of Reading Ability
Spelling skills	British Ability Scales Spelling Scale
Listening comprehension	Listening Comprehension Test
Alphabet knowledge	Alphabet

(a) Tests of general ability

(i) British Ability Scales (Short Form)

During this Phase of the study, the British Ability Scales was administered primarily for the purpose of generating an IQ score for each subject. To save time, the short form of the test was selected, and the appropriate subtests for the age group were administered. The short form test for this age group comprised of the following five subtests, some of which had been administered (and hence described fully) in previous phases of the study.

- **Matrices**

Matrices items have often been used in the construction of intelligence tests and this particular test was administered as a test of the subjects' reasoning ability. This matrices scale presented the child with a series of problems in which he or she was required to draw the correct design in a blank cell. The task involved the child deducing the relationship between the figures already present in the matrix in order to work out what should be in the empty cell. Ten matrices were presented in a booklet

(Test B) and for each one the child was asked to draw in the part that was missing. The matrices increased in complexity throughout the test. Examples of the matrices used can be found in appendix 3.1 (p. 26). A score of one was given for each correct figure drawn.

Informal Observations

This test was relatively straightforward to administer and there were no problems with understanding the task instructions. Performance of the subjects was therefore considered to be a good indicator of their reasoning ability.

- **Similarities**

This subtest of the BAS was also presented as a test of reasoning, contributing to an overall intelligence score. The test did not involve any materials as such, but required the experimenter to read out a list of three items (e.g. orange, strawberry and banana) and to ask the child what else would go with these items (e.g. an apple). Following this the child was asked to name the class to which all the items belong (i.e. fruit). This task involved the comprehension and retention of verbal instructions as well as reasoning skills.

Informal Observations

Children seemed to perform reasonably well on the majority of the first items of this test although later items proved more difficult. This seemed to be due to the increasingly abstract nature of the relationships between items (e.g. book, telephone, newspaper - media), plus a reduction in likelihood that the children would have such items in their vocabulary (e.g. Mosque, chapel, synagogue). This was particularly true for children who appeared to have lower receptive vocabulary scores in previous tests.

- **Block design**

This test was added to the list of four tests advocated for the short form of the BAS by its author. This was due to the fact that there was a danger of one of the recommended subtests - recall of digits, producing very low scores for dyslexic subjects. It was hoped therefore, that the increased range of tests contributing to the overall IQ score would overcome any major depression of IQ scores due to the recall of digits test. The test was administered as in Phases 1 and 2.

- **Naming vocabulary**

This test was administered as in Phase 1

- **Recall of digits**

This test was administered as in Phases 1 and 2.

Informal Observations

The above three tests which formed the remainder of the BAS (Short Form) produced performance of a somewhat higher level than in previous phases, however, in general the range of performance appeared similar to that found in Phases 1 and 2. No major problems were encountered by the subjects on any of the three subtests.

(b) Tests of mathematical skills

(i) British Ability Scales Basic number skills subtest

This test was administered as a test of the children's numerical and mathematical ability which, in the case of dyslexic children, may contrast with performance in written language skills. The test was administered using the materials and procedures outlined in Phase 1. Scores were obtained in terms of a raw score, a standard score, a centile score and a number age for each child.

Informal Observations

The performance of all subjects on this test was much better than when it had first been administered in Phase 1. However, some children did still seem to be experiencing difficulties with mathematical skills.

(c) Tests of reading skills

(i) British Ability Scales Word Reading (Test A)

This standardised test of single word reading was administered using the same materials and procedures as described in Phase 2.

(ii) Schonell Test of Single Word Reading

This test is also a standardised single word reading test and was administered to subjects using a sheet of words taken from the "The Psychology and Teaching of Reading" by Fred Schonell (1951) (see Appendix 3.5). The words increased in difficulty as the test proceeded moving from words of a reading age of 5 years to a reading age of 15 years. The number of words correctly read was counted and a reading age calculated by dividing this number by ten and adding five (for example, a child who correctly read 8 words would have a reading age of 5.8 years, whereas a child who read 20 words was calculated to have a reading age of 7 years)

(iii) Neale Analysis of Reading Ability

The Neale Analysis of Reading ability (Neale, 1966) consists of a series of six passages of prose providing a continuous reading scale from 6 to 13 years. This test, unlike the BAS and the Schonell is a standardised test of *contextual* reading - words of increasing difficulty are formed into meaningful passages. The materials required for this test included a booklet of passages (see Appendix 3.5 for an example) and a stopwatch. The test was administered using the simplest passage first. This passage was positioned on a page opposite which was a picture relating to the theme of the passage. For example, the first passage in the test given (form A) involved a short story about a cat, and on the page opposite was a simple drawing of a cat. As the child started to read the passage, timing began using the stopwatch and the speed of reading for each passage was noted. In addition, using the score sheet, the accuracy of reading was also noted. Finally, after the passage had been read, a series of simple questions relating to the passage were asked to establish reading comprehension. Two measures of reading ability were derived from the test:

- reading accuracy
- reading comprehension

When the child had read the first passage and answered the comprehension questions, the examiner opened the page at the next passage and the testing procedure began again. Testing was discontinued when a child was found to have made sixteen or more reading errors in a passage. Reading accuracy and comprehension scores were calculated using the procedure outlined in the test manual, whereby raw scores were converted into age equivalents.

Informal Observations

Many of the children found this test very difficult and did not progress much past the first passage of the booklet. Reading rates were relatively slow on the whole, as children laboured over unknown words. Subjects also appeared to have quite considerable difficulties with the comprehension questions that were administered. As they had concentrated so much on merely decoding the words in the passage, they had either not taken in what the passages were about, or had forgotten details of them by the time questions were asked. However the beneficial effects of context were apparent in the reading performance of some children who were able to go back and correctly read a word after having established some of the meaning of the passage.

(d) Tests of spelling skills

(i) British Ability Scales Spelling Scale (Test B)

The British Ability Scales Spelling Scale (Elliot, 1992) is a standardised test of single word spelling. It was given to subjects at this stage to measure their ability to spell a series of words of increasing difficulty. The child was presented with a blank sheet of paper and a pen and asked to write down how they thought that each of the words was spelled. It was emphasised that it didn't matter if they were not completely sure, they should just write down what they thought the word looked like. Each of the words was read clearly to the child, both on its own and then embedded in a sentence for emphasis (e.g. "up.....we climb *up* the stairs"). The number of words correctly written was then used to calculate a standardised score, percentile, and spelling age for each child (Spelling Scale Manual, Elliot, 1992). The list of stimuli used for this test can be found in Appendix 3.5.

Informal Observations

The performance of children on this test was interesting to observe. Encouraging the children to try to spell words that were not sure about produced examples of what has been called "invented spelling" (Read, 1971, 1986) which were assumed to reflect the development of phonological skills in the subjects. Reversal of letters and words written backwards (e.g. "no" for "on") were common for some children. However, only completely correctly spelled words were taken into account in the final score which was obtained for this task.

(e) Tests of listening comprehension

(i) Listening Comprehension test (adapted from the Neale Analysis of Reading Ability)

Using the passages from Form B of the Neale Analysis of Reading, a test of listening comprehension was devised. This test involved the experimenter reading each of the passages from the test to the child slowly and clearly. Beginning with the simplest passage, the child was told that they should listen carefully to the story and that after it had been read, the experimenter would ask some questions about it. After each passage, the comprehension questions for the passage were read to the child and the child was encouraged to answer as many of these as possible. A score of one was given for each question correctly answered. These scores were also converted into ages using the scores for reading comprehension provided with the test.

Informal Observations

The performance of subjects in listening comprehension tended to be significantly better than reading comprehension. As long as they could actually understand what the story was about, many of them were able to answer correctly most of the questions put to them. However, a very small minority of subjects appeared to have considerable problems with this task, producing only blank faces to questions asked.

(f) Tests of alphabet knowledge

(i) Alphabet (from the Neale Analysis of Reading Ability)

This very simple test adapted from Supplementary Diagnostic Test 1 of the Neale Analysis of Reading Ability was designed to test subjects' ability to identify the letters of the alphabet in upper and lower case. The letters were presented to the child in random order on paper, and the child was asked to tell the examiner what each of the letters were. A maximum score of 52 points was available for correct identification of all letters.

Informal Observations

The majority of subjects appeared to know most of their alphabet very well and few errors were made. Problems that were encountered usually concerned visually similar letters such as "b", "d", and "q", and also letters such as "s", "c" and "z" with similar sounds. A small number of children did not, however, seem to have any grasp of the alphabet, seemingly guessing at every letter.

3.4.3.3 Overall comments: Phase 3 method and procedures

The administration of test measures in Phase 3 was very similar to that encountered during Phase 2. The fact that children had been attending school for some time and had developed better attention and concentration abilities made testing procedures relatively straightforward. The measures obtained during this phase were therefore viewed a reasonably accurate measure of the performance of the subjects.

3.4.4 Phase 4

The primary goal of this study (that is, an investigation of those factors which may allow the prediction and early identification of dyslexia) is dependent upon the identification of a number of subjects who are dyslexic. To study children as young as four and five years of age with dyslexia is as yet an impossibility, as no child can be diagnosed as such at this early age (indeed, this is the very purpose of the present study). One approach to this problem, which has been adopted in this project is to include in the subject pool, a number of children with family members who suffer from dyslexia. The other method that has also been utilised here is to take measures from the four and five year old children, and then to follow the children to an age at which those with dyslexia can be formally identified. It is this identification that is the aim of the measures administered in the final phase of the project.

3.4.4.1 Subjects

Only those subjects in the lowest reading group (Group --) were included for testing in Phase 4 of the study. This final phase of data collection was carried out in order to establish which of these poorest readers could be regarded as dyslexic, which could be referred to as "slow learners" and which children could be considered as having no identifiable problems. Traditional approaches to the diagnosis of dyslexia regard seven years as the earliest age at which one might administer tests to diagnose the disorder. By this age, those tests which are most often used in the diagnosis of dyslexia (such as the Wechsler IQ tests) are suitable for administration and, in addition, significant discrepancies between observed and expected reading and spelling performance may be noticeable (see Chapter 2 for a review of traditional approaches to the diagnosis of dyslexia). Phase 4 of the study was, for the above reasons, administered to children when they were seven years of age. The primary goal of this phase was an initial diagnostic evaluation. However, it must be noted that seven years is the earliest age at which a diagnosis of this kind would generally be attempted, and for this reason, the outcome of such evaluation must be treated with caution.

Overall, of the twenty subjects in "Group --", nineteen were available for testing in Phase 4. The mean age of subjects was 7.3 years (87.68 months) with a standard deviation of 3.06 months. Two subjects were only six years and eleven months at testing, and one subject was already eight years old, however, the majority of subjects' ages fell between seven and seven and a half years of age. This variation in ages is of little significance to the comparison of scores obtained in this phase as all tests administered were standardised.

3.4.4.2 Test measures

Two tests were administered to the subjects in Phase 4: The Wechsler Intelligence Scale for Children - Third Edition UK (WISC III-UK) and the Wechsler Objective Reading Dimensions (WORD) test. The purpose of administering these tests was to establish the intellectual status of the subjects by obtaining an IQ score and a profile of performance from the WISC-III UK, and to calculate the level of ability in reading, spelling and reading comprehension of each child. As in Phase 3, the tests were chosen to examine the performance of the subjects in two areas of ability (general ability and written language ability), and to establish the presence of discrepancies between the two areas. Procedures for administration of the measures are outlined below.

(a) The Wechsler Intelligence Scale for Children - III UK.

The Wechsler Intelligence Scale for Children - Third Edition UK (Wechsler, 1992) is "an individually administered clinical instrument for assessing the intellectual ability of children" (Golumbok and Rust, 1992, p 1). It consists of 12 subtests each measuring different facets of intelligence with the child's performance summarised in three composite scores: Verbal, Performance and Full Scale IQ. The 12 subtests are listed in table 3.8 below:

Table 3.8 The 12 subtests of the WISC-III UK

Verbal tests	Information*
	Similarities
	Arithmetic*
	Vocabulary
	Comprehension
	Digit Span*
Performance tests	Picture Completion
	Coding*
	Picture Arrangement
	Block Design
	Object Assembly
	Symbol Search †

Notes

* the four subtests known as the "ACID" tests

† this subtest does not contribute to the IQ scores but was administered for interest as it was speculated that dyslexics would score poorly on this item

The WISC-III UK was administered using the appropriate materials and according to the instructions given in the manual. Scores were noted on the score sheets provided. On completion of the test, all raw scores were converted to standard scores using the tables provided and the three IQ were scores calculated. Following this, standard scores for each test were plotted on a graph to indicate a "profile of performance" for each child.

Aspects of the WISC-III UK have been found to be particularly useful in the diagnosis of dyslexia (see Chapter 2). It has been reported that dyslexic children tend to obtain lower verbal IQ scores on the test in comparison to their performance IQ scores and in addition, dyslexics' performance on four of the subtests of the WISC tend to be considerably poorer than other subtest scores. These subtests are highlighted with an asterisk in the table above and are: information, arithmetic, digit span and coding (the "ACID" profile). Therefore in addition to the three IQ scores obtained for each child, a profile of performance was able to provide evidence of lower scores on the ACID tests in some cases.

(b) The Wechsler Objective Reading Dimensions test (WORD)

This standardised reading test was designed to identify and quantify reading difficulties in children, particularly discrepancies between reading performance and overall achievement (based on WISC-III UK scores). Measures of Basic Reading and Spelling were obtained using the test. The WORD was administered to subjects using the test materials provided: a booklet of words and a score sheet, according to procedure outlined in the test manual.

- **Basic Reading** - For the reading test, the child was shown the first page of the booklet which contained a picture of a sun with four words written underneath it. The child was asked to select the word that had the same beginning sound as sun. The next three test items followed along similar lines although for these the child had to identify words with the same end sound. The next three items of the test presented the child with a picture (e.g. a cow) and a set of words, one of which was the name of the picture. The experimenter asked the child to point to the word that was the name of the picture. Finally, the test took the form of a single word reading test which increased in difficulty across test items. Testing was stopped after six consecutive failures.

- **Spelling** - The first items of the WORD spelling test required the child to write down (in upper case) a series of letters read out by the experimenter (e.g. X, D, P) and also two sounds (/b/ and /m/), Following this the child was asked to write down a series of words of increasing difficulty, until six consecutive failures had been made.

For both tests, a score of one was given for each correct answer and this raw score was converted into standard score, percentile and reading and spelling age for each child. Using these scores and the IQ scores gained from the WISC-III UK, it was then possible to calculate discrepancy scores between expected and actual performance in reading and spelling, and to establish the significance of any differences obtained.

3.4.4.3 *Overall comments: Phase 4 method and procedures*

The administration of tests traditionally used by many for the diagnosis of dyslexia was important to the overall aim of the study. Time limitations made it necessary to give such tests to the poorest readers only, although it would have been interesting to obtain WISC and WORD performances for all subjects. One further point that had to be considered when administering such measures was that at seven years of age, the children who were administered these measures were at the very lowest end of the age range for which the test was designed. Moreover, it is likely that children with dyslexia may not be as apparent at this age using the Wechsler measures as they might be at a later stage. However, using these measures it was possible to tentatively identify children falling into the diagnostic groups of dyslexics and slow learners. The criteria used for this diagnosis are outlined in the following chapter where the results for all analyses carried out across the phases of the study are presented.

3.5 Summary of the chapter

In this chapter the rationale and objectives of the study have been outlined. The practical aim of the study was the design of a workable and accurate early screening test for the identification of very young children at-risk for dyslexia. However, three other theoretical issues of relevance to this aim are also investigated. These objectives are: the establishment of early manifestations of dyslexia and consideration of what theoretical implications these may have for the nature of dyslexia; investigation of the relationship of dyslexia to other forms of poor reading, in children of four, five and six years of age; and the contribution of data from dyslexic children as young as four years old to our general understanding of dyslexia.

Following on from this the methods and procedures by which the study was carried out are described in detail. The longitudinal prospective study was carried out in four phases - two predictive and two criterion stages, at the ages of four, five, six and a half and seven years of age, respectively. For each phase, the nature of the subjects and the test measures is outlined, along with informal observations of test performance. In the following chapter, the enormous amount of data collected in these four phases is analysed to provide an indication of tests that may be predictors of dyslexia.

Chapter 4
Results

Preview to the chapter

Following collection of data from the longitudinal project, a number of statistical analyses have been carried out. The ultimate purpose of these analyses was to identify which of the predictive tests may have some use in the early identification of dyslexia. However, also of interest here is the relationship of the predictive tests to later reading performance in general, and also, possible differences which may exist between the performance of dyslexics, slow learners and children of other reading ability levels.

Therefore, this chapter presents analysis of data in a number of sections. In the first section information is presented in the form of descriptive statistics for all subjects on the tests presented in the first two (predictive) phases of the study and the third (criterion) phase.

Following this, subjects have been divided into four reading groups on the basis of their reading ability measured at Phase 3, and differences in performance between the groups have been examined using analyses of variance. Effect size analysis has also been carried out to examine the relative performance of the four groups on the predictive tests, in terms of standard deviations, rather than actual test scores. Finally, the proportion of each group scoring at one or more standard deviations *below* the mean for each predictive test is presented, providing incidence levels of poor scores for each test.

In section 4.6, the performance of all subjects on the predictive tests is related to their reading performance in the third phase of the study, using correlational analyses. This has allowed identification of the predictive tests which were most strongly related to the children's later reading ability.

The next section of the chapter presents analysis following the diagnostic testing carried out in Phase 4, allowing a re-grouping of the poorest readers into the final outcome categories for the study (dyslexics and slow learners). Descriptive statistics for those taking part in this final phase reveal the range and profiles of performance on the tests administered. The performance of the two diagnostic groups (on Phase 1, 2 and 3 measures) has been compared to that of the remaining subjects, who have been placed in two groups: normal readers and borderline poor readers. Analysis of the performance of the four groups has been carried out using the same methods as outlined above in the analysis following Phase 3 (ANOVA, effect size analysis and incidence levels).

The final section of the chapter addresses the key issue of the study: the prediction of dyslexia. This has been done using individual standardised scores on a number of the predictive tests. Using a formula involving a critical number of scores at one or more standard deviations below the population mean, the final analysis of the study has attempted to develop a positive index of risk for dyslexia in very young children.

4. Results of the study: A detailed outline of descriptive statistics and analyses

4.1 Descriptive statistics for all subjects

For the purposes of the presentation of descriptive statistics, the general population and siblings subjects have been combined into one group referred to as "all subjects". This has been done to provide a general description of the performance of children of this age group on the tests administered, regardless of initial or outcome status in the study.

Throughout this chapter it should be noted that the tests presented to subjects vary in terms of the unit of measurement that has been reported, with percentiles for standardised tests such as the British Ability Scales, but raw scores (or percentage scores) used for most of the non-standardised tests. In each case, non-standardised tests (such as the Rhyming Task or the Beads task) vary in the maximum possible score attainable, and specific details regarding this are outlined in Chapter 3 where each test is fully described (see also table 4.1, below). In addition to this, performance on some tests (such as the Pegboard Task) has been measured in terms of (mean or median) time taken to complete the task, and particular details of the time measurement used can also be found in Chapter 3.

4.1.1 Phase 1

The mean scores and times (with standard deviations) for all subjects on the measures administered in Phase 1 are presented in table 4.1 below. For each test the nature of the score (time, percentile or raw score) is shown, with the maximum score possible for the test where appropriate. Also indicated in the table is the range of scores for each test. The raw data for the Phase 1 measures is presented in Appendix 4.1 (a). Results of the laterality test are reported in a different form. For this reason, descriptive statistics for this test are not reported here, they are presented later in the chapter in an examination of the performance of the diagnostic outcome groups.

Table 4.1 Descriptive statistics (mean, SD and range) for the performance of all subjects in Phase 1

Test	mean	SD	range
BPVS percentile rank	54.10	26.66	6 - 99
BAS Copying percentile	56.23	27.07	2 - 99
BAS Block design percentile	64.82	25.62	18 - 99
BAS Naming Vocab percentile	51.63	27.06	5 - 98
BAS Basic no skills percentile	53.55	26.61	4 - 99
BAS Verbal Comp percentile	44.30	24.87	4 - 84
BAS Recall digits percentile	61.01	26.42	6.5 - 93
BAS Verbal Fluency percentile	54.09	26.95	16.5 - 97.5
BAS V-T Matching percentile	55.13	28.34	7 - 97
BAS Visual Recog percentile	65.43	29.35	3.5 - 98
BAS Match LLF percentile	52.91	24.09	13 - 99
BAS IQ score	105.16	11.89	77 - 131
Mean Pegboard time	20.60	4.87	10.98 - 42.76
Beads	5.98	1.71	3.5 - 10.5
Balance both feet	1.23	1.14	0 - 5.5
Balance romberg	6.70	5.22	0 - 19.5
Balance blindfold both feet	2.30	2.89	0 - 16
Balance blindfold romberg	7.60	5.22	1 - 25
Phon Discrimination (hits) (%)	90.52	14.56	11 - 100
Phon Discrimination (rej's) (%)	90.99	14.24	38 - 100
Nonword Repetition (max 30)	19.70	5.12	5 - 30
Rhyming Condition 1 (max 10)	7.71	2.15	2 - 10
Rhyming Condition 2 (max 10)	7.40	2.00	3 - 10
Rhyming Condition 3 (max 10)	6.88	2.14	2 - 10
Lexical Access score (%)	79.75	14.66	48 - 98
Lexical Access median time (secs)	0.90	0.32	0.22 - 1.71
Mean Articulation Rate (secs)	2.85	0.57	1.88 - 4.79
Naming pictures score (max 12)	11.76	0.81	5 - 12
Naming pictures median time (secs)	1.03	0.23	0.63 - 2.96
Naming colours score (max 6)	5.73	0.83	2 - 6
Naming colours median time (secs)	1.04	0.32	0.62 - 2.02
Naming numbers score (max 8)	6.43	2.68	0 - 8
Naming numbers median time(secs)	1.04	0.52	0.54 - 2.68
Naming letters score (max 8)	4.79	2.99	0 - 8
Naming letters median time (secs)	1.51	0.88	0.72 - 3.23
Visual Search number found (max 13)	10.71	2.24	1 - 13
Visual Search mean time	0.25	0.11	0.08 - 0.63
Prepositions score (max 10)	9.12	1.14	6 - 10
Clapping (max 5)	3.27	1.23	0 - 5

(a) Performance of all subjects on tests of general ability

Examination of table 4.1 reveals that the mean percentile performance of all subjects on the subtests of the BAS ranged from 44.30 (Verbal Comprehension) to 65.43 (Visual Recognition) with the mean BAS IQ score for all subjects at 105.16 (SD 11.89). The mean percentile score for all subjects on the British Picture Vocabulary Scale was 54.10 (SD 26.66).

(b) Performance of all subjects on tests of motor skill

The mean score for all subjects on the three tests of motor skill can be seen in table 4.1 above. On average, subjects completed the Pegboard Task in a total of 20.60 seconds (SD 4.87), and were able to thread an average of 5.98 (SD 1.71) beads in the one minute time limit. The final test of motor skills, the Blindfold Balance task provided a score in terms of the number of wobbles made by each child in each of the four conditions. It can be seen from table 4.1 that all subjects wobbled more in the romberg conditions (6.70, SD 5.22 and 7.60, SD 5.22) than in the two feet conditions (1.23, SD 1.14 and 2.30, SD 2.89), and that this tendency was exacerbated by the wearing of the blindfold.

(c) Performance of all subjects on the tests of phonological skill

The percentage of hits (correct identification of real words) for the Phonological discrimination task was 90.52 (SD 14.56) with a very similar number of correct rejections of nonsense words (90.99%, SD 14.24). The mean score for all subjects on the Nonword repetition test in this first phase of testing was 19.70 (out of a possible 30) with a standard deviation of 5.12.

The mean performance of all subjects was found to vary across the three conditions of the Rhyming Task, with highest scores obtained in the first condition (last sound different) (7.71 out of a possible 10, SD 2.15), and the lowest mean score in the alliteration condition (condition 3) (6.88, SD 2.14). The mean score for the middle sound different condition (condition 2) fell between the other two conditions at 7.40 out of a possible 10 (SD 2.00).

Subject's performance on the Lexical Access test was measured in terms of score, with a mean percentage score of 79.75 (SD 14.66) and median time to respond to the stimuli, with a mean for all subjects of 0.90 seconds (SD 0.32). Table 4.1 reveals that the average mean Articulation Rate (across the six words tested) for all subjects was 2.85 seconds (SD 0.57).

(d) Performance of all subjects on tests of reaction time

Mean scores for all subjects in the four conditions of the Naming Game are illustrated in table 4.1 above. From this it can be seen that all subjects scored at higher levels in the picture and colour naming conditions (11.76 out of a possible 12 and 5.73 out of 6 respectively) than in the number or letter naming conditions (6.43 and 4.79 out of a possible 8). The median time for all subjects to respond to stimuli in each of the conditions was very similar for naming of pictures, colours and numbers (1.03, 1.04 and 1.04 seconds respectively), but greater in the letter naming condition (1.51 seconds).

(e) Performance of all subjects on test of speed of processing

The test of speed of processing, Visual Search provided scores in two forms: number of targets correctly located (out of 13) and mean time to locate targets. The mean number of targets correctly found by all subjects was 10.71 (SD 2.24) with a mean time of target location of 25 seconds (SD 11 seconds).

(f) Performance of all subjects on test of verbal labelling

The mean score for all subjects on the Prepositions task was 9.12 out of a possible 10 (SD 1.14).

(g) Performance of all subjects on test of rhythm

The mean score for all subjects on the Clapping test was 3.27 out of a possible score of 5. The scores for the subjects ranged from 0 to 5.

4.1.2 Phase 2

Table 4.2 indicates the means, standard deviations and ranges of scores and times for all subjects in Phase 2 of the study. For each test the nature of the score is indicated (time, percentile or raw score), with the maximum score possible for the test where appropriate. The raw data for the Phase 2 measures is presented in Appendix 4.2 (b).

Table 4.2 Descriptive statistics (mean, SD and range) for the performance of all subjects in Phase 2

Test	mean	SD	range
BPVS percentile rank	64.52	24.88	5 - 99
BAS Block design percentile	72.32	23.66	14 - 99
BAS Recall digits percentile	56.31	24.52	4 - 97
Mean Pegboard time	15.83	2.67	10.32 - 25.51
Mean Beads score	8.11	2.27	3.67 - 13.50
Nonword Repetition (max 30)	22.67	4.22	8 - 30
Rhyming Condition 1 (max 10)	8.88	1.63	4 - 10
Rhyming Condition 2 (max 10)	8.31	1.76	2 - 10
Rhyming Condition 3 (max 10)	8.33	1.65	3 - 10
Lexical Access score (%)	85.42	9.66	58 - 98
Lexical Access median time	0.89	0.33	0.03 - 2.1
Phonological Segmentation (max 15)	7.80	3.18	3 - 15
Naming pictures score (max 12)	11.93	0.25	11 - 12
Naming pictures median time	0.95	0.26	0.64 - 1.94
Naming colours score (max 6)	5.99	0.10	5 - 6
Naming colours median time	0.88	0.39	0.48 - 2.98
Naming numbers score (max 8)	7.87	0.40	6 - 8
Naming numbers median time	0.83	0.26	0.51 - 2.38
Naming letters score (max 8)	6.95	1.64	1 - 8
Naming letters median time	1.06	0.49	0.64 - 3.9
BAS Word Reading raw score	20.24	21.52	0 - 85
BAS Word Reading percentile	50.99	28.60	3 - 99

(a) Performance of all subjects on tests of general ability

Three measures of general ability were administered at Phase 2 and all scores for these tests are in the form of percentiles. Inspection of table 4.2 shows that the mean percentile for all subjects on the short form of the BPVS was 64.52 (SD 24.88). This is over ten percent higher than the mean percentile for the long form of the test administered in Phase 1. The mean percentile score for the BAS Block Design test was

72.32 (SD 23.66) which showed an increase of 7.5 percent in mean score compared to performance in the first Phase. However, mean performance of all subjects on the BAS Recall of Digits subtest (56.31, SD 24.52) in the second phase of testing decreased, being 4.7 percent lower than performance in Phase 1.

(b) Performance of all subjects on tests of motor skill

The average mean time of completion of the Pegboard Task in Phase 2 was 15.83 seconds (SD 2.67) showing a reduction of the mean time by 4.77 seconds compared to performance in Phase 1. There was also an increase of 2.13 in the mean number of Beads threaded in the one minute time limit during this phase compared to Phase 1.

(c) Performance of all subjects on tests of phonological skills

Table 4.2 shows that the mean score for all subjects on the Nonword Repetition test in Phase 2 was 22.67 (SD 4.22), revealing an increase of 2.97 words correctly repeated compared to Phase 1 performance. Scores on the Rhyming Task also increased across the two phases, becoming more uniform across the three conditions. The mean score for all subjects in Condition 1 was 8.88 out of a possible 10 (SD 1.63), an increase of 1.17 compared to Phase 1. Subjects scored a mean of 8.31 (SD 1.76) for the second condition of the Rhyming Task in this phase, showing an increase of 0.91 word pairs correctly identified. In the alliteration condition, Condition 3, the mean score for all subjects was 1.45 higher than in Phase 1, at 8.33 (SD 1.65).

The mean score for all subjects on the Lexical Access test also increased in Phase 2 to 85.42 percent (SD 9.66), an increase of 5.67 percent. The mean time taken to identify a stimulus on the test was reduced by only 0.01 of a second to 0.89 seconds (SD 0.33).

The mean score for all subjects on the Phonological Segmentation test was 7.80 (out of a possible 15) (SD 3.18).

(d) Performance of all subjects on test of reaction time

Mean scores for the four conditions of the Naming Game did increase in the second phase of the study. In the case of pictures and numbers, this increase was not great as performance was already relatively high in the first phase. Increases in scores in the numbers and letters conditions were larger. The mean number of pictures correctly named by all subjects in the second phase was 11.93 (SD 0.25), and the number of colours, 5.99 (SD 0.10). Table 4.2 shows that the mean number of digits named by the subjects was 7.87 (SD 0.41), an increase of 1.44, and in the letters condition, the Phase 2 mean score for all subjects was 6.95 (SD 1.64), an increase of 2.16 since Phase 1.

The mean time to correctly identify stimuli in each of the four naming conditions by all subjects decreased when the test was presented in Phase 2. The median time taken to name pictures, colours and numbers remained relatively similar to one another as in Phase 1 at 0.95, 0.88 and 0.83 seconds respectively. Although faster than in Phase 1, the median time to name letters remained slower than for the other three conditions. (1.06, SD 0.49).

(e) Performance of all subjects on the test of word reading

The BAS Test of Word Reading was administered to subjects in the second phase of the study as an early criterion measure, and therefore is not strictly included in the battery of predictive tests. However, the investigation of the performance of very young children on a test of early reading and its relationship to the later development of sophisticated reading skills was of some interest, and in that sense, the test of word reading might be viewed as a predictive test. Table 4.2 reveals that the mean performance of all subjects on this test (recorded as percentiles) was 50.99 (SD 28.60).

4.2 Analysis following Phase 3: Performance of subjects in four reading groups on the predictive tests

This section of the chapter presents the data analysis that was carried out following administration of the first set of criterion measures of the study (Phase 3). Phase 3 measures were given to subjects to establish their performance in a number of areas following attendance at school for at least one year. Primarily, the experimenter was interested in gaining information regarding two main facets of the children's ability: subjects' general abilities (IQ levels) and their written language abilities (reading and spelling performance). In addition, measures of arithmetic ability, listening comprehension skills and alphabet knowledge were also taken to investigate whether subjects were performing uniformly on all measures or whether some children revealed evidence of discrepancies between their abilities on some tests compared to others.

The performance of the subjects on the three standardised measures of reading administered in Phase 3 was averaged to provide a Composite Reading score. This was obtained by computing the mean of the reading ages obtained from the BAS Test of Word Reading, the Neale Analysis of Reading Ability and the Schonell Test of Single Word Reading in months. This composite reading score was obtained for two major reasons:

(i) to establish membership of four reading groups (see section 4.3 below)

(ii) to carry out correlational analysis of the relationship between performance on the predictive tests and later reading performance (section 4.6).

Before analysis of the performance of the four reading groups is presented, the performance of all subjects on the measures administered in Phase 3, regardless of initial or outcome reading group is outlined below.

4.2.1 Descriptive statistics for Phase 3 performance (all subjects)

The mean performance (with standard deviations and ranges) for each of the measures administered in Phase 3 for all subjects is presented in table 4.3 below. Raw data for this phase can be found in Appendix 4.1 (c).

Table 4.3 Means, standard deviations and ranges of performance on Phase 3 measures for all subjects

Test	mean	SD	range
BAS Matrices percentile	78.09	17.26	26 - 99
BAS Similarities percentile	80.53	17.96	24.5 - 99
BAS Naming Vocab percentile	62.90	27.69	3 - 97
BAS Block Design percentile	75.17	21.73	18 - 99
BAS Recall digits percentile	53.06	26.48	3 - 97
BAS IQ score	113.08	15.10	87 - 139
BAS Basic no skills percentile	68.25	26.46	5.5 - 99
Number age (months)	84.95	9.55	56 - 98
BAS Word Reading percentile	56.18	27.69	5 - 99
BAS Word Reading RA (months)	86.19	21.43	60 - 173
Schonell RA (months)	80.06	20.73	60 - 173
Neale RA (months)	88.98	15.41	60 - 145
Composite RA (months)	85.16	18.63	60 - 163
BAS Spelling percentile	60.83	20.87	18 - 97
BAS Spelling age (months)	84.53	11.38	60 - 119
Reading comprehension age (months)	88.11	12.66	75-142
Listening comprehension score (max 28)	13	5.53	1 - 26
Listening comprehension age (months)	100.84	12.72	78 - 131
Alphabet (max 52)	48.75	7.20	12 - 52

(a) Performance of all subjects on tests of general ability

Inspection of table 4.3 reveals that the mean IQ score (BAS) for all subjects at this stage was 113.08 (SD 15.10). This IQ score was calculated on the basis of performance on five BAS subtests. Mean percentile scores on the individual subtests ranged from 53.06 (SD 26.48) for Recall of Digits to 80.53 (17.96) for the Similarities subtest. Three of the subtests had been administered to subjects in previous phases. Subjects were observed to have increased their performance on the Block Design subtest since Phase 2 by 2.85 percent to 75.17 (SD 21.73). The mean performance of all subjects on the Recall of Digits subtest was found to have decreased since administration of the test in Phase 2 by 3.25 percent to 53.06 (SD 26.48). Comparison of the performance of all subjects on the Naming Vocabulary subtest in Phase 3 to when it was last administered in Phase 1, revealed an increase in performance of 11.27 percent with a Phase 3 score of 62.90 (SD 27.69).

(b) Performance of all subjects on tests of reading

Table 4.3 provides details of the mean performance of all subjects on three measures of reading. For the BAS Test of Word Reading, two scores are presented: a percentile score and a reading age (in months). For the Neale and Schonell reading tests, scores are provided only as reading ages. The table reveals that the reading ages achieved for the BAS, Neale and Schonell reading tests were 86.19 (SD 21.43), 88.98 (SD 15.41) and 80.06 (SD 20.73) months respectively. The mean BAS reading percentile score for all subjects at this stage was 56.18 (SD 27.69). The reading comprehension measure from the Neale Analysis of Reading Ability yielded a mean comprehension age of 88.11 months for all subjects (SD 12.66).

(c) Performance of all subjects on tests of spelling

Performance of all subjects on the BAS Spelling Scale is indicated in table 4.3 with a mean percentile score and a mean spelling age (in months). The mean spelling percentile score was 60.83 (SD 20.87) and this was equivalent to an average spelling age of 84.53 months (SD 11.38) for all subjects.

(d) Performance of all subjects on tests of arithmetic

The mathematical ability of subjects was measured using the BAS Basic Number skills subtest which provided a percentile score and a number age for the subjects. The mean percentile for all subjects on this test was 68.25 (26.46) giving an average number age for the subjects of 84.95 months (SD 9.55).

(e) Other measures taken in Phase 3

Two other measures were presented to subjects at Phase 3. These were a Listening Comprehension test (adapted from the Neale Analysis of Reading Ability) and a test of knowledge of the alphabet in upper and lower case (also taken from the Neale Analysis of Reading Ability test). Table 4.3 shows that the mean score for all subjects on the test of Listening Comprehension was 13 (out of a possible 28) (SD 5.53). Of a maximum possible score of 52, the average score for the test of alphabet knowledge across all subjects was 48.75 letters correctly identified (SD 7.20).

4.3 The Phase 3 reading groups

Following administration of the criterion measures in Phase 3, an overall reading ability score for each subject was calculated by subtracting the child's chronological age at Phase 3 from the Composite Reading Age (in months) obtained from the three standardised reading measures (see section 4.2 above). This provided a figure which was either positive (if the child was reading at or above their chronological age) or negative (if the child's reading ability was lower than that expected for their chronological age).

Based on these reading age - chronological age discrepancy scores (RA - CA scores), the subjects were divided into four groups: poor (Group -) and very poor readers (Group --), and good (Group +) and very good readers (Group ++). The criteria for group membership are outlined in table 4.4. The usual discrepancy criteria of at least 18 months difference between chronological and reading age were not used due to the young age of the children. Thomson (1991) notes that using a fixed criterion of discrepancy is inappropriate in the identification of dyslexia because varying numbers of the population will be found to have such a discrepancy depending on the age group studied. For example, in the age group studied here, we would expect only 1% of the population to be 2 years retarded in their reading, but for a group of older individuals (e.g. 19 years), the figure would be nearer 25%. Indeed many reading age tests only provide minimum reading age scores of 5 or 6 years. Therefore the cut-offs that were employed were designed to take into account the young age of the subjects and to be over inclusive, so that *all* children reading below their chronological age were considered to be poor readers, with those reading at more than 6 months below their chronological age considered as *very poor* readers.

Table 4.4 Criteria for membership of the Phase 3 reading groups

Group	**RA - CA score (months)**
Group --	RA 6 or more months below CA
Group -	RA 0 to 6 months below CA
Group +	RA 0 to 9 months above CA
Group ++	RA 9 or more months above CA

The actual range of RA - CA scores and the number of subjects (including the number of males (m) and females (f)) in each of the groups was as follows:

Table 4.5 Characteristics of the Phase 3 reading groups

Group	**RA - CA score (months)**	**Number of subjects**
Group --	- 6 to -16.33 months	21 (m =13, f=8)
Group -	-1.50 to -5.67 months	17 (m=9, f=8)
Group +	0.33 to 7.67 months	25 (m=9, f=16)
Group ++	9.00 to 66.67 months	28 (m=9, f=19)

4.4 Analysis of differences in performance between the Phase 3 reading groups on predictive tests

The first set of analyses were based on an examination of possible differences in performance of the children on the predictive tests following their allocation into one of the four reading groups. This was done to investigate the question of whether children of differing reading abilities could be predicted using the screening measures without, at this stage, considering children as being dyslexic or otherwise. Differences between the groups on the Phase 1 and 2 measures were investigated using analysis of variance. All ANOVA summary tables for analyses of the performance of the Phase 3 reading groups can be found in Appendix 4.2.

4.4.1 Phase 1

In order to investigate whether there were significant differences between the performance of the poor, very poor, good and very good readers on the tests administered to the children at the age of 4 to 5 years, a number of one factor analyses of variance (SuperAnova) were carried out. For each test, the independent variable was the reading group and the dependent variable was the score or time taken to complete the test in question.

In addition, a one factor analysis of variance was carried out to examine if there were any significant differences in the age of the subjects in each group. This was found not to be significant ($F = 0.636$, $df = 3$, $p = 0.5937$ (ns)) and the mean ages in months (with standard deviations) of subjects in each of the four reading groups are presented below.

Table 4.6 Mean ages (with standard deviations) of subjects in the Phase 3 reading groups at Phase 1

	Group --	**Group -**	**Group +**	**Group ++**
mean age	55.81 (5.77)	58.18 (7.15)	58.60 (8.11)	58.50 (8.06)

The performance of the four groups on the first set of predictive tests can be seen from table 4.7, which outlines the mean scores and times (with standard deviations in brackets) for the four reading groups on each of the Phase 1 measures.

Table 4.7 Mean scores (and standard deviations) for the four Phase 3 reading groups on Phase 1 measures.

Test	Group --	Group -	Group +	Group ++
BPVS percentile rank	32.90 (22.81)	59.35 (24.36)	54.24 (25.51)	66.37 (23.22)
BAS Copying percentile	31.76 (22.55)	58.21 (22.82)	61.18 (25.09)	68.95 (23.24)
BAS Block design percentile	59.81 (23.72)	56.50 (25.24)	63.96 (26.55)	74.07 (24.88)
BAS Naming Vocab percentile	38.02 (23.93)	57.18 (24.90)	53.24 (32.81)	57.04 (22.26)
BAS Basic no skills percentile	32.33 (25.60)	49.71 (15.00)	57.70 (29.05)	68.09 (19.93)
BAS Verbal Comp percentile	36.76 (24.38)	45.33 (21.99)	47.65 (27.65)	46.42 (24.45)
BAS Recall digits percentile	45.07 (28.47)	56.59 (23.63)	64.50 (25.91)	72.52 (20.99)
BAS Verbal Fluency percentile	42.45 (27.20)	51.35 (23.66)	57.40 (25.47)	61.64 (27.99)
BAS V-T Matching percentile	36.69 (26.99)	60.91 (26.06)	68.06 (25.44)	53.87 (26.74)
BAS Visual Recog percentile	48.31 (31.37)	66.85 (30.02)	66.96 (27.59)	76.04 (24.15)
BAS Match LLF percentile	41.32 (24.60)	52.03 (24.24)	48.75 (21.84)	64.82 (21.34)
BAS IQ score	94.43 (11.05)	105.12 (8.94)	107.76 (11.95)	110.93 (8.74)
Mean Pegboard time	23.71 (6.84)	19.79 (3.09)	20.68 (3.80)	18.64 (3.60)
Beads	5.33 (1.70)	5.82 (1.93)	6.08 (1.57)	6.48 (1.63)
Balance both feet	1.68 (1.38)	0.85 (0.86)	1.26 (0.95)	1.09 (1.20)
Balance romberg	5.83 (4.12)	6.71 (5.42)	7.92 (5.98)	6.13 (4.79)
Balance blindfold both feet	1.75 (1.16)	2.50 (4.19)	2.34 (1.96)	2.61 (3.68)
Balance blindfold romberg	8.35 (6.65)	7.35 (5.78)	7.82 (4.39)	6.86 (4.39)
Phon Discrimination (% hits)	84.00 (22.23)	88.06 (14.90)	95.24 (7.81)	92.21 (10.91)
Phon Discrimination (% rej's)	83.63 (19.95)	95.77 (7.82)	89.28 (13.03)	94.61 (11.82)
Nonword Repetition	17.00 (5.29)	19.47 (5.17)	19.72 (4.72)	21.86 (4.51)
Rhyming Condition 1	5.57 (2.06)	8.18 (1.60)	8.04 (2.05)	8.75 (1.43)
Rhyming Condition 2	5.43 (1.40)	8.06 (1.69)	7.46 (2.13)	8.46 (1.32)
Rhyming Condition 3	4.86 (1.35)	7.06 (2.29)	7.46 (1.67)	7.82 (1.96)
Lexical Access score	71.94 (14.02)	77.54 (22.53)	79.92 (10.54)	86.35 (8.98)
Lexical Access median time	0.83 (0.34)	0.83 (0.27)	0.97 (0.34)	0.92 (0.33)
Mean Articulation Rate	3.165 (0.62)	2.95 (0.65)	2.78 (0.56)	2.63 (0.36)
Naming pictures score	11.57 (1.54)	11.88 (0.33)	11.72 (0.46)	11.86 (0.36)
Naming pictures median time	1.08 (0.29)	1.00 (0.15)	1.06 (0.20)	0.98 (0.25)
Naming colours score	5.57 (0.75)	5.77 (0.97)	5.80 (0.58)	5.78 (1.00)
Naming colours median time	1.06 (0.27)	1.05 (0.28)	1.16 (0.40)	0.90 (0.26)
Naming numbers score	3.86 (3.37)	6.94 (2.08)	6.72 (2.25)	7.79 (1.13)
Naming numbers median time	1.18 (0.85)	1.13 (0.42)	1.07 (0.43)	0.85 (0.20)
Naming letters score	1.91 (2.49)	4.65 (2.83)	5.08 (2.72)	6.79 (1.79)
Naming letters median time	1.54 (0.92)	1.90 (1.13)	1.70 (0.81)	1.12 (0.58)
Visual Search number found	9.91 (2.41)	10.88 (1.67)	10.39 (2.92)	11.46 (1.50)
Visual Search mean time	0.23 (0.08)	0.26 (0.10)	0.28 (0.14)	0.25 (0.11)
Prepositions score	8.69 (1.25)	9.38 (0.89)	9.50 (0.93)	8.93 (1.27)
Clapping	2.26 (1.24)	3.06 (1.06)	3.54 (1.14)	3.85 (0.95)

Table 4.8 indicates the F values and significance (see key below) of the differences in performance between the four reading groups on each of the tests administered in Phase 1, as calculated using ANOVA . The df value for all calculations is 3. For each analysis of variance, a Tukey-Kramer post hoc test was performed to examine if there were significant differences between particular groups. Post hoc differences between groups are indicated in the final columns of the table.

key	*	$p < 0.05$
	**	$p < 0.01$
	***	$p < 0.001$
	ns	not significant

Table 4.8 Significance of the differences in performance between the four reading groups on Phase 1 measures and post hoc differences

Test	F (df = 3)	p value	Post hoc analyses - - vs -	- -vs +	- -vs ++	- vs +	- vs ++	+ vs ++
BPVS percentile rank	7.818	***	ns	ns	**	*	**	ns
BAS Copying percentile	10.699	***	**	**	**	ns	ns	ns
BAS Block design percentile	2.135	ns	ns	ns	ns	ns	ns	ns
BAS Naming Vocab percentile	2.534	ns	ns	ns	ns	ns	ns	ns
BAS Basic no skills percentile	9.762	***	ns	**	**	ns	ns	ns
BAS Verbal Comp percentile	0.781	ns	ns	ns	ns	ns	ns	ns
BAS Recall digits percentile	5.282	**	ns	*	**	ns	ns	ns
BAS Verbal Fluency percentile	2.315	**	ns	ns	ns	ns	ns	ns
BAS V-T Matching percentile	5.742	***	ns	*	**	ns	ns	ns
BAS Visual Recog percentile	4.001	**	ns	ns	**	ns	ns	ns
BAS Match LLF percentile	4.485	**	ns	ns	**	ns	ns	ns
BAS IQ score	11.082	***	*	**	**	ns	ns	ns
Mean Pegboard time	5.122	**	*	ns	**	ns	ns	ns
Beads	1.932	ns	ns	ns	ns	ns	ns	ns
Balance both feet	1.829	ns	ns	ns	ns	ns	ns	ns
Balance romberg	0.751	ns	ns	ns	ns	ns	ns	ns
Balance blindfold both feet	0.349	ns	ns	ns	ns	ns	ns	ns
Balance blindfold romberg	0.303	ns	ns	ns	ns	ns	ns	ns
Phon Discrimination (hits)	2.562	ns	ns	ns	ns	ns	ns	ns
Phon Discrimination (rej's)	3.287	*	**	ns	**	ns	ns	ns
Nonword Repetition	3.978	**	ns	ns	**	ns	ns	ns
Rhyming Condition 1	13.624	***	**	**	**	ns	ns	ns
Rhyming Condition 2	14.645	***	**	**	**	ns	ns	ns
Rhyming Condition 3	11.828	***	**	**	**	ns	ns	ns
Lexical Access score	3.963	**	ns	ns	**	ns	ns	ns
Lexical Access median time	0.933	ns	ns	ns	ns	ns	ns	ns
Mean Articulation Rate	3.868	**	ns	ns	**	ns	ns	ns
Naming pictures score	0.660	ns	ns	ns	ns	ns	ns	ns
Naming pictures median time	0.889	ns	ns	ns	ns	ns	ns	ns
Naming colours score	0.349	ns	ns	ns	ns	ns	ns	ns
Naming colours median time	3.062	*	ns	ns	ns	ns	ns	*
Naming numbers score	12.661	***	**	**	**	ns	ns	ns
Naming numbers median time	1.932	ns	ns	ns	ns	ns	ns	ns
Naming letters score	16.223	***	**	**	**	ns	*	ns
Naming letters median time	3.382	*	ns	ns	ns	ns	*	ns
Visual Search number found	2.229	ns	ns	ns	ns	ns	ns	ns
Visual Search mean time	0.827	ns	ns	ns	ns	ns	ns	ns
Prepositions score	2.454	ns	ns	ns	ns	ns	ns	ns
Clapping	8.609	***	ns	**	**	ns	ns	ns

The table above reveals that the groups *did not* differ significantly in their performance on seventeen of the measures administered in the first phase of the study. These measures were: BAS Block design, BAS Naming vocabulary, BAS Verbal comprehension, Beads task score, Prepositions score, Visual search (number of targets found and mean time to find target), Phonological discrimination task (number of real words correctly identified), Naming score for pictures and colours and Naming time for pictures and numbers, Lexical Access time and all four of the Blindfold Balance conditions.

There were, however, significant differences between the performance of the reading groups on the remaining measures. Post hoc analyses indicated which of the reading groups performed significantly different from one another on each of the tests. In a great many of the cases where significant differences between groups was found, this has been due particularly to a difference between the performance of the poorest and the best readers (Groups -- and ++) at the 0.01 significance level. This pattern of performance can be observed in the case of BAS Visual recognition, BAS Matching Letter-Like forms, Articulation Rate, Clapping and Nonword Repetition.

For the other tests on which there was found to be a significant difference between the performance of the groups, the post hoc analyses revealed a pattern of differences, which although varying to some degree, illustrates a general trend for the poorest readers to score at lower levels or perform at a slower pace than some or all of the remaining reading groups. These tests include the BPVS, BAS Copying, BAS Basic number skills, BAS Recall digits, BAS Verbal-tactile matching, BAS IQ score, Pegboard task mean time, Phonological discrimination (percentage of correct rejections) all three conditions of the Rhyming task, Naming colours time, Naming numbers score and Naming letters (time and score) and Lexical Access percentage score.

4.4.2 Phase 2

The performance of the four reading groups on the predictive tests administered in Phase 2 was also analysed using a series of one factor analyses of variance. Again, the possibility of differences in the age of subjects in each of the reading groups was investigated using a one factor ANOVA, but this was found not to be significant ($F= 0.575$, $df = 3$, $p= 0.6322$ (ns)) and the mean ages (in months) (with standard deviations) of the groups in this Phase are presented in the table below.

Table 4.9 Mean ages (with standard deviations) of subjects in the Phase 3 reading groups at Phase 2

	Group --	Group -	Group +	Group ++
mean age	71.10 (6.25)	72.41 (6.04)	73.84 (9.62)	71.82 (6.88)

The means and standard deviations of the scores and times for the four reading groups on the Phase 2 measures are presented in table 4.10.

Table 4.10 Mean scores (and standard deviations) for the four reading groups on the Phase 2 measures.

Test	**Group --**	**Group -**	**Group +**	**Group ++**
BPVS Short form %ile	55.81 (24.55)	71.53 (16.56)	61.28 (28.33)	69.68 (24.76)
BAS Block design %ile	62.71 (19.16)	70.47 (26.80)	69.86 (26.63)	82.86 (18.53)
BAS Recall digits %ile	41.12 (25.69)	46.85 (24.00)	61.72 (19.90)	68.61 (20.05)
Pegboard Task mean time	16.82 (3.12)	16.02 (2.08)	15.62 (2.42)	15.17 (2.74)
Beads mean score	6.87 (2.33)	8.588 (2.29)	8.28 (1.92)	8.59 (2.26)
Nonword Repetition	20.05 (4.60)	22.41 (3.47)	23.60 (4.25)	23.96 (3.56)
Rhyming C1	7.29 (1.93)	9.12 (1.65)	9.40 (1.08)	9.46 (0.92)
Rhyming C2	6.95 (1.77)	8.24 (1.92)	8.68 (1.55)	9.04 (1.26)
Rhyming C3	6.62 (1.50)	8.53 (1.91)	8.88 (1.05)	9.00 (1.09)
Lexical Access score	76.65 (11.04)	87.59 (7.95)	87.48 (9.18)	88.54 (5.97)
Lexical Access median time	0.84 (0.28)	0.92 (0.35)	0.94 (0.32)	0.85 (0.36)
Phonological Segmentation	5.00 (1.82)	6.88 (2.26)	7.63 (2.43)	10.61 (2.85)
Naming pictures	11.95 (0.22)	11.94 (0.24)	11.88 (0.33)	11.96 (0.19)
Naming pictures median time	1.020 (0.31)	0.90 (0.13)	0.98 (0.33)	0.89 (0.17)
Naming colours	5.95 (0.22)	6.00 (0.00)	6.00 (0.00)	6.00 (0.00)
Naming colours median time	0.77 (0.14)	1.03 (0.61)	0.94 (0.45)	0.81 (0.22)
Naming numbers	7.67 (0.66)	7.82 (0.39)	7.92 (0.28)	8.00 (0.00)
Naming numbers median time	0.86 (0.25)	0.86 (0.24)	0.86 (0.37)	0.76 (0.11)
Naming letters	5.76 (2.21)	6.35 (2.03)	7.44 (0.71)	7.75 (0.52)
Naming letters median time	1.24 (0.74)	1.17 (0.56)	1.05 (0.41)	0.88 (0.17)

Table 4.11 indicates the F and values and significance of the difference in performance of the groups on each of the tests administered in Phase 2. For each analysis of variance, a Tukey-Kramer post hoc test was again performed to examine if there were significant differences between particular groups. Post hoc differences between groups are indicated in the final columns of the table.

key		
	*	p < 0.05
	**	p < 0.01
	***	p < 0.001
	ns	not significant

Table 4.11 Significance of the differences in performance between the Phase 3 reading groups on Phase 2 measures and post hoc differences

			Post hoc analyses					
Test	**F (df = 3)**	**p value**	**- - vs -**	**- - vs +**	**- - vs ++**	**- vs +**	**- vs ++**	**+ vs ++**
BPVS Short form percentile	1.907	ns	ns	ns	ns	ns	ns	ns
BAS Block design percentile	3.378	*	ns	ns	*	ns	ns	ns
BAS Recall digits percentile	7.684	***	ns	*	**	ns	*	ns
Pegboard Task mean time	1.655	ns	ns	ns	ns	ns	ns	ns
Beads mean score	3.027	*	ns	ns	*	ns	ns	ns
Nonword Repetition	4.460	**	ns	*	**	ns	ns	ns
Rhyming C1	12.123	***	**	**	**	ns	ns	ns
Rhyming C2	7.428	***	ns	*	**	ns	ns	ns
Rhyming C3	14.745	***	**	**	**	ns	ns	ns
Lexical Access score	9.068	***	**	**	**	ns	ns	ns
Lexical Access median time	0.542	ns	ns	ns	ns	ns	ns	ns
Phonological Segmentation	22.858	***	ns	**	**	ns	**	**
Naming pictures score	0.562	ns	ns	ns	ns	ns	ns	ns
Naming pictures median time	1.465	ns	ns	ns	ns	ns	ns	ns
Naming colours score	1.115	ns	ns	ns	ns	ns	ns	ns
Naming colours median time	2.024	ns	ns	ns	ns	ns	ns	ns
Naming numbers score	3.219	*	ns	ns	*	ns	ns	ns
Naming numbers median time	1.090	ns	ns	ns	ns	ns	ns	ns
Naming letters score	9.443	***	**	**	**	ns	ns	ns
Naming letters median time	2.554	ns	ns	ns	ns	ns	ns	ns

From table 4.11 it can be seen that, as in the case of Phase 1, there were no significant differences between the groups on a number of tests administered in the second predictive phase. These tests were the British Picture Vocabulary Scale (Short Form), the Pegboard Task, Naming of pictures and colours, Naming time for pictures, colours, numbers and letters, and Lexical Access median time.

The reading groups did differ significantly from one another on the other 11 predictive measures that were administered in this phase, and the post hoc analyses reveal which of the groups differed at each significance level. The poorest and best readers differed significantly from each other on the BAS Block design, the Beads task and Naming of numbers. Some or all of the groups differed from one another at either the p<0.01 or p<0.05 level on the following measures: BAS Recall digits, Phonological Segmentation, Nonword Repetition, all three conditions of the Rhyming test, Naming numbers and letters and Lexical Access percentage score. The exact details of which groups differed from which and at what significance levels can be found in the table above.

The other measure administered to subjects in Phase 2, the BAS Test of Word Reading, was also analysed to examine possible differences in the performance of the four groups at this stage. Using a one factor analysis of variance, it was found that even at this early point in the children's schooling, the four groups all differed significantly from one another at the p<0.01 level in terms of their percentile score on this test (F= 102.852, df = 3, p<0.0001). The mean scores for the four reading groups (with standard deviations) are presented in the table below.

Table 4.12 Mean performance of the four reading groups on the BAS Test of Word Reading administered at Phase 2 (percentiles)

	Group - -	**Group -**	**Group +**	**Group ++**
mean age	16.86 (12.90)	36.50 (12.19)	53.32 (13.43)	83.30 (15.10)

4.5 Effect size analysis of the performance of the Phase 3 reading groups

Following calculation of the significance of any differences in performance between the very poor, poor, good and very good readers on the predictive tests using analysis of variance, an effect size analysis was undertaken to compare the relative performance of the groups on the predictive measures (see e.g. Cohen, 1969). To do this, data for each group were normalised relative to the data for the subjects as a whole and this produced an "effect size" in standard deviation units for each child on each of the tests (analogous to a z-score). The sign of the effect size denotes whether performance on a test was above or below the mean performance for the subjects as a whole. The individual effect sizes for subjects in each of the four reading groups were then averaged to provide mean effect sizes for the groups. The following sections outline the relative performance of the groups on the predictive tests as indicated by the mean effect sizes for the groups. The summary effect size data for Phases 1 and 2 can be found in Appendix 4.3 (a) and (b) and individual effect size scores are located in Appendix 4.7.

4.5.1 Mean effect sizes and effect size graphs

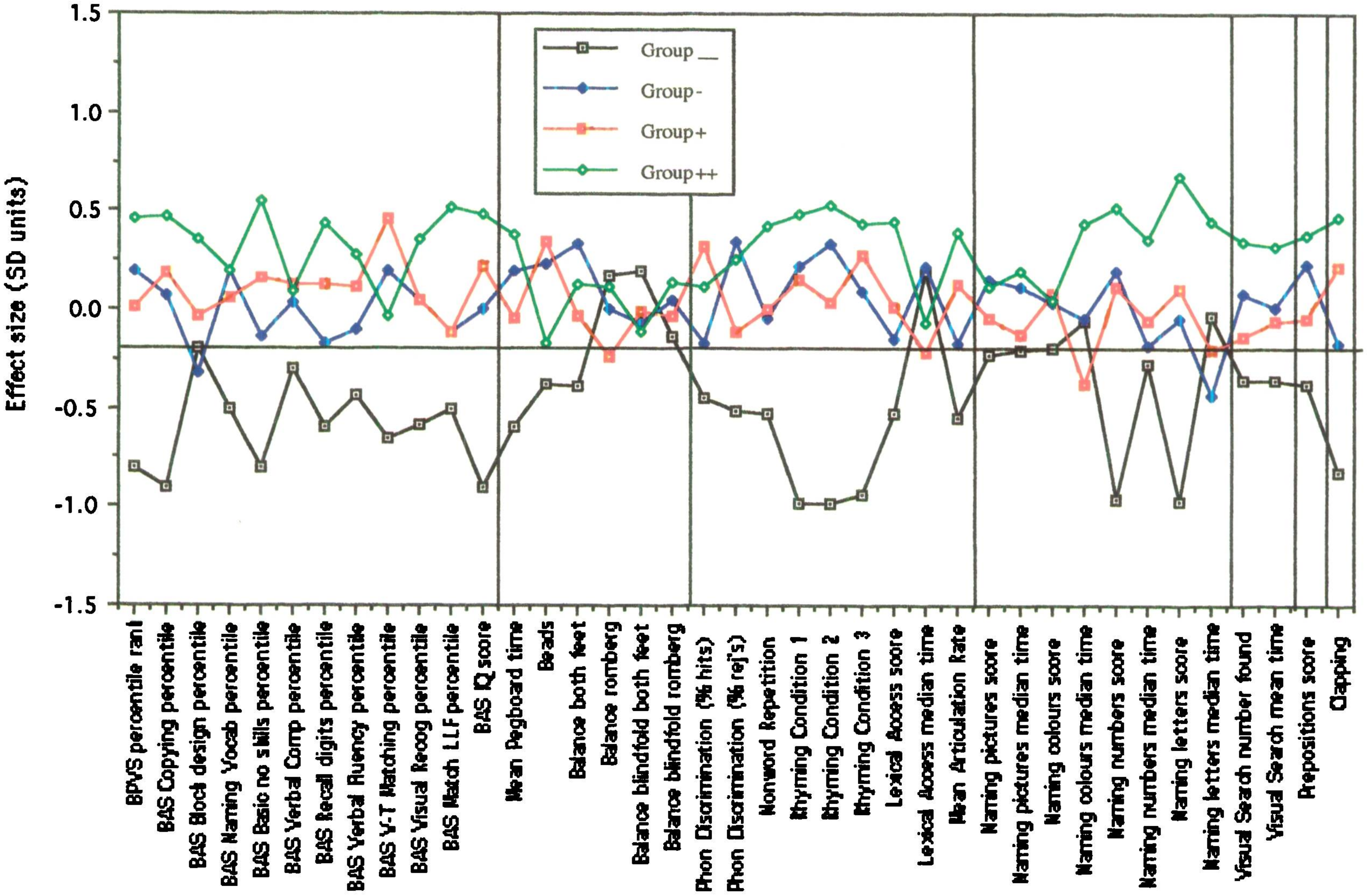
(a) Phase 1

Table 4.13 presents the mean effect sizes for each of the four Phase 3 reading groups on the tests administered in Phase 1. These data are also presented in the form of a graph in Figure 4.1. The graph indicates the performance of the four groups as a continuous line across all tests. The test are listed according to the skill which they were designed to measure (general ability, motor skills, etc.) along the x-axis of the graph. The mean score for all subjects in shown by a horizontal line running through the graph from point 0 on the y - axis. The position of each group with respect to the mean for all subjects is illustrated by the position of the line representing it. Therefore a group falling well above the mean line on a test has performed well on the test compared to other groups and to the mean for all subjects. Conversely, a group falling below the mean line have performed poorly on this test. The units of measurement for the graph are standard deviation units, and the actual effect sizes for each group can be found in table 4.13 below.

Table 4.13 Mean effect sizes for the Phase 3 reading groups on Phase 1 measures.

Test	Group - -	Group -	Group +	Group ++
BPVS percentile rank	-0.80	0.20	0.01	0.46
BAS Copying percentile	-0.90	0.07	0.18	0.47
BAS Block design percentile	-0.20	-0.32	-0.03	0.36
BAS Naming Vocab percentile	-0.50	0.20	0.06	0.20
BAS Basic no skills percentile	-0.80	-0.14	0.16	0.55
BAS Verbal Comp percentile	-0.30	0.04	0.13	0.09
BAS Recall digits percentile	-0.60	-0.17	0.13	0.44
BAS Verbal Fluency percentile	-0.43	-0.10	0.12	0.28
BAS V-T Matching percentile	-0.65	0.20	0.46	-0.04
BAS Visual Recog percentile	-0.58	0.05	0.05	0.36
BAS Match LLF percentile	-0.50	-0.12	-0.12	0.52
BAS IQ score	-0.90	0	0.22	0.48
Mean Pegboard time	-0.60	0.19	-0.05	0.38
Beads	-0.38	0.23	0.34	-0.17
Balance both feet	-0.39	0.33	-0.03	0.13
Balance romberg	0.17	0	-0.24	0.11
Balance blindfold both feet	0.19	-0.07	-0.01	-0.11
Balance blindfold romberg	-0.14	0.05	-0.04	0.14
Phon Discrimination (% hits)	-0.45	-0.17	0.32	0.12
Phon Discrimination (% rej's)	-0.52	0.34	-0.12	0.25
Nonword Repetition	-0.53	-0.05	0	0.42
Rhyming Condition 1	-0.99	0.22	0.15	0.48
Rhyming Condition 2	-0.99	0.33	0.03	0.53
Rhyming Condition 3	-0.94	0.09	0.27	0.44
Lexical Access score	-0.53	-0.15	0.01	0.45
Lexical Access median time	0.20	0.22	-0.22	-0.07
Mean Articulation Rate	-0.55	-0.17	0.13	0.39
Naming pictures score	-0.23	0.15	-0.05	0.12
Naming pictures median time	-0.21	0.12	-0.13	0.20
Naming colours score	-0.20	0.04	0.08	0.05
Naming colours median time	-0.06	-0.05	-0.38	0.43
Naming numbers score	-0.96	0.19	0.11	0.51
Naming numbers median time	-0.28	-0.18	-0.06	0.36
Naming letters score	-0.97	-0.05	0.10	0.67
Naming letters median time	-0.03	-0.44	-0.21	0.45
Visual Search number found	-0.35	0.08	-0.14	0.34
Visual Search mean time	-0.36	0.01	-0.06	0.32
Prepositions score	-0.38	0.23	-0.05	0.38
Clapping	-0.82	-0.17	0.22	0.47

Figure 4.1 Graph to show mean effect sizes for the Phase 3 reading groups on Phase 1 measures.



From the graph and the table above it can be seen that on the whole, Group -- have scored at the lowest levels on the Phase 1 tests. The other three reading groups have scored at relatively more similar levels to one another, although Group ++ has tended to achieve the greatest scores in most cases. This result therefore mirrors what was found with the ANOVA calculations in the previous section. Indeed, the significance of the differences between the points on the graph in figure 4.1 can be found from inspection of table 4.8.

Examination of the graph in figure 4.1 reveals a number of tests on which the lowest reading group have scored particularly poorly. In considering these tests in terms of the skills they were designed to measure, it can be seen that Group -- have scored at lower levels overall on tests of general ability, particularly BAS Copying and BAS Basic number skills, a number of tests of phonological skills (performance in the three conditions of the Rhyming task were particularly poor), naming of numbers and letters and Clapping. Scores on one test on motor skill, the Pegboard task, were also found to be low, although on other tests of motor skills, performance of this group was found to be close to or even better than that of other reading groups.

(b) Phase 2

The mean effect sizes for performance of the reading groups on predictive measures administered in Phase 2 are outlined in table 4.14 and shown in the form of a graph in figure 4.2.

Figure 4.1 Graph to show mean effect sizes for the Phase 3 reading groups on Phase 1 measures.

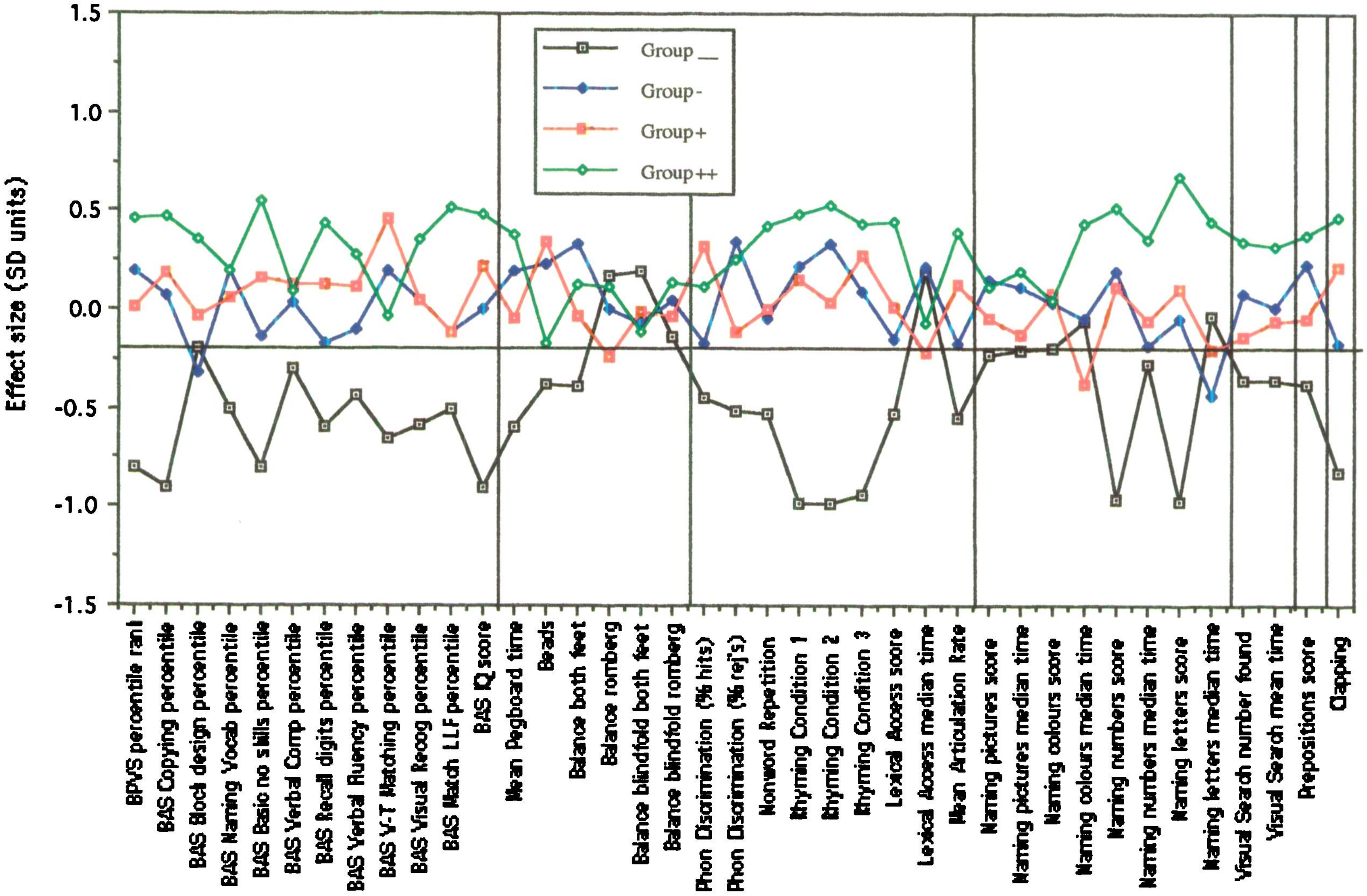


Table 4.14 Mean effect sizes for the Phase 3 reading groups on Phase 2 measures.

Test	Group - -	Group -	Group +	Group ++
BPVS Short form percentile	-0.35	0.28	-0.16	0.21
BAS Block design percentile	-0.35	-0.08	-0.12	0.45
BAS Recall digits percentile	-0.55	-0.39	0.31	0.50
Pegboard Task mean time	-0.36	-0.07	0.10	0.25
Beads mean score	-0.56	0.21	0.09	0.22
Nonword Repetition	-0.52	-0.02	0.25	0.19
Rhyming C1	-0.88	0.14	0.33	0.36
Rhyming C2	-0.75	-0.04	0.25	0.41
Rhyming C3	-1.03	0.11	0.35	0.42
Lexical Acces score	-0.81	0.22	0.19	0.32
Lexical Access median time	0.06	-0.11	-0.14	0.11
Phonological Segmentation	-0.83	-0.27	-0.07	0.79
Naming pictures score	0.07	0.03	-0.24	0.12
Naming pictures median time	-0.29	0.19	-0.16	0.23
Naming colours score	-0.38	0.10	0.10	0.10
Naming colours median time	0.30	-0.40	-0.08	0.18
Naming numbers score	-0.42	-0.13	-0.13	0.29
Naming numbers median time	-0.10	-0.13	0.13	0.29
Naming letters score	-0.76	-0.37	0.29	0.49
Naming letters median time	-0.41	-0.24	0	0.37

Inspection of the graph and table reveals a less pronounced difference in the performance of the four reading groups on the second set of predictive measures. However, the relative pattern of performance in Phase 2 is similar to that in Phase 1 whereby Group - - has tended to score at the lowest levels on most tests and Group ++ has tended to score at the highest levels. Again it is clear that the skill area on which Group - - have tended score at the lowest levels is phonological skills, with the greatest contrast between good and poor readers found on the Phonological segmentation test. In addition, poor performance was also found on the naming letters condition of the Naming game and Rhyming.

4.5.2 Incidence of poor scores in the four Phase 3 reading groups

(a) Phase 1

On the basis of the standardisation of the performance of the four reading groups on the tests administered in Phases 1 and 2, the incidence of poor scores on each test in the reading groups was examined. This was done by defining *poor* scores as a score of one or more standard deviations below the mean (for all subjects) on a particular test. The following table (table 4.15) outlines the percentage incidence of standard deviation scores of -1 or lower on the Phase 1 predictive measures for each of the reading groups. The tests are ranked in order of greatest incidence of poor scores in the lowest reading ability group (Group --). These incidence levels are also represented as a bar chart in figure 4.3.

Table 4.15 Incidence of poor scores (standard deviation scores of -1 or lower) for predictive measures administered in Phase 1 for the Phase 3 reading groups .

	Percentage incidence of scores of -1 SD or lower			
Test	**Group - -**	**Group -**	**Group +**	**Group ++**
Clapping	63.2	18.8	12.5	3.7
Rhyming Condition 1	57.1	6.3	12.5	3.6
Rhyming Condition 2	57.1	6.3	25	3.6
BAS IQ score	57.1	11.8	12	3.6
Naming letters score	57.1	17.6	20	3.6
BAS Basic no skills percentile	57.1	5.9	20	28
BAS Copying percentile	52.4	0	12	3.6
BPVS percentile rank	50	5.9	20	7.4
Naming numbers score	47.6	5.9	12	3.6
BAS Match LLF percentile	45	18.8	16.7	3.6
BAS Naming Vocab percentile	42.9	17.6	32	10.7
BAS Recall digits percentile	42.9	11.8	12	7.1
BAS Verbal Fluency percentile	42.9	17.6	16.7	17.9
BAS V-T Matching percentile	42.9	11.8	12	22.2
Lexical Access score	38.9	12.5	12.5	3.8
BAS Visual Recog percentile	38.1	11.8	12	14.3
BAS Block design percentile	38.1	43.8	37.5	21.4
Rhyming Condition 3	38.1	12.5	0	7.4
Mean Pegboard time	33.3	5.9	8.3	7.1
Beads	33.3	29.4	12	3.6
Mean Articulation Rate	31.6	17.6	16	0
Nonword Repetition	28.6	17.6	20	7.1
Phon Discrimination (hits)	26.3	29.4	4	7.1
Balance both feet	25	5.9	16	13
Prepositions score	21.1	0	8.3	7.4
Phon Discrimination (rej's)	21.1	0	20	7.1
Blindfold balance romberg	20	11.8	12	9.1
Naming letters median time	16.7	20	21.7	7.4
Naming pictures median time	15	6.3	4.2	11.1
Naming colours median time	15	12.5	28	3.7
Balance romberg	15	17.6	24	8.7
Naming colours score	14.3	5.9	8	3.6
Lexical Access median time	11.1	6.3	20.8	11.5
Naming numbers median time	10	6.7	4.3	0
Visual Search number found	9.5	12.5	26.1	7.1
Visual Search mean time	9.5	12.5	17.4	0
Naming pictures score	4.8	0	0	0
Balance blindfold both feet	0	17.6	0	18.2

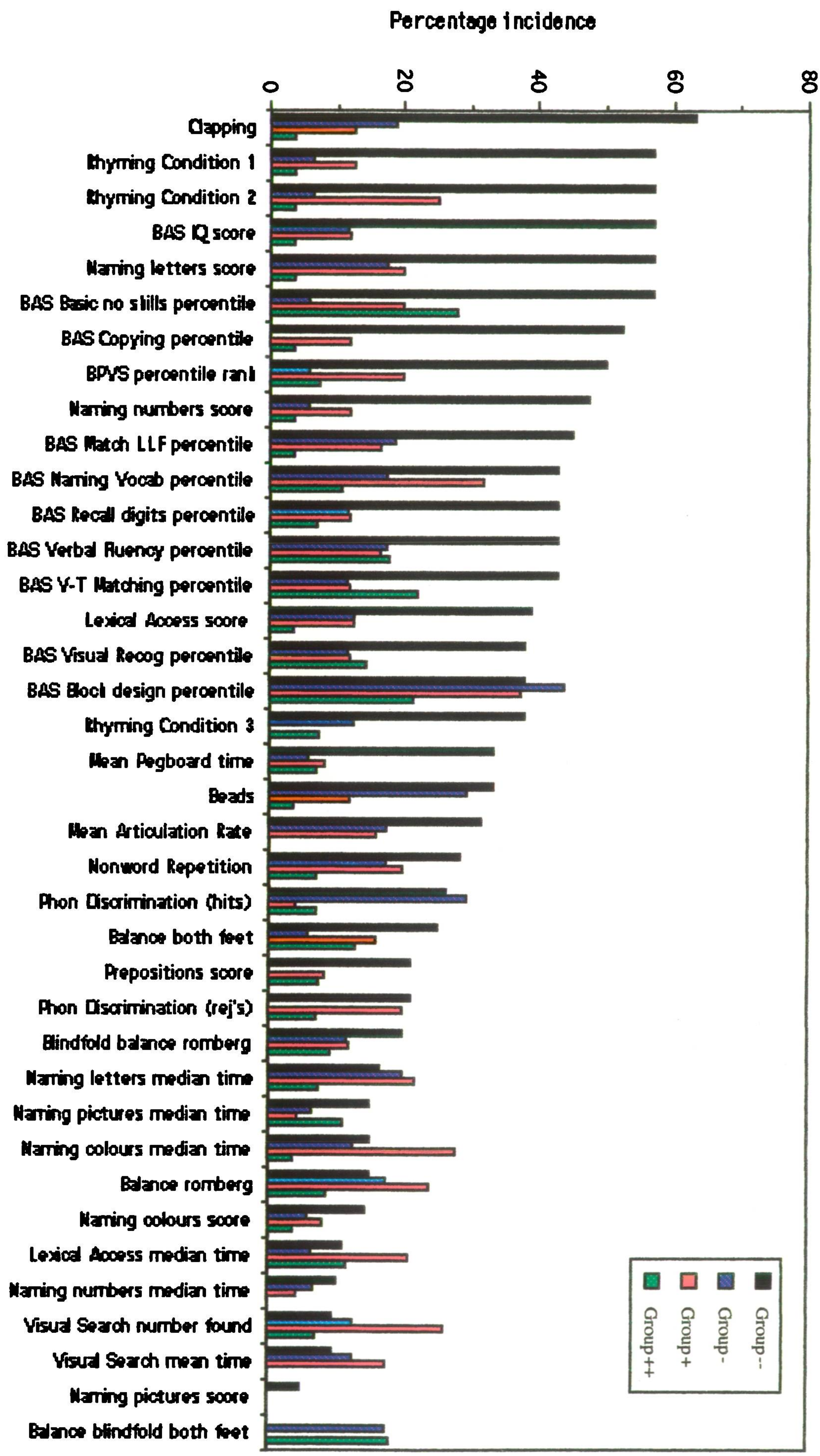


Figure 4.3 Incidence of poor scores for predictive measures administered in Phase 1 for the Phase 3 reading groups

From table 4.15 and figure 4.3 it can be seen that the tests on which the greatest proportion of Group -- subjects scored poorly (i.e. at one or more standard deviations below the mean) were Clapping, tests of phonological skill (particularly Rhyming), general ability (IQ, BAS Basic number skills, BAS Copying, BPVS), and also the letters and numbers conditions of the Naming game. In most cases these high incidence figures for the lowest reading group contrast with very low incidence of poor scores in the highest reading group. For example, in the Clapping test, Group -- had an incidence of 63.2% poor scores compared to only 3.7% for Group ++.

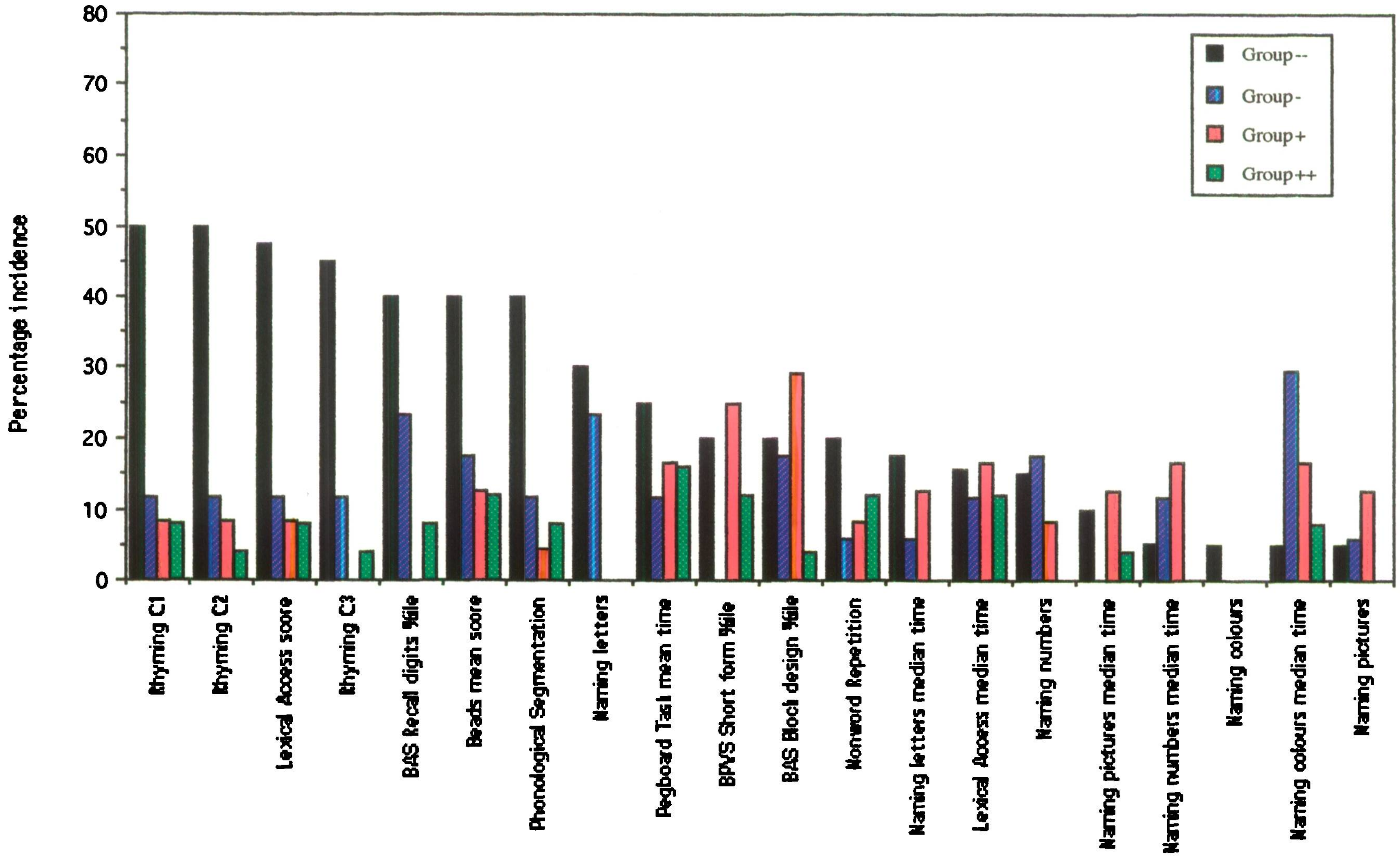
(b) Phase 2

Table 4.16 outlines the incidence of standard scores of -1 or lower in the four Phase 3 reading groups for the measures administered at Phase 2. Again the tests are ranked in order of greatest incidence of poor scores in the Group -- reading group. Figure 4.4 indicates the percentage incidence of poor scores as a bar chart.

Table 4.16 Incidence of poor scores (standard deviation scores of -1 or lower) for predictive measures administered in Phase 2 for the Phase 3 reading groups .

	Percentage incidence of scores of -1 SD or lower			
Test	**Group - -**	**Group -**	**Group +**	**Group ++**
Rhyming C1	50	11.8	8.3	8
Rhyming C2	50	11.8	8.3	4
Lexical Access score	47.4	11.8	8.3	8
Rhyming C3	45	11.8	0	4
BAS Recall digits %ile	40	23.5	0	8
Beads mean score	40	17.6	12.5	12
Phonological Segmentation	40	11.8	4.3	8
Naming letters	30	23.5	0	0
Pegboard Task mean time	25	11.8	16.7	16
BPVS Short form %ile	20	0	25	12
BAS Block design %ile	20	17.6	29.2	4
Nonword Repetition	20	5.9	8.3	12
Naming letters median time	17.6	5.9	12.5	0
Lexical Access median time	15.8	11.8	16.7	12
Naming numbers	15	17.6	8.3	0
Naming pictures median time	10	0	12.5	4
Naming numbers median time	5.3	11.8	16.7	0
Naming colours	5	0	0	0
Naming colours median time	5	29.4	16.7	8
Naming pictures	5	5.9	12.5	0

Figure 4.4 Incidence of poor scores for predictive measures administered in Phase 2 for the Phase 3 reading groups.



Inspection of table 4.16 reveals a similar pattern of results to that of Phase 1 above. The tests with the greatest incidence of poor scores in the lowest reading groups were again tests of phonological skills and general ability. It is also interesting to note that one test of motor skills, the beads task, was also found to have produced a relatively large proportion of poor scores (40%) in the lowest reading group.

4.6 Correlations between predictive tests and Phase 3 reading ability

As outlined in section 4.3 above, a composite reading age was calculated for each subject based on the reading measures administered in Phase 3. The composite age was obtained by computing the mean of the child's reading age (in months) for the BAS Test of Word Reading, the Neale Analysis of Reading Ability (reading accuracy age) and The Schonell Test of Single Word Reading.

Using a Pearsons Product Moment correlation (Statview) a series of x-y correlations were carried out to establish the strength of the relationship between each of the predictive tests administered in Phases 1 and 2 and the later reading performance of subjects in terms of their Phase 3 composite reading age. Table 4.17 presents the correlation coefficients for each of the tests grouped according to the particular skills which the tests were designed to measure.

A number of the correlation coefficients that were obtained were found to be significant. The significance level of the coefficients is marked with asterisks (see key below). The tests that were found to have significant strong relationships with later reading ability are outlined in table 4.17.

<u>key</u>		
	*	$p < 0.05$
	**	$p < 0.01$
	***	$p < 0.001$

Full correlation matrices for tests in Phase 1 and Phase 2 can be found in appendix 4.4. These indicate the relationships between *all* of the tests administered in each phase.

Table 4.17 Correlation between tests administered in Phases 1 and 2 and Phase 3 composite reading score

	Test	Phase 1	Phase 2
General ability	British Picture Vocabulary Scale	.51 ***	.35 ***
	BAS Copying	.43 ***	
	BAS Verbal Comprehension	.16	
	BAS Naming Vocabulary	.10	
	BAS Verbal Fluency	.29 **	
	BAS Basic Number Skills	.43 ***	
	BAS Recall Digits	.23 *	.27 *
	BAS Visual Recognition	.25 *	
	BAS Block Design	.22 *	.17
	BAS Matching Letter-Like Forms	.22 *	
	BAS Verbal Tactile Matching	.26 *	
	BAS IQ Score	.45 ***	
Motor skill	Pegboard Task mean time	-.37 ***	-.21 *
	Beads Task (mean) score	.11	.19
	Blindfold Balance (both feet)	-.11	
	Blindfold Balance (romberg)	-.06	
	Blind fold Balance (blindfold both feet)	-.02	
	Blindfold Balance (blindfold romberg)	-.08	
Phonological skills	Phonological Discrimination (hits)	.22 *	
	Phonological Discrimination (rejections)	.24 *	
	Nonword Repetition	.44 ***	.4 ***
	Lexical Access score	.38 ***	.41 ***
	Lexical Access median time	.32 **	.18
	Rhyming Task Condition 1	.49 ***	.38 ***
	Rhyming Task Condition 2	.47 ***	.45 ***
	Rhyming Task Condition 3	.55 ***	.42 ***
	Articulation Rate (mean time)	.05	
	Phonological Segmentation		.74 ***
Reaction time	Naming Game Pictures score	.15	.10
	Naming Game Pictures median time	-.16	-.11
	Naming Game Colours score	.08	.08
	Naming Game Colours median time	-.13	-.07
	Naming Game Numbers score	.38 ***	.30 **
	Naming Game Numbers median time	-.27 *	-.16
	Naming Game Letters score	.51 ***	.45 ***
	Naming Game Letters median time	-.32 **	-.31 **
Speed of processing	Visual Search Task mean score	.22 *	
	Visual Search Task mean time	-.13	
Verbal labelling	Prepositions Task	.06	
Rhythm	Clapping	.47 ***	

4.6.1 Predictive tests with a strong relationship to later reading ability

(a) Tests of general ability

The two major measures of general ability correlated very strongly with the composite reading score obtained in Phase 3. Performance of subjects on both the long form and the short form of the BPVS was found to correlate very significantly with reading performance in Phase 3 ($p<0.001$). In addition, the BAS IQ score was also strongly related to the later reading abilities of the subjects ($p<0.001$). A number of the individual subtests of the BAS were also found to correlate well with later reading. These were the Copying subtest and Basic Number Skills ($p<0.001$) and the Verbal Fluency test ($p<0.01$). Five other subtests, Recall of Digits (both phases), Visual Recognition, Block Design, Matching Letter Like Forms and Verbal Tactile Matching correlated moderately with later reading at the $p<0.05$ significance level.

(b) Tests of phonological skills

Examination of table 4.17 indicated that the predictive tests with the strongest relationship to later reading performance are mainly located in the measures of phonological skill. The following eleven measures were all found to have a very significant strong correlation ($p<0.001$) with later reading performance and are listed in order of strength of correlation:

- Phonological Segmentation (.74)
- Rhyming Task Condition 3 (alliteration) (Phase 1) (.55)
- Rhyming Task Condition 1 (Phase 1) (.49)
- Rhyming Task Condition 2 (Phase 1) (.47)
- Rhyming Task Condition 2 (Phase 2) (.45)
- Nonword Repetition (Phase 1) (.44)
- Rhyming Task Condition 3 (Phase 2) (.42)
- Lexical Access score (Phase 2) (.41)
- Nonword Repetition (Phase 2) (.4)
- Lexical Access score (Phase 1) (.38)
- Rhyming Task Condition 1 (Phase 2) (.38)

In addition, the significance of the correlation between the median time to complete the Lexical Access task in Phase 1 was $p<0.01$. The Phonological Discrimination Task, administered in Phase 1 only, was found to correlate moderately with later reading performance ($p<0.05$).

(c) Tests of motor skills

Only one of the tests of motor skills yielded a significant correlation with later reading performance. The mean time taken by subjects to complete the Pegboard Task in the first phase of the study correlated negatively with Phase 3 composite reading age at $p<0.001$ significance level, while the mean time to complete the task in the second phase negatively correlated at a significance level of $p<0.05$ (correlations coefficients were -.37 and -.21 respectively).

(d) Tests of reaction time

Of the four conditions of the Naming Game, Naming numbers score (Phase 1) and Naming letters score (Phases 1 and 2) all correlated very significantly with later reading performance ($p<0.001$). Phase 2 Naming numbers score (Phase 2) and Naming letters median time (Phases 1 and 2) correlated positively with later reading performance ($p<0.01$), with Phase 1 Naming numbers median time correlating at the $p<0.05$ level.

(e) Tests of speed of processing

The Visual Search mean score (but not the mean time taken to find targets) was found to correlate moderately with Phase 3 reading performance ($p<0.05$).

(f) Tests of verbal labelling

No significant correlation was found between performance on the Prepositions task and later reading performance.

(g) Tests of Rhythm

The Clapping test was found to significantly correlate with later reading ability ($r = .47$, $p < 0.001$

4.7 Analysis following Phase 4: Performance of dyslexics and slow learners on the predictive tests

The major goal of this study has been to identify those tests which are able to identify children aged 4 or 5 years who are at risk for dyslexia. To do this a number of children including those for whom the risk of dyslexia is greater than for the population as a whole (the siblings), have been administered a number of potentially predictive tests between the ages of 4 and 6 years. Phase 3 testing provided an indication of the level of each child's reading ability. The purpose of the tests administered in Phase 4 was to identify which of those children in the poorest reading group (Group --) could, at the age of seven years, be formally (but tentatively) diagnosed as dyslexic. In addition to this, children meeting the criteria for the diagnostic label of "slow learner", have also been identified. Two of the poorest readers were found not to show any signs that would indicate either dyslexia or slow learning and were therefore assigned to the one of the control groups for the analysis.

In order to establish the status of the poorest readers as either dyslexic, slow learners or otherwise, two main tests were administered: the Wechsler Intelligence Scale for Children - III UK and the Wechsler Objective Reading Dimensions. These two tests are commonly used in diagnostic procedures and a number of features assist in formulation of a diagnosis of dyslexia and other reading difficulties (see Chapter 2 for a more detailed explanation). The following section provides an outline of the criteria used for the identification of the poorest readers as either slow learners or dyslexics and provides some descriptive statistics regarding subjects in each of the diagnostic groups.

4.7.1 Dyslexics and slow learners

4.7.1.1 Dyslexics

Traditional definitions of dyslexia regard an IQ score of 90 or above and a reading age - chronological age discrepancy of 18 months to two years as the criteria upon which a diagnosis is made. In addition to this, examination of the profile of performance on the individual subtests of the WISC often reveals discrepancies, with some tests scores at particularly low levels and some at relatively higher levels. The subtests on which dyslexics tend to score most poorly are those which have been referred to as the "ACID" tests: arithmetic, coding, information and digit span.

In attempting to identify which of the children in the poorest reading group were dyslexic, the criteria outlined above were modified to allow for a slightly over inclusive approach to diagnosis. This was also due in part to the very young age of the subjects relative to the age at which children tend to be referred for assessment (10-11 years). For the purposes of this study, at age seven years, a group of the poorest readers were identified as "definite dyslexics" or "probable dyslexics", based on some or all of the following criteria:

(a) Definite dyslexics

(i) A full IQ score of 90 or above

(ii) A significant difference between the word reading score of the WORD and the expected score based on chronological age and Full Scale IQ.

(iii) A significant difference between the spelling score of the WORD and the expected score based on chronological age and Full Scale IQ.

(iv) A discrepancy of 9 months or more between chronological age and WORD reading age.

(v) Presence of relatively poor scores on the ACID subtests of the WISC-III UK compared to other subtest scores.

The following subjects were identified as definite dyslexics: JD, LC, RB, AN, and JB. The characteristics of these subjects are outlined in table 4.18.

Table 4.18 Characteristics of the "definite dyslexics"

	Full IQ	**Reading**	**Spelling**	**CA-RA**	**ACID**
JD	127	**	**	13 months	2
LC	99	*	**	17 months	0
RB	92 †	ns	*	14 months	3
AN	108	*	*	18 months	2
JB	94 †	ns	ns	13 months	4

key		
	*	$p < 0.05$
	**	$p < 0.01$
	***	$p < 0.001$
	ns	not significant

† It is noted that subjects RB and JB scores at levels very close to the slow learners in terms of their overall IQ. However, for the present time, a simple distinction between children scoring above or below

90 was maintained for identification of the dyslexics. These children were therefore included in the dyslexic group but with the knowledge that they their lower IQ's might have other implications.

(b) Probable dyslexics

Included in this group were two subjects who although having a discrepancy of nine or more months between their chronological and reading age, this difference was not significantly different from that expected based on chronological age and Full IQ scores. Details for the two subjects, CS and SJ are shown in the table below.

Table 4.19 Characteristics of the "probable dyslexics"

	Full IQ	Reading	Spelling	CA-RA	ACID
CS	104	ns	*	9 months	2
SJ	99	ns	ns	11 months	3

(c) Other dyslexics

Two of the poor readers were not tested using Phase 4 measures, but nonetheless have been included in the "dyslexic" group for the purpose of analysis. For one of the subjects, LH, who was not available for testing in the final phase, it was decided that available evidence supported his inclusion in this diagnostic group. This evidence included a strong family history of dyslexia (father and sister) and a significant number of reports of dyslexic characteristics displayed at home and school by the child.

The second child to be included in this group without administration of the Phase 4 tests (TR) was known to the experimenter to have been diagnosed at Sheffield Children's Hospital as suffering from Neurofibramatosis with particular dyslexic difficulties. It was felt that re-testing the child for dyslexia was therefore unnecessary. In many cases TR's condition of neurofibramatosis would have been used as an exclusionary criterion to propose against a diagnosis of dyslexia. However, in the present study, as the group of dyslexics was designed to be over-inclusive, he was grouped with the other children identified as dyslexic, but an awareness of his other difficulties was maintained.

All of the children discussed above (n=9) have been grouped together as "dyslexic" for the purpose of this analysis. Six of the group were male and three female. Although there may be reasons for questioning a diagnosis of dyslexia for some of these children using strict traditional criteria, it was felt that inclusion of this group together was of benefit to the study. This was because on the whole, this group had proved themselves to be of average or just below average IQ but nonetheless had been found to be experiencing unexpected reading problems. In this sense, they appear to be different from the slow learners and normal readers. In many cases, evidence of low scores on the "ACID" tests was also present. However, the point has been made a number of times that this is a very early stage to use conventional methods for the diagnosis of dyslexia. Therefore, the identification of this group of children is done in the knowledge of the limitations present.

Table 4.20 provides descriptive data from the tests administered during this phase for these subjects. This reveals the nature of the profiles obtained by the subjects on the WISC-III UK (all scores reported are standard scores), Full, Verbal and Performance IQ scores, plus reading and spelling ages and percentiles for the WORD.

Table 4.20 Descriptive data for dyslexic subjects on the Phase 4 tests

	JD	**LC**	**RB**	**JB**	**AN**	**CS**	**SJ**	**mean**	**SD**
chronological age	**7.7**	**7.5**	**7.2**	**7.1**	**8.0**	**7.3**	**7.5**	**7.47**	**0.29**
WISC-III UK									
Information	14	8	9	6	10	12	7	**9.43**	**2.61**
Comprehension	18	15	12	12	14	15	11	**13.86**	**2.23**
Arithmetic	13	9	6	6	10	9	7	**8.57**	**2.32**
Similarities	18	10	10	12	10	13	8	**11.57**	**3.02**
Digit Span	9	9	5	4	7	7	7	**6.86**	**1.73**
Vocabulary	14	7	6	6	13	13	6	**9.29**	**3.53**
Coding	5	9	7	8	7	2	9	**6.71**	**2.31**
Picture Completion	10	11	10	11	9	10	14	**10.71**	**1.48**
Block Design	13	11	9	6	15	12	11	**11.00**	**2.67**
Picture Arrangement	16	10	11	14	10	9	13	**11.86**	**2.36**
Object Assembly	13	9	9	13	14	11	13	**11.71**	**1.91**
Symbol Search	12	11	5	16	11	9	12	**10.86**	**3.09**
Full Scale IQ	**127**	**99**	**92**	**94**	**108**	**104**	**99**	**103.29**	**10.92**
Verbal IQ	**133**	**99**	**91**	**90**	**108**	**115**	**87**	**103.29**	**15.37**
Performance IQ	**110**	**99**	**94**	**103**	**107**	**91**	**115**	**102.71**	**8.01**
WORD									
Reading age	6.6	6.0	6.0	6.0	6.6	6.6	6.6	**6.34**	**0.30**
Reading percentile	10	8	10	•	19	25	19	**15.17**	**6.20**
Spelling age	6.9	6.0	<6.0	6.3	6.9	6.3	6.9	**6.55**	**0.36**
Spelling percentile	16	7	5	•	16	14	30	**14.67**	**8.08**

4.7.1.2 Slow Learners

The subjects in the Slow Learner group were selected on the basis of one major criterion: their Full Scale IQ score on the WISC-III UK was below 90. On the basis of this, discrepancies between actual and expected reading and spelling performance were not significant. Poor reading in such children could not be said to be *unexpected.* Obviously, it could be argued that such children could have dyslexic difficulties (see Chapter 1), but for the purpose of this study, the traditional approach regarding the diagnosis to dyslexia (to restrict it to those with IQ's of 90 or above) was followed.

Ten children fell into this category. Their IQ's ranged from 72 to 88 (mean = 81.90, SD = 6.44). Six of the children were male and four were female. Details of their performance on the tests administered in Phase 4 of the study are outlined in table 4.21 below.

Table 4.21 Descriptive data for the slow learners on the Phase 4 tests

	GR	AB	KL	LB	JM	AJ	KG	JB	SM	RL*	mean	SD
chronological age	**7.5**	**7.5**	**7.2**	**7.3**	**7.5**	**7.5**	**6.11**	**7.5**	**7.0**	**7.5**	**7.26**	**0.42**
WISC-III UK												
Information	6	7	6	8	7	7	7	4	7	7	**6.60**	**1.02**
Comprehension	10	10	5	10	9	9	6	6	10	6	**8.10**	**1.97**
Arithmetic	6	7	8	10	11	9	8	1	4	8	**7.20**	**2.79**
Similarities	4	7	8	8	9	4	8	7	8	9	**7.20**	**1.72**
Digit Span	6	6	7	6	15	7	7	4	10	11	**7.90**	**3.05**
Vocabulary	5	5	5	4	3	4	5	8	8	5	**5.20**	**1.54**
Coding	6	4	6	9	4	8	8	11	7	12	**7.50**	**2.54**
Picture Completion	9	10	8	7	10	9	10	9	11	7	**9.00**	**1.26**
Block Design	7	9	6	11	12	10	8	7	10	12	**9.20**	**2.04**
Picture Arrangement	12	8	4	8	10	10	15	1	9	6	**8.30**	**3.77**
Object Assembly	4	6	1	6	10	9	9	9	9	11	**7.40**	**2.94**
Symbol Search	6	4	12	12	11	12	11	14	-	11	**10.33**	**3.02**
Full Scale IQ	**77**	**80**	**70**	**86**	**88**	**84**	**88**	**72**	**87**	**87**	**81.90**	**6.44**
Verbal IQ	**77**	**83**	**80**	**88**	**87**	**80**	**81**	**72**	**84**	**82**	**81.40**	**4.43**
Performance IQ	**82**	**81**	**67**	**86**	**94**	**94**	**99**	**78**	**94**	**96**	**87.10**	**9.57**
WORD												
Reading age	<6.0	6.0	6.3	6.3	6.6	6.0	6.3	6.9	6.3	6.0	**6.30**	**0.28**
Reading percentile	5	2	14	14	18	9	27	23	14	6	**13.20**	**7.57**
Spelling age	<6.0	6.3	6.0	6.3	6.9	6.6	6.9	6.0	6.0	6.3	**6.37**	**0.34**
Spelling percentile	2	3	9	14	30	18	45	9	7	11	**14.80**	**12.65**

* **Subject RL** - this subject was included in the group of slow learners because of his poor performance on the tests administered in Phase 4. However, the child in question had been hospitalised for a period of about 5 months due to severe illness which affected his fine motor skills and had also delayed his academic progress due to absence from school. However, this child had been observed to encounter difficulties on a number of tests in earlier phases of testing before his illness, and it was believed that he did show evidence of being a slow learner despite illness.

4.7.2 Control subjects

The performance of the dyslexic and slow learning subjects was compared to that of the rest of the children involved in the study. These control subjects were divided into two groups:

(a) Borderline Poor Readers

This group included all the subjects in the poor reading group at Phase 3 (Group -) plus two subjects from the very poor group (Group --) who could not be diagnosed as either dyslexic or slow learners because their IQ's were too high and their reading age/chronological age discrepancy not severe enough. Therefore, subjects in the borderline poor readers group were reading at a level below their chronological age, but were not experiencing difficulties great enough to warrant diagnosis for learning difficulties. There were 19 subjects in this group (10 males and 9 females).

(b) Normal Readers

The second group of control subjects was referred to as Normal Readers and was made up of all the subjects from the good and very good reading groups established at Phase 3 (Groups + and ++). These subjects had all been found to be reading at or above their chronological ages at Phase 3, and were therefore not viewed as having any major reading difficulties. In total, this group consisted of 53 subjects, 18 of whom were male and 35 female.

4.7.3 Analysis of differences in performance between dyslexics, slow learners and control groups on predictive tests

4.7.3.1 Phase 1

In order to investigate whether there were significant differences between the performance of the dyslexics and slow learners in comparison to one another, and to the control groups, on the tests that were administered in Phase 1, a number of one factor analyses of variance (SuperAnova) were carried out. For each test, the independent variable was the "diagnostic" group and the dependent variable was the score or time taken to complete the test in question.

Inclusion of the two control groups was felt to be important in this analysis for a number of reasons, particularly to establish evidence regarding the relationship of dyslexia to other forms of good and poor reading. Comparison of dyslexics and slow learning children in terms of their performance on tests administered at a very young age is important in our understanding of the differences (or lack of them) between the two forms of reading difficulty. A number of questions can be asked: Are there some tests on which dyslexics perform better than slow learners, and some on which they perform worse? Does the performance of dyslexic subjects resemble or even exceed normal readers - do dyslexics have recognisable strengths in particular areas? Is the relationship between dyslexics, slow learners and the milder poor readers just one of degree, with a constant difference between the groups across all tests? The following section outlines analysis of the data from the four diagnostic groups.

A one factor analysis of variance was carried out to examine if there were any significant differences in the age of the subjects in each group. This was found not to be significant (F= 0.555, df = 3, p= 0.6463) and the mean ages (with standard deviations in brackets) of subjects in each of the four reading groups are presented below.

Table 4.22 Means age (in months) of dyslexics, slow learners, borderline poor readers and normal readers at Phase 1

	dyslexics	slow learners	borderline poor readers	normal readers
mean age	57.67 (7.71)	55.207 (3.08)	57.37 (7.21)	58.55 (8.51)

The means (and standard deviations) for the Phase 4 reading groups on the tests administered in Phase 1 are presented in table 4.23.

Table 4.23 Means (and standard deviations) of the performance of dyslexics, slow learners and control subjects on the Phase 1 measures

Test	dyslexic	slow learners	borderline poor reader	normal readers
BPVS percentile rank	49.25 (24.67)	22.90 (14.40)	54.95 (26.64)	60.54 (28.87)
BAS Copying percentile	32.94 (23.81)	31.60 (23.70)	54.95 (24.24)	65.28 (24.21)
BAS Block design percentile	73.33 (21.85)	48.10 (19.67)	56.61 (24.83)	69.40 (25.91)
BAS Naming Vocab percentile	49.22 (25.31)	30.30 (21.53)	53.92 (25.58)	55.25 (27.53)
BAS Basic no skills percentile	50.56 (28.71)	16.75 (9.49)	47.45 (16.12)	63.19 (24.97)
BAS Verbal Comp percentile	45.50 (32.43)	32.00 (17.16)	43.53 (22.45)	47.02 (25.78)
BAS Recall digits percentile	47.28 (31.14)	42.15 (28.53)	55.87 (23.52)	68.74 (23.56)
BAS Verbal Fluency percentile	52.00 (29.98)	39.05 (24.33)	47.68 (24.86)	59.68 (26.68)
BAS V-T Matching percentile	53.94 (30.33)	20.80 (14.76)	58.55 (25.61)	60.69 (26.84)
BAS Visual Recog percentile	51.78 (32.95)	49.65 (32.50)	62.55 (31.42)	71.76 (25.98)
BAS Match LLF percentile	55.19 (23.97)	25.67 (12.49)	52.53 (24.61)	57.40 (22.84)
BAS IQ score	100.88 (13.89)	89.40 (5.10)	103.58 (9.62)	109.43 (10.40)
Mean Pegboard time	24.41 (8.98)	23.86 (5.07)	19.79 (3.15)	19.57 (3.79)
Beads	5.78 (2.31)	5.20 (1.03)	5.63 (1.91)	6.29 (1.60)
Balance both feet	1.56 (1.40)	1.90 (1.45)	0.87 (0.88)	1.18 (1.07)
Balance romberg	4.88 (1.77)	6.15 (5.28)	6.84 (5.30)	7.06 (5.46)
Balance blindfold both feet	1.63 (1.55)	1.75 (0.89)	2.47 (3.96)	2.47 (2.86)
Balance blindfold romberg	5.88 (4.21)	10.15 (8.19)	7.55 (5.62)	7.37 (4.36)
Phon Discrimination (hits)	78.14 (32.23)	86.30 (15.31)	88.58 (14.32)	93.64 (9.60)
Phon Discrimination (rej's)	84.86 (21.56)	87.10 (17.64)	92.21 (14.01)	92.09 (12.58)
Nonword Repetition	19.33 (4.58)	15.70 (4.30)	18.79 (5.92)	20.85 (4.69)
Rhyming Condition 1	6.44 (2.70)	4.90 (1.20)	7.83 (1.86)	8.42 (1.76)
Rhyming Condition 2	5.78 (1.79)	5.10 (1.10)	7.78 (1.80)	8.00 (1.79)
Rhyming Condition 3	5.44 (1.67)	4.40 (0.97)	6.78 (2.32)	7.65 (1.82)
Lexical Access score	73 57 (13.51)	69.67 (12.32)	77.42 (22.41)	83.26 (10.19)
Lexical Access median time	0.66 (0.30)	0.87 (0.31)	0.88 (0.30)	0.95 (0.33)
Mean Articulation Rate	3.02 (0.64)	3.32 (0.66)	2.96 (0.61)	2.70 (0.47)
Naming pictures score	11.22 (2.33)	11.80 (0.42)	11.90 (0.32)	11.79 (0.41)
Naming pictures median time	0.96 (0.26)	1.18 (0.32)	1.00 (0.14)	1.02 (0.23)
Naming colours score	5.56 (0.88)	5.60 (0.70)	5.73 (0.93)	5.79 (0.82)
Naming colours median time	0.96 (0.31)	1.07 (0.20)	1.09 (0.29)	1.02 (0.35)
Naming numbers score	5.67 (3.46)	2.40 (2.91)	6.53 (2.34)	7.28 (1.81)
Naming numbers median time	0.89 (0.26)	1.05 (0.38)	1.35 (0.91)	0.95 (0.34)
Naming letters score	3.78 (2.77)	0.60 (0.84)	4.16 (3.04)	5.98 (2.41)
Naming letters median time	1.34 (0.60)	1.60 (1.08)	1.89 (1.12)	1.39 (0.75)
Prepositions score	9.25 (0.89)	8.33 (1.41)	9.22 (1.00)	9.20 (1.15)
Visual Search number found	10.33 (1.41)	9.50 (3.24)	10.78 (1.63)	10.98 (2.29)
Visual Search mean time	0.20 (0.08)	0.25 (0.09)	0.25 (0.10)	0.26 (0.12)
Clapping	2.33 (1.58)	2.11 (0.93)	3.06 (1.03)	3.71 (1.05)

Table 4.24 indicates F values and significance of the differences in performance of the groups on each test given in Phase 1 (df was 3 in all cases). For each separate analysis of variance, a Tukey-Kramer post hoc test was performed to examine if there were significant differences between particular groups. Post hoc differences are indicated in the final columns of the table.

<u>key</u>		
	*	$p < 0.05$
	**	$p < 0.01$
	***	$p < 0.001$
	ns	not significant

Table 4.24 Significance of differences in performance of the dyslexics, slow learners and control subjects on the Phase 1 measures (with post hoc analyses)

Test	F (df = 3)	p value	Post Hoc analyses D vs SL	D vs BPR	D vs NR	SL vs BPR	SL vs NR	BPR vs NR
BPVS percentile rank	6.792	***	ns	ns	ns	**	**	ns
BAS Copying percentile	8.773	***	ns	ns	**	ns	**	ns
BAS Block design percentile	3.134	*	ns	ns	ns	ns	ns	ns
BAS Naming Vocab percentile	2.586	ns	ns	ns	ns	ns	*	ns
BAS Basic no skills percentile	12.551	***	**	ns	ns	**	**	ns
BAS Verbal Comp percentile	1.014	ns	ns	ns	ns	ns	ns	ns
BAS Recall digits percentile	4.799	**	ns	ns	ns	ns	*	ns
BAS Verbal Fluency percentile	2.251	ns	ns	ns	ns	ns	ns	ns
BAS V-T Matching percentile	6.752	***	ns	ns	ns	**	**	ns
BAS Visual Recog percentile	2.630	ns	ns	ns	ns	ns	ns	ns
BAS Match LLF percentile	5.113	**	*	ns	ns	*	**	ns
BAS IQ score	11.720	***	ns	ns	ns	**	**	ns
Mean Pegboard time	4.802	**	ns	ns	*	ns	*	ns
Beads	1.614	ns	ns	ns	ns	ns	ns	ns
Balance both feet	2.152	ns	ns	ns	ns	ns	ns	ns
Balance romberg	0.451	ns	ns	ns	ns	ns	ns	ns
Balance blindfold both feet	0.334	ns	ns	ns	ns	ns	ns	ns
Balance blindfold romberg	1.120	ns	ns	ns	ns	ns	ns	ns
Phon Discrimination (hits)	3.095	*	ns	ns	*	ns	ns	ns
Phon Discrimination (rej's)	0.829	ns	ns	ns	ns	ns	ns	ns
Nonword Repetition	3.394	*	ns	ns	ns	ns	*	ns
Rhyming Condition 1	11.802	***	ns	ns	*	**	**	ns
Rhyming Condition 2	10.851	***	ns	*	**	**	**	ns
Rhyming Condition 3	10.741	***	ns	ns	**	**	**	ns
Lexical Access score	3.173	*	ns	ns	ns	ns	*	ns
Lexical Access median time	1.709	ns	ns	ns	ns	ns	ns	ns
Mean Articulation Rate	4.060	**	ns	ns	ns	ns	*	ns
Naming pictures score	1.573	ns	ns	ns	ns	ns	ns	ns
Naming pictures median time	1.811	ns	ns	ns	ns	ns	ns	ns
Naming colours score	0.296	ns	ns	ns	ns	ns	ns	ns
Naming colours median time	0.380	ns	ns	ns	ns	ns	ns	ns
Naming numbers score	13.545	***	*	ns	ns	**	**	ns
Naming numbers median time	2.902	*	ns	ns	ns	ns	ns	*
Naming letters score	14.432	***	ns	ns	ns	**	**	ns
Naming letters median time	1.556	ns	ns	ns	ns	ns	ns	ns
Visual Search number found	1.320	ns	ns	ns	ns	ns	ns	ns
Visual Search mean time	0.683	ns	ns	ns	ns	ns	ns	ns
Prepositions score	1.616	ns	ns	ns	ns	ns	ns	ns
Clapping	8.451	***	ns	ns	**	ns	**	ns

It can be seen from the table above that there were no significant differences between the performance of the dyslexics, slow learners and the two control groups on eighteen of the measures administered to subjects in Phase 1 of the study. These measures included: the BAS Verbal Comprehension, Verbal Fluency and Visual Recognition subtests, the Beads task, Prepositions, Visual Search (number found and mean time), Phonological Discrimination (correct rejection of nonwords), Naming score for pictures and colours, Naming time for pictures, colours and letters, Lexical Access median time and all four conditions of the Balance Task.

There were, however, significant differences between at least one of the four groups on the remaining twenty measures. In a number of cases this difference was only found to be significant between the slow learners and the normal readers. This was found to be the case for BAS Naming Vocabulary, BAS Recall of Digits, mean Articulation Rate, Nonword Repetition and Lexical Access percentage score (all at $p<0.05$). However, for other tests, differences between the performance of the groups were more varied and is outlined in more detail below.

(a) Tests on which dyslexics performed differently to control subjects

The tests on which the dyslexic subjects performed significantly differently to the control subjects are outlined below.

(i) BAS Copying: The dyslexic subjects performed significantly worse on this test than the normal readers ($p<0.01$). Their mean score was similar to that of the slow learners, whose performance was also significantly different from the normal readers at the $P<0.01$ level. The mean percentile scores for the dyslexics and slow learners on this test were 32.94 and 31.60 respectively compared to a percentile of 65.28 for the normal readers.

(ii) Pegboard Task: The mean time of completion of the pegboard task of the dyslexic subjects was significantly slower than that of the normal readers ($p<0.05$). However, their mean time for this task was similar to the slow learners who also differed at the $p<0.05$ level of significance from the normal readers. Dyslexics and slow learners took an average of 24.41 seconds and 23.86 seconds respectively to complete the pegboard task across the five trials, compared to a mean time of 19.57 seconds for the normal readers.

(iii) Phonological Discrimination Task (mean percentage for hits): The percentage of real words correctly identified by dyslexic subjects was significantly less than that of the normal readers ($p<0.05$).

(iv) Rhyming Condition 1 (last sound different): The number of pairs of rhyming words and non-rhyming words correctly identified by the dyslexic subjects was significantly lower than that for the normal readers ($p<0.05$). In addition, the slow learners scored significantly lower than both the normal and the borderline poor readers on this test ($p<0.01$).

(v) Rhyming Condition 2 (middle sound different): The dyslexic subjects were found to have scored significantly lower than the normal readers (at the $p<0.01$ significance level) and the borderline poor readers (at the $p<0.05$ significance level) on this test. The slow learners also scored at significantly lower levels than the normal and borderline poor readers ($p<0.01$).

(vi) Rhyming Condition 3 (alliteration): In the final condition of this test it was found that dyslexics scored significantly lower than the normal readers ($p<0.01$). As in the case of the other two condition of the Rhyming task, the slow learners were significantly outperformed by the normal and borderline poor readers ($p<0.01$)

(vii) Clapping: The dyslexic subjects scored at lower levels than control subjects on this simple test of rhythm ($p<0.01$).

(b) Tests on which dyslexics performed differently to slow learners

(i) BAS Basic Number Skills: Dyslexics (as well as borderline poor readers and normal readers) scored at significantly higher levels on this test than the slow learners ($p<0.01$).

(ii) BAS Matching Letter Like Forms: At the $p<0.05$ significance level, dyslexics (and borderline poor readers) were observed to outperform the slow learners on this test.

(iii) Naming numbers score: The dyslexic subjects were able to correctly name significantly more numbers than the slow learners ($p<0.05$)

4.7.3.2 Phase 2

The performance of the dyslexics, slow learners and control groups on the predictive tests administered in Phase 2 was analysed using a series of one factor analyses of variance. Again, the possibility of differences in the age of subjects in each of the reading groups was investigated using a one factor ANOVA, but this was found not to be significant (F= 0.666, df = 3, p= 0.5750) and the mean ages of the groups in this phase are presented in the table below.

Table 4.25 Means age of dyslexics, slow learners, borderline poor readers and normal readers at Phase 2

	dyslexics	slow learners	borderline poor readers	normal readers
mean age	73.83 (8.14)	69.60 (3.10)	71.76 (6.15)	72.77 (8.26)

Table 4.26 presents the mean scores for the dyslexic, slow learning and control subjects on the tests administered in Phase 2 of the study. Examination of the table provides an indication of the magnitude of the differences between scores and times on those tasks on which groups differently.

Table 4.26 Means (and standard deviations) of the performance of dyslexics, slow learners and control subjects on the Phase 2 measures

Test	dyslexics	slow learners	borderline poor readers	normal readers
BPVS Short form %ile	63.56 (28.71)	47.50 (20.33)	70.58 (16.59)	65.72 (26.59)
BAS Block design %ile	70.28 (16.20)	54.70 (21.00)	70.28 (25.33)	76.73 (23.42)
BAS Recall digits %ile	44.22 (35.64)	36.55 (14.24)	4.18 (23.57)	65.36 (20.09)
Pegboard Task	16.00 (3.12)	17.85 (3.19)	15.95 (2.04)	15.38 (2.58)
Beads	7.59 (2.93)	6.47 (1.83)	8.27 (2.36)	8.45 (2.09)
Nonword Repetition	19.33 (5.66)	20.10 (3.54)	22.47 (3.53)	23.79 (3.87)
Rhyming C1	7.44 (2.24)	6.90 (1.79)	9.05 (1.58)	9.43 (0.99)
Rhyming C2	7.56 (1.94)	6.60 (1.71)	8.00 (1.94)	8.87 (1.40)
Rhyming C3	7.22 (1.64)	6.30 (1.34)	8.21 (2.04)	8.94 (1.06)
Lexical Acces score	80.38 (13.69)	73.00 (8.73)	86.79 (8.05)	88.04 (7.59)
Lexical Access median time	0.80 (0.35)	0.86 (0.27)	0.92 (0.33)	0.89 (0.34)
Phonological Segmentation	5.67 (2.24)	4.20 (1.23)	6.79 (2.15)	9.23 (3.03)
Naming pictures	12.00 (0.00)	11.90 (0.32)	11.95 (0.23)	11.93 (0.27)
Naming pictures median time	0.92 (0.13)	1.12 (0.42)	0.91 (0.13)	0.93 (0.26)
Naming colours	6.00 (0.00)	5.90 (0.32)	6.00 (0.00)	6.00 (0.00)
Naming colours median time	0.74 (0.10)	0.80 (0.19)	1.01 (0.58)	0.87 (0.35)
Naming numbers	7.89 (0.33)	7.60 (0.70)	7.74 (0.56)	7.96 (0.19)
Naming numbers median time	0.77 (0.14)	0.95 (0.31)	0.86 (0.24)	0.81 (0.27)
Naming letters	6.56 (1.81)	5.60 (2.37)	6.00 (2.19)	7.60 (0.63)
Naming letters median time	0.85 (0.16)	1.41 (0.93)	1.21 (0.54)	0.96 (0.32)

Table 4.27 presents a summary of the results of the analyses of variance. F values, significance levels and post hoc differences are presented for each test.

Table 4.27 Significance and pattern of differences in performance between dyslexics, slow learners and control subjects on the Phase 2 measures

Test	F (df = 3)	p value	Post Hoc analyses D vs SL	D vs BPR	D vs NR	SL vs BPR	SL vs NR	BPR vs NR
BPVS Short form percentile	2.051	ns	ns	ns	ns	ns	ns	ns
BAS Block design percentile	2.672	*	ns	ns	ns	ns	*	ns
BAS Recall digits percentile	7.521	***	ns	ns	*	ns	**	*
Pegboard Task mean time	2.567	ns	ns	ns	ns	ns	*	ns
Beads mean score	2.438	ns	ns	ns	ns	ns	ns	ns
Nonword Repetition	4.940	**	ns	ns	*	ns	*	ns
Rhyming C1	13.101	***	ns	*	**	**	**	ns
Rhyming C2	6.740	***	ns	ns	ns	ns	**	ns
Rhyming C3	12.244	***	ns	ns	**	**	**	ns
Lexical Acces score	9.981	***	ns	ns	ns	**	**	ns
Lexical Access median time	0.260	ns	ns	ns	ns	ns	ns	ns
Phonological Segmentation	14.022	***	ns	ns	**	ns	**	**
Naming pictures score	0.308	ns	ns	ns	ns	ns	ns	ns
Naming pictures median time	1.739	ns	ns	ns	ns	ns	ns	ns
Naming colours score	2.868	ns	ns	ns	ns	ns	ns	ns
Naming colours median time	1.252	ns	ns	ns	ns	ns	ns	ns
Naming numbers score	3.418	*	ns	ns	ns	ns	**	ns
Naming numbers median time	1.115	ns	ns	ns	ns	ns	ns	ns
Naming letters score	9.401	***	ns	ns	ns	ns	**	**
Naming letters median time	3.818	**	ns	ns	ns	ns	*	ns

Examination of the ANOVA summary information in table 4.27 reveals that at least one of the groups of dyslexics, slow learners and control subjects differed from one another in their performance on twelve of the measures administered in Phase 2 of the study. On the remaining eight tests, there were no significant differences between the groups. These tests were: BPVS (Short Form), the Beads task, Naming score for pictures and colours, Naming median time for pictures, colours and numbers and Lexical Access median time.

As in Phase 1, a number of the differences observed between the groups resulted from a difference in performance between the slow learners and the normal readers (i.e. lower performance by the slow learners). This was the case for the BAS Block design test, the Pegboard Task, Condition 2 of the Rhyming and Naming letter median time (all at $p<0.05$) and Naming numbers score ($p<0.01$). Additionally, slow learners scored significantly lower than either or both of the control groups on Nonword Repetition, Rhyming Condition 1, Naming letters score and Lexical Access score.

(a) Tests on which dyslexics scored significantly differently to control subjects.

There were fewer tests in this phase on which dyslexics scored at significantly lower levels than control subjects.

(i) Rhyming Condition 1 (last sound different): Dyslexic subjects scored significantly less on this test than the normal readers ($p<0.01$) and the borderline poor readers ($p<0.05$). However, slow learners also scored poorly on this task.

(ii) Rhyming Condition 3 (alliteration): The dyslexic subjects were found to have scored significantly less well in their ability to correctly identify pairs of words that did and did not begin with the same letter in comparison to the normal reading subjects ($p<0.01$). Slow learners were also significantly outperformed by the control subjects on this task.

(ii) Phonological Segmentation: The dyslexic subjects (and also slow learners and borderline poor readers) scored at very significantly lower levels compared to normal readers on the test of Phonological Segmentation skills which was administered in this phase ($p<0.01$)

(b) Tests on which dyslexics performed differently to slow learners

There were no tests in this phase on which dyslexics scored significantly better or worse than the slow learning subjects.

4.7.3.3 Phase 2 reading

The other measure administered to subjects in Phase 2, the BAS Test of Word Reading, was also analysed to examine possible differences in the performance of the dyslexics, slow learners and control subjects at this stage. Using a one factor analysis of variance, it was found that even at this early point in the children's schooling, the four groups differed significantly from one another in terms of their percentile score on this test ($F= 45.777$, $df = 3$, $p< 0.0001$). Post hoc analyses revealed that the reading performance of the normal readers at Phase 2 was significantly better than that for all other groups at the $p<0.01$ level. The slow learners and the borderline poor readers also differed significantly in their performance on this test ($p<0.05$). The mean scores for the four groups are presented in the table below.

Table 4.28 Mean performance of the dyslexics, slow learners and control subjects on the BAS Test of Word Reading administered at Phase 2 (percentiles)

	dyslexics	slow learners	borderline poor readers	normal readers
mean age	19.89 (14.97)	14.00 (11.08)	34.50 (13.51)	69.16 (20.74)

4.7.3.4 Phase 3

To investigate possible differences in the performance of the diagnostic and control groups on the criterion measures administered in Phase 3, a series of one factor analyses of variance were carried out. Potential differences in the age of subjects in each of the groups was investigated using a one factor ANOVA, but this was found not to be significant (F= .340, df = 3, p= 0.7967). The mean ages of the groups in this Phase are presented in the table below (with standard deviation in brackets).

Table 4.29 Means age of dyslexics, slow learners, borderline poor readers and normal readers at Phase 3 (months)

	dyslexics	slow learners	borderline poor readers	normal readers
mean age	81.22 (5.76)	77.60 (4.14)	78.79 (5.41)	79.77 (10.35)

The mean scores for the Phase 4 groups on the tests administered in Phase 3 are presented in table 4.30 below and the significance of the differences in performance between the groups are outlined in table 4.31.

Table 4.30 Means (and standard deviations) of the performance of dyslexics, slow learners and control subjects on the Phase 3 measures

Test	dyslexics	slow learners	borderline poor readers	normal readers
BAS Matrices percentile	71.67 (21.75)	72.10 (13.78)	73.16 (14.07)	82.16 (17.39)
BAS Similarities percentile	68.39 (24.63)	70.80 (17.43)	81.24 (17.50)	84.24 (15.73)
BAS Naming Vocab percentile	51.83 (26.99)	49.30 (29.69)	57.61 (28.04)	69.62 (25.97)
BAS Block Design percentile	67.50 (17.66)	52.00 (23.86)	70.16 (19.37)	82.78 (18.93)
BAS Recall digits percentile	29.28 (25.82)	41.00 (26.18)	45.11 (28.36)	62.39 (21.77)
BAS IQ score	105.00 (10.61)	104.00 (8.67)	110.47 (7.78)	117.09 (17.23)
BAS Basic no skills percentile	58.28 (29.34)	48.22 (20.89)	67.21 (21.21)	73.93 (26.93)
Number age (months)	82.78 (10.64)	75.33 (10.05)	82.74 (5.66)	87.86 (9.22)
BAS Word Reading percentile	23.22 (12.76)	18.72 (7.76)	37.66 (6.33)	74.78 (18.85)
BAS Word Reading RA (mo)	71.67 (8.25)	67.50 (6.01)	75.11 (6.28)	96.15 (22.69)
Neale RA (months)	76.11 (8.21)	72.80 (7.42)	80.32 (6.60)	97.32 (14.09)
Schonell RA (months)	65.11 (7.51)	61.44 (1.51)	68.56 (6.90)	90.24 (21.45)
Composite RA (months)	70.96 (7.46)	67.82 (5.51)	75.00 (6.53)	94.51 (18.78)
BAS Spelling percentile	36.00 (9.78)	40.06 (14.55)	50.66 (14.04)	71.82 (17.08)
BAS Spelling age (months)	76.89 (4.51)	72.80 (7.21)	79.32 (4.70)	89.91 (11.33)
Reading comprehension age (mo)	79.80 (4.09)	78.00 (2.45)	76.07 (19.36)	94.49 (13.45)
Listening comprehension score	15.11 (5.09)	9.30 (5.42)	13.47 (5.09)	13.17 (5.60)
Listening comprehension age (mo)	106.56 (11.85)	90.90 (11.04)	101.50 (10.70)	101.56 (13.12)
Alphabet	47.00 (7.23)	40.90 (14.05)	46.53 (8.30)	51.32 (1.64)

Table 4.31 Significance and pattern of differences in performance of dyslexics, slow learners and control subjects on the Phase 3 measures

Test	F (df = 3)	p value	Post Hoc analyses: D vs SL	D vs BPR	D vs NR	SL vs BPR	SL vs NR	BPR vs NR
BAS Matrices percentile	2.408	ns	ns	ns	ns	ns	ns	ns
BAS Similarities percentile	3.343	*	ns	ns	ns	ns	ns	ns
BAS Naming Vocab percentile	2.638	ns	ns	ns	ns	ns	ns	ns
BAS Block Design percentile	8.240	***	ns	ns	ns	ns	**	ns
BAS Recall digits percentile	7.019	***	ns	ns	**	ns	ns	*
BAS IQ score	3.834	**	ns	ns	ns	ns	*	ns
BAS Basic no skills percentile	3.158	*	ns	ns	ns	ns	*	ns
Number age (months)	6.001	***	ns	ns	ns	ns	**	ns
BAS Word Reading percentile	64.551	***	ns	ns	**	*	**	**
BAS Word Reading RA (mo)	13.278	***	ns	ns	**	ns	**	**
Neale RA (months)	22.014	***	ns	ns	**	ns	**	**
Schonell RA (months)	14.561	***	ns	ns	**	ns	**	**
Composite RA (months)	16.727	***	ns	ns	**	ns	**	**
BAS Spelling percentile	23.467	***	ns	ns	**	ns	**	**
BAS Spelling age (months)	14.877	***	ns	ns	**	ns	**	**
Reading comprehension age (mo)	6.762	***	ns	ns	ns	ns	ns	**
Listening comprehension score	2.066	ns	ns	ns	ns	ns	ns	ns
Listening comprehension age (mo)	2.888	*	*	ns	ns	ns	ns	ns
Alphabet	8.830	***	ns	ns	ns	ns	*	*

The summary table of ANOVA calculations for the Phase 3 measures reveals a general pattern of significant differences in performance between the normal readers and the other three groups. Examination of the means table, table 4.30, shows that this is due in most cases to superior performance of the normal readers on the tests administered. There were no significant differences between any of the groups on BAS Matrices, BAS Naming vocabulary and Listening comprehension score.

(a) Tests on which dyslexics performed differently to control subjects

Dyslexics performed at lower levels than control subjects on BAS Recall digits, BAS Word Reading, Neale reading and the BAS Spelling scale ($p<0.01$).

(b) Tests on which dyslexics performed differently to slow learners

The dyslexic subjects performed at higher levels than the slow learners on the test of Listening comprehension ($p<0.05$), but only when the scores for this test were converted to Listening comprehension ages.

4.7.4 Differences in laterality of the dyslexic, slow learning and other subjects

One of the predictive tests administered in Phase 1 of the study measured the laterality of the subjects and results from this were reported in terms of the number of test items that were carried out with the right or left side. This data was not analysed using analysis of variance as it was felt that the most interesting aspects of the data would have been lost in the analysis (the side that was used most often and incidence of mixed laterality). Therefore the following table presents the laterality of the dyslexic and slow learning subjects. The figures indicate the number of the 20 items of the test that were performed with each side. Odd numbers indicate that an item was performed once with one side and once with the other (i.e. incidence of unresolved laterality). The outcomes for the two groups are compared and are also related to those of the control subjects. Full laterality data for all subjects is located in Appendix 4.6.

Table 4.32 Performance of the dyslexic and slow learning subjects on the test of laterality

Subject	Laterality	
	Right	Left
Dys 1 (JD)	13	7
Dys 2 (LC)	16	4
Dys 3 (RB)	12	8
Dys 4 (JB)	12	8
Dys 5 (AN)	19	1
Dys 6 (CS)	20	0
Dys 7 (SJ)	12	8
Dys 8 (TR)	16	4
Dys 9 (LH)	18	2
mean	**15.33**	**4.76**
SD	**3.20**	**3.20**
SL 1 (GR)	17	3
SL 2 (AB)	9	11
SL 3 (KL)	15	5
SL 4 (LB)	15	5
SL 5 (JM)	16	4
SL 6 (AJ)	18	2
SL 7 (KG)	12	8
SL 8 (JB)	12	8
SL 9 (SM)	14	6
SL 10 (RL)	17	3
mean	**14.50**	**5.50**
SD	**2.66**	**2.66**

The above table indicates that mean number of times an item was performed on the right and the left side by the slow learners and the dyslexic subjects. The mean laterality scores for the borderline poor readers and the normal readers are also illustrated below.

Subject	Laterality	
	Right	Left
Borderline poor readers		
mean	15.50	4.50
SD	3.48	3.48
Normal readers		
mean	16.16	3.84
SD	3.03	3.03

The results indicate that the slow learners had the highest incidence of non-right laterality on the test whereas the normal readers had the lowest incidence. The dyslexic and borderline readers performed similarly to each other in terms of the use of the right and left side for carrying out test items. Closer inspection of the data reveals that five of the ten slow learners performed test items with a different side for each of the two trials compared to only two of the dyslexics. It therefore appears that the slow learners have the greater degree of non-right sidedness and unresolved laterality.

4.8 Effect size analysis of the performance of the dyslexics, slow learners and control groups

An effect size analysis was carried out to examine the relative differences between the performance of the dyslexics, slow learners, borderline poor readers and normal readers on the measures administered in Phases 1, 2 and 3 of the study. The procedures for calculation of the effect sizes were the same as those outlined in section 4.5 above. Full effect size data and summary data for Phases 1, 2 and 3 can be found in Appendix 4.7.

4.8.1 Mean effect sizes and effect size graphs

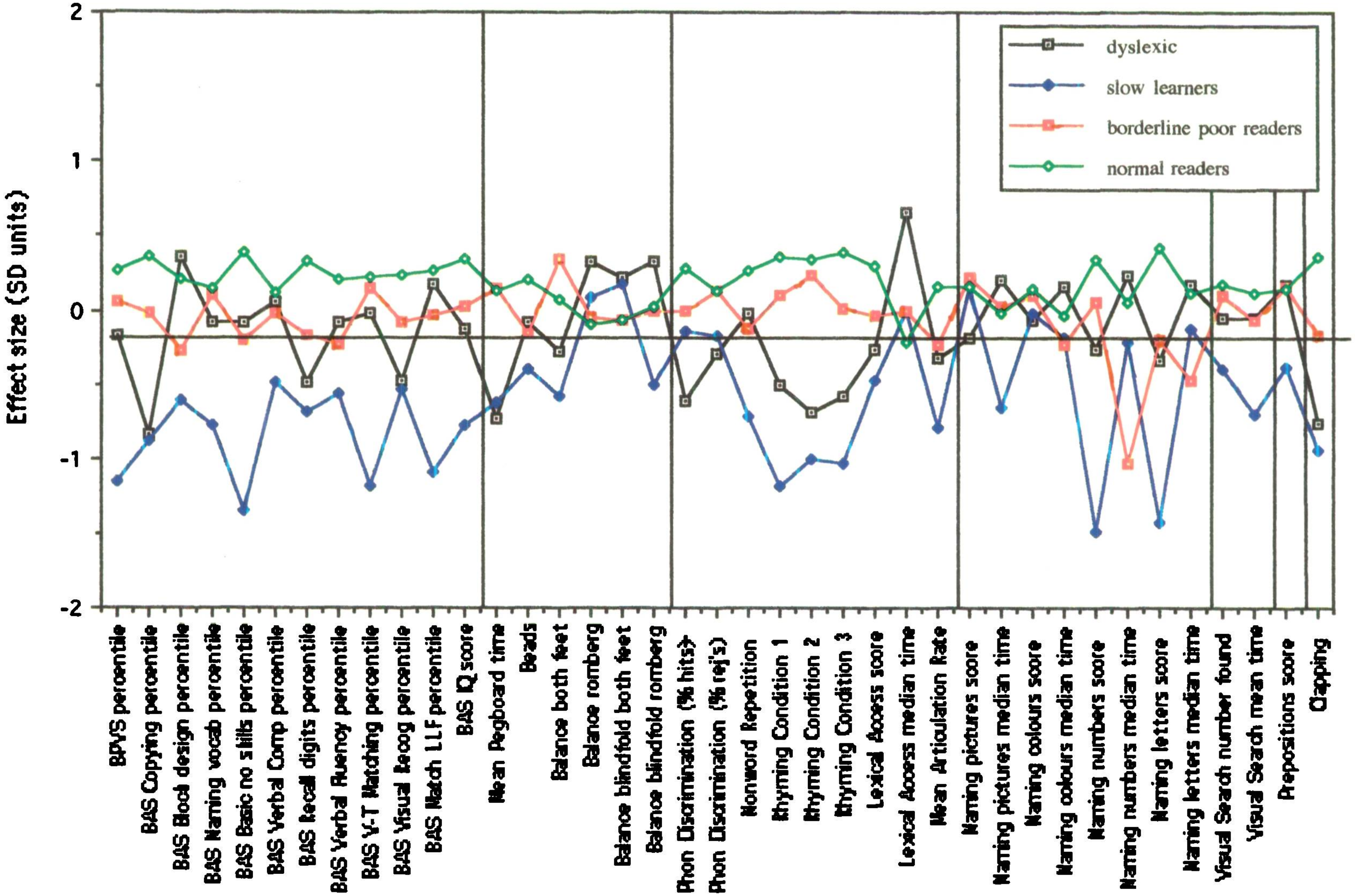
(a) Phase 1

Table 4.33 presents the mean effect sizes for each of the diagnostic and control groups on the tests administered in Phase 1. These data are also presented in the form of a graph in Figure 4.5. The graph indicates the performance of the four groups as a continuous line across all tests. Again, the tests are listed according to the skill which they were designed to measure (general ability, motor skills, etc.) along the x-axis of the graph. The mean score for all subjects in shown by a horizontal line running through the graph from point 0 on the y - axis. The position of each group with respect to the mean for all subjects is illustrated by the position of the line representing it. The units of measurement for the graph are standard deviation scores or effect sizes.

Table 4.33 Mean effect sizes for the dyslexics, slow learners and control groups on Phase 1 measures.

Test	dyslexics	slow learners	borderline poor readers	normal readers
BPVS percentile	-0.17	-1.16	0.05	0.26
BAS Copying percentile	-0.84	-0.89	-0.03	0.36
BAS Block design percentile	0.36	-0.61	-0.28	0.21
BAS Naming vocab percentile	-0.08	-0.78	0.10	0.15
BAS Basic no skills percentile	-0.09	-1.35	-0.20	0.38
BAS Verbal Comp percentile	0.06	-0.49	-0.02	0.12
BAS Recall digits percentile	-0.49	-0.69	-0.17	0.32
BAS Verbal Fluency percentile	-0.08	-0.57	-0.24	0.21
BAS V-T Matching percentile	-0.02	-1.18	0.15	0.22
BAS Visual Recog percentile	-0.47	-0.54	-0.09	0.23
BAS Match LLF percentile	0.18	-1.09	-0.04	0.27
BAS IQ score	-0.13	-0.77	0.02	0.34
Mean Pegboard time	-0.73	-0.63	0.14	0.13
Beads	-0.08	-0.40	-0.16	0.21
Balance both feet	-0.28	-0.58	0.34	0.07
Balance romberg	0.33	0.08	-0.05	-0.10
Balance blindfold both feet	0.22	0.18	-0.07	-0.07
Balance blindfold romberg	0.32	-0.51	0	0.03
Phon Discrimination (% hits)	-0.61	-0.14	-0.01	0.28
Phon Discrimination (% rej's)	-0.30	-0.17	0.13	0.13
Nonword Repetition	-0.03	-0.71	-0.13	0.26
Rhyming Condition 1	-0.51	-1.18	0.10	0.36
Rhyming Condition 2	-0.69	-1.00	0.23	0.34
Rhyming Condition 3	-0.58	-1.04	0.01	0.39
Lexical Access score	-0.26	-0.48	-0.04	0.30
Lexical Access median time	0.66	0	-0.01	-0.22
Mean Articulation Rate	-0.33	-0.79	-0.23	0.16
Naming pictures score	-0.19	0.16	0.22	0.16
Naming pictures median time	0.21	-0.66	0.03	-0.02
Naming colours score	-0.07	-0.03	0.10	0.15
Naming colours median time	0.16	-0.19	-0.23	-0.04
Naming numbers score	-0.27	-1.49	0.05	0.34
Naming numbers median time	0.23	-0.22	-1.04	0.06
Naming letters score	-0.34	-1.42	-0.21	0.41
Naming letters median time	0.17	-0.13	-0.47	0.12
Visual Search number found	-0.06	-0.40	0.10	0.18
Visual Search mean time	-0.06	-0.70	-0.07	0.11
Prepositions score	0.18	-0.38	0.16	0.15
Clapping	-0.76	-0.94	-0.17	0.36

Figure 4.5 Graph to show mean effect sizes for dyslexics, slow learners, and control groups on Phase 1 measures.



From the graph and table 4.33 it can be seen that the general pattern of performance across all tests is such that the slow learners score at the poorest levels whereas the normal readers score at the highest level in most cases. The profile of performance for the dyslexic subjects is very varied with scores falling above the mean on some tests (e.g. BAS Block design, BAS Matching letter like forms, three conditions of the balance test, Lexical access median time and Naming median time), but on other tests performance is seen to fall well below the mean for all subjects. These tests include BAS Copying, BAS Recall of digits, the Pegboard task, Phonological discrimination (hits), all three conditions of the Rhyming task and Lexical Access score. Dyslexics also scored at relatively low levels on the test of Articulation rate and Naming of numbers and letters.

(b) Phase 2

The mean effect sizes for performance of the dyslexics, slow learners and control groups on predictive measures administered in Phase 2 are outlined in table 4.34 and shown in the form of a graph in figure 4.6.

Figure 4.6 Graph to show mean effect sizes for dyslexics, slow learners, and control groups on Phase 2 measures.

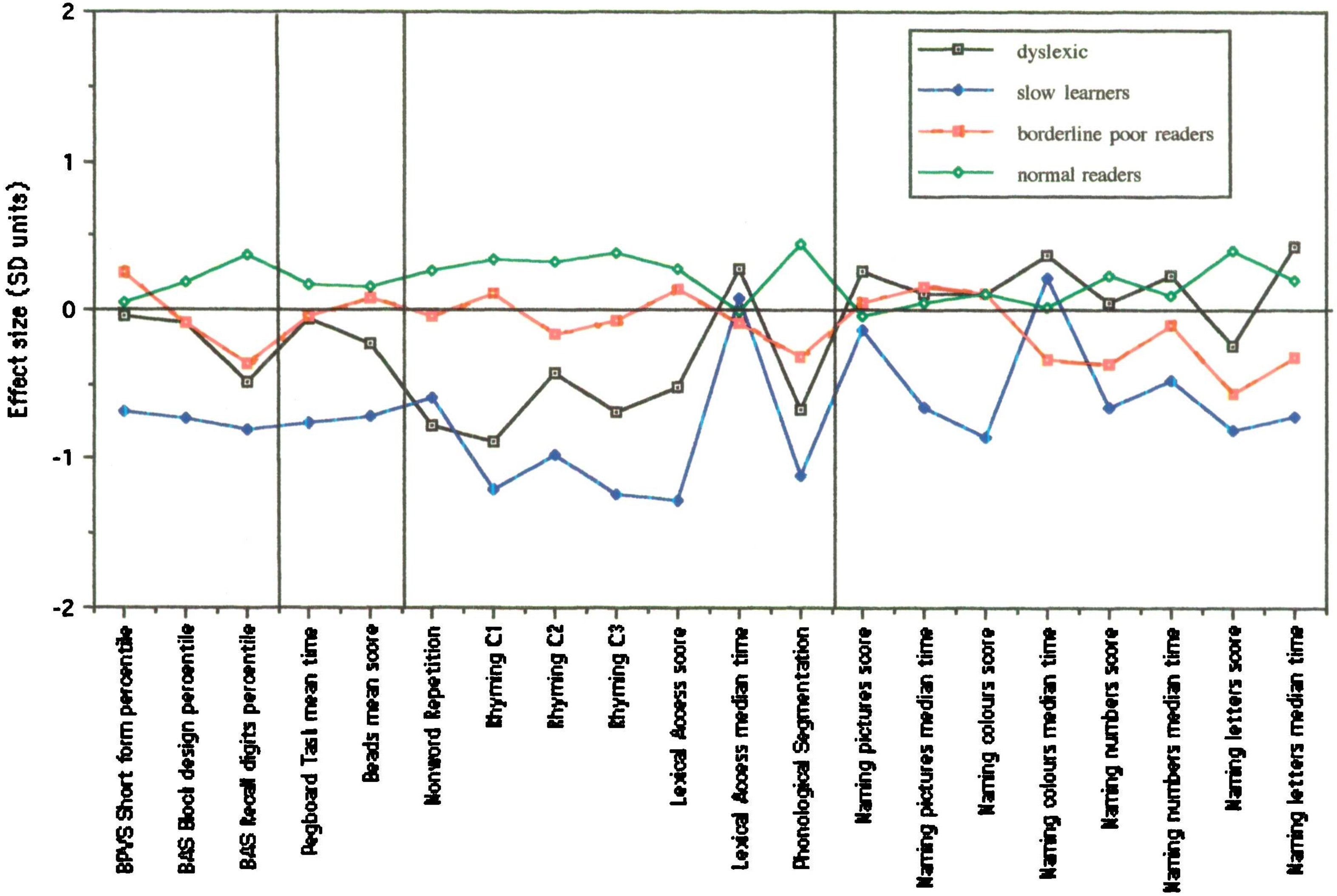


Table 4.34 Mean effect sizes for the dyslexics, slow learners and control groups on Phase 2 measures.

Test	dyslexics	slow learners	borderline poor readers	normal readers
BPVS Short form percentile	-0.04	-0.68	0.24	0.05
BAS Block design percentile	-0.09	-0.74	-0.09	0.19
BAS Recall digits percentile	-0.49	-0.81	-0.37	0.37
Pegboard Task mean time	-0.06	-0.76	-0.04	0.17
Beads mean score	-0.23	-0.72	0.07	0.15
Nonword Repetition	-0.78	-0.60	-0.05	0.26
Rhyming C1	-0.88	-1.21	0.11	0.34
Rhyming C2	-0.43	-0.97	-0.17	0.32
Rhyming C3	-0.68	-1.23	-0.08	0.38
Lexical Acces score	-0.52	-1.29	0.14	0.27
Lexical Access median time	0.27	0.07	-0.09	-0.02
Phonological Segmentation	-0.67	-1.12	-0.32	0.45
Naming pictures score	0.26	-0.14	0.05	-0.04
Naming pictures median time	0.11	-0.66	0.15	0.05
Naming colours score	0.10	-0.85	0.10	0.10
Naming colours median time	0.37	0.22	-0.33	0.01
Naming numbers score	0.05	-0.66	-0.36	0.23
Naming numbers median time	0.23	-0.47	-0.11	0.09
Naming letters score	-0.24	-0.81	-0.57	0.40
Naming letters median time	0.43	-0.72	-0.32	0.20

Examination of the graph and table reveals a pattern of performance on the Phase 2 measures which is similar to that found in Phase 1. The lowest scoring group on the majority of measures are again the slow learners and the highest scoring group, the normal readers. The performance of the dyslexics is again variable. The dyslexics scored at levels above the mean for all subjects on the Naming game in all conditions except for naming of letters and were at least as fast at naming the stimuli as the control groups. They also scored at relatively high levels on the Lexical access median time to respond. However, on all remaining measures, the dyslexics scored below the mean for all subjects , and particularly poorly on the Nonword repetition test, all conditions of Rhyming, Lexical access score and Phonological segmentation.

(c) Phase 3

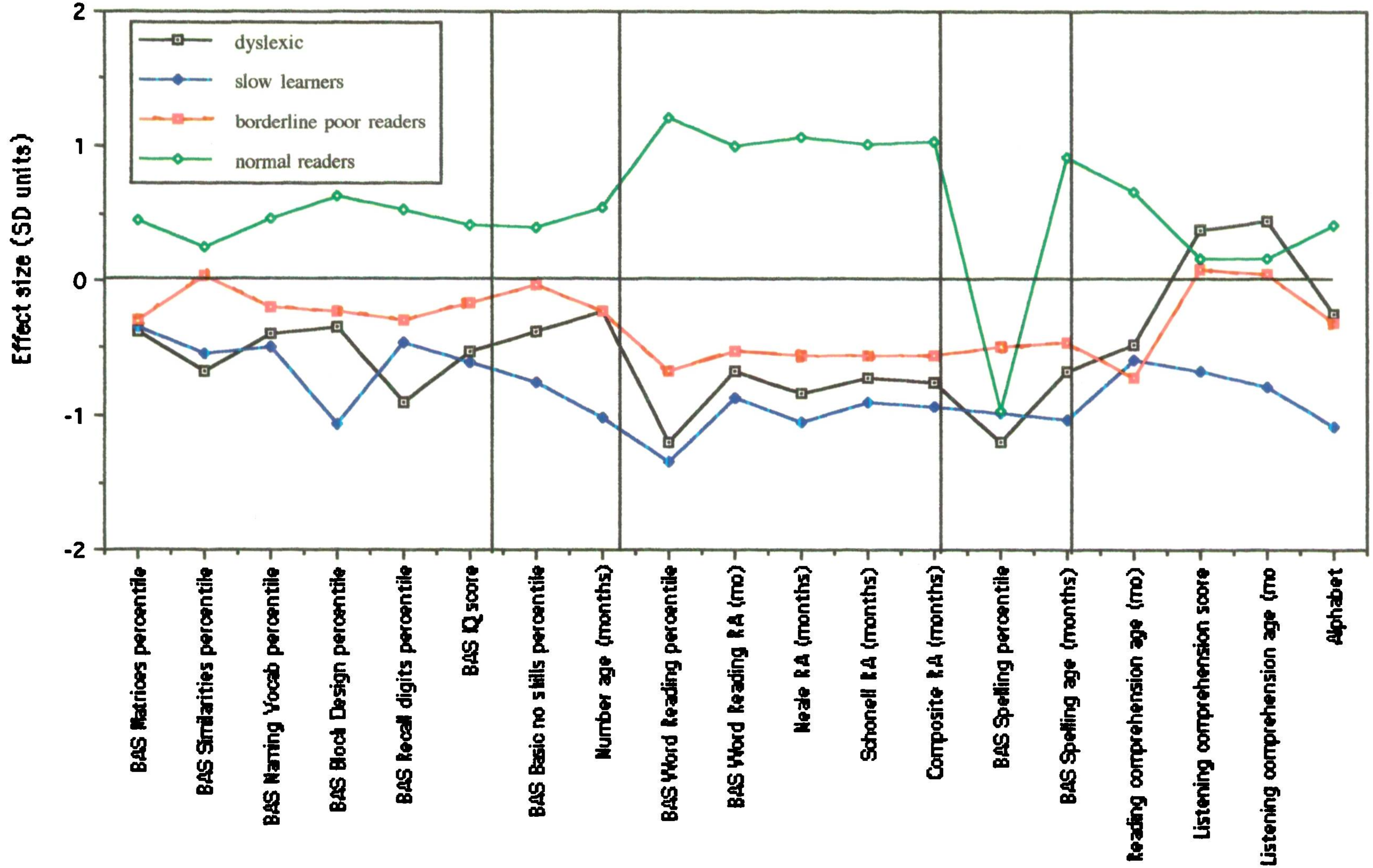
The mean effect sizes for performance of the dyslexics, slow learners and control groups on predictive measures administered in Phase 2 are outlined in table 4.35 and shown in the form of a graph in figure 4.7.

Table 4.35 Mean effect sizes for the dyslexics, slow learners and control groups on Phase 3 measures.

Test	dyslexics	slow learners	borderline poor readers	normal readers
BAS Matrices percentile	-0.37	-0.35	-0.29	0.45
BAS Similarities percentile	-0.68	-0.54	0.04	0.25
BAS Naming Vocab percentile	-0.40	-0.49	-0.19	0.46
BAS Block Design percentile	-0.35	-1.07	-0.23	0.62
BAS Recall digits percentile	-0.90	-0.46	-0.30	0.52
BAS IQ score	-0.53	-0.60	-0.17	0.41
BAS Basic no skills percentile	-0.38	-0.76	-0.04	0.40
Number age (months)	-0.23	-1.01	-0.23	0.54
BAS Word Reading percentile	-1.19	-1.35	-0.67	1.22
BAS Word Reading RA (mo)	-0.68	-0.87	-0.52	1.00
Neale RA (months)	-0.84	-1.05	-0.56	1.07
Schonell RA (months)	-0.72	-0.90	-0.55	1.01
Composite RA (months)	-0.76	-0.93	-0.55	1.04
BAS Spelling percentile	-1.19	-0.99	-0.49	-0.96
BAS Spelling age (months)	-0.67	-1.03	-0.46	0.92
Reading comprehension age (mo)	-0.47	-0.59	-0.72	0.65
Listening comprehension score	0.38	-0.67	0.09	0.16
Listening comprehension age (mo)	0.45	-0.78	0.05	0.16
Alphabet	-0.24	-1.09	-0.31	0.41

The relative performance of subjects on some of the tests administered in Phase 3 is predictable in the sense that it was the results of these tests that were used to define the groups (i.e. the reading measures), however, the performance of the diagnostic and control groups on the other measures was of interest. As in the case of the two predictive phases, performance of the slow learners tended to be the lowest of all groups on the criterion measures. Two interesting exceptions to this are the BAS Recall of digits test and the BAS Spelling scale, where the dyslexics are the lowest scoring group. The graph reveals that the normal readers have scored at significantly superior levels to the other three groups on almost all measures. Exceptions to this are the BAS Spelling scale, where their performance is very low, and the listening

Figure 4.7 Graph to show mean effect sizes for dyslexics, slow learners, and control groups on Phase 3 measures



comprehension test where they have scored at similar levels to the borderline poor readers but *below* the dyslexics. This is the one test administered in Phase 3 on which the dyslexics have scored above the mean for all subjects.

4.8.2 Incidence of poor scores in the dyslexics, slow learners and control groups

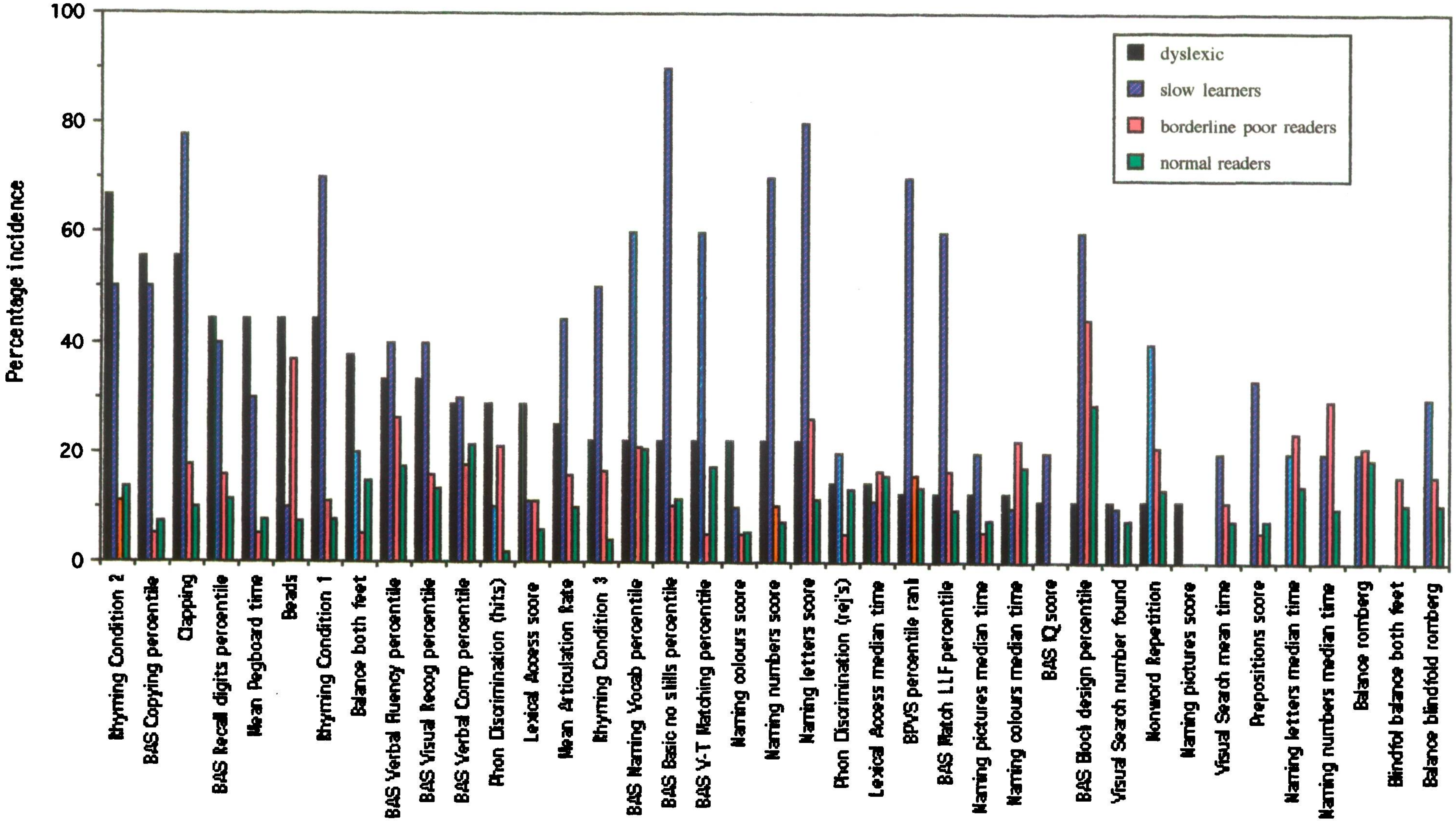
(a) Phase 1

On the basis of the standardisation of the performance of the four groups on the tests administered in Phases 1, 2 and 3, the incidence of poor scores on each test in the reading groups was examined. This was done as before, by defining *poor* scores as a score of one or more standard deviations below the mean (for all subjects) on a particular test. Table 4.36 outlines the percentage incidence of standard scores of -1 or lower on the Phase 1 predictive measures for each of the reading groups. The tests are ranked in order of greatest incidence of poor scores in the dyslexics group. The percentage incidence of poor scores for each of the groups is also illustrated as a bar chart in figure 4.8.

Table 4.36 Incidence of poor scores (standard deviation scores of -1 or lower) for predictive measures administered in Phase 1 for the dyslexics, slow learners and control groups

Test	Percentage incidence of scores of -1 SD or lower			
	dyslexics	**slow learners**	**borderline poor readers**	**normal readers**
Rhyming Condition 2	66.7	50	11.1	13.5
BAS Copying percentile	55.6	50	5.3	7.5
Clapping	55.6	77.8	17.6	9.8
BAS Recall digits percentile	44.4	40	15.8	11.3
Mean Pegboard time	44.4	30	5.3	7.7
Beads	44.4	10	36.8	7.5
Rhyming Condition 1	44.4	70	11.1	7.7
Balance both feet	37.5	20	5.3	14.6
BAS Verbal Fluency percentile	33.3	40	26.3	17.3
BAS Visual Recog percentile	33.3	40	15.8	13.2
BAS Verbal Comp percentile	28.6	30	17.6	21.3
Phon Discrimination (hits)	28.6	10	21.1	1.9
Lexical Access score	28.6	11.1	11.1	6
Mean Articulation Rate	25	44.4	15.8	9.8
Rhyming Condition 3	22.2	50	16.7	3.9
BAS Naming Vocab percentile	22.2	60	21.1	20.8
BAS Basic no skills percentile	22.2	90	10.5	11.3
BAS V-T Matching percentile	22.2	60	5.3	17.3
Naming colours score	22.2	10	5.3	5.7
Naming numbers score	22.2	70	10.5	7.5
Naming letters score	22.2	80	26.3	11.3
Phon Discrimination (rej's)	14.3	20	5.3	13.2
Lexical Access median time	14.3	11.1	16.7	16
BPVS percentile rank	12.5	70	15.8	13.5
BAS Match LLF percentile	12.5	60	16.7	9.6
Naming pictures median time	12.5	20	5.6	7.8
Naming colours median time	12.5	10	22.2	17.3
BAS IQ score	11.1	20	0	0
BAS Block design percentile	11.1	60	44.4	28.8
Visual Search number found	11.1	10	0	7.8
Nonword Repetition	11.1	40	21.1	13.2
Naming pictures score	11.1	0	0	0
Visual Search mean time	0	20	11.1	7.8
Prepositions score	0	33.3	5.6	7.8
Naming letters median time	0	20	23.5	14
Naming numbers median time	0	20	29.5	10
Balance romberg	0	20	21.1	18.8
Blindfold balance both feet	0	0	15.8	10.6
Balance blindfold romberg	0	30	15.8	10.6

Figure 4.8 Incidence of poor scores for measures administered in Phase 1 for the dyslexics, slow learners and control groups



A general pattern of decreased incidence across the groups is clear for many of the tests, with dyslexics having greatest incidence of poor scores followed by slow learners, then borderline poor readers and finally normal readers. Inspection of the table of incidence and bar chart reveals the tests with the highest incidence of poor scores (44 to 67%) in the dyslexic group to be tests of general ability (particularly BAS Copying), tests of phonological skills (Rhyming task conditions 1 and 2), motor skills tests (beads and pegboard tasks) and Clapping. Slow learning subjects were found to have very high incidence of poor scores on a number of tests including BAS Basic number skills (90%), Naming letters score (80%), Clapping (78%), Rhyming condition 1, Naming numbers score and BPVS (70%), BAS Naming vocabulary, BAS verbal-tactile matching, BAS Matching letter like forms and BAS Block design (60%). Figure 4.8 reveals that the incidence of poor scores for the slow learners was greater than that for the dyslexics across most of the Phase 1 tests.

(b) Phase 2

The percentage incidence of poor scores in the diagnostic and control groups on the Phase 2 measures is illustrated in table 4.37 and figure 4.9.

Figure 4.9 Incidence of poor scores for Phase 2 predictive measures for dyslexics, slow learners and control groups

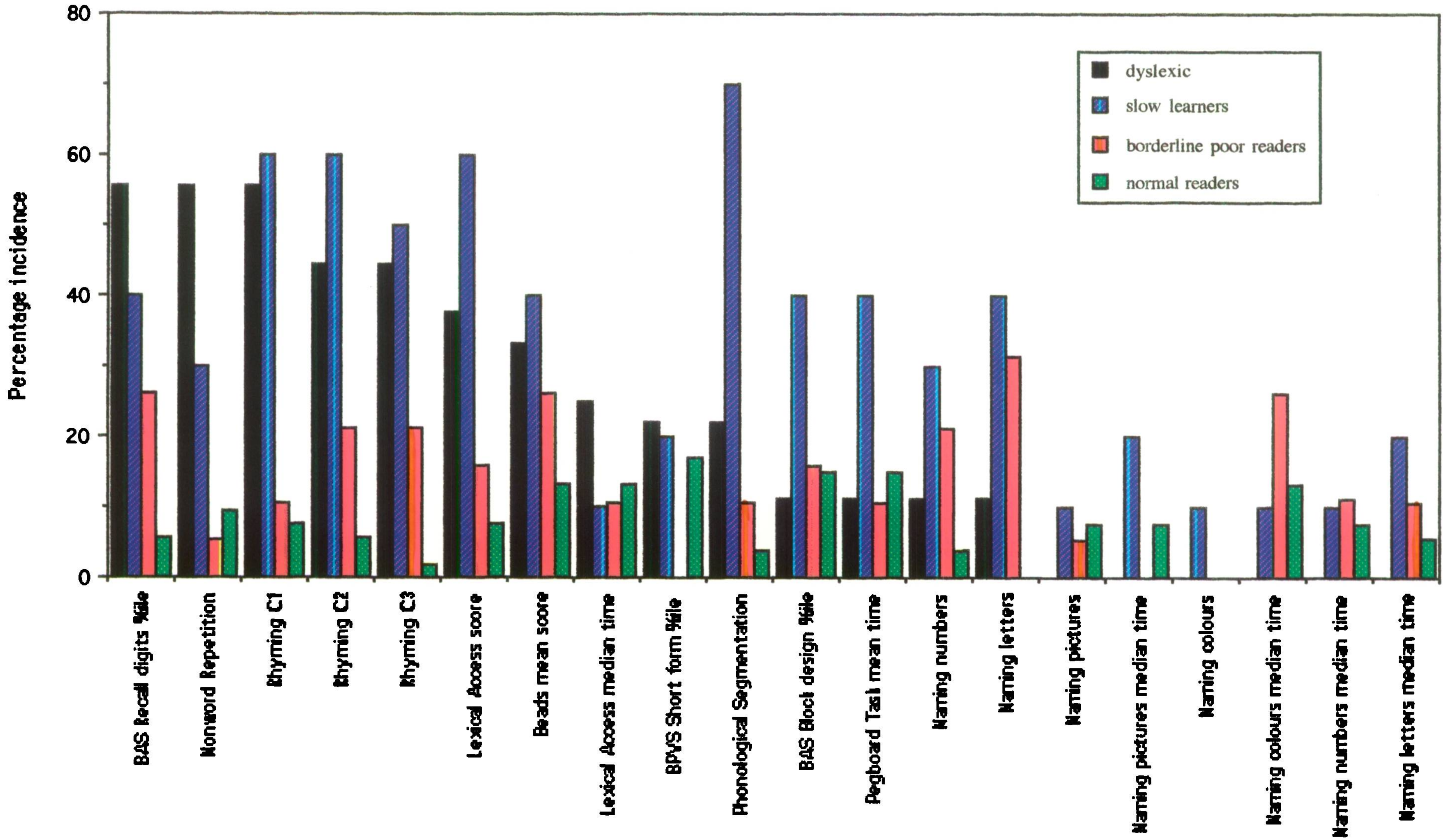


Table 4.37 Incidence of poor scores (standard deviation scores of -1 or lower) for predictive measures administered in Phase 2 for the dyslexics, slow learners and control groups.

	Percentage incidence of scores of -1 SD or lower			
Test	**dyslexics**	**slow learners**	**borderline poor readers**	**normal readers**
BAS Recall digits %ile	55.6	40	26.3	5.7
Nonword Repetition	55.6	30	5.3	9.4
Rhyming C1	55.6	60	10.5	7.5
Rhyming C2	44.4	60	21.1	5.7
Rhyming C3	44.4	50	21.1	1.9
Lexical Access score	37.5	60	15.8	7.5
Beads mean score	33.3	40	26.3	13.2
Lexical Access median time	25	10	10.5	13.2
BPVS Short form %ile	22.2	20	0	17
Phonological Segmentation	22.2	70	10.5	3.8
BAS Block design %ile	11.1	40	15.8	15.1
Pegboard Task mean time	11.1	40	10.5	15.1
Naming numbers	11.1	30	21.1	3.8
Naming letters	11.1	40	31.6	0
Naming pictures	0	10	5.3	7.5
Naming pictures median time	0	20	0	7.5
Naming colours	0	10	0	0
Naming colours median time	0	10	26.3	13.2
Naming numbers median time	0	10	11.1	7.5
Naming letters median time	0	20	10.5	5.7

Examination of the bar chart and table reveals that as in the case of Phase 1, the slow learners have the greatest proportion of poor scores across the range of Phase 2 tests, and the normal readers, the lowest proportion. The tests on which the dyslexic group were found to have relatively large proportions of poor scores were BAS Recall of digits, Nonword repetition and all three conditions of the Rhyming task (percentage incidence 44.4 - 55.6%).

(c) Phase 3

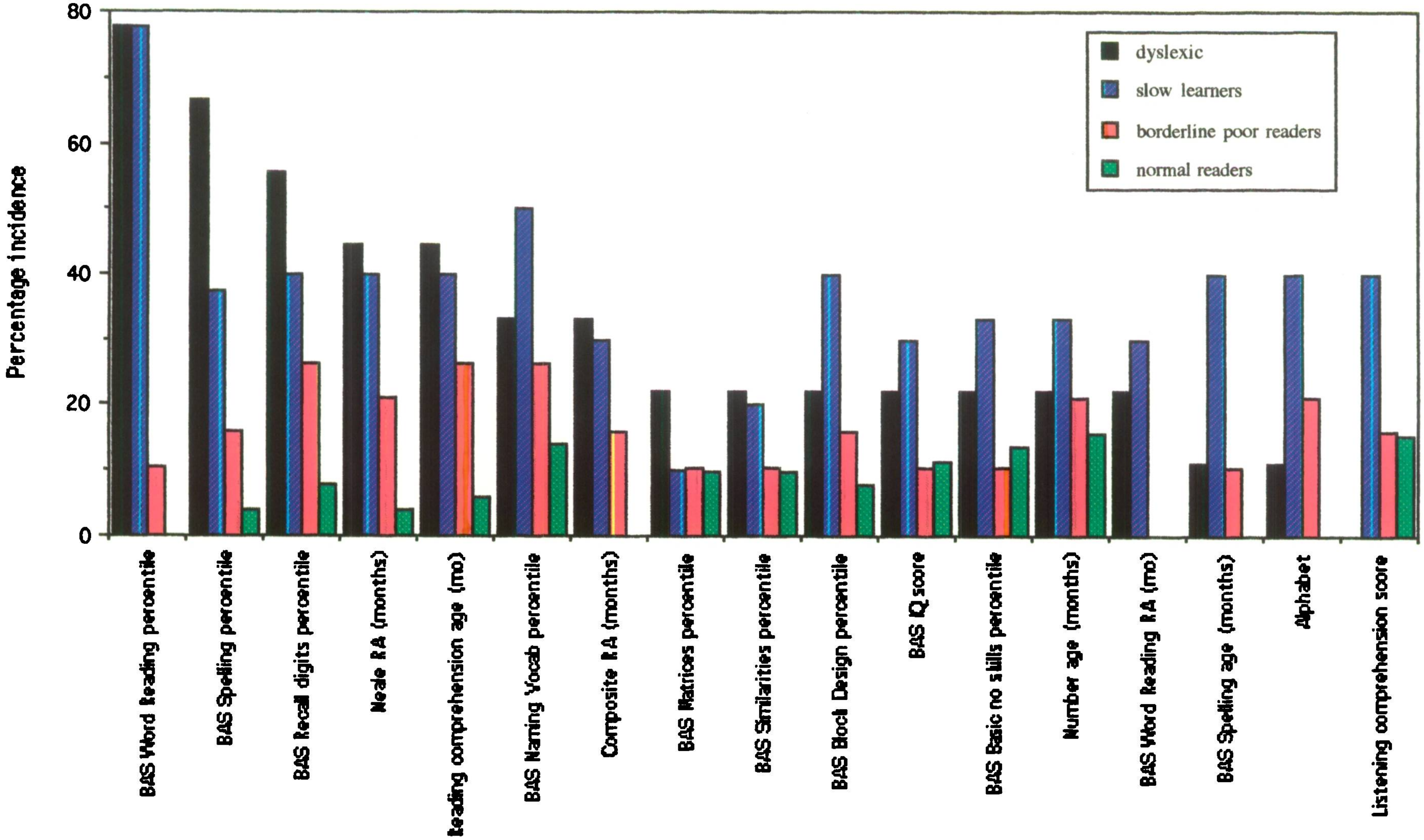
The percentage incidence of poor scores was also calculated for the criterion measures administered in Phase 3 for the diagnostic and control groups. The results are illustrated in table 4.38 and figure 4.10.

Table 4.38 Incidence of poor scores (standard deviation scores of -1 or lower) for predictive measures administered in Phase 3 for the dyslexics, slow learners and control groups .

	Percentage incidence of scores of -1 SD or lower			
Test	**dyslexics**	**slow learners**	**borderline poor readers**	**normal readers**
BAS Word Reading percentile	77.8	77.8	10.5	0
BAS Spelling percentile	66.7	37.5	15.8	3.8
BAS Recall digits percentile	55.6	40	26.3	7.7
Neale RA (months)	44.4	40	21.1	3.8
Reading comprehension age (mo)	44.4	40	26.3	5.7
BAS Naming Vocab percentile	33.3	50	26.3	14
Composite RA (months)	33.3	30	15.8	0
BAS Matrices percentile	22.2	10	10.5	9.6
BAS Similarities percentile	22.2	20	10.5	9.6
BAS Block Design percentile	22.2	40	15.8	7.7
BAS IQ score	22.2	30	10.5	11.3
BAS Basic no skills percentile	22.2	33.3	10.5	13.7
Number age (months)	22.2	33.3	21.1	15.7
BAS Word Reading RA (mo)	22.2	30	0	0
BAS Spelling age (months)	11.1	40	10.5	0
Alphabet	11.1	40	21.1	0
Listening comprehension score	0	40	15.8	15.4

It can be seen that of the measures other than reading administered in Phase 3, dyslexic subjects were found to have a relatively high proportion of poor scores on three tests. These were BAS Spelling (66.7%), BAS Recall of digits (55.6%) and Reading comprehension (44.4%). As in previous phases, slow learners were found to have a relatively great incidence of poor scores on the majority of measures and normal readers, very low incidences.

Figure 4.10 Incidence of poor scores for measures administered in Phase 3 for the dyslexics, slow learners and control groups



4.9 Prediction of dyslexia

The analyses which have been reported so far in this chapter have revealed that a number of the tests administered in the predictive phases of this study have correlated well with later reading performance and have significantly distinguished different groups of subjects in terms of their performance on the tests. The final section of this results chapter attempts to address the issue of prediction of dyslexia by selecting tests with a strong relationship to later reading and ability to distinguish dyslexic, slow learning and control subjects from one another to develop a prediction matrix. This matrix uses the presence or absence of standard scores of -1 or lower on each of the selected tests for each individual child to create an at risk index for dyslexia.

Table 4.39 presents the presence or absence of standard scores of -1 or lower (referred to as "at risk markers") for each of the dyslexic and slow learning subjects identified in the study for the following tests: BAS Copying, Phase 1 Pegboard task, Clapping, Rhyming Phases 1 and 2 all conditions, Phase 2 BAS Recall of digits, Phase 2 Nonword repetition, and Phonological segmentation. The final column of the table indicates the total number of at risk markers for each subject.

4.9.1 Prediction of dyslexia

The mean number of at risk markers for subjects identified as dyslexic was 5.56, with a range of 2 to 12 at risk markers found for the subjects on the selected tests. The subject with the greatest number of at risk markers was TR with 12 scores of -1 standard deviations or lower below the mean for all subjects. RB and SJ were found to score poorly on 9 and 8 of the selected tests respectively. Subjects JD and LH were found to have -1 scores or over on only two tests. The test measures with the greatest concentration of at risk markers for the dyslexic subjects were the three Rhyming test conditions administered in both predictive phases of the study.

4.9.2 Prediction of slow learning children

The average number of at risk markers found for the slow learning children across the selected tests was 6.3 (range 3 to 10). Compared to the dyslexic subjects, more slow learners were found to be at risk on the BAS Copying test, and this was also true for most of the other selected tests. Exceptions to this were the Pegboard task where four of the nine dyslexics were found to be at risk on this test compared to three of the ten slow learners, and Phase 2 Nonword repetition (5/9 at risk markers for the dyslexics compared to 3/10 for the slow learners).

Table 4.39 Table to show the number of at risk markers on each of the "predictive" tests for dyslexic and slow learning subjects

	BAS Copying	P1 Pegboard task	Phon Dis (hits)	P1 Rhyming C1	P1 Rhyming C2	P1 Rhyming C3	Clapping	P2 BAS Recall Digits	P2 NWR	P2 Rhyming C1	P2 Rhyming C2	P2 Rhyming C3	Phon Segment	Total at risk markers
Dys 1 (JD)	-	-	*	-	-	-	*	-	-	-	-	-	-	2
Dys 2 (LC)	-	-	-	-	*	-	-	-	-	*	*	-	-	3
Dys 3 (RB)	*	*	-	-	-	-	*	*	*	*	*	*	*	9
Dys 4 (JB)	-	*	-	*	*	*	-	*	-	-	-	-	-	5
Dys 5 (AN)	-	-	-	*	*	-	*	*	-	*	-	*	-	6
Dys 6 (CS)	-	*	-	-	-	-	-	-	*	-	*	-	-	3
Dys 7 (SJ)	-	-	-	*	*	-	*	-	*	*	*	*	*	8
Dys 8 (TR)	-	*	*	*	*	*	*	*	*	*	*	*	*	12
Dys 9 (LH)	-	-	-	-	*	-	-	-	*	-	-	-	-	2
SL1 (GR)	*	-	-	*	-	-	*	-	-	-	*	-	*	5
SL 2 (AB)	-	-	-	*	*	-	*	-	-	-	-	-	*	4
SL 3 (KL)	*	-	-	-	*	*	-	-	-	*	-	*	-	5
SL 4 (LB)	*	-	-	*	*	*	*	*	*	-	*	-	*	9
SL 5 (JM)	-	-	-	-	-	-	-	*	-	-	*	*	-	3
SL 6 (AJ)	-	*	*	*	-	-	*	*	*	*	-	*	-	8
SL 7 (KG)	-	*	-	*	-	*	*	*	-	*	-	*	-	7
SL 8 (JB)	*	-	-	*	*	*	*	*	*	*	*	-	*	10
SL 9 (SM)	*	*	-	-	-	-	*	-	-	*	*	*	*	7
SL 10 (RL)	-	-	-	*	*	*	-	-	-	*	-	-	*	5

4.10 Summary of the chapter

The results from the four phases of the study have been analysed in a number of ways in order to investigate the major questions of the study. Differences in performance between good and poor readers, and dyslexics, slow learners and normal readers have been found for a number of the predictive tests administered. In addition, strong correlations between a number of the tests and later reading performance have also been found. Performance of dyslexic and slow learning subjects on a set of selected tests incorporated into a predictive index have also been presented.

These results are interpreted in the following chapter, where the success in designing a screening test for the identification is evaluated and the questions regarding the early manifestations of dyslexia, the relationship of dyslexia to poor reading in general, and the nature and causes if the disorder are also discussed.

Chapter 5

Discussion

Preview to the chapter

The diagnosis of dyslexia is not possible until the age of seven years or above using existing methods. However, these methods have a number of limitations which mean that children may not in fact be diagnosed until much later, if at all. The negative outcomes of this include academic, emotional and behavioural problems, which may be very resistant to help. Late diagnosis of dyslexia can be costly in both financial and human terms. One way of overcoming such limitations is to screen all children of a certain age (for example, five years) to identify those who may be at risk for the disorder. This study has attempted to design an early screening test for dyslexia based on a number of measures administered at four and five years of age. In addition, a number of theoretical objectives have also been explored. The first objective was the establishment of early manifestations or precursors of dyslexia in young children, the second was investigation of the relationship between dyslexia and other forms of poor reading, and the final objective was to consider the findings of the study in terms of our general understanding of the nature and causes of dyslexia.

This chapter begins with a summary of the major findings from the study as provided by the analyses reported in Chapter 4. Results are evaluated in terms of the four major objectives of the study. Firstly, the success of the study in terms of designing a useful and reliable test for the prediction of dyslexia is considered. Secondly, the relationship of particular abilities at the age of four years to later reading performance and to dyslexia is discussed and possible early manifestations or precursors of the disorder are outlined. Following this, the relationship of dyslexia to poor reading in general is evaluated by comparing the performance of the dyslexic and slow learning subjects across the study. Finally, the findings of the study are considered in terms of their contribution to our current understanding of dyslexia.

The second section of the chapter presents a review of some of the limitations of the study as it was carried out, and in the final section some of these limitations are addressed, as directions for future research are considered in the search for successful early identification of dyslexia.

5. The objectives and findings of the study

The objectives of this study, as stated at the beginning of Chapter 3, fell into two main categories: practical and theoretical. The practical objective of the study was to design an early screening test for dyslexia which could be used to identify children at risk from the disorder before or at school entry. The theoretical objectives were the establishment of early manifestations of dyslexia, investigation of the relationship between dyslexic and other poor reading children, and contribution of information regarding our general understanding of dyslexia. The major findings of the study are considered in terms of these objectives.

5.1 Practical Objectives

5.1.1 Development of a screening test for the early identification of dyslexia

The major practical objective of this study was to develop a test for the early identification of dyslexia. Evidence presented in Chapter 2 regarding the limitations of present approaches to the identification of dyslexia, and the prognosis for children who are diagnosed late or not at all, revealed a need for earlier and better identification of the disorder. Children not diagnosed as dyslexic until the age of around ten or eleven years have effectively been denied access to the whole of their primary school curriculum and begin senior school at a great disadvantage to their peers. As well as academic difficulties, there have been found to be many secondary emotional and behavioural correlates of dyslexia such as anxiety and withdrawal or acting out and delinquency (Brown, 1978; Butler, 1979; Catts, 1991; Gordon, 1993; Thomson, 1991). In addition to this, it is generally considered that early remedial efforts for dyslexic children are much more successful than later ones (Strag, 1972). This had been hypothesised to be due to the greater plasticity of the young nervous system (Satz et al., 1976) and extra support with the fundamental aspects of language learning at a time when all children are acquiring such skills (Augur, 1985).

However, as intuitively good as the idea of early screening is, it is a far from straightforward undertaking. One major reason for this is the lack of theoretical consensus regarding dyslexia itself. In Chapter 1, the major areas of debate regarding dyslexia were outlined along with some of the prominent current explanations of the disorder. Of particular importance in designing a screening test for dyslexia is an adequate definition of the disorder to be predicted (Felton, 1992). This is an issue upon which there is considerable disagreement, but for the purposes of the study, a traditional definition of the disorder in terms of a discrepancy between general ability and written language skills was adopted. However, the major source of debate in this issue, the relationship between dyslexia and other forms of (poor) reading is specifically investigated in the second of the theoretical objectives of the study which is outlined later in this chapter.

The second area of debate that has an important impact on the design of an early screening test for dyslexia is explanation of the cause of the disorder. To be able to predict a disorder in a child which does not manifest itself until later, an understanding of the mechanisms of the disorder is needed. However, no one agreed theory of dyslexia as yet exists, although certain explanations, such as the phonological deficit hypothesis, have received a great deal of support from researchers over the last decade or so. Alternative formulations, such as the dyslexia automatisation deficit (DAD) hypothesis have revealed the limitations of purely phonological explanations of dyslexia. For this reason, in selecting tests that may have the potential to predict dyslexia in young children, a number of explanations of the disorder have been taken into account. For example, although tests of phonological skills have been included in the present study, tests of motor skills, inspired by the DAD account have also been included.

In designing an early screening test for dyslexia other important issues have also been considered. For example, studies which have identified precursors of dyslexia or early manifestations of the disorder have been noted (e.g. the work of Badian, Scarborough and others, see Appendix 1). The growing research into factors affecting later reading ability, particularly the development and phonological awareness and phonological skills has been considered in selecting tests for prediction of dyslexia. In addition, the particular challenges inherent in testing children of such a young age (such as processes and rates of development, and attention and language capacities) were also important considerations in designing a test of practical use.

Practical considerations for a screening test involve issues such as speed and ease of administration and scoring. A test needs to be designed to take account of the personnel who are going to be administering it, the setting in which it is to be given and the equipment facilities that will be available. Singleton (1992) has argued that the use of modern computer technology provides a very appropriate means for administration of a screening test for dyslexia in that it is efficient, reliable and consistent. The present study selected and designed tests that were computer-based for ease and consistency of presentation and scoring, as well as administering a number of "pencil and paper" tests. In addition, the role of the screening test as a first stage in a process of investigation of children with learning problems was noted. The test was designed to merely identify children as being at risk from dyslexia and not definitively diagnose them as being dyslexic.

In the present study a large battery of potentially predictive tests were administered to 91 subjects in two phases. Based on evidence regarding the likelihood of sons and daughters of affected parents becoming dyslexic (Pennington and Smith, 1988), and the work of Scarborough (1989) the subject group included not only a general population group, representative of children of the age group from the city, but a "Siblings" group with a dyslexic parent or sibling. This was believed to increase the possibility of finding dyslexic subjects at follow-up.

In the first phase of the study, the majority of children were aged around 4 years and 9 months of age and attending local nursery schools, although some of the children in the siblings group were older due to difficulties in recruitment of subjects fitting the exact requirements of the study. The second Phase of the study was carried out approximately one year later, after all subjects had been attending primary school for at least one school term. The tests administered in the two phases were selected based on a review of a large number of existing screening studies (see Chapter 2) and a consideration of the current major theoretical approaches to dyslexia. The predictive tests were designed to measure skills in eight areas:

- general ability
- motor skills
- phonological skills
- reaction time
- speed of processing
- laterality
- verbal labelling
- rhythm

The ability of the measures to predict dyslexia was investigated in a number of ways. Firstly, analyses were carried out to investigate the ability of the measures in the two phases to differentiate subjects when they had been divided into four groups, based solely on their reading performance at Phase 3 (mean age 6.7 years). In addition to this, the strength of the relationship of the predictive measures to later reading performance was also investigated. When they had reached the age of seven years, children found to be reading at the lowest level (six or more months below their chronological age at Phase 3) were identified as either dyslexics or slow learners using the diagnostic measures administered in Phase 4. Following this, differences in performance of these two groups of children were investigated by comparing them with each other, and to two control groups. Finally, the measures to be incorporated into the early screening test were selected based on evidence from the above analyses These measures included a small number of tests that were able to distinguish good and poor readers, dyslexics and control subjects and found to have a strong relationship with later reading performance.

5.1.2 Development of a screening test for the early identification of dyslexia: A summary of the findings of the study

The following sections provide an outline of the major findings of the study which led to selection of the tests for the screening battery. It begins with a review of the tests administered at four and five years of age on which children of different reading levels were found to have performed differently.

5.1.2.1 Tests administered at four and five years which were able to differentiate between good and poor readers

The first set of analyses that were carried out to examine the predictive ability of the test measures looked merely at the differentiation of good and poor readers without use of measures such as IQ scores to distinguish between dyslexic and slow learning children. On the basis of the reading performance of the subjects in Phase 3, four reading groups were identified (Group --, Group -, Group +, Group ++) and the performance of the groups on the Phase 1 and 2 predictive measures was analysed using analysis of variance (with post hoc analyses). It was found that although there were no significant differences in the age of the subjects in each of the groups at either Phase 1 or 2, significant differences in performance were identified. The majority of the differences were found between the performance of the poorest readers, Group -- and the other reading groups, particularly the most capable readers, Group ++. Significant differences ($p<0.01$) were found between these two groups on many of the measures of general ability administered at Phase 1 including the British Picture Vocabulary Scale and six subtests of the British Ability Scales (Copying, Basic number skills, Recall digits, Verbal tactile matching, Visual recognition and Matching letter like forms) as well as a significant difference in overall BAS IQ scores. The poorest readers were found to have scored at lower levels than the other reading groups on all of these tests. At Phase 2, there were no significant differences between performance of the groups on the (short form) BPVS , but the best and worst readers did significantly differ in their performance on the BAS Recall of digits subtest ($p<0.01$) and the Block design subtest ($p<0.05$).

At the age of four and five years, subjects were also found to differ in their motor skill ability. Significant differences were found between the performance of subjects at Phase 1 in moving pegs in a pegboard, with the poorest readers taking on average 5 seconds more to complete the task than the Group ++ subjects ($p<0.01$). However, no significant differences were found between the performance of any of the reading groups on the other two tests of motor skill (Beads and Blindfold balance) at this Phase. A year later at Phase 2, there were no differences between the groups on the Pegboard task, but significant differences between Group -- and ++ on the Beads task ($p<0.05$) with the lowest reading group threading almost two less beads in the sixty second time limit compared to the other groups.

Looking at the tests of phonological skills, the pattern of performance outlined above also holds true, with Group -- scoring at lower levels than the other reading groups. At Phase 1, the very poor readers performed at significantly lower levels than the poor and very good readers on the items of the Phonological discrimination test that required the child to correctly identify a nonsense word ($p<0.01$), although there were no significant differences between the performance of the reading groups in their ability to identify real words. On the Nonword repetition test at this phase, subjects in Group ++ correctly repeated almost five more nonsense words than the poorest readers ($p<0.01$). The subjects in Group -- scored at significantly lower levels than the other reading groups in all three conditions of the Rhyming task ($p<0.01$) correctly identifying on average three less rhyming/non-rhyming pairs than the other subjects. Lexical access score was also found to be lower for this group compared to Group ++ ($p<0.01$) but not the median time taken to respond, and mean Articulation rate was found to be significantly slower for the poorest readers compared to the very good readers ($p<0.01$).

At Phase 2, subjects' performance on the phonological tests was found to be similar to that at Phase 1 with significant differences between the performance of the poorest readers and the other reading groups on many of the tests. Subjects in Group -- actually improved their performance on the Nonword repetition test across the two phases but not at the same rate as the good readers, so that significant differences were found between them and Group + ($p<0.05$) and Group ++ ($p<0.01$) on this test. Performance of the groups in the first and last conditions of the Rhyming task (last sound different and first sound different) was found to have improved since Phase 1, but the same pattern of differences was found between the poorest and other reading groups ($p<0.01$). In Condition 2, however, only Groups -- and ++ differed at the $p<0.01$ level and Groups -- and + at the $p<0.05$ level, on this task. As in Phase 1, subjects did not significantly differ in their speed to respond in the Lexical access task, but the poorest readers did score at significantly lower levels than all of the other reading groups ($p<0.01$). On the Phonological segmentation task it was found that rather than the poorest readers scoring at lower levels than the other groups, the very good readers (Group ++) scored significantly better than the other three groups ($p<0.01$).

The test of reaction time - Naming Game - produced similar patterns of results at both of the predictive phases of the study. At the age of four and five years, no significant differences were found in the ability or speed of subjects to correctly name the series of twelve common pictures that were presented. At Phase 1 the speed of naming in the colours condition of the test was actually slowest for the good readers (Group +) and this meant that they performed at a significantly lower level than very good readers on this part of the test ($p<0.05$), although no significant differences were found in naming accuracy. In Phase 1, the poorest readers scored at significantly lower levels than the other three groups in terms of accuracy of naming letters and numbers ($p<0.01$), but were not slower to name the stimuli. In Phase 2, this was true only of the letters condition, as the poorest readers seemed to have caught up to some extent in their ability to name numbers.

Other tests administered in Phase 1 only, Visual search and Prepositions did not produce any significant differences between the reading groups. However, very significant differences were found between the performance of Group -- and Groups ++ and + on the Clapping test. The poorest readers were less able to correctly repeat rhythms that were clapped to them by the experimenter.

Overall it can be seen that the tests which best distinguished the reading groups from one another at the age of four and five years were tests of general ability, phonological tests, some naming tasks and some motor skills tasks. In the light of previous research most of these findings are unsurprising. There is evidence to suggest that IQ or general ability accounts for some of the variance in later reading performance (Miller and McKenna, 1981), and here it has been found that measures of general ability in terms of receptive vocabulary (BPVS) and standardised IQ scores based on range of tests have been lower for the subjects found later to be the poorest readers.

In Chapters 1 and 2 of this thesis, the role of phonological skills in the successful development of reading skills has been outlined in some detail. A great deal of evidence now suggests that the development of phonological awareness and the skills to manipulate phonetic information are some of the most important building blocks of reading acquisition (e.g. Bradley and Bryant, 1983; Catts, 1991; Felton, 1992). The results from this study indicate that compared to very good readers, good and even marginally poor readers, the very lowest reading group were experiencing significant difficulties with skills involved in recognising nonsense words, repeating nonsense words and detecting rhyme at the age of four and five years They were also slower to articulate common one, two and three syllable words than the other groups. These differences between the groups were present even after the subjects had been at school for at least one term and had begun to receive some basic instruction in reading.

Accuracy and speed of naming has been found to be problematic for children with reading difficulties (e.g Wolf and Obregon, 1992). Many of the tests of naming that have been used (such as the RAN) have been "continuous" naming tests, however, the test devised for this study was presented in a "discrete-trial" format. No major differences were found in the speed of naming of pictures, colours, numbers and letters across the four groups, however, significant differences were found in the accuracy of naming in the numbers and letters conditions of the test in both of the predictive phases, suggesting that children who are later found to be very poor readers have difficulties with the identification of digits and letters at the ages of four and five years.

Some motor skills tasks have been found to be predictive of later reading problems, particularly dyslexia (e.g. Augur, 1985, 1990; Haslum, 1989) and in the present study it was found that very poor readers scored at lower levels on two tests of fine motor skills at the ages of four and five years. Both tasks required the child to move relatively small items (beads and pegs) under time pressures, and in both cases the speed of performance was slower for the poorer readers. No major differences were found on the Balance test, however. One other test which was designed to measure children's sensitivity to Rhythm was also found to show up significant differences between the reading groups at the age of four years. It is possible that there is a motor skill component to this task which may interfere with performance for the poor reading subjects, as well as the demands of the task in terms of perception and replication of specific rhythms.

5.1.2.2 Tests administered at four and five years of age with a strong relationship to later reading ability

As well as identifying a number of tests administered at preschool and the first year of primary school on which children later found to be reading at varying levels scored differently, correlations between predictive tests and Phase 3 reading performance were also carried out. From this, a number of tests with a strong relationship to later reading performance were identified. It was noted in the previous section that intelligence has been found to contribute to some of the variance in reading performance and in this study it was found that a number of the tests of general ability correlated very significantly with later reading, particularly the British Picture Vocabulary Scale and the British Ability Scales overall IQ score ($p < 0.001$). A number of the BAS subtests also correlated significantly with later reading, in particular the Copying, Basic number skills and Verbal fluency subtests.

Only one test of motor skills correlated significantly with later reading performance - the Pegboard task. This was a strong negative correlation, revealing that faster performance on the test was related to better later reading ability ($p<0.001$). All of the measures of phonological skill other than articulation rate correlated significantly with later reading performance, particularly, Rhyming, Nonword repetition, Lexical access accuracy score and Phonological segmentation ($p<0.001$). Naming score and time were found to be related to later reading performance for the numbers and letters conditions of the test only. Visual search task accuracy score was significantly correlated with later reading ($p<0.05$), but not mean time to find targets. Performance on the Clapping test was found to be very strongly related to later reading ($p<0.001$).

Overall the tests with the strongest relationship to later reading ability appear to be tests of general and phonological ability, and knowledge of numbers and letters. The role of these skills in the development of reading is well established and therefore these findings are not unexpected. More surprising perhaps is the finding that the Pegboard task and the Clapping task were also related to later reading performance. The role of such skills in the development of successful reading and reading failure is considered in detail later in the chapter when possible precursors of dyslexia are considered. In the development of the dyslexia screening test, the above tests found to have strong relationships with later reading ability, were noted for selection of measures for the final screening instrument. However, the findings discussed so far have related only to the prediction of *good or poor* reading and not specifically to the *identification of dyslexia*. Therefore further analyses making a distinction between the poor readers in terms of IQ (i.e. as dyslexics or slow learners) were carried out. The findings of these analyses are described below.

5.1.2.3 Tests administered at four and five years which were able to differentiate between dyslexics, slow learners and control subjects

By administering a set of diagnostic tests (the WISC-III UK and WORD) to the subjects in Group -- it was possible to tentatively identify some of the children as being dyslexic. Some of the children were also identified as being slow learners (or garden variety poor readers). These diagnostic measures constituted Phase 4 of the study, and were administered to subjects at approximately seven years of age. The remaining subjects were not retested in this Phase, but were allocated into one of two control groups depending on their Phase 3 reading performance. Subjects who were in Group - were now referred to as borderline poor readers (along with two subjects from Group -- who were reading at improved levels at Phase 4), and all subjects who were reading at or above their chronological age at Phase 3 (Groups + and ++) were referred to as normal readers. Analysis of the differences in performance of subjects in these diagnostic and control groups, using one factor analysis of variance with post hoc tests, revealed some interesting differences between the groups at age four and five years.

The most common pattern of significant differences between the groups on the predictive tests was found between the slow learners and the normal readers. The performance of the slow learners on almost all tests was lower than that for other groups, particularly the normal readers. Slow learners scored at significantly lower levels than the normal readers (and borderline poor readers) on tests of general ability at Phase 1 including the BPVS, British Ability Scales Coping, Basic number skills, Recall of digits, Verbal tactile matching and Matching letter like forms ($p<0.01$ and $p<0.05$). The overall BAS IQ score for the slow learners was significantly lower than the score for the normal and borderline poor readers ($p<0.01$) at 89.40 compared to 109.43 and 103.58 respectively. At Phase 2, the slow learners scored at significantly lower levels than the normal readers on the BAS subtests of Block design ($p<0.05$) and Recall of digits ($p<0.01$), but there were no significant differences between the performance of any of the groups on the short form of the BPVS at this age.

The dyslexic subjects were found to score significantly differently from other groups on a number of the general ability measures at Phase 1. On the BAS Copying subtest they scored very significantly lower than the normal readers ($p<0.01$), but scored at significantly higher levels than the slow learners on the Basic number skills subtest ($p<0.01$). The dyslexic subjects were also found to have significantly outperformed the slow learners on the Matching letter like forms subtest of the BAS ($p<0.05$). At Phase 2, the dyslexic subjects scored at significantly lower levels than the normal readers on the BAS Recall of digits subtest ($p<0.05$).

On the tests of motor skills, differences in performance were found on the Pegboard task only, at both predictive phases. In Phase 1, both the dyslexics and slow learners were much slower on average to move pegs in the pegboard than the normal readers ($p<0.05$) with the dyslexic subjects actually performing slowest of all the groups (24.41 seconds). At Phase 2 the only significant difference in performance on this task was found between the slow learners and the normal readers ($p<0.05$).

Significant differences in the performance of the Phase 4 groups were found on many of the phonological tests at both of the predictive phases. At Phase 1, the dyslexics performed at significantly lower levels in terms of the number of real words correctly identified on the Phonological discrimination task, compared to the normal readers ($p<0.05$). On the Nonword repetition test the slow learners were able to correctly repeat significantly less nonsense words than normal readers at Phase 1 and 2 ($p<0.05$), and at Phase 2 the dyslexic subjects also scored significantly lower than the normal readers on this test ($p<0.05$). At Phase 1, the slow learning subjects performed significantly worse in all three conditions of the Rhyming task compared to the normal readers and the borderline poor readers ($p<0.01$). The dyslexics also scored at lower levels than the normal readers in conditions 2 (middle sound different) and 3 (first sound different) ($p<0.01$) and condition 1 (last sound different) ($p<0.05$). In addition, they were outperformed by the borderline poor readers in condition 2 of the test ($p<0.05$). At Phase 2, there were also significant differences between the performance of the slow learners and normal readers in all conditions of the Rhyming task ($p<0.01$), although the slow learners and borderline poor readers, and the dyslexics and normal readers only differed significantly in their performance in conditions 1 and 3 ($p<0.01$). The dyslexics were found to be performing at significantly lower levels than the borderline poor readers in condition 1 in this Phase ($p<0.05$).

On the test of Lexical access, significant differences were found with the accuracy score but not time to respond to the stimuli. At Phase 1, these differences were found between the slow learners and normal readers only ($p<0.05$) but in Phase 2 the slow learners were significantly outperformed by both the normal and the borderline poor readers at the $P<0.01$ level. The mean articulation rate for the slow learners was found to be significantly slower than that for the normal readers at the age of approximately four years ($p<0.05$). At Phase 2, the normal readers scored at significantly higher levels than the dyslexics, slow learners and borderline poor readers on the Phonological segmentation test ($p<0.01$).

Differences in performance on the Naming game were only found with accuracy rather than speed of naming, between the slow learners and the normal and borderline poor readers in the numbers and letters conditions ($p<0.01$). The only differences in speed of naming were found at Phase 1 between the normal readers and the borderline poor readers ($p<0.05$), with the latter being very slow to name the numbers presented, and in Phase 2 between the slow learners and the normal readers ($p<0.05$), the slow learners naming letters at a much slower rate than the control subjects.

No significant differences were found between the diagnostic and control groups on the measures of speed of processing (Visual search) and verbal labelling (Prepositions) at the age of four years. Differences were found, however, in the performance of the subjects at this age on the test of rhythm - Clapping. The dyslexic and slow learning subjects both scored at significantly lower levels than the normal readers on this task ($p<0.01$).

From the results obtained from the diagnostic and control groups for the tests administered at the age of four and five years, it can be seen that the greatest differences in performance tended to be found between the slow learners and the normal readers on a number of the tests. Many of these tests were measures of general ability and phonological skills. The number of tests on which the dyslexics performed differently to other groups was much smaller, but nonetheless, the pattern which has emerged is an interesting one. The dyslexic subjects performed worse than the normal reading subjects on the BAS Copying subtest, scoring at levels very similar to the slow learners (33rd percentile). However, they significantly outperformed the slow learners on the Basic number skills and Matching letter like forms subtests of the BAS. In terms of performance on tests of motor skills, the time to complete the Pegboard task in Phase 1 was actually slowest for the dyslexics than for any of the other groups. Their performance in attempting to correctly repeat a series of clapped rhythms was very similar to the slow learners and significantly below that of the normal readers.

On the phonological tests, the dyslexics tended to score quite similarly to the slow learners at both predictive phases of testing. However, their score on the Phonological discrimination test for correct identification of real words was lower then any of the other groups, including the slow learners, and this was also true for the repetition of nonsense words in the second phase of testing. Dyslexic subjects performed at lower levels than the control subjects in their ability to detect rhyme and alliteration, but in both phases, their performance was marginally better than the slow learners on this task. The dyslexic subjects also scored worse than control subjects when attempting to phonologically segment a series of words presented to them, but again, slightly better than slow learning subjects. The dyslexic subjects also performed poorly on another test which has been linked to phonological skills, the Recall of digits test.

5.1.2.4 Comparison of the findings of this study to previous early screening studies

Comparison of the findings of the present study to the findings of existing early screening studies reveals some similarities. Many of the previous studies, for example, found that measures of general ability and IQ were good predictors of later reading performance or reading disability. Badian (1982, 1986, 1988a) found that two subtests of the Wechsler Preschool and Primary Scale of Intelligence - Information and Sentences, were good predictors of later reading performance at age four years. Feshbach and colleagues (1977) and Butler (1979) also found that IQ was a significant predictor of reading problems. In this study measures of general ability have been found to be good predictors of reading in general, but children found to be dyslexic at the age of seven years have performed at varying levels on the subtests of the British Ability Scales compared to slow learning children who have tended to score poorly on all aspects of the test. Therefore, the findings of this and other studies suggest that although some aspects of intelligence are related to some aspects of reading performance, the exact relationship is more difficult to understand (see also Jansky et al., 1989). Moreover, the notion of specific reading disabilities is based on the idea that for some children the relationship between reading and IQ is not a straightforward one because a discrepancy is found between the two. This idea has been supported by the findings of the present study. In addition, some researchers have found that IQ measures (including receptive and expressive language measures) are actually more related to reading at later ages (e.g. second grade) where decoding has become relatively fluent and comprehension becomes the major goal (e.g. Catts, 1991).

The measures found to be most predictive in many studies included measures of language and psycholinguistic abilities. For example, Butler (1979) and Butler at al. (1982, 1985) found these measures to be the best predictors of reading achievement up to seven years later. As in the case of the present study, many researchers have found that phonological skills in particular are significantly able to identify future good and poor readers. Catts (1991) found that phoneme awareness, especially deletion of phonemes, correlated very highly with later reading performance. Felton (1992) also reported that the ability to identify same and different initial consonants in words was a very good predictor of later reading. Other researchers with similar findings include

Jorm at al. (1986), Kelly and Peverly (1991), Lundberg et al. (1980), Mann (1984), Menyuk at al. (1991) and Scarborough (1991).

Other predictors of reading performance and dyslexia found in this and previous studies include naming, counting, alphabet knowledge, laterality, figure drawing and memory. Naming in particular has been found to be a good predictor of later reading ability. Scarborough (1991) found that at the age of five years, performance in picture and letter naming were good predictors, and Kelly and Peverly (1991) found that letter and picture naming performance was predictive of first grade reading. Although accuracy of naming was found to be related to reading performance in the present study, it has been noted that the discrete trial format of the test may not have been sensitive enough to differences in speed of naming as continuous naming tests such as the RAN.

Very few of the screening studies reviewed in this thesis found that aspects of motor skill predicted later reading ability. Those that did include Haslum (1989) who found differences between dyslexics and non-dyslexics at the age of five years on tests of walking backwards and catching a ball, and Badian (1990a) found that dyslexics performed at significantly low levels on a test of visual-motor integration. It has already been noted that Nicolson and Fawcett (1995) found that eight-year old dyslexics were impaired in their performance on a range of "primitive skills" including fine and gross motor skills. The present study has found that dyslexics do have difficulties with tests involving speeded performance in fine motor skills but not the gross motor skill of balancing. Possible reasons for this finding centre around the observation that the task in question - the Blindfold balance - may have been too difficult for all of the four year old children to carry out and therefore may not have been a good index of dyslexic difficulties. When the test was administered to the subjects they appeared to be unable to hold a balanced position for the time limit of 30 seconds, particularly when the blindfold was placed on. A simpler test of gross motor skills and balancing may have found differences between the dyslexic and non-dyslexic subjects.

5.1.3 The predictive index and "at risk markers"

On the whole, a picture emerges of the dyslexic subjects as having difficulties with motor skills such as copying, moving pegs in a pegboard and clapping; perceptual and short term memory difficulties such as perceiving and remembering shapes and sounds long enough to repeat them (for example copying, clapping, nonword repetition, recall of digits); and perception and manipulation of phonological information (rhyming, phonological discrimination). On the basis of identification of these areas of difficulty, a small number of tests which significantly discriminated the dyslexic subjects from other subjects were selected to form a predictive index for dyslexia (see Chapter 4, section 4.9). These tests are listed in table 5.1 below:

Table 5.1 Tests selected for the predictive index for dyslexia

British Ability Scales Copying
Phase 1 Pegboard task
Phonological discrimination (hits)
Phase 1 Rhyming Conditions 1, 2 and 3
Clapping
Phase 2 British Ability Scales Recall of digits
Phase 2 Rhyming Conditions 1, 2, and 3
Phonological Segmentation

Using standard deviation scores calculated as part of an effect size analysis, a score of at least one standard deviation below the mean for all subjects was taken as an "at risk marker" for a child on a particular test. The predictive index was used to examine the number of at risk markers that were found for each of the dyslexic subjects and also the slow learning subjects. The index revealed that the mean number of at risk markers for the dyslexic subjects was 5.56, but that across the subjects, the actual number of markers ranged from 2 to 12. Standard deviation scores of at least -1 were found for relatively large numbers of subjects on the tests of Rhyming in particular. The slow learners were found to have a mean number of 6.3 at risk markers, with a range of 3 to 10 markers for individual subjects. On the whole, the number of scores of -1 or more standard deviation below the mean was spread more evenly across the tests for the slow learners than for the dyslexics.

5.1.3.1 A screening test for the early identification of dyslexia: The Screening Predictive Index

The practical objective of the study was to design a screening test for the early identification of dyslexia that is both accurate and straightforward to use. This has been done by including the tests outlined above into the final screening instrument - the Screening Predictive Index (SPI) with a criterion of one or more standard deviations below the mean for all subjects set as an indicator of at risk on a particular test (an at risk marker).

Using the Screening Predictive Index, prediction of dyslexia is potentially possible by selecting a number of at risk markers on the index as a critical figure for identification as at risk. On this basis, children who are found to have scored at one or more standard deviations below the mean on the critical number of tests or more would be identified as potentially dyslexic and extra help can be provided. In this study, one difficulty in using this method to identify children with dyslexia is immediately obvious. Selection of the critical figure for the at risk markers at, for example, 6 (the mean number of at risk markers for the dyslexic group) not only fails to pick up five of the subjects who had been identified as dyslexic at Phase 4, but also identifies five of the slow learning subjects. Selection of a cut-off score for at risk on a screening test is a difficult process, and in this case, increasing the cut-off score results in children identified as dyslexic not being detected, whereas lowering it increases the chance of identifying children without dyslexic problems. The major difficulty with identification here appears to stem from the fact that on the majority of tests selected for Screening Predictive Index and indeed, the majority of those administered in the study, slow learning subjects actually perform worse than the dyslexic subjects. In other words, the predictive battery may be capable of identifying very poor readers, but at first glance, it does not seem able to make a distinction between dyslexic and slow learning subjects.

To investigate the ability of the SPI to accurately predict children in the poor reading groups but not children who were found to be reading normally, the number of at risk markers in all of the groups was examined. Appendix 5.1 indicates the subjects in the borderline poor and normal reading groups who were found to have scored at -1 standard deviations below the mean on one or more of the predictive index tests (this can be compared with the predictive index in Table 4.39, Chapter 4). This reveals that the maximum number of at risk markers for the non-dyslexics/non-slow learning subjects was 5. These were obtained by two subjects in the borderline poor reading group: NL and ST. NL had originally been identified as a very poor reader at Phase 3, but was included in the borderline poor readers following diagnostic testing at Phase 4.

This was because it was found that her reading performance at this stage was not significantly lower than would have been predicted based on her age and IQ level (Full scale IQ = 102). However, it was 8 months below her chronological age and therefore this subject was a poor reader of some kind. The other subject, ST was not tested in Phase 4 as he was placed in "Group -" at Phase 3. At this phase he was found to be reading at 5.67 months below his chronological age.

Subject CC scored poorly on four of the predictive tests (*data was not available for Clapping) and like NL, this child had also been placed in the very poor reading group at Phase 3. He was considered a borderline poor reader at Phase 4 because the difference between expected and actual reading performance was not significant, but IQ was above 90 with low performance on only two "ACID" tests. The finding that these children have scored at low levels on the predictive tests is therefore not unexpected, based on the fact that they are all relatively poor readers and would almost certainly benefit from extra help early in school. Two of the children found to be reading at or above their chronological age at 6 and a half years also had poor scores on 4 of the SPI tests. The first child, MS-B had a probable family history of dyslexia (undiagnosed parent) and the possibility of him also having the condition had been considered by the family. The second child, NF, was very immature for his age at the first phase of testing, and poor scores may have been a result of this immaturity.

The predictive ability of the Screening Predictive Index to accurately identify the poor readers for a number of selected cut-off scores is outlined below. Table 5.2 shows the percentage of each of the groups of subjects that would be identified with the SPI based on a series of cut-off scores. This is similar to the prediction-performance comparison matrix proposed by Mercer and colleagues (1979).

Table 5.2 The percentage of children in the four reading groups predicted as being at risk using the SPI based on a number of different cut-off scores

At risk cut-off score	dyslexics	slow learners	borderline poor readers	normal readers
2	100%	100%	52.63%	18.87%
3	77.78%	100%	31.58%	11.32%
4	55.56%	90%	15.79%	3.77%
5	55.56%	80%	10.53%	0
6	44.44%	50%	0	0
7	33.33%	50%	0	0
8	33.33%	30%	0	0
9	22.22%	20%	0	0
10	11.11%	10%	0	0
11	11.11%	0	0	0

From table 5.2 above it can be seen that using a cut-off score of 2 on the Screening Predictive Index, all of the dyslexics and slow learners would have been identified as at risk along with 52.63 % of the borderline poor readers and 18.87% of the normal reading subjects. Increasing the cut-off score to 4 identifies just over half of the dyslexics, 90% of the slow learners and only 16 and 4% of the borderline poor readers and normal readers respectively. However, further increasing the cut-off score to five results in no normal readers being identified by the Screening Predictive Index, only 10.53% of the borderline poor readers (two subjects), 80% of the slow learners and just over 50% of the dyslexics.

The table also indicates that up to a cut-off score of 9, the index is more accurate at identifying slow learners than dyslexics. This is the key limitation of the Screening Predictive Index - it is better able to predict slow learners and is unable to make a distinction between slow learners and dyslexics. Obviously it is still useful for a teacher to know who the poor readers in his or her class will be before they try and fail to acquire written language skills. However, is it possible to improve the screening predictive index so that the teacher also knows which of the children may be traditionally viewed as dyslexic, and which children would later be performing as garden variety poor readers? This information may have important consequences for the provision of particular forms of intervention for the children.

One method of improving the prediction of dyslexia, garden variety poor reading and normal reading is to consider information in addition to the Screening Predictive Index. In the study, it was noted that there were a number of tests that significantly discriminated the slow learners from the dyslexic subjects, particularly measures of general ability. Although there is nothing surprising about the fact that there are differences in general ability between dyslexics and slow learners (this is one basis on which the two groups are differentiated at diagnosis) such measures administered at four or five years of age may be able to provide teachers with a more accurate idea of the profile of difficulties of the children, and hence be able to provide better and more appropriate remedial help. In the following two sections, methods of improving the accuracy of prediction of dyslexia are explored by the use of the Screening Predictive Index (II) and background information.

5.1.4 Improving the prediction of dyslexia: The SPI (II)

In the above section it was found that although the Screening Predictive Index was able to pick out the poorest readers from the whole group, it was not able to distinguish between the dyslexic and slow learning subjects. One possible implication for this is that there are no major differences between dyslexic and slow learning children (apart from IQ), a view advocated by researchers such as Stanovich and Siegel. However, on a practical level, there may be an important case for making a distinction between these two groups in the primary school classroom. This is that the groups may respond differently to intervention, making certain approaches more suitable for one group than another. This issue has some intuitive validity as approaches to learning by children who are specifically rather than generally cognitively impaired may well be different.

There is a possibility that extending the measures included in a screening index to include a small number of measures of general ability may be able to distinguish between dyslexic and slow learning children at the age of four and five years. This has been done in the present study by combining four measures of general ability into an annex to the Screening Predictive index - the Screening Predictive Index (part II). The additional tests include the BPVS (Long Form), and the BAS subtests of Block design, Basic number skills, Verbal-tactile matching and Matching letter like forms. Table 5.3 shows the number of at risk markers on the SPI (II) for the dyslexics and slow learning subjects.

Table 5.3 Table to show the number of at risk markers for the dyslexics and slow learners on the SPI (II)

	BPVS	Block design	Basic number skills	Verbal tactile matching	Matching letter like forms	Total number of at risk markers
Dys 1 (JD)	-	-	-	-	-	0
Dys 2 (LC)	-	*	*	*	-	3
Dys 3 (RB)	-	-	*	*	-	2
Dys 4 (JB)	-	-	-	-	-	0
Dys 5 (AN)	-	-	-	-	-	0
Dys 6 (CS)	-	-	-	-	*	1
Dys 7 (SJ)	*	-	-	-	-	1
Dys 8 (TR)	-	-	-	-	-	0
Dys 9 (LH)	-	-	-	-	-	0
SL1 (GR)	*	-	*	-	-	2
SL 2 (AB)	*	*	*	*	*	5
SL 3 (KL)	-	-	-	*	*	2
SL 4 (LB)	*	*	*	*	*	5
SL 5 (JM)	-	-	*	*	*	3
SL 6 (AJ)	*	*	*	-	-	3
SL 7 (KG)	*	*	*	*	*	5
SL 8 (JoB)	*	*	*	*	*	5
SL 9 (SM)	-	*	*	*	-	3
SL 10 (RL)	*	-	*	-	*	3

It is clear from table 5.3 that the number of at risk markers for the slow learners is much greater than that for the dyslexic subjects on the SPI (II). The mean number of scores of -1 SD below the mean or lower for the dyslexics is .78 (range 0-3) compared to a mean of 3.6 for the slow learners (range 2 to 5). The following table indicates the proportion of subjects in each of the four groups of dyslexics, slow learners, borderline poor readers and normal readers who scored at -1 SD below the mean or lower on the SPI (II) tests.

Table 5.4 The percentage of dyslexics, slow learners and control subjects having poor scores on the SPI (II) tests

	dyslexics	slow learners	borderline poor readers	normal readers
BPVS	12.5% *	70%	15.8%	13.5%
BAS Block design	11.11%	60%	44.4%	28.8%
BAS Basic number skills	22.22%	90%	10.5%	11.3%
BAS Verbal tactile matching	22.22%	70%	5.3%	17.3%
BAS Matching letter like forms	12.5% *	70%	16.7%	9.6%

* The percentages reported here are 12.5 as opposed to 11.11 because for the BPVS and BAS Matching letter like forms, data were not available for one of the dyslexic subjects.

Using a series of cut-off scores for the SPI (II) the ability of this test to predict children who have lower general cognitive performance was investigated. It is proposed that with use of the SPI and SPI (II) a teacher may be able to identify children in three main groups: dyslexics, slow learners, and normal readers. The following table provides an indication of the number of subjects in the dyslexic, slow learning, borderline poor reading and normal reading groups that would have been identified using a series of cut-off scores.

Table 5.5 The percentage of dyslexics, slow learners and control subjects identified as having generally low cognitive abilities based on a number of different cut-off scores for the SPI (II)

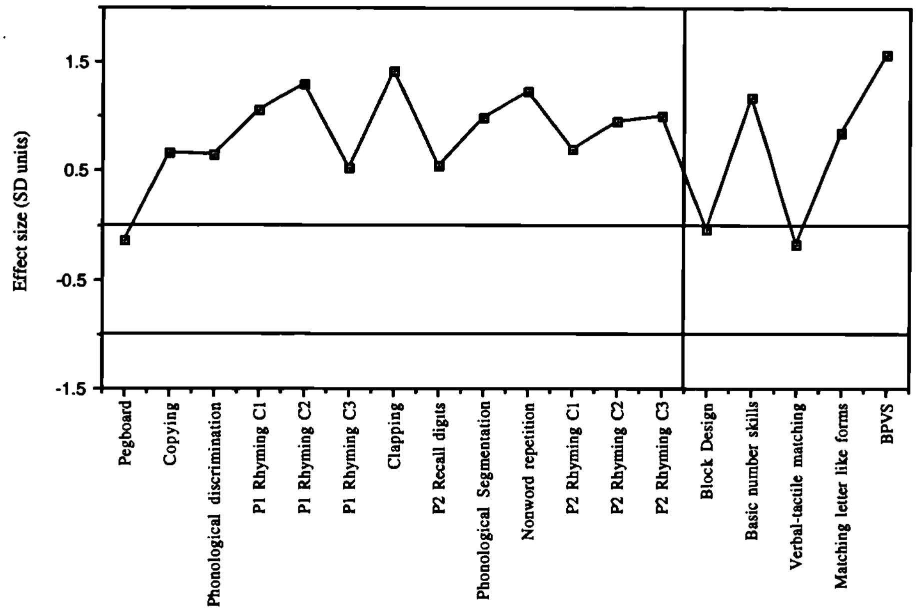
At risk cut-off score	dyslexics	slow learners	borderline poor readers	normal readers
2	11.11%	100%	26.36%	13.21%
3	11.11%	80%	0	5.66%
4	0	40%	0	3.77%
5	0	40%	0	0

The table shows that all of the slow learners would have been identified using a cut-off score of 2 on the SPI (II) as opposed to only one dyslexic who would have been identified. Increasing the SPI (II) cut-off score to 3 picks out 80% of the slow learners, 11% of the dyslexics, no borderline poor readers and less than 6% of the normal readers. Therefore combined with the SPI, the SPI (II) is capable of distinguishing between children whose poor reading is unexpected and those for whom it is part of a more general cognitive deficit. It is interesting to note that there are a proportion of normal readers who also scored poorly on a number of the SPI (II) tests. The number of at risk markers for the borderline poor readers and normal readers on the SPI (II) is indicated in Appendix 5.2. This reveals that two of the normal readers scored at -1 SD below the mean or lower on 4 of the tests (SP and HPa) and one subject, CSy, scored poorly on 3 of the tests. At first it seems unusual for children with lower general ability performance at age four years to have become normal readers at the age of 6 and half years, particularly as none of the borderline poor readers scored poorly on more than 2 tests. However, a number of factors may explain such a finding. The first of these is that the number of subjects in the normal readers group was much greater than that in the other groups (53 subjects). The range of variation in profiles of cognitive performance of these subjects is therefore greater than for the smaller groups. It is not surprising therefore that three of the subjects were not performing well on these measures of general ability in the context of the size of the group as a whole.

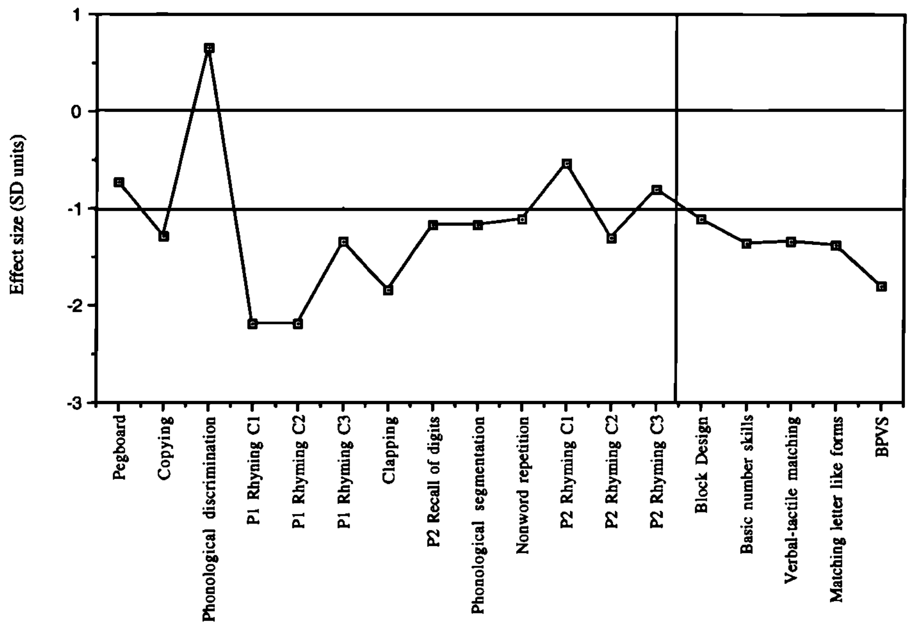
Secondly, although intelligence has been found by many to account for some of the variability in reading performance, it does not account for it entirely, and therefore it is possible to find children with low general ability who nonetheless learn to read and spell perfectly adequately. This is one of the major arguments put forward by Siegel (1989) in her rejection of the use of IQ scores in the definition of dyslexia. It is possible therefore, that in the group of 53 normal readers, there are a number of children who are actually "slow learners" in the sense that their total cognitive performance is not as good as that of other children, but who may *not* be poor readers. It may be particularly useful for the classroom teacher to be aware of these children as well as the dyslexics and garden variety poor readers.

The following graphs in figure 5.1 indicate an example of the performance profile of a dyslexic, a slow learner and a normal reader on the SPI and the SPI (II). Following administration of the screening tests to a group of children, profiles such as these could be plotted for the purpose of identification of children at risk for future learning difficulties. The profiles show the performance of each of the subjects relative to the performance of all subjects in the study, expressed as effect sizes (standard deviations form the mean). The x-axis shows the tests in the SPI and the SPI (II) and the performance of the child is indicated by the points joined by a continuous line. Two horizontal lines marked on the profile indicate the mean performance for all subjects and the point chosen to indicate poor scores (-1 SD below the mean). It is possible to quickly gauge the relative performance of the child by looking to see whether scores on

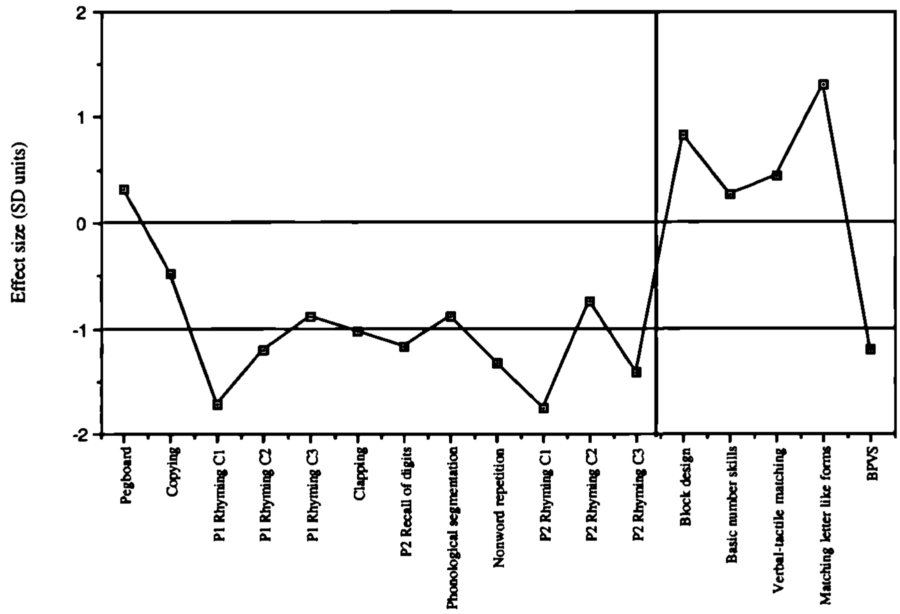
SPI and SPI (II) profile - normal reader KW



SPI and SPI (II) profile - slow learner LB



SPI and SPI (II) profile - dyslexic subject SJ



the SPI and the SPI (II) fall above the mean, below the mean, or below the -1 SD mark. If the child's scores are found to fall above the mean on both parts of the test results of this study suggest that it is likely that they will be a normal reader. If the child's scores are found to fall below the 1-SD mark on the SPI and SPI (II) then it is possible that they are at risk for being slow learners. If however, the scores on the SPI are found to fall below the -1 SD mark on the SPI but above the mean for the SPI (II) then it is possible that the child is at risk for dyslexia and appropriate help can be given early in primary school. SPI and SPI (II) profiles for all dyslexic and slow learning subjects and a selection of normal readers can be found in Appendix 5.3.

Using the two parts of the screening index it may also be possible for the teacher to identify children who are likely to be performing at slightly lower levels in their reading and spelling performance but not to the same extent as the dyslexics and slow learners (i.e. borderline poor readers). Future normal readers with generally low cognitive performance may also be identified. The test is designed as an early warning system and not to be used as a method of definitive diagnosis, so selection of tests and cut-off scores could be varied depending of the needs of the teacher. For example, if the teacher merely wanted to identify later poor readers, only the SPI could be administered, and the cut-off score could be lowered if borderline poor readers were also to be identified. However, if he or she wanted to know for which of these was "at risk" for dyslexia, the SPI and SPI (II) could both be administered. Although it could be said that this is a rather circular endeavour in terms of the present study in that the groups are being differentiated on the basis of the very measures that were used to define them in the first place, the ability of the test the identify poor readers with high and low general ability is a valuable activity in the school classroom. While perhaps mirroring the process of diagnosis used with older children (the identification of discrepant profiles) the SPI still allows the identification of children with reading problems more than two years before it is presently possible.

One additional benefit of identifying profiles of performance on an early screening test is that the remedial help provided for the child can be geared to the strengths and weaknesses that have been found. For example, in the case of dyslexic subject SJ, there appear to be particular weaknesses in phonological coding in working memory (Recall of digits, Nonword repetition) as well as problems with phonological awareness (e.g. Rhyming). However, this child's general abilities seem good, particularly her visual-spatial skills (Block design and Matching letter like forms). Therefore teaching could be geared to her visually based strengths to overcome her weaknesses with language and memory.

Some of the tests used in this study and found to be of predictive value include full tests or subtests of standardised published instruments such as the BPVS or the British Ability Scales. It would be preferable for a screening test like the SPI to include specially designed tests based on what the tests found to be predictive are measuring (fine motor skills, copying, phonological awareness and skills, memory, receptive vocabulary, comprehension, visual matching, visual-spatial skills, and visual recognition), rather than including published tests. This allows tests to be modified to be shorter and better indexes of the skills being measured. For example, a smaller number of items may be required to allow an accurate identification of children performing at high and low levels on a test. An increased number of the measures may be administered using computer facilities. Use of specially designed tests based on the tests selected above also overcomes a difficulty in terms of personnel required for administration. Tests such as the British Ability Scales require specially trained and experienced administrators (e.g. educational psychologists) and would be unsuitable for a classroom teacher to use. However, a screening index can and should be designed to allow use by teaching personnel and administrators other than psychologists to be of any practical use.

The results of this study suggest that a screening index based on the performance of four and five year old children on a series of simple cognitive and motor tests may allow a teacher to assess which of the children will later be dyslexic, slow learners, normal readers without general deficits, and normal readers with general deficits. Appropriate teaching methods for these groups to overcome their difficulties can then be used. The SPI and SPI (II) includes tests which are relatively quick and easy for a teacher to administer, score and interpret. For example, three of the tests (Phonological discrimination, Nonword repetition and Rhyming) are administered quickly using computer facilities which are now widely available in many schools. Other tests require simple equipment such as pegs and a pegboard or blocks.

However, in addition to cognitive measures, other background information may also be of use in identifying children at risk for dyslexia. This information may be collected using a number of methods including observation of children, teacher interviews and parental questionnaires. The possible benefits of background information in the prediction of dyslexia is discussed below.

5.1.5 Background information for the dyslexic and slow learning subjects

A number of researchers have investigated the ability of factors other than performance on a series of cognitive tests to differentiate children with dyslexia from non-dyslexics. For example, Melekian (1990) and Badian (1984a) found that a large proportion of dyslexic children came from large sibships and were often the youngest in the family. Melekian and also Haslum (1989) found that educational qualifications of the parents were often related to dyslexia, and Melekian also found that low SES sometimes aggravated the condition. Month of birth has been related to dyslexia with more dyslexic children born in the hotter summer months (Badian, 1984a; Livingston et al., 1993) and there has been general speculation about the role of birth history problems in dyslexia. Some researchers have found that the presence of early speech problems was a good predictor of dyslexia (e.g. Badian, 1986; Scarborough, 1990, 1991b) and the role of early spoken language disorders to later reading disorders is currently an area of great research interest (e.g. Catts, 1991). Based on genetic and clinical evidence, many researchers have found that family history of dyslexia is a good predictor of the disorder (e.g. Badian, 1986; Miles, 1982; Scarborough, 1989).

On the basis of these findings, the role of background factors in improving the prediction of dyslexia was considered. In the present study, background information was collected for some subjects via the use of teacher interviews and questionnaires for parents. Although complete data were not obtainable using these methods, due to lack of returned questionnaires and restricted access to teachers, some background information for the dyslexic and slow learning subjects was available and is outlined in Appendix 5.4. The major findings from this information are presented here.

(a) Socio-economic status

Children in the study were selected to represent a cross-section of the population of the city in terms of socio-economic background. The three nursery schools that subjects attended were located in different parts of the city and covered different SES groups. One of the findings of the study was that a large number of children from the Wybourn Nursery School were found to be very poor readers, particularly slow learners. This nursery school was located in a relatively disadvantaged area of the city and on the whole, educational qualifications and occupational status of the parents of the Wybourn children tended to be lower than that for other subjects. Although one of the Wybourn children was found to be dyslexic at Phase 4, six of the ten slow learners came from this area. Although many children from this nursery school seem to have scored at lower levels than children from other areas, some of the Wybourn children were also found to be very good readers at follow-up.

The relationship between SES and later reading performance is a difficult one to understand. Although the performance of many of the children from lower SES homes was worse on many of the tests than for children from more middle class backgrounds, the mechanisms that are responsible for this are far from clear. Different or restricted vocabularies, less imput from parents and lower expectations are just some of the possible reasons why children such the Wybourn subjects have tended to perform less well on the tests given. In the present study, therefore, it is very likely that SES has played a role in the development of reading problems, but the way in which it has is far from obvious. This is particularly clear when the occupations of some of the other slow learners are examined. Children with qualified parents (e.g. engineers) have been found to be slow learners as well as children with parents who were unemployed.

(b) Family history of learning difficulties

Four of the nine dyslexic children had at least one family member with dyslexia. None of the slow learners were recorded as having family with learning problems although the spelling ability of the mother of KG was relatively poor. Many researchers (e.g. Scarborough, 1989) have found that family history of dyslexia is a very good predictor of the disorder. However, in the study, twenty children with dyslexic family members were included and for sixteen of these, reading performance was *not* found to be very significantly lower than would be expected. Therefore, this factor is only one of many that might predict the existence of dyslexia in young children.

(c) Speech problems

Two of the dyslexic subjects and three of the slow learners had been found to have speech problems as a young child, many of these severe enough to warrant attendance for speech therapy. The role of speech problems in the generation of written language disorders is as yet unknown, but it is possible that speech problems represent an early manifestation of the difficulties underlying the reading and spelling problems. For example, failure to articulate phonological information accurately may interfere with the acquisition of phonological awareness skills (Catts, 1991) and lower speed of articulation may reduce working memory capacity (Gathercole and Baddeley, 1990; Nicolson, Fawcett and Baddeley, 1992). However, in selecting background information to assist with the prediction of dyslexia and poor reading in general, noting the presence of speech problems may be useful.

(d) Birth history

Although birth history has been considered by some as a background factor in dyslexia, no clear pattern emerged from the small number of results obtained in the present study. However, one interesting finding was that two twin sisters were both found to have poor reading at Phase 4, with one performing as a dyslexic but the other more as a slow learner. The twin who was born second (AJ) (by 33 minutes) was the slow learner and unlike her sister was a breech delivery. Both girls were born early (36 weeks gestation), although only the dyslexic twin (SJ) was of a low birth weight. The implication of this early twin birth is not clear, but information such as this may be of use in the early identification of dyslexia.

(e) Other information

Other information collected in this study concerned aspects of the child's temperament and behaviour. For example, teacher and tester comments tended to express the ability of the child to get on with others, their ability to deal with tests and nursery school activities, and their level of maturity. Information was collected from parents regarding developmental milestones as well as the preferred pastimes of the child. For example, the child's attitude to books was recorded and it was found that all but one of the poor readers for whom data were available enjoyed and actively sought books. An interesting finding regarding developmental milestones was that slow learner AJ did not crawl, but moved around only on her bottom.

For some of the children, emotional upheavals in their lives appeared to have had some significant effects (e.g. RB, LH, and possibly KG) which were manifested by either acting out or withdrawal. In terms of positive rather than negative factors, some of the children were known to have received extra help to overcome their difficulties (e.g. AN, TR, JB), however, they were still found to be performing relatively poorly in this study.

In terms of assisting the accurate prediction of dyslexia, background information that is relatively easy to obtain may be of use. Low SES, speech problems, family history of dyslexia and other factors have been found to be associated with some of the cases of dyslexia and garden variety poor reading in this study. Therefore in addition to administering the SPI and SPI (II) it may be useful for teachers to obtain brief details of, for example, unusual birth history, other family members with dyslexia and speech problems for the children they are screening.

5.1.6 Development of an early screening test for dyslexia: The SPI, SPI (II) and background factors

The early identification of dyslexia using screening measures for all children of a certain age is one way of overcoming the limitations of the present approaches to diagnosis of the disorder. A number of researchers have attempted to design tests for the prediction of poor reading or dyslexia but no one test has so far been able to predict later academic status with one hundred percent accuracy (Jansky, 1989). This study has attempted to improve on existing early screening efforts by selecting predictive measures based on more recent theoretical developments in dyslexia. Using tests that measured motor and other skills as well as tests of phonological ability, the performance of children at the age of four and five years was analysed to select tests for an early screening test. This test, the Screening Predictive Index (SPI) was found to be able to identify a large proportion of the children found at the age of seven to be slow learners, more than half of the children identified as dyslexic, but very few of the borderline poor readers and normal readers. However, it was not able to make the distinction between dyslexics and slow learners, both groups scoring poorly on many of the SPI test items. Therefore an annex to the SPI, the SPI (II) was devised to differentiate between children with reading difficulties that were unexpected and those for whom these problems were part of a more general cognitive deficit. The SPI (II) was able to identify most of the slow learners but picked up very few of the dyslexics. Background information obtained for the subjects, such as family history of dyslexia, may also assist with the identification of such children when used in conjunction with the SPI and SPI (II).

It was envisaged that a classroom teacher would be able to use the SPI to screen all children using the following procedures. Some of the SPI tests (Pegboard, Copying, Rhyming and Phonological discrimination) and the SPI (II) could be administered shortly before the child left nursery school with the remaining tests (Recall of digits, Rhyming, Nonword repetition and Phonological segmentation) administered after attendance for one term at primary school. In addition, a short questionnaire for parents could also be administered at this point collecting information regarding family history of learning problems, birth history problems, developmental milestones and speech problems. Results for each child would then be standardised on the basis of norms for a large group of children on the test and plotted onto a performance profile graph as in figure 5.1. Using this performance profile, decisions could be made regarding the nature of the future academic status of the child and at this point, background information could also be considered. In this way, the teacher is able to identify all those children who may be at risk for dyslexia or garden-variety poor reading and a number of responses may be made. Firstly, the teacher may wish to refer to child or children in question for more detailed testing by an educational psychologist or other professional. Secondly, the teacher may wish to draw up a program of intervention for the at risk child based on the profile of weaknesses and strengths obtained during screening. Finally, the teacher may wish to monitor the progress of the child in the primary school to prevent major reading and spelling problems developing to an unrecoverable extent.

However, a glance at the performance profiles of the dyslexic and slow learning children in Appendix 5.3 reveals something of a problem for the SPI and the SPI (II). The profiles are incredibly varied and appear quite hard to interpret in terms of prediction of dyslexia and poor reading. For example, the profile of dyslexic subject LC looks more like that of a slow learner with poor scores on a number of the SPI (II) tests. Therefore is it the case that the SPI is not an improvement on previous screening batteries?

There are a number of limitations of the present study which may go some way to account for the failure of the SPI and SPI (II) to accurately identify all the dyslexics, slow learners and normal readers. These limitations centre on selection of tests for the screening battery, selection of subjects for the study, timing of administration of test phases and identification of outcome groups. The particular problems that have been encountered in each of these areas and the effect that they may have had on the findings of the study are considered in section 5.3 of this chapter. The following section moves away from the practical objective of the study to consider the three theoretical objectives that were investigated.

5.2 Theoretical Objectives

5.2.1 Establishment of early manifestations of dyslexia

The first of the theoretical objectives of the study was to provide evidence to indicate possible manifestations of dyslexia observable in children of four and five years of age. A number of important outcomes of the identification of such manifestations exist. Firstly, identification of the early manifestations of dyslexia allows the design of early screening tests for the disorder as attempted in this study. In addition, a thorough appreciation of the particular early difficulties experienced by the young dyslexic child provides the best basis for the design of intervention programs and remedial help. On a more theoretical level, an understanding of the early signs of dyslexia can assist our understanding of the condition in general, for example, is it purely a language based disorder or are there early manifestations of difficulties in other areas of skill? Are the early differences between dyslexics and non-dyslexics just manifestations or do they actually effect the development of the disorder? The results of the present study and what they tell us about dyslexia in young children are discussed below.

Differences between the performance of the dyslexic and other subjects in the study were analysed using analysis of variance and effect size analysis as presented in the previous chapter. The major differences found between the dyslexics and normal readers have been outlined in the first section of the chapter when the process of selection of measures for the screening test was described. From the analyses it was found that the dyslexics differed from children with normal reading performance at the age of four years in a number of ways.

(a) BAS Copying

The first major difference found between the dyslexics and normal readers was that compared to the normal readers, the dyslexic subjects appeared to have considerable difficulties with the Copying subtest of the British Ability Scales. The dyslexic subjects scored at a mean percentile of 32.94 for this test compared to 65.28 for the normal readers. Elliot (1983a) considers this test to be a measure of perceptual matching ability and believes the skill of copying to have an important place in the development of writing skills. Research has indicated that children with dyslexia often have difficulties with copying information from the classroom blackboard (e.g. Miles and Miles, 1990). This is believed to be due to difficulties with the accurate perception and maintenance of information for periods long enough for it to be written into the child's own work. The test also involved motor skills. For the test, children were required to perceive a shape or series of shapes from a small booklet that was placed in front of them on the table. Many of the children put so much effort into the creation of the designs that they were often forced to look away from the source design in front of them. In many cases, errors in the design were often made (for example, drawing too many of a particular shape or drawing "b" shapes instead of "d" shapes). In some cases, errors were due to lack of motor control and problems with pencil grip.

The finding of a deficit in the performance of the dyslexics on this test is very interesting in that it is the only test of general abilities on which they were found to perform poorly. However, this was also found to be a test on which the slow learning subjects scored at low levels (a percentile score of 31.60), although they scored poorly on a number of the BAS tests, and also in terms of their overall BAS IQ score. The skills associated with the Copying test: perception, short term memory and motor skills have all been implicated as areas of dyslexic deficit and therefore it is perhaps no surprise that young dyslexic children had difficulty with the task. Copying is also an example of a test which requires the integration of a number of components of skill for successful completion, and according to explanations of dyslexia in terms of a Dyslexic automatisation deficit, this would be particularly difficult for the young dyslexic child. Deficits in Copying would also be reconcilable with visual accounts of the disorder, but are not easily explained by phonological deficit accounts. It seems probable that the skills associated with Copying would be involved in the development of writing skills, but not reading and spelling. Therefore it is speculated that the poor performance of the slow learners on this test represents their poor general ability in general rather than problems specific to their later poor reading performance. For the young dyslexics, on the other hand, this test may represent an index of difficulties with perception, memory, motor skills, and integration of component skills.

(b) Motor skills: Pegboard task and Beads task

The dyslexic subjects at the age of four and five years were found to have performed more slowly on two of the tests of motor skills than normal readers, although this difference was only significant on the Pegboard task at the age of four years. At this stage, the dyslexics took longer on average to move small pegs in a plastic pegboard than subjects in any of the other groups, including the slow learners, with an average of time of 24.41 seconds. The normal readers, on the other hand completed the task in an average of 19.57 seconds. Motor skills difficulties have often been associated with dyslexia, but it is only recently that they have been considered as a fundamental characteristic of the disorder of equal importance as written language difficulties. A number of researchers (e.g. Augur, 1985; Fawcett and Nicolson, 1994; Haslum, 1989) have proposed that there is a link between motor difficulties and dyslexia and the Dyslexic automatisation deficit has attempted to account for such difficulties in terms of a dyslexic failure to automatise skills, including motor skills. The Pegboard task requires that the child achieve an accurate and speeded performance in terms of picking up each peg and moving as quickly as possible to the appropriate hole in the pegboard. In attempting to perform this test accurately, speed appears to have been lost for the young dyslexic subjects.

However, although the dyslexic children performed slower than all groups on this test in the first phase of the study, the slow learning children were only marginally quicker and were also significantly slower than the normal readers on this task. In fact, relative to the performance of the slow learners, the performance of the dyslexics on the same task at the age of five years actually improved to levels that were not significantly different from the normal readers. Only the slow learners had significantly slower performance than the normal readers at this stage.

Therefore, at the age of four, young dyslexic children appear to have difficulties with speeded and accurate performance on a task of fine motor skills but these difficulties become less pronounced as the children get older. For the slow learners however, these difficulties appear to persist. Explanations for these difficulties in the dyslexic children are provided by the dyslexic automatisation deficit hypothesis in terms of a failure to automatise skills. However, for the slow learning children, difficulties such as these may be part of a more generalised learning problem.

(c) Phonological skills

(i) Phonological discrimination task

The dyslexic subjects were found to have difficulties on a number of tests of phonological skills compared to the normal readers at the age of four and five years. At the age of four years, the young dyslexics were less able to identify a series of simple words and nonsense words presented by a computer in the Phonological discrimination task. They were found to have particular difficulties in correctly identifying the real words, scoring at significantly lower levels than normal readers on this aspect of the task. This test involved the accurate perception of the word as spoken in human speech by the computer, and a decision as to whether it was a real word (that matched a picture presented on the screen) or a similar sounding nonsense word. The fact that the children performed worse in the real words condition of this test may have been due to difficulties in phonological discrimination for all words presented but a bias towards answers of "no". This meant that for the nonsense words they would have been correct on a number of occasions regardless of accurate perception of the stimuli, but for the real words, answers of "no" resulted in lower scores.

The role of phonological awareness in the development of reading skills has been discussed in some detail in Chapter 2. Evidence from researchers such as Liberman and colleagues, Lundberg, Olofsson and Wall, and Mann has indicated the importance of the ability to accurately perceive and discriminate phonological information for later success in reading. Many researchers (e.g. Bryant and Bradley, 1985) have found that dyslexics have particular difficulty with tasks that require this awareness. The findings from this test therefore suggest that the preschool dyslexic child may have problems with the perception of auditory information and the discrimination of phonemes.

(ii) Nonword repetition

Following entry into school, but not before it, the performance of the dyslexic subjects on the test of Nonword repetition was found to be significantly lower than that for the normal readers. The performance of the dyslexic subjects at the age of five had not improved on this test whereas the performance of the other groups had increased with age. It appears therefore that the ability to accurately perceive and repeat nonsense words for the dyslexic children at four years of age, reflected a level of phonological skill that was not open to as much improvement as the other subjects. The performance of the dyslexic subjects on this test appears to highlight difficulties in phonological working memory. These difficulties have been noted in older dyslexic subjects, and are hypothesised to play a significant role in problems in the acquisition of language skills (e.g Gathercole and Baddeley, 1990).

(iii) Rhyming task

This test of phonological awareness proved difficult for the dyslexic subjects both at age four and five years. Scores were lower than the normal readers in all conditions but were found to be above those for the slow learners. At age four, the dyslexic subjects performed at significantly lower levels in their ability to detect words that ended with the same or different sounds, words that had same or different sounds in the middle and words that began with same or different sounds. At age five, only the first and last sound different conditions appeared to cause major problems for the dyslexics, compared to the normal readers. The ability to detect rhyme and alliteration in words has been found to be strongly related to the development of reading and spelling skills in children (Bryant and Bradley, 1983; Bradley, MacLean and Crossland, 1989; Bryant, MacLean and Crossland, 1990) and has been found cause problems for children with dyslexia. The dyslexic subjects did improve in their ability to correctly identify the rhyming and non rhyming pairs of words from age four to five but were still lagging behind the performance of the normal readers. The mean performance of the two groups is contrasted in table 5.6 below.

Table 5.6 Comparison of the mean performance of the dyslexic and normal reading subjects on the Rhyming task at Phases 1 and 2

	Phase 1			**Phase 2**		
	dyslexics	**normal readers**	difference	**dyslexics**	**normal readers**	difference
Condition 1 (last sound different)	6.44	8.42	1.98 *	7.44	9.43	1.99 **
Condition 2 (middle sound different)	5.78	8.00	2.22 **	7.56	8.87	1.31
Condition 3 (first sound different)	5.44	7.65	2.21 **	7.22	8.94	1.72 **

The table clearly indicates that the dyslexics are less able to perceive and identify pairs of words that share certain sounds. This is a fundamental skill required for reading and spelling new words and recognising patterns between words (e.g. Goswami and Bryant, 1990). However, the slow learners also experienced difficulties with task and actually performed at lower levels than the dyslexics. This is not therefore, a deficit that is specific to dyslexia, but is perhaps better viewed as an early manifestation of one of the major characteristics of the disorder - difficulties with reading and spelling.

(iv) Phonological segmentation

The dyslexic subjects were found to have experienced difficulties with the Phonological segmentation test at age five, scoring at significantly lower levels than the normal readers. This test was designed to measure the ability of the subjects to perceive and synthesise syllables and phonemes in words. It was found that the dyslexic subjects were able, in most cases, to segment the stimuli words into syllables but not phonemes. The normal readers, on the other hand were more able to perceive and manipulate sounds at the level of the phoneme. Many researchers have found that phonological segmentation is a problem in young children with reading difficulties (see section

5.1.2.4 above). Like many of the measures of phonological awareness, it is hypothesised that rather that being a deficit specific to dyslexia, problems with this task are an early manifestation of the characteristics of dyslexia associated with written language problems. The performance of the slow learners on this test was worse than the dyslexic subjects.

(d) Clapping

The dyslexic subjects were found to have difficulties with the perception and production of simple rhythms that were clapped to them by the experimenter. Results from this test appear to provide evidence that young dyslexic children have difficulties in maintaining the correct rhythm in a simple motor action (see also Katz and colleagues, 1992). The motor skill element in the task may also have proved difficult for the subjects. However, like many of the tests which have been reviewed here as early manifestations of dyslexia, the slow learning subjects were also observed to have performed poorly on this test.

5.2.1.1 What are the early manifestations of dyslexia?

The above review appears to suggest that a number of the early manifestations of dyslexia may be better thought of as the early manifestations of poor reading, which is of course, a major characteristic of dyslexia. Early deficits in phonological awareness and phonological coding in working memory have been found in the young dyslexic children. Nevertheless, these deficits have also been found in the performance the slow learners. Copying, clapping and moving pegs in a pegboard also proved relatively difficult for the dyslexic subjects, however, providing a comprehensive explanation of these deficits is not as straightforward as for the phonological deficits. This is particularly true in light of the finding that poor performance was also found for the slow learners on these tasks.

What do these findings tell us about the early manifestations of dyslexia? To begin with, the early manifestations of dyslexia appear to be relatively specific. They do not include difficulties with broad aspects of general ability. Indeed, performance of the dyslexics on some of the subtests of the British Ability Scales was at very similar levels to, or even exceeded that of the normal readers. For example, on the Block design subtest the mean percentile score for the dyslexics was 73.33 compared to 69.40 for the normal readers. This is a particularly interesting finding in light of speculation by some researchers regarding the existence of dyslexic strengths, particularly in constructional and creative skills (Miles, 1993). The young dyslexics were found to have problems with fine motor skills in speeded conditions compared to the normal readers, but not the gross motor skill of balancing on two feet. Language skills such as phonological ability, articulation rate and phonological memory appeared to be impaired compared to the normal readers. However, the ability to search for a target against a background of visual noise did not seem to be affected. Generation of verbal labels for pictures, letters, numbers and colours and understanding of prepositions also seemed relatively unaffected in the dyslexic subjects at four and five years of age.

The implications for a theoretical basis for the early identification of dyslexia are therefore not yet completely clear. In terms of being able to distinguish the children from normal readers at the age of four and five years, tests of phonological skills, fine motor skills, copying and clapping appear to be relatively successful. What these tests say about the mechanisms responsible for the disorder is less obvious. More importantly, as has been seen above, the same deficits are also manifest, often to a greater degree in another group of children - the slow learners.

In terms of recommendations for remedial intervention for young children with dyslexia, the implication of these findings seems to be that training in phonological skills, and help with the development of fine motor skills would be of use. One benefit of early identification of dyslexia is that the delivery of such help would not be out of character with what would already be being taught in the primary school classroom. Children identified as being at risk for dyslexia could be taught such skills more explicitly or intensely than other children in the class. Identification of particular strengths in areas, may allow alternative methods of presentation of information, to teach to the strengths in order to overcome weaknesses.

One point that has been made here, and in the first section of this chapter in the designing of the screening test, is the finding that on the tests that distinguish dyslexics from normal readers, the slow learning subjects have also been found to perform poorly. This finding raises the very important issue of the relationship between dyslexia and the generalised reading difficulties experienced by the slow learning children. This issue is now examined in the light of the findings of the study.

5.2.2 The relationship of dyslexia to other forms of poor reading

When outlining approaches to the definition of dyslexia in Chapter 1, it was noted that at the present time there is considerable debate regarding the validity of considering dyslexia as a distinct entity, different from other forms of poor reading. Siegel (1989, 1989, 1992), Stanovich (1988, 1989, 1994) and other authors have argued in favour of a rejection of the use of the discrepancy formula for the definition of dyslexia. Instead, the researchers propose that dyslexia merely represents a form of poor reading in children with high as opposed to low IQ. In this view, children with dyslexia and slow learning children differ only in the criteria that were used to define them in the first place - IQ scores. Evidence to support this view has been provided by, for example, B.A. Shaywitz and colleagues (1992) who found no differences in the performance of discrepancy defined and low achieving poor readers on a range of measures other than those that reflected the difference in IQ between the groups. They found that poor readers with high and low IQ levels performed similarly in kindergarten on tests of dexterity and gross motor function, visual perception, and language, and in terms of teachers assessment of learning and behaviour at grades 2 and 5. Differences were found between the performance of the groups on tests of finger agnosia, The Boston Naming test and Sentence Memory in kindergarten, and reading and rate of reading improvement in later years. Nevertheless, it was found that differences in IQ accounted for almost all the variance between the two groups.

However, Badian (1994) found that dyslexics and garden variety poor readers performed differently from one another in that although the dyslexic group was on average 21 points higher in verbal IQ than the poor readers, they performed at lower levels on one phonological task: RAN numbers (digit naming speed) and one orthographic task: Recognition of reversals in uppercase letters and numbers. She also found that the groups differed in their cognitive profiles, with the dyslexics scoring at one standard deviation below the population mean on tests of nonword reading, RAN numbers and objects, RAN letters and the Jordan test. The slow learners, on the other hand were found to have scored at one standard deviation below the mean on nonword reading, RAN objects and RAN letters. Badian therefore concluded that "in spite of their much higher general verbal ability, the dyslexic subjects were more impaired on specific cognitive processing tasks" (p. 57).

This study has attempted to address the issue of the relationship of dyslexia to generalised poor reading by comparing the performance of the dyslexics and slow learners on a range of measures administered at four, five and six years of age. Possible differences in performance on the individual test measures and differing profiles of performance between the two groups were investigated at each age.

(a) Differences between dyslexics and slow learners at age four years

The slow learning children performed at lower levels on the majority of the tests administered at four years of age compared to the dyslexic subjects. Many of these differences were not actually found to be statistically significant, however. Measures on which there were differences between the two groups are outlined below.

(i) Measures of general ability

Not surprisingly, the slow learners performed worse than the dyslexic subjects on all of the tests of general ability administered at the age of four years . Significant differences were found between the groups on the Basic number skills subtest ($p<0.01$) and the Matching letter like forms subtest ($p<0.05$). There was a difference of over 10 points in the overall IQ scores for the two groups at this stage (mean IQ score for the dyslexics = 100.88, slow learners = 89.40), but this difference was not found to be statistically significant.

(ii) Motor skills

There were no significant differences between the performance of the two groups on the tests of motor skills, although on the whole, scores for the slow learners were lower than those for the dyslexics. The one exception to this was in the case of the Pegboard task where the slow learners were 0.55 seconds faster on average to complete the task than the dyslexics (ns).

(iii) Phonological skills

There were also no significant differences between the slow learners and the dyslexics on the measures of phonological skills. Inspection of the means table 4.23 in the previous chapter reveals that, apart from the condition of the Phonological discrimination task where real words were presented, the slow learners scored at slightly lower levels than the dyslexics on all of these tests.

(iv) Reaction time and naming

The slow learners were found to have scored at significantly lower levels than the dyslexics in the numbers condition of the Naming game ($p<0.05$). The dyslexics were able to accurately name an average of 5.67 of the 8 numbers presented whereas the slow learners were able to name only 2.40.

(v) Other measures

There were no significant differences between the two groups on any of the other measures administered at four years of age, although there was a general trend for the slow learners to score at marginally lower levels on the tests.

(b) Differences between dyslexics and slow learners at age five years

There were no significant differences between the performance of the dyslexics and slow learners on the measures administered shortly after school entry. However, the general pattern of poorer scores for the slow learners was also found to be present at this stage.

(c) Differences between dyslexics and slow learners at age six years

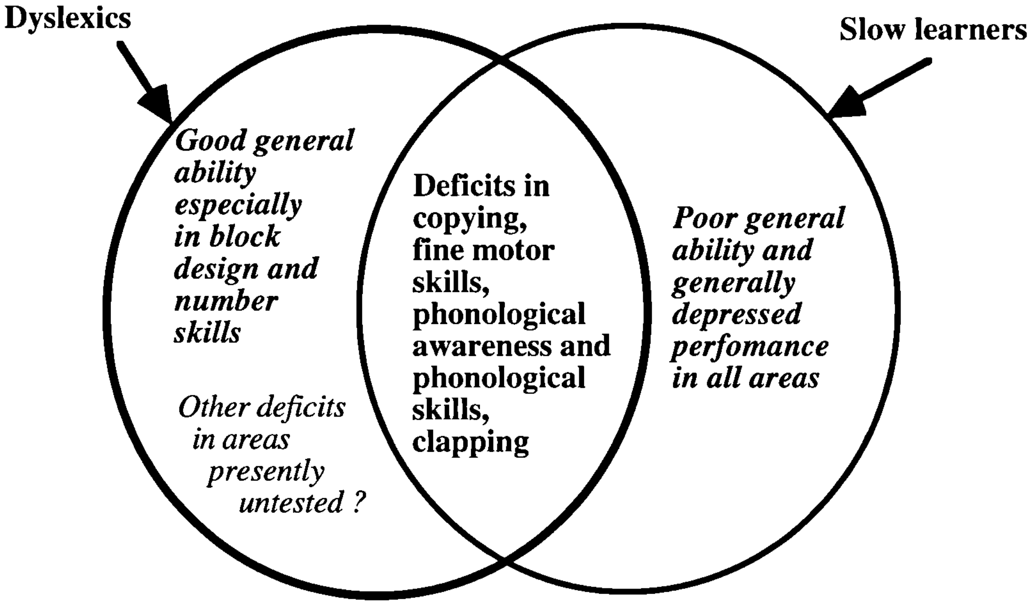
Despite lower scores for the slow learners on the majority of tests administered in the third phase of the study compared to the dyslexics, significant differences were found for only one test - the Listening comprehension test. When the scores were transformed into Listening comprehension ages, the slow learners were found to be performing over 15 months below the dyslexic subjects on this test. Indeed, the dyslexic subjects were found to have scored at higher levels than the control subjects on this measure.

5.2.2.1 Consideration of the evidence regarding the relationship of dyslexia to other forms of poor reading

The evidence from the present study suggests that although there is a general pattern of poorer scores for the slow learning subjects compared to the dyslexics, there are very few cases in which this difference is actually statistically significant. Examination of the graphs in figures 4.5, 4.6 and 4.7 in the previous chapter indicates the relative performance of the two groups in terms of the scores for all subjects. Consideration of relative profiles reveals that the performance of the slow learners is more consistent than that of the dyslexics in that it is generally low on all tests. The dyslexics, on the other hand have a more varied profile of performance with relatively good scores on the tests of general ability (apart from Copying and Recall of digits) but poorer scores on the phonological tests and some fine motor skills tests. However, one major limitation of this analysis is the small number of subject in each of the two groups. With only nine dyslexics and ten slow learners, the ability to generalise the results of this study to all dyslexic and slow learning children is restricted.

As far as providing evidence in the debate regarding the relationship of dyslexia to other forms of poor reading, the present study is able to largely confirm what has already been found by researchers such as B.A. Shaywitz et al. (1992) in that the major differences found between the two groups appear to largely reflect differing IQ levels. The results also confirm Badian's finding of more specific cognitive impairment in the dyslexics compared to the slow learners. However, when Gough and Tunmer (1986) coined the term "garden variety poor readers" they did so based on the notion of this group of children having difficulties with both the decoding and comprehension of language, whereas the dyslexics were viewed as having a decoding deficit only. In the present study, at the age of six years, the dyslexics were found to have been performing at significantly higher levels on a measure of listening comprehension than the slow learners, despite similar reading performance. Taken overall, the findings of the present study suggest that the relationship of dyslexia to generalised or garden variety poor reading can be viewed as in figure 5.2 below.

Figure 5.2 The relationship of dyslexia to generalised poor reading as indicated by the findings of the present study



The results of this study do not resolve the issue of whether the differences between dyslexic and slow learning children are more than just those based on IQ. However, this does not mean to say that there is not a fundamental difference between the two groups of children. It may merely be the case that the tests administered in the study did not tap the nature of this difference. It appears that the dyslexics and slow learners have scored poorly on the tests of phonological skills, but it may be the case that this deficit is at the level of the symptom rather than the cause. That is to say, it may be the case that both groups score poorly in this area because these skills are the building blocks of the basic manifestation of the two conditions - poor reading and spelling. It may not be the case, however, that deficient phonological skills are the root cause of either of the two conditions. For example, in the case of dyslexia, this may be due to a specific failure to automatise skills, whereas for the slow learners it may be due to generally depressed cognitive function in all areas. A definitive answer to this issue cannot be provided based on the evidence from this study. Further research investigating a greater range of skills in the two groups may provide information to resolve the debate.

Brief examination of the performance of the dyslexic subjects in comparison to children with mild reading deficits (the borderline poor readers) reveals only one significant difference on the measures administered at four years (Rhyming condition 2, $p<0.05$) and also at five years (Rhyming condition 1, $p<0.05$). On both of these conditions of the Rhyming task, the dyslexic subjects scored at lower levels than the borderline poor readers. The dyslexics performed more slowly on the Pegboard task in comparison to the borderline poor readers, but not significantly so. The borderline poor readers appear to have scored similarly to the dyslexics on the tests of general ability, although on many of the other tasks they have scored at slightly superior levels. It seems therefore, that the dyslexics are similar to the borderline poor readers in terms of general intellectual abilities, but on tests more directly related to language, the borderline poor readers are at a slight advantage. These findings add weight to the idea that the dyslexic deficit on these tests is related to the key manifestation of the dyslexia - the written language difficulties, because the same pattern of performance, but less severe, is found in the borderline poor readers.

5.2.3 Evidence to contribute to our current understanding of dyslexia

Although the key purpose of this study was to design an early screening test for dyslexia, a number of theoretical issues have also been explored. The final theoretical objective of the study was a more general examination of the findings in terms of their contribution to our understanding of dyslexia. Specifically, the issues of incidence, subtypes and causes of the disorder are considered. Underlying this final objective was the possibility that information collected from dyslexic children at four, five and six years of age might provide evidence to support the notion of differing forms of dyslexia or a particular explanation of the causes of the disorder. These issues are discussed below.

(a) Incidence of dyslexia

In the present study, nine children from a total of 91 completing all phases of the study were identified as dyslexic at age 7 years (9.89%). However, the criteria for identification were less strict than those used by many practitioners, in order to provide an over-inclusive group for the study. Therefore this may not reflect the incidence of "pure dyslexia" often proposed by researchers. Five of the children at age seven were found to have reading ages that were twelve or more months below their chronological ages although only three of these discrepancies were significantly lower than would be expected based on age and full scale IQ. In addition, children who were identified as "probable dyslexics" and children with additional problems to their dyslexia (e.g. neurofibramatosis) were also included.

It is likely, therefore, that the incidence of dyslexia found in this study is greater than the incidence of "pure dyslexia" (based on an IQ of above 90 and a reading discrepancy of 18 months or more below chronological age) found by other researchers (e.g. Yule and colleagues, 1974). However, the fact still remains that nine of the children in the study were found to be experiencing difficulties with their written language development that could not be explained by generally low abilities or lack of access to teaching. These children require help to be able to progress in the academic system, and therefore whether traditionally recognised as dyslexic or not, almost ten percent of the children taking part in this study were found to have been unexpected poor readers.

(b) Subtypes of dyslexia

For a number of years some researchers have proposed that there is not just one form of dyslexia, but a number of subtypes of the disorder (e.g. Boder, 1973; Johnson and Myklebust, 1967). In general, distinctions have been made between more visually-based and more auditory-based forms of dyslexia. In the present study the issue of subtypes has been addressed by examination of the profiles of performance of the dyslexic subjects on the range of tests administered in Phase 1 of the study. Appendix 5.5 presents the profiles for the nine dyslexic subjects. Close examination of the children on a range of tests does not reveal any major subtypes of the disorder. The performance of the dyslexic group appears to be as a number of researchers have found - heterogeneous. Performance of all dyslexics on many of the tests of phonological skills was poor compared to the subject group as a whole (the mean is indicated by a horizontal line running through zero on the y-axis). Evidence of visual deficits can be found for some of the children such as LH and LC, in that their scores on the BAS Visual recognition subtest and the Visual Search task were relatively low. Other dyslexic subjects do not appear to have shown deficits on these tasks.

In short, examination of the profiles of performance on the range of tasks administered at four years of age does not appear to able to contribute to the debate regarding subtypes of dyslexia. However, the tests that were administered in the study may not have been appropriate for measuring the sorts of visual and auditory deficits that have been found by researchers such as Boder (1973) or Thomson (1982). Performance of young dyslexic children on test measures other than those used in the present study many be able to provide more definitive information regarding the existence of subtypes.

(c) Theoretical explanations of dyslexia

The tests included in the predictive phases of this study were developed to reflect some of the current theoretical approaches to dyslexia at the present time. A large number of tests were designed to measure deficits in phonological skills as predicted by the Phonological deficit hypothesis explanation of dyslexia. Some tests were investigating motor skills difficulties as predicted by the Dyslexic automatisation deficit hypothesis (Nicolson and Fawcett, 1990). Others attempted to examine speed of processing or visual aspects of the disorder. In Chapter 1, the relative contributions of these current approaches to our understanding of the nature and cause of dyslexia were presented. It was noted that none of the theoretical approaches had been able to provide a comprehensive explanation of the disorder at the present time. Therefore, the results of this study are briefly examined to see whether they lend any weight to one or other of the competing explanations, and go any way to furthering our understanding of the disorder.

One of the most consistent findings of the present study was that dyslexic children appear to have significant difficulties with most aspects of phonological skill and phonological awareness. Cognitive profiles of all the dyslexic children at the age of four and five years of age were characterised by lower performance on some or all of the tests of phonological discrimination, nonword repetition, rhyming, lexical access, phonological segmentation and articulation rate. These findings were in contrast to the performance of normal readers who scored relatively well on the phonological tests. Therefore deficits in phonological awareness and phonological skill appear to be a major aspect of dyslexia. However, these deficits were also found in the performance of the slow learners and therefore cannot be said to be specific to dyslexia.

In addition to the phonological deficits found, poor performance was observed in three tests with a motor skill component: copying, pegboard and clapping. These findings cannot be accounted for solely in terms of a phonological deficit and therefore call into question the ability of this theory to fully explain the causes of dyslexia. However, it is not to say that the visual explanations or temporal processing explanations are more appropriate for these deficits. Fawcett and Nicolson (1994) have reviewed the evidence regarding motor skills in dyslexia. Problems have been found in handwriting, tying shoe laces (e.g. Miles, 1993) and copying (Rudel, 1985), although early explanations for copying deficits tended to be centred around visual deficits. Tapping of fingers and related movements have also been found to cause problems for dyslexic children, particularly in terms of speed of performance (Denckla, 1985). Awareness of these deficits has led to the proposal of a maturational lag in the "motor analyser" which programmes timed sequential movements, particularly in the acquisition of new tasks (Denckla, 1985).

The findings of the present study suggest that children with dyslexia do have difficulties with tasks involving fine motor skills, particularly under speeded conditions. Fawcett and Nicolson (1994) have interpreted the research regarding motor skills and dyslexia and their own finding that dyslexic children are impaired in a balance task (dual task or blindfold conditions) in terms of their dyslexic automatisation deficit and conscious compensation hypothesis, whereby lack of proficiency in motor skills represents incomplete automatisation of the skills. They argue that far from being a specific deficit as proposed by the Phonological deficit hypothesis, the major difficulty in dyslexia is in terms of all primitive skills (e.g. speed of processing and motor skills). Children are able to consciously compensate for the deficits in some situations by trying harder or employing strategies, but deficits will be apparent when conscious compensation is not possible. This is particularly the case in complex skills that require fluency in component subskills, skills requiring the integration of information from more than one modality, and situations where processing speed is important. Better than average performance is possible, however, when these task demands are low and good general ability is able to show through.

One aspect of this study which did not support the DAD hypothesis was the finding that these children were not impaired on the Blindfold balance task. This task has previously been used with children of eight years and above and it has been found that dyslexics tend to "wobble" much more than non-dyslexics when trying to balance with their attention directed away from the task. The failure to find evidence of a dyslexic balance deficit in this study can probably be accounted for in terms of the task being too difficult for *all* children to carry out, and therefore, no real differences between groups were apparent.

The implications of this and other findings of the present study suggest that for many skills, dyslexics are slower to fully automatise and learn, but in time they are able to catch up with their non-dyslexic peers. By the same token, there will also be a period where all children are poor at certain skills before development and automatisation of the skill occurs. In the case of the balance task, the sensitive period for measuring this skill may actually be later than four or five years of age, and therefore more pronounced differences are found between older children on this task. Other skills may develop at different rates in dyslexics, but nonetheless, with enough exposure to learning and practice, may be acquired to the same levels as in non-dyslexics. For example, Scarborough (1990) found that spoken language difficulties were found in children with dyslexia up to the age of five years, but by this time the dyslexics were performing similarly to their non-dyslexic peers. It is possible that the finding of differences between dyslexics and non-dyslexics is dependent on the nature of the differences investigated and the period in the development of the child.

The dyslexic automatisation deficit hypothesis is able to account for the phonological deficits found in the dyslexic children in this study, in terms of skill acquisition difficulties, but the Phonological deficit hypothesis is not able to account for the deficits found in motor skill. However, as a complete explanation of dyslexia, the DAD hypothesis is not fully specified as, as noted in Chapter 1, its proponents think of it more as a "theoretical "half-way house"" whose explanation lies in terms of some form of neurological deficit.

In terms of contributing to our understanding of biological aspects of dyslexia such as genetic and structural explanations, the present study is limited. No measures of structural difference were possible for reasons outlined later in the chapter, but evidence regarding genetic aspects can be found in terms of the number of dyslexics having a parent or sibling. In considering the background information for the dyslexic subjects and slow learners it was found that four of the nine dyslexic children identified at follow up had at least one family member with dyslexia compared to none of the slow learners. However, a significant number of children with dyslexic relatives (n=16) were not found to be dyslexic at follow up. Therefore although there does appear to be some hereditary mechanism in dyslexia, its role in the development of the disorder is not clear from this study.

The contribution of the findings of this study to our theoretical understanding of dyslexia can therefore be thought of as a confirmation of the position of phonological deficits in the characterisation of the condition along with difficulties with motor skills, particularly in speeded conditions. These findings challenge the ability of phonological deficit and visual deficit theories as complete explanations of the disorder, but lend some support to automaticity based explanations. However, in light of the results of this study, even the DAD hypothesis is found to be incomplete as one of the key tests of automaticity deficits - the Blindfold balance test - did not reveal any significant differences between dyslexics and slow learners. Considerable further work is therefore needed to fully account for the causes and mechanisms of dyslexia.

5.3 Limitations of the present study

In the light of findings from studies, researchers often become aware of aspects of their investigations that could have been carried out differently, producing better or more accurate outcomes. This is particularly true in longitudinal studies, where, due to the nature of the research method, less opportunity for modification of research plans is possible. This has been the case in the present study, and as a consequence, a number of limitations have been identified that may have negatively effected the findings of the project. These limitations are based around selection of test measures, selection of subjects, timing of test administration and selection of outcome groups. Each of these limitations is dealt with in turn below.

5.3.1 Limitations in the selection of test measures for the study

One of the major difficulties for a study such as this one is the selection of tests to identify the children of interest - the dyslexics, before they are known to be dyslexic. The approach taken in the present study was to select tests for inclusion on the basis of a number of factors:

(i) tests that had been used in previous studies found to have predictive value

(ii) tests appropriate for the age group to be studied (four years)

(iii) tests selected and designed to reflect current theoretical explanations of dyslexia.

One major limitation of the present attempt to predict dyslexia is that due to time pressures, tests had to be selected quickly for the initial screening battery before testing could begin. Although a relatively large body of literature was reviewed before this was done, literature subsequently discovered and published has identified tests that would possibly have been of more use to the study. One major example of this is the research concerning spoken language difficulties as precursors of dyslexia. Measures of spoken language at four years could have been collected as part of the predictive data for subjects, and may have had a greater predictive value than some of the tests given.

Only tests that were thought to have been suitable for children of four years of age were selected for the screening measures. This meant that a number of tests that would perhaps have been useful in the early identification of dyslexia were not included. One example of this is the Finger localisation test (Lefford at al., 1974; Lindgren, 1978). This test has been found to be useful in the prediction of dyslexia and later reading ability (e.g. Satz and Friel, 1973), but was felt to be too difficult for children of four years of age to carry out. Other examples included phoneme awareness measures such as tapping (e.g. Liberman et al., 1974). Finally, tests were selected to reflect current theoretical explanations of dyslexia. However, the extent to which this was possible was limited because, for example, tests of neurological difference or deficit were not possible to administer, as they are too costly and/or dangerous for routine use with very young children, and also some of the more recent theoretical advances (such as the role of the cerebellum) were made after the start of the study. The predictive ability of these tests may have been greater than those tests that were used, particularly in distinguishing dyslexics from slow learning children.

In addition to this it was found that some of the tests were administered to the children proved particularly difficult for them to understand or carry out, so that differences in performance may not have reflected genuine differences in ability. One example of this already mentioned is the Blindfold balance task. Problems were also found with some of the computer based tasks where the concentration span of the child was not long enough for them to complete the task properly (e.g. Lexical access). Another difficulty in the selection of tests for a screening battery is an adequate understanding of what exactly the test is measuring. A number of tests such as the Lexical access test were almost certainly measuring more than one dimension of a child's ability, and therefore deficits in performance on the task could be for a number of reasons. In selecting tests for a predictive index it may be important to simplify tests and to examine the specific skills that are being tapped by each test. Factor analysis would go some way to doing this, but was unfortunately not possible in this study due to the very large number of tests compared to subjects.

Therefore, although some of the tests that were used in the screening phases of the study did show some ability to predict children with later reading difficulties, the fact that they had to be chosen relatively quickly, early in the project, almost certainly means that there exist tests which would have been more effective predictors.

5.3.2 Limitations in the selection of subjects

A second limitation of the present study is that of selection and maintenance of subjects. The initial selection of the general population group of subjects did not provide many problems and at the beginning of the study, 100 children attending nursery schools in a range of areas across the city were recruited with parental consent to be involved in the study for the 3 year duration. However, recruitment of the "Siblings" group proved much more difficult and despite considerable advertisement and contact of organisations such as the local Dyslexia Institute, only 30 children were recruited. In addition, the characteristics of this group were more variable than was hoped. The age of the subjects varied so that children as old as 7.5 years were eventually included in the subject group. Some of the children were brothers or sisters of children who were dyslexic, whereas others had a parent with the disorder. It would have been much more desirable to have selected children with a family history of dyslexia who matched the general population subjects in age and social background. However, this did not turn out to be possible as restriction of the group to the target age (4.6 years) would have resulted in a very small number of subjects in the "Siblings group". It was therefore decided to include all of the children in the group, but to make note of situations where superior performance on a test may have been due to age. For many of the tests this was not necessary however, as the scores were standardised based on age, and results were therefore comparable.

Over the course of the three and a half years during which the data from the subjects were collected, 29 of the general population group and 10 of the "Siblings" were lost from the study. The children were lost at various point across the four phases, usually due to moving from the area, moving school, or becoming consistently uncontactable so that a phase of testing was missed. Although it is believed that the characteristics of the subjects who left the study were no different from those who remained and therefore this did not bias the results, the loss of subjects to a study like this does have some important consequences. The most important one of these is that collection of data for a greater number of children, particularly those with a family history of dyslexia, may have resulted in a greater number of definite dyslexics being identified at follow-up. This may have meant that the distinction between the dyslexics and slow learners would have been clearer. On the whole, the present findings would have been much more reliable if a greater number of subjects had been included in the study, and therefore the loss of subjects, particularly the "Siblings", was a limiting factor.

5.3.3 Limitations in the timing of test administration

The major difficulty in carrying out a longitudinal project to predict dyslexia is that the children need to be old enough at follow up for diagnosis of dyslexia to be accurate. In this study, the timing of test administration, particularly in the follow-up phases (Phases 3 and 4) was earlier than would have been preferred due to time restrictions for the project. Satz and Fletcher (1988) noted that the follow-up period for an early identification study should be at least three years. However, for the majority of children in the study, Phase 3 criterion testing was carried out only two years after the first predictive testing, at the age of six and a half years. For subjects taking part in Phase 4, this was carried out at the very earliest age that a diagnosis of dyslexia would normally be attempted, at seven years.

The major implication of this limitation in the timing of administration of criterion tests is that an accurate picture of the abilities of the children was not obtained. Some of the children may have been lagging behind their peers due to a general immaturity, but may have caught up during the primary school years. One possible outcome of this is that the children who were identified as dyslexic and slow learners may have not have been so. This limitation is discussed in the following section.

5.3.4 Limitations in the selection of the outcome groups

As indicated above, restriction of the timing of the final follow up phase to the age of seven years may have resulted in the mis-identification of some of the subjects, particularly the dyslexics and slow learners. The dyslexic subjects were selected using criteria that were designed to produce an over-inclusive group and may have therefore included children who would not have been traditionally though of as dyslexic. The group was very small in number and contained children who although having evidence of dyslexic difficulties, also had additional factors such as medical problems, emotional and behavioural problems and relatively low IQ's. In some cases the discrepancy between observed and expected reading performance was not significant. All these factors may have meant that the children in the "dyslexic" group were not true representations of "pure" dyslexics.

Administration of the diagnostic measures at the age of seven years may have underestimated the reading and spelling abilities of the children. For example, some of the subjects may have been found to have caught up with their peers if tested at the age of eight years instead of seven. In addition, it is possible that some children not identified as dyslexic in the present study may have actually been suffering from the disorder. Three subjects: BB, CN and MS-B were strongly suspected by parents to have dyslexic difficulties, and were known to have had some extra help from parents on this basis. Therefore their reading and spelling difficulties may have been masked at Phase 3 testing and therefore not considered severe enough for the child to be assessed at Phase 4. However, these children may have been found to be dyslexic if measures such as the WISC-III UK and WORD had been administered.

The outcome of this limitation is that children with dyslexia may not have been identified at follow up and children not having dyslexia may have been included in the group labelled as dyslexic. Examination of the evidence in Appendix 5 suggests that this is quite likely as subject MS-B was found to have scored at least one standard deviation below the mean on four of the SPI tests. Subjects CN and BB were both found to have scored one or more standard deviations below the mean on two of the SPI tests. In addition, the SPI and SPI (II) profiles of some of the "dyslexics" (see Appendix 5.3) reveal few poor scores on the predictive tests. This limitation also applies to the slow learning subjects who may also have been found to have improved their reading performance if the final follow up testing had been carried out at a later stage.

In summary, therefore, the limitations in test selection, subject panel recruitment and maintenance, timing of test administration and, perhaps most importantly, selection of outcome groups has meant that the results of this study are not as reliable as would have been hoped. Despite this, it is believed that the screening test designed in the study is a valid tool for the identification of dyslexia. However, it remains for further studies to determine how successful it can be in achieving this goal. Considerations for directions for future research in this area are considered in the following section.

5.4 Directions for future research

In light of the limitations of this study and the findings of more recent research, a number of pointers for future research have been noted. These are outlined below in terms of the four objectives of the present study.

5.4.1 Design of a screening test for the early identification of dyslexia

There are a number important issues involved in the design of an early screening test for dyslexia which became apparent in the present study and would benefit from further investigation. The first of these is the selection of tests for the screening battery. In further exploring the potential of measures to accurately predict dyslexia in very young children, additional tests may be considered for inclusion in the test battery. Established measures such as Finger localisation may add to the predictive value of the index. In addition, tests based on more recent research, such as the Postural stability test used by Nicolson and Fawcett (personal communication) may also be useful. This test is based on the idea that the cerebellum is involved in dyslexia and moreover, has been found to identify dyslexics but not slow learners. This may be one of a small number of tests that is able to distinguish between the two groups. Other tests used in this study but not found to be highly predictive may be altered to increase their contribution to prediction. One example of this is the Naming game which may be altered to continuous format with better results.

As research into the characteristics and biological and cognitive mechanisms of dyslexia develops, the range of tests that are able to accurately predict dyslexia may increase. In particular, increases in knowledge regarding the neurological underpinnings of the disorder can allow tests to be designed to measure these biological changes at an early age. A solid foundation of understanding of the causes of dyslexia is the best basis for the design of a practical instrument such as an early screening test. However, other considerations are also important.

A screening test needs to be valid - it should identify the children it sets out to identify. The Screening Predictive Index designed in this study was able to identify some of the children identified as dyslexic at the age of seven years, but it also identified other subjects. It would be very useful to follow the subjects in this study until the age of eight years of age or above to monitor the accuracy of predictions using the SPI. An important aspect for future research is the validation of the present screening measures on a much larger sample of children (for example, one thousand preschoolers including those with a family history of dyslexia). The generation of norms for the SPI measures based on the performance of a wide range of children on the test will allow the comparison of the performance of young dyslexic children.

In addition to establishing the validity of the SPI, the utility of the test also needs to be examined. This test was designed for teachers or other school personnel to administer in the school environment. It should be quick and straightforward to administer, score and interpret. Use of computer technology available in schools may enhance speed and ease of use of the screening measures. A test that is too difficult to use will not be a benefit to teachers. Piloting of the test in schools can allow feedback from teachers regarding possible improvements.

Therefore, a number of directions for future research exist. These include the search for new and better tests for the prediction of dyslexia and improvement of the format of some existing tests, the validation of the SPI with a much greater sample of children over a longer time period, and the investigation of efficient ways for the test to be implemented in schools.

5.4.2 Theoretical issues: early manifestations of dyslexia, dyslexics and slow learners, and the development of a theory of dyslexia

In terms of the theoretical issues examined in this thesis, the scope for future research is enormous. The practical issues outlined above represent some of the key research questions in dyslexia today. Establishment of the early manifestations of dyslexia is an area of research that is important for practical endeavours such as early identification but also for more theoretical questions such as the development of dyslexia over time (for example from a spoken to a written disorder). An understanding of the characteristics of the condition before the development of written language skills may highlight symptoms unrelated to language. This may have tremendous implications for the development of theoretical explanations for dyslexia.

The relationship of dyslexia to "garden variety" poor reading is an issue which looks set to be debated a great deal in the near future. Evidence to suggest that dyslexia is a distinct entity may contribute to our understanding of the structural basis of the disorder. On the other hand, research that suggests that dyslexia is merely a form of poor reading found in children with average to above average IQ levels indicates that the wealth of research activity currently investigating the normal processes of reading acquisition can be applied to children with dyslexia.

5.4.3 Summary of directions for future research

Although movement towards an understanding of dyslexia has been made over the last decade, there is still very little consensus regarding the cause of the disorder. This has an impact on the way we currently view dyslexia and how we diagnose and remediate it. In terms of future research, a great deal remains to be done to fully explain how children with good abilities in some areas can also have great difficulties with reading and spelling, as well as a range of often more subtle problems. Developments in theoretical understanding may lead to better practical understanding and the accurate diagnosis of dyslexia at an age at which the greatest chances of remediation are possible.

5.5 Summary of the chapter

This chapter has reviewed the findings of the study in the context of the four research objectives investigated. It has been found that prediction of children's later reading status is possible to some degree, although differentiating between dyslexics and slow learners is somewhat more difficult. In addition to the design of a screening test, the theoretical basis of the early manifestations of dyslexia was examined. The relationship of dyslexia to garden variety poor reading (or slow learners) was also examined. Implications for our general understanding of dyslexia were also considered. The second part of the chapter outlined some of the limitations that were found with the present study and this was followed by a review of some directions for future research.

Chapter 6
Conclusions

Dyslexia is a disorder regarding which there is much debate and disagreement. Although some significant progress in dyslexia research has been made in the last ten years, many questions remain unanswered. No one agreed definition exists, and more recently some researchers have questioned the validity of considering dyslexia as a distinct disorder that is different from other forms of poor reading. The mechanisms responsible for dyslexia are being actively sought, however, no complete theoretical explanation has yet been found.

Against this backdrop of theoretical uncertainty, a practical problem exists. This is that children with dyslexic difficulties do exist, and for these children diagnosis and remedial help is important. However, in the light of disagreement regarding fundamental aspects of dyslexia - how is diagnosis achieved? Traditionally diagnosis has been based on the major manifestations of dyslexia - the written language problems. One difficulty with this approach is that in view of the characterisation of dyslexia as unexpected reading problems, dyslexic children need to be differentiated from children for whom reading problems are part of a more general cognitive deficit (garden variety poor readers or slow learners). This has traditionally be done by use of an intelligence test. For many dyslexia practitioners, diagnosis of dyslexia involves the establishment of an IQ score of 90 or above, a sizeable discrepancy between the reading and spelling performance of the child and what would be expected based on age (and IQ), and the existence of no other factors that could have been responsible for the reading failure (such as lack of access to teaching or emotional problems).

However, there are a number of limitations which result from use of this form of diagnosis. One of these is that often diagnosis is only be carried out when parents and teachers can find no other reason for the child's problems. In many cases the child may be thought of as lazy or stupid. Parents may be told not to worry - that things will come in time. This may mean that problems are left undiagnosed for many years or may never be identified at all. The measures used in diagnosis - IQ tests and standardised reading and spelling tests - are often not suitable for use with children below a certain age. This has tended to mean that diagnosis is not possible before the age of seven years. However, it has been found that children are often not referred for assessment until around the age of ten or eleven years, often at senior school entry. Negative outcomes of late diagnosis, or no diagnosis at all, include academic, emotional and behavioural problems.

One method of improving the identification of dyslexia is to screen all children of a certain age for the disorder. Research has indicated that this may be possible before or at school entry. Recent advances in theoretical understanding of the biological, cognitive and behavioural aspects of dyslexia suggest that there may be manifestations of the disorder present before reading failure begins. For example, the work of Galaburda and colleagues has provided evidence of structural differences in the brains of dyslexic and non-dyslexic individuals, in areas of the brain associated with linguistic processes and the rapid processing of visual and auditory stimuli. Other researchers have also found differing patterns of brain activity. More recently Nicolson, Fawcett and Dean have found that dyslexic children perform poorly on tests of cerebellar function.

Miles (1993) has speculated on how the manifestations of dyslexia may develop. He suggests that for neurological reasons, there may be some difference in the process of development which results in an "unusual balance of skills". This may be caused by hereditary factors. He proposes that: "Reasoning is unaffected, and in some areas such as art and engineering there may be exceptional talent. There are weaknesses, however, which may show themselves as early as age 3 in spoken language, and thereafter when the child is required to deal with written language. Many of these weaknesses are overcome by practice and suitable training" (p. 190). The challenge for an early screening test is measurement of the early manifestations of the mechanisms responsible for dyslexia, in order to identify young children as at risk for the disorder. This means that children can be given early remedial help and therefore, be prevented from falling by the wayside, or being labelled as incapable or unwilling.

The concept of early screening is not a recent one - screening studies have been carried out since as long ago as 1935. A number of researchers have attempted to design tests to identify later poor readers or dyslexics. However, despite some success in identification, no test has ever been one hundred percent accurate in predicting later reading status. This has led to critisisms by some researchers that early screening is not a worthwhile activity, particularly in terms of the costs of implementing such a scheme in all schools. More recently, a number of developments in early screening and dyslexia research have meant that early identification procedures may now be more efficient and accurate than ever before. These developments include new theories regarding the cause of dyslexia (such as the Dyslexic automatisation deficit and speed of processing hypotheses), and the availability of new forms of technology to enhance ease and reliability of test administration.

The benefits of a multi-stage process of early identification of children with academic difficulties are considerable, both in terms of financial and human cost. Many researchers have proposed that early screening of all children should form the first stage of a process of identification, involving quick and simple measures administered and interpreted by school personnel. Following this, children for whom there is some concern may be noted as "at risk" (*not* labelled as dyslexic) and given remedial help, monitored closely by the teacher, and perhaps referred for more detailed testing by an educational psychologist. This procedure would not be financially costly to implement and would prevent the prolonged suffering of the child with dyslexia, by bringing in assistance at the time when it was most beneficial to the child. The cost of providing teaching that is similar to that already available in the primary school classroom, but perhaps at a more intensive level for the at risk child, is much less than that of providing an educational psychologist to visit a school, or placement in a special residential school for children with dyslexia. The case for early screening is, therefore, a strong one.

This study has attempted to design an early screening test for dyslexia which is more effective than existing screening tests. This has been done by selecting test measures to reflect current explanations for the disorder, therefore providing a theoretical basis for the test. Recent findings from dyslexic children at the age of eight years have been taken into account, for example. In addition, computer technology has been used to present many of the tests, to allow easier, more flexible and more consistent administration. The study was carried out by administering potentially predictive tests to a group of children (including a number with parents or siblings with dyslexia) in two phases. It was found that a number of tests of phonological skills (rhyming, phonological discrimination, phonological segmentation, nonword repetition, and recall of digits) and motor and related skills (copying, pegboard, and clapping) (the Screening Predictive Index - SPI) were able to identify many of the dyslexics and slow learners, but very few of the normal readers. However, prediction of dyslexics as distinct from slow learners was not possible using this screening test. Use of an annex to the Screening Predictive Index, the SPI (II) did allow differentiation of the poorest readers into dyslexics and slow learners. Background information from teacher and tester comments, and questionnaires from parents, although incomplete, provided additional information useful in prediction.

The prediction of dyslexia using the SPI, SPI (II) and background information was therefore found to be possible to some degree. However, prediction was not found to be one hundred percent accurate. Possible reasons for this included failure to incorporate better tests into the predictive battery (such as tests of cerebellum function) and also limitations in the groups designated as dyslexic and slow learning in the study. It was speculated that a some of the children in the "dyslexic" group may not have been dyslexic, particularly in light of limitations in diagnosis due to the young age of the subjects at follow up (seven years) and the decision to relax the criteria for diagnosis. An additional difficulty was the small number of subjects in the dyslexic and slow learning groups compared to the number of normal readers (nine and ten as compared to fifty-three). This may have meant that the differences found between the groups may have reflected large deficits in the performance of one or two of the subjects.

Nonetheless, the theoretical basis of the test is believed to be valid. It is capable of identifying children with phonological and motor skills deficits but who are also found to have good verbal comprehension, visual-spatial skills and other aspects of general ability. In other words, these are children of four and five years of age who have the early signs of being *unexpected poor readers*. Information such family history of dyslexia and history of speech difficulties may also assist in identifying these children. They can be differentiated from children who also perform poorly in terms of phonological and motor skills but who are found to have low scores on tests of general ability.

However, it would be preferable to have an all-inclusive test that is able to differentiate children with dyslexia and slow learning children without the use of general ability measures, but merely reflecting the mechanisms and deficits responsible for each condition. The postural stability test, used by Nicolson and Fawcett has been found to cause problems for dyslexics but not slow learning children. In improving the SPI, it would certainly be useful to include this test.

Like many screening studies, therefore, it has to be concluded that prediction using the selected measures was possible to some extent, but not with one hundred percent accuracy. However, this was a relatively small scale study, restricted in terms of finance and time. Future research may allow the development of the present findings to the point where a highly efficient, low cost early screening test can be implemented in our schools.

In terms of the three theoretical objectives of the study, limited results were found. It was noted that the early manifestations of dyslexia included deficits in skills other than phonological abilities, therefore calling into question purely phonological causes of dyslexia. However, deficits in phonological skills were most definitely evident at the age of four years. The key differences between the dyslexics and slow learners largely appeared to be in terms of general ability, with listening comprehension at the age of six years also making a distinction between the groups. Therefore, these findings do not contradict what has been proposed by researchers such as Siegel and Stanovich. However, it is believed that the range of measures administered in this test did not tap the differences that exist between the two groups but instead merely measured aspects of ability which are found to be poor in both groups, but for different reasons. The dyslexics have specific difficulties in language and motor skills due to structural neurological differences in specific areas of the brain. The slow learners, on the other hand have a general problem with many skills due to a generalised neurological deficit. Tests such as postural stability may well identify a difference between the two groups.

Coming back to the beginning of this study where the theoretical basis of dyslexia was examined, it is possible to consider whether the results of this study have made a contribution to our general understanding of dyslexia. In terms of incidence and subtypes, the evidence was found to be unclear. Indeed, a number of the study's findings are somewhat clouded by the uncertainty of the validity of the group of children identified as "dyslexic". However, it did appear to be the case that the findings confirmed the existence of deficits in speeded fine motor skill performance, in four and five year old children, later found to have unexpected reading problems. These findings challenge the ability of the phonological deficit hypothesis to fully explain dyslexia and lend some support to broader explanations such the dyslexic automatisation deficit. However, support for this is also limited by the finding that young "dyslexic" children were no worse than the non-dyslexics at balancing whilst wearing a blindfold. However, this may have been partly due to problems in the design of the task.

It can be concluded, therefore, that further research is needed in this extremely valuable area, to establish the early manifestations of dyslexia, and reliable and accurate ways of measuring them. Children will then be able to benefit from the early identification of dyslexia.