Theory and Intervention

A Complete Analysis for Children with Learning Difficulties

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by

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Summary

The two main aims of the research presented in this thesis are firstly; to develop theoretically valid methods of distinguishing between dyslexic and non dyslexic poor readers (ND-PR) through the use of behavioural tests in a range of primitive skill areas and secondly; to develop and evaluate three intervention programmes for learning disabled children based on sound theoretical principles. The implications of these findings for the traditional discrepancy definition of dyslexia are considered.

In the first set of studies, dyslexic and ND-PR were tested at 8 and 10 years of age on a battery of theoretically chosen tests of primitive skills. As expected from the literature, both the dyslexic and ND-PR showed difficulties in phonological skills (Bradley and Bryant, 1983; Snowling *et al.,* 1986; Vellutino, 1979). However, by contrast the dyslexic children also showed difficulties in certain tests of cerebellar dysfunction, whereas the ND-PR did not. This dissociation presents evidence for the cerebellar impairment hypothesis (Nicolson, Fawcett and Dean 1995). Findings give early support for the supposition that the phonological deficit theory may be subsumed within a broader causal framework of cerebellar impairment. Findings also suggest that there is value in retaining the discrepancy definition of dyslexia.

The second set of studies compared three types of training on skill acquisition for children of varied ability ages 5 to 6 years. The groups were given systematic training over a period of several weeks using a phonological, motor and arithmetic skill programme. Training was designed for administration by a relatively unskilled instructor. Parents successfully delivered the first training programme, the author the second. Promising results were reported for both small-scale studies. Persistent performance improvement in all training groups were shown in measures of reading and spelling age and IQ, together with cautious evidence of skill transfer. Interpretation of the results suggests that each of the training programmes had generic value for metacognition. The findings provide a demonstration of both the effectiveness and cost-effectiveness of this type of structured and regular training intervention with young children, particularly those with learning difficulties. Implications for both the phonological and cerebellar impairment hypotheses are discussed. It is proposed that a motor skill training programme in conjunction with a phonological training programme has potential in any home/school based intervention.

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'Today'

Many of the things that we need can wait
Not the child
Now is the moment when her bones are being formed,
His blood is being made,
And her senses are being developed,
We cannot answer him with 'Tomorrow'
Her name is 'Today'

(Gabriela Mistral)

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Preface

This thesis holds two main aims, which is reflected in the presentation of the thesis, which falls into two clear parts; part one comprising chapters one to three, and part two comprising chapters four to six.

The first aim of this research is to develop valid methods of distinguishing between dyslexic and non discrepant poor readers (ND-PR) through the use of behavioural tests in a range of primitive skill areas; whilst the second aim is to develop and evaluate an intervention programme for learning disabled children based on the sound theoretical principles which the first part of the thesis will help elucidate.

If justification is needed for the research presented in the first part of the thesis, then it lies in the fact that, unlike the dyslexic child, little comprehensive research has been carried out to investigate the performance characteristics of ND-PR children. What little work there has been has had a tendency to be variable in nature, and few have compared performance directly with matched dyslexic children. This research will redress this imbalance. The lack of research investment seems surprising when we consider the ongoing debate surrounding the discrepancy definition of dyslexia and the role of IQ in defining dyslexia. Stanovich is one of the leading names behind this debate and this research will be discussed in terms of his phonological core variable-difference theory of dyslexia (Stanovich, 1988).

Performance differences between the dyslexic and ND-PR will be assessed across a range of primitive tests, both informing and testing causal dyslexia theory by revealing the pattern of performance for both dyslexic and ND-PR children. Moreover, it will also inform the development of more theoretically motivated approaches to screening, such as the Dyslexia Screening Test (Fawcett and Nicolson, 1996), and give indications of appropriate support methods for both dyslexics and ND-PR children. A valid screening tool needs to incorporate tests which dissociate between not only dyslexic and controls, but also dyslexic and

ND-PR. (It should be noted that the term ND-PR should be considered interchangeable with the term mild learning disabled (MLD) wherever it may appear in the appendix. The term ND-PR is based on the discrepancy definition of dyslexia (Orton, 1995) whilst the term MLD is considered a British term used to refer to children with an IQ of 70-85).

Part one of the thesis comprises of chapters one to three. Chapter one presents a general introduction to the research, outlining the motivations behind the research and providing an overview of debates surrounding the definition and diagnosis of dyslexia, focussing particularly on the ideas of Stanovich and his phonological core variable-difference theory (Stanovich, 1988). Each of the main causal theories of dyslexia are described set within the context of the discrepancy definition of dyslexia and the Stanovich debate. The case is made for the retention of the discrepancy criterion on the grounds that with ever growing evidence of dyslexic deficits outside the phonological domain, symptoms of the 'true' underlying cause of dyslexia may well lie outside the area of phonology. Particular focus is given to the cerebellar deficit hypothesis and the predictions made by this theory, as early indications are that this may provide the long sought after parsimonious account for the range of deficits now established in the dyslexic. However, a stringent test of the adequacy of any theory of dyslexia is whether a similar pattern also arises for ND-PR children. Recent research comparing dyslexic and ND-PR children are critically reviewed in terms of Stanovich's theory.

Chapter two is primarily concerned with the performance of dyslexic and ND-PR children in tests of phonological ability. The phonological deficit hypothesis has been the dominant causal framework for dyslexia, and so much research has been invested in this skill area for the dyslexic individual. Furthermore, the phonological deficit hypothesis is central to the theories of Stanovich. Unfortunately, since research into the performance of ND-PR in skill areas including phonology is relatively scarce, performance predictions are made somewhat tentatively.

The study in chapter two involves testing dyslexic and ND-PR children of 8 and 10 years of age on a wide range of phonological skills. The pattern and extent of the difficulties demonstrated between the two groups are discussed in terms of the fresh and interesting implications they hold for Stanovich's theory and the IQ debate. Moving from theory to practice, the implications of the findings for the inclusion of phonological tasks in screening tools for children are considered. The chapter concludes by reflecting on the need to continue and expand this research to include a broader range of skill areas before firm conclusions can be drawn in both areas of causal theory and practice.

In chapter three the phonological data from the preceding chapters is incorporated into a broad range of primitive skill evaluations. Again the groups used are the same, allowing direct comparisons of dyslexic and ND-PR performance. The tasks used are those in which rough performance predictions can be made for the dyslexics based on both established and more recent key causal dyslexia theories. In term of predicting the performance of the ND-PR group, the situation is again less clear due to the slight and variable nature of research into this group of children to date.

This chapter proceeds to report the performance findings in the range of primitive skill tests (including cerebellar deficit tests) for 8 and 10 year old dyslexic and ND-PR children. With the addition of this broader test battery, the resulting picture is much clearer producing an interesting dissociation between the two groups. Implications for the cerebellar impairment hypothesis, (Nicolson, Fawcett and Dean, 1995) and the phonological deficit theory are discussed. Furthermore, the validity of distinguishing between poor readers with discrepancy and those without are considered in the light of these findings.

Part one of the thesis concludes by first looking back and recognising the contribution the research in part one will make in areas of causality, early identification and differential diagnosis, before turning forward to consider the implications of the findings for support and intervention. Part two of the thesis comprising of chapters four to six addresses this by reporting on the development and evaluation of an intervention programme for learning disabled children based on sound theoretical principles including that of cerebellar involvement in dyslexia.

In chapter four, an introduction to the intervention programmes is provided which includes an historical account of motor based intervention studies to date. A motor based programme is included as one of the training programmes since the historical account reveals that few formal controlled evaluations of these techniques have been carried out. In view of the recent research proposing a cerebellar deficit hypothesis as a causal theory of dyslexic, it seemed theoretically worthwhile to revisit this neglected area with a systematically controlled study. With its well established involvement in motor skill execution and more recent involvement in language areas of the brain, it is tentatively proposed that a balance training regime may result in skill transfer through activation of the cerebellum. This has interesting theoretical and applied implications for the cerebellar deficit hypothesis, which are discussed.

In chapters five and six the second aim of this thesis are addressed; namely to develop and evaluate a remedial programme of skill acquisition for learning disabled children. The adequacy of any intervention programme is measured not just in terms of its effectiveness in improving skill levels, but also in terms of its cost effectiveness. This latter consideration is noted in the design of these intervention regimes and results are equated against this 'economic' measure.

Three separate training programmes are compared; each based on sound theoretical principles, a phonological skills programme, a motor (balance) skills programme and an arithmetic programme. The children used are of mixed ability and the programmes are designed so that a relatively unskilled instructor can administer the training. The parents of the children participating successfully administered the first intervention study (which is reported in chapter five) and the author the second (reported in chapter six).

Since the success of phonological training is well established, it is particularly exciting, when considering research into the role of the cerebellum in motor control, to consider the potential of motor skills training on skill acquisition. The relevant literature on skill acquisition and the proposed route for skill transfer through motor (balance) training is discussed in the introduction in chapter four.

In chapters five to six the two intervention studies are presented. Firstly the parental training study (chapter five) and secondly the school-based intervention study, administered by the author (chapter six). The studies are virtually identical in the form and format of the results presented, enabling direct comparisons between the studies to be made. The skills presented for analysis in these intervention studies are measures of reading age, spelling age and IQ.

Promising results were found for both intervention studies. However, the small-scale of these studies imposes restrictions on the implications that can be drawn. The effects of the training on the above measures of literacy and IQ are evaluated and the implications for skill transfer, metacognition and causal theories of dyslexia are considered. The results are debated in terms of their relative effectiveness and cost-effectiveness. A clear demonstration of any beneficial effects from this novel approach to intervention, particularly young children with learning disabilities, would hold exciting implications for the future.

In chapter seven's concluding remarks, the author reflects on the success of the research in achieving the original aims that the thesis title makes explicit. The implications of the research for the theory and intervention of children with learning difficulties are summarily discussed. The chapter concludes by reflecting on the inherent limitations of the work performed. Furthermore, fruitful avenues of further work are suggested in order to build on these findings. This should ensure that the frontiers of research in this fascinating area continue to be pushed forward.

Part One

Chapter 1

Differentiating between Non Discrepant Poor Readers and Dyslexic Children

Introduction

During the late 1980's and early 1990's, the issues of classification and definition were still at the forefront of any discussion of learning difficulties. Indeed, it was this ongoing debate which both motivated and prompted this research. The resulting implications for causal theories of learning difficulties and also intervention approaches were a topic of hot debate (Siegel, 1988; Siegel, 1989; Stanovich 1988a, Stanovich 1988b; Rispens Yperen *et al*, 1991). As the title of this thesis suggests, ('Theory and Intervention. A Complete Analysis for Children with Learning Difficulties') it is hoped that the work reported in this thesis will in some way influence and clarify both theoretical and intervention issues surrounding the identification and support of children with learning difficulties. If it does, its primary aim will have been adequately met.

The following pages will help set the research in context by looking at both historical and current debates surrounding the definition of dyslexia and learning difficulties. More specifically, this will naturally introduce the studies presented in part one of the thesis which attempt to clarify definition and differentiation issues between two major subgroups of learning disabled children, namely dyslexic and non-dyslexic poor reading children.

Part two of the research, which compares the effectiveness of intervention programmes with children 'at risk' of developing learning difficulties, will have its own introductory section covering issues surrounding intervention research and reviewing previous related intervention research.

In this introduction to part one of the research, traditional definitions of learning difficulties and dyslexia will first be overviewed in an historical format. The difficulties with diagnosis and support of learning difficulties will generally be considered before focussing on the developments of the traditional discrepancy definition of dyslexia. The work of Siegel and Stanovich was key in the development of debates surrounding the validity of this traditional definition and their work will be critically discussed as appropriate. Furthermore, the research of others in this area will be outlined to give an overview of work to-date involving non-dyslexic poor reading children. Finally, the key causal theories of dyslexia will be presented, including not only the traditionally accepted phonological accounts of dyslexia, but more recently posted theories which cover a range of symptoms, not only in areas directly linked to phonology and reading. This overview of related research work will enable tentative predictions to be drawn about the performance of the non-dyslexic poor reading children in the studies presented in chapters two and three of this thesis. The aims of the studies in chapters two and three will be outlined.

Dyslexia and Learning Difficulties – The Definitions

Learning Difficulties in the Classroom

A child with learning difficulties is described, at the most general level, as any child who has great difficulty in achieving the academic standards required by school (Gaskins, 1982). However, in recent years many attempts have been made to try to divide this category into subcategories in order to identify more specific groups of children, and also to amalgamate certain groups. This dividing and joining, has been carried out with varying degrees of precision and with the employment of a diverse nomenclature to produce ill-defined groups of children with labels such as reading retarded, slow-learners, dyslexic and learning disabled. Much debate still exists on how best to subdivide children with learning difficulties into meaningful groups (e.g. Zigler and Hodapp, 1991).

The following definition of a child with learning difficulties from the Department for Education, helps give an impression of the broadness in definition within this area:

"A child has special educational needs if he or she has a learning difficulty which calls for special educational provision to be made for him/her. A child has a learning difficulty if he/she:

a) has significantly greater difficulty in learning than the majority of children of the same age.

b) has a disability which either prevents or hinders the child from making use of educational facilities of a kind provided for children of the same age".

(DfE, 1994)

This definition from the Code of Practice on the Identification and Assessment of Special Educational Needs, is virtually unchanged from the 1981 Education Act. The Warnock Committee, established in the late 1970's to investigate provision and support systems for children with special educational needs and whose findings led to the production of the Act, argued that there was a continuum of severity of special educational needs, and that up to 20% of the school population at any one time could have such needs. Only 2% of these would have had statements of special educational needs which entitled them to appropriate provision. This left 18% of pupils whose needs were largely unmet.

Both Warnock and the 1981 Act promoted a need for greater understanding of the difficulties that these children have and their right to be educated and supported appropriately. These difficulties range from general learning difficulties, speech and language difficulties, emotional and behavioural difficulties and specific learning difficulties e.g. dyslexia.

Furthermore, Warnock and the 1981 Act instigated an increase in visibility for the learning disabled child and witnessed the beginning of the idea, that all teachers are teachers of special educational needs, since every classroom will hold a significant proportion of pupils with learning difficulties of some kind. However, in practice most teachers in ordinary schools were considered ill equipped, either to understand why some pupils had difficulties in learning, or to provide intervention programmes that would help overcome these difficulties and promote effective learning.

Dyslexia – The Problems of Definition and Diagnosis

The term "'dyslexia' carries with it so many empirically unverified connotations and assumptions that many researchers and practitioners prefer to avoid the term." (Stanovich, 1994)

Specific Learning Disabilities or Dyslexia is estimated as affecting approximately 4 to 5% of the population, in other words approximately 2 million people in the United Kingdom. However, it is extremely hard to be precise in estimatates of prevalence, because great confusion and contention still surround the research, diagnosis and treatment of dyslexia. Much of the problem stems from the lack of a consensual model of dyslexia, which is agreeable to all researchers and practitioners in the field. "The field of education is badly in need of a canonical model of reading disability" (Stanovich, 1994).

Developmental dyslexia is far from being a new concept having 'many faces' (Rawson, 1986) and certainly having had as many names (for example, specific reading retardation, specific learning difficulties, word blindness etc). Dyslexia particularly increased in visibility after its official recognition by the 1981 Education Act (Dobbins and Tafa 1991) and is normally characterised by unexpected problems in learning to read for children with average or above average intelligence. This is known as the 'discrepancy definition' of dyslexia. However, this IQ based definition of dyslexia has caused much contention and debate amongst researchers.

The discrepancy definition of dyslexia has resulted in exclusionary dyslexic diagnostic procedures which have been met with a battery of debate (Siegel, 1988a, 1988b, 1989; Stanovich, 1988a; Rispens *et al*, 1991). Many feel that the root of the diagnostic problem comes from relying on thepoor performance of a learned skill, reading, which is so vulnerable to environmental influences. Thus, its validity as the criterion for excluding certain categories of children from certain forms of intervention is considered morally dubious. As Wood *et al*, (1991) articulate: 'no consensual concepts of the term's meanings are available to guide the defining operations. In other words we have not yet defined dyslexia because we have not yet understood it' (Wood *et al*, 1991).

As with many disorders, dyslexia cannot be expected to demarcate a completely discrete category from other reading disabled children. This only serves to confound the problem of diagnosis, resulting in a graded continuum of difficulties with indistinct boundaries existing between dyslexic and non dyslexic poor reading children. As Stanovich (1988a) succinctly states, dyslexia represents 'the outcome of the application of an arbitrary criterion in a continuous distribution'. But he is quick to stress that this does not 'render the concept of dyslexia scientifically useless' (ibid). He compares the concept to obesity, 'no one doubts that it is a very real health problem, despite the fact that it is operationally defined in a somewhat arbitrary way by choosing a criterion in a continuous distribution' (ibid). The traditional discrepancy definition of dyslexia shall now be looked at in more detail.

The Discrepancy Definition of Dyslexia

Developmental dyslexia is traditionally defined as, "*a disorder in children who, despite conventional classroom experience, fail to attain the language skills of reading, writing and spelling commensurate with their intellectual abilities*" (World Federation of Neurology, 1968).

A recent redefinition as "*a specific language based disorder of constitutional origin, characterised by difficulties in single word decoding, usually reflecting insufficient phonological processing abilities*" (Orton Society, 1994) reflects a major achievement of dyslexia research – the identification and analysis of a phonological deficit (Bradley and Bryant, 1983; Shankweiler *et al.,* 1995; Stanovich, 1988; Vellutino, 1979) which became the consensus view of many dyslexia researchers. (The phonological deficit hypothesis of dyslexia will be described in more detail later in this chapter alongside other key causal theories for dyslexia). The redefinition also reflects a more controversial change, however, in that unlike the traditional definition, there is no mention of discrepancy (between reading performance and that expected on the basis of the child's intelligence). The discrepancy-based research on reading performance that has led to the conclusion that poor reading children are poor readers regardless of IQ will now be briefly reviewed. This finding was a major factor in the aforementioned redefinition.

The Discrepancy Debate

Dyslexia is traditionally defined through the demonstration of a discrepancy between reading ability and measured intelligence or IQ. Such 'discrepancy definitions' lead to the implicit assumption, that the underlying pathology of the dyslexic, is distinctly different from that characterising the non dyslexic poor reader, who does not demonstrate this discrepancy. This is because their general intelligence is below average and so their reading is in line with that predicted on the basis of their intelligence. Central to this debate, is the value of distinguishing between these two groups, the poor readers who have a discrepancy between their reading and that predicted on the basis of their intelligence (thus satisfying the traditional criteria for dyslexia), and poor readers who do not. Two key names in this area are Stanovich and Siegel. They have argued that the phonological skills which are the key to the development of effective reading skills, are indistinguishable in both dyslexic and non dyslexic poor readers (e.g. (Stanovich, 1986; 1988a and 1988b; 1993; 1999; Siegel, 1988; 1989; Stanovich and Siegel, 1994)). Therefore, for as long as phonological skill deficits remain implicitly part of the reading-IQ discrepancy definition of dyslexia, then they argue that it is inappropriate for this definition to exclude non dyslexic poor readers. The work reported in chapters two and three will further investigate this issue to see whether support is found for the views of Stanovich and Siegel. It is important to note at this stage that it is quite possible, that although the reading-related symptoms of both groups may be indistinguishable (Stanovich, 1986; 1988a and 1988b; 1993; 1999; Siegel, 1988; 1989; Stanovich and Siegel, 1994) the underlying causes may nonetheless differ. To take everyday examples, many diseases or many automobile mechanical faults have similar symptoms despite different causes. It will be argued throughout part one of this thesis, that a powerful method of addressing the discrepancy issue is to investigate performance outside the reading domain. A set of such tasks that should discriminate between the extant hypotheses for the causes of dyslexia have been identified. This analysis led to the design of the studies used in the following two chapters. A range of tasks were administered to groups of non dyslexic poor readers, children with dyslexia and control children matched for chronological age. Analysis of the profile of scores for the different groups allowed decisive tests to be undertaken. However, there is a vigorous and still ongoing debate focusing on the importance of IQ in defining dyslexia (see Stanovich, 1999; Nicolson 1999). (In this chapter and the following chapters, this latter group will thus be referred to as ND-PR children (non discrepant poor readers) and the former as children with dyslexia).

Siegel and the Issue of IQ Based Definitions

"There has never been a measure that has been so ardently endorsed and widely validated and yet so persuasively controversial as IQ" (Ceci, 1991).

An important early criticism of the use of IQ in defining dyslexia was presented by Siegel (1988) in her highly controversial paper entitled 'Evidence that IQ Scores are Irrelevant to the Definition and Analyses of Reading Disability' (Siegel, 1988) (see below for a critique of her earlier work). Siegel made a number of important criticisms arguing against the discrepancy definition saying that IQ should have no place in the definition of learning disabled children. She considered many 'reading disabled' children as being 'ignored' on the basis of low IQ scores (Siegel, 1988). She considered that this score was not a true estimate of the child's potential, so disadvantaging these children in terms of opportunities for intervention and support. (Its interesting to note here, that the emphasis on IQ in diagnosis, also resulted in certain 'gifted' children with too *high* an IQ to meet the diagnostic criteria for classification of learning disabled, 'falling through the cracks' as well, i.e. not receiving the special services they also require to meet their specific needs (Macmillan, 1989)).

The rationale for Siegel's early arguments had many facets. She questioned the validity of IQ tests in measuring 'intelligence', saying that they measured constructs which were not independent from achievement measures and were therefore not good predictors of low performance on reading. Her research led her to state, that reading disabled children, with similar problems, have a wide variety of IQ scores as well as there being some low IQ scores failing to demonstrate reading problems. Her consequent conclusion that IQ was irrelevant to the definition of reading disability produced great contention amongst researchers in the field. The crux of her argument was stated succinctly in a subsequent commentary, *"IQ scores do not predict different cognitive abilities within the population with reading disabilities. Poor readers of all IQ levels show equivalent difficulties with reading, spelling, phonological processing, short-term memory, and syntax"* (Siegel, 1989b). Siegel (1992) presented a metastudy that further supported these conclusions and she has continued to espouse these views in subsequent commentaries (e.g. Siegel 1999). Additional problems for the use of IQ derived from analyses of the Connecticut Longitudinal Study (S.E. Shaywitz, Escobar, Shaywitz, Fletcher and Makuch, 1992) which concluded that *"reading difficulties, including dyslexia, occur as part of a continuum that also includes normal reading ability. Dyslexia is not an all-or-none- phenomenon, but like hypertension, occurs in degrees"* (ibid) and moreover that dyslexia was not stable over time, in that only 7 of the 25 children identifiable as dyslexic in grade 1 were also identifiable as dyslexic in grade 3. This idea of dyslexia being a continuum is supported by Stanovich (see below) (e.g. Stanovich, 1988, 1993, 1994) and the possible 'instability' of dyslexia over time has recently been supported in the work of Van Daal and Van der Leij (1999). Nicolson and Fawcett (1994) who compared dyslexic groups at the ages of 8, 13 and 17 years found a "heartening developmental trend" with dyslexics 'catching up' in skill performance as they grow older.

The shortcomings and possible biases of IQ tests have long been recognised and so it is hardly surprising, that the complete validity of the discrepancy score, has been seen as questionable by so many over the years (e.g. Bryan, 1989; Rispens *et al*, 1991; Stanovich 1988a, 1988b, 1989, 1993, 1999; Stanovich and Siegel, 1994; Siegel, 1992, 1999). For instance Stanovich (1989) discussed how the well documented 'hump' at the bottom of the reading ability distribution (discovered during the epidemiological work of Rutter and Yule in 1975 and used as evidence and validation of a discrete pathology model for dyslexia) appears to be a statistical artefact created by ceiling effects on the tests employed (also Van der Wissel, 1987; Leong, 1989; Share *et al.*, 1987).

Criticisms of Siegel's Approach

It is interesting to note at this point that Siegel's conclusion, that ND-PR children and dyslexics do not demonstrate qualitative differences in cognitive performance, has been met by conflicting views. Much criticism of her methodology and rationale is to be found in the literature in the years following the publication of her controversial papers (e.g. Tunmer and Chapman 1999, Nicolson 1999). For instance, could the low IQ children she identified in her studies as being *non* reading disabled, since their explicit reading performance appeared in line with their chronological age, *really* read in the true sense of the word, as their comprehension of the text was considered dubious (Tyler, 1988). Many researchers at the time (e.g. Tyler, 1988; Elliott, 1989) pointed towards apparent differences in cognitive ability for the two groups on, for example, the British Ability Scale Psychometric Test (C.D. Elliot, 1983).

Many criticised Siegel's propositions as too extreme. Bryan (1989) stated that good "practical, political and philosophical reasons for inclusion of IQ exist". Nicolson (1996) also argues convincingly for the inclusion of IQ in definitions of dyslexia, stating that abandoning the use of IQ is acceptable so long as the 'symptoms' rather than the cause of the reading difficulties is the only area of interest. Furthermore, he argues that abandoning the use of IQ, assumes that the phonological deficit is the only possible causal explanation of dyslexia. Certainly it generally seems that IQ is still one of the best predictors of academic success despite its many problems (see Torgeson, 1989). Bryan considers that the generally held view of intelligence as being stable, is perhaps the crux of the problem (Bryan, 1989). He considers, that in learning disabled children this may reinforce maladaptive notions about themselves, if they know that their intelligence levels are low. His alternative is a dynamic definition of intelligence in which intelligence is seen to change as new skills are acquired, (Elliott and Dureck, 1981; cited in Bryan 1989; Ceci, 1991). This is an increasingly popular, less rigid approach to intelligence and has interesting possibilities, although its practical instigation in IQ testing is hard to imagine, due to the constantly changing, fluid nature of the intelligence construct when defined in this way.

Meyen (1989) criticised Siegel's method as being too 'non-exclusionary', providing no criteria as opposed to too strict a criterion for who should and should not warrant special education. He considered the discrepancy model as being necessary for narrowing down those who really needed special help beyond that possible in school. He thought "garden-variety poor readers" (so called by Gough and Turner (1986) and subsequently adopted by Stanovich, Siegel and many others to describe what are ND-PR children in our terminology) who have only a low intelligence could probably be helped effectively in school. However, contentious views such as this only seem to raise again the whole question, whether a highly contentious construct like IQ should be used as the single factor in determining the nature of support and intervention. Furthermore, such opinions just add emphasis to the importance of trying to establish whether differences do exist, between dyslexic and ND-PR children in reading related cognitive areas, for if this is not the case then arguably the same pedagogical techniques will suffice for both groups (Ellis *et al.*, 1996; Stanovich 1996).

The Matthew Effect and IQ

The problem of definition and diagnosis is further complicated by what Stanovich (1986) refers to as the 'Matthew effect'. Stanovich first identified this effect in learning disabled children. It is a biblical reference to the poor getting poorer and stresses the pervasive ramifications of problems in an area as fundamental as reading. This produces a cumulative vicious cycle of underachievement and motivational problems. Stanovich (1988) used the 'Matthew effect' to initially explain the ever increasing evidence pointing towards deficits in dyslexics outside the phonological domain. He felt that such deficits may be an artefact due to; either the cumulative effect of lack of motivation and/or opportunity arising from reading failure (the 'Matthew effect'); or because ND-PR children may have been included unwittingly in so called 'dyslexic' samples; or because there is actually a continuum between dyslexics and ND-PR children. The often underemphasised bi-directional nature of IQ and reading is demonstrated by this 'Matthew effect'; reading problems may arguably be the result of limitations in cognitive ability resulting in low IQ, but equally, low IQ may be due to poor reading due to Matthew effects adversely affecting the general underlying (metacognitive) skills under pressure in IQ tests such as attention, concentration etc. This is called the 'reciprocal causation of effects'

(Stanovich, 1986; cited in Wolf, 1991; also Ceci, 1991). However, Stanovich (1999) argues that due to intelligence being a "panoply of different skills and metacognitive abilities", it is logically and empirically impossible to say that low intelligence causes poor reading. "The concept of intelligence does not provide the specific process model that explains poor reading. The phonological deficit model does," (Stanovich 1996).

ADHD and Dyslexia

Another theoretical issue which is still unresolved and further complicates diagnostic debates is that of the relationship between reading disabilities, dyslexia and Attention Deficit Hyperactivity Disorder (ADHD). The question is often asked whether children with ADHD should be classified separately from those with dyslexia. Also whether comorbid occurrence of dyslexia with ADHD is possible, and if so how does this effect their cognitive performance and diagnostic issues. In recent years, further research in this area has shown that comorbidity of dyslexia with ADHD is very possible (Fletcher, Shaywitz and Shaywitz, 1999; Pennington *et al.*, 1993; Shaywitz *et al.*, 1995). It has thus become considered by some to be a significant methodological oversight not to screen dyslexic (and ND-PR) subjects for ADHD before carrying out any performance assessment work, since results could become confounded by effects of the attention deficit in those children who are comorbid. It is worth saying at this point that the ND-PR children focussed on in the studies presented in this thesis were all screened using the DSM-IIIR assessment for ADHD. (The DSM-IIIR assessment for ADHD involves 14 simple yes/no questions, with a 'yes' on at least 8 being the minimal criterion for diagnosis of weak ADHD). In order to give an unbiased view of the literature, it is interesting to note that this omission to screen for ADHD has been a criticism of the earlier work of Nicolson and Fawcett from which the research in this thesis grew (e.g. Nicolson and Fawcett, 1990). This work demonstrated significant differences in a wide range of basic skill areas between dyslexic and control children and led to the postulation of the Dyslexic Automatisation Deficit (DAD), later supplemented with the Conscious

Compensation (CC) Hypothesis. However, many have failed to fully replicate these findings (for example, Yap and Van der Leij, 1994a; Stringer and Stanovich, 1998; Wimmer, Mayringer and Landerl, 1998). The latter researchers have reported that, in trying to replicate the findings of Nicolson and Fawcett (1994) and Fawcett, Nicolson and Dean (1996), all differences between dyslexics and controls on the various balance tasks, disappeared when participants with ADHD were removed from the sample. This suggests that the demonstrated differences had been due to characteristics of ADHD rather than dyslexia. (Due to these criticisms, Nicolson and Fawcett have subsequently checked their subject panels for ADHD, finding no indication of ADHD in any subject). In the United States of America, children diagnosed with ADHD have tended for some time to be labelled dyslexic (for debates on this issue see Levine, 1982; Felton *et al.* 1987; Swanson and Cochrane, 1991). It is logical to assume that attention ability is partially dependent on intelligence, and therefore if IQ is considered fundamental in traditional definitions of dyslexia, then children with ADHD may not be included within the dyslexia category, being grouped instead with ND-PR children. But, as with reading, attentional capacity is accepted as being affected by so many external factors, that the issue is by no means clear-cut, with large overlaps no doubt existing between all three groups of dyslexic, ADHD and ND-PR children. As Tansley and Gulliford (1959) recognised nearly half a century ago, "the quality of concentration is related to lack of intelligence, but many factors such as motivation and expectation of success or failure, are also influential".

The whole debate about IQ is inherently problematical because as Stanovich (1989) stresses, it really "depends on our concept of intelligence" and we have to accept the results of this. We can not complain about the "fairness of IQ tests" (ibid) because they are intricately bound up with our conceptions of intelligence.

It seems however, that there is a danger of becoming too immersed in the quagmire of debate surrounding IQ tests. Siegel has been criticised for focussing too much on the validity of IQ tests and not enough on her main argument as to the possible cognitive differences between the "garden-variety poor readers" (ND-PR in our terminology) and children with dyslexia. As with Siegel's research, it is this issue which is of primary interest here from a diagnostic and interventional point of view. The exact nature of the deficits identified in dyslexics and the question of whether their patterns of performance are specific to them, or whether similar impairments in performance are found in ND-PR children, (i.e supporting the views of Stanovich and Siegel, 1994), is one of the main issues to be investigated in the following chapters. The implications of the findings for diagnostic and interventional procedure will also be addressed.

In conclusion on the value of IQ tests, it seems that the issue is eloquently summed up by Sattler (1988; cited Graham and Harris, 1989), "IQ scores when used appropriately and interpreted in light of learner's characteristics and background can provide valuable information about certain cognitive strengths and weaknesses and help evaluate change and progress" (Sattler, 1988).

Stanovich and the Phonological Core Deficit Theory

Implicit in the traditional discrepancy definition of dyslexia is the assumption of a specific phonological deficit underpinning the literacy difficulties so typically associated with dyslexia. Also inherent in the traditional definition, as discussed by Siegel, has been the question of whether ND-PR children should be considered different with regard to this specific reading difficulty. Traditionally dyslexia has been seen as being caused by a specific brain/cognitive deficit in the area of phonology and reading, whereas the situation with regard to ND-PR children has been less certain. ND-PR children were generally considered to have many more deficits extending into much broader areas of cognitive domain, affecting more global intellectual skills and resulting in the depressed IQ scores so typical of the ND-PR child. Meanwhile the 'specific' nature of the dyslexic's phonological deficits were still considered to allow ability in certain areas to in effect boost their IQ scores.

Stanovich has been and still is one of the main contributors to the discrepancy debate. His theories on this matter have evolved and been modified over a period of ten years or so. He has provided various incisive analyses (Stanovich, 1988a, 1988b; Stanovich and Siegel, 1994) framing the following question: Do "garden-variety poor readers" show phonological difficulties commensurate with those of children with dyslexia? Or are dyslexics unique in the severity of phonological deficits demonstrated? This is a key question in the debate. Stanovich's question has been answered fairly decisively by several researchers: Yes, ND-PR children do show equivalent phonological difficulties to those with dyslexia (Aaron, 1997: Ellis, McDougall and Monk, 1996; Siegel, 1989; 1992) (see below for more detail on these studies).

Irrespective of debates as to whether IQ measures intelligence, learning potential or learning aptitude, the all important question in the discrepancy debate is whether the process of reading, its underlying cause and also its remediation, are identical in the two reading disabled groups. Stanovich and Siegel and their supporters (e.g. Share, 1988 and 1996) argue, that since there have been few if any valid demonstrations of differences between the two groups in the cognitive processes underpinning the skill of reading, (including research within their own research groups (e.g. Siegel, 1989, 1992; Stanovich 1994), then the discrepancy definition should be dispensed with. The research in chapters one and two of this thesis will further investigate this area.

From this, and in consequent agreement with Siegel, Stanovich reasoned that poor phonological skills resulted in poor reading regardless of IQ, and that therefore IQ was irrelevant to the definition of reading disability (Stanovich, 1991). Stanovich, then developed this theory yet further to hypothesise that dyslexia may not exist as a separate or 'specific' syndrome at all (Stanovich, 1994). This led to the conclusion that discrepant and non-discrepant poor readers show a similar "phonological core" deficit, with variable differences outside the phonological area (Stanovich and Siegel, 1994). In more detail their results demonstrated differences between dyslexics and both chronological and reading age-matched controls on phonological tasks. However, differences between dyslexic and "garden-variety poor readers" were found in general language and memory skills, but not reading and phonological skills. Their meta-linguistic study (Stanovich and Siegel, 1994) in which the data from several different studies was aggregated to give a considerably larger panel of subjects than normally considered, (401 non dyslexics, 341 dyslexics, 167 "garden-variety poor readers"), unequivocally demonstrated that the dyslexic and ND-PR groups showed similar phonological deficits. This led to their hypothesis being named the Phonological-Core Variable-Difference Model.

This influential view of reading disability is one in which the dyslexia syndrome is thus seen as representing a 'core' deficit in phonological processing which is severe and modular (see Fodor, 1983) in character. ND-PR children ("garden-variety poor readers" Stanovich, 1988a) despite displaying the same extent of reading-related/phonological core deficits, are considered to display further deficits extending into broader areas of their cognitive functioning, resulting in the general depression of their measured intelligence and reduction in their reading/IQ discrepancy. Stanovich has hypothesised that dyslexic and ND-PR children exhibit the same phonological core deficit, but differ increasingly when tasks are less dependent on phonological processing. This is because it allows for the use of higher level processes like strategy use and the use and consolidation of all kinds of knowledge (reflected by their difference in general IQ).

The Discrepancy Definition: Abandon or Retain?

The "phonological core" theory of dyslexia posited by Stanovich and supported by Siegel, has led some researchers in the field to argue, that there is no longer any point in attempting to differentiate between children with dyslexia and those with more generalised learning difficulties (ND-PR in our terminology), because they both show the same pattern of phonological difficulties. This view underlies the downplaying of discrepancy in the 1994 redefinition of dyslexia (see above).

Some supporters of this view include Gustafson and Samuelsson, (1999); Siegel, (1999); and Stanovich, (1999).

However, it seems that Stanovich's views can be criticised on a number of aspects and that certain valuable considerations have been overlooked in deciding whether to abandon the discrepancy definition. The author feels that there are strong grounds for retaining the discrepancy definition and these will now be discussed.

Criticisms of Stanovich's Approach

Terminology

Despite the accepted difficulties in the use of IQ in any definition of reading disability, it seems that Stanovich's justifications for abandoning the IQ-based discrepancy definition altogether may not be completely justified. Nicolson (1996) argues that Stanovich's insistence on using the somewhat 'neutral' term 'reading disability' rather than 'dyslexic' or even the more inclusive US term 'learning disability' has led to considerable confusion in the field. Stanovich, argues that since reading is the fundamental problem, then this is the term that is appropriate, irrespective of IQ. It seems that this term is so broad and all encompassing that its use may understandably cause confusions, leading to ambiguity and uncertainty on how to classify, select, label and group children with reading difficulties. Stanovich (1993) himself admits to the 'muddled research' for garden-variety designs and uses this as proof of the difficult in demonstrating cognitive differences between poor readers of differing IQs. This seems rather a large 'inferential leap' to make. One can not help but wonder whether this confusion is due in the first place to confusions on how to classify, select, label and group subjects due to Stanovich's ambiguous definitions, resulting in contradictory results in the literature.

'Cause' versus 'Symptoms'

Stanovich's phonological core variable-difference hypothesis is inextricably bound up in an analysis of reading skills and the underlying cognitive phonological skills crucial for acquiring the skill of reading. As Nicolson (1996) argues, it seems that this analysis of phonological skills and reading is appropriate only (a) if the investigators' aim is merely to characterise the symptoms of poor reading in dyslexia or (b) if the phonological deficit account is the only possible causal explanation of dyslexia. The underlying cause of the reading problems experienced by the discrepant and non-discrepant poor readers may in fact be different. To help readers understand his argument more clearly, Nicolson (1996) makes the point, that it is important to distinguish between the cause(s) and the symptom(s) of a disorder, citing the analogous example of malaria and influenza, both of which have symptoms of high temperature, aching limbs and so forth, but have very different underlying causes (and treatments). In other words, it is quite possible that even though phonological deficits (symptoms) occur for both types of poor readers, symptoms of the 'true' underlying cause of dyslexia - symptoms that distinguish between poor readers with and without discrepancy - may arise outside the phonological domain, and even outside of the literacy domain.

The Locus of Causality

Stanovich (1996) does appear briefly to recognise this issue. In his 1996 paper he begins by providing an overview of 'established empirical findings' in the reading disability research area, which clearly demonstrate the now accepted fact, that phonological processing difficulties underpin the reading problems in reading disabled children. He then goes on to state that beyond this, considerable confusion and controversy exists. "For example, the more fundamental processes that might underpin the phonological processing problem is a source of much contention" (Stanovich, 1996). By 'fundamental processes' it would seem that Stanovich is obliquely referring to the underlying causes of the phonological problem. However, he then summarily dismisses these debates (for example, Tallel, Sainburg and Jernigan, 1991; Nicolson, Fawcett and Dean, 1995;

Studdert-Kennedy and Mody, 1995; Studdert-Kennedy and Brady, 1997) as irrelevant to his discussion.

This also seems odd when we consider that, by very definition, his phonological core variable-difference model recognises and in fact, expects differences in cognitive performance between discrepant and non-discrepant poor readers outside of the 'core' phonological domain. In fact it would be concluded that Stanovich further expects these differences to increase the further they are from the phonological core, eventually falling outside the literary domain. Yet he fails to analyse these demonstrated differences outside the literacy domain since in his opinion they have nothing to do with the phonological skill problems that lie at the heart of the reading difficulties for both groups. By focussing on the cause of reading disability rather than the cause of dyslexia, it seems that Stanovich may be missing valuable empirical evidence, that the phonological deficit theory may not account for the full range of deficits found in reading disabled children.

This critique of Stanovich's theory raises two further points of interest for debate:

Does IQ matter for diagnosis?

It has already been stated that from a theoretical viewpoint, it seems important to distinguish between non discrepant and discrepant poor readers, but is this the case from a diagnostic viewpoint? As mentioned earlier, it is felt that children with reading disabilities should be supported appropriately whatever their classification based on analysis of their strengths and weaknesses, so in this sense maybe formal differential diagnosis is not so crucial. In fact, it may well be that initial support for a ND-PR may well be appropriate for a dyslexic and visa versa due to the similarities in their reading difficulties. Phonological training for instance will undoubtedly be important for both groups, however it would seem logical to presume that before long, the strengths in the dyslexic's profile would open up varying opportunities for support that ND-PR children may not find accessible. Even utilising IQ testing techniques, it may at times prove difficult to differentially diagnose these two groups in a single diagnostic session due to the 'continuum' of difficulties between the two groups and indistinct boundaries between them (Stanovich, 1988a). However, when it is possible to study their performance over a period of time, then differentiating between the two should become easier.

Does IQ matter for support?

If dyslexics and ND-PR children differ in their strengths and weaknesses in reading-related cognitive processes, then arguably different teaching methods would be appropriate for the two groups. If conversely no significant differences are found between the two groups, then it could be argued that irrespective of differences in IQ levels, the same teaching techniques would be appropriate for both groups, (Ellis *et al.*, 1996; Hurford, 1994).

However, the author feels that this 'whole group' approach would not allow for modification of support according to individual variation within groups. Any good support system looks at the child as an individual, not as a group member. The author feel that where the issue is one of support, then all children have a right to equal levels of educational support investment, based on analysis of their *individual* profile of strengths and weaknesses, irrespective of their diagnostic group classification. Nicolson (1996) appears to support this view, explaining, "An ideal support system would identify each *individual* child's pattern of strengths, weaknesses and attainments on the range of sub-skills and knowledge relevant to the skill to be supported". An individualised support system would then be designed to best utilise these strengths and improve on weaknesses.

Higher IQ children may well be expected to make faster progress, and may be able to gain benefits from accelerated versions of support systems (although it is interesting to note that the evidence is somewhat equivocal on this issue (Siegel, 1992). Stanovich (1994) agrees with this view, "Indirect validation of the idea of differentiating poor readers on the basis of reading-IQ discrepancies would come from data showing that high- and low-IQ poor readers are differentially sensitive to specific educational interventions. There is, however, no body of evidence indicating that poor readers with reading-IQ discrepancy respond differently to various educational treatments than do poor readers without such discrepancies". One would expect that the general procedure for developing an individualised support programme and then monitoring and adapting it would be very similar irrespective of IQ/reading discrepancy. So in this sense, IQ is not crucial in terms of support.

The IQ Debate: The Current Position and Recent Research

It is clear from the literature that the situation with regards to the discrepancy definition of dyslexia and the issue of specificity is still far from being resolved. There is still a lively ongoing debate as to whether the discrepancy approach is valid and/or useful in the diagnosis of dyslexia. However, surprisingly there has been relatively little research work performed comparing ND-PR subjects alongside dyslexic children in order to help answer this question, and what research there is can be confusing and contradictory (Stanovich, 1993). This is despite the theoretically weighty implications of such findings for the discrepancy definition of dyslexia and the practical implications for practitioners striving to isolate poor readers of high IQ from those of low IQ.

A quick survey of the recent literature reveals, that there are a few researchers continuing to address this question (for example Van Daal and Van der Leij, 1999; Stanovich, 1996; Nicolson, 1996). (See below for more detail of these studies where they are discussed in relation to the studies presented in this thesis). The following chapters in which the skills of discrepant (dyslexic) and non-discrepant poor readers (ND-PR) are examined and compared, played a role in ensuring that the debate has continued. An overview of the somewhat limited recent research work into dyslexics and 'garden-variety' poor readers (ND-PR in our terminology) and issues pertaining to differentiation between the two groups, will now be presented to help set the work within this thesis into context and help in the tentative drawing of predictions for the research. Examples from various areas of cognitive performance will be mentioned to help demonstrate the wide range of skill deficits now being identified in dyslexia and to correspond with the broad skill areas examined in the studies reported in this thesis. The findings of each of the studies will be considered in relation to Stanovich and his phonological core variable–difference theory.

Recent Studies involving ND-PR Children and Dyslexic Children

The Studies:

i) Dyslexia: A General or Specific Skill Deficit?

Prompted by the published findings of this thesis (Fawcett, Nicolson and Maclagan, 2001) Van Daal and Van der Leij (1999) examined afresh the issue of specific versus general deficits in dyslexia. In order to avoid the issues resulting from selection based on IQ discrepancy, they classified participants according to the degree of discrepancy between their word recognition and listening comprehension scores. Their study of 12-year-old dyslexic students at the beginning of secondary education in the Netherlands, aimed to investigate whether problems were confined to the domains of reading and spelling, or whether difficulties in other areas were evident. They included a "garden-variety" group of poor readers as well as a hyperlexic group of poor readers. They looked at the areas of phonology, naming, working memory, speed of processing and motor tests. Interestingly they found specific deficits in the dyslexic subjects in some but not all areas of phonology, also in spelling and naming speed of letters and digits. This led to the conclusion, that certainly at the age of 12, dyslexia is a difficulty "rather isolated from deficiencies in other cognitive and motor skills" (Van Daal and Van der Leij, 1999) and thus rather more specific in nature than had previously been thought. In terms of the "garden-variety" poor readers, the profiles suggested that they performed less well than dyslexics on all phonological processing tasks, on rapid naming (letters and digits), articulation speed, and working memory (digit span, star counting test). With regard to the 12 year old dyslexic subjects and the phonological core variable-difference hypothesis (Stanovich 1988a), these findings did not add support for the pure phonological processing deficit aspect of this theory. What is more, they did not reveal total independence of the phonological core from general intelligence, since the ND-PR group performed less well than the dyslexic group on all the phonological processing tasks. These findings did not support the generally held view of dyslexia as representing a general phonological processing deficit since deficits between Chronological Age (CA) / Reading Age (RA) matched controls and dyslexics were only found in the specific phonological areas of phonological recoding (i.e. non-word reading), spelling and word recognition. Furthermore, the study did not support hypotheses of a general naming deficit (as in Denkla and Rudel, 1976; Badian, 1997) (see below for more detail on naming studies) or a general working memory deficit (De Jong, 1998). Interestingly, the ND-PR group appeared to better support the hypotheses of a general naming deficit, a general working memory deficit and a general phonological processing deficit. However it should be noted, that unlike the subjects used in the studies investigated in this thesis, which were classified according to IQ, these subjects were not. Closer analysis of the psychometric data for the subjects used in the Van Daal and Van der Leij study reveals, that the ND-PR group actually could have included subjects who would have been classified as dyslexic in our studies due to their IQ score. This fact is admitted by the authors themselves "...the garden-variety group in the current study, with an average non-verbal IQ of 105 and verbal IQ of 87, were of low-average intelligence and could easily have been placed in the dyslexic group in other studies" (Van Daal, Van der Leij, 1999, pg95). Furthermore, the control group used in this study were themselves taken from a school for learning disabled children (low vocational stream) and thus were likely to possess difficulties themselves. This may have resulted in reduced size of deficit than would have been found between groups if a non learning disabled control had been used. This study therefore is of interest in relation to the study reported in the following chapters, comparing performance of ND-PR children and dyslexic children on a range of skills, but it is not directly comparable due to the significant differences in selection methodology between the two studies, as well as participant classification and task demands.

ii) Arithmetic Skills and The Discrepancy Definition

Gonzales and Espinel (1999) chose to move away from the traditional area of phonology by asking the question whether IQ-achievement discrepancy is relevant to the definition of arithmetic learning disabilities? In looking at the area of arithmetic, this study classified subjects according to the differences between IQ and achievement standard scores (standard-score discrepancy method). They had three groups of subjects, those with arithmetic learning disabilities (ALD), garden-variety (G-V) poor mathematics performance (i.e. children of below average intelligence whose poor arithmetic performance is non-discrepant being in-line with their lower cognitive abilities, i.e. ND-PR children in our terminology) and normally achieving children. The subjects' performance was compared on tests of addition and subtraction word problems, as well as other cognitive abilities related to mathematics such as working memory. Their investigation revealed no differences between the ALD and G-V groups in solving arithmetic word problems or in the area of working memory, with both groups' performance being significantly below that of normally achieving children. They thus concluded that the criterion based on the IQ-achievement discrepancy does not seem to be relevant for differentiating between children with ALD and children with G-V poor mathematics performance. These findings do not appear to add support for the views of Stanovich (1988a) and his phonological core variable-difference model, since there appears to be no significant differences between the non-discrepant and discrepant poor readers in the area of mathematics performance. Implicit in Stanovich's theory is the understanding that differences *do* appear between the two groups, when tasks become less dependent on phonological processing and allow for the use higher level processing abilities and knowledge. Arguably the mathematics tasks here could be considered an example of such tasks, and in fact Stanovich agrees that high IQ readers will do better at arithmetic tasks than low IQ readers (Stanovich and Siegel, 1994) (Stanovich 1996). However, it is difficult to be sure on this point since the arithmetic tasks were 'addition and subtraction *word* problems' and thus involved phonological processing skills as well as arithmetic skills leading to confounding of results.

iii) ADHD and Phonological Performance

Swanson, Mink and Bocian (1999) found further support for the theory of a common phonological core deficit amongst 'garden-variety' and dyslexic poor readers. Their study was entitled: 'Cognitive deficits in poor readers with symptoms of reading disabilities and ADHD: More alike than different?' Their study was interesting in that they were attempting to separate out and study the effects of ADHD (Attention Deficit Hyperactivity Disorder) on cognitive processing deficits, particularly phonological processing. They included a group of subjects with ADHD, a group with comorbid symptoms of reading disabilities (dyslexia) and ADHD, alongside a 'traditional' 'garden-variety' group and a reading disabled (dyslexic) group (see earlier for more discussion on the issue of ADHD and Dyslexia). Measures of phonological processing and executive processing were investigated. Of interest to the work in this thesis was the finding of no significant differences between the groups on phonological processing. The results appeared to support the notion that poor readers whether suffering from reading disabilities (dyslexia), ADHD or whether 'garden-variety', share a common phonological core deficit. Also since comorbid children were not significantly worse in phonological tasks than children with no comorbidity, these results would seem to suggest tentatively that there is no 'double whammy' effect of suffering from both ADHD and dyslexia in the area of phonology.

iv) Naming Skills and Phonological Performance

Much work has been done to study the naming ability of dyslexics. Although naming performance was not one of the areas directly studied in this thesis, it is worth outlining briefly some of the recent research into this area, since early discoveries of naming deficits in dyslexics (Denkla and Rudel, 1976; Spring and Capps, 1974) were important in helping establish one of the main causal theories of dyslexia, i.e. the speed of processing deficit theory. (This theory will be explained in more detail further on in this chapter). Furthermore, this theory and the other key causal theories of dyslexia will be used to tentatively draw predictions as to the performance of the ND-PR children in our studies. It is also important to include relevant naming studies with ND-PR children to assist in these predictions since research comparing ND-PR children with dyslexics is generally so limited. Speed and accuracy in naming have a long history in the clinical arena for identification of subtle deficits between groups of patients. It was first used with dyslexics by Geschwind in 1967 and since then it has been taken up by a number of researchers with Denkla and Rudel's (1967) work in producing the 'rapid automised naming' (RAN) task achieving particular prominence. They proved that dyslexic children were slower to name colours, pictures, digits and letters than not only control children, but also ND-PR matched for reading age. They also demonstrated that speed of naming was strongly related to reading performance, a finding supported by many subsequent studies (Ackermans *et al.*, 1990; Blanchman, 1984). A naming deficit has been consistently replicated (for example, Wolf, 1984; Bowers, 1988; Swanson, 1987). More recently the theory of naming deficit has been expanded with current research suggesting that phonological processing and naming deficits are always found together in more severe dyslexic cases. This has been named the 'double deficit hypothesis' (Wolf and Bowers, 1999). The following studies examine this area more thoroughly by including ND-PR children in their subject panel.

Badian, (1994) challenged the discrepancy definition of dyslexia by directly examining whether differences exist between dyslexic and ND-PR children in reading-related cognitive skills. Her rationale was that if differences did exist between the two groups, then there would be justification for believing dyslexia to be a distinct entity (i.e. refuting the phonological core variable-difference hypothesis, Stanovich 1988a). She used a fairly large subject panel of 110 children aged 6 to 10 years divided into three groups; dyslexic, ND-PR and good readers. She found that both ND-PR children and dyslexics shared deficits in phonological awareness skills and non-word reading when compared with normal readers. However, deficits unique to dyslexics were demonstrated in automatic visual recognition and phonological recoding for graphic stimuli. She thus concluded firstly; that there are valid grounds for believing dyslexia is a separate entity from ND-PR children due to the unique deficits found amongst the dyslexic subjects and secondly; that the study supported the phonological-core variable difference model of Stanovich (1988a) in that both the dyslexic and ND-PR children showed phonological deficits, but these deficits were more extensive in the dyslexic. It is interesting to note that Badian (1993) found significant differences on pseudoword reading at a 2 year follow-up (age 9) of dyslexic and non-dyslexic poor readers matched on a composite measure of word recognition and word attack at age 7. She found that the dyslexics were actually better at this skill than the ND-PR children at this age, a finding not predicted by Stanovich's theory.

Badian (1996) next set out to study whether the concept of dyslexia as a phonological deficit could be considered valid at two age levels. The 144 subjects were administered tasks related to reading. The two age levels were 8 to 10 years old, and 6 to 7 years old. Both age groups included three groups of poor readers (matched for reading age but differing in the amount of discrepancy from expected reading level) and age matched average (control) readers. Older poor readers also had a control group of reading matched younger subjects. Interestingly, Badian found no support for the concept of dyslexia at age 6 to 7 years (i.e. no significant performance differences between the three poor reading groups despite the varying levels of discrepancy) thus adding support to the views of Stanovich and Siegel (1994) and others that at this age at least, the discrepancy based definition of dyslexia is unworkable. However, among the older participants she did find support for the concept of dyslexia as a phonological deficit (i.e. the most discrepant poor readers had deficits significantly below reading age matched controls), with the non discrepant poor readers (ND-PR) demonstrating a developmental lag (i.e. their performance was not significantly lower than reading age matched controls, although significantly lower than age-matched controls). In more detail, the more discrepant poor readers with dyslexia exhibited orthographic (spelling) and serial naming-speed deficits, as well as phonological deficits and were a distinctive group. Less discrepant participants with dyslexia were more similar to the ND-PR group than the more discrepant poor readers with dyslexia. This study seems to add support to the idea of many (including Stanovich (1988a) mentioned above) that dyslexia is best viewed as falling on a continuous distribution, with indistinct boundaries existing between dyslexics and ND-PR children.

Building on her work above, Badian (1997) performed a further study in which direct comparisons were made between ND-PR children and dyslexic children. The performance of the two groups in areas of naming-speed and phonology were investigated in order to add support or otherwise to the double deficit hypothesis of Wolf and Bowers, (1999) which maintains that children with both phonological and naming-speed deficits, will be poorer readers than children with just one or neither of these deficits (see below for more detail on causal theories of dyslexia). Badian added the third construct of orthographic difficulties to explain why some children have particularly severe reading difficulties, and named this the triple deficit hypothesis. Her participants included a subject panel of 90 children aged 6 to 10 years, made up of dyslexic children, ND-PR children, low verbal IQ good readers and reading age-matched younger controls. She found that the dyslexic children performed significantly lower than the ND-PR children and the low verbal IQ good readers on most measures, and lower than the RA-controls on phonological measures. Badian concluded that these deficits support not only the double deficit hypothesis but also the triple deficit hypothesis. She stated that "most of the poorest readers, nearly all of whom qualified as dyslexic, had a double or triple deficit in phonological, naming-speed and orthographic skills." (Badian, 1997). Her conclusion from the findings was that dyslexia results from an overload of deficits in skills relating to reading, for which the child cannot easily compensate. In terms of the discrepancy debate and the views of Stanovich, it would seem that these findings add little support for the phonological core variable-difference theory, since significant differences between the dyslexics and ND-PR group were found on most of the phonological and naming tasks.

Looking also at naming ability in dyslexia, and building on the early work of Denkla and Rudel, (1976), Swan and Goswami (1997) compared the picture and word naming performance of both dyslexics and ND-PR children, using reading age and chronological age-matched controls. Word frequency and word length were varied within the stimulus list, and furthermore, an object name recognition task was included in order to assess each subject's vocabulary knowledge of names, which they were unable to spontaneously label in the picture naming task. This is an interesting addition to an investigation of naming ability in dyslexics, and builds on criticisms of the many earlier studies (e.g. Wolf, 1984; Bowers *et al*, 1988; Swanson, 1987) in this area which did not take account of the possible confounding effect of vocabulary knowledge in naming tasks. (The effects of vocabulary knowledge were tested by Wolf *et al* (1992) on dyslexics and ND-PR children using the Boston naming task. Interestingly, Wolf found no difference in accuracy for the two groups, both being significantly worse than the chronological age controls. She did demonstrate however that the dyslexics appeared to understand the words and just could not retrieve them, whereas ND-PR children appeared not to know the word when presented in a multiple choice test. The results of Swan and Goswami's study indicated that both the dyslexic and ND-PR groups exhibited a picture naming deficit relative to both chronological and reading matched controls. Furthermore, both groups of impaired readers performed better on the word naming task than the picture naming task, unlike the controls who showed no difference in performance between these two tasks. It was noted that the dyslexic's difficulty with pictures seemed particularly pronounced with polysyllabic words and/or low frequency words and yet they recognised significantly more unnamed target words than all comparison groups (including the ND-PR group). This was not the case with the ND-PR group who showed no relationship between syllables, frequency and degree of difficulty. Findings suggest that unlike the ND-PR child, the dyslexic child has a particular difficulty in retrieving the phonological code of known picture names rather than a vocabulary deficit. In terms of Stanovich's phonological core variable-difference theory, these findings at face value support this theory as no significant quantitative differences were found between the dyslexic and ND-PR group in the naming tasks. However, this gives an oversimplified view of the findings, making no reference to the between group qualitative differences found in the nature of the deficits shown. These qualitative differences are interesting in that they may be useful symptoms of the different underlying cause of reading difficulty in the two groups.

Ellis, Mcdougall and Monk (1996) have provided recent support for the theories of Stanovich in their study. They compared the performance of dyslexic, ND-PR children and precocious readers with reading age controls on a range of tasks including reading related tasks, phonological processing and visual processing. In summary they found no significant differences in areas of phonology between the dyslexic and ND-PR group, thus adding support to Stanovich's view that IQ is irrelevant to the definition and analysis of reading disability. Interestingly, the authors then go on to discuss how they do not agree, that IQ is irrelevant to the analysis of reading and listening comprehension, since the ND-PR group showed less ability than the dyslexics in both these areas. However, these findings would in fact be predicted anyway by the 'variable-difference' part of Stanovich's phonological core variable-difference theory, which hypothesises that the two groups will differ increasingly, when tasks are less dependent on phonological processing and allow for the use of higher level processes (Stanovich 1988a; Stanovich 1996).

v) Word Recognition, Reading and Spelling Skills in Dyslexia

It is generally accepted that the underlying sub-skill in reading which is problematic for children with reading difficulties is word recognition, (Stanovich, 1982, 1986, 1992; Snowling, 1987; Olson, 1994) and that this then leads to pervasive problems in reading including orthographic difficulties in spelling.

Share (1996) set out to investigate what if any differences exist between ND-PR children and dyslexic children on word recognition and spelling skills. This study was a more detailed follow-up of children identified earlier as dyslexic or ND-PR using regression techniques, (Share *et al.* 1998). The two groups were matched on age, sex and word recognition. Tasks were 26 different measures of spelling and word recognition. Performance of the two groups was virtually the same (i.e. no statistically significant differences measured) in 25 of the 26 measures. The only significant difference found was that dyslexic subjects made a higher proportion of real word (lexicalisation) errors (i.e. phonetically incorrect pronunciations) when reading regular high frequency words. Yet five other measures of real-word errors were insignificant. Furthermore, the only other study that has examined this area (Fredman and Stevenson, 1988) found no significant difference. This led Share to conclude that his one significant finding should be viewed with caution, maybe being nothing more than a statistical artefact. He concluded that his findings therefore give little if any evidence of qualitative differences between dyslexic and ND-PR children in word recognition and spelling, thus supporting Stanovich's theory of a phonological 'core' deficit in both dyslexic and ND-PR children, or to use his inclusive terminology, 'reading disabled' children.

However, Aaron (1987 and 1989) found substantial pre-existing differences in reading rate and reading comprehension between ND-PR and dyslexic children, with dyslexic children actually performing better in these skills than the ND-PR children. These findings do not appear to support Stanovich's theory and seem to suggest that IQ may have a role to play in reading disability classification. However, this study is not directly comparable to the study reported in the following chapter due to the age of subjects and participant matching techniques. His study (1987) involved dividing a group of 14 reading disabled college aged students participating in a reading skills programme for disabled readers into dyslexic and garden-variety poor readers (n=7). These two groups were not matched as such. In his (1989) study, preadolescent dyslexic and garden-variety poor readers were matched on a passage comprehension measure but not on word recognition.

A highly relevant study for the work reported in this thesis is that performed by Yap and Van der Leij (1994a), who examined the automaticity of word and non-word reading in 9-11 year old dyslexics. They compared dyslexic performance to both chronological and reading age controls and also reading age matched poor readers (ND-PR in our terminology), in order to examine whether the dyslexics were simply delayed or actually deficient in the reading skill. By comparing the poor reading group with the dyslexics they aimed to discover whether dyslexia represented a unique disorder that differs from generalised poor reading i.e. a direct test of Stanovich's theory (1988a). Their tasks involved presenting both speeded and unspeeded words. Results suggested that the dyslexics were specifically impaired on the speeded non-word reading test. The poor readers did not demonstrate this deficit, showing a more similar performance profile to the normal readers. This suggested that the dyslexics suffer a deficit in automatic word decoding even at the most simple level of word structure. This finding does not add support to Stanovich's theory that no significant differences exist between the dyslexics and ND-PR groups in phonological skills.

Interestingly, Yap and Van der Leij (1994a) then developed these findings to include a longitudinal aspect in order to assess the rate of progress in the dyslexic subjects in their accuracy and rate of word processing. The dyslexics were matched for reading age with normal readers at two time points. It was found that in order to match the two groups on reading age at both the initial and final tests, the period between the two assessments was much longer for the dyslexics, i.e. 18.8 months for the dyslexics and 9.2 months for the reading-age controls. This result demonstrated that the dyslexics reading development was about twice as slow as the normal readers.

vi) Visuospatial Skills and Dyslexia

For some time it has been suggested that dyslexics have difficulty not only in areas of phonology but also areas involving vision which seriously effects their ability to develop literacy skills. One aspect of visual skills was looked at in the research in this thesis (the visual search task) and so it is important to outline relevant research involving ND-PR children and dyslexics in order to help in predicting the performance of subjects in our studies. Furthermore the demonstration of visual deficits in dyslexics was partly responsible for the development of another key causal theory of dyslexia, namely the sensory deficit hypothesis. For more detail on this theory, see below where all the key causal theories of dyslexia are described in more detail in order to help predictions to be drawn.

As a result of the growing evidence for phonological and visual deficit theories of dyslexia, Eden and Stein (1996) have recently investigated whether dyslexics have difficulties in either of these areas. More interestingly for our research, they also decided to test whether these deficits were unique to dyslexia by including a group of 12 ND-PR children in their subject panel, along with 39 controls matched for reading age and chronological age with 26 dyslexic children. The Benton Judgement of Line Orientation Test was used for its simplicity and clinical reliability. Results revealed that dyslexic children were significantly worse at the phonological and visuospatial tests than the control groups but at a similar level to the ND-PR children. (Dyslexics showed a tendency to scan the task from left to right rather than the usual right to left scanning pattern observed in the control group). In summary the results suggested that the dyslexic children had problems in both areas of phonological awareness and also visuospatial skills, but interestingly so did the ND-PR group, suggesting that these deficits are not unique to dyslexia. Again this finding can be considered as further indirect support for Stanovich and Siegel (1994) in casting doubt on the use of the discrepancy definition in defining dyslexia, since similar difficulties were found in both reading disabled groups in areas of phonology. In terms of visuospatial skills, the situation is less clear, as according to the phonological core variable-difference hypothesis (Stanovich 1988a) one might expect clearer differences between the two reading disabled groups in this area which is so unrelated to reading. According to Stanovich (1996), this is undoubtedly the case, "high IQ poor readers.....will undoubtedly solve spatial puzzles faster". The authors suggest that this finding adds support to the hypothesis that dyslexia cannot solely be attributed to phonological impairment, since other impairments (e.g. visuospatial impairment) exist, possibly caused by a common mechanism.

vii) Motor skills and dyslexia

There is considerable evidence for a deficit in certain motor skills in children with dyslexia. Denkla (1985) recorded deficits in speed of tapping, heel-toe placement, rapid successive finger opposition, and accuracy in copying. Children with dyslexia, Denkla suggested, are characterised by a 'non-specific developmental awkwardness', so that even those children with dyslexia who show reasonable athletic ability, are poorly coordinated. This awkwardness is typically outgrown by puberty (Rudel, 1985), leading Denkla and Rudel to argue for a maturational lag in the 'motor analyser' which programmes timed sequential movements (Denkla, 1985). Moreover they suggest that these deficits are primarily in the acquisition of new tasks, which is typically awkward and effortful, but once the skill is successfully acquired, dyslexic performance is essentially normal. Haslum (1989) as part of his extensive longitudinal study, (the British Births Cohort study of 1700 children at birth, five and ten years) one of the aims of which was to identify predictors of dyslexia in children, discovered that two motor tasks were predictive at age 10. These were failure to throw a ball up, clap several times and catch the ball, and failure to walk backwards in a straight line for six steps. Fawcett and Nicolson (1995b) using their panel of dyslexic children of ages 8, 13 and 17 years matched with reading and chronological age controls, found strong evidence of deficits in peg placing, bead threading and articulation rate in the dyslexics. This suggested that children with dyslexia have persistent and unexpectedly severe problems in motor skill. Considerable other evidence suggests that dyslexics have problems in articulation, (Stanovich 1988; Snowling 1981; Wolff *et al.*, 1984, 1990b), although it is difficult in such studies to differentiate the effects of phonological difficulties from motor problems in this area of skill.

However, none of these studies have compared dyslexic performance with ND-PR children. Some slightly indirect research into comparative motor performance between children of high average IQ and low IQ is provided by Ghaziuddin and Butler (1998). However, their high IQ subjects are not dyslexic but sufferers of Asperger's syndrome (average IQ 104.9), and the control groups are an autistic group (average IQ 78.4) and a pervasive developmental disordered group (average IQ 78.2), the latter group probably comprising some ND-PR children. Using the BruininksOseretsky test (a standardised test of motor coordination) the Apergers children were found to be less impaired than the autistic and developmental disordered groups. Interestingly however, this effect disappeared after adjusting for the level of intelligence, suggesting that lower levels of clumsiness in the Asperger's children may be due to their higher intelligence. However, the authors accepted that their sample size was small and that more investigation of the role of clumsiness in the classification of developmental disorders was necessary.

Overview of Previous Studies

Before drawing conclusions from the studies reported here, it should be remembered that these are only a small selection of studies taken from the somewhat scant area of research comparing ND-PR children with dyslexics, and so conclusions are only tentatively proposed. Much more research investment is needed in this area before firm conclusions can be drawn.

When we step back and consider the overall findings of the studies reported above, it seems that the results are mixed. Many of the studies reveal findings which appear to disagree with Stanovich's theory (namely that ND-PR and dyslexic children exhibit differences in their phonological core deficit), for example Yap and Van der Leij (1994a), Aaron (1987, 1989) and Badian (1993). However, the rest of the studies appear to support his theory, finding little difference between the two groups. Nevertheless, these broad conclusions give an overly simplistic impression of the situation, since closer analysis of the phonological performance of the subjects in some of these studies revealed interesting differences between the groups. For example Swan and Goswami's (1997) study of naming ability in dyslexic and ND-PR children. Here Stanovich's theory was initially supported by the fact that both groups showed similar quantitative deficits in naming. Yet qualitative naming differences were revealed between the two groups, suggesting that ND-PR children's difficulties were due primarily to a vocabulary problem, whereas the dyslexics appeared to have a more complex retrieval problem underpinning their performance difficulties. Also Badian (1994) who found initial support for Stanovich demonstrating that both her ND-PR group and her dyslexic group showed similar difficulties with phonological skills and non word reading. However, the dyslexic group revealed additional phonological deficits not exhibited by the ND-PR group suggesting that the dyslexics were more severely deficient in areas of phonology than the ND-PR. This led Badian to conclude that dyslexia is a separate entity, thus appearing to disagree with Stanovich. Another effect that seems to bear influence on Stanovich's views is that of age. Both Badian (1996) and Van Daal and Van der Leij (1999) found that differences both within and between groups varied considerably with age, a factor that Stanovich does not appear to address fully.

So, the discussion is far from resolved, but there does appear to be a good degree of basic support for the phonological core of Stanovich's theory in both dyslexic and ND-PR children. However, when we consider areas outside of this phonological 'core' the situation is even less clear. Stanovich proposed, that differences between the two groups should increase, the less dependent the tasks are on phonological skills and the more they allow for the use of higher level processing skills like strategy use, knowledge, experience and so on. This is the idea behind his phonological core variable-differences theory. So, for example Stanovich would expect the dyslexic to be better at arithmetic skills than the ND-PR child, be faster at spatial awareness tasks and have better listening comprehension ability (Stanovich, 1996). However, Gonzales and Espinel (1999) found no significant differences in arithmetic ability between the two groups in their study, and Eden and Stein (1996) despite finding that ND-PR and dyslexic children did, as expected, have the same phonological problems, found that they also demonstrated the same visual-spatial orientation skill ability. So results remain somewhat inconsistent in areas outside the phonological domain.

Such differences both within and without the area of phonology are important, since they may be valuable pointers towards differences in the underlying cause of the reading disability in dyslexic and ND-PR children. If a specific cause for dyslexia as defined through the IQ-discrepancy can be identified that is not shared by the ND-PR child, then this would seriously challenge Stanovich's theory that the term 'dyslexia' as defined by the IQ-discrepancy should be abandoned altogether. It seems that the role of IQ in dyslexia is still far from being resolved.

Causal Theories for Dyslexia

Three further possible causal explanations of dyslexia have now been posited (in addition to the phonological deficit hypothesis). All these theories suggest not only that children with dyslexia will show phonological difficulties, but also that they will show difficulties outside the phonological domain, thereby allowing critical tests to be undertaken. Specifically, the magnocellular (primitive visual system, dealing with the analysis of form, movement and depth) deficit hypotheses, the double deficit hypothesis (a speed of processing theory) and the cerebellar deficit hypothesis all suggest (different) explanations of why discrepancy is still crucial, even though phonological performance does not distinguish discrepant and non-discrepant groups. It is not necessary to give an overly detailed review of these theories, but it is certainly helpful to give a thorough overview here. Explained below is the hypothesis, the evidence in its favour, and the means by which it addresses the known phonological deficits of children with dyslexia. The author also feels that, irrespective of the extent of differences or otherwise between these two groups of learning disabled children, whilst deficits exist, regardless of aetiology, all children have the right to equal educational investment.

(i) The Phonological Deficit Hypothesis

As noted above, the phonological deficit hypothesis (PDH) has been the dominant explanatory framework for dyslexia. It was first proposed by the Haskins Laboratory in the 1970's (Liberman, 1973) and was refined by many researchers over the next decade, with Stanovich's evolving theory of phonological deficit being a prime example of this point (e.g. Stanovich, 1988a, 1993, 1996; Stanovich *et al.*, 1984; Stanovich and Siegel, 1984). The PDH predicted that early phonological problems should precede emergence of reading problems. This was confirmed by various researchers around the globe including Bradley and Bryant, 1983; Lundberg and Hoien, 1989; Olson, Wise and Rack, 1989 whose research revealed that young pre-reading children who showed early phonological difficulties (detectable in their poor rhyming ability, alliteration and phonemic segmentation skills) went on to show typical dyslexic problems when attempting to learn to read (see below for more detail). Furthermore, early instruction in phonemic segmentation seems to alleviate later difficulties with the early stages of reading suggesting that phonological segmentation holds a key role in learning to read. The research involved proactive training of 'at risk' children on phonological awareness leading to relatively normal acquisition of reading (Bradley, 1988; Lundberg, Frost and Petersen, 1988 see below for more detail). There is also evidence that phonological awareness deficits persist through life (Elbro, Nielson and Petersen, 1994; Fawcett and Nicolson, 1995a; Pennington *et al.,* 1990; Russell, 1982).

It is appropriate now to overview in more detail this research into areas of skill both within and without the reading domain which add support to the PDH and explain resulting difficulties in reading. Furthermore many of these skills areas are investigated in the research in this thesis, so this overview may help in drawing tentative predictions on some of the performances of subjects used in this research work.

Short-term memory deficits

Short-term memory deficit is probably the most often quoted and reliable non-phonological deficit associated with dyslexia. Its assessment is included in the Wechsler Intelligence Scales for Children (WISC) with the Digit Span subtest, where poor reading children typically perform worse than normal readers of equal intelligence (Rugel, 1974). It may at first consideration seem strange that short-term memory is involved in phonological processes at all. However, evidence for this interrelationship was found many years ago. Baddeley, 1966 and Conrad, 1964, demonstrated that short-term memory performance is worse for normal readers on phonologically confusable (rhyming) letters (e.g., B C G P and T) than non rhyming letters (e.g., H K S L and Q). They suggested that information is thus held in short-term memory in a phonological form. It was originally thought that dyslexics did not show this same form of storage (Siegel and Linder, 1984; Siegel and Ryan, 1988) but it is now accepted that they do, although it has been shown that they are less efficient at using these phonological codes in short-term memory and thus have a more limited short-term memory capacity (Johnston, Rugg and Scott, 1987; Holligan and Johnston, 1988).

Evidence that short-term memory ability is related to difficulties in reading and therefore may well be attributable in part to the dyslexic children's problems is found in the following studies: Jorm *et al.*, (1984) tested the memory ability of 5 year old children just starting school. Even after controlling for factors such as IQ and age, it was found that these early memory abilities were predictive of later success in reading. These findings were supported by Mann and Liberman, (1984). It is interesting however that as well as studies suggesting directional causality from short-term memory to reading, evidence has been gathered suggesting that reading ability also effects short-term memory capacity. Ellis (1991) has shown that reading ability scores are predictive of later short-term memory scores. Rack (1985, 1986) suggests that this may be because reading expands children's spelling knowledge, which they can then use as the basis for a memory code. He also suggests that another possible cause may be a third factor common to both measures, such a phonological processing skills. It seems that training studies are necessary to disentangle the complex relationship between memory and reading (Bryant and Goswami, 1987). However, as Rack (1986) states this would involve having to isolate and train short-term memory capacities in a group of children and demonstrate the consequence of this manipulation on later reading ability. This training of short-term memory in isolation would in practise be incredibly hard to do because of the ease with which training programmes can influence memory abilities along with other skills.

Nonsense word repetition

For some time it has been reported that dyslexics have difficulty in repeating a single word, particularly if polysyllabic (Miles, 1983) or pseudowords (nonsense words). Snowling (1981) found that dyslexics were worse than normal reading age matched readers at repeating nonsense words such as *bagmivishent.* Snowling *et al.* (1986) concluded that the problem lay with the processes of speech-segmentation, and not perceptual difficulties since the manipulation of background noise appeared to have no differential effect on nonsense word reading. Gathercole and Baddeley (1989) carried out a longitudinal study of nonsense reading to study its effect on the acquisition of spoken vocabulary. They found that children's nonsense word reading ability at age 5 was a good predictor of oral vocabulary at 6 years. They concluded that non-word repetition ability was a measure of short-term memory which explains its effect on vocabulary acquisition. Other explanations include the possibility that non-word reading, influences oral vocabulary via reading, due to the beneficial effects of being able to read 'novel words' on reading progress and thus the corresponding increase in vocabulary (see Hulme and Snowling, 1991).

Naming

One possible explanation for dyslexic's phonological difficulties is that the phonological information stored in memory is difficult to retrieve or is poorly coded. These difficulties would lead to problems 'finding the right word' and to mispronunciations of some words (Miles, 1983). However disagreement is found amongst researchers on the cause of naming deficits and thus it can be found classified as a deficit under differing causal theories of dyslexia (see the speed of processing theory below). For example, a naming difficulty was identified by Denkla and Rudel (1976) in their Rapid Automised Naming test where it was considered due to difficulties in speed of processing in dyslexia. However, Snowling *et al.* (1988) when using a younger reading age matched control group with dyslexic children (thus avoiding any effect of reading ability on results), found that the dyslexics were the same as the younger controls at naming pictures and that this finding was robust, even when an additional control group matched for vocabulary knowledge was added. Findings were taken to indicate that the dyslexics have a specific deficit in word naming relative to their knowledge of word meanings.

Phonological skills

All of the above demonstrated difficulties in memory, naming and nonword repetition, suggest that dyslexics have a deficit in phonologically based information. The subskills more directly and obviously involved with phonological skills and their associated studies will now be examined.

Rhyme

Even before they are able to read, children enjoy playing rhyming games dependent on sensitivity to the sound-structure of words. Bradley and Bryant have been key names in investigating the causal role of rhyme in the development of reading and its role in dyslexia (Bradley and Bryant, 1978, 1983, 1985). Their studies comparing dyslexics with reading age controls on rhyming tasks (such as indicating the odd one out in a sequence of words e.g. *sun sock see* *rag* or *cap map* *bag* *rap* - a simplified version of these tasks was used in the research reported here) show that dyslexics have difficulties in detecting rhyme. Bradley and Bryant (1983) performed a four year longitudinal study to try and see whether sensitivity to rhyme and alliteration had a causal role in reading and spelling development. They discovered that initial rhyming (sound-categorisation) ability accounted for 4-10% of the variance in reading and 6-10% of variance in spelling, yet less of the variance in mathematics ability, suggesting the skill is fairly specific to literacy skills. In the second part of their longitudinal study, Bradley and Bryant then performed a two year intervention programme on children with sound-categorisation difficulties, showing that sound-categorisation training had a beneficial effect on later reading and spelling, so long as it was integrated with letter knowledge. Whilst demonstrating clearly that there is a causal link between sound-categorisation ability and reading, Bradley and Bryant's work has been met with two reservations: Firstly that since the training was only successful when it was integrated with letter knowledge, then maybe the children in this condition were effectively being taught to read thus making their progress unsurprising; and secondly, there is debate as to whether sound-categorisation is in fact measuring memory rather than phonological skill (Wagner and Torgeson, 1987).

Phonological awareness

Phonological awareness has been measured by a vast array of tests including counting phonemes, deleting phonemes, substituting phonemes, segmenting words into phonemes. Many tests of phonemic awareness have been used primarily to study normal reading development, the impetus coming from the work of the Haskins Laboratories, who were among the first to show the importance of language processes in learning to read and that poor readers have difficulties with these tasks (see Shankweiler and Liberman 1990 for a review). Again, such studies demonstrated a relationship between reading and phonological awareness but not the direction of causality.

To clarify this, longitudinal and reading level match studies are needed. One of the first of such studies was that of Olson *et al* (1989) using the 'Pig Latin' game where the initial phoneme of a word had to be moved to the end of the word and the sound 'ay' added (pig therefore becomes ig-pay). Dyslexic readers were worse than reading level matched controls on this task. Another study by Olson *et al* (1990) showed the same deficit in a phoneme deletion task, indicating that dyslexic children are able to acquire reading skills but that their poor phonological awareness skills makes this more difficult for them.

Unfortunately longitudinal studies of phonological awareness skills have been criticised for their many methodological problems (see Rack, Hulme and Snowling, 1993). A rather appropriate example of such a study, considering the ongoing debate about the role of IQ and the discrepancy definition in part one of this thesis, is that of Stanovich, Cunningham and Cramer (1984). They demonstrated that performance on a wide range of phonemic awareness tasks was highly predictive of later reading ability. They concluded that phonemic skills were better predictors of reading ability than general IQ (often considered one of the best predictors of academic success), thus concluding that IQ was irrelevant to the definition of learning disabilities. However, their study can be criticised due to the fact that the children in the study had learnt to read at the time that their phonological skill was measured. This means that it is completely possible that the children with better phonological skills were already better readers, making it impossible to uncover the direction of causality.

Lundberg *et al.,* (1988) provided clearer evidence on the importance of phonological skills in reading acquisition with their large Danish study of kindergarten children. 235 children were given phonological training of 15-20 minutes a day for a year, with a battery of linguistic and metalinguistic tests given at the beginning and end of training to measure any performance change. A control group were given no training and just attended kindergarten as usual which did not involve any direct reading training. Neither group was given any direct training in reading thus it meant that the effects of 'pure' phonological awareness training could be assessed without any interaction occurring due to parallel reading development. Results showed that not only the training group improved pre to post test on measures of phonological ability, but that both control and training groups improved equally pre to post test on measures of general language comprehension and letter knowledge. This suggested that the effects of phonological skill training were highly specific to the phonological domain and not just the result of receiving extra attention (thus producing improvements across the board). Results were found to be persistent when children were assessed three months later and to have affected, in a positive direction, the reading and spelling skills of the training group seven months into the children's first year in school. Of importance was the finding, that the control group outscored the training group in a test of mathematics ability in the first year, showing that the effects of training were not global but specifically affected targeted skills of reading and spelling. This study thus demonstrates that manipulating children's phonological skills before reading instruction begins, influences children's eventual reading ability and consequently that phonological skills do have a causal role in reading development. (This study is an interesting comparison study for the phonological training study in part two of this thesis and will be commented upon).

Finally, to bring a neuroanatomical angle onto the PDH, it is argued that neurological abnormalities in the language areas around the Sylvian fissure i.e.

the peri-Sylvian region (Clark and Plante, 1998; Galaburda, Sherman, Rosen, Aboitiz and Geschwind, 1985; Jackson and Plante, 1996; Pennington *et al.*, 1999) lead to failure to develop phonological awareness skills at the age of five, thereby interfering with the learning of phoneme-grapheme and grapheme-phoneme conversion, critical requirements in learning to read (Bradley and Bryant, 1983; Wagner, 1998). Additional recent research has revealed that there is abnormal brain activation when adults with dyslexia process phonological stimuli (Fulbright *et al.*, 1997; Georgiewa *et al.*, 1999; Paulesu *et al.*, 1996; Rumsey *et al.*, 1997).

Undoubtedly this research points towards the PDH as a theoretically plausible hypothesis. It satisfactorily explains the reading-related problems in young children, it is supported by longitudinal studies in young children and more recently by neuro-anatomical research and when its principles are applied in the remedial/interventional field it has produced direct benefits (see part two of the thesis for further verification). It has not surprisingly become the dominant cognitive theory for the underlying cause of dyslexia. Nonetheless, as Frith concludes (1985) it should not be forgotten that *"the precise nature of the phonological deficit remains tantalisingly elusive."*

(ii) Sensory (Magnocellular) Deficit Hypotheses

There is extensive evidence of difficulties in sensory processing of almost all stimuli, at least for some children with dyslexia.

The Core Visual Deficit Theory

For many years the 'visual deficit' hypothesis of dyslexia did not receive much support within the reading disability literature, with researchers considering that dyslexics do not differ in terms of visual processing from normal children (Benton, 1962; Vellutino, 1979). However, there has been a particular focus in the last 10 years on this issue, due in part to developments in the study of vision generally. This extensive research work has proved clearly that these two groups do differ in terms of visual processing, although whether this is a cause of the dyslexic difficulties is still a relatively new area of research. Early eye control problems were identified by researchers such a Pavlidis (1981) and Stein (1989), and following on from this Lovegrove *et al*, (1980) identified problems in rapid visual processing. Lovegrove has been of considerable influence in this area and some of his influential research will now be reviewed.

Spatial frequency processing: Low level processing in dyslexic and controls

Spatial frequency processing has often been the focus of investigation in visual deficit research in dyslexia. As explained by Lovegrove (1994), spatial frequency refers to the number of cycles (one dark plus one light bar) per degree of visual angle (c/deg) in a pattern. High spatial frequency patterns contain narrow bars and are believed to stimulate the visual channels to the brain which process detail. Low spatial frequency patters contain very broad bars and stimulate channels which transmit information about general shape. Contrast refers to the difference between the maximum and minimum luminances of the grating. It has been shown that with large stimuli (low spatial frequencies) we are more sensitive to rapidly changing stimuli, but with small stimuli (high spatial frequencies) we are more sensitive to stationary or slow moving stimuli. These two functions are believed to measure two subsystems in the visual system, the transient (magnocellular –'where') and sustained ('what') subsystems. These two systems can inhibit each other, particularly if the sustained system is responding when the transient system is stimulated. Looking now at research revealing evidence of differences in this area between dyslexic and control subjects, the first area to look at is that of visual persistence (the continued perception of a stimulus after it has been physically removed). Several studies have compared dyslexic and controls on this measure finding, that dyslexics aged 8 to 15 years have a significantly smaller increase in persistence duration with increasing spatial frequency than controls (Lovegrove, Heddle and Slaghuis, 1980; Slaghuis and Lovegrove, 1985). These differences essentially disappear when transient system activity is reduced, (Slaghuis and Lovegrove, 1984) suggesting that dyslexics may differ from controls mainly in the functioning of their transient systems. More support for differences in the functioning of the transient system was found by Lovegrove and his colleagues in the area of contrast sensitivity. It has been shown that dyslexics are less sensitive than controls at low spatial frequencies, and differences have also been found at high spatial frequencies (Martin and Lovegrove, 1984;). More recently Lovegrove and his colleagues (1993) demonstrated that dyslexic children have impaired sensitivity to flicker, see also Talcott *et al,* (1998). Evidence suggest that dyslexics are not impaired in the functioning of their sustained systems (see Lovegrove *et al,* 1986) but are in their transient systems.

Higher level perceptual processes and dyslexia

It is accepted that the transient and sustained systems are involved in higher level perceptual processes than those described above. Studies in this area support those above in coming to the conclusion that dyslexics suffer from a transient system deficit. For example, Williams, Molinet and LeCluyse (1989) have shown that dyslexics have a slower transient system than controls, in their experiment using line targets within a metacontrast masking paradigm. Other studies have supported this view that there are temporal differences between the two groups which contribute to high-level perceptual problems in the dyslexics (e.g. Williams, Brannan and Bologna, 1988). It is important to note that although recent research has on the whole demonstrated that dyslexics perform more poorly than controls in all measures of visual processing, they have been shown to perform at least as well and even better on some tasks. These include high spatial frequency sensitivity, visual acuity and the oblique effect and on general task measuring sustained system functioning. However more work is necessary in this area in order to confirm findings (Lovegrove et al, 1986).

The Core Auditory Deficit Theory

In the auditory system, it has been shown that dyslexics have difficulty in the processing of rapidly changing sounds, (for example Tallal and Piercy, 1973; Tallal, 1977). Tallal is the leading name behind the auditory deficit hypothesis and although she acknowledges the difficulty in dyslexic children is phonological, she sees this difficulty as stemming from an underlying general auditory deficit rather than a phonological one. She and her colleagues (1993) have claimed that, like language disordered children, children with dyslexia require longer to process rapidly changing auditory stimuli, i.e. they have a problem in 'temporal processing'. This slowness in temporal processing results in two areas of difficulty for the child: (i) They can be poor at perceiving signals that follow one another rapidly (i.e. that have short interstimulus intervals (ISIs); (ii) they can be poor at perceiving signals that are very brief. Tallal (1980) hypothesises that during language acquisition, dyslexics never actually hear certain sounds as they are too rapid for them to detect (whether speech or non-speech). They therefore cannot represent a full set of phonemes for a given language. This fundamental problem then 'snowballs' resulting in difficulty segmenting words into proper phonemes and mapping phonemes on to graphemes and thus ultimately significant difficulties in acquiring the skill of reading. In more detail their problems involve difficulty in judging the temporal order of brief, rapidly presented non-speech tones, as well as stop-consonant-vowel syllables contrasting in their initial formant transitions (e.g. /ba/-/da/ versus /ba/-/sa/). Much of Tallal's earlier work used her findings with developmental aphasics and aphasic adults to support this position (e.g. Tallal and Piercy, 1973; Tallal and Newcombe, 1978). In her work with Piercy (1973) she identified problems in aphasics in identification and discrimination of stop consonant-vowel syllables, but improvements in this skill when transitions were lengthened, adding support to this theory of temporal processing deficit. However, this seminal work and her later work with aphasics was never replicated successfully. Tallal then went on to extend her work to include those with dyslexia (Tallal, 1980). She concluded from similar study methodologies and similar results employed to those with her aphasics, that dyslexics had difficulties in auditory temporal processing.

However, her research has been criticised by Mody *et al* (1997) on a number of grounds. Firstly that her conclusions are misleading in that the dyslexics actually only had difficulties in identifying tones correctly (when presented in rapid succession) rather than difficulties in auditory temporal perception itself (since their temporal order judgement of tones was not significantly worse than their tone discrimination ability). Secondly, Tallal was criticised for drawing unfounded inferences from tone performance to performance on syllable discrimination. Her findings that the reading-impaired children had difficulties in identifying brief tones at short ISIs did not then warrant her inference that they would have similar difficulties with /ba/ and /da/, since as Mody *et al* (1997) point out, tones and syllables contrast on entirely different acoustic dimensions. (Tones are discrete steady-state events which contrast in fundamental frequency, the transitions of synthetic /ba/ and /da/ syllables are continuous sweeps, contrasting in spectral locus and direction). Finally, she was criticised for not using appropriate controls in her study with dyslexics, concluding that their /ba/ and /da/ difficulties were due to difficulties in processing the *rapidly changing* nature of the acoustic information. In fact her earlier studies with aphasics had shown this same initial hypothesis to be rejected in favour of the conclusion that it was the *brevity* rather than the *transitional (changing)* nature of the stimuli that was the problem. However, she failed to study the performance of dyslexics with non-speech stimuli under rapid acoustic change conditions in her subsequent studies, a necessary control condition in order to test this theory.

Mody *et al.* (1997) directly tested Tallal's core auditory deficit theory against the established phonological theory in their study. They used two groups of children, 20 "good readers" compared to 20 "poor readers" matched for age and intelligence and compared their performance directly on /ba/ and /da/ temporal order judgement (TOJ) tasks since, according to Tallal's theory, these two groups should show clear differences in their performance difficulties on this task. Their results revealed that in fact the two groups did not differ significantly in TOJ tasks when /ba/ and /da/ syllables were paired with more easily discriminated syllables (e.g. /ba/ and /sa/) and also no differences were demonstrated between the two groups on two other critical auditory dimensions (such as sensitivity to brief transitional cues varying along a synthetic speech continuum). This led to the conclusion that the poor readers difficulties with /ba/ and /da/ reflected perceptual confusion between phonetically similar syllables rather than difficulty in perceiving rapid spectral changes. These findings were seen as being consistent with a speech-specific (phonological) deficit, rather than a general auditory deficit. Undoubtedly, dyslexics have some specific difficulties with auditory processing, but, as with visual deficits the direction of causality is still unclear and the possibility of an underlying common cause for the deficits, still an option.

Brain findings in dyslexia and the magnocellular deficit

In the last 10 years, brain studies on autopsied dyslexic brains have added a valuable additional dimension to dyslexic research. Neuroanatomical abnormalities have been identified (Galaburda, Menard and Rosen, 1994; Livingstone, Rosen, Drislane and Galaburda, 1991) in both visual and auditory magnocellular pathways to the thalamus, adding support to both the auditory and visual deficit hypotheses, and giving hints at a possible common underlying mechanism for both of these sensory deficits. Stein (e.g., Stein and Walsh, 1997) suggests that visual magnocellular pathway abnormality may cause visual persistence, which would in turn lead to specific difficulties in reading. Both Stein (from a visual research background) and Tallal (from an audition research background) argue (independently) that there may be a pan-sensory magnocellular abnormality that leads to difficulties in most types of rapid processing (i.e. in both auditory and visual domains). It is important to note however, that magnocellular deficits are likely to lead to qualitatively different problems in the visual and auditory modalities. In vision, deficits are predicted to occur for low contrast and/or slowly moving stimuli (Eden *et al.*, 1996; Stein and Walsh, 1997), whereas in audition, deficits are predicted to occur for rapidly changing stimuli (Tallal, Merzenich, Miller and Jenkins, 1998), though see Mody, StuddertKennedy and Brady (1997) for a critique.

(iii) Speed of Processing Deficit Theories

Interestingly, slow speed of processing appears to be a recurring symptom of dyslexia. Many researchers and practitioners have noted that dyslexic children appear to show more marked deficits under paced or timed tests than under more relaxed conditions (e.g. Ellis and Miles, 1981; Seymour, 1986). Lack of fluency in reading is a key characteristic of dyslexia, and there is also a substantial literature on deficits in speed of access to the spoken word (see Denkla and Rudel, (1976) below). Finally, extensive evidence exists of difficulties in speed of processing for almost all stimuli, including those for which sensory delay is an unlikely contributor and some of this evidence will now be outlined.

The Core Speed Theory

Naming Deficits

The strongest and best early established demonstrations of a 'core' speed deficit in dyslexia was derived from the 'Rapid Automatised Naming' (RAN) technique (Denkla and Rudel, 1976). However, it should be noted that since this deficit was originally regarded as a name retrieval problem (Ellis, 1981) and because there was confusion amongst researchers as to its relation to reading, this speed deficit was seen for some time as being part of the established phonological processing deficit by many researchers. However, it has been shown more recently, that naming speed and phonological skills show only moderate correlation (Wolf *et al.*, 1999; De Jong and Van der Leij, 1999). Each be independent characteristics of the dyslexic child (see the double deficit hypothesis below), or equally phonological and naming skills could share a common aetiology (see the cerebellar deficit hypothesis below).

The basic technique for the RAN is to present a card containing several rows and columns of stimuli (simple pictures or colours, digits or letters), and ask the subject to name each stimulus in order, as fast as possible. The time taken is the dependent variable. There is now a wealth of evidence showing deficits in dyslexics on the RAN (for example, Wolf, 1984; Bowers, 1988; Swanson, 1987). Children with dyslexia show robust speed deficits on these tasks, being slower than both age and reading matched controls. One of the most intriguing aspects of the RAN task, in terms of differential diagnosis and support and in terms of the direction taken by part one of this thesis, is the finding (Denkla and Rudel, 1976) that RAN differentiates children with dyslexia from other groups with learning disabilities such as ND-PR children. There is some evidence to suggest that children with dyslexia perform less well on naming speed than ND-PR children. (Gough and Tunmer, 1986; Wolf and Obregon, 1992). However in the study mentioned earlier by Swan and Goswami (1997), where they directly compared similar aged dyslexic and ND-PR children to the children in our studies on picture and word naming tasks, they found similar deficits in both groups. It seems that in the area of naming, there is certainty that dyslexics have a clear deficit in this area compared to control groups (although the cause of this deficit is unclear, see below), but the research findings with regards to ND-PR children are mixed.

Explanations of impaired RAN speed include phonological deficits (Mann and Brady 1988; Stanovich, 1990) and deficits in the precise timing mechanisms needed to integrate the phonological and orthographic codes in reading (Bowers and Wolf, 1993). However, a significant problem in the interpretation of RAN deficits, which might explain the inconsistencies in results hinted at above, is that a variety of underlying problems would lead to qualitatively similar results. It might be, for instance, that a child had difficulty keeping pace on the page of stimuli, or difficulties recovering from an error, or mild attentional problems which caused occasional lapses in concentration. It might be that the subject had a continuous workload problem and found the lengthy paced task particularly difficult, or being less skilled on the naming task, had to try harder to name the stimulus quickly and thus tired more quickly. It could be that children with dyslexia have a slower rate of articulation (see the cerebellar deficit hypothesis). It could also be that variations in vocabulary knowledge would effect results (e.g. Swan and Goswami, 1997).

One approach to try and limit the effects of all of the above is to reduce task variables by using discrete trials (where stimuli are presented individually) as opposed to the continuous trial format used by Denkla and Rudel, but this technique has produced mixed results. Fawcett and Nicolson (1994) used this format to demonstrate that dyslexics were significantly worse than their chronological controls and even reading controls on some measures of naming, whilst the performance of the ND-PR children were equivalent to the youngest children with dyslexia. Wolf and Obregon (1992) note that deficits in speed of object naming may be attributable either to lack of speed or lack of vocabulary. Using the Boston Naming test, in which subjects have to name pictures of objects, they established that children with dyslexia obtained equivalent scores to ND-PR children, even though their receptive vocabulary was better (assessed by multiple choice on the Boston Naming Test pictures). A further methodological issue was identified by Bowers and Swanson (1991) who showed that poor readers were differentially impaired by use of a paced continuous discrete trial procedure, as opposed to a 1.5 second interstimulus interval.

In summary, the RAN procedures lead to robust effects in terms of naming speed deficits, but the complexity of the RAN task allows interpretations in terms of rapid tiring, vigilance, place keeping, and error-recovery, thereby clouding theoretical interpretations. The discrete trials procedure rules out the above interpretations and so provides a more sensitive index of pure processing speed than the RAN task, but other uncertainties over the extent and task specificity of the speed deficit with a discrete trials procedure has made theoretical interpretation equally problematic.

Choice Reaction Time and Decision Making

Surprisingly reports in dyslexia literature of direct investigations of information processing speed are not abundant. An early study by Sobotka and May (1977) investigated visual selective choice reaction times and found that dyslexics demonstrated a deficit in this task. However, the author's main focus here was on the event-related potentials (ERP) corresponding to the bright stimuli, finding that dyslexics exhibited a greater amplitude of ERP than controls to the unattended stimuli. Subsequent research has investigated the ERP route (e.g. Duffy *et al*, 1980; Alonso *et al*, 1990). However, it is difficult to draw conclusions from this early work with regards to standard information processing analyses, due to the focus on the evoked potentials rather than overall reaction times and the variety of tasks used.

Many tests have been derived as part of the information processing approach in order to test information processing speed. Many, such as the Posner task

(Posner and Keele, 1967) and the Sternberg task (1966) are explicitly or implicitly linguistically based, leading to confounding of results due to established phonological deficits. In order to get an uncontaminated estimate of underlying speed of processing deficit, tasks need to be kept as simple as possible with no contamination due to phonological deficit. In an attempt to investigate speed of processing deficits in dyslexics, Nicolson and Fawcett (1994) used a series of reaction time tasks of lesser and lesser complexity to find the point at which deficit appeared. They used dyslexic children of 11 and 15 years of age with age and reading matched controls. The tasks used were simple reaction (SRT) and selective choice reaction tasks (SCRT) involving pressing a button with the preferred hand every time a tone was heard in the simple reaction task, and in the choice reaction task pressing a button every time a low tone was heard, but not pressing for a high tone. This task involved no literacy aspect so no confounding due to phonology was possible. The authors also repeated the tests using visual (flashing) rather than auditory stimuli to balance out any possible effects of deficits in each of these sensory domains. These are established experimental tasks, introduced by Donders well over a century ago. His rationale was that the only difference between the tasks was the need to classify the stimulus before responding in the SCRT trials, and he argued that subtracting the simple reaction time from the SCRT time gave an estimate of 'stimulus classification' time. Most subsequent research has two buttons, and the subject presses, for example, the left button for the low tone and the right button for the high tone. Unfortunately, dyslexic children have problems with distinguishing left and right, and so any deficit in a choice reaction might plausibly be attributed to left/right confusions. The comparison between SCRT and SRT is not subject to this type of problem since only one hand is used. It was demonstrated that children with dyslexia were faster than both control groups in the simple reaction task, but slower in their choice reaction to an auditory tone or visual flash than their age controls and no faster than their reading controls, in the complete absence of phonological task components (Nicolson and Fawcett, 1994b). The results of this study were intriguing. There appeared to be a progressive and relative penalty for the children with dyslexia as the tasks grew more demanding.

Even more direct data derives from an EEG study (Fawcett *et al.*, 1993). In principle, event-related potentials (ERP) offer the potential for identifying whether this slowing is attributable entirely to stimulus categorisation problems, or whether there is some response selection component. In ERP research, a set of electrodes is attached to selected points on the subject's skull, and the electrical activity following some external event (presentation of a stimulus) is then monitored. SCRTs have been extensively studied using ERPs, and there is a robust finding that in these types of task the ERP trace shows a broad, positive component, peaking around 300 ms, and this peak is known as the P300 (or alternatively as P3). Both the origin and the functional role of the P300 remain active research frontiers (Jolicoeur, 1999; Woodward, Brown, Marsh & Dawson, 1991). Although the P300 amplitude has been most researched, the P300 latency is of more direct relevance here, in that the latency is thought to provide an index of stimulus classification speed uncontaminated by response selection factors (Coles, Gratton & Fabiani, 1990). In the study (Fawcett *et al.*, 1993), eleven subjects, six dyslexic and five control, were selected from their older panels of dyslexic and control 16-year-old children. Furthermore, availability of their SRT and SCRT allowed us to match the groups on SRT. In summary, the group of dyslexic children showed a temporal processing speed deficit, compared with same age controls in P300 latency in selective choice reaction to auditory tones. The differences between the groups were sufficient to allow a differential diagnosis purely on the basis of the ERP data. Furthermore, the latencies correlated highly with selective choice reaction latencies obtained in earlier experimentation. So there was direct evidence of slow auditory information processing for a pure tone in that the P300 event-related potential wave was of longer latency in this 'oddball' paradigm. The data provided convergent evidence that the deficit is not attributable to motor response selection or execution, and appears to be linked to the need to make a discrimination between stimuli. This is particularly significant in that it provides further evidence that dyslexic children have a deficit in response categorisation even for non-linguistic stimuli.

Of interest to the studies reported here was the work of Vernon and Mori (1992) who demonstrated that speed of processing deficits appear to be related to intelligence. Their studies involved analysis of the relationship between intelligence, speed of information processing and peripheral nerve conduction velocity (NCV). They found that IQ scores were significantly correlated with NCV (rs = .42 and .48) and that reaction times were as well (rs = -.28 and -.18). Thus faster NCV was associated with higher IQ scores and a faster speed of processing. Reaction times and NCV when taken in combination, contributed significantly to the prediction of full-scale IQ and this was explained in terms of a 'neural efficiency' model of intelligence which is supported by other studies of physiological correlates of human intelligence.

Word Recognition and Orthography

A particularly interesting demonstration in the reading domain was provided by Yap and Van der Leij (1993), who established that children with dyslexia needed a longer exposure time to read a known word than normally achieving children matched for reading age. Recently, Van der Leij and Van Daal (1999) have argued, on the basis of speed limitations, that children with dyslexia have difficulty in automatising word recognition skills. Their automatic decoding deficit hypothesis (Yap and Van der Leij, 1993) states that dyslexics fail to automatise the skill of reading. This manifests itself in the slowness with which they read overlearned or highly familiar words, even when they are able to maintain a high level of accuracy. Moreover, if task demands are increased by, for example, presenting words of lower frequency, non-words, longer real words, or words with complex orthographic structures, or emphasising speed of response, reading performance will break down since the underlying skill is not fully automatic. Van Daal and Van der Leij (1999) suggest that this may lead to a 'compensation' strategy in the dyslexic for processing large orthographic units in reading (whole words) in order to try and maintain acceptable accuracy and speed. This study is particularly relevant to the research reported here and predictions drawn since it is one of the few studies in which the performance of dyslexics was compared to ND-PR children as well as control groups. Van Daal and Van der Leij (1999) tested their subjects in areas of reading, word recognition, phonological skills, working memory, motor skills and general speed of processing using the SRT/SCRT similar to those of Fawcett and Nicolson (1994). They failed to find support for Fawcett and Nicolson's (1994) study of evidence of deficits in the SCRT condition in dyslexics, finding instead no significant differences between the controls and dyslexics. Interestingly, they discovered no significant differences between the ND-PR children and the dyslexics or controls as well. As mentioned in the 'Recent studies' section above, it should be born in mind however that Van Daal and Van der Leij's study differed significantly from the Fawcett and Nicolson study in selection methodology, as well as participant classification and task demands. So although the study is of interest, it is not directly comparable to the study of Fawcett and Nicolson (1994) on which the research here is also based.

The Double Core Deficit Theory

It is now generally accepted that dyslexics have deficits in phonology, as is shown by the general acceptance of the phonological deficit hypothesis of dyslexia. As mentioned above however, there has been growing evidence of naming deficits in dyslexia also for many years. There was for some time confusion over where to 'place' naming deficits in terms of the established causal hypotheses for dyslexia due to confusions over the cause of this deficit. Many thought it should be classified under the phonological deficit hypothesis, until it was shown that naming speed correlates only moderately with phonological skills (Wolf *et al.*, 1999; De Jong and Van der Leij, 1999). It has now been suggested that deficits in rapid naming constitute a second independent characteristic of dyslexia, although the cause of naming deficits still produces debate. This suggestion by Wolf *et al* (1999) led to their recent proposition of the double deficit hypothesis.

In a synthesis of phonological and speed problems, Wolf and Bowers, (1999) have recently proposed an alternative conceptualisation of the developmental dyslexias, the double-deficit hypothesis, which holds that phonological deficits and processes underlying naming-speed deficits, represent two separable sources of reading dysfunction, and that developmental dyslexia is characterised by both phonological and naming speed 'core' deficits. Naturally, the most severe impairments are found in those children who show both of these deficits. However, Wolf *et al* (1999) state that they do not consider all dyslexic children to suffer this double deficit, but rather that it may be characteristic of a subgroup of dyslexics, recognisable by the more severe nature of their difficulties (due to the 'double whammy' effect of both deficits). Van daal and Van der Leij (1999) recognised this fact as an explanation for their results of naming deficits in only a subgroup of their more severe dyslexic subjects, although they admit that much more work is needed in this area before firm conclusions can be drawn. Interestingly they found that their ND-PR subjects better seemed to support the theory of a naming deficit in dyslexia (cf Fawcett and Nicolson, 1994) revealing deficits in this skill compared to all groups. However, caution should again be given in applying this finding to predictions for this research, due to the significant differences in subject selection, classification and task demands.

Taking the double deficit hypothesis one stage further, Badian (1997) extended the phonological and naming-speed deficits to include an orthographic factor to explain why some children have serious reading impairment. This focus on orthographic difficulties is similar to the conclusions of Van Daal and Van der Leij outlined above. This study used children of similar age to the studies reported in the following chapters and was described more fully earlier. In brief, she found that the six to ten year old dyslexic children performed significantly lower than the age matched ND-PR children and the low verbal IQ good readers on most measures, and lower than the RA-controls on phonological measures. Badian named this the triple deficit hypothesis, concluding that children with serious reading impairment many of whom are dyslexic have difficulties not only in naming-speed and phonology, but also orthographic skills. She concluded that dyslexia results from an overload of deficits in skills related to reading, for which the child cannot easily compensate.

(iv) The Cerebellar Deficit Hypothesis

Before outlining the evidence supporting this causal theory of dyslexia, it seems appropriate to spend some time giving more detail on the anatomical structure and functioning of this crucial but sadly neglected structure of the brain. This structure is clearly key to the cerebellar deficit hypothesis, a hypothesis which will not only be the focus of a significant section of part one of this thesis, but also part two where this hypothesis will be put to good use in an intervention programme.

The cerebellum

The cerebellum is a very densely packed and deeply folded subcortical brain structure situated at the back of the brain, sometimes known as the 'hind-brain' (Holmes, 1939). In humans, it accounts for 10-15% of brain weight, 40% of brain surface area, and 50% of the brain's neurons. There are two cerebellar hemispheres, each comprising folded cerebellar cortex, which receive massive inputs from all the senses, from the primary motor cortex, and from many other areas of cerebral cortex, either by 'mossy fibres' from the pontine nuclei or via 'climbing fibres' from the inferior olive. Output from the cerebellum is generated by Purkinje cells, goes via the deep cerebellar nuclei (dentate, interposed and fastigial nuclei), and is generally inhibitory. The cerebellar cortex comprises several phylogenetically ancient structures, including the flocculonodular node, which is situated at the caudal end, and receives input from the vestibular system and projects to the vestibular nuclei. The vermis, located on the midline, receives visual, auditory, cutaneous and kinesthetic information from sensory nuclei, and sends output to the fastigial nucleus, which connects to the vestibular nucleus and motor neurons in the reticular formation. On both sides of the vermis, the intermediate zone receives input from the motor areas of cerebral cortex through the pontine tegmental reticular nucleus. Output is via the interposed nucleus, which projects to the red nucleus, and thence the rubrospinal system for arm and hand movements, and also to the ventrothalamic nucleus. The lateral zone of the cerebellum is phylogenetically more recent, and is much larger in humans (relative to overall brain size) than in other primates and is referred to as the neocerebellum. It is involved in the control of independent limb movements and especially in rapid, skilled movements, receiving information from frontal association cortex and from primary motor cortex via the pontine nucleus. It also receives somatosensory information about the current position and rate of movement of the limbs. Its role in skilled movement execution is generally thought to be the computation of the appropriate movement parameters for the next movement (possibly the next but one movement), and to communicate these via the dentate nucleus and the ventrolateral thalamic nucleus to the primary motor cortex. The lateral zone also sends outputs to the red nucleus, and thus the rubrospinal tract.

Damage to different parts of the cerebellum can lead to different symptoms. In humans, damage to the flocculonodular system or vermis may typically lead to disturbances in posture and balance. Damage to the intermediate zone causes problems such as limb rigidity in the rubrospinal system. Damage to the lateral zone causes weakness (loss of muscle tone) and dyscoordination or decomposition of movement (that is, previously coordinated sequences of movements, such as picking up a cup, may break down into a series of separate movements). Lesions of the lateral zone also appear to impair the timing of rapid ballistic (pre-planned, automatic) movements. However, one of the features of cerebellar damage is the great plasticity of the system. Typically normal or close to normal performance is attained again within a few months of the initial damage (Holmes, 1922).

One of the fascinating aspects of the cerebellum is that the structure of the cerebellum appears to be quite different from that of the rest of the brain. In particular, the cerebellar cortex comprises a mosaic of relatively independent 'microzones', comprising a Purkinje cell and its associated inputs and output. These microzones, in combination with the associated pathways to and from the associated extra-cerebellar nuclei, may be thought of as a 'cerebellar-cortico-nuclear microcomplex' (CCMC) able to undertake a range of tasks (Ito, 1984). The complexity of the set of outputs and inputs for the CCMC allows the output from a deep cerebellar nucleus to be fed back in to the system, either immediately or after further processing. This allows the cerebellum to work as a comparator, comparing the predicted input with the actual sensory input. Any difference (the 'error signal') may then be used to improve the predictions the next time. A particularly interesting observation is that of Ito (1990), who noted that many skills could be construed as developing from a feedback model (in which a movement is made under conscious control, and the match between say hand and target is monitored continually), to a feedforward model (if I send these instructions to my hand it will end up at position P at time t) to an inverse model (in order to achieve the target, I need to execute the following [set of actions]). He makes it clear that the CCMC provides the appropriate learning and monitoring equipment to achieve these learning changes from voluntary to automatic movements, and goes on to speculate that a very similar set of cerebellum-based procedures could be used to acquire more and more practised cognitive skills.

This proposed involvement of the cerebellum in cognitive skills led to considerable controversy in the field, in that the cerebellum had traditionally been considered as a motor area (Eccles, Ito & Szentagothai, 1967; Holmes, 1917; Holmes, 1939; Stein & Glickstein, 1992), and it is also claimed to be involved in the automatisation of motor skill and in adaptive learning control via the cerebellar structures (Ito, 1984; Ito, 1990; Jenkins, *et al*, 1994; Krupa, *et al*, 1993). However, as Leiner, Leiner & Dow (1989) note, the human cerebellum (in particular, the lateral cerebellar hemispheres and ventrolateral cerebellar dentate nucleus) has evolved enormously, becoming linked not only with the frontal motor areas, but also some areas further forward in the frontal cortex, including Broca's language area. (Leiner *et al.,* 1989; Leiner, Leiner & Dow, 1991; Leiner, Leiner & Dow, 1993) concluded that the cerebellum is therefore central for the acquisition of 'language dexterity'. In effect then, they proposed that the cerebellum is critically involved in the automatisation of any skill, whether motor or cognitive. There remains controversy over the role of the cerebellum in cognitive skills not involving speech or 'inner speech' (Ackermann, *et al*, 1998; Glickstein, 1993), but there is now overwhelming evidence of the importance of the cerebellum in language (Ackermann &

Hertrich, 2000; Fabbro, *et al*, 2000; Silveri & Misciagna, 2000), including a recent demonstration of specific cerebellar involvement in reading (Fulbright *et al.*, 1999)

The Automatisation Deficit

In their longstanding research program Nicolson and Fawcett (1990) attempted initially to characterise the symptoms of dyslexia from a learning perspective, leading to their 'automatisation deficit' hypothesis (Nicolson & Fawcett, 1990). This hypothesis states that dyslexic children have difficulties becoming expert in any skill that requires 'automatic' performance, and consequently will suffer problems in fluency for any skill that should become automatic via extensive practice. The hypothesis is of course directly consistent with the established problems in reading for dyslexic children and adults: " ... Laboratory research indicates that the most critical factor beneath fluent word reading is the ability to recognise letters, spelling patterns, and whole words effortlessly, automatically and visually. The central goal of all reading instruction – comprehension – depends critically on this ability." (Adams, 1990). The hypothesis also accounted neatly for the problems in acquiring phonological skills, which also have to be learned over a long period until they are automatic (Fawcett & Nicolson, 1995).

However, the distinctive strength of the hypothesis was that it was also consistent with the outcome of a series of studies in the early 1990s, in which Fawcett and Nicolson investigated a range of skills outside the literacy domain, and found that their panel of dyslexic children showed severe deficits in a range of skills. Of particular interest was the discovery of balance deficits amongst dyslexics in comparison to reading and chronological age matched controls (Fawcett & Nicolson, 1992; Nicolson & Fawcett, 1990) (see also Yap & Van der Leij, (1994a) who partially replicated these findings). Wimmer, Mayringer and Raberger (1999) however offer an alternative explanation for balance deficits found in German-speaking children with dyslexia. In their research they found that balance problems were only found in children suffering from comorbid symptoms of ADHD. They thus proposed that this was also the case in Nicolson and Fawcett's study, i.e. their balance deficits were the result of preselection which had resulted in a high incidence of both dyslexia and attentional disorders among participants. However later testing of subjects for ADHD from the Fawcett and Nicolson subject panel showed this was not the case). Fawcett and Nicolson also found evidence of motor skill deficit (Fawcett & Nicolson, 1995b) - see also Daum et al. (1993), and rapid processing (Fawcett & Nicolson, 1994; Nicolson & Fawcett, 1994). Furthermore, taking all the data together (Nicolson & Fawcett, 1995a; Nicolson & Fawcett, 1995b), the majority of (individual) dyslexic children showed problems 'across the board', rather than with different children showing different profiles, as would be expected if there were a range of sub-types (Boder, 1973; Castles & Holmes, 1996). The automatisation deficit therefore provided an excellent account of the range of symptoms of dyslexia, (Nicolson and Fawcett, 1990), which states that dyslexic children will suffer problems in fluency for any skill which should become automatic via extensive practice. However this theory did not specify an underlying neurological structure that might provide the aetiology for the pattern of deficits shown. In subsequent research they subsumed this 'cognitive level' hypothesis within the 'neurological level' hypothesis of cerebellar deficit, as outlined below.

The Cerebellar Deficit Hypothesis

As discussed above, deficits in motor skill and automatisation point clearly to the cerebellum. Levinson (Frank & Levinson, 1973; Levinson, 1988) on the basis of studies of nystagmus and optokinetic fixation in dyslexic children, has for some time argued for mild cerebellar dysfunction as a causal factor in dyslexia. However, Levinson's work had been discounted owing to shortcomings in research methodology (Silver, 1987), allied of course to the then belief that the cerebellum was not involved in language-related skills. Furthermore, the hypothesis falls foul of the 'assumption of specificity' (Stanovich, 1988). If there are indeed problems in the cerebellum, why are the major symptoms specific to the reading domain?

In attempting to address these issues, Fawcett and Nicolson, (1999); Fawcett, Nicolson and Dean, (1996) undertook a range of studies, using a panel of dyslexic children who had been tested extensively previously, and who could be described as having 'pure' dyslexia, with IQ over 90, reading age at least 18 months behind their chronological age, no sign of ADHD, and no significant emotional or behavioural problems. They were compared with a control group from a similar social background, matched for age and IQ.

Time Estimation

First, they undertook a theoretically motivated study. In earlier research, Ivry & Keele (1989) had suggested that the cerebellum might be centrally involved in timing functions. This hypothesis was based on a comparative study of patients with cerebellar lesions and patients with other neuropsychological disorders. The cerebellar patients showed a specific disability in estimating the duration of a short (c 1s) tone, whereas their ability to estimate loudness was unimpaired. Given that other causal hypotheses for dyslexia made no differential predictions for these two conditions, this study gave us a good opportunity to provide a rigorous test of the CDH. Nicolson and Fawcett therefore replicated the study using their panel of dyslexic and control children (Nicolson, Fawcett & Dean, 1995). The results were exactly as predicted, with the dyslexic children showing significant difficulties with the time estimation, but no such difficulties with loudness estimation. It should be stressed that this study does not in any way involve rapid processing (and thus no direct comparison to Tallal's theories). The task is merely to listen to tone 1 (a standard tone of length 1s), wait 1s, listen to tone 2 (which will be either slightly more or less than 1s), then say which one is the longer. Given that the memory component is exactly the same in the time estimation and loudness estimation tasks, it was considered that no alternative causal explanation for dyslexia (then or now) was able to predict the dissociation between these two tasks.

Clinical tests of cerebellar function

If there is indeed a cerebellar dysfunction in dyslexia, then dyslexic children should show marked impairment on the traditional signs of cerebellar dysfunction. Clinical evidence of the range of deficits evident following gross damage to the cerebellum has been described in detail in classic texts by Holmes, and by Dow & Moruzzi (1958). Traditional symptoms of cerebellar dysfunction are dystonia (problems with muscle tone) and ataxia (disturbance in posture, gait, or movements of the extremities). Apart from the work of Fawcett and Nicolson on balance and Levinson's controversial findings (Levinson, 1990), there was no evidence in the literature that dyslexic children do suffer from this type of problem. Consequently, in another stringent test of the cerebellar impairment hypothesis, the clinical cerebellar tests described in Dow and Moruzzi were replicated using groups of dyslexic children and matched controls. Three groups of dyslexic children participated, together with three groups of normally-achieving children matched for age and IQ. The children had been in the research panel for some years, and at the time of testing had mean ages of 18, 14 and 10 years. This gave six groups, D18, D14 and D10; and C18, C14 and C10 for the three age groups of dyslexic children and matched controls respectively. A fuller report is provided in Fawcett, Nicolson & Dean (1996).

The tests in the Dow and Moruzzi (1958) battery may be divided into three types: first, two tasks assessing the ability to maintain posture and muscle tone while standing and in response to active displacement of station; second, a series of seven tests for hypotonia of the upper limbs in both a standing and sitting position, in response to active or passive displacement of the limbs; and finally, a series of five tests of the ability to initiate and maintain a complex voluntary movement.

The performance of the dyslexic children was significantly worse than that of the chronological age controls on all of the 14 tasks. The performance of the dyslexic children was significantly worse on 11 out of the 14 tests when compared to reading age controls. It was clear, therefore, that the between-group analyses indicated significant deficits, even compared with reading age controls, on most cerebellar tests. Further analyses were required to investigate two central issues: the relative severity of the deficits on the various tasks, and the relative individual incidence of deficit for the tasks. Effect size analyses were undertaken on the data. A child was deemed to be 'at risk' on a given task if his or her effect size on that task was –1 or worse i.e. at least one standard deviation below the expected performance for that age. If data is normally distributed one would expect 15% of the population to be at least one standard deviation below the mean, and 2% to be at least 2 standard deviations below.

Groups D18 and C18 were normalised relative to C18; groups D14 and C14 were normalised relative to C14; and groups C10 and D10 were normalised relative to C10. All but one task (finger to finger) produced an overall effect size for the groups with dyslexia of -1 or worse (at least 1 standard deviation worse than the controls). The performance of the 10 year old dyslexic children was markedly poorer than for the older dyslexic children on several tests of muscle tone, with effect sizes of -4 and worse.

The above studies provide clear behavioural evidence that dyslexic children do indeed show behavioural evidence of cerebellar abnormalities. This provides strong evidence that there is indeed some abnormality in the cerebellum or related pathways for many dyslexic children. Nonetheless, the cerebellum is a large structure with many functions, it is important to investigate this issue further, attempting to obtain direct evidence of cerebellar problems, in the hope that more direct investigation may lead to a clearer indication of which parts of the cerebellum are not used in the normal fashion.

Summary of the cerebellar findings

Traditionally problems in motor skill and automatisation point to the cerebellum, but for some years there has been clear evidence that the cerebellum is involved in language and cognitive skill (Allen, Buxton, Wong and Courchesne, 1997; Leiner, Leiner and Dow, 1989; Thach, 1996), including a recent demonstration of specific cerebellar involvement in reading (Fulbright *et al.*, 1999). Cerebellar deficit therefore appears to provide a parsimonious explanation of the range of problems suffered by children with dyslexia. Recently Nicolson and Fawcett have established extensive multi-disciplinary evidence directly consistent with their cerebellar deficit theory. Firstly they demonstrated (Nicolson, Fawcett and Dean, 1995) that dyslexic children showed a dissociation (claimed by Ivry and Keele, 1989) to be specific to patients with cerebellar damage between time estimation and loudness estimation; and second, that children with dyslexia showed a range of classic cerebellar signs (Fawcett and Nicolson, 1999; Fawcett, Nicolson and Dean, 1996). A recent study also established abnormally weak cerebellar activation when adults performed a motor sequence learning task (Nicolson *et al.*, 1999).

It is clear, therefore, that at least for some children with dyslexia, cerebellar impairment provides a parsimonious account of the range of symptoms established by earlier research. Furthermore, the hypothesis provides a potentially unifying framework, in that it has been suggested that cerebellar impairment would almost certainly give rise to articulatory difficulties, and thence to phonological problems - see Heilman, Voeller and Alexander (1996); and Snowling and Hulme (1994) for advocacy of the latter link. Furthermore, cerebellar deficit would lead to slowed central processing (cf. the double deficit hypothesis), and deficits in motor skill, but not necessarily to sensory processing speed deficits. It is not necessary to present a full analysis of the putative causal chain between early cerebellar impairment via articulation, to phonological deficits, to the criterion measures for dyslexia, reading, spelling and writing. In summary though it has been proposed that cerebellar problems are present from birth and lead to difficulties in acquisition and automatisation of elementary articulation skills as well as auditory skills (and hence to difficulties in phonological processing). Also affected are visual skills such as eye movement and letter recognition, which not surprisingly lead to the already established early problems in learning to read and spell. In terms of the assumption of specificity (Stanovich, 1988) reading is particularly severely impaired because it depends on two aspects of cerebellar function; first, learning new skills, and second, becoming expert in these skills. This dual role for the cerebellum in reading thus produces a "double whammy" effect (for a review see Nicolson and Fawcett 1999). Nevertheless, with the arrival of the cerebellar deficit hypothesis and the demonstration of so many skill deficits in areas unrelated to reading, it seems that the "death knoll for the assumption of specificity" (Stanovich, 1988) may fast be approaching.

Overview of the Studies Chapters Two and Three

This introductory chapter has provided a thorough overview of issues and problems surrounding the definition and diagnosis of dyslexia, focusing on Stanovich and the evolution of his theories on IQ, the phonological theory of dyslexia, the discrepancy debate, and research comparing dyslexia and ND-PR children's performance. Finally, a thorough overview of both the phonological deficit causal theory of dyslexia as well as other key causal theories of dyslexia was given.

It is now appropriate to turn the focus towards the studies in chapter two and three of this thesis. In chapter two, the focus on the phonological deficit hypothesis and the theories of Stanovich will continue in a comparative study of the phonological awareness skills of ND-PR children and dyslexic children. In chapter three the data from chapter one will be incorporated into a broader comparative analysis of ND-PR children and dyslexics performance in a wide range of basic skills areas, both within and without the literacy domain.

It seems appropriate that the phonological performance of ND-PR children and dyslexic children be written up as a separate study in chapter one before being included in chapter two. The phonological deficit hypothesis is by far the dominant explanatory framework for dyslexia. Furthermore one of the main problems for the phonological deficit theory has been the issue of discrepancy based definitions in dyslexia. Stanovich is the leading name in this prominent debate and his theories are inextricably bound up in the phonological deficit theory. Chapter one has focussed on this ongoing discrepancy debate and thus chapter two will focus, through its examination of phonological performance in ND-PR and dyslexic children, on providing fresh research to help forward this discussion. It is only by writing up this first experiment as a separate study that these issues of phonology can be fully and clearly explored.

Chapter three will draw upon all the causal theories of dyslexia outlined in chapter one in order to predict and discuss the performance of dyslexic and ND-PR children. Unlike chapter two where the focus was on phonology and the issues surrounding the discrepancy debate and Stanovich, chapter three will have a completely separate focus. In chapter three the focus will be on trying to find proof of a common underlying cause from the range of deficits shown in dyslexic and ND-PR children. The phonology data from chapter two will be included unaltered in this analysis, but discussion of the implications of the phonological results will take a different direction and form just a small part of a much broader discussion of the data from the broad testing battery presented in this chapter.

Before the study in chapter two is presented, it is appropriate to consider two more issues, which have influenced the design of this particular study.

A Study of Phonological Awareness Deficits in Non Discrepant Poor Readers and Dyslexic Children

Differential Diagnostic Tests

Returning to the discrepancy debate and matters of differential diagnosis between ND-PR children and dyslexics, the applied issue of diagnostic value of phonological tests for discriminating between these two groups will now be considered. Tests based on phonological awareness ability have long been an integral and often central part of dyslexia diagnostic tests, whether in the simple format of the tests presented here or via higher meta-phonological skill analysis such as reading.

This is a result of the general acceptance that phonological tests discriminate between dyslexic and non-dyslexic children based on the wealth of research evidence for a phonological deficit in dyslexia (Bradley and Bryant, 1983; Wagner, 1988). However, it is agreed that it may prove much more difficult to differentially diagnose ND-PR children and dyslexics either in a single session or using a variety of diagnostic tests, including phonological tests due to the 'continuum' of difficulties between the two groups (Stanovich 1988a). Furthermore, Stanovich considers that ND-PR and dyslexic performance in 'core' phonological areas is so similar that it is not worth discriminating between these two groups on the basis of their IQ (Stanovich, 1988a). From this viewpoint it would seem that using phonological tests in isolation to differentially diagnose dyslexic and ND-PR children is pointless. Phonological tests will identify all children with ‘reading disabilities’ (Stanovich 1996) but not differentiate between dyslexic and ND-PR children within this broader category. However, if phonological tests are to be seen as holding maximum diagnostic potential, then it is important that these tests when used in isolation are shown to distinguish between not only dyslexic and normal children, but also dyslexic and ND-PR children. The study reported in the following chapter will provide fresh evidence on the comparative phonological performance of dyslexic and ND-PR children, thus giving helpful information as to the diagnostic value of phonological tests.

Early Pre-School Screening

The earlier children with dyslexia can be identified and then supported, the better the chance that their difficulties will be successfully remediated and they will fulfill their true potential in school. It is not the main purpose of this study to enter into the fast emerging debates and research into early diagnosis or screening of dyslexia. However, with regard to differential early diagnosis, the potential gained from a screening test design employing analysis of simple, low-level phonological skills is obvious. It provides a screening test that is accessible to all ages of child, even pre-literate children. (This accessibility consideration was influential in designing the basic skills intervention programme for children with learning difficulties in chapters five and six.) The phonological tasks used in the study reported here were simple, low level tasks, which would be accessible to pre-literate children.

It is frequently suggested that reading problems might be prevented if phonological processing deficits could be ameliorated early in the 'at risk' child's academic life. (Bradley, 1998; Lundberg, Frost and Petersen, 1988). Nevertheless as Hurford *et al* (1994) state "the remediation of phonological processing deficits in at risk children is dependent on researchers ability to *accurately* identify these very children." Obviously, at 4-5 years, it is going to be impossible to categorically say whether a child has reading problems or not, as level of development is still pre-literate. However, what does seem more plausible is the employment of simple phonological tests at this stage, which may be shown to have been predictive of later reading problems when a retrospective analysis is done.

Stuart (1995) carried out such a study, identifying one particular phonological test at 4-5 years as being particularly predictive of problems at 6 years. More recently Nicolson and Fawcett (1996) have developed an early screening method using a battery of tests of basic skills including phonological awareness (The DEST, The Psychological Corporation, 1996). The work reported in the following chapter has contributed significantly to the development of this screening test. Nevertheless, little investigative work has been carried out on the potential of *early* phonological skills to discriminate between ND-PR and dyslexic children, this being a somewhat neglected area in the literature. If basic phonological skills can be shown not only to be predictive of later problems, but also to be discriminative, then this would not only hold implications for Stanovich's theory, but also suggest that they are of key importance in any early screening battery. From an applied viewpoint this would also break new ground in the identification of learning difficulties in children of pre-school age.

Part One

Chapter 2

A Study of Phonological Awareness Deficits in Non Discrepant Poor Readers and Dyslexic Children

The Studies

Aim of Study

The issues outlined in chapter one were the motivation behind the research reported here, and influenced the design of the experiment. A primary aim behind this study was to provide fresh research with which to consider the Stanovich debate and the value of the traditional discrepancy based definition of dyslexia. This will involve examining in more detail whether the extent of any differences between the ND-PR children and dyslexic children in phonological performance are significant enough to suggest that they do indeed represent two distinct groups. The implications of such findings for Stanovich's phonological core variable difference theory will be considered. Finally, the resulting applied issues will be discussed. This will include looking at the validity of phonological tests in differential diagnosis of dyslexia and their potential in the early diagnosis of learning difficulties at 4-5 years. Leading on from this we will enter into the educational politics of reading disabilities by examining afresh the justification for the differential educational treatment of dyslexic children based on our results.

The design of the study extends the research completed by Fawcett and Nicolson with dyslexics and controls (Fawcett and Nicolson 1995a; Fawcett *et al*, 1996) to include two comparable groups of ND-PR children matched for reading age and chronological age with the youngest group of dyslexics. This will enable the important between-groups comparison to be carried out in this area of early phonological awareness. It will also enable some analysis of the developmental progression of phonological awareness skills in the ND-PR children since two age groups of 8 and 10 years will be tested. Low level phonological processing tests will be used which minimise the need for rapid processing, reduce the scope for strategic variation and keep working memory load as low as possible. Verbal memory will also be assessed, as it is a fundamental precursor to the development of phonological skills. As mentioned, this work had already been published in part (Nicolson and Fawcett, 1994a; Fawcett *et al*, 1996). However, the published data should not be directly compared to the data reported in this study due to slight differences in the subjects used. This produced some differences in results. The published data (Nicolson and Fawcett, 1994a; Fawcett *et al*, 1996) only included 10 year old ND-PR children, and thus included some of the oldest ND-PR 8 group from this study (9.2.years of age) in their ND-PR 10 group, in order to increase group size.

Predictions and Hypotheses

As stated previously, the literature on ND-PR performance is relatively small and often inconsistent, which makes the task of making performance predictions difficult. However, tentative predictions are possible, particularly in the area of phonology. Chapter one provided an overview of recent research work comparing the performance of ND-PR and dyslexic children and furthermore thorough details of the phonological deficit theory and Stanovich's theories were given. The area of phonology is the most studied for dyslexics and subsequently it seems also for ND-PR children.

It seems that one can predict with some certainty that at a general level the ND-PR children will demonstrate deficits in phonological skills. After all, the whole of the discrepancy debate and Stanovich's phonological 'core' theory revolved around the fact that the ND-PR children have consistently been shown to suffer phonological deficits compared to normal children. (Stanovich, 1988a, 1988b; Stanovich, 1996; Siegel, 1992; Stanovich and Siegel, 1994). All of the studies outlined in chapter one which looked at phonological skills, showed that ND-PR children were deficient in this area when compared to controls (e.g. Van Daal and Van der Leij, 1999; Badian 1994, 1996, 1997; Swanson *et al.,* 1999; Ellis *et al.,* 1996).

However, when it comes to hypothesising as to the comparative performance of the ND-PR group against the dyslexic group then predictions become harder. Stanovich would have us believe that the differences between the two groups in the area of phonology will be insignificant, leading to his conclusion that IQ is irrelevant to the definition of dyslexia (Stanovich, 1994). Although the research reviewed in chapter one adds some support to this prediction (e.g. Ellis *et al.,* 1996; Siegel 1992; Share, 1996) there appears to be convincing evidence that this may not always be the case, (e.g. Aaron 1987, 1989; and Badian, 1993 where dyslexics were shown to perform significantly better than the ND-PR children and Yap and Van der Leij, 1994a; where dyslexics were significantly worse than poor readers). Also, inconsistencies due to effects of age have been identified (e.g. Badian, (1996) who showed that younger dyslexics demonstrated phonological abilities commensurate with the ND-PR group, thus supporting Stanovich, but older dyslexics showed significantly worse deficits than the ND-PR group suggesting a developmental lag in the latter group and a deficit in the dyslexic group. Also the study of Van Daal and Van der Leij. However, in this study older dyslexics were found to perform *better* on many phonological tests than the ND-PR group). This effect will be studied afresh in this chapter where both age eight and age ten subjects are compared.

There may be significant between group differences in some of the tasks yet not others. Van Daal and Van der Leij, (1999) found that at age twelve, their dyslexics did not show deficits in all phonological skill area, and that in fact the ND-PR children were worse on all phonological tasks at this age than the dyslexics. They suggested that the phonological core deficit is thus not completely independent from intelligence, and that dyslexics may not (at this age anyway) suffer a *general* phonological deficit, and that in fact the ND-PR children seemed to show more evidence of a general deficit. It will be interesting to see if support for these conclusions can be found in this study.

So in conclusion, a hypothesis is put forward that ND-PR children will show deficits in phonological skills across the board when compared with dyslexics. When compared to the dyslexic children, it is tentatively predicted that, as Stanovich (1988a) proposes, the ND-PR children will generally reveal deficits commensurate with those of children with dyslexia, although there may well be some variation on individual tests and the effect of age is unclear.

Method

Participants

All children in this ND-PR study were drawn from two Sheffield local authority schools with a special unit for children with learning difficulties. In order to check for any changes in performance with age the full intake from grades 3 to 6 were tested – 36 children in all, aged from 7.3 to 11.1 years. Most had entered special education between 6 and 7 years of age. All these children were white, from middle to lower S.E.S. families (social classes 3, 4 or 5). Children were tested blind (i.e. the experimenters did not know whether the children were to be classed as ND-PR children or dyslexic children at the time of testing), with the experimenters having no knowledge of their IQ since psychologist's reports were read and IQ testing was performed after testing. ('Experimenters' consisted of the author and three additional final year psychology undergraduate students. These students had all been trained by the author to administer and score the phonological and memory tests. This ensured standardisation between testers). After testing, psychologist reports were accessed wherever possible by the author which showed that the group contained children with IQ scores ranging from 68 to 130, with the majority having IQ scores below 90. (As stated above, caution should be applied before directly comparing results from the work reported here with that in Fawcett *et al.,* (1996) due to the slight differences in group membership outlined above).

All the ND-PR children had been identified by their teachers as having learning difficulties. The majority of the 10-year-olds were statemented, and so were receiving regular extra support in school and careful progress monitoring by educational psychologists. Psychologist reports were thus accessible to the author for most of these children. However, because of their age, the 8 year olds had not yet been statemented, and so initial selection was based on teachers' reports of classroom learning problems. However, after initial selection and after testing, IQ measurements were obtained using the full-scale WISC-III R (Wechsler, 1976) for the 8-year-olds and the short form British Ability Scales (Elliott, 1983) for the 10-year-olds (comprehensive IQ testing having already been administered due to statementing). The WORD tests of reading and spelling (Wechsler, 1993) were also administered to enable reading age assessment.

Children with IQ score below 90 were allocated to the 'no discrepancy' group, who would be classified in the UK as children with mild learning difficulties[1].

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[1] The terminology and also the criterion vary between countries. In the UK, the cut-off for this group is IQ below 90, whereas in the US a cut-off of 85 is often

These children with ND-PR were divided into two age groups (around 8 years and around 10 years respectively) to form an NDPR8 group (n=14), and an NDPR10 group (n=15).

These two age groups were chosen in order to permit a design which allows not only a standard chronological age match comparison (of 8 year old ND-PR children, controls and dyslexics), but also (by comparing the older ND-PR children with the younger dyslexics) a reading age match comparison. The reading age match comparison is important for helping elucidate the exact nature of any performance differences displayed. A deficit compared with chronological age controls may indicate only delay, whereas a deficit compared with reading age controls provides evidence of a disorder in that skill (Bryant and Goswami, 1986).

The composition of the ND-PR group ranged from IQ 67 to 87, with only one child in each group with a discrepancy of 18 months or more between chronological age and predicted reading age. The majority of the children in each ND-PR group, read somewhat in advance of their predicted reading age, although behind that appropriate for their chronological age.

Children with IQ levels of at least 90 formed a small group with dyslexia (n=7) with mean age around 8. These children have been labelled D8-new. For analyses except those given in Table 2(1) they have been integrated with the group (n=9) of 8 year old children with dyslexia previously reported in Fawcett *et al.,* (1996). It was considered justifiable to include these 'new' dyslexics in an attempt to increase group size since the D8 group had previously been so small. Small subject group size will limit the strength of any significant results found, so any attempt to boost subject size is welcome. The 'new' dyslexics were classified and diagnosed as part of the search for the ND-PR group, and were diagnosed by appropriately qualified assessors using the WISC-IIR. This was the same process undertaken for the 'old' dyslexic group, and so the validity of their

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taken. In fact only one ND-PR child (NDPR10 group) had an IQ greater than 85, so in this study the difference is not important.

inclusion in the dyslexic group was considered acceptable. This slight lack of experimental control is inevitable given that, to avoid any possibility of implicit selection bias, no subject who met the criterion for dyslexic (or ND-PR) was excluded.

The overall group of children with dyslexia aged around 8 years is referred to as D8. A group of 10 year old children with dyslexia (D10) previously reported were also included in the analyses, as were data from two groups of control children aged around 8 and around 10-11 years respectively. The latter groups are referred to as C8 and C10 respectively.

Data collection and analysis for the D8 (n=9), D10 and C8 and C10 groups previously reported in Fawcett *et al.,* (1996) and Fawcett and Nicolson (1995a) was performed by the first author in both publications. The dyslexic and control children had been in the Fawcett and Nicolson dyslexia research panel for some years, and had been initially located through the local Dyslexia Institute or the local branch of the British Dyslexia Association.

All children in the original dyslexic and control comparison groups were white, drawn from mixed S.E.S. families (social classes 1-5), and also from the Sheffield area. In view of the potential danger of implicit selection bias, it is important to note that, other than checking that the children met the 'standard exclusionary criteria' of dyslexia, and were willing to undertake testing on a long-term basis, no other screening or selection whatsoever was undertaken. Dyslexic and control subjects were paid around £7.50 per hour and participated with fully informed consent. It should be noted that additional dyslexic and control children have been added to the 8 and 10 years old groups since the Fawcett and Nicolson (1995a) study, in order to boost group size. These subjects were selected from various private schools in the Sheffield area, were white and of mixed S.E.S (social class 1-5) and underwent the same selection procedures as the other subjects. All dyslexic and control children had previously undertaken a full WISC intelligence test (Wechsler, 1976; Wechsler, 1992) together with the WORD tests of reading and spelling (Wechsler, 1993). Children with dyslexia satisfied the standard exclusionary criteria of 'children of normal or above normal IQ (operationalised as IQ equal or greater than 90), without known primary emotional, behavioural or socio-economic problems' whose reading age (RA) was at least 18 months behind their chronological age (CA). Control children satisfied the same criteria, with a RA a minimum of 6 months below their CA or better, and with no history of reading problems. (In fact, as study of Table 2(1) reveals, some children in the control group were reading considerably ahead of their CA, i.e. the C8 group were ahead by approximately 2.5 years and the C10 groups by about 1.5 years. This phenomenon is due in part to the addition of control subjects from private schools (in order to match the dyslexic children drawn from these schools) and reflects the benefits of small class teaching. Again, this slight lack of experimental control is inevitable, given that in order to avoid any possibility of implicit selection bias, no subject who met the criterion for dyslexia (or control) was excluded. This factor will be taken into consideration when comparing against control data.

In view of the known comorbidity of dyslexia with attention deficit (hyperactivity) disorder (ADHD) (Fletcher, Shaywitz and Shaywitz, 1999; Pennington *et al.*, 1993; Shaywitz *et al.*, 1995), all ND-PR children were screened for ADHD by the author at initial assessment using the DSM-IIIR scales (American Psychiatric Association, 1987)[2] (see Appendix 1 for example score sheet). (The dyslexic and control children had all been screened for ADHD with none of the children showing evidence of ADHD). Any child revealing ADHD, was omitted from the study, because of the overlap in conditions confounding any results obtained. Furthermore, as well as resulting in an invalid IQ (due to inattention), the behavioural problems would make it likely that the child would fail in many of the tests for reasons other than those primarily

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[2] The DSM-IIIR assessment for ADHD involves simple yes/no questions, with a 'yes' on at least 8 being the minimal criterion for diagnosis of weak ADHD. It should be noted that the incidence of ADHD in the UK is currently low (c0.5%, Reason, 1999). ADHD is a condition characterised by problems in attentional control with evidence of hyperactive behaviour in children. However, much remains to be explained in the relationship between dyslexia and the neuropsychologically distinct ADHD (Turner, 1997).

attributable to dyslexia. One child (in the ND-PR8 group) showed clear evidence of ADHD, together with behavioural problems. Only this child showed co-morbid emotional and behavioural problems. One further child in the ND-PR8 group had been diagnosed as dyspraxic/dyslexic. The child with ADHD, was omitted from the study as a result of screening. However the dyspraxic child, was included in the study, as it was not of theoretical interest to exclude this child. A dyspraxic/dyslexic child will show great similarities to a dyslexic in the difficulties demonstrated. Psychometric details (including a breakdown by gender, chronological age, reading age, and IQ mean and range) are given below in Table 2(1).

Table 2(1). Psychometric Data for the Four Subject Groups.

The groups of children with ND-PR are labelled ND-PR8, ND-PR10 – with the suffix indicating the mean age. The group of children from the present study who were identified as having dyslexia are labelled D8-new. Participants with dyslexia were augmented with existing data for children with dyslexia, leading to the creation of two further groups (labelled D8-overall and D10). Two control groups (labelled C8 and C10) have also been added for comparative purposes. The data for groups D8, D10 and C8, C10 were reported in Fawcett, Nicolson and Dean (1996). The mean value for each group is presented first, with the range of values bracketed. WISC III refers to the Wechsler Intelligence Scale for Children (1992), and BAS to the British Ability Scales (Elliott, 1983). WORD refers to the Wechsler Objective Reading Dimension (1993).

(Mean data are given. Ranges in brackets).

Group	**N (M/F)**	**IQ (WISC-R/BAS)**	**Chronological Age**	**Reading Age**
D8-new	7 (6/1)	103.3 [90-130]	8.28 [7.7-9.1]	6.52 [5.8-8.7]
ND-PR8	15 (9/6)	75.8 [68-84]	8.02 [7.3-9.2]	6.31 [5.1-7.5]
ND-PR10	14 (11/3)	77.2 [67-87]	10.32 [9.5-11.1]	7.91 [5.9-10.8]
Comparative Data				
D8-overall	23 (18/5)	107.0 [90-133]	8.19 [7.7-9.1]	6.66 [5.6-8.7]
D10	15 (15/0)	111.6 [96-133]	10.70 [10.2-11.0]	8.1 [7-9.9]
C8	32 (24/8)	119.3 [91-141]	8.48 [7.0-9.4]	11.16 [7.7-13.3]
C10	29 (22/7)	112.6 [92-135]	11.0 [10.1-12.1]	12.49 [10.0-17]

Procedure

At the time of writing, there was limited evidence that children of low IQ might have slower speed of reaction, and smaller working memory capacity than matched dyslexics (Vernon and Mori, 1992). Consequently tests of phonological processing were used, which minimised the need for rapid processing, and which kept working memory load as low as possible. This avoided confounding interpretation of deficits. Further support for this suggestion of low speed of reaction and working memory capacity, was found by the author in continuing research, the results of which are reported again in chapter three. Also, in order to reduce scope for strategic variation, simple phonological awareness tests were used, ranging in difficulty from sound categorisation (detection of rhyme and alliteration) to the more complex phoneme deletion and non-word repetition. Five tasks were administered; a sound categorisation task, based on the procedure used by Bradley and Bryant (1983); a phonemic deletion task, based on the procedure used by Rosner (1971); a non-word repetition task, taken from Gathercole and Baddeley (1990); and an articulation time and verbal memory span test. All testing was completed in as quiet an environment as possible, in school, with one of the experimenters present throughout all testing periods (for experimenter details see 'Participants' section). The length of sessions varied, in order to integrate with the daily school timetable over one month, but not one session exceeded one hour, and breaks were given between each subtest. Each child was given generalised reassurance - 'Well done'; 'That was a bit tricky' etc - throughout, but no comparative comments were made on the quality of each child's performance. Each child was tested individually. Variability in test application, and scoring between experimenters, was reduced as much as possible by ensuring all experimenters received thorough training from the author in administration and scoring of all tests prior to beginning the study. This included observing the experimenters administering tests, and double marking score sheets as part of training.

Experimental Tasks

(i) Sound Categorization

This test was based on the three-stimulus 'Odd man out' format devised by Bradley and Bryant (1983). Here the experimenter would present a series of words, such as *sun, sock, see* and *rag* (with *rag* the odd one out on the basis of the first letter), and the subject had to say which was the odd one out. On all the tasks presented, the children with dyslexia were significantly worse at judging which was the odd one out than younger children, who had reached the same level in their reading.

In pilot work, performed by Fawcett and Nicolson (Fawcett and Nicolson, 1995), using the three-stimulus 'Odd man out' format devised by Bradley and Bryant (1983), it had been established that several of the oldest dyslexic group had difficulty in *remembering* all three stimuli long enough to make the necessary comparison. Typically they would repeat the first two stimuli, and then question the experimenter as to the third stimulus. Since the aim was to dissociate memory function from pure phonological awareness skills, the memory load was reduced by presenting only two stimuli at each trial, and asking whether or not they had the same beginning, middle or end, depending on the condition.

This experiment was carried out on an Apple Macintosh computer, using Apple's HyperCard multimedia environment. The stimuli used were taken from the 90 single-syllable three or four letter words derived by Bradley and Bryant (1983). (See Appendix 2 for the full word list used by Bradley and Bryant (1983)). It should be noted that only the 'Rhyming' and the 'Alliteration' conditions were used in this test. In Fawcett and Nicolson's study (Fawcett and Nicolson, 1995) and Bradley and Bryant's seminal work (Bradley and Bryant, 1983) with older children, a 'Middle of Word Rhyme' condition was also used, but this condition was omitted here, being considered too difficult for the age group being tested.

Each stimulus was spoken by the first author from the Fawcett and Nicolson study (Fawcett and Nicolson, 1995), digitised at a 22KHz sampling rate, and stored as a HyperCard sound resource, which could then be played under experimental control. In the pilot work described above, it had been confirmed that the stimuli were clearly discriminable.

Two different experimental conditions were presented, in a fixed order, with ten trials in each condition, following two practices. For each trial, a word triple was selected (without replacement) pseudorandomly from the pool of thirty word triples, and the first word was chosen, together with either the second or the third word, so that the two stimuli rhymed on exactly 50% of the trials for each condition. (It is therefore impossible to list the exact words presented in this and the alliteration condition, since words selected from the triples were pseudorandomly varied by the computer for presentation. However, all word triples from which this selection was made, were identical to those used by Bradley and Bryant (1983) as seen in Appendix 2).

The two conditions, a simplified version of the tests used in Bryant and Bradley (1983), were as follows:

<u>Condition 1: Rhyming</u>. This condition was introduced by asking the child to recite a nursery rhyme, and emphasising the ends of lines that rhymed, to ensure that the child was familiar with the concept. The child was then asked to generate a word that rhymed with *'cat'*, with feedback and resolution of uncertainties given as necessary. This was followed by a computer-presented practice, with feedback, and then the experimental condition. The experimental instructions were presented by the computer in synthesised speech and were *"I will say two words. Sometimes they rhyme. Listen carefully and tell me whether they rhyme or not"*. Synthesised speech was used, to indicate that the children were not expected to read the instructions, and also because it was found that the children responded well to the robot-like voice, which added an element of fun. In order to check that the participants had followed the instructions, these were repeated by the experimenter, and subjects were instructed to say 'yes' if the word ended with the same sound, or 'no' if it did not.

Condition 2: Alliteration. The alliteration condition was introduced with the idea of 'I-Spy', and the child asked to generate words starting with any selected letter from the alphabet, for example the experimenter would say *"I spy with my little eye something beginning with the letter /b/"*. As soon as the child correctly guessed a visible object beginning with a /b/ e.g. 'book', they would be asked to think of another word beginning with the same sound e.g. 'blackboard'. This stage would be repeated two to three times, with different letters to ensure the concept was fully grasped by the child, before moving onto the main test.

The instructions were *"I will say two words. Sometimes they start with the same sound. Listen carefully and tell me whether they start with the same sound or not."* The instructions were repeated by the experimenter, and the subjects were instructed to say 'yes' if the word started with the same sound or 'no' if it did not. (Again, it is impossible to list the exact words presented in this and the rhyming condition, since words selected from the triples were pseudorandomly varied by the computer for presentation. However, all word triples from which this selection was made, were identical to those used by Bradley and Bryant (1983) as seen in Appendix 2).

This experiment had no speed component, and the experimenter recorded the child's decision for each trial. The experimenter ensured that the participant repeated the two words, to check that the words had been correctly heard and remembered. Results were analysed automatically, giving overall accuracy in each condition, with a maximum score of 10 in each condition, and 20 overall.

(ii) Test of Auditory Analysis and Segmentation Skills

The TAAS (Rosner and Simon, 1971) test is a spoken test of the ability to segment words into syllables and to delete phonemes. It starts with two simple practice items, with feedback and resolution of uncertainties, where the child is asked to analyse a two syllable compound word into syllables ("say 'cowboy' without the 'cow'" and "say 'steamboat' without the 'steam'"). The experimenter records the response. If the child continually fails both practise items, then the main test is discontinued. Then a series of 13 items of increasing complexity is presented. (See Appendices 3(3a and b) for example test and score sheet). At the phoneme level, the position of the sound is controlled for difficulty, starting with the easiest, substituting the first phoneme, then the final sound, and finally part of the consonant blend for e.g. "say 'smack' without the '/m/'". This test is suitable for use from kindergarten onwards. The discontinuation rules suggest that presentation should stop after two consecutive failures within the main test. However, we were particularly interested in variability in performance across the levels, and as the complete test took only a few minutes to administer, it was presented in its entirety to each child. Again this test had no speed component.

iii) Nonword Repetition

This test measured the ability to repeat a nonsense word spoken by the experimenter. Performance typically declines as the nonsense words get longer, and thus it is taken to be a valuable early test of working memory performance. The nonsense word test is thought to be a useful indicator of a child's ability to acquire new vocabulary, since any word will appear to be a non-word the first time it is heard by the child.

The Gathercole & Baddeley (1990) test was used in which the subject has to repeat a nonsense word immediately after hearing it, with stimuli taken from a set of 30 ranging from 1 to 3 syllables (including 'fot' and 'skiticult') (see below for full list of nonsense words used). Subjects were presented with all 30 stimuli in a random order with a score of 1 for a correct answer and 0 for an incorrect answer. The total score, out of a possible maximum of 30, was then calculated and converted into a percentage score for results presentation.

Full nonsense word list (order is random):

DOPELATE, GLISTERING, PENNEL, SEP, HAMPENT, FOT, HOND, TULL, GLISTOW, FRESCOVENT, BANNIFER, BALLOP, SMIP, NATE, BIF, TRUMPETINE, SLADDING,

TAFFLEST, CLIRD, BARRAZON, COMMERINE, THICKERY, THIP, RUBID, BRASTERER, DILLER, GRALL, BANNOW, PRINDLE, SKITICULT.

iv) Articulation Time

Articulation rate was measured by asking the children to say a given stimulus several times, speaking as rapidly as possible. The speech was recorded onto an Apple Macintosh microcomputer in the Soundedit programme, using a Farallon MacRecorder microphone/digitiser.

Participants repeated the stimuli, until instructed to stop, after more than 5 sequences had been generated. They were not told that exactly 5 repetition was needed, because counting the number of repetitions can impact on the speed of performance. The dependent variable was the time taken for one complete articulation determined to the nearest centisecond from the digitised signal recorded. The words used were, 'bus', 'monkey and 'butterfly', which have high frequency and early age of acquisition. They were selected as representative from a larger pool of 1, 2, and 3 syllable words (Nicolson, Fawcett and Baddeley, 1991).

The time taken for one complete articulation, was measured for each word and then the mean for all three words calculated and presented in the results.

v) Memory Span

The procedure used was adapted from those used recently by Hitch, Halliday, Dodd and Littler (1989) and Hulme and Tordoff (1989) in investigating the development of memory span as children get older.

The stimuli used were taken from: A pool of one-syllable words (pig, bus, car, fish, leaf, spoon, bed, and egg); a pool of two-syllable words (monkey, rocket, tiger, apple, pencil, scissors, hammer, and flower); and a pool of three-syllable words (helicopter, elephant, banana, butterfly, umbrella, Christmas tree, kangaroo, and fire engine). The memory span data was collected with four cycles of presentation of lists of 2, 3, 4, 5 and then 6 words for each of the three word pools. Stimuli were presented auditorily at the rate of one per second. Subjects attempted spoken recall of the list in order, directly following each presentation. Results were recorded online, and memory span determined automatically, as the mean for words of 1, 2 and 3 syllables (measured as the longest list of words that the subject can recall in the correct order).

The formula used was: 'span = 0.5 + mean number of correct trials per cycle + 1', which allows credit to be given where, say, the child errs on lists of length 3, but gets some right at length 4.

The articulation rate test and the memory span test were included here, because memory span and articulation rate are known to co-vary (Baddeley, Thomson and Buchanan, 1975) and both are important in the development of effective phonological skills (Jorm *et al.,* 1984; Ellis 1991; Nicolson and Fawcett, 1995b).

Results

Mean results and standard deviations are shown in Table 2(2). It can immediately be seen that the ND-PR and the dyslexic group performed less well than the age matched controls on the majority of the tests. Furthermore the ND-PR 8 group appeared to perform better than the ND-PR 10 group in all but the non-word repetition test.

Table 2(2). Summary of Mean Scores for each Group on each Phonological Test

(Standard deviations are given in parentheses).

Task	ND-PR8	ND-PR10	D8	D10	C8	C10
Segmentation	5.73	4.44	7.29	9.40	10.90	12.80
(max 13)	(2.43)	(2.70)	(3.86)	(2.30)	(1.20)	(0.50)
Rhyme	26.10	24.40	27.20	28.60	29.50	29.80
(max 20)	(2.30)	(2.56)	(2.15)	(1.14)	(1.04)	(0.45)
Memory Span	3.17	2.93	3.81	4.32	4.24	4.52
	(0.68)	(0.55)	(0.81)	(0.27)	(0.49)	(0.64)
Nonword Repetition	60.30	71.70	73.70	72.10	83.30	86.40
(%)	(15.9)	(7.30)	(15.8)	(5.48)	(5.45)	(7.89)
Articulation Time	0.51	0.44	0.56	0.45	0.46	0.36
(s)	(0.12)	(0.08)	(0.13)	(0.08)	(0.05)	(0.05)

A series of two factor analyses of variance was undertaken separately for each task, with the factors being disability type (ND-PR, dyslexia or control) and age (2 levels). A summary of these analyses is presented in Table 2(3). For all but articulation time, the effect of age was not significant. In none of the tasks was there a significant interaction between age and disability type. By contrast, there was a significant effect of disability type in all five tasks[3]. When the 'type' main effect was significant, Fisher protected LDS a posteriori analyses were undertaken, to establish which of the three disability types differed significantly. Compared with the ND-PR group, the controls performed significantly better on all four tasks save the articulation rate. Compared with the groups with dyslexia, the controls performed significantly better on four out of five phonological tests (excluding memory span). The groups with dyslexia performed significantly better than the groups with ND-PR on four out of five phonological tests

[3] It is common practice in the case of multiple analyses of variance to apply the Bonferroni correction to take account of the possibility of the odd significant difference arising by chance. This is not appropriate in the present study given that every analysis led to a significant difference.

(excluding articulation rate, for which the groups with dyslexia were near-significantly slower (p< .07) than those with ND-PR).

Table 2(3). Inferential statistics for Chronological Age and Disability Type

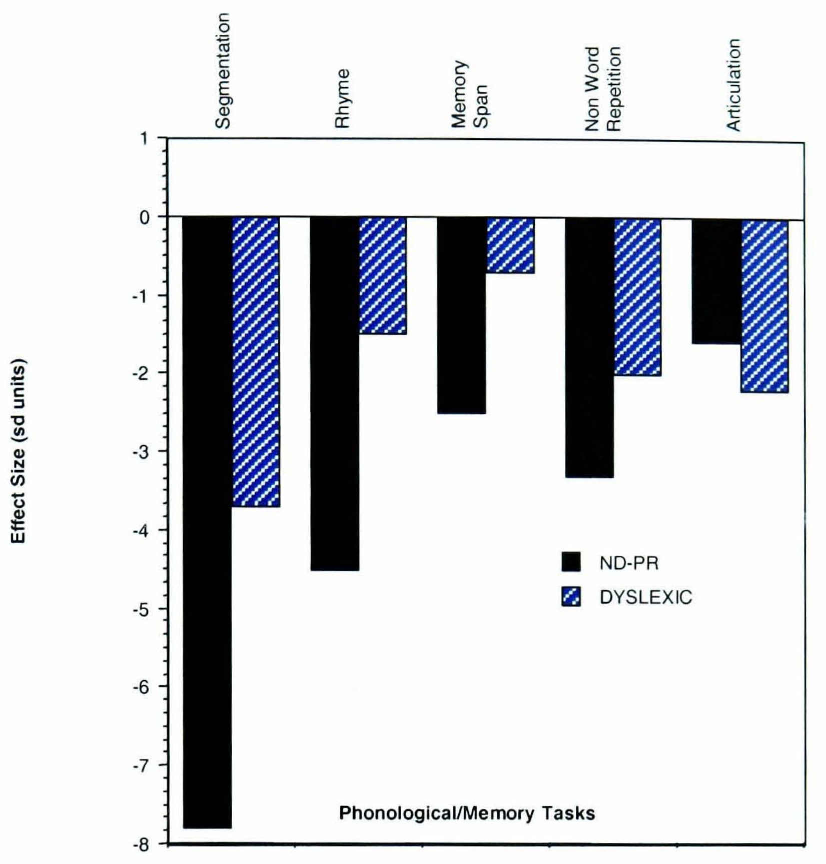
Groups included were ND-PR8, D8, C8 and ND-PR10, D10, C10.

Task	Disability	Age	Interaction
Segmentation	F(2,44)=29.2, p<.0001 C>D, C>ND-PR, D>ND-PR	F(1,44)=1.4, NS	F(2,44)=2.5, NS
Rhyme	F(2,49)=22.6, p<.0001 C>D, C>ND-PR, D>ND-PR	F(1,49)=0.01, NS	F(2,49)=2.9, NS
Memory Span	F(2,51)=24.6, p<.0001 C>ND-PR, D>ND-PR	F(1,51)=1.2, NS	F(2,51)=1.9, NS
Nonword Repetition	F(2,60)=12.7, p<.0001 C>D, C>ND-PR	F(1,60)=2.0, NS	F(2,60)=1.8, NS
Articulation Time	F(2,61)=4.6, p<.05 C>D	F(1,61)=13.6, p<.001	F(2,61)=0.3, NS

Effect Size Analyses

Effect size analyses (e.g., Cohen, 1969) were used in order to facilitate comparison between the tests, and to elucidate the patterns of results (Loftus, 1996). Data for each test for each disability type and age, were first normalised relative to the data for the corresponding control group. For example, for the D8 group, the data for rhyme for each subject was normalised by obtaining the difference of that subject's rhyme score from the mean rhyme score for group C8, and then dividing this difference by the standard deviation of the C8 group for rhyme. Groups ND-PR8 and D8 were normalised relative to the C8 group and groups ND-PR10 and D10 were normalised relative to the C10 group. The sign was adjusted such that a negative effect size indicated below-normal performance. This procedure led to an age-appropriate 'effect size' in standard deviation units (analogous to a z-score) for each test for each child. Comparison of effect size magnitudes between tasks, gives an index of which tasks prove the most problematic for the children with dyslexia and the children with ND-PR, though it should be noted that the small numbers involved per group, limit the precision of the analyses. The effect sizes (averaged across the two ages) for the different tasks for ND-PR and dyslexia respectively are shown graphically in Figure 2(1). Performance at control level would have a zero effect size, an effect size of –1 indicates performance one standard deviation below the control level, and so on. As a rule of thumb, an effect size of –2 or worse is likely to indicate a significant deficit compared with control performance. If data is normally distributed, one would expect 15% of the population to be at least one standard deviation below the mean, and 2% to be at least 2 standard deviations below.

Figure 2(1). Effect Size Analyses



It may be seen that a clear dissociation is present, with ND-PR children performing less well than the dyslexic children in all tasks except for articulation rate. In fact, the differences were significant in memory span, segmentation and rhyme. In articulation rate, the difference was approaching significance ($p<.07$).

Individual Analyses

The group effect size analyses shown above suggest interesting differences at the group level between the groups with dyslexia and those with ND-PR – the ND-PR group generally perform worse than the dyslexic group in this area of phonology and memory span. A key question is the extent to which these differential group patterns apply also at the level of the individual. Consequently, a further set of individual analyses was undertaken, in which effect sizes (relative to the age-appropriate control group) were calculated for each child. The phonology and memory tests were aggregated into one group, with two analyses then reported on these data. Analysis 1 averages the effect size for the group and determines at-risk incidence per the group for each participant, with 'at-risk' defined first in terms of $p<.05$ one-tailed ($z<-1.28$) and also at the stricter criterion of $p<.01$ one-tailed ($z<-2.05$). Analysis 2 determines the at-risk incidence differently, by calculating whether the child is significantly at risk ($p<.05$) on at least half of the tests in the test-group. The results are presented in Table 2(4). For this analysis the D8 children from the current study (n=7) have been disaggregated from the children with dyslexia from the previous analyses.

Table 2(4). Percentage of individual at-risk scores for the phonological tests

Group		p-value	Phonological/Memory (tests aggregated into one group)
NDPR8	Analysis 1	p<.05	93.33
	Analysis 1	p<.01	80.00
	Analysis 2	=50%	100.00
NDPR10	Analysis 1	p<.05	92.86
	Analysis 1	p<.01	78.57
	Analysis 2	=50%	92.86
D8 (new)	Analysis 1	p<.05	33.33
	Analysis 1	p<.01	16.67
	Analysis 2	=50%	66.67
D8 (overall)	Analysis 1	p<.05	53.33
	Analysis 1	p<.01	33.33
	Analysis 2	=50%	66.67
D10	Analysis 1	p<.05	71.43
	Analysis 1	p<.01	42.86
	Analysis 2	=50%	100.00

It may be seen that for the two ND-PR groups, there is a very high percentage with significant deficit on the phonological tests. Taking the two ND-PR groups together, 27 out of 29 (93%) were significantly impaired on the phonological tests. Close to 100% of the ND-PR children were significantly impaired on at least half of the component tests making up the phonological test-group. Interestingly, it may be seen in both Table 2(2) and Table 2(4) that the NDPR8 group performed better than the NDPR10 group in the phonological tests, with the exception of the non-word repetition test, where the NDPR10 group slightly outperformed the NDPR8 group. Arguably this would go against predictions, since the NDPR10 group have a two year maturational advantage over the NDPR8 group. Possible reasons for this result will be discussed in the discussion section.

For the children with dyslexia a different pattern emerges. Taking them as a whole, only 53% showed a significant deficit for the phonological tests. The proportions of deficit on at least half the component tests were considerably higher, with the percentages for all the children with dyslexia being 82% for the phonological tests.

Discussion

Returning to the aims outlined at the beginning of this chapter, the main purpose of the study reported here was to provide fresh research from which to consider the Stanovich debate and the value of the traditional discrepancy based definition of dyslexia. It was suggested, that this would involve examining whether the extent of any differences in phonology between the ND-PR children and dyslexic children, were significant enough to suggest that they do indeed represent two distinct groups. The first hypothesis to be put forward, was that the ND-PR children would be worse than controls at all phonological performance. The second more tentative hypothesis, based on the work of Stanovich (1988a, 1988b, 1996) was that ND-PR children would be similar to the dyslexic children in this skill area. Before considering the results, it is important not to loose sight of the fact that this is only a small study with a small subject group being tested. Thus, if for no other reason, these results should be considered interesting and worthy of debate, but treated with appropriate caution, until replication of these findings using a bigger subject base can be undertaken.

A quick overview of the results, shows that the first hypothesis has been proven. However, the situation with regards to the second hypothesis is less clear. The controls, as expected, performed significantly better than the ND-PR children on all of the tasks. Of more interest, was the finding that both groups of ND-PR children performed significantly poorer than the dyslexic group on four out of five of the phonological tasks (excluding articulation rate). When compared to the dyslexics, the controls performed better on all tasks again and significantly better on four out of five tests (this time excluding memory span).

This finding, that the ND-PR children are more severely effected than the dyslexic children on four out of the five phonological tests, is interesting. In terms of Stanovich's phonological core variable difference theory, these findings do not appear to add complete support for this theory. Stanovich (1996) states; "...there exists no strong evidence that poor readers of high and low intelligence display marked differences in the fundamental cognitive and neurological processes that are the source of their reading difficulties." It seems that this study may provide some evidence that there *are* marked differences between poor readers of high and low intelligence. These 'fundamental cognitive processes' undoubtedly refer to phonological skills. It is established that phonological coding difficulties are the primary psychological processes underlying the reading problems in dyslexic children (Stanovich, 1996; Fawcett and Nicolson, 1995; Snowling, 1987).

These findings suggest that dyslexic children have difficulties in phonological skills and to this extent, they support Stanovich's theory (Stanovich 1988a). However, the results do not completely support the supposition that ND-PR children will show equal deficits, and that Stanovich's 'phonological core' is independent from general intelligence, a central argument in his theory. Stanovich's theories on the performance of poor readers with low and high IQs in the area of phonology, have developed and evolved over the past twenty years. Stanovich (1988) had, in fact, argued that dyslexics might show a more severe phonological deficit than ND-PR children. This hypothesis is definitely not supported by these findings, as ND-PR children are shown to be worse than dyslexics. By 1994, Stanovich and Siegel (1994) were in agreement that there are no critical differences between dyslexic and ND-PR children in the area of phonology.

The findings of this study, seem to add some support to the findings of Van Daal and Van der Leij (1999), who demonstrated that the 'garden-variety' subjects in their study performed less well than the dyslexic students on all phonological processing tasks, including many tasks similar to those used here. However, it is important to remember that this study is not directly comparable to that study, due to the different selection criteria, participant classification and task demands used in the study of Van Daal and Van der Leij (1999). This finding of significant differences between discrepant and non-discrepant poor readers in phonological tasks, is more in line with the findings of Badian (1993) who, using groups of similar age to the subjects here, (aged 9) found that there were significant differences between the two reading disabled groups on non-word reading. The dyslexics performed better than the ND-PR children on this task. These findings also seem in line with those of Aaron (1987, 1989). These studies were also outlined in chapter one, and as stated there, caution should be applied before drawing correlations from those studies to the study reported here, due to considerable differences in both the age of subjects and selection methods (subjects in Aaron's studies were either college-aged students (Aaron, 1987) or 'preadolescent' (Aaron, 1989), and not chronological or reading age matched.)

This finding that the ND-PR children are in fact more severely deficient than the dyslexic children in phonological performance, immediately raises theoretical questions as to the true validity of the phonological core deficit, and the functionality of IQ in the definition and diagnosis of dyslexia. The findings of more severe deficits in ND-PR children, suggest that in the area of phonology, maybe dyslexia *should* be considered a discrete category, and that there *is* use in retaining the IQ discrepancy based definition of dyslexia (Nicolson, 1996).

There appears to be an interesting anomaly on articulation rate, in that there is a dissociation from the other phonological and memory tasks, in which the ND-PR children performed significantly less well. For articulation rate, they performed noticeably (but not significantly) better. The reason for this is not clear, although it is tentatively proposed that the reason may be more to do with motor planning deficits in dyslexics than phonology. After all, articulation involves fine motor skill execution as well as phonology skills. It may be that dyslexics suffer difficulties in both these skills, and there is growing evidence to support this view (e.g. Denkla, 1985; Haslum, 1989). With articulation, there is in effect, a 'double whammy' effect for the dyslexic, due to problems in both phonology and motor skill execution. This finding would support the considerable amount of research which has found evidence of impaired articulatory skills in children with dyslexia (e.g. Snowling, 1981; Stanovich, 1988; Wolff *et al.,* 1984).

Another aim of this study, was to consider from an applied viewpoint, the validity of using phonological awareness tests in the differential diagnosis of ND-PR children from dyslexic children, and their potential for use in any early screening programme. These applied issues will be considered, after looking in more detail at comparisons between the ND-PR and the dyslexic children's performance.

Closer study of Table 2(2) reveals that the performance of the 10 year old ND-PR children was inferior to that of the 8 year old dyslexics in all the tasks, and usually significantly so. Considering that these latter two groups were matched for reading age, these findings suggest that ND-PR children's phonological awareness skills are more persistent and severe than may previously have been thought (Stanovich 1988a, Stanovich and Siegel, 1994). However, as discussed below, the 10 year old ND-PR were children performing at a lower level than the 8 year old ND-PR children on the majority of tasks, which seems strange considering that they have two year's more maturational experience. As will be discussed below, it seems that the particular severity of the 10 year old ND-PR group, may be in part an artefact of the different teaching environments the two groups experienced. So in this sense, the two groups should only be directly compared with caution, since they were receiving different teaching experiences. Cross-sectional findings should never be interpreted longitudinally except with extreme caution. It is appropriate at this stage in the discussion to emphasise that a clear improvement to this study would have been to add the necessary longitudinal aspect to the design, by following up the ND-PR group two years later when they were 10 years old. This would have allowed clearer interpretation of any maturational effects, increasing or decreasing lags and so on.

It has been a criticism of Bryant and Goswami's reading age match design (Bryant and Goswami, 1986) that it is inadequate for understanding the exact nature and depth of the dyslexia phonological deficit (Fawcett and Nicolson, 1992). However, the results presented here would tentatively suggest instead that it is the nature and depth of the ND-PR children's phonological deficit which may be inadequately understood.

It is unlikely that the finding of more severe deficit in the ND-PR group when compared to the dyslexics group, can be attributed to task complexity. Tasks used were made as low-level and simple as possible, so reducing possible performance differences as a result of differences in intelligence. There is some evidence to suggest that children of low IQ have slower speed of reaction than children with higher IQ levels (Vernon and Mori, 1992), and so it was important to reduce the likelihood of difficulties in these areas confounding interpretation of results. For example, the sound categorisation and phoneme deletion tests used early age of acquisition one syllable words, with the stimuli clearly discriminable, easily remembered and no particular pressures on the speed of the response being made. Nevertheless, results show that even under the most advantageous methods of presentation possible, the performance of the ND-PR children was generally even worse than that of the comparable chronological age matched and all importantly reading age matched dyslexic group.

It could be argued, that although the tasks were designed explicitly to minimise memory processing load, it is still the case that a certain amount of memory storage was necessary during the testing. It is virtually impossible to eliminate *all* memory load in any processing task. ND-PR children are often notoriously poor at keeping 'on task', and it is well established that attention abilities are related to short-term memory (STM) capacity (Larson *et al*, 1988; Felton *et al*, 1987). It could therefore be the case, that the deficits demonstrated by the ND-PR children in the phonological tasks, were in part a result of the greater effect of STM deficits in this group when compared to the dyslexics. This view would appear to be supported by the results in the memory span test, where the ND-PR group was significantly worse than the dyslexic children.

As stated at the beginning of this discussion, it was also the aim of this study to address the issue of whether phonological tests, assuming that ND-PR children and dyslexics *do* represent two discrete groups, differentially diagnose between dyslexic and ND-PR children. The fact that this important consideration seems to have been somewhat overlooked in the past, is evident from the wealth of phonological research comparing the performance of dyslexic versus control children, yet the relatively limited nature of research comparing dyslexics with ND-PR children. In terms of the diagnosis of dyslexia in children, simple rhyming has been the most favoured of the phonological tests used (e.g., Bradley and Bryant 1983). The findings of this study serve to show that not only the rhyming test, but also the phonological tests may be partially inadequate, if used in isolation, for providing a clear differential diagnosis of ND-PR children from dyslexics. This is because in all tests, with the exception of articulation rate, the ND-PR group actually performed significantly worse than the dyslexics.

It should be remembered, that this does not mean that such tests have no potential for identifying learning disabilities in very young children, i.e. pre-schoolers of age 4-5 years. Valid discrimination of ND-PR children from dyslexic children may be difficult at this age, but in many ways this is not the primary objective of screening at this age anyway. What is more important, is the identification of all children who are generally 'at risk', in order to begin remediation and support as soon as possible, before the negative effects of the reading disability expand and grow (cf. 'Matthew effects', Stanovich 1986). From the results of this study, it seems that this could well be achieved through using phonological tests alone, (Stuart, 1995) or as part of a larger more comprehensive battery (Nicolson and Fawcett, 1995a) which could eventually form an early pre-school screening tool (cf. The Dyslexia Early Screening Test, (DEST) Nicolson and Fawcett, 1996; The Psychological Corporation).

So the research documented here is not unequivocally stating that these phonological awareness tests do not hold *any* potential as a diagnostic tool for dyslexia. The phonological deficit in dyslexia is a well-established, accepted and respected fact, and certainly these tests discriminate clearly between dyslexics and controls. In this respect, they still hold value as a diagnostic tool, so long as the necessary caution is applied when they are used in isolation, and their limitations recognised. If used within a broader battery of diagnostic tests, where other areas of skill were also being investigated, then their contribution would undoubtedly be valuable (cf. The Dyslexia Early Screening Test, Nicolson and Fawcett, 1996; The Psychological Corporation).

It could be that these phonological awareness tests might hold greater potential as diagnostic tools with older dyslexics. As already mentioned, dyslexics tend to have enduring problems with phonology well into adolescence, despite showing "a heartening developmental trend" (Nicolson and Fawcett, 1994) in other skill areas. ND-PR children might be expected to have 'caught up' by adolescence in this area of basic skills, so long as the appropriate remedial help were given, and the potentially disastrous 'Matthew effects' kept to a minimum. However, more work looking at the performance of older ND-PR children, is needed to clarify this.

It is interesting to compare the general patterns of performance between the ND-PR8 and ND-PR10 groups themselves. However, before discussing these results it is appropriate to stress again that these were two different subject groups being compared cross-sectionally rather than longitudinally. Therefore, any hypotheses about maturational effects, are only tentatively proposed and with the appropriate caution. At this point it is also important to note, that with the exception of articulation rate, the control groups show no significant age effect across the tasks, despite differing on average by two and a half years of age. It seems unlikely that this is due to ceiling effects, with the possible exception of rhyme, and may be due to large individual performance differences within the groups (large standard deviations in many tasks), or unavoidable 'environmental' differences between the two control group's members (e.g. teaching experiences). It is thus difficult to see any (normal) development with age across the tasks.

Without such evidence, it is difficult to give valid comparative evaluations of maturational increases or lags.

Across the range of tests, the ND-PR8 were performing better than the ND-PR10 group, which might initially seem odd when considering their age differences despite the similarity of their IQ scores and reading ages (in fact the ND-PR10 group are slightly higher than the ND-PR8 group on both counts). Since the lower scores in the ND-PR10 group could not be offset by either depressed IQ or RA scores when compared to the ND-PR8 group, it seems that an explanation for this result could possibly be found in the 'Matthew effect' described earlier. Again it should be stressed, that such hypotheses based on a 'longitudinal and maturational' analysis of cross-sectional data, should be considered only tentatively, particularly since the controls showed no maturational increase in performance. The introduction of a follow-up study, would have enabled clearer conclusions on maturational performance to be drawn.

The 'Matthew effect' produces a cumulative vicious cycle of underachievement and motivational problems. It is easy to see how these issues can increasingly confound performance and make a clear diagnosis increasingly cloudy as learning disabled children get older. According to this argument, any 'Matthew effects' could be expected to be greater in the M10 group than the M8 group. It could well be that the phonological deficits are in fact 'secondary symptoms' arising as a consequence of some other primary problem in the ND-PR group. This is because secondary symptoms are known to be particularly sensitive to the 'Matthew effect', (Stanovich, 1996) and typically increase with age. In fact these secondary symptoms may be entirely due to the 'Matthew effect' in some cases. This can complicate and 'mask' the primary cause, making it a very challenging task to then try and unravel the underlying aetiology and consequences of the learning disability, (Rack, 1997). However, it is not the purpose of the research to investigate the underlying cause of poor reading, suffice to say that such a finding *could* suggest that the phonological deficits were in fact secondary symptoms of some other primary cause of difficulty in children with more generalised learning difficulties. However, before firm conclusions can be drawn on this issue, the two ND-PR groups would need to have been followed up at regular stages throughout their education. This was clearly beyond the remit of this study.

Another contributing factor to these results could be found in the nature of the pedagogy employed at the ND-PR8 school. Consultation with the teachers from the ND-PR8 school, revealed that all their children with learning difficulties received very specific and regular extra tuition in the area of literacy. This tuition took the form of a multi-sensory approach to handwriting, based on the programme developed by Kathleen Hicke, and adapted for use in the classroom by one of the teaching staff (Hicke, 1992). Although the ND-PR10 group also received extra tuition, this did not, as far as is known, take the form of any particular programme, be it multi-sensory or otherwise, tending rather to be added practice to support those exercises done in the classroom. The Kathleen Hicke programme stresses the importance of a multi-sensory approach to writing, insisting on the speaking of words and letters as they are written, and the use of cursive script. It is easy to see how strict adherence to such a sound-based programme would improve skills needed to perform the phonological tests in this study, and certainly our results appear to show that this is the case. The beneficial effects of a multi-sensory approach to learning are well documented (e.g. Bradley 1979; Hatcher, Hulme and Ellis 1994; Rosner, 1979). It seems that the introduction of this structured multi-sensory programme could have helped these 8 year old ND-PR children with their phonological awareness skills, to the extent that they are performing better than RA and IQ matched ND-PR 10 children. Early phonological awareness skills provide the foundations for the acquisition of higher levels of metaphonological skill (Hatcher, 1994; Adams, 1990). It would therefore not seem presumptuous to suggest that, with continued exposure to this multi-sensory training, the beneficial effects could soon be expected to affect the reading and spelling ages of these children as well. However, as stated above, further follow-up work in this NDPR8 group would be needed to discover whether there was a true persistence of these effects, or whether in fact performance grew worse with maturation.

What is without doubt, is the support this finding gives for early intervention for *all* learning disabled children, be they dyslexic or generally learning disabled, and the earlier the better. In fact, these particular results would make it seem even *more* important in the case of ND-PR children, that help is given as early as possible. Secondly, and more positively, the results with the 8 year olds suggest that although ND-PR children show persistent phonological problems when compared to those of dyslexics, these problems, despite what the depressed IQ scores may lead us to believe, can improve significantly when appropriate remedial teaching is used. The saying 'a stitch in time saves nine' would seem an appropriate rule of thumb here. In other words, the sooner appropriate help is given the better. It seems that IQ is of little importance in this regard. This opinion is supported by research such as that of Hurford *et al.,* (1994), which provides evidence that there is little difference in response to phonological training in high and low IQ readers (also Nicolson, 1996).

It can therefore be concluded, that when it comes to support, IQ is of comparative unimportance in defining dyslexia (as suggested by Stanovich, 1991). This view was outlined in chapter one. Reading disabled children should be supported irrespective of their diagnostic classification, and according to their individual strengths and weaknesses. It may well be that the appropriate initial support for a dyslexic child, would be similar to that required for a ND-PR child. From a phonological viewpoint, it is likely that systematic phonological training will be of benefit to both reading disabled groups irrespective of their IQ (Nicolson, 1996).

However, it should be mentioned that there are many other problems now recognised as symptomatic of dyslexia, beyond those residing in the phonological domain (Nicolson and Fawcett, 1993). This study has made explicit the need for more work looking at a whole range of basic skills in ND-PR children, and comparing these skills with those in diagnosed dyslexic children, in order to get a clearer picture of skill differences between these two groups. Furthermore, in terms of Stanovich's phonological core variable-difference model (1988a), it will be necessary to look at areas outside of the phonological domain, in order to add support or otherwise to the 'variable–difference' part of this theory. This states that ND-PR and dyslexic children will differ increasingly when tasks are less dependent on phonological processing. Such research will add valuable support to Stanovich or proponents of the discrepancy definition of dyslexia. It is difficult to fully judge the functionality of the IQ discrepancy definition until such further research work has been performed on the ND-PR group.

In terms of finding the actual *cause* of dyslexia as opposed to simply looking at symptoms, the same need is present to look beyond the area of phonology. Stanovich (1996) comments on the growing genetic and neuro-anatomical evidence for a distinct aetiology of dyslexia. However, he finds little correlation between this evidence and degree of reading-IQ discrepancy. For example, genetic linkage studies have provided evidence of a distinct aetiology in dyslexia, however Stanovich states that such studies have usually employed a discrepancy definition in defining the dyslexic subjects. The key question ,which according to Stanovich appears to be unanswered, is whether similar evidence of genetic linkage would be found if reading disability were defined without reference to discrepancy. At the time of writing, a cerebellar deficit had increasingly been causing interest as a possible cause of dyslexia. The arguments for this hypothesis seem particularly persuasive and seem to provide an all-encompassing explanation of the range of symptoms shown by dyslexic children (Nicolson, Fawcett and Dean, 1995). It would be interesting to study correlation with reading-IQ discrepancy in direct tests of cerebellar dysfunction, as well as a broader range of basic skill areas. Results from such a study, would impact strongly on theories of dyslexia, both old and new.

Summary and Conclusions

In summary, let us return to the main aims, predictions and hypotheses made at the start of this chapter. A primary aim behind this study was to provide fresh research with which to consider the Stanovich debate and the value of the traditional discrepancy based definition of dyslexia. It seems that this aim has been met.

It was predicted that at a general level, the ND-PR children would demonstrate deficits in phonological skills, this prediction was supported. In terms of the Stanovich debate, a second more tentative hypothesis was put forward that ND-PR children would show deficits in phonological skills across the board when compared to dyslexics. This would be in line with Stanovich's theory (1988a). This hypothesis was not supported, as the ND-PR children performed more poorly on all tests, accept the articulation test, throwing some doubt on Stanovich's theory that the phonological core is totally independent of intelligence.

It thus seems that IQ may be important in the definition of dyslexia, and is not, as Stanovich would suggest irrelevant, particularly in terms of differential diagnosis. In the area of phonology, dyslexia appears to represent a distinct group, which is separate from the ND-PR children.

However, these findings are only taken from a small sample size and should be treated with appropriate caution until further studies can be shown to replicate these findings using larger sample sizes. Until then, it would be pre-emptive to draw any firm conclusions on this IQ issue. Furthermore, until other skill areas have been researched in the ND-PR group, a full picture of performance in the ND-PR children cannot be obtained, and thus a true evaluation of Stanovich's phonological core variable-difference theory cannot be performed.

It was noted that the ND-PR10 group appeared to perform more poorly than the ND-PR8 group across the tasks (although not significantly so). 'Matthew effects' and different teaching experiences were tentatively put forward to account for this finding. However, the necessity of applying caution in interpreting cross-sectional findings longitudinally was stressed. To draw any firm conclusions with regards to maturational lags or increases, the ND-PR groups would need to have been followed up at regular stages throughout their education. Furthermore, support would be needed through the demonstration of an age effect in the control group (there was no age effect in the control group in this study). This proposed longitudinal investigation was beyond the remit of this study.

From an applied point of view, these findings could be taken as suggesting that tests of phonological deficits are not at their most effective, when used in isolation, to differentially diagnose dyslexic from ND-PR children. If these results were replicated with bigger sample sizes, it would seem that when testing at 8 years of age, there may be a tendency to catch too many children in the diagnostic net, when these phonological awareness tests be used as the basis of differential diagnosis for dyslexia. These tests have traditionally formed the backbone of differential diagnosis both at 8 years of age and older. It seems that this situation may need reconsideration.

It may be that any policy of differential educational classification and treatment for dyslexic children is poorly justified as long as the demonstration of a reading-IQ discrepancy remains its fundamental prerequisite. After all, it appears that the ND-PR children have more severe problems than the dyslexics, and it is likely that both groups would therefore benefit from a similar structured phonological intervention programme. It would be better policy instead to identify *all* children who are at risk, across the board, and as early as possible, and then begin structured intervention. This is a system advocated by an increasing number of researchers including Hurford (1994). Such a screening, diagnostic and intervention programme would ensure that *all* learning disabled children are given the special help, which is their basic right, without discrimination or privilege. This way the full potential of the *whole* of the reading disabled population is more likely to be fully realised.

The Way Forward

As already mentioned, this somewhat limited study serves only to highlight the need for research in this area to be continued and expanded. The results tentatively suggest that Stanovich's phonological core variable difference hypothesis may not account for the true extent of the ND-PR children's phonological deficits. However, before firm conclusions can be drawn on this, broader research is needed into wider skill areas of performance in ND-PR children and dyslexics. The following two chapters will meet this need, by presenting the findings in a wider range of performance areas. The implications of the findings for theories of dyslexia will be discussed.

It is important to make clear again at this point that the phonological data from this chapter will now be used in a complete and unaltered form within the broader database in chapter three. The justifications for writing up the phonological data as a separate chapter were given at the beginning of chapter two.

Part One

Chapter 3

Cerebellar Tests Differentiate Between Non Discrepant Poor Reading and Dyslexic Children

The Studies

Aim of Study

A large proportion of chapter one was given to addressing debates surrounding the traditional discrepancy definition of dyslexia and the importance of IQ in defining dyslexia. In particular, the value of distinguishing between poor readers who have a discrepancy between their reading and that predicted on the basis of their intelligence (thus satisfying the traditional criteria for dyslexia), and poor readers who do not have such a discrepancy (ND-PR children in our terminology) was discussed. Chapter two examined these issues within the area of phonology, by comparing the performance of ND-PR children and dyslexics on a range of phonological skills. Results were discussed in terms of their implications for the traditional discrepancy definition of dyslexia and the IQ debate. Results demonstrated the need to extend this research to compare performance between ND-PR and dyslexic groups in a much wider range of skills.

The argument for investigating a broader skill area will now be summarised. As was comprehensively discussed in chapter one, Stanovich (e.g. Stanovich 1988a) has asserted that careful analysis of differences between children with dyslexic and ND-PR children should provide insights (i) into the specific nature of the reading problems in dyslexia, and thence (ii) to the underlying cause of dyslexia.

While adopting Stanovich's general approach, the author considers that step (i) above (investigating reading) is not the only skill evaluation necessary for investigating the cause of dyslexia. Indeed researchers have identified a range of deficits in dyslexia in addition to those within the reading domain (see chapter one for a review of the literature). Moreover, it is argued that the performance differences between the two groups of poor readers in <u>any</u> domain may be diagnostic of the specific causes of dyslexia. Consequently the aim of this study is to administer a wide-ranging set of tests to dyslexic and ND-PR children, going well beyond the reading domain, and in particular tasks where different causal hypotheses lead to distinctive predictions.

In summary, a range of tasks assessing phonological awareness, motor skill, speed and 'static' cerebellar tests were administered to groups of ND-PR children, children with dyslexia and control children matched for chronological age. Analysis of the profile of scores for the different groups allowed decisive tests to be undertaken.

This chapter will report on a study undertaken to examine the performance of ND-PR children and dyslexic children in this broader range of skills. Skill selection has been influenced by predictions of dyslexic deficit taken from various causal theories for dyslexia. The general aim of this chapter will be to explore the discrepancy definition afresh in the light of recent research and new causal theories for dyslexia, (which were outlined in chapter one) most particularly the cerebellar deficit hypothesis (Nicolson *et al*, 1995), around which this chapter takes its direction. More specifically, the aim will be to present selected tests from the range developed for Nicolson and Fawcett (1994b) and Fawcett *et al.* (1996)[6] to groups of ND-PR and children with dyslexia. By examining the pattern of differences between groups (and compared with normally achieving controls) it should be possible to undertake a critical comparison of the different predictions based on the theories of dyslexia and thus obtain support or otherwise for the cerebellar deficit hypothesis. Furthermore, additional information will be provided on the value of these tests in discriminating between dyslexics and ND-PR children.

Predictions and Hypotheses

An assessment of the predictions for the different theories is given in Table 3(1). Only specific predictions are made. Skill predictions in certain skill areas are often impossible since the theory does not cover that skill area; for example, the phonological theory claims a deficit in phonological processing, but holds no implication for the areas of motor, speed or cerebeller simply because the theory neglects these areas. In these cases, no prediction is made and a '?' symbol is used to denote 'not predicted by theory'. Predictions for the different theories for 'dyslexia vs. same age controls' are derived directly from the causal models, (no indirect predictions are made) but in order to derive predictions for 'dyslexia vs. same-age ND-PR' it is necessary to make indirect predictions about the ND-PR performance based on research in this area, since it is impossible to make clear predictions from the causal theories. As discussed in chapter one, the literature on ND-PR is relatively slight and somewhat variable and studies comparing dyslexic with ND-PR subjects even more uncommon. However, tentative proposals are possible to make in key areas of ND-PR performance based on the

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[6] Again, as stated at the beginning of chapter two, the published data (Nicolson and Fawcett (1994b) and Fawcett *et al.* (1996)) should not be directly compared to the data reported in this study due to slight differences in the subjects used, resulting in some differences in results. (The above studies only included 10 year old ND-PR children and thus included some of the oldest from the current ND-

relevant studies which were critically reviewed in chapter one. In line with the predictions given in chapter two, it is predicted that ND-PR children should have phonological problems compared to normal children, (Stanovich, 1988a, 1988b; Stanovich, 1996; Siegel, 1992; Stanovich and Siegel, 1994) a conclusion receiving some additional support from the results of chapter two. When comparing dyslexics with same-age ND-PR children, it is difficult to predict performance, since evidence is inconsistent. For example Aaron, (1997) and Van Daal and Van der Leij, (1999); found evidence that ND-PR children are worse than dyslexics, yet Badian (1994, 1996, 1997) and Yap and Van der Leij (1994a) suggest dyslexics are more severe. However, Stanovich (Stanovich, 1988a; Stanovich and Siegel, 1994; Stanovich, 1996) suggests that these two groups will show *no* significant differences between their phonological skills, and this forms the basis of his influential phonological core variable-difference theory. His theory was supported by various researchers (Ellis *et al.,* 1996; Siegel, 1989, 1992). It is thus tentatively proposed that the two groups will show similar phonological performance. For speed of information processing and motor skills, there is even less literature to refer to in making predictions. It is tentatively proposed that ND-PR children will have difficulties in speed of processing (see Vernon and Mori, 1992, outlined in chapter one), and mild motor difficulties (Ghaziuddin and Butler, 1998, outlined in chapter one) when compared to control children. The ND-PR data collected in the present study obviate the need to make more detailed ND-PR predictions.

The specific predictions made in Table 3(1) will now be spelled out in full. (These predictions are partly based on the thorough descriptions given for each of the causal theories in chapter one):

Core phonological deficit

Unsurprisingly, it is predicted that the dyslexics will suffer particularly severe deficits in phonological skills compared to controls. A wealth of evidence now

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PR 8 group (9.2.years of age) in this ND-PR 10 group in order to increase group size. This obviously resulted in slight differences in results).

exists from around the world to support this view, (e.g. Snowling, 1981; Stanovich, 1988a; Bradley and Bryant, 1983; Lundberg and Hoien, 1989; Olson, Wise and Rack, 1989). With regards to ND-PR children, the situation is less clear. However, Stanovich's phonological core variable-difference theory suggests no significant difference between the two groups (Stanovich, 1988a). As this was an influential theory, supported by various researchers, this will be the prediction used here; dyslexics and ND-PR children will show no significant differences on phonological tasks.

Core speed deficit

Motor skill execution always involves some aspect of speed. Many motor skill tests are performed under timed conditions and dyslexic children appear to show more marked deficits under paced or timed conditions rather than more relaxed conditions (e.g. Ellis and Miles, 1981; Seymour, 1986). So it can be expected that dyslexics, if suffering from a core deficit in processing speed and fluency, will show a deficit relative to control children in this skill. The speed theory applies to the processing of all sensory information (kinesthetic, visual, auditory) at speed. When considered in conjunction with visual and auditory deficit theories, the speed theory would also predict particular difficulties for the dyslexic in processing rapid visual and rapid auditory information, since these skills involve particularly 'finely tuned' speeded motor control.

ND-PR children have traditionally been recognised to show general motor problems or slowness, sometimes being referred to as 'clumsy', or 'slow learners'. As already mentioned (and explained more fully in chapter one), the findings of Vernon and Mori, (1992) suggest, albeit somewhat tentatively, that ND-PR children will reveal reduced speed of processing, whilst the study by Ghaziuddin and Butler(1998) allows tentative suggestions that they may also show mild motor difficulties. It is therefore predicted within this theory that the two groups will show equal motor difficulties, but that the dyslexics will still be worse in the more 'finely controlled' areas of speeded visual and auditory performance, since they show a more severe impairment in these areas.

Core visual deficit

The core visual deficit theory would clearly predict that dyslexics will show deficits in processing rapidly presented visual stimuli. Lovegrove *et al.,* (1980) have identified problem in rapid visual processing, showing that dyslexics are less sensitive to visual flicker (however as explained in chapter one stimuli size will influence this speed deficit). The core visual deficit makes no clear or direct predictions for ND-PR children and there appears to be no research literature comparing ND-PR and dyslexic children on this skill. It is tentatively suggested that the dyslexics will be worse in speeded visual tasks than the ND-PR children since this is the 'core' area affected.

Core auditory deficit

Tallal and her colleagues have demonstrated that dyslexics have considerable difficulty in the processing of rapidly changing sounds (e.g. Tallal, 1977). She concluded that dyslexics have a difficulty in 'temporal processing'. Thus it can easily be predicted that dyslexics will be deficient at speeded auditory tests. The core auditory deficit makes no clear or direct predictions for ND-PR children and there appears to be no research literature comparing ND-PR and dyslexic children on this skill. It is tentatively suggested that the dyslexics will be worse in speeded auditory tasks than the ND-PR children, since this is the 'core' area affected.

Double core deficit

This deficit produces a 'double whammy' effect in the dyslexic, with deficits being predicted in both speed of processing and phonological skills. Dyslexics who suffer this double effect will be severely effected in their ability to read effectively (Wolf and Bowers, 1999). It can be predicted that dyslexics will perform more poorly than controls, particularly in areas involving phonology and speeded visual and auditory tests, but also in motor tests. ND-PR children may well perform better than the dyslexics in phonological skills due to complications caused by this 'double whammy' effect, and also in the finely controlled visual and auditory tests. In the motor tests it is suggested that the two groups may perform about equally, due to the mild motor difficulties in the ND-PR group.

Cerebeller deficit

This theory (Fawcett, Nicolson and Dean, 1996) predicts that dyslexics will show deficits across the board in all tests, due to the central influence of the cerebellum in both language and motor skill execution. This theory does not however hold direct predictions for the ND-PR children. If anything, assuming that ND-PR children do not suffer this specific cerebellar deficit, and when considering predictions solely from within this theory, then it could (somewhat indirectly) be predicted that they would actually perform better than the dyslexics in all areas effected by cerebellum deficit. However, for the sake of clarity in this discussion, no direct predictions will be drawn, except for a prediction that the ND-PR group will perform better than the dyslexics on direct tests of cerebellar deficit.

Table 3(1) Outline Predictions for the Different Theories for Dyslexia on the Range of Tasks Administered

Predictions for the ND-PR group are based on the assumption that they will show some phonological, motor and speed deficits compared with same-age normally achieving children. (In cases where no prediction is made, a '?' symbol will be used to denote 'not predicted by theory').

	Core Phonological Deficit	Core Speed Deficit	Core Visual Deficit	Core Auditory Deficit	Double-Core Deficit	Core Cerebellar Deficit
Dys. vs Control						
Phonological	- -	?	?	?	- -	-
Motor	?	-	?	?	-	-
Speed (visual)	?	- -	-	?	- -	-
Speed (auditory)	?	- -	?	- -	- -	-
Cerebellar	?	?	?	?	?	- -
Dys vs ND-PR						
Phonological	=	?	?	?	-	?
Motor	?	=	?	?	=	?
Speed (visual)	?	-	-	?	-	?
Speed (auditory)	?	-	?	-	-	?
Cerebellar	?	?	?	?	?	-
Key	- -	very significantly impaired				
	-	significantly impaired				
	=	roughly equivalent				
	+	significantly better				
	?	not predicted by theory				

Design

As already discussed, a stringent test of the adequacy of any theory of dyslexia is whether a similar pattern also arises for non-discrepant poor readers (ND-PR). In designing the study, a range of tests was selected, from which differential predictions were made for the different theories. Many of the form of analyses used here are as those used in chapter two where the phonological data was reported. Those phonological results have been incorporated, unchanged and in their entirety, into the study here as an invaluable part of the 'bigger picture'.

Method

Participants

The participants used in this study are exactly the same subjects as those used in the chapter two studies (see chapter two - page 74). It is therefore unnecessary to repeat all the participant details. The 'experimenters' referred to here, were mainly the same as those referred to in chapter 2, namely the author and three psychology final year undergraduate students who had all been trained by the author in administration and scoring of the tests. This ensured standardisation in testing and scoring between testers. However, for training, administration and scoring of the cerebellar tests, the primary author from the Fawcett *et al* (1996) cerebellar study, (who developed and adapted the cerebellar tests for objective testing procedures), also assisted, in order to help maximise standardisation across different experimenters. It should be noted that as in chapter two, the D8 (n=9) group, D10 and C8 and C10 groups were taken for comparative purposes from work previously reported in Fawcett *et al* (1996) and Fawcett and Nicolson (1995a), with data collection and analysis for these groups thus performed by the first author in that earlier study and not by the author of this thesis. (These two publications also included data from the ND-PR 10 group collected and analysed by the author of this thesis and reported in this chapter and chapter two.

However, caution should be applied before directly comparing results from the work reported here with that in these published works due to the slight differences in group membership mentioned earlier). The dyslexic and control children reported previously were not retested for this study, because they no longer matched for age. It should also be noted that many of the additional dyslexic and control children had undertaken the cerebellar tests at a later time than the other tests. Only those children who had taken a given test at the appropriate time for inclusion within the appropriate age group were included in the analyses. Consequently the numbers and constituents of the control and dyslexic groups vary between the different tests. Data from these children was reanalysed by the author for this study.

As in the chapter two study, because of the known comorbidity of dyslexia with ADHD (Fletcher, Shaywitz and Shaywitz, 1999; Pennington *et al.,* 1993; Shaywitz *et al.*, 1995), and because of the suggestion that cerebellar problems in dyslexia may be due to an overlap with ADHD (Denkla *et al.,* 1985; Swimmer *et al.*, 1999) all ND-PR children had been screened for ADHD by the author at initial assessment using the DSM-IIIR scales (American Psychiatric Association, 1987). As previously mentioned, the subjects used in this study are the same as those used in the chapter 2 study. Therefore, psychometric details (including a breakdown by gender, chronological age, reading age, and IQ mean and range) are the same as those given in Table 2(1) (page 80, chapter 2) (and should be referred to at this stage.

Experimental Tasks

A total of seventeen tests were selected from those employed in Nicolson and Fawcett (1994a) and Fawcett *et al.* (1996). The selected tests covered the three major domains known to be affected in dyslexia, namely phonological processing (and verbal memory), rapid processing and 'cerebellar' tests. Clinical evidence of the range of deficits evident following gross damage to the cerebellum, has been described in detail in classic texts by Holmes (1917, 1939) and Dow and

Moruzzi (1958). Standard symptoms of cerebellar dysfunction are dystonia (problems with muscle tone) and ataxia (disturbance in posture, gait, or movements of the extremities). However, it should be noted that tests of this type typically involve a range of brain structures, and in recognition of this these tests are therefore described as 'cerebellar'. The 'cerebellar' tests were based directly on those described by Dow and Moruzzi, because standardised motor skill batteries do not capture the range of deficits associated with cerebellar abnormalities. The Dow and Moruzzi tests are clinically based and are somewhat dependent on clinical judgement. Consequently, considerable care was taken in the previous experiments to adapt the tests for experimental use, and wherever possible, equipment was designed to facilitate fully objective procedures for each test. In previous research (Fawcett, Nicolson and Dean, 1996), children with dyslexia had been found to perform particularly poorly on these tasks. Based on the standard symptoms of cerebellar dysfunction described above, the 'cerebellar' tests were divided into tests for dystonia and ataxia. These tests are referred to more neutrally as 'static' and 'dynamic' cerebellar tests. It should of course be stressed again that none of the tests in this battery can be simply ascribed to a single brain structure, and that abnormalities in a range of structures might potentially cause problems in any one of the tests. It is only by analysis of the pattern of difficulties on a range of tests that a potentially abnormal brain structure may be targeted. The test labels should therefore be seen as descriptive rather than as diagnostic. The tests used were as follows:

Static Cerebellar Tests

Hypotonia (reduced muscle tone)

Limb Shake – the wobbliness of each hand when shaken. Subjects were asked to sit down, with their elbows resting on the chair arm and forearms held up vertically. The experimenter rolled up the child's sleeves and removed any watch, bracelet etc., and then took hold of each forearm and held it vertically so that the child's hands were about level with his/her shoulders. The subject was asked to let his/her hands "flop" as much as possible, like a puppet or rag doll. The experimenter shook both hands slightly to make sure that they were limp. The experimenter then grasped each hand at the wrist and shook it lightly from side to side. Degree of movement was assessed on a scale from 1 (little movement) to 3 (large, floppy movement). Mean score for both hands therefore ranged between 1 and 3.

Muscle Tone – the ability to resist a push on the forearm. Subjects adopted the same position as that used for the 'limb shake' test. However, this time the experimenter told them that she was going to push gently against the child's muscles, and the child's task would be to try and resist. The experimenter pushed against the resistance of the right and left arm, and finally both arms together. Each response was scored for the ability to resist the experimenter's push, on a scale from 0 (no resistance) to 2, (firm resistance) generating a maximum score of 6.

Arm Displacement – the amount of disturbance caused by a gentle tap on the outstretched hands. Subjects were blindfolded and asked to stand with their feet together, with their arms held out in front of their body. The experimenter tapped each hand gently in turn, for a series of three taps to each hand. Subjects were scored for the amount of movement in the limb, on a three point scale from 0 (virtually no movement) to 2 (large movement), generating a maximum score of 12 for the six taps.

Maintenance of posture

Postural Stability – the amount of disturbance from an upright stance when pushed gently in the back. Subjects were asked to stand upright, looking straight ahead, arms by their sides, and were then blindfolded by the experimenter. The experimenter then stood behind the child, and explained that she was going to push him/her gently in the back, and that he/she should try to stand still. The experimenter then pushed gently in the small of the child's back, with her index finger at a 2 Kg pressure (the experimenter "calibrated" herself prior to the session by practising pushing at 2 Kg on a set of kitchen scales). Pressure was applied for 1.5 seconds and then released. The degree of sway was assessed and recorded for each trial (on a scale of 0 for good performance, 1 for a small movement and 2 for stepping forwards or overbalancing). The test was performed six times, three times with the children's arms at their side, followed by three pushes with their arms straight out in front, which is slightly more difficult. Children with signs of cerebellar deficit would be predicted to generate a high score. The maximum score for this test was 12. Scoring was checked by video taping a sample of children and getting independent ratings by a trained observer who was unaware of the subject's group, with an inter-rates reliability of 0.94.

Dynamic Cerebellar Tests

Complex Movements

Finger to thumb – speed of completing a series of ten alternating oppositions of finger and thumb. Subjects placed the index finger and thumb of one hand onto the index finger and thumb of the other hand. Keeping the top thumb and finger together, they were shown how to separate the lower finger and thumb, and turn one hand clockwise and the other counterclockwise, so that the finger and thumb touched again. This sequence of movements was repeated and practiced until the subject was able to complete the movement fluently five times. The child was then told to perform the successive opposition ten times, as fast as possible. The score noted was the time taken.

Toe tapping – the time to tap the toes on the floor ten times. After an initial practice, subjects were asked to tap their foot as fast as they could on a tin lid. The sounds were recorded on an Apple Macintosh computer, and the speed of tapping assessed accurately using standard waveform analysis software. The score was the time taken to execute ten taps.

Motor Skill

Pegs – the time taken to transfer a row of ten pegs from one row of a pegboard to the next row. The pegboard used for this task was a commercially available child's pegboard consisting of ten rows of ten holes. It resembled that used by Annett (1985) but was somewhat smaller (6x6 inches). At the start of the test, the top row of the board was filled with pegs by the experimenter. The child was instructed to move the pegs with the preferred hand as quickly as possible, jumping over the empty row into the third row of holes, while holding the board steady with the non-preferred hand. The child was instructed to pick up only one peg at a time, and the trial was restarted if he/she picked up more. If a peg fell off the board, the child was told to ignore it and carry on. A stopwatch was used to record the time to complete each row, from touching the first peg to releasing the last. At the end of the row, the child was given verbal feedback and encouragement. He/she was then instructed to move the pegs a further two rows down the board, and so on. Testing continued until five rows had been completed. The mean time for the five trials was the dependent variable.

Beads – the number of beads successfully threaded in 30 seconds. A basket containing eighteen round wooden beads (4 cm in diameter with a hole of approximately 0.5 cm) was placed on the table in front of the child, and a string (85 cm long and 3 mm in diameter) laid on the table. The child was instructed to take the beads from the basket one at a time, and thread them on the string as quickly as possible. The number threaded in one minute (from touching the first bead) was the dependent variable.

With the exception of pegs and beads, these tests are clinically based and somewhat dependent on clinical judgement. Consequently, considerable care was taken to adapt the tests for experimental use, and wherever possible, equipment was designed to facilitate fully objective procedures for each test. The only tests defying full objectivity were muscle tone, arm displacement and limb shake. The remaining tests were explicitly designed for objective interpretation. Toe-tap was entirely computer-based, and wherever possible tests were scored by subjects blind to subject's group, with inter-rate reliability checks performed.

Tests of Phonological Processing and Verbal Memory

Since the phonological data from the study in chapter two has been incorporated unchanged into this study, it is unnecessary to replicate all the procedural details for this section. A summary is provided here with the reader referred back to Chapter two – page 82 for full procedural details.

Memory Span – the mean for words of 1, 2 and 3 syllables (measured as the longest list of words that the subject can recall in the correct order).

Segmentation – the Test of Auditory Analysis and Segmentation (Rosner and Simon, 1971), in which the subject has to be able to break down a word into its phonemes (starting with easier tasks such as "say 'cowboy' without the 'cow'", and moving to more difficult ones such as "say 'smack' without the '/m/'").

Rhyme – rhyme and alliteration / sound categorisation ability (a simplified version of the tests used in Bradley & Bryant, 1983) for phonemes at the beginning and end of words, with representative questions being "does cat rhyme with map?" and "do map and man start with the same sound?"

Nonword Repetition – the Gathercole & Baddeley (1990) test in which the subject has to repeat a nonsense word immediately after hearing it, with stimuli taken from a set of 30 ranging from 1 to 3 syllables (including 'fot' and 'skiticult').

Articulation Time –time to articulate a single word (one fifth of the time for 5 repetitions). Mean of time for 'bus', 'monkey and 'butterfly'.

Tests of Processing Speed

Word Flash – score on reading a series of words, where each word is presented for a shorter duration (starting with 27 one syllable words – 'dog' for 1 second, down to 'bat' for 16 ms, followed by 11 two syllable words – 'water' for 500 ms down to 'leather' for 100 ms). This experiment was carried out on an Apple Macintosh compute, using Apple's Hypercard multimedia environment. The stimuli used were 27 one syllable words and 11 two syllable words selected from the Thorndike-Lorge (1944) list of AA frequency words. The experimenter recorded the number of words correctly read from a possible maximum score of 38.

The Simple Auditory Reaction Time (SRT) and Selective Choice Reaction Time (SCRT) tasks were controlled by a BBC micro computer, using the sound generator to create the tones. The low tone used in both experiments was 350 Hz, and the high tone used in the SCRT experiment was 1400 Hz, a two octave difference. In each task, subjects held a micro-switched button in their preferred hand. Results were recorded automatically, and mean and median latencies, latency variance and overall accuracy were calculated with a further programme.

Simple Auditory Reaction Time (SRT) – median response latency for pressing a button on hearing a 350 Hz tone. The experiment was computer-controlled, and 100 stimuli were presented. The interstimulus interval was varied randomly with a mean of 1.5 seconds and a range of 0.5 to 2.5 seconds. Subjects were instructed to 'press the button as soon as you can when you hear the tone, trying not to press the button too soon'. In the event of an anticipation, the stimulus was delayed for a further 1.5 to 2.5 seconds in order to discourage such over-fast responding. Following a familiarisation and ten practice trials, one hundred trials were administered, grouped into sets of ten to allow a rest between each set of trials. Results were automatically recorded, with the score being the median response latency.

Selective Auditory Choice Reaction Time (SCRT) – median response latency for pressing a button on hearing a 350 Hz tone in the context of an equally probable 1400 Hz tone for which no response must be made. The experiment was again computer-controlled, and one hundred stimuli were presented. The interstimulus interval was again varied randomly with a mean of 1.5 seconds and range of 0.5 to 2.5 seconds in order to discourage an anticipation strategy. Subjects were instructed to "press the button as soon as you can when you hear the low tone. Do nothing if you hear the high tone. Try to do it as fast as you can without making many mistakes". In the event of an anticipation, the stimulus was delayed for a further 1.5 to 2.5 seconds. No time was recorded for any responses erroneously made to a high tone. Following a familiarisation and 10 practice trials, one hundred trials were administered, pseudo-randomly assigned so that half were high and half were low tones. Trials were again grouped into sets of ten to allow for a rest between each set of trials. Median response latencies were recorded automatically.

Visual Search – the time taken to locate a distinctive spotty dog on each of several crowded pages in a child's puzzle book. The puzzle book was taken from the 'Spotty Dog' range of puzzle books published by Orchard books. It was explained to the child prior to starting the test that the aim was for him/her to locate the spotty dog in the picture as quickly as he/she could and to point to the dog as soon as it was located. In order to ensure that the child was familiar with and would recognise the dog image, he/she was shown a separate picture of the spotty dog before beginning the test. The child was then shown the first page in the puzzle book and asked to point out the spotty dog from amongst the crowded characters on the page. This process was repeated five times using consecutive pages in the puzzle book. The scenes on each page were similar, depicting common family scenes such as 'a trip to the sea-side'. The position of the spotty dog varied on each page. Each child was shown the same five pictures from the puzzle book. The time was recorded for each trial by stopwatch, starting from the moment the child was shown the page until the moment the dog was correctly pointed out. If the child incorrectly pointed, the child would be told to try again and timing was continued. The mean time for the five trials was the dependent variable.

Procedure

Children were tested individually. A detailed protocol for each test had been developed previously and was adhered to as closely as possible. The experimenters (see participant section for full details of the experimenters) were 'blind' to participant status in all tests until after the data was collected (since psychologist's reports and IQ testing were only accessed or performed at the completion of testing and then only by the author). Generalised reassurance ('Well done', 'that was a bit tricky' etc) was given throughout, but no comparative comments were made on the quality of each child's performance. Testing was completed over three sessions in the course of one month, with each session taking around thirty minutes overall. Variability in test application and scoring between experimenters was reduced as much as possible by ensuring all experimenters received thorough training from the author in administration and scoring of all tests prior to beginning the study. This included observing the experimenters administering tests and double marking score sheets as part of training. Tests were administered in random order within the sessions, to avoid the possibility of order effects. Owing to the unexpected malfunction of the computer software necessary to facilitate testing in the allotted time span, the ND-PR10 group did not undertake two tests (word flash and selective CRT). Furthermore the static cerebellar tests had not been administered to the original 8 year old group with dyslexia. Consequently all static test for the D8 group derive from the D8-new group.

Results

The means and standard deviations for the battery of tests are presented in Table 3(2). It may be seen that both the children with ND-PR and those with dyslexia performed less well than the age-matched controls on the majority of the tests.

Table 3(2). Summary of Mean Scores for each Group on each Test

(Standard deviations are given in parentheses).

Task	ND-PR8	ND-PR10	D8	D10	C8	C10
Postural Stability	3.73	4.00	7.43	9.00	2.25	1.00
(max 12)	(2.79)	(3.61)	(3.82)	(3.13)	(2.26)	(2.12)
Limb Shake	1.87	1.83	2.00	2.63	1.64	1.12
(max 3)	(0.64)	(0.72)	(0.71)	(0.52)	(0.39)	(0.44)
Arm Displacement	1.80	1.39	3.00	3.83	1.57	0.50
(max 12)	(1.37)	(1.12)	(1.53)	(0.58)	(0.79)	(0.93)
Muscle Tone	2.20	0.77	3.14	3.92	1.43	0.38
(max 6)	(2.43)	(1.64)	(2.34)	(2.71)	(0.79)	(0.74)
Finger to thumb (s)	30.2	23.3	25.2	17.6	7.65	9.27
	(14.0)	(9.80)	(13.4)	(12.3)	(1.46)	(2.96)
Toe tapping (s)	3.89	3.90	3.54	2.82	2.44	2.04
	(0.74)	(0.79)	(0.44)	(0.71)	(0.41)	(0.34)
Beads (s)	8.07	9.78	9.29	10.0	12.0	12.4
	(2.40)	(1.56)	(2.56)	(1.87)	(1.23)	(3.85)
Pegs (s)	14.8	13.2	14.1	11.9	10.5	10.3
	(3.80)	(1.64)	(2.82)	(4.14)	(1.29)	(1.50)
Segmentation**	5.73	4.44	7.29	9.40	10.9	12.8
(max 13)	(2.43)	(2.70)	(3.86)	(2.30)	(1.20)	(0.50)
Rhyme**	26.1	24.4	27.2	28.6	29.5	29.8
(max 20)	(2.30)	(2.56)	(2.15)	(1.14)	(1.04)	(0.45)
Memory Span**	3.17	2.93	3,81	4.32	4.24	4.52
	(0.68)	(0.55)	(0.81)	(0.27)	(0.49)	(0.64)
Nonword Repetition	60.30	71.70	73.70	72.10	83.30	86.40
(%)**	(15.90)	(7.30)	(15.80)	(5.48)	(5.45)	(7.89)
Articulation Time**	0.51	0.44	0.56	0.45	0.46	0.36
(s)	(0.12)	(0.08)	(0.13)	(0.08)	(0.05)	(0.05)
Word Flash*	22.50	•	30.10	33.2 0	36.50	37.60
(max 38)	(4.02)		(6.67)	(5.81)	(0.97)	(0.89)
Visual Search* (s)	23.10	•	21.20	15.00	13.50	8.92
	(8.78)		(12.0)	(8.32)	(6.48)	(3.11)
Simple Reaction	52.10	54.40	48.30	34.10	40.00	33.40
Time (cs)	(26.50)	(16.40)	(12.20)	(6.61)	(7.55)	(5.80)
Selective CRT (cs)	88.90	73.56	71.00	65.90	60.60	45.70
	(27.00)	(13.90)	(32.00)	(22.50)	(17.00)	(7.70)

*The group ND-PR10 did not undertake these tests

**(Mean scores for the phonological tests (segmentation, rhyme, memory span, nonword repetition, articulation time) are taken from Table 2(2) on page 88 of Chapter two).

A series of two factor analyses of variance was undertaken separately for each task, with the factors being disability type (ND-PR, dyslexia or control) and age (2 levels). A summary of these analyses is presented in Table 3(3). For all but two of the 17 tasks (toe tap and articulation time) the effect of age was not significant. In only one task (arm displacement) was there a significant interaction between age and disability type. By contrast, there was a significant effect of disability type in all 17 tasks[5]. When the 'type' main effect was significant, Fisher protected LDS a posteriori analyses were undertaken to establish which of the three disability types differed significantly, and the findings are given in Table 3(3). Compared with the ND-PR group, the controls performed significantly better on all 17 tasks save the four static cerebellar tasks and articulation rate. Compared with the groups with dyslexia, the controls performed significantly better on all four static cerebellar tests, 4 out of 5 phonological tests (excluding memory span), on one speed test (word flash) and on three dynamic cerebellar tests (finger to thumb, toe tap and beads). The groups with dyslexia performed significantly better than the groups with ND-PR on 4 out of 5 phonological tests (excluding articulation rate, for which the groups with dyslexia were near-significantly slower ($p<.07$) than those with ND-PR); on two speed tests (word flash and simple reaction), and one of the dynamic cerebellar tests (toe tapping). The groups with ND-PR performed significantly better than the groups with dyslexia on all four static cerebellar tasks.

[5] It is common practice in the case of multiple analysis of variance to apply the Bonferroni correction to take account of the possibility of the odd significant difference arising by chance. This is not appropriate in the present study given that every analysis led to a significant difference.

Table 3(3). Inferential statistics for Chronological Age and Disability Type

Groups included were ND-PR8, D8, C8 and ND-PR10, D10, C10.

Task	Disability	Age	Interaction
Postural Stability	F(2,61)=22.7, p<.0001 C>D, ND-PR>D	F(1,61)=0.03, NS	F(2,61)=1.2. NS
Limb Shake	F(2,54)=8.8, p<.001 C>D, ND-PR>D	F(1,54)=0.1, NS	F(2,54)=3.0, NS
Arm Displacement	F(2,56)=22.0, p<.0001 C>D, ND-PR>D	F(1,56)=0.5, NS	F(2,56)=3.2, p<.05
Muscle Tone	F(2,56)=7.9, p<.001 C>D, ND-PR>D	F(1,56)=1.1, NS	F(2,56)=1.6, NS
Finger to thumb	F(2,54)=14.2, p<.0001 C>ND-PR, C>D	F(1,54)=2.2, NS	F(2,54)=1.0, NS
Toe tapping	F(2,54)=13.6, p<.0001 C>D, C>ND-PR, D>ND-PR	F(1,54)=4.3, p<.05	F(2,54)=1.6, NS
Beads	F(2,44)=8.8 p<.001 C>ND-PR, C>D	F(1,44)=1.9, NS	F(2,44)=0.5, NS
Pegs	F(2,44)=6.8, p<.01 C>ND-PR	F(1,44)=2.2 NS	F(2,44)=0.9 NS
Segmentation**	F(2,44)=29.2, p<.0001 C>D, C>ND-PR, D>ND-PR	F(1,44)=1.4, NS	F(2,44)=2.5, NS
Rhyme**	F(2,49)=22.6, p<.0001 C>D, C>ND-PR, D>ND-PR	F(1,49)=0.01, NS	F(2,49)=2.9, NS
Memory Span**	F(2,51)=24.6, p<.0001 C>ND-PR, D>ND-PR	F(1,51)=1.2, NS	F(2,51)=1.9, NS
Nonword Repetition**	F(2,60)=12.7, p<.0001 C>D, C>ND-PR	F(1,60)=2.0, NS	F(2,60)=1.8, NS
Articulation Time**	F(2,61)=4.6, p<.05 C>D	F(1,61)=13.6, p<.001	F(2,61)=0.3, NS
Word Flash*	F(2,37)=33.9, p<.0001 C>ND-PR, C>D, D>ND-PR	F(1,37)=1.6, NS	F(1,37)=0.3, NS
Visual Search*	F(2,36)=3.9, p<.05 C>ND-PR	F(1,36)=2.5, NS	F(1,36)=0.6, NS
Simple Reaction Time	F(2,60)=5.9, p<.01 C>ND-PR	F(1,60)=2.0, NS	F(2,60)=1.5, NS
Selective CRT	F(2,50)=7.0, p<.01 C>ND-PR	F(1,50)=3.5, NS	F(1,42)=0.3, NS

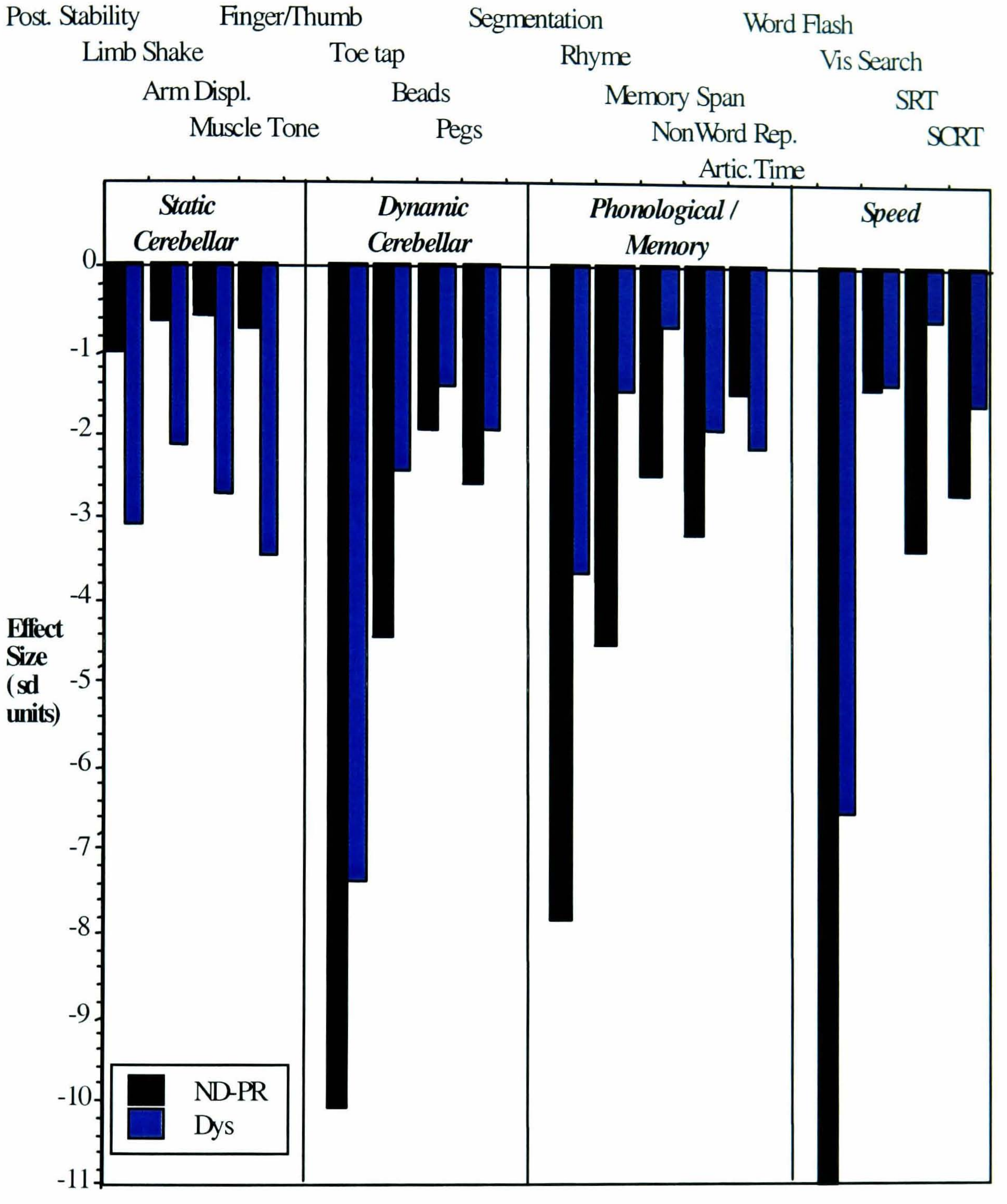
*The group ND-PR10 is not included in these analyses

**(Data for the phonological tests (segmentation, rhyme, memory span, nonword repetition, articulation time) are taken from Table 2(3) on page 89 of Chapter two).

Effect Size Analyses

Effect size analyses (e.g., Cohen, 1969) were used in order to facilitate comparison between the tests and to elucidate the patterns of results (Loftus, 1996). Data for each test for each disability type and age were first normalised relative to the data for the corresponding control group. For example, for the D8 group the data for postural stability for each subject were normalised by obtaining the difference of that subject's postural stability score from the mean postural stability score for group C8, and then dividing this difference by the standard deviation of the C8 group for postural stability. Groups ND-PR8 and D8 were normalised relative to C8 and groups ND-PR10 and D10 were normalised relative to C10. The sign was adjusted such that a negative effect size indicated below-normal performance. This procedure led to an age-appropriate 'effect size' in standard deviation units (analogous to a z-score) for each test for each child. Comparison of effect size magnitudes between tasks gives an index of which tasks prove the most problematic for the children with dyslexia and the children with ND-PR, though it should be noted that the small numbers involved per group limit the precision of the analyses. The effect sizes (averaged across the two ages) for the different tasks for ND-PR and dyslexia respectively are shown graphically in Figure 3(1). Performance at control level would have a zero effect size, an effect size of –1 indicates performance one standard deviation of the controls below the control level, and so on. An effect size of –2 or worse is considered likely to indicate a significant deficit compared with control performance. If data is normally distributed one would expect 15% of the population to be at least one standard deviation below the mean, and 2% to be at least 2 standard deviations below.

Figure 3(1). Effect Size Analyses



(Effect size analyses for the phonological tests (segmentation, rhyme, memory span, nonword repetition, articulation time) are taken from Figure 2(1) on page 89 of Chapter two).

It may be seen that a clear dissociation is present. For the majority of tasks, the children with ND-PR did somewhat worse than the children with dyslexia (significantly in 5/17 cases, as indicated by the first column of Table 3(3)). This is true in the main for the phonological tasks (with ND-PR significantly worse than D (Dyslexia) in memory span, segmentation and rhyme), for the speed of processing tasks (with ND-PR significantly worse than D for the Word Flash task) and the dynamic cerebellar tasks (with ND-PR significantly worse than D for toe tapping). By contrast, for the static cerebellar tasks the children with ND-PR performed at close to normal and significantly better than the children with dyslexia on all four tasks. This is a particularly interesting and notable finding. It might seem that the cerebellar theory would predict worse performance in the dyslexic children in both static and dynamic tests when compared to the ND-PR children. Interestingly however, closer consideration of the cerebellar theory reveals that in fact this theory may well predict this dissociation, due to lesions in specific sections of the lateral posterior cerebellum. (See the discussion section for further exploration of this issue).

Individual Analyses

The above analyses indicate a pattern of dissociation in specific tests at the group level between the groups with dyslexia and those with ND-PR; the groups with dyslexia tend to do relatively well on SRT and memory span, and relatively badly on the static cerebellar tests. The groups with ND-PR do badly on the speed tests and well on the static cerebellar tests. A key question is the extent to which these differential group patterns apply also at the level of the individual. Consequently a further set of individual analyses was undertaken, in which effect sizes (relative to the age-appropriate control group) were calculated for each child. Tests were also aggregated into four groups: static cerebellar, dynamic cerebellar, phonological and speed, as described above. Two analyses are reported on these data. Analysis 1 averages the effect sizes per test-group (e.g. static cerebellar) and determines at-risk incidence per test-group for each participant, with 'at-risk' defined first in terms of $p<.05$ one-tailed ($z<-1.28$) and also at the stricter criterion of $p<.01$ one-tailed ($z<-2.05$). Analysis 2 determines the at-risk incidence differently by calculating whether the child is significantly at risk ($p<.05$) on at least half of the tests in the test-group. The results are presented in Table 3(4). For this analysis the D8 children from the current study (n=7) have been disaggregated from the children with dyslexia from our previous analyses since it was already known that the individuals in the latter group showed difficulties with static cerebellar tests.

Table 3(4). Percentage of individual at-risk scores for the four types of test.

Group		p-value	Static cerebellar	Dynamic Cerebellar	Phono-logical/ Memory (tests aggregated into one group)**	Speed
NDPR8	Analysis 1	p<.05	26.67	100.00	93.33	100.00
	Analysis 1	p<.01	13.33	93.33	80.00	100.00
	Analysis 2	=50%	33.33	100.00	100.00	100.00
NDPR10	Analysis 1	p<.05	30.77	100.00	92.86	92.86
	Analysis 1	p<.01	7.69	86.67	78.57	78.57
	Analysis 2	=50%	46.15	100.00	92.86	92.86
D8 (new)	Analysis 1	p<.05	42.86	100.00	33.33	66.67
	Analysis 1	p<.01	42.86	0.00	16.67	66.67
	Analysis 2	=50%	85.71	100.00	66.67	66.67
D8 (overall)	Analysis 1	p<.05	42.86*	71.43	53.33	53.33
	Analysis 1	p<.01	42.86	57.14	33.33	53.33
	Analysis 2	=50%	85.71	100.00	66.67	66.67
D10	Analysis 1	p<.05	100.00	58.82	71.43	57.14
	Analysis 1	p<.01	91.67	35.29	42.86	42.86
	Analysis 2	=50%	100.00	64.71	100.00	57.14

*The original D8 group did not undertake the static cerebellar test and so these scores derive only from the D8 (new) group.

**The phonological/memory data is taken from chapter 2.

It may be seen that for the two groups with ND-PR, there is a very high percentage of significant deficit on dynamic cerebellar, phonological and speed tests. Taking the two groups with ND-PR together, 30 out of 30 (100%) were significantly ($p<.05$) impaired on dynamic cerebellar tests, with 27 out of 29 (93%) significantly impaired on phonological tests and 28 out of 29 (97%) significantly impaired on speed tests. By contrast, only 8 out of 28 (29%) were impaired ($p<.05$) on static cerebellar tests. Only 3 out of 28 (10%) were highly significantly impaired ($p<.01$) on the static cerebellar tests. Close to 100% of the children with ND-PR were significantly impaired on at least half of the component tests making up the dynamic, phonological and speed test-groups, with only 40% for the static cerebellar test-group.

For the children with dyslexia a different pattern emerges. Taking them as a whole, the greatest proportion (79%) show a significant ($p<.05$) deficit on the static cerebellar tests, with 74%, 53% and 53% deficits for the dynamic cerebellar, phonological and speed tests, respectively. The picture is slightly less clear for the new D8 group, for whom only 3 out of 7 (43%) showed a significant deficit on the static cerebellar tests. The proportions of deficit on at least half the component tests were considerably higher, with the percentages for all the children with dyslexia being 95%, 71%, 82% and 50% for the static cerebellar, dynamic cerebellar, phonological and speed tests, respectively. For the 'new D8' group all but one child [KN] (86%) was impaired on at least half the static cerebellar tests. Accessing the psychometric records of the children with dyslexia indicated that KN had a Dyslexic/ND-PR diagnosis, as did one of the other 6 children with dyslexia. Inspection of the individual data for the new D8 group indicated that KN had an IQ of 90 – right on the borderline between ND-PR and dyslexia. Her performance showed a profile very typical of ND-PR (effect sizes 0.08, -1.63, -2.68 and -2.37 for the static cerebellar, dynamic cerebellar, phonological and speed tests, respectively).

By contrast, the groups with ND-PR, showed no particular pattern of association with static cerebellar test performance. Six children with ND-PR showed impairment on more than half the static cerebellar tests. Their IQs were 68, 71, 71, 72, 81 and 82 respectively. Accessing the psychometric records of the children involved indicated that four of the six had been given a diagnosis of ND-PR/Dyslexia, and had a distinctly 'spiky' profile of scores on the WISC-R sub-tests unlike those who had been given an unequivocal ND-PR diagnosis. Only 5 of the remaining 24 children with ND-PR had been given a mixed diagnosis, with the remainder having a definite ND-PR diagnosis.

Clearly, therefore, there was something about this group of children with ND-PR with poor static cerebellar performance that suggested 'dyslexia' as well as ND-PR. It seems likely, therefore, that the groups with ND-PR are not homogeneous, and that some of the children with ND-PR show signs both of mild learning difficulties and of dyslexia. It would be appropriate to undertake a separate analysis for the groups with signs of both ND-PR and dyslexia, but there are not enough children in each group to make this approach viable.

A striking feature reported by the experimenter (FM) from her notes is that the children with dyslexia showed a qualitative difference from the children with ND-PR on the static tasks. Naturally, the experimenter was 'blind' to subject status during testing, but her informal observations of the children suggested that children with dyslexia show a characteristic pattern of low muscle tone or hypotonia, ('floppyness') evident from their posture as well as their limb control. The brightest child with dyslexia (IQ 130) tried to shift his balance backwards to compensate in the postural stability task, leading him to stumble backwards and thus generate a higher score and lower performance than the ND-PR children. By contrast, most of the children with ND-PR showed a much more controlled and solid stance, resulting in better scores. Similarly, the toe tap of the ND-PR group was typically steady and measured, resulting in a poor overall time and thus worse performance than the dyslexics, leading to the speculation that these ND-PR children were unable to initiate the requisite motor program quickly. The children with dyslexia, by contrast, were more variable in their output, producing an initial flurry of toe-taps interspersed with pauses, which resulted in an overall lower time score.

Correlations with 'Discrepancy'

It should be noted that the above analyses have defined groups merely in terms of the IQ cut-off of 90, and have not investigated directly the *magnitude* of the discrepancy between reading age and reading age expected on the basis of IQ. In order to investigate directly which of the tests do appear to be associated with the concept of 'discrepancy', a further analysis was undertaken in which the correlation between each task and 'discrepancy', defined here as difference between reading age and 'mental age' (i.e., chronological age * IQ /100) was calculated[6]. The correlations are shown in Table 3(5), with the sign adjusted such that a positive correlation indicates that better performance goes with greater discrepancy. It may be seen that the correlations are in the main positive, reflecting the fact that the children with ND-PR (who have low discrepancy) perform worse than the children with dyslexia (who have high discrepancy). The two highest correlations are for simple reaction time (0.594) and word flash (0.542). Other tests with high correlations (accounting for at least 20% of the variance) are toe tap (0.419) and memory span (0.473). By contrast, five tasks have a negative correlation; namely the four static cerebellar tests together with articulation rate, with the most negative correlation being arm displacement (-0.449).

[6] It should be noted that this simplistic expectancy formula ignores the dilution of the expected discrepancy caused by the imperfect correlation between IQ and reading, together with issues such as measurement error. The regression discrepancy model (Reynolds, 1984), which explicitly accounts for these factors, suffers from the drawback that estimated population correlations between ability and reading need to be entered. It is not clear that this is an appropriate procedure for either of the special populations under study here.

Table 3(5). Correlations with IQ/Reading Age Discrepancy.

The analysis is limited to participants in the groups with ND-PR and the groups with dyslexia. The correlations have had the sign adjusted such that a positive correlation indicates that better performance goes with greater discrepancy (between reading age and 'mental age'). The partial correlations involve the elimination of the effect of chronological age.

Task	Full: ND-PR and Dys		Partial: ND-PR and Dys
Postural Stability	-0.218		-0.211
Limb Shake	-0.244		-0.266
Arm Displacement	-0.449	**	-0.442
Muscle Tone	-0.179		-0.277
Finger to thumb	0.335	*	0.318
Toe tapping	0.419	**	0.395
Beads	0.513	**	0.094
Pegs	0.261		0.071
Segmentation	0.361	*	0.354
Rhyme	0.295		0.314
Memory Span	0.473	**	0.208
Nonword Repetition	0.400	**	0.339
Articulation Time	0.115		0.243
Word Flash	0.542	*	0.180
Visual Search	0.227		0.143
Simple Reaction Time	0.594	***	0.564
Selective CRT	0.252		0.055

Legend: *** p<.001, ** p<.01, *p<.05.

There is a clear positive correlation between discrepancy and chronological age ($r=0.291$, $p<.05$), indicating that discrepancy increases with age. This 'Matthew effect' is a factor highlighted by a number of researchers following Stanovich (1986). Consequently further partial correlation analyses were undertaken eliminating chronological age. It may be seen (Table 3(5), column 3) that this reduces somewhat the correlations for the speed tests and the dynamic cerebellar tests (as expected) but has relatively slight effect on the static cerebellar tests and the phonological tests.

Overall, therefore, the correlational analyses further support the between-group and individual analyses in identifying a dissociation between the ND-PR and groups with dyslexia between the static cerebellar tests and the other tests. This dissociation obtains even when the effects of age are partialed out.

Discussion

The major objective of the studies was to compare the performance of children with ND-PR, against children with dyslexia and normally achieving controls of the same age. Through this comparison it was hoped that two aims would be met: Firstly, to assess the strength of the cerebellar deficit hypothesis (Fawcett *et al.,* 1996) through critical comparisons of predictions against other causal theories; and secondly to provide additional research data from which to assess the validity of Stanovich's phonological core variable-difference theory (Stanovich, 1988a).

The phonological data from chapter two was incorporated into the broad skill base assessed in this chapter. Here it assists in giving a more complete picture of ND-PR children's skill performance allowing further discussion of the Stanovich debate as well as providing clues as to the underlying aetiology of dyslexia.

The performance of the groups with ND-PR was significantly poorer than that of the groups with dyslexia on 2 (of 4) speed tests, 4 (of 5) phonological tests and 1 (of 4) 'dynamic' cerebellar tests, with worse mean performance on all the remainder tests (save articulation rate and 'static' cerebellar). By contrast, a dissociation was observed in that the performance of the groups with ND-PR on all 4 of the 'static' tasks was significantly better than that of the groups with dyslexia.

It remains to consider the theoretical significance of these results. In the introduction we outlined the predictions of five major classes of causal theory for dyslexia (see Table 3(1)). The results (averaged across the different tasks in each category) are presented in Table 3(6).

Predictions and outcomes

Predictions and outcomes for the ND-PR group will now be summarised: For the phonological core theory it was predicted that dyslexics and ND-PR children would show similar phonological difficulties. As discussed fully in chapter two this prediction was not supported, with dyslexics performing significantly better in 4 out of 5 phonological tests. For the core speed theory, it was predicted that the dyslexics would perform equally on motor tasks, but more poorly than the ND-PR group on speeded auditory and visual tasks. The motor performance was correctly predicted, but the ND-PR group did perform more poorly than the dyslexics, just not significantly so. The ND-PR children performed less well than the dyslexics on all the visual and auditory speeded tasks, significantly so on two of them. For the core visual theory, the only prediction made was that the dyslexics would be weaker than the ND-PR group in the speeded visual task. This prediction was unsupported with the dyslexics performing significantly better than the ND-PR children in this task. For the core auditory theory, the only prediction made was that the dyslexics would be worse than the ND-PR group in the speeded auditory task. This prediction was also unsupported with the dyslexics performing significantly better than the ND-PR children in this task. For the double core theory, it was predicted that the ND-PR group would be better than the dyslexics on phonological skills, but in fact the significant difference was in the opposite direction, with dyslexics better than the ND-PR children. For motor skills, equal performance was predicted, the ND-PR group was actually worse on this skill, but not significantly so. In speeded visual and auditory task it was predicted that the ND-PR group would do better than the dyslexics. This prediction was not supported, with the dyslexics doing better than the ND-PR group on these tasks. The cerebellar deficit predicted that the ND-PR group would do better on cerebellar tasks than the dyslexics. This single prediction was supported.

It is acknowledged that justice is not done to the the visual deficit hypothesis by this analysis, insofar as we were not able to use tasks for which one might predict a specific deficit for the children with dyslexia. Furthermore, if we consider only the results for the children with dyslexia compared with the chronological age controls, only the double deficit and cerebellar deficit hypotheses correctly predict more than 2 of the 5 results. The cerebellar deficit hypothesis is excellent in prediction, in that the only failure is an unfulfilled one of deficit on auditory processing speed. However, since this hypothesis has been proposed to cover other theories, it is not too surprising that it corroborated by the majority of findings in the skill areas.

Table 3(6) Comparison of Results with the Predictions of the Different Theories

	Core Phono-logical Deficit	Core Speed Deficit	Core Visual Deficit	Core Audit-ory Deficit	Double-Core Deficit	Core Cere-bellar Deficit
Dys. Vs Control						
Phono-logical	- - ++	?	?	?	- - ++	- ++
Motor	?	- ++	?	?	- ++	- ++
Speed (visual)	?	- - ++	- ++	?	- - ++	- ++
Speed (auditory)	?	- - -	?	-- -	- - -	- -
Cere-bellar	?	?	?	?	?	- - ++
Dys vs ND-PR						
Phon-ological	= -	?	?	?	- - -	?
Motor	?	= +	?	?	= +	?
Speed (visual)	?	- - -	- - -	?	- - -	?
Speed (auditory)	?	- - -	?	- - -	- - -	?
Cere-bellar	?	?	?	?	?	- ++

(Note: Refer to page 142 for Key to Table)

Key

Predictions:		**Outcomes:**	
- -	very significantly impaired	++	significant difference *correctly predicted*
-	significantly impaired	+	no significant difference *correctly predicted*
=	roughly equivalent	-	no significant difference predicted, significant difference obtained, or vice versa
+	significantly better	- -	significant difference predicted, significant difference in opposite direction obtained
?	not predicted by theory		

Turning to the predicted differences for the ND-PR groups, many of these predictions were impossible to draw since the theories were specific to dyslexia. Where tentative predictions *were* given, it is again evident that most of the theories are very inaccurate in these predictions. However, although only one prediction was made for the cerebellar deficit hypothesis, this one prediction was well supported. All the other theories made at least one clearly unconfirmed prediction (predicting significantly better when the results indicate significantly worse, or vice versa). It seems therefore that the data provides the strongest support for the cerebellar deficit hypothesis compared with the other extant hypotheses.

Static/dynamic test dissociation

Moving on to the pattern of results, and in particular the dissociation obtained between static and dynamic cerebellar tests, it seems that the cerebellar deficit may best be able to predict this dissociation (see below). The dissociation between static and dynamic cerebellar tests for these groups may indicate that the abnormalities for the children with dyslexia lie within the lateral parts of the posterior lobe (the neocerebellum). The neocerebellum is a phylogenetically more recent part of the cerebellum and is much larger in humans than in animals. Lesions in this area are often associated (Holmes, 1922) with dysmetria (inaccurate limb movement) and hypotonia (low muscle tone). As mentioned in the result section, the experimenter noted that the dyslexics seemed noticeable 'floppy' in these tasks compared to the ND-PR children, which could be a result of poor muscle tone. These findings are particularly interesting in view of recent findings of abnormal activation patterns in the ipsilateral posterior lobe of adults with dyslexia both when executing a previously over learned motor sequence task, and when learning a new motor sequence (Nicolson *et al.*, 1999). However, this work is in its infancy and needs further research performed before any firm conclusions can be drawn. More particularly there is a need for the work on autopsied dyslexic brains to focus now on the cerebellum, to see if predicted lesions can be found.

Differentiating between dyslexic and ND-PR groups

In terms of differentiating between dyslexic and ND-PR children, it seems that the cerebellar tests may hold valuable potential for differentiating between these two groups due to the dissociation found. Static cerebeller tests appear to differentiate between ND-PR and dyslexic children rather nicely and in dynamic cerebellar tests there is a general tendency for the ND-PR to be slower than the dyslexics. Children with ND-PR showed problems equivalent or significantly greater than children with dyslexia on dynamic speeded tests, on phonological and verbal memory tests, and on speed of processing tests.

An important methodological issue relates to the static cerebellar tests. These tests were derived from the classic clinical cerebellar tests (Dow and Moruzzi, 1958), but it must be noted that such tests are notoriously difficult to operationalise and quantify. Furthermore, unlike most of the other tests, these tests involve direct interaction with the experimenter, and may therefore raise issues of socialisation and personal space. In parallel research, as part of an extensive screening battery (Fawcett and Nicolson, 1996), a more objective and more easily quantified index of balance has been developed, using a specially designed 'postural stability' tester that allows the experimenter to push the small of the participant's back with a metered force. Furthermore, in recent research (Nicolson *et al.*, 1999) a brain imaging study was undertaken on young adults with dyslexia in whom it had previously been established that evidence of problems on the static cerebellar tests were present. These participants showed, on average, only 10% of normal cerebellar activation on a motor sequence learning task known normally to involve strong cerebellar activity. Consequently (in addition to the strong clinical evidence) there is evidence that these static tests do provide a valid index of cerebellar abnormality. Nonetheless, development of objective and simple static tests remains an important research priority.

Implications for Stanovich

Chapter two discussed in detail the implications of the phonological performance for the Stanovich phonological core variable-difference theory (Stanovich 1988a) and the traditional discrepancy-based definition of dyslexia. The key points will be outlined again before the implications of the wider findings from this study for Stanovich and the discrepancy definition are discussed.

The study reported in chapter two revealed that the ND-PR children were surprisingly poor at phonological performance when compared to the dyslexic group. Stanovich's (1988a) theory predicted that there would be no significant differences between these two groups on phonological performance and he used this conclusion to support his view that the discrepancy-based definition of dyslexia should be abandoned. The findings of more severe phonological performance in ND-PR children appeared to throw doubt on this theory for this age group at least, and to support the notion that dyslexia may form a distinct group, and that there *is* a role for IQ-based definitions of dyslexia. However, it was stressed in chapter two that these findings should be viewed with caution due to the limitations of the study, including the narrow skill area investigated. It was acknowledged that it was important to explore the performance of these two groups in a much wider range of skills before clearer conclusions could be reached as to the validity of the phonological core variable-difference hypothesis. This study examines the performance of matched dyslexic and ND-PR groups in a wide range of basic skills, phonology (data taken from study one), speed of processing, motor and cerebellar skills.

Central to the phonological core variable-difference model is the understanding that although dyslexics and ND-PR children will show similar deficits on phonological skill, they will differ increasingly when tasks are less dependent on phonological processing and allow for the use of higher level processes such as strategy use, and many kinds of knowledge (reflected by their difference in general IQ). By demonstrating significant differences between dyslexics and ND-PR groups in phonological performance, chapter two threw some doubt on the 'phonological core' aspect of Stanovich's theory. It is now interesting to look at the broader range of skills represented here to see if more support is given to the 'variable-difference' part of the theory.

When basing predictions on each of the causal theories, each prediction stated that the dyslexics would perform more poorly than the ND-PR group in the skill directly utilising that 'core' effect (with the exception of the phonology skills). For example for the core auditory theory, it was predicted that the dyslexics would perform more poorly in speeded auditory tasks than the ND-PR group, no other predictions were considered possible for these groups from this theory. With the exception of the static cerebellar tests and articulation, it seems that the dyslexic group was out-performing the ND-PR group in not only phonology, but many of the other skill areas. It seems that the ND-PR group demonstrated significant difficulties across the board, difficulties which were more severe than that demonstrated by the dyslexic group in the majority of tests, even in the core area of phonology. If we now consider the phonological core variable-difference model in the light of these findings, it seems that a possible explanation for these results could be found. According to this theory, one could expect the performance of the dyslexics to improve relative to the ND-PR group the less dependent the task was on phonology. Broadly speaking, this appears to be the case here, with the dyslexics showing superior performance to the ND-PR group in the majority of non-phonological tests. For example, the dyslexics were better in the SRT and SCRT tasks, visual search, and most of the dynamic cerebellar tests (significantly so in toe tap). A possible explanation for this latter finding in terms of the cerebellar deficit hypothesis is postulated elsewhere in this discussion. However, in terms of Stanovich's phonological core variable-difference theory, the dynamic cerebellar results seem to demonstrate this argument most clearly. As well as evaluating cerebellar ability, these tasks more simply assess fine motor co-ordination skills. Pure motor co-ordination skills, have nothing to do with phonological processing ability and would be vulnerable to strategy use and the effects of experience-based knowledge i.e. practice. In this regard, fine motor co-ordination skills would be predicted to represent an area of comparative strength for the dyslexic when compared to the ND-PR group. It seems that partial support for the theory of Stanovich is found here.

Finally it is interesting to look afresh at the apparently anomalous finding of comparative dyslexic weakness in articulation skills. It was suggested in chapter two that maybe this effect could be attributed to difficulties in motor skill execution in the dyslexics. We are now in a better position to assess the validity of this hypothesis due to the motor skill tasks included in the battery of tests presented here. It was hypothesised that the dyslexic difficulty in articulation was due to a 'double whammy' effect of combined difficulties in not only phonology but also fine motor skills in the dyslexic. The results presented here do confirm that the dyslexics have difficulties in both these skill areas when compared to controls, however, the ND-PR group appear to have more severe difficulties in both areas. Thus it could reasonably be expected that the ND-PR group would demonstrate a more severe deficit than the dyslexics in this task as well. Why this is not the case is unclear and warrants further investigation.

Study limitations

Despite the apparent support for the cerebellar hypothesis obtained here, and the cautious support for the phonological core variable-difference model, it is important to stress the limitations of the current study. First, and foremost, the numbers of participants are not large, and further studies would need to be undertaken in order to address the issue of generality of the results. Secondly, although a wide range of tests was undertaken, direct tests of magnocellular deficit (sensory deficit hypothesis) were not undertaken. Such tests would include for example tests of sensitivity to visual flicker (Lovegrove, 1993) and tone identification (with short inter stimulus intervals) tasks (Tallal, 1980), both tests which have been found to cause difficulties for dyslexics by the above researchers (see chapter one). Tests of speeded visual and auditory skill were included, but it is probable that performance in these was more influenced by general speed of processing deficits than a specific magnocellular deficit. So it is possible that some (or even all) of the children with dyslexia would show magnocellular deficit (visual or auditory). It seems certain, however, that at least for these participants with dyslexia, there were cerebellar deficits over and above any hypothetical sensory deficit. Thirdly, there was not a complete dissociation between children with ND-PR i.e. some, albeit a few, of the ND-PR demonstrated significant weaknesses in the static cerebellar tests (29%, see results section). A possible explanation for this was discussed above, but it could be that some children with ND-PR also have cerebellar deficit. It is accepted that dyslexia occurs along a general continuum of reading difficulties with ill-defined boundaries existing between dyslexic and ND-PR children (Stanovich, 1988a). Moreover, the incidence of comorbidity in the present study was 20% – well above the prevalence of dyslexia in the general population. Finally, the study does not allow for direct analysis of maturation effects in these skills. Although two different age groups are used in this study, caution should always be applied before drawing longitudinal conclusions from cross-sectional data. Without follow-up data, it is difficult to draw any valid conclusions on maturational increase or decrease in these skills. To detect differences in normal development in the groups, it is necessary to compare against control performance. However, it appears that there was no effect of age even for the control group. It is consequently difficult to draw conclusions about normal development, and thus impossible to draw conclusions about development in the two reading disabled groups. It is unclear why these results are as they are. It could be that closer analysis of group membership in the control group will reveal unavoidable 'environmental' differences between the two control groups (e.g. in teaching experiences) which could account in part for these results. It may also be due to large individual performance differences within the groups (large standard deviations in many tasks). It seems unlikely that ceiling effects are responsible for this result in the control group (with the possible exception of rhyme and word flash). The important point is however, that by introducing a longitudinal aspect to this study through follow-up work, an important additional dimension would have been added to this study, allowing clearer investigation of maturational effects.

Summary and Conclusions

The study reported here was intended to establish whether poor readers with IQ discrepancy (children with dyslexia) can be distinguished from poor readers with no discrepancy (ND-PR), using a range of skill tests known to be impaired in children with dyslexia. A dissociation was established between the groups with dyslexia and those with ND-PR. The children with ND-PR performed at near-normal levels on 'static cerebellar' tests and were significantly better than children with dyslexia on these tests. By contrast, children with ND-PR showed problems equivalent or significantly greater than children with dyslexia on dynamic speeded tests, on phonological and verbal memory tests, and on speed of processing tests. The findings provide evidence of the generality of phonological and speed deficits in both ND-PR and dyslexia, compared with the specificity to dyslexics of static 'cerebellar' tests of muscle tone and stability.

The results cast doubt on the ability of the sensory processing hypotheses to account for the range of problems in dyslexia, and suggest rather that sensory processing deficits, where they occur, are more likely to be sub-types than core deficits for dyslexia. The results are also inconsistent with the 'pure' phonological deficit hypothesis and the 'pure' double-deficit hypothesis. It should be stressed, however, that the results do not disconfirm the above two hypotheses – indeed, in comparing children with dyslexia and age-matched normally achieving children, clear deficits were obtained in both phonological and speed tasks. Rather, the pattern of results indicates, first, that these hypotheses in themselves are not sufficient to account for the pattern of difficulties found in dyslexia, and, second, that the 'core' deficits predicted by these theories are not sufficient to distinguish between children with dyslexia and children with ND-PR. By contrast, the cerebellar deficit account, which predicts phonological and speed deficits in addition to cerebellar deficits for the children with dyslexia, gave an excellent account of the results obtained and did correctly predict the dissociation between the children with dyslexia and the children with ND-PR on cerebellar tasks.

In terms of Stanovich, these results have produced mixed findings. Although at the age of 8-10 years, phonological results do not appear to support the view held by Stanovich and others that phonological skills are independent of intelligence, more support is found for the wider non-phonological parameters of his theory. Taken together, these conflicting findings should be considered evidence of the need to continue with the discrepancy debate using a wide age range of subjects since the debate is still far from resolved.

In conclusion, from a theoretical viewpoint, this study does however suggest that there are differences between the phenotypes of children with dyslexia and children with more generalised learning difficulties. Although we may well expect some overlap between the two groups, these results suggest that the majority of children with dyslexia suffer from a mild 'cerebellar' abnormality in static tests, whereas the majority of children with ND-PR do not. Naturally enough, these results need to be replicated with further groups of children with dyslexia and groups with ND-PR. In particular it would be highly informative to perform a follow-up study on the two groups of children in any replication work. This would allow the maturational effects in phonological and cerebellar skill area to be more directly studied. If the cerebellar theory *was* to be used as a predictive tool, one would expect that deficits in cerebellar and phonological skills would be persistent in the dyslexic children, with comparative improvements in phonological skills in the ND-PR children. Such a pattern of results would add real weight to the supposition that the phonological deficit theory may be subsumed within a broader causal framework of cerebellar impairment. Nevertheless, the dissociation between cerebellar tests and phonological tests demonstrated in these groups provide further strong support for the cerebellar deficit hypothesis (Nicolson, Fawcett & Dean, 1996).

The Way Forward

The work reported in this chapter and chapter two have provided valuable new research information for discussion in areas of causality, early identification and differential diagnosis. It is now appropriate to consider the implications of these findings for support and intervention. Without a structured support and intervention system, the gains made through early, accurate identification will soon become obsolete. More specifically, with the demonstration of performance deficits in cerebellar influenced skills areas, theoretically based consideration can now be given to a remedial program which focuses on training in these skill areas. The second part of this thesis from chapter four to six will now report on the development and evaluation of a remedial program for learning disabled children based on the theory of cerebellar involvement in dyslexia.

Overview of Part One

The previous four chapters have been concerned with evaluating and discussing the comparative performance of non discrepant readers (ND-PR) against the dyslexic in a wide range of primitive skill areas. The research programme investigated the performance of matched dyslexic and control subjects on a battery of theoretically chosen tests of primitive skills, including diagnostic cerebellar deficit tasks. The ND-PR added a valuable third dimension to an already established database of performance data on dyslexic and control subjects. One of the central thrusts of the research was to create the first solid corpus of comparative performance data for ND-PR children to set against that of matched dyslexic children. There was a clear need for comprehensive studies of this kind, since research to date was comparatively scarce and variable.

The two groups of children were tested first in phonological skills and then in a broader range of primitive skill areas, including cerebellar deficit skills. As expected from the literature on this subject, both the dyslexic and ND-PR groups revealed difficulties in phonological skills. However, the ND-PR children were considerably worse than the dyslexics in their phonological ability, suggesting that in terms of differential diagnosis, the phonological tests, when applied in isolation, may be somewhat inadequate at specifically diagnosing dyslexia at age 8-10 years. The finding cast some doubt on the established theories of Stanovich and his colleagues for this age group and suggested that the IQ debate is still far from resolved. Furthermore, in terms of causal theory, the findings suggest that the true underlying cause of dyslexia may rest in skill areas outside of phonology. When the two groups were then tested in a broader range of skill areas including tests of cerebellar dysfunction, an interesting dissociation was found between the two groups.

Results suggested that from a theoretical viewpoint, phenotypic differences do exist between children with dyslexia and those with more generalised learning difficulties of this age range. In particular, the pattern of differences between the performance profiles of the two groups led to the conclusion that children with dyslexia suffer from mild 'cerebellar' dysfunction, whereas the majority of the ND-PR children do not. This conclusion adds support to the cerebellar deficit hypothesis (Nicolson, Fawcett and Dean, 1996) whilst suggesting that this hypothesis would more than adequately provide an all encompassing account of the range of deficits occurring in dyslexia. Moreover, and irrespective of the specific causal interpretations made, the findings of clear performance dissociations between ND-PR and dyslexic children give theoretically valid reasons for distinguishing between these two groups of children.

It is cautiously proposed that this research may have gone some way towards meeting its primary intention to inform both dyslexia theory and practise.

However, this was only a small study, and although many intriguing findings have emerged, replication of results and further work is now necessary.

Implications of Part One: The Need for Intervention

The evidence these studies give to the theory of mild cerebellar involvement in dyslexia is important in terms of implications for early differential screening/diagnosis of learning difficulties. Furthermore, for those interested in the abilities of a some what under-investigated section of the learning disabled population, the stand-alone value of this corpus of ND-PR data is clear. A wealth of literature exists comparing dyslexic performance with controls, but comparatively little is to be found for studies comparing dyslexic with ND-PR children. However, it is clear that two important strands of future research have emerged from this work.

The first as stated is in the area of early identification and screening. The research presented in part one of this thesis has informed recent advances in screening in the UK, by helping in identification of skill areas in which non dyslexic poor reader's performance was differentiated from that of dyslexics. This differentiation is of critical importance in the development of any rigorous dyslexia screening programme. In other words a dyslexia screening programme needs to incorporate into its subtest battery not only those tests which discriminate between dyslexic and controls, but also those which reliably differentiate between dyslexics and those with more generalised learning difficulties. Unfortunately, the latter split is often overlooked by those developing screening batteries, leading to a screening test which is poorly discriminative and has a tendency to be overly inclusive in its selection of those 'at risk'.

Furthermore, this dyslexia research programme was one of the first applied research projects to implicate the cerebellum with dyslexia. By thoroughly investigating the comparative performance of ND-PR children within this new theoretical framework, a fresh angle of supportive evidence for the theory of cerebellar involvement was established. Moreover, it enabled inclusion in the screening test of innovative subtests based on the cerebellar hypothesis, adding an important facet to screening test batteries (cf. The Dyslexia Early Screening Test, (DEST), Nicolson and Fawcett, 1996; The Dyslexia Screening Test (DST), Fawcett and Nicolson, 1996).

By informing the development of the DEST (Nicolson and Fawcett, 1996), this research has been instrumental in enabling prediction of those children 'at risk' of failure in the first term of infant school, using a simple 30 minute battery of tests designed to be delivered by school professionals (Nicolson and Fawcett, 1996; see Fawcett, Singleton and Peers, 1999 for a review). However, it is not enough to identify children as 'at risk'. In order to break into the cycle of failure, screening children to identify their risk levels must lead naturally to intervention targeted to their areas of weakness. Intervention is as important as early identification, in fact early identification and diagnosis soon becomes obsolete if not followed up by a structured support programme. Research has shown clearly that the earlier the intervention, the easier it is for a child with dyslexia to learn to read, and the less danger there is of psychological trauma (Strag, 1972). Thus the second strand of future work to emerge from part one of the thesis is in the area of intervention. In part two the focus will be upon the development and evaluation of three different intervention programmes based on the theoretical principles which part one has helped to elucidate.

In terms of intervention programmes, the implications of these research findings could be considered to hold potential. By demonstrating deficits in both ND-PR children and dyslexic's performance outside the traditional phonological domain, fresh new avenues of intervention research can be considered. Demonstration of dyslexic deficits in motor skill areas is growing (e.g. Fawcett and Nicolson, 1995b) and deficits in motor skills areas have been accepted for some time as being a characteristic trait of children with more generalised learning difficulties (Ghaziuddin and Butler, 1998) although scientific research into this group remains scarce. The author has explicitly linked these deficits to the cerebellar deficit hypothesis, and now intends to take this hypothesis forward and utilise the theory in intervention. This has not been done before.

The following two chapters of this thesis will evaluate and develop three intervention programmes one of which will focus on motor skill training, through balance based tasks. Unlike previous motor intervention programmes, (outlined below) this applied research will have a strong theoretical base in the cerebellar deficit hypothesis (cf. Nicolson, Fawcett and Dean, 1995; Fawcett and Nicolson, 1999; Fawcett, Nicolson and Dean, 1996), thus pushing forward the frontiers of both applied and theoretical research in this area.

Part Two

Chapter 4

A Comparative Evaluation of Successful Intervention Techniques for Children 'At Risk' in Primary School

Introduction

Learning Disabilities: Issues of Definition and Classification

As discussed in more detail in part one of this thesis, the term 'learning disabled' appears to cover a highly heterogeneous group. It is normally used to refer to children with a cognitive disorder of some kind. However, those who are learning disabled, can show vast differences in their IQ (see chapter one for a review of the debate surrounding IQ discrepancy), and in the degree and kind of deficits manifested, for example in language expression and reception, mathematical skills, visual spatial and motor deficits, behavioural problems and so on (see chapter one for a full review of these findings). These subcategories are by no means discrete. A 'clumsy child' for instance, besides having motor problems, may have many other learning difficulties, all of which overlap. The range of deficits now accepted as existing in the dyslexic child is good evidence of this point in question (Nicolson and Fawcett, 1995a; Nicolson and Fawcett, 1995b). Some of these deficits may well be 'secondary symptoms', arising as a consequence of the primary problem. Again using the dyslexic child as an example of this point, it is appropriate to consider the cerebellar deficit hypothesis, within which deficits in areas of phonology, previously considered primary deficits, may now be considered 'secondary symptoms' of an underlying mild cerebellar deficit. Secondary symptoms often increase with age ('Matthew effects', Stanovich, 1998a) and can complicate and 'mask' the primary cause, making it a very challenging task to then try and unravel the underlying aetiology and consequences of the learning disability (Rack, 1997). Although it was not the purpose of the research in chapter two to investigate the underlying cause of poor reading, it was suggested that the phonological deficits may in fact have been secondary symptoms of some other primary cause of difficulty in children with more generalised learning difficulties. However, the necessity of formal follow-up work being performed on these groups before firm conclusions can be drawn was stressed.

When it comes to nomenclature the situation is equally unclear. 'Dyspraxic', 'developmental co-ordination disordered' 'clumsy' are just a few of the terms employed to describe this group of learning disabled children. As described more fully in chapter one, changes in educational thinking over the past three decades reflect this difficulty in classification of learning disabled children. The publication of the Warnock Report in 1978 (Warnock, 1978) reflected an acknowledgement of these difficulties, by its abolishment of extreme categories of handicap. Instead the use of broad, non-categorical terms were preferred, helping change the emphasis from that of labelling the child, to actually trying to determine the extend and nature of the learning difficulty. The 1981 Education Act following on from the Warnock Report with its 'whole school approach' and discouragement of labelling, ensured further progress in this area in the classroom. Nevertheless, there is a danger of becoming immersed in issues of classification and grouping in the field of learning disabilities. Although there may often be a need for practitioners to 'place' each child according to clearly defined classification systems, ultimately the key issue is one of setting up an appropriate and individual learning support plan for the child at the earliest stage possible. Irrespective of whether the child is primarily classed as dyslexic, dyspraxic, attention deficit disordered or a non discrepant slow reader, each individual profile of strengths and weaknesses can still be studied, and an appropriate intervention and support system considered. These considerations should look beyond the visible problems in areas of literacy, and evaluate the potential of the full range of skill difficulties in terms of intervention.

Learning Disabilities: Support and Issues of Cost Effectiveness

One of the most fundamental aims of all civilised educational systems, however challenging, is the establishment of an early identification programme for learning disabled children. Clearly such a programme needs to balance effectiveness with cost-effectiveness. The Dyslexia Early Screening Test (DEST) (Nicolson and Fawcett, 1996) is a cost-effective screening tool. It can predict those children 'at risk' of failure as early the first term of infant school, using a simple battery of tests deliverable by school professionals and only taking thirty minutes to administer (Nicolson and Fawcett, 1996; see Fawcett, Singleton and Peers, 1999; for a review). However, it is never enough to identify children as 'at risk', without following this with intervention targeted at their areas of weakness. Furthermore, research has shown clearly that the earlier the intervention is given, the easier it is to break the negative viscous cycle of underachievement and motivational problems for the child with learning difficulties. The negative effects of unsupported learning difficulties, can impact on increasingly diverse areas of children's lives, throughout their school days and into their future careers (cf. 'Matthew effects' Stanovich, 1996).

The intention of a comprehensive intervention and support system for children with learning difficulties, is to ensure that the benefit of early identification is utilised to the full, giving each individual child maximum opportunity to achieve their true potential. Even with appropriate cost-effective screening tools in place to measure progress, the difficulty confronting designers of an intervention programme for children with special needs such as a reading intervention scheme, is the same as that for screening test developers; a scheme must be devised that is both effective and cost-effective. For an approach to be effective, it needs to be systematic, comprehensive (covering all aspects of the early reading processes) and individual, requiring extended support from a highly trained professional. This is inevitably costly, and though arguably cost-effective when one considers the subsequent costs of *not* providing early support, it may be too costly to justify in a climate of economic stringency. In a recent controlled study, (Nicolson *et al.* 1999) the effectiveness and cost-effectiveness of an early intervention approach designed to be viable in a realistic funding climate was evaluated. Six year old children 'at risk' of failure were given support in groups of four, twice weekly, over ten weeks (Nicolson *et al.*, 1999), and their performance compared with matched controls, who did not receive the programme. The techniques used were based on Reason and Boote (1994), an individually adaptive, curriculum-based, approach with the emphasis on word building and phonics skills in the broad reading context. The interventions proved both effective – with a significant improvement in reading standard score – and cost-effective, with improvements comparable to those reported for Reading Recovery (Clay, 1993), yet with only 10% of the costs. Moreover, the positive effects of the intervention persisted over a six month period for more than half of the children, a stringent test of the (cost-) efficacy of any training programme (Fawcett *et al*, 1999).

The Importance of Phonology

The development of good phonological skills in pre-literate children is a fundamental precursor to the acquisition of literacy skills (Borstrom and Elbro, 1997; Hatcher, Hulme and Ellis, 1994; Lundberg, Frost and Peterson, 1988).

There are regular news reports that recent governmental figures are suggesting that levels of illiteracy in teenagers are still increasing. Recent government proposals for education have responded to this by focusing on the critical importance of schools allocating a significant proportion of each day to the teaching of basic skills in reading, writing and spelling with young children. The newly established 'Literacy Hour' in all primary schools is a clear indicator of nationwide efforts to improve literacy levels in our schools. We live in a highly literacy conscious society, where despite the advent of computers with their 'invisible' editing facilities, spell checkers and word glossaries, a well developed ability to read, write and spell proficiently is still considered fundamental to lifetime success.

Since the early 1980's, the benefits of reading support for children with learning disabilities has been well proven and widely accepted, with increasing scientific validation of many methods of intervention for reading difficulties, (see Snowling, 1996 for a review). Traditional phonological approaches to intervention have thus dominated the learning disabled arena. Indeed the literature particularly supports the idea of early intervention, suggesting that structured, early phonological support can lead to near normal acquisition and development of reading skills. As the literature in this area is so vast, a small selection of key studies, which seem to hold particular relevance to the intervention work reported here, will be discussed in more detail.

Phonological Intervention Studies

Bradley and Bryant (1983, 1985) set out to determine whether sensitivity to rhyme and alliteration had a causal role in reading development. Their work was outlined in chapter one and will be discussed in more detail here. They administered sound-categorisation tasks to four hundred and three 4-5 year olds and their progress in reading and spelling was monitored over a period of four years. Subjects who had begun to read at the start of the project were excluded so that there was certainty that the sound-categorisation scores were not confounded with reading ability. After accounting for general factors such as IQ, age at initial testing and memory for word lists, sound categorisation accounted for 4-10% of the variance in reading, and 6-10% of the variance in spelling. The influence of the sound categorisation skill appeared to be fairly specific, since it was shown to account for less of the variance in later mathematics ability. The second part of Bradley and Bryant's longitudinal study (1985) involved an intervention programme. A sample of sixty five children who had poor sound-categorisation skills were used, divided into four groups each of which received one of the following training types: sound-categorisation training, sound-categorisation training supported with concrete 'reading' material (plastic letters), semantic categorisation training (control), and a no-treatment control group. Results revealed that sound-categorisation training was the most beneficial training for later reading and spelling skills, but it was only significantly better than the semantic categorisation control when plastic letters were also used as part of training. As explained in chapter one, although demonstrating a causal link between sound-categorisation ability and reading, the results of this study should be treated with caution (Rack, 1994). The effects were only found when sound-categorisation training was integrated with letter knowledge, therefore it could be argued that the children in this condition were, effectively, being taught to read and thus their greater progress is unsurprising. Also, there is debate as to what skill is actually being measured by the sound-categorisation task. It has been suggested that it may actually be measuring memory primarily rather than phonology (Wagner and Torgeson, 1987) whilst Rack, Hulme and Snowling (1993) have suggested that effects may be due to complexity.

Lundberg, Frost and Peterson, (1988) demonstrated the importance of phonological skills in reading acquisition with their Danish training study. This study was outlined in chapter one and will be described in more detail here. They trained two hundred and thirty five Danish kindergarten children on phonological awareness with a further one hundred and fifty five children as controls. All the subjects were given a battery of linguistic and metalinguistic tests at the beginning and end of their kindergarten year. In the intervening period, the experimental group received daily 15-20-minute training sessions designed to promote phonological awareness. The control group were given no special attention, but followed the normal pre-school activity programme. Neither group was given any direct training in reading, thus accounting for criticisms of earlier training studies (e.g. Mann and Liberman, 1984) where phonological training occurs alongside reading development and the outcome may well be a function of the interaction of these activities. Using this 'no reading' design, it was possible to assess the effects of 'pure' phonological awareness training. Their results revealed significant beneficial effects of the training on phonological skills, and all importantly permanent beneficial effects of the training were found in reading acquisition by measuring reading and spelling some seven months into the children's first year in school and in the middle of their second year.

Hurford, Johnston *et al.,* (1994) investigated the early identification and remediation of phonological-processing deficits in first grade children (5-6 years) 'at risk' of reading disabilities. They assessed four hundred and eighty six first-quarter first graders on their reading and phonological-processing skills and intelligence. Based on this assessment and using their own classification data (see Hurford *et al.,* 1993), 99 children were classes as being 'at risk' of reading difficulties: 53 at risk of reading disabilities (RD) and 46 at risk of becoming "Garden-variety" poor readers (GV). Half of the RD and GV groups received the phonological-processing training. Post training assessment indicated that the training procedure no only was effective in increasing the phonological-processing skills of both of the trained participants, but also increased their reading ability. Follow-up analyses indicated 85% accuracy in identifying at-risk children. Results indicated that it is possible to identify children at risk for reading difficulties and to significantly improve their phonological-processing and reading abilities.

Lovett, and Lacerenza (2000) set out to establish what were the key components of effective remediation for developmental reading disabilities. They compared the efficacy of a combination of phonological and strategy-based remedial approaches for reading disability (RD) with the efficacy of each approach separately. Eighty five children with severe reading disability were randomly assigned to seventy intervention hours in one of five sequences: PHAB/DI (Phonological Analysis and Blending.Direct Instruction), WIST (Word Identification Strategy Training), WIST and PHAB/DI, Classroom Survival Skills (CSS) or Maths (the latter two were control groups). Performance was assessed before, three times during and after intervention. It was found that a combination of PHAB/DI and WIST proved superior to either programme alone on non-word reading, letter-sound and keyword knowledge and three word identification measures.

Support for this finding was given in the recent work of Schneider, Roth and Ennemoser (2000). The authors compared the effects of three kindergarten intervention programmes on 'at-risk' children's subsequent reading and spelling skill. From a sample of 726 screened kindergarten children, 138 were selected as children potentially at risk for dyslexia and randomly assigned to one of three training conditions : (a) letter-sound training, (b) phonological awareness training, and (c) combined training in phonological awareness and letter knowledge. A control group of 115 unselected ("normal") kindergarten children were recruited to evaluate the training effects. Results indicated that the combined training yielded the strongest effects on reading and spelling in Grades 1 and 2. Thus, these findings were considered to confirm the phonological linkage hypothesis (Hatcher, Hulme and Ellis, 1994), in that combining phonological awareness training with instruction in letter-sound knowledge has more powerful effects on subsequent literacy achievement than phonological awareness training alone.

(See also Hatcher, Hulme, and Ellis, 1994; Iversen and Tunmer, 1993; Lazo and Pumfrey, 1996; Rego and Bryant, 1995; Snowling, Goulandris and Defty, 1996; Sylva, Hurry and Plewis, 1991; and Vellutino *et al.,* 1996. A review of slightly earlier work is provided by Wasik and Slavin (1993).

Such language orientated approaches have undoubtedly achieved much success for a wide range of children from varying backgrounds, nature and degree of learning disability. For this reason, the intervention studies reported here include a phonological intervention group. The implications of the results for the phonological intervention programmes will be discussed.

However, there is a growing realisation in the learning disabled field, that phonological approaches do not represent an intervention panacea, and that in fact other less traditional approaches to intervention hold valuable potential for helping children with learning disabilities. This view has been considerably supported by recent research including that documented in this thesis, which demonstrates that children with developmental dyslexia not only suffer from difficulties in phonological skill areas, but moreover demonstrate more general problems in motor skills (Fawcett and Nicolson, 1995b; also Haslum, 1989; Rudel, 1985; Wolff, Michel and Ovrut, 1990) and more specifically balance skills (Fawcett and Nicolson, 1992; Nicolson and Fawcett, 1990; Yap and Van der Leij, 1994). As documented so clearly in Nicolson and Fawcett (1990) it seems that balance deficits are another symptom of dyslexia. The resulting hypothesis of an automatisation deficit in dyslexic children (Nicolson and Fawcett, 1990) and subsequent development and validation of the Cerebellar Deficit Hypothesis (Nicolson, Fawcett and Dean 1995; Nicolson and Fawcett, 1999) provided new openings for intervention research. The interesting question which then arises from the balance studies, is whether, as well as phonological focused intervention, it would be possible to look at training in these motor areas as well. Common sense suggests that you could, and furthermore, it seems logical to hypothesise from evidence presented in the Cerebellar Deficit Hypothesis that skill transfer could be expected with this form of intervention. It seems appropriate at this point to summarily overview key theories of skill transfer.

Skill Transfer – A Historical Perspective

As quoted in Singley and Anderson (1989), 'Does a knowledge of Latin facilitate the learning of computer programming? Does skill in geometry make it easier to learn music? The issue of the transfer of learning from one domain to another is a classic problem in psychology as well as an educational question of great importance,' (Singley and Anderson, 1989).

A key theme historically in theories of skill transfer has been the issue of specific versus general transfer. The first psychologist to systematically consider this question was Edward L. Thorndike, who at the beginning of the 1900's proposed his 'theory of identical elements' (Thorndike, 1906). Put simplistically, this theory was based on the idea that transfer between two tasks would only occur if they shared common stimulus-response elements i.e. transfer was quite specific and limited in scope. Thorndike's approach was criticised by educational psychologists as being too incompatible with traditional notions of transfer, which stressed adaption and flexibility in skill transfer.

Piaget's stage theory of cognitive development (Piaget, 1936/1952) represented the opposing end of the general-specific transfer continuum and was particularly influential and longstanding through the 1950's and 1960's. This theory held that transfer is broad, and ranges across diverse tasks and disciplines. Piaget attempted to characterise a child's developing ability to think and learn, by progress through an invariant sequence of fairly stable stages, on their way to cognitive maturity. Learning and transfer of skill at a certain age was therefore limited by general knowledge structures characteristic of each discrete stage for that age. Many aspects of Piaget's theory are now subject to debate and dispute, the theory being considered too inflexible and rigid to explain fully the development of children's ability to learn.

Since Thorndike and Piaget, many psychologists of different theoretical orientations, such as verbal learning (Osgood, 1949), gestalt (Wertheimer, 1945) and information processing (Shiffrin and Schneider, 1977; Newell and Simon, 1972; Singley and Anderson, 1989), have attempted to address various aspects of skill transfer with different and often inconclusive results.

In the last ten years, it has become increasingly clear to cognitive psychologists that the process of skill transfer could be better addressed from a cognitive perspective. The emergence of gradually more detailed and complex theories of skill acquisition have made this possible (e.g. VanLehn, 1983; Rosenbloom and Newell, 1986; Anderson, 1983) (see Singley and Anderson, 1989 for a review). As science research continues to increase our understanding of the functioning of the body and more particularly the brain, it has become increasingly possible to draw links between external performance and the internal cognitive/neurological processing that this performance represents. This has enabled those in motor intervention research to posit strong neurological principles for their research and clear hypotheses as to the underlying cause of results obtained. This approach is termed neurolinguistic programming and combines both cognitive and neurological/anatomical approaches to skill transfer. It is beyond the scope of this thesis to consider all approaches to skill transfer in any further detail, however, the neurolinguistic programming approach to skill transfer will now be considered further as it seems particularly relevant to the process of cerebellar skill training.

Neurolinguistic Programming and the Cerebellar Deficit Hypothesis

Increasingly research is emerging which has adopted this perspective to skill acquisition. This theory shares related principles with the intervention approach on which the studies reported here are based (Belgau and Belgau, 1982). Neurolinguistic programming research is rapidly pushing forward the frontiers of knowledge in skill acquisition, performance and thus skill transfer.

A study by McPhillips *et al.*, (2000) into the role of primary reflexes in dyslexia is a good example of a more recent motor training programme based on the principles of neurolinguistic programming and addressing skill transfer. In this study the role of persistent primary reflexes in disrupting the educational functioning of dyslexic children was investigated. The premise was that a continuum of reflex persistence exists (e.g. severe persistence results in cerebral palsy (Bobath *et al.*, 1975 cited in McPhillips *et al.*,). Milder persistence is hypothesised as tending to less severe disorders, for example dyslexia. The intervention programme focused on replicating the movements generated by the primary reflex system during foetal/neonatal life. Results showed very significant improvements in reading attainment linked with a significant decrease in primary reflex level for those children completing the intervention programme. Significant improvements in ocular control and writing speed were also found, although spelling and phonological skills remained similar for both groups. These results were interpreted as demonstrating a link between reading difficulties and motor problems, since training in motor areas produced improvements in reading. This study appears to demonstrate transfer through motor training as a result of neurolinguistic programming.

The Dyslexia Cerebellar Hypothesis is a strong example of a neuro-developmental perspective on dyslexia allowing causal theories at the anatomical/neurological level. The intervention studies reported here include interventions based on the theories encompassed in the Cerebellar Deficit Hypothesis and demonstrate how to unite the disciplines of neuroscience, cognitive and developmental psychology, to ensure a strong theoretical base to the research.

The motor training programme used in this study was based on the Learning Breakthrough Programme (Belgau and Belgau, 1983) grounded in the ideas of Ayres (1968, 1972a, 1972b). This approach is clearly related to neurolinguistic programming approaches and this lends itself ideally to application within the Cerebellar Deficit Hypothesis. It worked on the idea that sensory integration can lead to 'fine tuning' of the brain, with resulting ongoing improvements in learning and thinking. We shall now look at the specific neurolinguistic pathway by which training of the cerebellum may lead to skill transfer.

Skill Transfer through Balance Training:

Training the Cerebellum

The cerebellar hypothesis (Nicolson, Fawcett and Dean 1995; Nicolson and Fawcett, 1999) assumes that mild cerebellar dysfunction is the underlying and primary cause of the range of dyslexic difficulties established. This hypothesis and the functions of the cerebellum were described in detail in chapter one. However, a summary shall be given here for the sake of clarity. The cerebellum has long established links with motor performance control, and more recently clear evidence has been found of its involvement in cognitive task execution (Allen, Buxton, Wong and Courchesne, 1997; Leiner, Leiner and Dow, 1989; Thach, 1996), including a recent demonstration of specific cerebellar involvement in reading (Fulbright *et al.*, 1999). Cerebellar deficit therefore appears to provide a parsimonious explanation of the range of problems suffered by children with dyslexia. The findings of the studies in chapter three gave cautious support to this theory.

Predictions can be made from this hypothesis in terms of intervention. It seems logical to conclude, that if one of the key indications of cerebellar deficit is motor /balance problems, then it may prove fruitful to look to these areas in terms of intervention. Established theoretical evidence now suggests that the cerebellum is involved in the automatisation of motor skill and in adaptive control (Ito, 1990). It is proposed that this is due to its relatively homogenous structure, comprising of a wide range of individual microcircuits which would be responsive to learning (Ito, 1990). This research would naturally lead to the conclusion that motor/balance training would involve the cerebellum in some way, because of its direct involvement in motor skill execution. Furthermore, the recent neuroanatomical and neurophysiological work indicating cerebellum involvement in language-related activities (Leiner *et al.*, 1989) would appear to open up the possibility of skill transfer from motor-based skill areas to high-level cognitive skills like reading. Nicolson and Fawcett (1999) provide a persuasive explanation of the link between cerebellar deficit and literacy difficulties in order to explain how the cerebellar deficit hypothesis could provide an explanation for the range of deficits established in the dyslexic individual.

A full analysis of the putative causal chain between early cerebellar impairment via articulation, to phonological deficits, to the criterion measures for dyslexia, reading, spelling and writing will not be presented here. In summary though, it has been proposed that cerebellar problems are present from birth, and lead to difficulties in acquisition and automatisation of elementary articulatory skills (a primarily fine motor controlled ability) as well as auditory skills (and hence to difficulties in phonological processing). Visual skills such as eye movement (a fine motor controlled ability) and letter recognition are also likely to be affected. It is thus easy to see how the culmination of all these skill difficulties, will lead to the established early problems in learning to read and spell. This is a complex route between elementary cognitive difficulties via neurological substrate to high-level cognitive skills such as reading (for a review see Nicolson and Fawcett (1999).

The description of this pathway of connections from low to high level cognitive skills allows two interesting hypotheses to be drawn. The first pertains to skill transfer. The explanation of the causal link between cognitive deficit and literacy difficulties would seem to hold the key for possible skill transfer through training. It is proposed that training in the basic cognitive level skills of balance and motor skills will eventually lead to skill transfer to high-level cognitive areas by activation of the neurological route summarily outlined above. This activation would take place through the process of fine-tuning the brain's processing through the execution of repeated and increasingly challenging motor activities. This process is based on the principles of neurolinguistic programming described earlier. It is predicted that some skill transfer will occur by this route in the balance based training programme described below and in the following chapters. The subjects participating in the motor training programme will participate in daily balance training involving integration of motor, visual and auditory skills. The difficulty of the tasks will be increased in line with the increasing ability of the subject. Skill improvement is necessary for facilitating skill transfer. Maintaining the challenging aspect of the training is crucial for continuing the fine-tuning of the brain, and thus optimising skill transfer.

The second hypothesis that can be drawn from this proposed learning route, is to do specifically with dyslexic performance under such training conditions. According to the cerebellar deficit hypothesis, diagnosed dyslexics suffer global weaknesses in their cerebellar function resulting in the broad range of skill deficits now associated with cerebellum deficit and thus dyslexia. As with the non-dyslexic (ND-PR in our terminology), it would be expected that training the dyslexics in motor skills, will eventually lead to improvements in higher level cognitive areas due to skill transfer. However, the cerebellum is the key structure in facilitating this skill transfer, and in the dyslexic is not functioning to full effectiveness if the cerebeller deficit hypothesis is to be believed. So, it would be expected, that the diagnosed dyslexic will take longer to show direct skill improvement and subsequently skill transfer. This is because of the cerebellar deficit resulting in weaker cerebellar activation across this proposed learning route (see Nicolson *et al*, 1999).

Before going on to describe in more detail the motor training programme designed for this study, the issue of motor proficiency in those with learning disabilities will be examined and a review of motor based intervention studies presented. This is necessary to set the research reported here within the broader historical context.

Motor Proficiency and Learning Disabilities

The research of Nicolson and Fawcett (Nicolson & Fawcett, 1990; Fawcett & Nicolson, 1992; - see also Yap & Van der Leij, 1994) was one of the first to move attention away from traditional phonological difficulties to focus attention strongly on the balance deficits in dyslexics. Throughout the 1980's, the overwhelming obsession with phonological deficits in dyslexic children resulted in many other demonstrated deficits being either underestimated or ignored completely. The work of Nicolson and Fawcett broke new ground by positing an underlying anatomical aetiology for this range of previously unrecognised skill deficits, and this was its real strength. The cerebellar deficit hypothesis (Nicolson, Fawcett and Dean 1996; Nicolson and Fawcett, 1999) was based on convincing anatomical, neurological and applied evidence, some of which was presented in chapters two and three of this thesis. It presented a new and all-encompassing theory of dyslexia, that not only accommodated all previous theories of dyslexia, but also subsumed them.

Interestingly, a general association between motor deficits and learning disabilities has been recognised for some time. An impairment in motor proficiency is often found in children with learning disabilities, (Haubenstricker, 1982; Sherrill, 1986).

'A substantial proportion of students with learning disability manifest motor behaviour that is either inadequate of inappropriate. Such children are commonly describes as uncoordinated, awkward or clumsy'. (Bluechardt *et al*, 1995).

Deficits in motor proficiency have typically been considered secondary symptoms of some underlying primary problem often cognitive in nature. In fact until quite recently, the prognosis for children identified in their early years as being deficient in the acquisition of motor skills was considered 'benign' by many paediatricians (Henderson, 1995). In other words, it was thought that these children would simply 'grow out of' their difficulties as a result of a fairly autonomous recovery process. This led to an attitude of non-intervention amongst many practitioners. However, despite this, children with motor deficits *have* gradually becoming an increasing focus of interest. There has been quite a lot of general interest in the 'clumsy child', and motor deficiency is now increasingly being thought to represent a learning disabled condition in its own right. "Further investigation of learning disabled and non-disabled students on a wide range of motor-skills tasks is needed both for the purpose of increasing understanding of the motor characteristics of learning disabled students and for the purpose of designing more effective motor training programmes" (Bruininks, 1977).

Motor Intervention Studies

Nevertheless, because of the lack of strictly controlled scientific research in this area, and a strong theoretical foundation on which to establish research respect, these children have traditionally been considered to form an under-investigated group with formal studies in this area relatively few in number. Studies involving these 'clumsy children' as well as being minimal have tended towards poor control and design (Bruininks, 1977; Bluechardt *et al* ,1995), presenting problems in the interpretation of individual studies and so limiting the potential for pooling the available data. In general, available studies possess important limitations such as use of small, unrepresentative and vaguely described samples of learning disabled children, which span large age ranges. Subjects are often drawn from many disparate sources (for example perceptual-motor clinics, school-based programmes and segregated schools for students with learning disabilities). The nature and extent of the learning disability has often been poorly explained, and in some instances, the children have had associated disabilities. Typically these evaluation studies have made use of very limited measures of motor skills within the same sample.

An example of this is Knuckey and Gubbay's study (1983). As a result of the climate of 'non intervention' mentioned above, Knuckey and Gubbay in 1983 published the first longitudinal study of children selected exclusively on the basis of their motor disability, (Knuckey and Gubbay, 1983). They described an eight-year study of twenty-four 'clumsy' children and age-matched controls, first seen between the ages of 8 and 12 years. At follow-up, the 'clumsy' group remained consistently less proficient on all of the motor tasks, but there did seem to be individual differences in the extent to which change had taken place. In order to explore this variation further, Knuckey and Gubbay made an arbitrary decision to divide the 'clumsy' group into three subgroups, on the basis of their impairment at first testing. Perhaps not surprisingly, this analysis revealed that the children who had originally been the most 'clumsy', lagged furthest behind at follow-up, while others appeared to have recovered. On the basis of these results, Knuckey and Gubbay took what could be called a rather optimistic view that only the most severely 'clumsy' children failed to catch up. It is felt that this conclusion should be viewed with caution, as the study can be criticised on a number of points. Firstly the retrospective subdivision of the 'clumsy' group was somewhat arbitrary. It looked as though some of the test items employed were incapable of revealing differences between the groups because they were too easy (i.e. subjects scoring at ceiling on tests used). Also, no account was given of socio-economic status, IQ and ethnic group of the groups, leading to questions on just how well matched the groups were initially. Furthermore, half of Knuckey and Gubbay's sample was lost at follow-up.

Goldstein and Britt (1994) in their study to see if a relationship exists between visual-motor skills and academic abilities, stressed the importance of controlling for intelligence in such studies of motor abilities. They rightly criticised the results of many earlier studies, as being difficult to interpret, due to the failure of investigators to measure or control for intelligence in their group selection, as well as employing only one test of visual-motor ability and so drawing general conclusions from very narrow and limited data. For example Nielson and Sapp. (1991); McKay and Neale, (1985), cited in Goldstein and Britt (1994).

Pyfer and Carlson (1972) studied the motor ability of 28 male children with learning disability, aged 5.1 to 13.6 years. All of the children in their sample were of average or above average intelligence. However, they noted poor average scores on a test purporting to measure general static co-ordination. Comments on this study would be that only a small number of subjects were used and no effect of gender studied. Furthermore, a very wide age range was studied and only one performance area, that of static co-ordination, was reported.

Doll-Tepper (1987) examined 160 children with learning disabilities aged 6 to 16 years; many of her sample had associated disabilities and she did not specify gender. She found disturbed motor responses in 57% of her sample, with 25% of the group showing a major deficit in their motor responses.

Johnson and Rubinson (1983) tested children with learning difficulties aged 6 to 12 years. They noted that scores were within normal limits for gross motor items such as the standing broad jump, flexed arm hang and sit-and-reach tests, but that performance was impaired on bent-knee sit-ups, a 320m run, a shuttle run and tests of awareness of space and tempo of movement. It is difficult to interpret this study since the number of subjects were not specified and such a wide mixture of tests was employed.

Researchers have hypothesised (e.g. Bluechardt and Shephard, 1995) that for children with primary motor proficiency difficulties, the same debilitating problems can arise as for those with primary cognitive, literacy difficulties. Directly or indirectly, inappropriate or inadequate motor behaviour can actually effect learning in the classroom, (Harding, 1986). More specifically, by leading to exclusion from games in various contexts, a negatively spiralling and vicious cycle of decreased motivation, participation and thus competence is created. This affects confidence, self-esteem and perceptions of self-worth, which can result in withdrawal or disruptive behaviour (Gottlieb *et al.*, 1986; Silver, 1989) increasing the likelihood of social maladjustment with time.

The examples given above, of formal studies of motor proficiency in children with learning disabilities, give no reference to intervention studies for these children. An overview of motor intervention programmes from the 1930's to the present-day will now be presented and critically discussed. This will give the reader an historical perspective on motor skill intervention studies before the motor-based intervention study developed by the author is presented.

A Historical Perspective: Motor Intervention Programmes (1930-1990)

Alternative approaches to intervention are not new, with many varied and interesting studies having been documented over the years, with practitioners suggesting that motor skill intervention can help learning disabled children (Kephart, 1971; Frostig and Maslow, 1973; Belgau and Belgau, 1982; Farnham-Diggory, 1992). Based on the theories pioneered by Galton (1883), the work by early specialists in learning disabilities focused on the idea of individual differences (traits) combined into what they termed 'processes', which were activated when a child performed a certain task. A child's performance in a particular task was considered directly attributable to a particular process. The idea was simple and logical; through strengthening the relevant process, improvements in the task performance would result, comparable to the idea of strengthening arm muscles to improve a child's batting average (Farnham-Diggory, 1992). The work of these early process theorists, such as Kephart (1970), Frostig and Maslow (1973), created a lot of interest in the educational field, and pointed strongly towards the potential of motor based intervention programmes with learning disabled children (see Farnham-Diggory, 1992 for a review). It was hypothesised that intervention at a motor skills level, would produce beneficial effects not only directly in motor skill areas, but all importantly show generalisation to social and academic skill areas. Unfortunately, the work of these early theorists, was often perceived as tending towards informality and circularity (Farnham-Diggory, 1992) and their motor intervention programmes as lacking in strong theoretical principles.

The decreasing popularity of these programmes throughout the 1980's and 1990's is considered the result of a combination of two main factors; a lack of rigorous scientific evidence and evaluation of the motor intervention programmes, and the rapidly increasing popularity of scientifically validated phonological training. The motivations behind phonological intervention were clearly based on solid theoretical principles, and rapidly became well proven and widely accepted.

At this point it is worth mentioning, that although attempts by academics at strict scientific research in this area of motor based intervention waned during the 1980's, a number of practitioners and clinicians incorporated these ideas fairly successfully into certain intervention programmes. The Head Start Programme (see Zigler *et al.,* 1994 for a review and critique) and the Learning Breakthrough Programme (Belgau and Belgau, 1983) (see below for more detail on the latter programme) are examples of this. However, despite the undoubted value of these programmes, there continues to exist little if any scientifically controlled evaluation of their success.

More recently, various studies, (e.g. Knight and Rizzuto, 1993) have attempted to redress the imbalance of research in this area of motor deficiency. These studies suggested a relationship between motor-skills and academic achievement, leading to the hypothesis of motor skill intervention possibly generalising to academic or cognitive skill areas. However, these studies were few in number, and furthermore there was little solid evidence emerging to support this hypothesis of generalisation and skill transfer, in other studies being performed around this time, (Bluechardt *et al.,* 1995; Kavale and Mattson, 1983). Not surprisingly, in a number of studies, there was evidence of direct improvement in motor tasks through motor training, (Cammisa, 1994). This would have been predicted by the process theories back in the 70's (for example Kephart, 1970; Frostig and Maslow, 1973). As described above, the process theorists considered a child's performance in a particular task to be directly attributable to the activation of a certain 'process'. In other words, if the appropriate 'process' was activated then the child's performance directly linked to that 'process' would improve. So in the case of motor training where the appropriate 'process' being trained might for example be hand-eye co-ordination, process theories would predict motor task performance to then improve because of the direct link between the process of hand-eye co-ordination and motor task execution. However, when an adequate control was used, it seems that this improvement was often found in the control group as well (Bluechardt *et al.,* 1995;). This suggested results were not so much an indication of training success, as a reflection of the extra attention both groups were receiving (i.e. the Hawthorne effect, (see Rubinson *et al.,* 1989)).

In summary then, unlike the widely accepted success of phonological intervention programmes, intervention techniques based on motor proficiency improvement through motor skill training, have produced a mixed bag of results. Rigorous scientific research in this area is somewhat limited, with many reported results of intervention success being somewhat anecdotal in nature, or comprising of a case study approach. Evidence of skill transfer to academic and social domains through motor skill training is scarce. What is more, the specificity of motor training as the primary cause in this improvement when improvements *are* found, is unclear and open to debate. Many of the more recent scientific studies fail to stand up to strict scientific scrutiny, and can be criticised in terms of weak methodology and/or design (see Bluechardt *et al*, 1995 for a review). Studies typically comprise of weak or no control groups and allow for many confounding factors to cloud a clear interpretation of results (e.g. Cammisa, 1994).

As will be seen in this and the following chapter, the balance intervention programme designed as part of this research, will attempt to be both scientifically rigorous, well controlled and furthermore based on sound theoretical principles. For this reason the findings produced are particularly exciting and innovative since earlier studies have fallen some considerable way short on all or some of these criteria. For this reason their results have not been well received within the field of educational research.

The Maclagan Balance Intervention Programme

The balance intervention programme developed and evaluated here was based on the Balametric approach, which is described below:

Balametrics

This is the basis of a successful and comprehensive 'Learning Breakthrough Programme' being developed in the USA (Belgau and Belgau, 1983). This 'Balametric' system focuses on generic motor programmes with 'cross-hemispheric' skill integration developed around a calibrated variable-difficulty balance board, the balameter, (see Appendix 4 for photographs of the balance board). The programme aims to stimulate and increase the efficiency of brain function through, quote 'the integration of motor, visualisation and balance activities (body-teaming)', (Belgau and Belgau, 1983). The training in automatic 'body-teaming' is said to enhance the quality of perceptual information available for cognitive processing, thus improving educational efficiency. The primary component of the programme is a wobble-board, namely the Belgau Variable-Difficulty Balance Board (balameter) on which subjects stand centred whilst carrying out various activities. Belgau and Belgau concur that the balameter allows for regulation of balance difficulty in wide-based balance tasks and forces the two hemispheres to balance their own operation whilst carrying out the activities. It is claimed that as little as ten minutes of activity on the board can result in significant improvements in high-level brain function, thus holding potential for helping young and old alike, in a whole range of both academic and non-academic areas.

Anecdotal evidence suggests that the Balameter-based studies of Belgau and Belgau, have been very successful for a number of years in the USA. Yet no comprehensive and scientifically rigorous evaluation of the effects of the balametric based activities has ever been carried out.

The Justification for the Motor Intervention Programme

Both the theoretical and applied implications of this research are new and exciting. As described earlier, the cerebellar deficit hypothesis broke new ground in attempting to establish a unifying theory of dyslexia that took account of the wide range of skill deficits being discovered in dyslexia. The research reported here is irrevocably linked to the cerebellar hypothesis. It allows a unique investigation into the receptiveness of the cerebellum to training. Findings from this research will hopefully influence further developments of theories implicating the cerebellum with dyslexia. Furthermore, this research is the first direct comparison of the effectiveness of phonological training against motor skill training. What is more, the training programme was taken into the home, where parents were allowed to supervise and control the training. This added a valuable new dimension to the research enabling exciting *applied* implications to be drawn from the research. The potential of a motor skills training programme for incorporation into home-based intervention programmes could now be evaluated.

Of particular interest was the discovery that little work has been done to investigate the potential of this form of intervention with very young children. Clearly many literacy-based forms of intervention would be inappropriate for the very young. Motor training is a highly accessible form of intervention for all ages, but particularly so for those below the age of seven or eight. In children of this age, comparatively well developed motor abilities may be utilised in a way that less mature literacy skills may not. Children start practising and using their motor skills from birth onwards. For children with learning disabilities, a motor based intervention offers the possibility of intervention support in a form which is not so threatening to the child, and is less likely to foster negative associations with failure in the classroom than more traditional forms of intervention. Despite the benefits such an accessible form of training would appear to hold for young children, few have explored this area in any depth.

Researchers, practitioners and politicians are now unanimous in their agreement that, if later problems are to ameliorated or avoided altogether, then the earlier intervention can be given the better. Literary intervention techniques are not accessible to the very young. Consequently if this motor-based intervention can be shown to be effective with very young children, then it would be welcomed by many. As mentioned earlier however, research to date in this area with children has been minimal and of poor design. Research into early intervention for those with learning disabilities seems particularly pertinent when considering the recent publication of various early screening techniques onto the market e.g. the Dyslexia Early Screening Test (DEST) (Nicolson and Fawcett, 1996) and the Cognitive Profiling System (CoPS1) (Singleton *et al*, 1996, 1997). (For a review see Fawcett *et al*, 1998). Once early screening has identified a problem, there is a moral obligation to attempt to provide structured support and intervention for the child.

Early identification and support – Political background in the United Kingdom

The recent publication of these screening techniques, are indicative of the intense pressure currently upon the British government to implement an early identification and support system for children with learning difficulties. Formal reading instruction begins comparatively early in the UK with children being taught letter sounds in their first few weeks of school at 4.5 years of age. (In the United States for example, formal reading instruction is typically starts with six year olds in grade 1). In Britain it is generally expected that the average child will be reading their first reading book by the end of their first year in school. This provides an excellent opportunity for early identification and support of reading difficulties.

The Education Act (1993) and Code of Practice (1994) placed dyslexia firmly on the mainstream school agenda by explicitly defining specific learning difficulties (dyslexia). Paragraph 3.60 of the Code of Practice (1994) states:

Specific Learning Difficulties (for example Dyslexia)

"Some children may have significant difficulties in reading, writing, spelling or manipulating numbers, which are not typical of their general level of performance. They may gain some skills in some subjects quickly and demonstrate a high level of ability orally, yet may encounter sustained difficulty in gaining literacy or numeracy skills. Such children can become severely frustrated and may also have emotional and/or behavioural difficulties".

Furthermore, the Code of Practice (1994) reflected the current trend in the United Kingdom, to integrate those children with learning difficulties into mainstream schooling. This immediately placed responsibility on the school to identify and support children with Special Educational Needs (SEN), and in the early years of school. For this reason, any early identification and support system needs to be accessible to young children and ideally able to be easily administered by teachers in school. The motor programme described below appears to meet both these requirements. It is easily accessible even to pre-literate children, and can be administered by either parents or teachers.

The Intervention Studies

The sequences used for the training in this thesis were closely based on those developed in the Belgau programmes. The same principles were employed, if adapted somewhat, to be suitable for the age of children used in this study. The studies reported here, present a direct comparison of a phonological based intervention programme (based on Hatcher, Hulme and Ellis, 1994) with an innovative motor based intervention programme (adapted from the 'Balametric' techniques used by Belgau and Belgau, 1982) and an arithmetic programme (adapted from age-appropriate books) in comparison with a no-intervention control. These programmes are compared against each other in both a strictly controlled training environment, and also a less controllable, home-based environment, where parents implement the programmes.

The phonological and arithmetic training programmes were designed to complement and support what the child was learning in class. This involved giving them extra practise in skills they had already been taught as well as introducing new concepts as part of the training. The approach taken in the phonological training programme was one that encouraged combination of phonological training with the teaching of reading and was modelled on the work of Clay (1985). In this regard it is important to note that since reading was being taught in combination with phonological training, any beneficial effects may well be a function of the interaction of these activities (Rack, 1994). The phonological training was considered representative of good teaching practise, enabling individual teachers to use the materials within their existing teaching approach. The phonological and literacy training received by the children in school was based on a multi-sensory approach combining phonics-based methods with visual teaching methods. Children received daily tuition in literacy of about an hour's duration in line with the 'literacy hour' recommendations.

Our prime area of interest was the effect of the interventions on literacy skills (reading and spelling). Whether or not skills generalise, is one criteria for effectiveness, and so we were also interested in potential improvements in sub-tests of the WISC-R IQ tests (Wechsler, 1976) not withstanding the implications such transfer may hold for cerebellar transfer predictions. Finally the cost-effectiveness of the programmes was of particular interest in the current economic climate.

Part Two

Chapter 5

A Comparative Evaluation of Intervention Techniques for Children 'At Risk' in Primary School: A Home-Based Intervention Programme

Introduction

There are many possible causes of literacy failure, and different research groups have targeted different aspects of the problem. One of the challenges facing educators, is to identify literacy support best suited to different types of children.

One promising approach, is that adopted by Hannon, Nutbrown and their colleagues, in which poor home environment was identified as a major source of difficulty in early literacy development (Nutbrown and Hannon, 1997). Consequently, in the REAL (Raising Early Achievement in Literacy) project, they developed and evaluated the effectiveness of a home-based system, for helping parents to help their children with literacy skills.

In the first evaluation study reported here, we adopted a similar approach to Hannon and colleagues, using untrained parents to deliver the intervention, but in this case working with children from middle-class backgrounds. In earlier research using parents as trainers (Fawcett and Nicolson, 1990) it was found that the commitment of parents to the programme is a critical factor in success. The rationale for selecting a higher socio-economic group was the high level of parental compliance needed to undertake a training programme of this intensity. As an untried intervention was being evaluated, there was particular concern that results should not be compromised by any variability in the implementation of the programme.

Design

This study investigated the comparative effectiveness of a range of early intervention programmes, and so the children selected were in reception and first year, with a mean age of 5.5 years. The study aimed to assess the effectiveness of interventions that would be viable within a climate of limited funding. Consequently, the training regime was designed to be delivered by untrained parents working at home with their own children, in daily sessions of around 10 minutes, over a period of 8 weeks. A control group, matched for reading and age with the experimental groups, but with no explicit intervention, was used to allow comparative progress to be assessed. Performance of the groups on reading-related standardised tests was measured both before and after the 8 week training period. The critical variable was the amount of improvement for the experimental groups and the control group from pre-test to post-test. The differential improvement of the experimental groups would give an indication of the relative effectiveness of the interventions.

It should be noted that a total of 27 subjects (9 in each training group) started the training. This is a very small sample size resulting in a small-scale study. Due to the nature of the training programmes, it was unworkable for a bigger scale programme to be undertaken by the author single-handedly. However, the scale of this study should be born in mind when interpreting results.

Predictions and Hypotheses

The general prediction for this parental training programme was that there would be a significant interaction between training group and time of test: All training groups would improve from pre to post in the tests measured, but the training groups would improve significantly more than the no training group. Furthermore, it was predicted that in the literacy pre and post tests (Reading, spelling and IQ) the phonological and balance training groups would perform significantly better than the maths 'control' group. This latter prediction was based on the confident hypothesis that phonological training would directly impact on phonological skills (see Bradley and Bryant, 1983, 1985; Lundberg *et al.*, 1988*)* and the more tentative hypothesis based on cerebellar involvement in language and motor skills (Allen *et al.,* 1997) that balance training would indirectly stimulate the cerebellum and thus indirectly improve language skills.

In terms of ability grouping, according to the cerebellar hypothesis, it is tentatively predicted that children of low ability (i.e. 'at risk' of developing dyslexia) would show less beneficial effects of training, particularly in balance, due to weaker cerebellar activation across the proposed learning route (see Nicolson *et al.,* 1999). However, this is only a cautious prediction since children are not formally diagnosed with dyslexia at this young age. More generally, children of lower ability can be more resistant to intervention of any kind.

Overriding all these predictions is the somewhat subjective and 'uncontrollable' factor of (parental) training rigour. This research is exciting in that it investigates the accessibility of training regimes for application within the home, but it does unavoidably introduce a certain amount of between subject variation in the standard of training received. This will influence all results.

Selection of Subjects and Groups

The three training conditions were balance, maths and phonological training, with equal numbers in each condition of children classed 'at risk', 'mild at risk' and 'no risk' on the DEST (Nicolson and Fawcett, 1996). Despite its name, the DEST is not a specific screening test for dyslexia, but was designed to identify any child at risk of poor reading acquisition (centiles 1 to 10). In addition to the overall at risk score, the DEST derives a 'profile' of scores on the individual sub-tests (see footnote 1 for a brief description of the sub-tests[1]). Subjects were assigned randomly to training condition. This design allowed study of the effects of two factors, namely training type and level of ability.

Subjects

Subjects were selected from Reception and Year 1 classes at Lydgate Infant School, Sheffield (average age 5.54 years), drawn from a white, middle class

[1] The DEST comprises 11 sub-tests in five areas (literacy skills, phonological awareness, verbal memory, motor skill and balance, and auditory processing). The sub-tests are as follows. Digit names tests knowledge of digits 1-9, Letter names tests knowledge of letters a-z. Rhyme tests both for understanding of rhyme and of first letter sounds; Rapid naming involves the time taken to speak the names of pictures on a page full of common objects; Discrimination is the score on saying whether word pairs such as 'fuse' and 'views' are identical. Digit span tests verbal memory for sequences of digits. Beads is the number of beads threaded in 30 s; Postural stability reflects the degree of movement when pushed gently in the back; Shape copying tests the accuracy of copying simple geometrical shapes. Sound order tests the ability to determine which of two

catchment area. Parents participated with fully informed consent and commitment to undertake the full training. Subjects were grouped according to their scores on the DEST, which provides a simple 'at risk' index (ARQ) with a profile of strengths and weaknesses to guide ongoing support at the school. For this study, children were divided into three groups based on the following criteria: ARQ of 0.8 or greater were deemed to be 'at risk', ARQ of 0.3 to 0.7 were 'mild risk', and ARQ 0.2 or less were 'no risk'[2]. 27 subjects (13m, 14f) were split evenly between the groups with equal numbers for each 'at risk' category within each training group. None of the subjects had emotional or behavioural problems, or any evidence of ADHD (based on teacher's reports). No children had any prior experience of the training, but some overlap between concepts learnt in training and in class was inevitable for the maths and phonological skills training. See Table 5(1) below for psychometric details of the subjects.

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sounds played shortly after each other was first. The overall DEST score is essentially the average of the scores on the individual sub-tests.

[2] Note that the level of 0.3-0.7 as mild risk, and 0.2 and under as no risk is not consistent with the published norms for the DEST, but applied specifically in this intervention to produce discriminable groups.

Table 5(I). Psychometric data for the three groups. Study 1

Training Group	**Year**	**Number (at pre test)**	**Mean CA[3] (at pre test)**
Balance	Reception	6	5.35
	Year 1	3	5.67
Phonological	Reception	6	5.33
	Year 1	3 (1)*	6.08
Maths	Reception	6	5.28
	Year 1	3	5.76
Total subjects		**27 (25)***	**Av = 5.54**

* numbers in parenthesis represent number of subjects participating at post-training session.

The numbers in each of the training groups were equivalent at the start of the study. There were nine subjects in each training group with three of each risk category within each training group. Due to attrition effects, there were only seven subjects in the phonological group by the end of training (see Table 5(2)). One subject lost was 'at risk' and the other was 'no risk'.

[3] Mean CA at pre test is calculated from those children who were still present at post-test, i.e. this CA calculation does not include children present at pre-test who were subsequently lost though attrition

Experimental Tasks

Pre and post training tasks were selected to cover a wide range of skills relating to the training regimes, both academic related and less academically related. Only those in the most academically related (literacy and IQ) areas will be presented here. Performance and Full scale IQ results will only be presented in some of the analyses in order to help given a general impression of comparative performance changes in these areas. The main thrust of the analysis will be in Verbal IQ, reading and spelling since it is generally accepted that performance in these areas are the best predictors of academic ability and achievement.

i) Wechsler Objective Reading Dimensions test (WORD, Psychological Corporation, 1993) of single word reading and spelling

ii) Wechsler Intelligence Scale for Children (Revised) (WISC-R) (Wechsler 1976) shortform, (Picture completion, Block design, Coding, Similarities, Arithmetic, Vocabulary) with IQ scores prorated[4].

Training Tasks

Guidance on the appropriate level for each task was provided by Margaret Nicolson, an experienced teacher. The author met individually with all the parents prior to the start of training to explain thoroughly the aims and purposes of the training to them and to ensure that they understood how to administer the training. Parents were instructed to work with their children on activities for approximately 10 minutes daily. Each parent was provided with a 'workbook' with general instructions, a 40-day calendar, and a general diary. This ensured

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[4] The children were young for the WISC-R, (mean age 5.54, WISC-R for children aged 6 years and above). All the children could score on all the tests,

that the session duration (10 minutes daily for each training group) and the number of sessions (one session daily for each training group) for the training period (40 days for each training group) was equivalent for the three training groups. (See Appendix 5 for details of an example workbook).

In this section, full methodological details are given for the balance, phonological and mathematics training tasks. The latter two training programmes utilised materials, books and training manuals already published and available for purchase by the public. However, the balance training tasks, despite being based on the Belgau work (Belgau and Belgau, 1982), were significantly redesigned and rewritten by the author for the purpose of this study (see Appendix 6 for some sequence details from the Belgau manual). Furthermore, comparatively few detailed investigations of the effects of balance based motor training exist. As explained in the previous chapter, this situation provided the motivation for the research studies reported here.

Balance Training Tasks

Parents were instructed to work with the children on the balance activities on a daily basis for approximately 10 minutes. They were asked to aim to complete one sequence within the 10 minutes, and to rotate between the different activities on a day to day basis for the 40 days training duration. This should ensure equal exposure to each of the four sequences. The aim was to perform each sequence 10 times within the 40 daily 10-minute sessions. Understandably, children were sometimes unable to complete individual day's training due to unforeseen circumstances such as illness. Parents were instructed to note such 'days off' in the 40 day calendar provided, and wherever possible to complete the missed training days at the end of the 40 day period, thus ensuring that all subjects completed a full forty sessions. Parents were instructed to carry out the training

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but their scores were lower than an average 6 year old, and there was scope to demonstrate a wide range of improvement.

in a room free from distraction as the children needed to be able to hear and concentrate in order to perform at their best. Parents were instructed to give children constant positive verbal feedback and praise, such a "well done", and "that's the idea" to maintain motivation.

Four separate training sequences were outlined for parents, each based around one of the following activities adapted from the Belgau (1982) regime for the Primary range (see Appendix 5 for an example of a balance 'workbook' with sequences outlined and Appendix 6 for details of the Belgau routine):

- bean-bag
- shapes
- skittles and bucket
- general coordination and movement.

Since the children in the study reported here were taken from the reception class of primary school, it was necessary for the author to simplify the sequences to make them appropriate for children of this age (with advice from a trained teacher). Although the Belgau programme was developed for use with children through to adults, it was clear that the majority of the motor tasks incorporated into the Belgau sequences would prove too advanced for children of 5 to 6 years of age. However, the four motor sequences were similar to those provided in the Belgau programme, each focusing on one particular piece of equipment and associated motor movements.

It was stressed to the parents that the main aim of the programme was, of course, enjoyment, but also to maintain the challenging aspect of the training programme, if improvements were to be seen and the child's interest maintained. In order to keep the sequences challenging, it was necessary for the parents to incorporate a certain amount of flexibility into the training. This meant modifying the sequences at their own pace, on a daily basis if necessary to maintain a level of difficulty that was challenging for the child as their skill level increased. As Belgau explained in his Learning Programme manual, an activity done in a sloppy, disorganised manner will not result in much brain tuning. However, *'an activity done in a routine and rigid manner maintains the function; but an activity performed with an eye to perfection, or one that challenges ability should build on and refine the child's performance efficiency'* (Belgau and Belgau, 1982).

Methods for increasing and decreasing difficulty of the training sequences were explicitly outlined in the parental manual, (see Appendix 5 for full details). The basic method of increasing difficulty was to increase the distance of both feet from the central vertical grid line on the balance board (see Appendix 4 for photographs of the balance board). This served to make maintenance of a level state of balance more difficult. Other methods included the trainer insisting on more fluency and accuracy in execution of movements and also increasing the number of repetitions of a particular movement and making each individual movement more demanding. This could be achieved by increasing the required throwing distance for bean bags, by decreasing target size, by increasing target distance from the balance board and so on.

It should be noted that although maintenance of the challenging aspect of sequence execution was important, conversely it was imperative not to over-stretch the child. If the child was pushed too far, this would prevent movements being executed in a fluid, smooth and relaxed manner, and thus the potential beneficial effects due to the repeated execution of movements in such a manner would be greatly diminished if not dissipated altogether.

As parental experience in administering the sequences increased, it was hoped that they would begin to create their own sequences based on a combination of the four activities provided, and even use their own apparatus. This would help stimulate fresh interest and enthusiasm for both the child and parent and thus maximise beneficial effects of the training.

Prior to each day's training, parents were instructed to follow 6 points:

- Remove the child's shoes and socks to ensure maximum grip and sensitivity.

- Centralise the child on the board, i.e. ensure that the child's feet are equidistant from the centre of the platform and toes are lined up on the same horizontal grid line.

- Familiarise the child with balancing on the board, e.g. by going through a simple reaching, stretching and twisting exercise.

- Get all chattering and possible distractions out of the way at this familiarisation stage.

- Try to ensure board is level and child can remain still for a few moments before starting, (both these requirements may be difficult at first, but will improve with practise). Some children will have a slightly inaccurate perception of what is level. This perception should become more accurate as the training proceeds.

It was suggested to the parents that the best way to perform the training was for them to stand in front of the balancing child (approximately 3 to 4 feet away from the board, i.e. close enough to catch them should they overbalance!) and the child then to imitate the parent performing the motor sequence. A 'Simon says' format was suggested as a good way to put this into practise. Obviously, as the child became more familiar with the sequences, less and less visual imitation would become necessary, verbal commands soon sufficing.

Phonological Training Tasks

The phonological training included 2 components:

i) Sound Linkage (a more challenging training, for the first 5 minutes of intervention). (See Appendix 7 for a photocopied example of Sound Linkage activity sections 1 and 2).

ii) Letterland activity books (for the second half of the session, when the child is becoming tired). (See Appendix 8 for a photocopied example of some of the contents of a Letterland activity book.

Parents were instructed to work with the children on the phonological activities once a day for 10 minutes for the 40 days training duration. Understandably, children were sometimes unable to complete individual day's training due to unforeseen circumstances such as illness. Parents were instructed to note such 'days off' in the 40 day calendar provided, and wherever possible to complete the missed training days at the end of the 40 day period, thus ensuring that all subjects completed a full forty sessions. Parents were instructed to carry out the training in a room free from distraction as the children needed to be able to hear and concentrate in order to perform at their best. As outlined above, parents were requested to divide each 10 minute training session into two five minute sessions, spending the first 5 minutes working on the arguably more challenging Sound Linkage activities, and the second 5 minutes working from the Letterland activity books. Parents were instructed to give children constant positive verbal feedback and praise, such a "well done", and "that's the idea" to maintain motivation.

Parents were given a workbook which consisted of general training instructions and background to the training material plus a 40 days calendar for marking completion of each day's session. This calendar was the same for all three training programmes, an example can be seen at the beginning of the balance workbook found in Appendix 5. The bulk of the workbook comprised two main sections, the phonological training programme and the 'Letterland' book material. Enough material was included to cope with the varying abilities of the children taking part in the study (based on teacher's comments of ability and workbook content).

Sound Linkage

The Sound Linkage training exercises were taken from the manual 'Sound Linkage: An Integrated Programme for Overcoming Reading Difficulties' (Hatcher, 1994). This programme contains phonological training activities and phonological linkage activities. The phonological training activities derived from the work of researchers such as Rosner (1975), Stanovich, Cunningham and Cramer (1984) Lundberg, Frost and Peterson (1988). The phonological linkage activities were based on the phonological linkage hypothesis (Hatcher, Hulme and Ellis, 1994) which states that a combination of phonological training and reading is critically important in improving literacy (see also Schneider *et al.*, (2000)). For the phonological training programme described here, only the phonological training activities were used.

The phonological training activities formed the bulk of the parental workbook and involved a graded sequence of tasks. There were 66 phonological training activities given to each parent, divided into 8 sections, ordered in terms of difficulty (see Appendix 7 for photocopied examples of section 1 and 2 activities):

- (1) identification of words
- (2) identification and manipulation of syllables
- (3) phoneme blending
- (4) identification and supply of rhyming words
- (5) identification and discrimination of phonemes
- (6) phoneme deletion
- (7) phoneme substitution
- (8) phoneme transposition

Parents were instructed to work through the exercises in order of difficulty. Each activity began with three examples. If the child successfully completed these examples the parent was to assume that he/she could progress with the activity. Once the majority of an activity was successfully completed the parent could progress to the next activity. If at any time the child appeared to be struggling to understand the concept, parents were instructed to stop and use the examples as teaching points to try and explain the concept. Complete photocopies of record sheets and picture sheets found in the original Sound Linkage manual and necessary for completing the activities were provided in each workbook. The programme was intended to be as user-friendly as possible. Parents were encouraged to read each day's activity before working with the child to ensure they were happy with the material and could present it in a natural way. In keeping with this, and provided that the intent of the instructions were not altered, parents were told it was not necessary to stick rigidly to the text and encouraged to think of ways of making a game out of an activity. (All of these instructions were included in the front of the handbook).

Three additional general instructions were included in the workbook for parents;

(1) Keep consonants as phonetically correct as possible. Consonants such as p, t, k, th, f, v, s, z, sh, ch and h, should be pronounced without adding a vowel. For example Spot should be pronounced 'sss' 'p' 'o' 't' and not 'suh' 'puh' 'o' 'tuh'. With other consonants, such a b, d, g, j, w, r, l, and y, the following vowel should be kept as short as possible.

(2) Try to avoid giving non-phonological clues when a child has to respond by choosing between two or more stimuli. It is possible to prime children by a change of intonation, stress or volume or by pausing before a word. Body language, such as changing eye contact, can also give a clue to the expected answer. For these reasons, try to present items in a smooth and even manner.

(3) The sequence of concept activities at the start of some sections has been devised to introduce understanding of a concept in a series of steps.

These involve discussion linked to practical activities, visual example, auditory examples and examples linked to phonological activities. Help your child to see the progression. The goal of these activities is mastery of the concept, not to identify sounds. To avoid confusion, parents should not refer to sounds while presenting these activities. If a child refers voluntarily to sounds, however, accept the responses as evidence that he/she is thinking about sounds.

Letterland

The Letterland activity books are popular in many schools and introduce the letters of the alphabet through fun activities, games and puzzles. These activity books were included to give children practice in phonological orientated activities which were arguably less challenging than the Sound Linkage training. For this reason parents were instructed to spend the second five minutes of each training session, when the child would be more tired, on Letterland activities. On days when the child was particularly tired, parents were told to spend the whole ten minutes on the Letterland activities rather than abandon a day's training altogether. However, it was stressed that this should be considered the exception rather than the norm and that on as many days as possible the Sound Linkage training should be given too. It was hoped that working through the books would be fun and stimulating for both parents and children. (See Appendix 8 for photocopied examples from part of a Letterland Activity Book)

Completion of the Letterland exercises were considered self-explanatory due to the full instructions on how to use the books included inside the front cover of each book. The parents were told where to find these instructions. Instructions inside the front cover were as follows:

How to use this book:

As you start each page, take time to read the directions to your child and answer any questions he or she might have.

Approach each page with enthusiasm and build your child's confidence with encouragement and praise. Continue only for as long as your child is interested.

This book is fun. Never let it feel like hard work!

Look for opportunities to talk about the letters and words you meet. On each new letter page, you could draw your child's attention to other words beginning with that letter, leading to a simple I Spy game. "Clever Cat went shopping and bought a cabbage, a camera, a ..." is another game you can enjoy together.

How to pronounce the letters:

Don't use the alphabet names "aee, bee, cee". These names are no help to a child learning to read. You can hear the correct letter sound as soon as you start to say the Letterland character's name, i.e. Clever Cat. Don't add "uh" to the sound.

How to hold the pencil:

Check that your child is holding the pencil correctly. It should be held lightly between the thumb and forefinger, about 2 cms from the point. The pencil rests on the middle finger.

Four activity books were included in each workbook to account for all abilities. The order in which they were found in the folder was one of increasing difficulty:

- Red book 1 (intended to help in child's pre-school skills, including pencil control, co-ordination and concentration).
- Red book 2
- Yellow book 1
- Yellow book 2 (intended to introduce child to the shapes and sounds of letters including lower case letters and capital letters)

It was not intended that there be a fixed progression through the Letterland folder and this was made clear to parents.

Extract from workbook instruction: "I did not really intend there to be a fixed progression through the Letterland folder. I have structured it so that you can dip in where you please. However the books are presented in order of difficulty, and so you may decide to progress through the books in an orderly fashion, or you may choose to give them more practice in the particular area they are covering in class at that time. Its completely up to you how you do it, so long as they are practising some form of phonology each day".

As with the other training, parents were told to try and keep the Letterland and Sound Linkage training challenging for the children, yet were warned against over-stretching their children on the activities. One of the intentions of the phonological training was to support what the child was learning in class, giving them extra practice in areas which they had already been taught. However, it was also inevitable that new concepts would be introduced to the children at some stage in the training, particularly in their progression through the Sound Linkage programme. Many of these concepts could be expected to be quite taxing for this age of child, so parents were told to have no hesitation in returning to and expanding on easier work as necessary. As explained above, clear discontinuation instructions were given throughout the Sound Linkage programme.

Mathematics Training Tasks

(This condition was included as a control for the Hawthorne effect).

Parents were instructed to work with the children on the maths activities once a day for 10 minutes for the 40 days training duration. Understandably, children were sometimes unable to complete individual day's training due to unforeseen circumstances such as illness. Parents were instructed to note such 'days off' in the 40 day calendar provided, (this calendar was the same for all three training programmes, an example can be seen at the beginning of the balance workbook found in Appendix 5) and wherever possible to complete the missed training days at the end of the 40 day period, thus ensuring that all subjects completed a full forty sessions. Parents were instructed to carry out the training in a room free from distraction, as the children needed to be able to hear and concentrate in order to perform at their best.

Care had been taken to ensure that the books used in the training study were not those utilised by the children's teacher in class. This ensured that the concepts taught within the classroom were presented in a different format and not avoided altogether. The underlying aim of the training was not to teach new mathematics skills to the children, but simply to ensure that they spent the requisite amount of time each day working through maths problems. Parents were warned against attempting to teach their children too many new concepts, and thus over-stretching them, since this could interfere with their classroom learning, affect motivation levels, and lead to constant struggling with new material rather than working towards fluency of performance in acquired skill areas. Equally however, it was important to keep the training challenging to ensure possible training effects were maximised and the children's interest maintained.

Enough material was provided to cover the different ability levels of all the children participating in the study (based on teacher's comments of ability and workbook content). Parents were under instructions to inform the author if they ran out of material, or if material was found to be inappropriate for the child's ability at any stage of the training programme.

The mathematics folder was divided into four different sections, which corresponded with the different activity books used, roughly speaking the easier books being found at the front end of the folder, and the harder ones towards the back. The complete books were photocopied in each workbook. Each exercise within the books was self explanatory, with brief explanation given before each exercise as necessary:

(1) Dot to Dot in Space (Usborne Books)

(2) 'I can learn' Counting – book three (Whiteford and Fitzsimmons)

(3) Number Books – book one and two (Parker and Stamford)

(4) Maths Challenge Activity Books – level 1 and 2 (Kirkby)

The 'dot-to-dot' activity book was deliberately included to provide a less intensive and lighter alternative to the majority of the rest of the folder. Parents were instructed in the workbook, that in order to keep the training challenging, the 'Dot to Dot' should not be used everyday and/or for a complete 10 minutes training session. Rather it was to be used for part of the training session (say 5 minutes) when the child was 'having a bad day' and was tired or inattentive. Also a number of mathematical games were included in the activity books, along with less intensive tasks such as colouring pictures by numbers. This ensured a good selection of less demanding, yet still mathematically based task.

Unlike the Sound Linkage training, no fixed progression through the mathematics folder was intended, rather that parents 'dip into' the folder where they pleased, never being afraid to go back to easier work if they found they had overestimated their child's ability level. This was clearly explained to the parents in the workbook. The programme was intended to be as user-friendly as possible. Parents were encouraged to read each day's activity before working with the child to ensure they were happy with the material, understood it, and could present it in a natural way. In keeping with this, and provided that the intent of the instructions was not altered, parents were told it was not necessary to stick rigidly to the text and encouraged to think of ways of making a game out of a maths activity, particularly if the child was struggling to understand a concept. Parents were instructed to give children constant positive verbal feedback and praise, such a "well done", and "that's the idea" to maintain motivation. They were also instructed in the workbook to try to avoid giving any non-verbal clues when a child has to choose between two possible answers whilst completing the written maths tasks. It is possible to prime children by a change of intonation, stress or volume or by pausing before a word. Body language, such as changing eye contact, can also give a clue to the expected answer. For these reasons, parents were told that if helping verbally with maths tasks, to try to present items in a smooth and even manner.

No Training Group

This group was included as a control group for comparison with the three training groups. As its name suggests, this group did not participate in any kind of training with their parents. All subjects in this group underwent the same pre and post testing battery as the three training groups and attended school as normal along with the training group members.

Materials

Balance training group (Equipment given to each parent participating)

- Calibrated Variable Difficulty balance board based on Balamatric board designed and developed by Dr Frank Belgau.
- Coloured bean bags (approximately 4 per parent); plastic buckets (approximately 3 per parent) and skittles (approximately 4 per parent).
- Parental workbook, including general instructions, four example balance training sequences, daily diary, notes.

Phonological training group (Equipment given to each parent participating)

Phonological folder containing;

- Sound Linkage, (Hatcher, 1994) + photocopied record sheets and picture sheets.

- Selection of Letterland Activity Books (red and yellow books, suitable for ages 3 to 6 years)

- Parental workbook, including general instructions, daily diary, notes.

Mathematics training group (Equipment given to each parent participating)

Mathematics folder containing a selection of mathematics activity books to suit a variety of ability.

- Maths Challenge Activity books (Kirkby) (Level 1 and 2)

- Number books - Parker and Stamford. (Book one and two)

- 'I can learn' counting - Whiteford and Fitzsimmons. (Book 3)

- Dot to Dot in Space - Usborne Books.

- Parental workbook, including general instructions, daily diary, notes.

Results

The effects of the three intervention training programmes were evaluated in a wide range of skill areas, both academic related and 'non-academic'. However, for the purpose of this research and to allow for the scope of this thesis, performance changes in skill areas most pertinent to academic attainment will be presented.

Data is reported here for reading and spelling age and standard score, and for performance, verbal and full scale IQ. A standard score of 100 for a child indicates average performance for a child of that age, with scores of 90 and above falling in the average range. The means and standard deviations of the standard scores for reading and spelling are presented in Table 5(2) (see below), and the IQ scores are presented in Table 5(3) (see below).

Although study of Table 5(2) shows that the 'no training' group was slightly worse in literacy than the training groups, this difference was not significant. Statistical analysis revealed that there was no significant difference between the control group (no training) and the three training groups in the pre-test scores:

- Full scale IQ $F(3,29)=0.64$, NS
- Verbal IQ $F(3,29)=0.63$, NS
- Performance IQ $F(3,29)=0.63$, NS
- Reading Age $F(3,29)=0.61$, NS
- Spelling Age $F(3.29)=0.42$, NS

Table 5(2). Changes in WORD Reading and Spelling Standard Scores

'Literacy' standard score is the average of the reading and spelling standard scores

Standard deviations are in parentheses

	Age		Reading Standard Score		Spelling Standard Score		Literacy Standard Score	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Study 1								
Balance N=9	5.45	5.62	99.56	104.8	89.11	92.0	94.33	98.39
	(0.21)	(0.21)	(10.10)	(9.16)	(10.70)	(13.10)	(10.40)	(11.10)
Phonol. N=9 (7*)	5.44	5.61	95.43	101.3	87.71	94.00	91.57	97.64
	(0.29)	(0.29)	(6.68)	(8.56)	(13.30)	(12.50)	(10.00)	(10.50)
Maths. N=9	5.43	5.60	96.78	102.2	85.67	92.00	91.22	97.11
	(0.28)	(0.28)	(7.84)	(14.3)	(15.00)	(15.20)	(11.40)	(14.80)
No train. N=6	5.22	5.39	93.50	95.67	82.00	85.17	87.45	90.42
	(0.10)	(0.10)	(2.88)	(5.92)	(6.78)	(8.30)	(4.83)	(7.11)

* Two subjects from the phonological group were unavailable for post-test.

Table 5(3). Changes in Verbal, Performance and Full Scale IQ

	Age		Verbal IQ (prorated)		Performance IQ (prorated)		Full scale IQ	
	Pre	Post	Pre	Post	Pre	Post	Pre	Post
Study 1								
Balance N=9	5.45 (0.21)	5.62 (0.21)	93.33 (10.50)	104.6 (9.15)	90.00 (8.87)	106.10 (9.36)	90.56 (9.51)	106.00 (8.14)
Phonol. N=9(7*)	5.44 (0.29)	5.61 (0.29)	87.57 (15.80)	99.86 (18.80)	96.86 (12.60)	108.9 (17.6)	90.71 (14.8)	104.57 (19.2)
Maths. N=9	5.43 (0.28)	5.60 (0.28)	89.33 (13.50)	105.44 (11.80)	100.56 (17.10)	115.89 (14.96)	94.11 (14.59)	111.33 (13.32)
No train. N=6	5.22 (0.10)	5.39 (0.10)	84.33 (18.60)	84.5 (18.20)	84.50 (13.18)	96.33 (12.61)	83.33 (16.38)	89.00 (16.89)

* Two subjects from the phonological group were unavailable for post test.

Results continued:

At a general level, it may be seen that unsurprisingly and as predicted, all groups improved from pre to post training. A series of three factor analyses of variance was undertaken separately for each task, with the factors being pre/post, training type (phonological; maths; balance; no training control) and risk (at risk; mild risk; no risk). A summary of these analyses is presented in Tables 5(4) (see below), with Table 5(4a) presenting the effects of group, and Table 5(4b) the effects of risk levels.

Effect of training type: Reading and Spelling

It may be seen that for training type (Table 5(4a)), there is a significant main effect of intervention on all tasks, with significant differences from pre to post training. The overall effect of training type was not, however, significant for reading and spelling scores and there was no significant interaction between training type and time of test on any measure. This implies that for reading and spelling the training groups all improved significantly with no significant differences between the groups (i.e. the maths group improved as much as the phonology and balance groups). Furthermore, these results reveal that there were no significant differences in amount of improvement between the no training group and the three training groups, suggesting no additional benefit from training over and above normal maturational improvement.

Figure 5(1) provides a graphical display of the formal WORD reading and spelling test improvements between the groups, with data converted into age equivalents[5]. (The data for IQ improvements is presented graphically in Figure 5(2)).

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[5]The published WORD reading scales provide only a coarse conversion of raw scores to centiles and reading ages. Linear interpolation was used where appropriate to give a more sensitive conversion, with a slight underestimation of

Effect of training type: Verbal IQ

For verbal IQ, there is a significant main effect of intervention and a significant interaction between training type and time of test, ($F(3.19)=3.8$, $p<.05$). Post hoc analyses would have been beneficial here in order to see clearly which training groups showed significant improvements relative to the control group. Unfortunately, this technique was not available with the SuperAnova package used. An alternative approach is to look at a graphical display of the differences pre to post test for each training group (see Figure 5(2) below) to see which group showed the biggest improvement (performance and full IQ scores are also included here).

Effect of risk factor: Reading, Spelling and Verbal IQ

It may be seen from Table 5(4b) that the effect of time was significant on all but the reading age. The main effect of 'at risk' score was significant on all measures, however, as there was no interaction between time of test and risk levels, it seems that all three risk categories improved equally.

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ability for children younger than the 5.6 year olds for whom the interpolated scores were designed in previous studies (Nicolson *et al*, 1998).

Table 5(4a). Inferential Statistics for Training Type and Time of Test (Pre/post). Study 1

Study 1 Pre/post

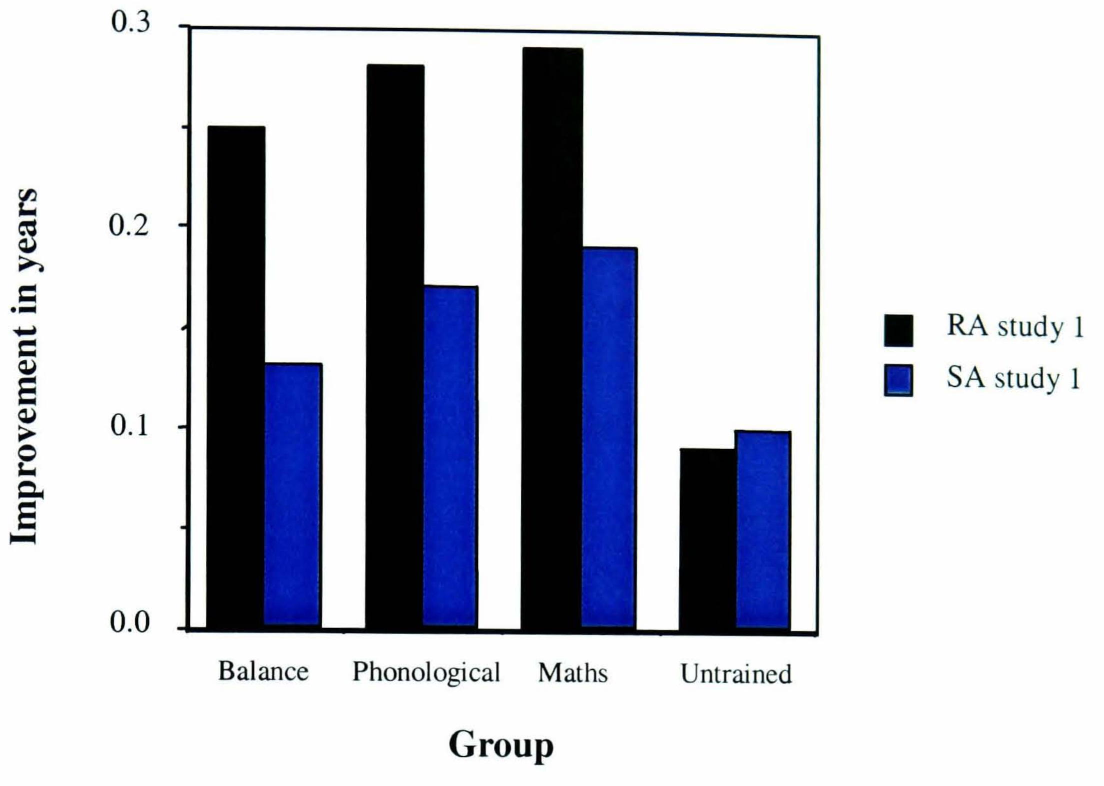
Task	Training Type	Time	Interaction
Reading standard score	F(3,19)=1.5 ,NS	F(1,19)=23.0, p<.0001	F(3,19)=0.6, NS
Spelling standard score	F(3,19)=0.8 ,NS	F(1,19)=14.8, p<.001	F(3,19)=0.8, NS
Reading age	F(3,19)=1.2 ,NS	F(1,19)=24.4, p<.0001	F(3,19)=0.9, NS
Spelling age	F(3,19)=0.9 ,NS	F(1,19)=11.3, p<.01	F(3,19)=0.3, NS
Verbal IQ	F(3,19)=2.7, p<.1	F(1,19)=34.7, p<.0001	F(3,19)=3.8, p<.05

Table 5(4b). Inferential Statistics for Risk Factor by Time of Test (Pre/post). Study 1

Study 1 Pre/post

Task	Risk Group	Time	Interaction
Reading standard score	F(2,19)=6.6, p<.01	F(1,19)=4.4, p<.05	F(2,19)=1.3, NS
Spelling standard score	F(2,19)=11.2, p<.001	F(1,19)=5.5, p<.05	F(2,19)=0.3, NS
Reading age	F(2,19)=7.5, p<.01	F(1,19)=2.5, NS	F(2,19)=0.7, NS
Spelling age	F(2,19)=9.1, p<.01	F(1,19)=3.55, p<.05	F(2,19)=0.9, NS
Verbal IQ	F(2,19)=9.1, p<.01	F(1,19)=3.8, p<.05	F(2,19)=0.6, NS

Figure 5(1) Improvements in Reading and Spelling Age by Intervention Group. Study 1



Age equivalent increases spelling and reading:

Figure 5(1) gives a clear graphical indication that there are improvements in reading and spelling for the intervention groups, with less striking improvements for the no-intervention group. Unfortunately though, as Table 5(4a) demonstrates, these differences are not significant. However, if we look at the actual age equivalent improvements, then it can be seen that comparable benefits were gained in the training groups: Over the two months of the study, the mean increases in reading age for the trained groups were at least three months, compared with one month for the controls. This does mean, however, that the improvement in the controls was less than the elapsed time, and so they were in effect getting further behind over the course of the study.

Closer analysis of individual scores shows that the majority of this effect can be accounted for by the size of increase in the 'at risk' children in the control group.

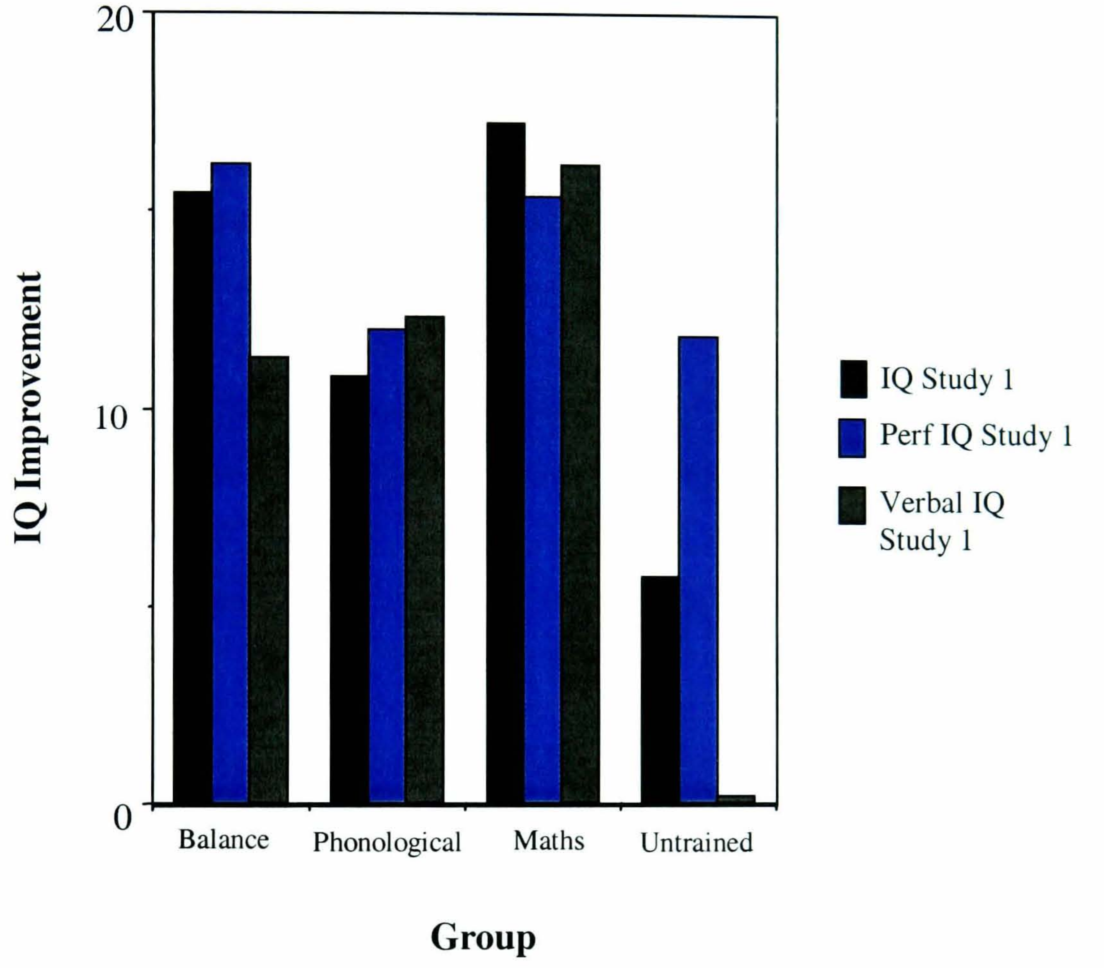
Assuming that these children may well have developed dyslexia, then it seems that this phenomenon is approximately in line with previous work (with older dyslexic children) in which Thomson (1984) estimates that on average dyslexic children improve only five months and three months for reading and spelling respectively per year. As will be discussed in the discussion, it would have been interesting to follow-up the no-training controls to see if they did, in fact, develop dyslexia in order to shed light on these results retrospectively.

By contrast with the no training group, the mean performance of the training groups has actually improved more than the elapsed time, so that they really are 'accelerating' to catch up with the rest of the class. Improvements in spelling are less striking, but in line with previous findings that spelling problems are more difficult to remediate (Thomson, 1984).

Increases in IQ:

Figure 5(2) below indicates that there are large improvements in all aspects of the IQ for the intervention groups. Of critical importance, however, is comparison with any improvement in the control group. Interestingly, the control group (no training) showed virtually no improvement in verbal IQ. This produced a significant improvement due to training for verbal IQ ($F(3,19)=3.8$, $p<.05$), which appears to be attributable to the maths group (note earlier comments about post-hoc analyses).

Figure 5(2). Improvements in IQ by Intervention Group. Study 1



Discussion

The results of this intervention study are mixed. When looking at the effects of training group, it can be seen that although there were improvements in all the training groups as predicted, there were also comparable improvements in the 'no-training' control group in all but the verbal IQ measure. This meant that with the exception of verbal IQ, intervention effects failed to reach significance and the prediction of an interaction between group and time of test was not met in the areas of reading and spelling. For verbal IQ, our prediction *was* met however, with analyses suggesting that training resulted in significantly improved performance compared to the non training group. However, it appears that this effect was due to the performance increase in the maths group, which was the group predicted to benefit the least in reading, spelling and IQ scores from training.

For seven hours of training by parents, all groups show a striking increase in verbal IQ of around thirteen points above the 'no training' condition. This may be attributable to the interaction between parent and child, with the child learning to listen, to concentrate, and to try to carry out the instructions, in other words, 'learning how to learn'. Most satisfactorily, ten out of eleven children with below average IQ's at pre-test, had improved to the extent that after training, their IQ had moved into the average range (moving from IQ range 70-90 to 90-110). By contrast, none of the no-intervention group demonstrated improvements in their IQ classification in this way. Of course, the children are still a little young for the WISC-R, and therefore the test as a whole tends to underestimate their abilities. Nevertheless, it has proved a useful tool in indicating generalisation from the training.

The impact of training on performance IQ scores is also of considerable interest here. It may be seen from Figure 5(2) that even the children in the no-intervention group show a marked improvement in their performance IQ score. Three factors may be at work here; attending school; normal development; and practice effects. These are sufficient to increase scores on performance IQ, because all develop awareness that speed is an important factor in success. By contrast, there is no natural improvement in the verbal IQ score, which is untimed.

It was predicted that the maths group would not show the same degree of improvement as the phonology and balance training groups in measure of literacy and verbal IQ. However, despite the fact that maths training would not appear to hold obvious benefits for reading, spelling and verbal IQ skill improvement, the maths group improved to the same extent as the other training groups. In fact, study of Figure 5(1) and 5(2) suggest that if anything the maths groups improved slightly more than the other two training groups, producing the significant verbal IQ improvement,

When looking at the 'at risk' categories, statistical analysis revealed that there was no significant interaction between risk group and time of test i.e. there were no significant differences in the amount of improvement pre to post training between the different risk categories. It was tentatively predicted that the 'at risk' group would show less improvement in the balance (and phonology) training due to cerebellar involvement in this skill execution and proposed weakened cerebellar activation in the 'at risk' group. This prediction failed to be met since there were no significant differences in the improvements shown by the different risk categories in any of the training groups for any of the measures.

This prediction was however based on the assumption that the 'at risk' group were in effect undiagnosed dyslexics. However, this was in part speculation based solely on scores on the DEST (Nicolson and Fawcett, 1996). It would have been interesting to see whether these children did in fact develop dyslexia (with or without intervention) by performing a follow-up study on the 'at risk' children (see below for further discussion).

Despite the apparent failure of this study to produce many significant findings. It should not be overlooked that the training groups did still show a greater improvement over the eight weeks training than the control groups in literacy, suggesting that they were actually beginning to accelerate in their literacy abilities with training. The phonological skill intervention produced small improvements in reading and spelling skills, which generalised to overall improvement in IQ scores. Precisely as predicted, the balance training had equivalent or slightly stronger results, giving some tentative indication of support for skill transfer (possibly due to cerebellar influenced skill transfer) through balance training. For seven hours of training by parents, all groups show a reading age increase of around two months, and a spelling age increase of around one month more than the 'no training' condition. However, somewhat surprisingly, our maths control study also produced equally strong results.

Looking at the performance of the no intervention group, by contrast, it may be seen that improvements in reading and spelling are minimal.

However, as the differences between the groups failed to reach significance on any task[6], it remains that our original predictions were not confirmed. The large improvements in the maths group indicate that the Hawthorne effect may have been playing a more significant role in the demonstrated performance improvements than expected. Certainly it seems that this effect may be stronger than any proposed effect due to skill transfer through cerebellar training.

It is worth considering again at this point the limitations of this study: Firstly, it was an extremely small-scale study. This programme needs re-examination with a much larger subject group before firm conclusions can be drawn; Secondly, the children were young and only just on the point of 'taking off' with their literacy skills. Older children might have shown greater sensitivity to training. Also the subjects were slightly too young for the WISC, a more valid indication of IQ performance might have been found with older children; Thirdly, it should be remembered that this training was carried out by unskilled parents at home and so control was difficult. In many ways, the degree of performance improvement shown, although small is still an immense achievement when this is considered. The balance training needed particular dedication since it was not a simple 'paper and pencil' form of training, and this may have 'dampened' results somewhat. Arguably the phonological Sound Linkage training involved the most skill from the trainer (parent), and again this may have resulted in somewhat lower scores for this group. These opinions were supported in the comments received from parents, some of which have been summarised in Appendix 9. Taken together, these considerations may also go some way towards explaining why, comparatively, the maths group did so well (see below for further discussion).

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[6] Apart from a significant difference on the verbal IQ improvements, attributable to the maths intervention group

Children 'at risk':

An important issue arising here and worthy of further discussion is how successful the interventions have been for the 'at risk' children, who can be resistant to intervention. The balance training is the most successful in improving reading for the children in the 'at risk' group, giving some support for the hypothesis of skill transfer through balance (cerebellar influenced) training, with phonology a close second (see Table 5(5) below). The pattern for spelling is more variable, with a slight decline for the balance 'at risk' group. This however contrasted with a striking ten point increase in standard score for the 'mild' risk, and an impressive twenty one point improvement in standard score for the phonological 'mild' risk group. The maths group show a steady 5-7 point increment in standard score across the risk groups, whereas the untrained group, by contrast show little or no improvement. In summary, unlike many studies of this type, improvements are not limited to the higher achievers[7], but are most striking in those children with mild difficulties. However, although all these results are in a positive direction, it should be remembered that results are not significant.

Effects of parents administering training:

However, one issue which we had not been able to address in this study was the special effect of parents working with their own children. As already emphasised, the format adopted necessitated a certain loss of experimental control in maintaining exact consistency, particularly in the balance training programme. This was unavoidable in training implemented by parents at home,

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[7] The children in the no risk group improve their reading with intervention of all types, with an 11 point increase from the maths training, and even a 6 point increase in the untrained group. Interestingly however, they show little or no effect of intervention on spelling across the conditions.

working with children of different initial skill levels with different rates of progress. Moreover, parental reports suggested that some of the interventions were easier to implement than others. The maths training proved the easiest, the most clearly prescribed and the least interactive.

Consequently, parents of the maths group, having developed a commitment to intervention, may have augmented their prescribed programme with extra literacy-based tasks. By contrast, the balance and the phonological skills training proved somewhat taxing for untrained parents. The phonological programme was complex, demanding not only pronunciation of the stimuli, but also evaluation of the response. In the balance programme, parents tended to repeat sequences which they and their child found accessible, rather than developing more challenging sequences to stretch the children.

This parental feedback information was gained in a number of ways. Entries were made by parents at random during the balance training period in the general comments section of the workbooks, (some parents chose to note down observations on a daily basis, resulting in a progressive diary of performance changes during the training period). Also, the author visited all parent and child balance volunteers at their homes mid-way through the training programme to elicit from parents any informal comments on the training to date. Furthermore, as part of this visit, the author videoed all subjects performing a section of one balance training sequences (chosen by the child and parent) to enable a qualitative record to be made of performance to compare with parental comments. At the end of the training session, the author telephoned the parents involved in all three studies, balance, phonology and maths. The purpose of this was to ask the parent's opinions as to the success of the programme and whether they had any particular comments to make or observations to bring to the attention of the author. More detailed reports of the feedback from parents can be found in Appendix 9.

Notwithstanding these difficulties, a certain loss of scientific control seemed justified by the importance of evaluating the potential of these programmes for future home-based intervention programmes. Nevertheless, it was clearly important to check that these results were not simply an artefact of the experimental design.

Looking forward:

The question arises, would significant differences be found by addressing some of the shortcomings of Study 1; firstly by using a slightly older group of more appropriate age for the WISC-R; and secondly by adopting a more strictly controlled approach? If the training was administered consistently within groups by using a researcher to deliver the intervention rather than parents could these results be replicated and extended? This would suggest that any future parent based interventions would benefit from ongoing structured support within the school environment.

These questions provided the motivation for Study 2, which was designed to address these issues.

Table 5(5): Outcome as a Function of 'At Risk' Scores for the Intervention Groups in Study 1

Groups for Study 1 are based on the Dyslexia Early Screening Test (Nicolson and Fawcett, 1996). An 'at risk' index corresponds in this study to a score of 0.8 or above, a mild index has a score 0.3-0.7, and a 'not at risk' index has a score 0.2 or less.

	Verbal IQ	Reading Standard Score			Spelling Standard Score			Literacy Standard Score			Effect size	
		Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up	Post vs pre	Follow-up vs pre
At risk												
Balance	87.67	93.33	99.33	N/A	80.33	77.67	N/A	86.83	88.5	N/A	0.18	N/A
Phon	74.33	89.5	93.50	N/A	74.50	77.50	N/A	82.00	85.50	N/A	0.38	N/A
Maths	78.33	90.33	93.00	N/A	75.00	79.00	N/A	82.67	87.5	N/A	0.52	N/A
Untrain	85.00	91.00	93.00	N/A	75.00	79.00	N/A	83.00	86.00	N/A	0.32	N/A
Mild												
Balance	98.33	107.33	109.33	N/A	91.33	101.67	N/A	99.33	105.50	N/A	0.66	N/A
Phon	77.67	92.00	96.00	N/A	81.50	102.00	N/A	86.75	99.00	N/A	1.32	N/A
Maths	90.33	96.00	98.33	N/A	84.00	91.00	N/A	90.00	94.67	N/A	0.50	N/A
Untrain	64.00	92.50	91.00	N/A	81.00	87.00	N/A	86.75	89.00	N/A	0.24	N/A
No risk												
Balance	94.00	98.00	105.67	N/A	95.67	96.67	N/A	96.83	101.17	N/A	0.47	N/A
Phon	102.00	101.67	110.00	N/A	100.67	99.67	N/A	101.17	104.83	N/A	0.40	N/A
Maths	99.33	104.00	115.33	N/A	98.00	103.00	N/A	101.00	109.17	N/A	0.88	N/A
Untrain	104.00	97.00	103.00	N/A	90.00	89.50	N/A	93.50	96.25	N/A	0.30	N/A

Part Two

Chapter 6

A Comparative Evaluation of Intervention Techniques for Children 'At Risk' in Primary School: A School-Based Intervention Programme

Introduction

Motivated by the questions arising from study one, study two was designed with the primary intention to address these issues. A number of questions arise from the first study which this second study attempts to address: Firstly are the mixed results in study one an artefact of parental involvement and lack of experimental control? If so, can they be strengthened and improved using an experimenter working within a more tightly controlled training regime? Secondly, will older children produce stronger findings, thirdly will similar increments in IQ scores be found and finally, is the length of the intervention of critical importance, or can similar results be found using an intervention programme which is even shorter if more tightly controlled? An important addition to study two was a follow-up study, which was undertaken six months after the intervention, to check whether or not there were any persisting effects due to the intervention, and whether the type of intervention was critical to long term outcomes.

Design

The overall design of study two was the same as that for study one. The two studies were identical in the three methods of training adopted; phonological, balance and mathematics. Again a no-training control group, matched for reading and age with the experimental groups, but with no explicit intervention, was used to allow comparative progress to be assessed. Virtually identical materials for training were used in all training groups. The intervention techniques were modified on two counts. Firstly the phonological skills training omitted the Letterland component, thus ensuring that the full programme was set at the more complex level; and secondly the balance training incorporated a pendulum and target stand, which introduced a further layer of challenge into the training programme. The maths programme remained unchanged in each training programme. The experimenter worked through an identical workbook as that given to parents in study one. Performance of the groups on the same reading-related standardised tests was measured both before and after the four week training period. As before the critical variable was the amount of improvement for the experimental groups and the control group from pre-test to post-test. The differential improvement of the experimental groups would give an indication of the relative effectiveness of the interventions.

The key differences between the two studies were the person administering training, the environment in which the training was undertaken and the duration of the training programmes. Unlike study one, the experimenter (author) performed the pre and post testing as well as the training. In study one, the author carried out the pre and post testing, but it was the parents (at home) who managed the training study. In this study the training was managed single-handedly by an experimenter (the author) in school (i.e. the subjects were removed from class for the duration of the 10 minute training session, every day, for the duration of the training period). Furthermore, a shorter four week intervention was undertaken. There were also differences in the initial classification procedure for subjects. Instead of using the DEST (Fawcett and Nicolson, 1996), teacher's recommendations of ability were used to group subjects.

The children chosen for this second study were from a deprived area of Sheffield, and it was reasonable to predict that they were strongly at risk of failure in literacy skills. The short-term nature of the intervention coupled with the severity of deficits in these children was a stringent test of the efficacy of the interventions under evaluation.

It should be noted that a total of 12 subjects (4 in each training group) started the training. This is an even smaller sample size than study one, resulting in a very small-scale study. Due to the fact that the author was carrying out all the training for each child on her own, it was unworkable for a bigger scale programme to be undertaken. However, the scale of this study should be born in mind when interpreting results. As sample size is so small, the effects of attrition are felt particularly strongly. Unfortunately the duration and intensive nature (daily training) meant that a number of subjects were lost through attrition. To be precise, one child from each of the training groups was lost; two for post testing and one before follow-up.

Predictions and Hypotheses

The general prediction for this school training programme was that put forward for study one, namely there would be a significant interaction between training group and time of test, i.e. all training groups would improve from pre to post in the tests measured, but that the training groups would improve significantly more than the no training group. It was predicted that the increased rigour of school-based training, and the older children would produce stronger findings than study one. This time, it was more cautiously predicted that in the literacy pre and post tests (reading, spelling and IQ), the phonological and balance training groups would perform significantly better than the maths 'control' group. It was hoped, that as the author was performing all training, and was highly familiar with all three programmes (having designed them), any effects due to differences in ease of application of the three training programmes would be reduced.

In terms of ability grouping, it was predicted again (albeit even more cautiously) that children of low ability ('poor' in the study two classification) would show less beneficial effects of training, particularly in balance, due to weaker cerebellar activation across the proposed learning route (see Nicolson *et al.,* 1999). However, this prediction is even more cautious than in study one (where this effect failed to be found) due to the subjective nature of selection based on teacher's recommendations, compared to the more objective screening test (the DEST) used to classify children in study one.

In this study, much greater control of the training was possible due to the author carrying out all training. It was expected that this increased control would be reflected in an increased strength of results when compared to study one.

Selection of Subjects and Groups

The three training conditions were balance, maths and phonological training, with equal numbers in each condition of children classed as 'poor', 'medium' and 'good' on teacher's recommendations of ability. Subjects were assigned randomly to the training condition. This design allowed study of the effects of two factors, namely training type and level of ability.

Subjects

The children selected for this study were somewhat older than those used in study one. The mean age for the group was 6.3years, and all children were drawn from year one of Wyborne School, Sheffield. The Wyborne estate is a deprived area of Sheffield, and it was reasonable to predict that the children were strongly at risk of failure in literacy skills. Children participated with fully informed parental consent and commitment to undertake the full training. Unlike study one where children were split into groups by objective measurement of performance on a range of skill areas, in study two ability grouping was based on teacher's recommendations derived from their knowledge of the children's ability in the classroom. Accordingly, groups were split into poor, medium and good ability. In view of the intensive nature of the training for the researcher, smaller numbers were included in each training group. Twelve subjects (six male, six female) were split evenly between the groups with at least one of each ability category within each training group. None of the subjects had emotional or behavioural problems, or any evidence of ADHD (based on teacher's reports). No children had any prior experience of the training, but some overlap between concepts learnt in training and in class was inevitable, for the maths and phonological skills training. See Table 6(1) below for psychometric details of the subjects.

Table 6(1). Psychometric Data for the Three Groups. Study 2

Training Group	**Year**	**Number (at pre test)**	**Mean CA[8] (at pre test)**
Balance	Year 2	4 (3)* (3**)	6.24
Phonology	Year 2	4 (3)* (3**)	6.23
Maths	Year 2	4 (4*) (3**)	6.25
Total subjects		**12 (10*)** (9**)	

* numbers in parenthesis represent number of subjects participating at post-training session.

** numbers in parenthesis represent number of subjects participating at follow-up session

There were four subjects in each training group at the start of the study, with at least one of ability category within each training group: Balance – one poor, two medium, one good; Phonology – one poor, one medium, two good; Maths – two poor, one medium, one good.

Due to attrition effects, there were only three subjects in each of the training groups by the end of training (see Table 6(2)). The balance group lost one

[8] Mean CA is calculated using only those children still present at post-test, i.e. it does not include those children present at pre-test who were subsequently lost through attrition.

medium ability child and the phonology its only poor ability child at post-test. The maths lost one of its poor ability children at follow-up.

Results

The effects of all three intervention programmes were evaluated in a wide range of skill areas, both academic related and 'non-academic'. As in study one, performance changes in skill areas most pertinent to academic attainment will be presented.

Data is reported here for reading and spelling age and standard score, and for performance, verbal and full scale IQ. A standard score of 100 for a child indicates average performance for a child of that age, with scores of 90 and above falling in the average range. The means and standard deviations of the standard scores for reading and spelling are presented in Table 6(2) (see below), and the IQ scores are presented in Table 6(3) (see below).

Statistical analysis revealed that there was no significant difference between the control group (no training) and the three training groups in the pre-test scores:

- Full scale IQ $F(3,14)=0.37$, NS
- Verbal IQ $F(3,14)=0.22$, NS
- Performance IQ $F(3,14)=0.34$, NS
- Reading Age $F(3,14)=0.69$, NS
- Spelling Age $F(3,14)=1.14$, NS

Table 6(2). Changes in WORD Reading and Spelling Standard Scores

'Literacy' standard score is the average of the reading and spelling standard scores

Standard deviations are in parentheses

	Age			Reading Standard Score			Spelling Standard Score			Literacy Standard Score		
	Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up
Study 2												
Balance N=4 (3*)	6.25 (0.08)	6.33 (0.09)	6.78 (0.04)	94.33 (7.77)	100.0 (15.00)	100.70 (23.90)	92.33 (13.50)	104.70 (33.80)	103.3 (20.7)	93.33 (10.6)	102.3 (24.1)	102.00 (22.25)
Phonol. N=4 (3*)	6.28 (0.09)	6.39 (0.05)	6.78 (0.09)	101.30 (11.60)	103.0 (9.54)	107.30 (18.50)	98.67 (3.79)	108.70 (14.50)	109.00 (17.6)	100.0 (13.0)	105.8 (13.6)	108.17 (5.1)
Maths N=4 (3**)	6.17 (0.09)	6.28 (0.05)	6.67 (0.09)	91.67 (3.51)	98.33 (4.16)	92.00 (6.56)	92.67 (12.20)	97.67 (10.50)	91.67 (4.51)	92.17 (7.82)	98.00 (6.87)	91.83 (5.1)
Control N=6	6.49 (0.14)	6.57 (0.14)	6.99 (0.14)	92.83 (9.93)	93.67 (8.55)	92.33 (11.08)	98.33 (15.20)	100.20 (17.80)	95.5 (14.8)	95.58 (12.6)	96.92 (13.2)	93.92 (11.7)

* 1 subject from each of the balance and phonological groups were unavailable for post-test

** 1 further subject from the maths group was unavailable for follow-up

Table 6(3). Changes in Verbal IQ, Performance and Full Scale IQ

Standard deviations are in parentheses

	Age			Verbal IQ (prorated)			Performance IQ (prorated)			Full scale IQ		
	Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up
Study 2												
Balance N=4 (3*)	6.25 (0.08)	6.33 (0.09)	6.78 (0.04)	89.33 (23.7)	103.00 (13.64)	102.33 (12.1)	97.00 (14.00)	117.00 (7.07)	117.67 (9.24)	92.33 (20.43)	110.00 (12.36)	110.00 (10.54)
Phonol. N=4 (3*)	6.28 (0.09)	6.39 (0.05)	6.78 (0.09)	84.00 (18.25)	103.30 (10.21)	96.67 (12.9)	93.67 (3.21)	110.67 (6.94)	105.00 (6.56)	87.00 (10.44)	107.67 (6.13)	100.67 (7.23)
Maths N=4 (3**)	6.19 (0.08)	6.31 (0.08)	6.69 (0.08)	86.00 (26.9)	102.67 (13.42)	87.67 (24.58)	97.33 (10.69)	118.67 (6.94)	106.67 (3.51)	90.67 (21.46)	111.00 (8.29)	95.33 (17.16)
Control N=6	6.49 (0.14)	6.57 (0.14)	6.99 (0.14)	87.33 (20.8)	95.00 (25.13)	92.42 (20.75)	87.83 (18.90)	106.67 (26.64)	100.61 (22.97)	86.83 (18.72)	100.67 (23.24)	95.97 (20.47)

* 1 subject from each of the balance and phonological groups were unavailable for post-test

** 1 further subject from the maths group was unavailable for follow-up

Results continued:

At a general level, it may be seen that all training groups improved from pre to post training. However, the critical question, as in study one, is how much the control group also improved and whether training groups improved significantly more than this control.

In order to address this question, a series of three factor analyses of variance was undertaken separately for each task, with the factors being pre/post, training type (phonological, maths, balance, no training control) and ability (poor, medium, good). A summary of these analyses are presented in Tables 6(4) (see below), with Table 6(4a) presenting the effects of training group and Table 6(4b) the effects of ability level.

Effects of training type: Reading and Spelling

It may be seen that for all training types (Table 6 (4a)), there is a significant main effect of intervention on all tasks, with significant differences from pre to post training. The critical finding here, for spelling is the significant interaction between training group and test time for spelling age ($F(2,5)=6.2$, $p<.05$), with a significant interaction 1 tailed also found for spelling standard score ($F(2,50=3.9$, $p<.1$). The latter finding indicates that there was significantly greater improvement for the trained groups than the untrained group in spelling at post-test. There was also a significant 1 tailed effect for reading age ($F(3,5)=4.5$, $p<.1$). (Reading standard score did not show a significant interaction).

As mentioned in study one, post hoc analyses would have been beneficial here, in order to clearly see which training groups showed significant improvements relative to the control group. Unfortunately this analysis was not available with the SuperAnova package used. Again the reader is directed towards the graphical displays of the differences pre to post test for each training group (see

Figure 6(1) below) to see which group showed the biggest improvement (follow-up scores were also included here).

Effect of training type: Verbal IQ

It can be seen from Table 6(4a) that although there was a significant effect of time (i.e. all the training groups improved significantly from pre to post test) in verbal IQ scores, there was no significant effect of training group and no interaction between time and training group, suggesting that all four groups increased significantly.

Effect of ability level: Reading, Spelling and Verbal IQ

Data was also analysed in terms of ability levels within the groups (see Table 6(4b)). There were significant improvements pre/post for spelling age (and one tailed for standard score), with interactions between time and ability level for Spelling standard score ($F(2,5)=8.4$, $p<.05$), Spelling age ($F(2,5)=10.5$, $p<.01$) and a one tailed interaction for Reading age ($F(2,5)=4.9$, $p<.1$). However, there was no significant interaction for verbal IQ, with no evidence of significant improvements in this measurement from pre to post test.

Table 6(4a). Inferential Statistics for Training Type by Time of Test (Pre/post). Study 2

	Study 2 Pre/post		
Task	**Training Type**	**Time**	**Interaction**
Reading standard score	F(3,5)=0.4, NS	F(1,5)=7.5, p<.05	F(2,5)=0.4, NS
Spelling standard score	F(3,5)=1.6, NS	F(1,5)=31.1, p<.01	F(2,5)=3.9, p<.1
Reading age	F(3,5)=1.1, NS	F(1,5)=51.4, p<.01	F(3,5)=4.5, p<.1
Spelling age	F(3,5)=3.1, NS	F(1,5)=34.0, p<.01	F(2,5)=6.2, p<.05
Verbal IQ	F(3,5)=1.7, NS	F(1,5)=17.6, p<.01	F(3,5)=1.2, NS

Table 6(4b). Inferential Statistics for Ability level by Time of Test (Pre/post). Study 2

	Study 2 Pre/post		
Task	**Ability Group**	**Time**	**Interaction**
Reading standard score	F(2,5)=12.6, p<.01	F(1,5)=0.3, NS	F(2,5)=0.3, NS
Spelling standard score	F(2,5)=41.0, p<.001	F(1,5)=3.8, p<.1	F(2,5)=8.4, p<.05
Reading age	F(2,5)=19.2, p<.01	F(1,5)=1.0, NS	F(2,5)=4.9, p<.1
Spelling age	F(2,5)=27.4, p<.01	F(1,5)=14.002, p<.01	F(2,5)=10.5, p<.01
Verbal IQ	F(2,5)=17.4, p<.01	F(1,5)=0.9, NS	F(2,5)=1.2, NS

Follow-up Test

It is particularly important to assess the extent to which any improvements survive the absence of continuing special support. Consequently follow-up tests of WORD reading, WORD spelling and WISC-R subtests were administered six months after the end of the intervention. The results are shown below in Table 6(4c) and 6(4d). Analyses of variance were undertaken with training group (intervention type vs control) and time of test (pre-test vs follow-up test) as factors, and taking the reading and spelling ages, standard scores and verbal IQ as dependent variables.

Effect of training type: Reading, Spelling and Verbal IQ

For reading and spelling age, the main effect of time was significant. However there was no interaction between training group and time, suggesting that all groups improved, but with no significant differences between them. When analyses were conducted with data collapsed across ability grouping, there was a significant main effect of time on spelling standard score ($F(3,11)=4.9$, $p<.05$). There was also a significant interaction between training group and time for spelling standard score ($F(3,11)=3.8$, $p<.05$), indicating that the balance and phonological skills interventions resulted in a significant and enduring change (see Figure 6(1)). In terms of the improvements in spelling score at follow-up, it should be noted that the success of the phonological skills intervention over time was inflated by attrition. Due to small group sizes, there was only one child in the 'poor' ability grouping at pre-test. This child was lost due to attrition before the post-tests and subsequent follow-up (see Table 6(5)).

The significant improvement in verbal IQ for all four groups persisted at follow-up, i.e. although there was no interaction between time and training group, the effect of time was significant.

Effect of ability grouping: Reading, Spelling and Verbal IQ.

Data were also analysed in terms of ability within the groups (see Table 4(d) below). With the exception of reading, none of the measures showed a significant effect of time. There were no significant effects on verbal IQ by ability grouping from pre/follow-up or spelling (spelling age and standard score). The effects on reading age did persist at follow-up with a significant interaction between time and ability grouping for reading standard score ($F(2,5,)=6.2$, $p<.1$).

Overall, results appear to suggest that the effect of the intervention had dissipated in the subsequent six months, particularly for the maths group, but that patches of improvement had been maintained, specifically for the balance and phonological groups in spelling.

Table 6(4c). Inferential Statistics for Training Type by Time of Test (Pre/follow up). Study 2

Study 2 Pre/follow up

Task	Training Type	Time	Interaction
Reading standard score	F(3,5)=4.0, NS	F(1,5)=2.7, NS	F(3,5)=1.2, NS
Spelling standard score	F(3,5)=0.7, NS	F(1,5)=3.7, NS	F(3,5)=2.9, NS
Reading age	F(3,5)=9.8, p<.05	F(1,5)=38.5, p<.01	F(2,5)=1.2, NS
Spelling age	F(3,5)=1.7, NS	F(1,5)=14.5, p<.05	F(2,5)=2.2, NS
Verbal IQ	F(3,5)=1.7, NS	F(1,5)=10.6, p<.05	F(3,5)=2.4, NS

Table 6(4d). Inferential Statistics for Ability Group by Time of Test (Pre/follow up). Study 2

Study 2 Pre/follow up

Task	Ability Group	Time	Interaction
Reading standard score	F(2,5)=91.9, p<.001	F(1,5)=1.2, NS	F(2,5)=6.2, p<.1
Spelling standard score	F(2,5)=20.7, p<.01	F(1,5)=0.2, NS	F(2,5)=0.3, NS
Reading age	F(2,5)=154.7, p<.001	F(1,5)=7.5, p<.05	F(2,5)=0.2, NS
Spelling age	F(2,5)=15.0, p<.05	F(1,5)=2.4, NS	F(2,5)=0.5, NS
Verbal IQ	F(2,5)=13.8, p<.05	F(1,5)=3.2, NS	F(2,5)=2.4, NS

Figure 6 (1) Reading and Spelling Improvements at Post Test and Follow-up (f. up). Study 2

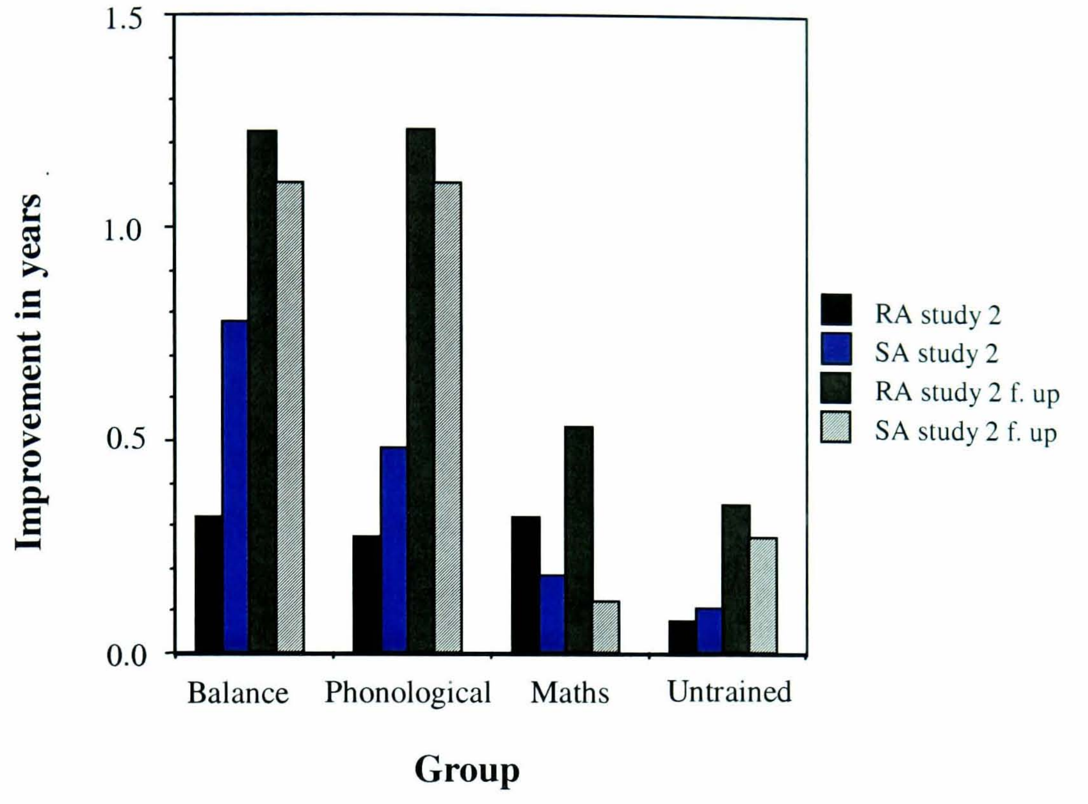
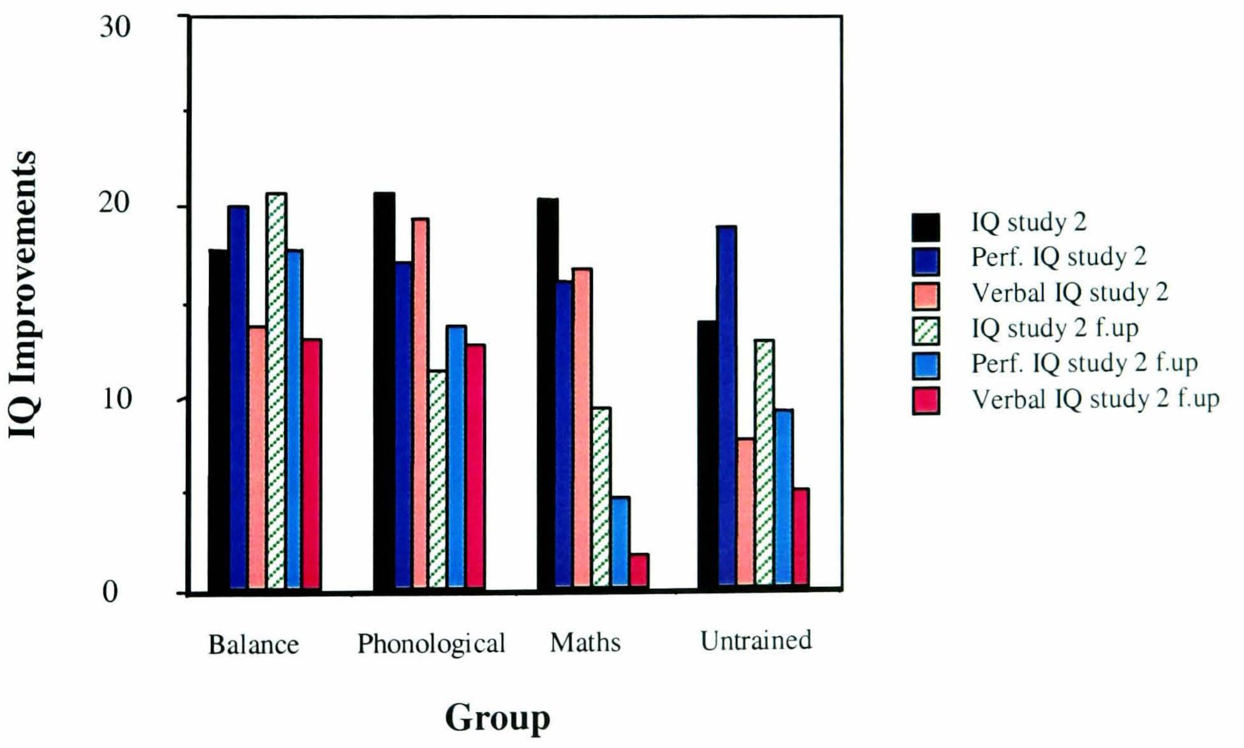


Figure 6 (2) IQ Improvements at Post Test and Follow-up (f. up). Study 2



Discussion

As in study one, original predictions for this study were that the training groups would show greater improvements than the no training control, and that the balance and phonological groups would show bigger improvements than the maths group in the literacy and verbal IQ measured presented. This hypothesis was not satisfactorily met in study one. In study two, training was more rigorous and children were older, so it was hypothesised that results would be stronger. It was again hypothesised, albeit tentatively, that in this study with more tightly controlled training, it might be possible to see the effect of cerebellum activation more clearly through bigger improvements in the balance group. Moreover, it was proposed that the 'poor' ability group in the balance group might show smaller benefits from this training compared to other ability groups, due to weakened cerebeller activity (Nicolson *et al.,* 1999).

As in study one, all groups showed improvements from pre to post training. However, unlike study one, in measures of spelling and reading there was a critical interaction between training group and time. This suggested that the training groups did actually improve more than the control group in these two measures from pre to post. In fact for 3.5 hours of training in school, the three intervention groups showed an average reading age increase of three months, and spelling age increase of six months more than the 'no training' condition. Improvements in the balance condition are particularly impressive here with an average spelling age increase of ten months. It thus seems that two of the original hypotheses have at least been partly met; the training groups showed a greater increase than the no training control in reading and spelling and particularly for the balance group. This latter finding gives tentative support for the possibility of skill transfer occurring (possibly due to cerebellar influenced skill transfer). However, it must be stressed that in all interpretations of results, the size of sample should not be forgotten. With so few subjects, it is impossible to make any firm conclusions as to the cause of results or in fact the pattern of results themselves. Findings should be viewed more as interesting indications of areas of research worthy of further investigation with a much larger sample size. Furthermore since the author performed both the pre and post testing as well as training, she was not blind to subject grouping and this may have influenced results to some degree, introducing a partial Hawthorne effect.

In this study, greater impact is made on spelling than reading ability, and the improvements in spelling persist at follow-up for the balance and phonological skills intervention. Again this finding appears to add support to the original hypothesis, that the phonological and balance groups would show the most benefit from training in these literacy and IQ measures. This benefit appears to persist six months after training. It seems that, in as much as any firm conclusions can be drawn for such a small-scale study, these findings confirm the benefits of intervention with this age group, even over this short time-scale and with the small numbers involved.

It should be stressed that standard scores automatically take age into effect, and so a stationary standard score value indicates that a child is maintaining normal progress. A significant standard score improvement is therefore very encouraging. It may be seen that overall, the trained groups were 'accelerated' over the period of training, moving from a mean standard score of 94.6 for reading to a mean standard score of 98.7, and a mean standard score of 92.5 to 101.7 for spelling. By contrast the control group improved from only 92.83 to 93.67 and from 98.3 to 100.17 for reading and spelling respectively

Not only were significant improvements made in reading and spelling, but this benefit of training also transferred to subskills of the WISC-R IQ test. The trained groups improved on both the verbal and performance scale, by contrast with the untrained group, who showed improvements only in the performance subscale, reflecting the effects of practice. All the trained groups showed an increase in verbal IQ of around eight points above the untrained condition. However, unlike study one, this increase was not statistically significant.

Children of poor ability

The question arises again – how successful was this intervention for children with difficulties, or is it only effective with children with strengths at pre-test? (See Table 6(4b and 4d) for statistical analyses and Table 6(5) for data). There was an eight point improvement in reading standard score for children with moderate difficulties on the balance intervention. Similarly, there was an eight point increment in reading standard score for the phonological training group with moderate difficulties. The children with moderate difficulties made the most progress overall. It was notable that the no training group made less than one point improvement in their standard score, therefore only maintaining their achievement level, rather than improving on it.

By contrast, it was largely the children in the 'good' group who improved their spelling standard score, with a quite exceptional thirty seven point increment for the balance training, and an eleven point increment for the phonological training. Only the maths training produced an improvement in spelling for the poor and medium group (7.5 and 8 points respectively), with an eight point improvement for the medium phonological group. The untrained group made variable progress, with the poorest children falling even further behind their peers over the course of the study. It was tentatively hypothesised that the 'poor' balance children would show less improvement than the other ability balance groups due to weakened cerebellar activation. It appears that for reading and spelling measures there is some evidence that this may be occurring. However, as stated before, all these results should be interpreted within the context of this very small scale study.

It seems therefore, that just as in study one, the training produced an increment in reading skills for children with difficulties, whereas improvement in spelling is more variable. However, results are as predicted, stronger in this study, with significant interactions between time and ability grouping for spelling and reading. It seems that a similar pattern is obtained in children classified 'at risk' by the DEST in study one and children identified by their teachers as showing poor literacy skills in study two. The children most 'at risk' ('poor' ability in this study) showed less improvements than the 'mild risk' ('medium' ability) and 'no risk' ('good' ability) children, with the 'mild risk'/'medium' ability children generally showing the biggest improvements in literacy.

In terms of transfer through balance training, it could be tentatively proposed that transfer may be happening for all ability children, but that a better initial ability is needed in spelling rather than reading for the largest effects of transfer (through cerebellar training) to be realised. This would support the general idea that spelling deficits tend to be more entrenched than reading deficits. Moreover, this finding supports predictions of cerebellar transfer, logically assuming those with high 'at risk' scores are most likely to be (as yet undiagnosed) dyslexics who thus suffer weaker cerebellar activation during motor learning processes (Nicolson *et al*, 1999). However, interpretation of the training effect is not easy and this study needs replication with a much larger sample size before any further conclusions are drawn. As with study one, it would have been interesting to follow the 'poor' ability children to identify dyslexia at a later stage. It would have been particularly informative to follow the no-training control group to identify the dyslexics at a later stage and then compare incidence back with the trained groups to see if he training appeared to have a beneficial effect on dyslexic symptoms (see Hurford *et al,* 1994; and also Borstrum and Elbro, 1997).

Interestingly enough, exactly as in study one, following intervention both children with below average IQ's moved into the average range (moving from the 70-90 range to the 90-110 range). By contrast, the IQ's of the children in the no intervention group remained low. Irrespective of whether increases are statistically significant or not, findings such as these, even from such a small-scale study, can only be encouraging.

Persistence of Effects

The final question arising is how persistent any improvements in literacy skills prove to be. In terms of the long-term progress of these children, improvements from intervention studies are notoriously difficult to maintain over time, once the direct intervention has ended. Based on predicted changes over time (Thomson, 1984) one might expect a decline over the six month period, so that the standard scores drop below the standard scores at post-test. However, the results here are encouraging. For reading and spelling the follow-up test results for both the balance and phonological groups are equivalent or better than the post test (a remaining six and nine point improvement respectively). The maths group shows less persistent effects, retaining only four and three point improvements. By contrast, the no-training group do not maintain any improvements at follow up. In terms of individual progress, all the children in the intervention groups (with one exception) maintained their improvement in spelling, whereas by contrast all the untrained group lost ground or at best performed at the same level as pre-test. The persistence of this spelling improvement was significant for both the balance and phonological groups when collapsed across risk score ($F(3,11)=3.8$, $p<.05$).

However, one of the most striking aspects of the follow-up data (see Figure 6(2)) is that children with medium to good skills continued to improve, whereas those with poor initial scores fell back over time, with standard scores at the end of the follow-up period somewhat lower than their initial pre-test scores (see Table 6(5) below for details).

It is clear that many of these children need ongoing support, though not necessarily at the same level of intensity as during the intervention itself. The children with poor initial scores, falling at standard scores of around 90 or less, showed particularly entrenched difficulties, which warrant more sustained intervention in order to maintain the improvements noted directly after the intervention.

Only 56% of children in the intervention groups did not slip back over the subsequent six months, as measured by a delayed test literacy standard score of at least 92.5, or having a follow-up test literacy score at least equal to the post-test score. These children had accelerated to the stage where they could keep up with the rest of the class.

Table 6(5): Outcome as a Function of Ability Scores for the Intervention Groups in Study 2
Groups for Study 2 are based on teacher's ratings.

	Verbal IQ	Reading Standard Score			Spelling Standard Score			Literacy Standard Score			Effect size	
		Pre	Post	Follow-up	Pre	Post	Follow-up	Pre	Post	Follow-up	Post vs pre	Follow-up vs pre
Poor												
Balance	63.00	88.00	85.00	84.00	79.00	79.00	89.00	83.50	82.00	86.50	-0.14	0.28
Phon*	-	-	-	-	-	-	-	-	-	-	-	-
Maths	55.00	88.00	97.00	85.00	82.00	87.00	87.00	85.00	92.00	86.00	0.66	0.09
Untrain	63.00	83.00	84.5	80.5	80.00	78.00	77.00	81.50	81.25	78.75	-0.02	-0.26
Medium												
Balance	109.00	92.00	100.00	90.00	92.00	92.00	94.00	92.00	96.00	92.00	0.38	0.00
Phon	63.00	89.00	97.00	86.00	82.00	90.00	89.00	85.50	93.50	87.50	0.75	0.19
Maths	100.00	92.00	95.00	98.00	90.00	98.00	92.00	91.00	96.50	95.00	0.52	0.38
Untrain	94.50	91.5	93.50	91.50	105.50	111.00	104.00	98.50	102.25	97.75	0.35	-0.07
Good												
Balance	96.00	103.00	115.00	128.00	106.00	143.00	127.00	104.50	129.00	127.50	2.30	2.16
Phon	94.50	10750	106.00	118.00	107.00	118.00	119.00	107.25	111.50	118.50	0.45	1.06
Maths	103.00	95.00	103.00	9300	106.00	108.00	96.00	100.50	105.50	94.50	0.47	-0.56
Untrain	104.50	104.00	103.00	105.00	1095	111.5	105.5	106.75	107.25	105.25	0.05	-0.14

* The only child with poor skills in the phonological group left before the post-tests.

Limitations of Study Two

Inevitably, a study of this type, whereby intervention is conducted on an individual daily basis, can only involve a limited number of children. As stated throughout the discussion, all results must therefore be interpreted within the context of such a restricted design. Unfortunately, there was also a high level of attrition within the catchment area, based on a mobile population transferring between different council estates, typically without leaving a forwarding address. As group sizes were so small, the loss of even one subject could have a large impact on results. For this reason these findings should be considered interesting, pointing towards areas worthy of further research investment in order to add weight to the findings here.

Comparing Study One and Study Two: Results and Discussion

In both short term intervention studies, either using the parents as trainers or providing in-school intervention, encouraging improvements were found in literacy standard scores. Both these studies were extremely small, but it is still worth examining whether one study was more effective than the other in order to provide valuable information for future researchers developing intervention programmes. Although study one was run for twice the length of study two, it was conducted by untrained parents, which unavoidably introduced a lack of training control, so the two studies are therefore roughly comparable.

Effect size analysis

In intervention studies of this type when comparing two different training programmes, it is normal to convert the improvement to an 'effect size' that gives an index of the improvement relative to the original performance mean and variation of the class (Cohen, 1977). The effect size is calculated as the amount of improvement divided by the standard deviation of the original performance of the class(es). This allows us to compare the effects of the two interventions, uncontaminated by any differences in initial ability and differences in variability within the groups. However, it should be noted that effect sizes can therefore exaggerate findings to a certain extent, especially when the standard deviations of the reference group are small. Using effect size analysis, the literacy scores of the two training studies will be analysed, with data presented both as standard scores and achievement age.

Table 6(6)

Effect Sizes for the Improvements in the Different Groups.

Effect sizes are calculated by dividing the amount of improvement from pre-test to post-test (or delayed test, as appropriate) for each group by the standard deviation of the cohort of all the classes in the pre-test.

	Post-test vs Pre-test			*Follow-up test vs Pre-test*		
	Reading	Spelling	Literacy	Reading	Spelling	Literacy
Study 1						
Balance	0.68	0.24	0.44	N/A	N/A	N/A
Phonol.	0.77	0.53	0.65	N/A	N/A	N/A
Maths	0.71	0.53	0.63	N/A	N/A	N/A
Control	0.28	0.27	0.29	N/A	N/A	N/A
Study 2						
Balance	0.64	0.90	0.84	0.71	0.80	0.81
Phonol.	0.19	0.73	0.55	0.67	0.75	0.77
Maths	0.53	0.46	0.55	0.04	-0.07	-0.03
Control	0.09	0.13	0.13	-0.06	-0.21	-0.16

Figure 6(3) Comparison of Effect Sizes for Reading and Spelling Ages for Study 1 and Study 2

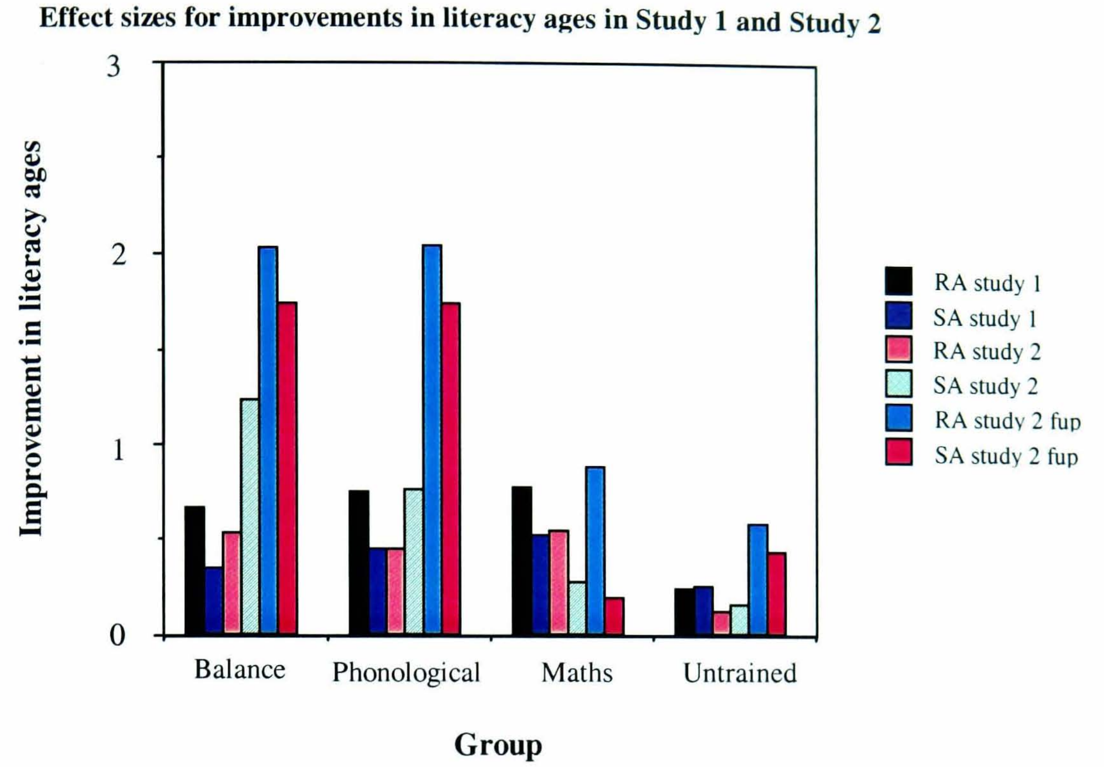
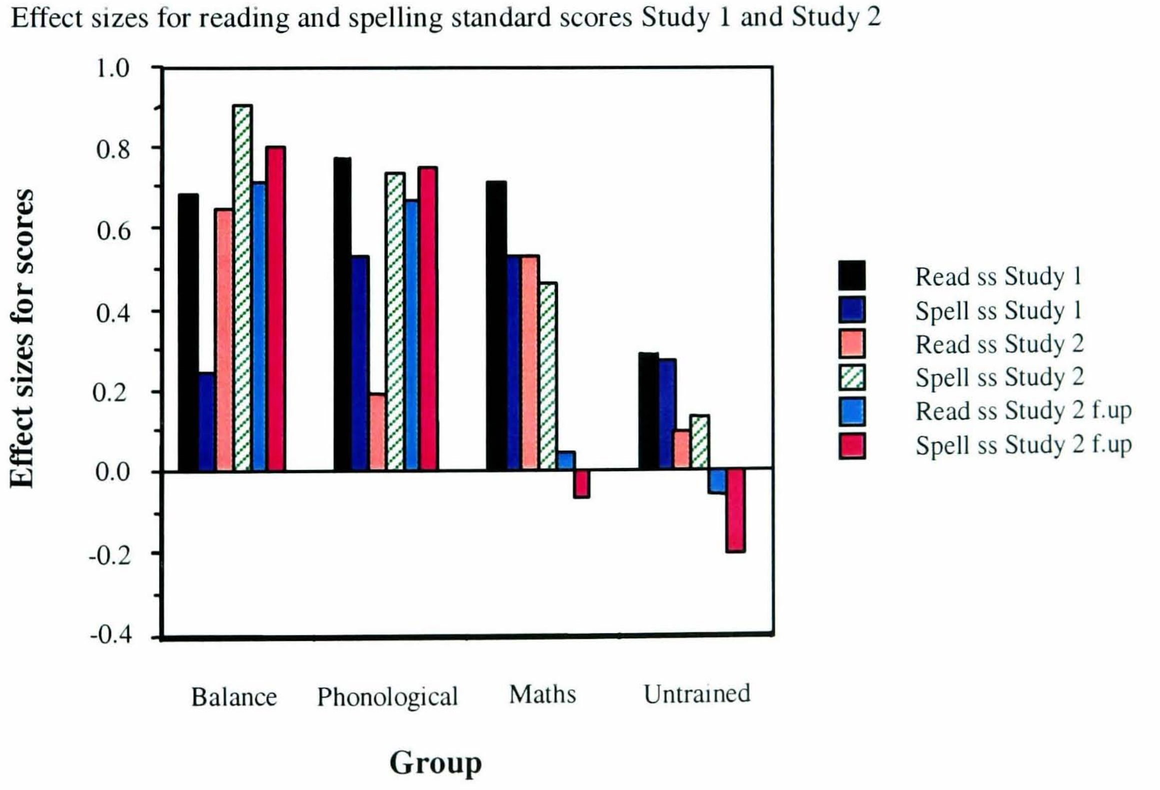


Figure 6(4) Comparison of Effect Sizes for Standard Scores for Study 1 and Study 2



It may be seen from Figure 6(3) and 6(4) above, that the children in the intervention groups show higher effect sizes overall than the untrained group. Let us consider which is the most useful outcome measure, achievement age or standard score. It seems that using the improvements in reading age alone may give an over optimistic picture of progress. From Figures 6(3) and 6(4), age equivalents show higher effect sizes than standard scores, because age is automatically controlled for in the latter, and so the improvements seem smaller. The decline in effectiveness of the maths intervention over time can be clearly seen from the effect sizes for standard scores.

Inevitably, there are improvements in the untrained group as well, reflecting the natural processes of development and exposure to the school curriculum. By this stage, reading and spelling might be predicted to 'take off' in response to normal school input. Does this mean that children of this age would progress adequately without any intervention? Figure 6(4) above clearly indicates negative effect sizes for the untrained group in the follow up study. Moreover, if we subtract the effect size for the control group from that for the intervention groups, we can see that the 'added value' effect size for literacy overall in the parent intervention study is 0.15 for balance training, 0.37 for phonological training and 0.35 for maths training, whereas the 'added value' effect size for the in-school study is 0.72 for balance, 0.42 for phonological, and 0.42 for maths training.

Interestingly, at follow up the 'value added' effect persists and strengthens for both balance and phonological training (0.97 and 0.92 respectively). By contrast the effect size for maths dissipates, falling to 0.13 (see Figure 6(4) above). We can therefore conclude that all interventions appear to lead to greater progress than the no training condition. However, it seems that despite its effectiveness in the short term, the maths training produces little lasting effect on literacy scores.

Overall, these comparative results suggest that phonological intervention, as predicted, has a lasting impact on the early development of literacy skills in young children. This would support a wealth of evidence to suggest that phonological intervention has such benefits (for example, Bradley, 1988; Bradley and Bryant, 1983, 1985; Lundberg Frost and Peterson, 1988). More specifically, the strength of improvement in the phonological groups, would appear to add indirect support to the phonological-linkage theory (see Scheider *et al,* 2000). This states that phonological intervention will be particularly significant in effect when combined with reading. The phonological group, were being explicitly trained in phonological awareness as part of the training, but in addition were also receiving structured daily reading support in class as part of the literacy hour. This theory could maybe provide an additional explanation as to the comparative strength of increase in the phonological groups.

Although, results in the balance training group are particularly hard to interpret, they seem to indicate that, exactly as predicted by the cerebellar deficit hypothesis, balance training may have considerable potential for lasting improvements. Little research into the effects of balance training exists, and as discussed in Chapter 4, the research that does exist tends to be of weak methodology and design (see Bluechardt *et al.,* 1995). So despite the considerable limitations of the study reported here, these balance findings are still surprisingly positive and so warrant further investigation.

Cost-effectiveness

Next, in order to consider cost-effectiveness, it is necessary to derive a quantitative measure of the gains and the costs. There were really no costs involved in the parental training, but for the sake of comparison with the school-based study, cost-effectiveness is calculated on the number of hours involved. The researcher in Study two was neither a teacher nor a reading specialist, but represents the type of support that should be widely available with 'ordinary' teachers or Child Care Assistants (CCA's) if such a system were to be adopted in school. Both studies were designed specifically to minimise the attendant costs, and it is appropriate to compare the overall cost-effectiveness for the two approaches.

A simple analysis of cost-effectiveness is to calculate 'added value effect size per 100 teacher hours' i.e., to divide the effect size by the teacher/researcher input needed to achieve it. A British evaluation reported in Sylva, Hurry and Plewis (1995), evaluated Reading Recovery and phonological training, again using 'at risk' six year old children. Reading Recovery proved very effective ('added value' effect size for word reading 0.70, falling to 0.41 after one further year), whereas the phonological intervention was less effective (corresponding 'added value' effect sizes 0.11 and 0.27). The Reading Recovery intervention was lengthy, involving on average, 77 half hour daily individual lessons over 21 weeks, as opposed to 40 individual 10 minute sessions over 7 months for the phonological training. The calculated cost-effectiveness for these two interventions is 1.8 and 1.1 for Reading Recovery (post-intervention and one year delay) and 1.1 and 2.7 for phonological intervention.

Cost-effectiveness for the interventions administered here works out as follows, calculated for overall literacy based on standard score improvements: firstly for the 7 hour parental training; 2.14 for the balance intervention, 5.24 for the phonological intervention, and 4.96 for the maths intervention; secondly, for the 3.5 hour in-school training; 20.55 for balance, 12.06 for phonological, and 12.05 for maths. There is no data on persistence of the effects in the parental intervention. However, the follow-up data for study two indicates an improvement in cost-effectiveness for balance and phonological training to 27.70 and 26.36 respectively, coupled with a decline in maths to 3.57. In work reported on 10 week interventions in infant school, figures were generated of 27.0 (post-test) and 21.7 (delayed test) (Nicolson *et al*, 1999). It may be seen that overall the controlled in-school intervention is as effective as Nicolson and colleagues' intervention. The main differences between the studies are that this study included a subgroup with good initial skills, whereas Nicolson *et al* (1999) included only children with deficits, thus dealing with more intractable and entrenched problems.

Of course, it would be unwise to make too much of the comparison of effect sizes between these studies, particularly as the group sizes here are so small, but even so, it seems that for this scale of study, both the parental and in-school training proved both effective and cost-effective. Moreover, the data (albeit somewhat limited) suggests that both the balance and phonological interventions are equally effective with children with poor skills. The maths intervention, by contrast, has only a transitory effect on the children's skills, suggesting that this may be a Hawthorne effect, related to the extra attention the children are receiving. The maths intervention by its nature was less interactive than the other two interventions, which may suggest that the degree of interactivity could be a critical factor in continuing improvement. However, it should be remembered, that the experimenter carried out both the pre and post testing as well as the training and so may have inadvertently activated a partial Hawthorne effect since she was not blind to the subject grouping.

Interestingly enough, as with the training reported in Nicolson *et al*, 1999, the phonological intervention in study two has its greatest initial impact on the development of spelling skills. This transfers to reading skills, over the six month follow-up. This seems to be a characteristic of phonological skill training, with improvements in spelling ability at age six feeding in to reading performance over time (Frith, 1985; Cataldo and Ellis, 1988; – see Brown and Ellis, 1994 for a review). The balance skills training, by contrast, shows an immediate improvement in reading standard scores in both studies, but only produced strong effects on spelling standard scores in Study two, when administered by a trained experimenter.

This finding would seem to add small-scale support for the general idea that spelling skills are more entrenched and take longer to influence than reading skills, particularly when not directly targeted by the intervention programme. In terms of skill transfer through balance (cerebellar controlled) training, this small-scale result tentatively suggests that two things *may* be happening: Firstly skill transfer from motor areas to literacy may be occurring; and secondly that this skill transfer may be effecting the more entrenched skill of spelling, but only when more rigorous and tightly controlled balance training it available (i.e. balance administered by a trained experimenter).

Conclusions

In conclusion, the primary aim of these studies was to evaluate a range of intervention techniques for infant school children, to establish their effectiveness, cost effectiveness and persistence over time. Findings were also of interest in terms of providing evidence of cerebellar skill transfer. Two short-term, small-scale intervention studies, using either parents as trainers, or an in-school intervention, appeared effective in accelerating the literacy development of children with a range of abilities. This generalised to increases in IQ scores in the trained groups. Findings could be interpreted as giving general evidence of skill transfer, with possible cerebellar involvement in any balance group effects. However, because of the scale of the studies, due caution should be applied in interpreting results. These are summarised as follows:

- After seven hours of training by parents, all groups show an increase in verbal IQ of around thirteen points above the 'no training' condition.

- After three and a half hours of training by the experimenter (author) in school, all groups show an increase in verbal IQ of around eight points above the 'no training' condition.

- By the end of training, 92% of children with below average IQ's (70-90), had moved into the average range (90-110), by contrast with 0% of the no-intervention group.

- Performance IQ increases did not seem to be related to intervention, and were more likely to be influenced by practice effects.

In terms of the main aim of the studies, improving the literacy standard scores of the children, so that they can keep pace with their peers, the following pattern of results was found:

- After seven hours of training by parents, all groups show a reading age increase of around two months, and a spelling age increase of around one month more than the 'no training' condition.

- After three and a half hours of training by the experimenter in school, the three groups showed an average reading age increase of three months, and spelling age increase of six months more than the 'no training' condition.

- Improvements in the balance condition are the most significant here, suggesting possible skill transfer, maybe as a consequence of 'fine tuning' of the cerebellum.

Moreover, the children's standard scores for literacy appeared to have been accelerated by the interventions, with all children trained in both studies improving on their pre-test scores, or at the very least maintaining their standard scores over time.

Bearing in mind the extremely restricted size of these studies, the combined findings of the two studies are cautiously interpreted as indicating the following:

i) Intervention in a child's first years at school is an effective and cost-effective method of avoiding reading failure.

ii) Even with early intervention some children will need continuing support.

iii) A range of interventions proved effective, including not only well researched phonological interventions, but also balance interventions which had not previously been systematically evaluated in a controlled study.

iv) Interventions were successful with children with mild and moderate difficulties, as well as those with reasonable skills at pre-test.

v) The effects of the phonological and balance interventions persisted and developed over the six months follow-up period. The programmes seemed to hold generic value for persistent metacognitive strategy improvement, with the children 'learning how to learn'.

vi) By contrast, the success of the maths intervention over the short-term seems most likely to be a Hawthorne effect, which dissipates over time. Improvements in verbal IQ scores in this group were probably attributable to the children's development of metacognitive skills, in other words they were 'learning how to learn'.

vii) Children with mild impairments on the Dyslexia Early Screening Test or on teacher's ratings have a good chance of catching up with their peers following a relatively short intervention, but those with high 'at risk' scores are likely to need continuing support over a relatively long period.

viii) Balance interventions would provide a useful adjunct to phonological training, if incorporated into school gymnastics. They would also present an accessible vehicle for parental support, particularly as part of a home/school based intervention.

Part Two

Chapter 7

Concluding Remarks

The title of this thesis, 'Theory and Intervention: A Complete Analysis for Children with Learning Difficulties' makes clear the overall aims of this research. It now seems appropriate in the concluding pages of this thesis to return briefly to those aims and reflect on the relative success of this research in achieving them.

The Theory

In chapters one to three, this thesis set out to analyse the performance of children with learning difficulties in a range of primitive skill areas. More specifically the aim of this research was to directly compare the performance of children with more generalised learning difficulties (termed ND-PR children), with that of matched groups of dyslexic children. By so doing, this research was hoping to achieve a number of things: Firstly, to provide fresh research with which to consider the Stanovich debate and the value of the traditional discrepancy based definition of dyslexia; secondly to assess the value of a range of basic skill tests (including tests of cerebeller dysfunction) in differentiating between these two groups; and thirdly, based on these findings, to critically evaluate the validity of the cerebellar deficit hypothesis for dyslexia.

Although research work comparing dyslexic performance with matched controls is fairly abundant, there is a lot less evidence of research work comparing ND-PR children with dyslexics despite the on-going discrepancy debate. It is hoped that this research, by carrying out a comparison of dyslexic and ND-PR children in a wide range of skill areas, will provide a useful addition to the somewhat limited research in this area.

More particularly, in terms of dyslexia causal theory, this research has helped provide additional support for the causal theory of mild cerebellar impairment in dyslexia. This conclusion was reached through the critical demonstration of a dissociation in the performance between the ND-PR and dyslexic children in cerebellar task performance. It was concluded that the cerebellar deficit hypothesis may provide a parsimonious account of the range of difficulties demonstrated in dyslexia, subsuming the traditionally accepted phonological deficit theories within a broader causal framework.

The applied benefits of this work should not be overlooked. This performance dissociation in cerebellar tasks, along with performance differences demonstrated in phonology and other primitive skills, should influence the development of valid, reliable and theoretically sound methods of differentiating between dyslexic and ND-PR children. These tests may then hold potential for incorporation into early screening and diagnostic tools. The discriminative ability of such screening tools should ensure that they prove both effective and cost effective.

These applied considerations in the screening and diagnosis of dyslexia and learning disabilities, naturally lead onto the issue of intervention and support. In addition to posing fresh theoretical considerations for the learning disabilities research arena, this research suggests intriguing avenues for investigation in the area of intervention.

The Intervention

By adding theoretical support for both the phonological hypothesis and the cerebellar theory, the second part of the thesis set out to directly compare the effectiveness (and cost-effectiveness) of intervention programmes based on these causal theories. This research was the first of its kind to utilise the principles of the cerebellar deficit hypothesis in an intervention programme based on motor skills (balance) training. Moreover it was the first to directly compare the effectiveness of this balance training with traditionally accepted phonological approaches to intervention. Additionally the intervention was administered in not only a strictly controlled scientific environment, but also by parents in the home. This intervention approach was thus innovative and exciting. Unfortunately, the extremely small-scale of the two intervention studies, restrict the interpretations that can be drawn.

However, for the small sample sizes used, each of the training programmes under both training conditions appeared to be generally successful in improving the literacy abilities and IQ ratings of these young children of mixed ability. Particularly exciting was the finding that the novel balance training approach had such beneficial effects on these children. This brings us back to the earlier theoretical considerations of the role of the cerebellum in dyslexia, allowing tentative suggestions that skill transfer may be occurring during this balance intervention and moreover that the cerebellum may be influential in this process.

Within the context of such a restrictive design, from a general theoretical viewpoint the intervention studies serve to provide further support for the well-researched phonological approaches to intervention for children with literacy difficulties. Indirect support is given to the phonological hypothesis of dyslexia and its inherent assumption that proactive training of 'at risk' children will lead to relatively near normal acquisition of reading (Bradley, 1988; Lundberg, Frost and

Petersen, 1988). More broadly results give indirect yet intriguing indications of cerebellar impairment in dyslexia (cf. Nicolson and Fawcett, 1999). From an applied angle, the findings provide evidence of the beneficial effects of structured and regular training intervention with young children, particularly those with learning difficulties. It is concluded that a motor skills training programme in conjunction with a phonological training programme may have considerable potential for incorporation into any home/school based intervention programme.

Limitations and Future work

Inherent in the makeup of this doctoral research was many limitations of time and resources.

Part One

In part one of this research, these limitations resulted in a relatively small subject groups being tested and only a selection of the primitive skill data for the ND-PR children being presented for analysis and interpretation. The data chosen was selected on the basis of its value for allowing the hypothesis and predictions of the work to be assessed. To present further data was unnecessary in this context and furthermore beyond the remit of this thesis.

Performance in the cerebellar tests was of central importance in supporting the cerebellar deficit theory and influencing the Stanovich debate. However, the cerebellar tests arguably incorporate the most subjectivity when it comes to testing and scoring. Considerable care was taken to facilitate fully objective procedures for administering these tests, but some subjectivity remained. Also direct tests of magnocellular deficit were not included in the battery, which will have influenced the predictive success of this theory in comparison to the cerebellar hypothesis.

Subject selection always causes a lot of debate in research of this kind. Whilst factors such as SES and ADHD have all been effectively been controlled for in these studies, it is always difficult to ensure that subjects selected for the ND-PR group do not show some degree of dyslexia and vice versa, particularly in young children. Dyslexia occurs along a continuum with more general learning difficulties, and it may well be that some of the subjects showed co-morbid symptoms of both ND-PR and dyslexia. Furthermore, there were two different comparison dyslexic groups used in this study, one a much more recent sample than the other. This was an unavoidable situation due to the necessity to increase subject size within tight time restrictions. However, these two groups would not have shown the same consistency of schooling and tuition as would one group drawn from the same school or dyslexic institution. This may have influenced results collapsed across these two groups.

This research needs to be replicated with further groups of ND-PR children and children with dyslexia. More specifically, it would be particularly informative as part of further replication work to perform a follow-up study on the two groups of dyslexic and ND-PR children. The design of the studies used two subject age groups, only allowing for cross-sectional analyses and interpretation. To introduce a longitudinal aspect to this research through follow-up work, would have enabled clearer interpretation of any maturational effects. If the cerebellar theory is to be used as a predictive tool, one would expect a clear maturational dissociation in performance between the two groups. Deficits in cerebellar and phonological skills have been shown to be persistent in the dyslexic children, (Bradley and Bryant, 1983) but comparative improvements in phonological skills over time might be expected in the ND-PR children. The control group in these studies failed to show an age effect in the majority of tasks. Again this made interpretations of decreasing or increasing lag additionally difficult.

Despite these various limitations and weaknesses, it remains that studies comparing ND-PR children with dyslexics appears to have been a somewhat neglected area in the literature, with research being both limited and variable.

The data this research has produced should therefore hold potential for helping redress this imbalance through the replication, continuation and expansion of the work presented here.

Part Two

Inevitably there were also considerable limitations to the intervention work described in part two of the thesis. The intensive nature of a daily administered training programmes where children are tested individually, ensured that only a limited number of children were evaluated. This was particularly the case for study two where one experimenter (the author) administered all training. This research urgently needs to be replicated and expanded with a much larger subject group. The extremely restricted nature of the studies, ensured that all results were viewed with caution and considered more indicators of interesting findings rather than solid proof.

Another limitation inherent to the intervention study particularly in study two was the high level of attrition. This attrition was particularly significant in such a small sample size, ensuring hat just one loss through attrition could produce significant changes in results. This attrition rate was due to the nature of the school catchment area, with a mobile population transferring between different council estates, typically without leaving a forwarding address. If anything, despite its particularly small subject size, the results of study two were stronger than those of study one despite this problem of attrition. It would be particularly exciting to replicate this controlled study with a larger group of children to see if findings persist.

Another difficulty for the second intervention study was the fact that the same experimenter performed the pre and post testing as well as carrying out the interventions. Ideally, the pre and post tester should have been blind to the grouping of the subjects and certainly not involved in the training. However, this situation was unavoidable, but it should be remembered that the experimenter may consequently have initiated a partial Hawthorne effect in the second intervention study. A further weakness of study two was that the teacher's grouped the children according to ability level. This may have resulted in somewhat subjective grouping. Grouping in study one was a lot more objective, using the DEST (Fawcett and Nicolson, 1996).

Similarly to the first part of the thesis, additional raw data was originally collected, but only a selection subsequently chosen for presentation in this thesis. Data was collected from both the academic related areas of reading, spelling and IQ as well as in various less academically related areas. Selection was fundamentally influenced by the primary intention of the intervention research to study academic related performance changes through intervention. Suffice to say that it would be interesting and informative as part of future work to expand these findings by analysing the effects of the intervention programmes on less academically related areas too.

Conclusions

In conclusion then, it would appear that this research has gone a considerable way to achieving its original aim of providing a 'complete analysis' of theory and intervention for children with learning difficulties. New considerations for causal dyslexia theory have been postulated based on the persuasive findings from discriminative work with ND-PR and dyslexic children. These considerations have been applied to novel intervention regimes, which although small-scale have been shown to hold potential for being both effective and cost-effective for children with learning difficulties. It is now hoped that research efforts will continue to build on these findings, to ensure that children with learning difficulties are given every opportunity to achieve their true potential.

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Appendix 1

Example score sheet – ADHD (DSM III)

(See Chapter Two – Page 78)

Diagnostic Criteria For Attention-deficit Hyperactivity Disorder

Please circle appropriate score

0 = not present above normal levels
1 = present at above normal levels

1	often fidgets with hands or feet or squirms in seat	*Score*	*0 / 1*
2	has difficulty remaining seated when required to do so	*Score*	*0 / 1*
3	is easily distracted by extraneous stimuli	*Score*	*0 / 1*
4	has difficulty awaiting turn in games or group situations	*Score*	*0 / 1*
5	often blurts out answers to questions before they have been completed	*Score*	*0 / 1*
6	has difficulty following through on instructions from others (not due to oppositional behaviour of failure of comprehension), e.g., fails to finish chores	*Score*	*0 / 1*
7	has difficulty sustaining attention in tasks or play activities	*Score*	*0 / 1*
8	often shifts from one uncompleted activity to another	*Score*	*0 / 1*
9	has difficulty playing quietly	*Score*	*0 / 1*
10	often talks excessively	*Score*	*0 / 1*
11	often interrupts or intrudes on others, e.g., butts into other children's games	*Score*	*0 / 1*
12	often does not seem to listen to what is being said to him or her	*Score*	*0 / 1*
13	often loses things necessary for tasks or activities at school or at home (e.g., toys, pencils, books, assignments)	*Score*	*0 / 1*
14	often engages in physically dangerous activities without considering possible consequences (not for the purpose of thrill-seeking), e.g. runs into street without looking	*Score*	*0 / 1*

1

Appendix 2

Word list for 'Rhyming' and 'Alliteration' Tests – Bradley and Bryant (1983)

(See Chapter Two- Page 82)

Appendix 3(a)

The Rosner (1971) TAAS

(See Chapter Two – Page 85)

The Rosner (1971) test of auditory analysis skills (TAAS)

Say *sunshine*	Say it again, but don't say *shine*
Say *picnic*	Say it again, but don't say *pic*
Say *cucumber*	Say it again, but don't say *cu*
Say *coat*	Say it again, but don't say */k/*
Say *meat*	Say it again, but don't say */m/*
Say *take*	Say it again, but don't say */t/*
Say *same*	Say it again, but don't say */m/* †
Say *wrote*	Say it again, but don't say */t/*
Say *please*	Say it again, but don't say */z/*
Say *clap*	Say it again, but don't say */k/*
Say *play*	Say it again, but don't say */p/*
Say *stale*	Say it again, but don't say */t/*
Say *smack*	Say it again, but don't say */m/*

† We substituted the word '*same*' for the original '*game*', because in pilot studies we established that even the 8 year old children were reluctant to produce the answer '*gay*'.

Appendix 3(b)

The Rosner (1971) TAAS – Example Score Sheet

(See Chapter Two – Page 85)

TAAS Phonemic segmentation test
(Rosner 1977)

Tick each correct answer, and write in any errors

Name
Age 10
Date 6/3/96

Item	Item	Question	Correct response	Actual response	Score
A	Say cowboy	Now say it again but don't say boy	Cow	cow	1
B	Say steamboat	Now say it again but don't say steam	Boat	Boat	1
1	Say sunshine	Now say it again but don't say shine	sun	Sun	1
2	Say picnic	Now say it again but don't say pic	nic	nic	1
3	Say cucumber	Now say it again but don't say cu(q)	cumber	cumber	1
4	Say coat	Now say it again but don't say /k/ (the k sound)	oat	oat	1
5	Say meat	Now say it again but don't say /m/ (the m sound)	eat	eat	1
6	Say take	Now say it again but don't say /t/ (the t sound)	ache	ache	1
7	Say same	Now say it again but don't say /m/	say	Say	1
8	Say wrote	Now say it again but don't say /t/	row	row	1
9	Say please	Now say it again but don't say /z/	plea	Plea	1
10	Say clap	Now say it again but don't say /k/	lap	ap	0
11	Say play	Now say it again but don't say /p/	lay	lay	1
12	Say stale	Now say it again but don't say /t/	sale	Stay	0
13	Say smack	Now say it again but don't say /m/	sack	clap	0
Total					

(10)

Beads

1) 10·6
2) 8·9
3) 10·6
4) 9·4
5) 12·1

51·6 mean = 10·32

MOUSE/DUCK 14/16

toe tap = 3·658.

p = 1·91.
t = 0·92.
c = 0·966.

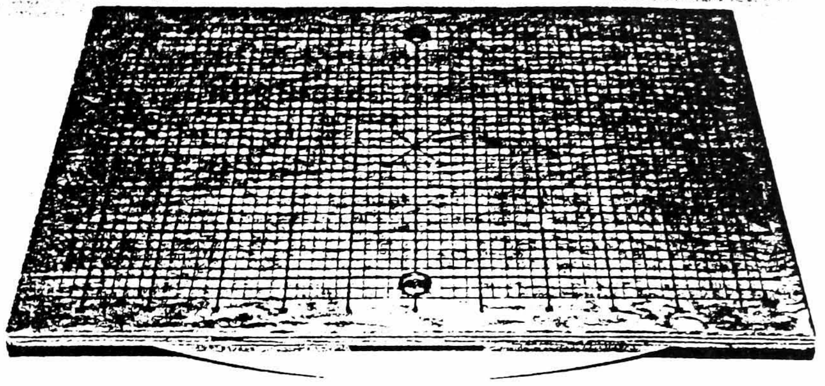
Appendix 4

Photographs of the Balance Board used in the Intervention studies (Chapters five and six) by the Balance training group.

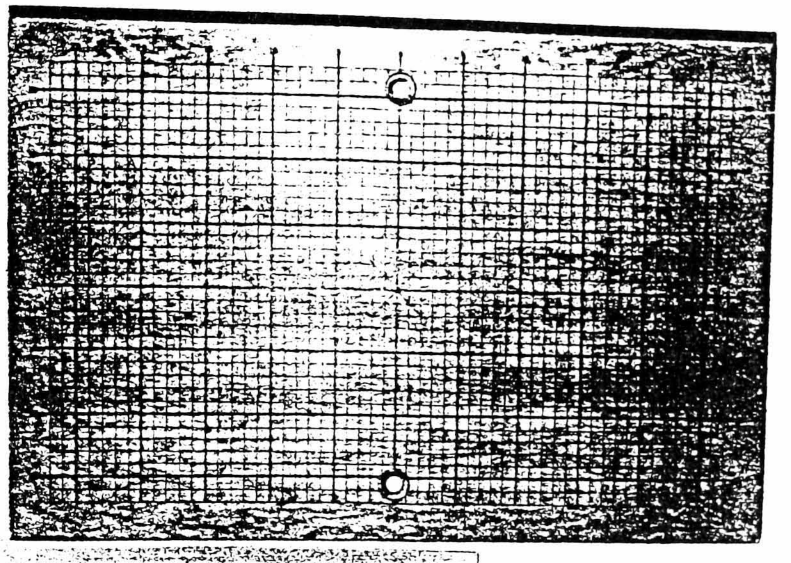
(See Chapter Four – Page 177)

THE BALANCE BOARD

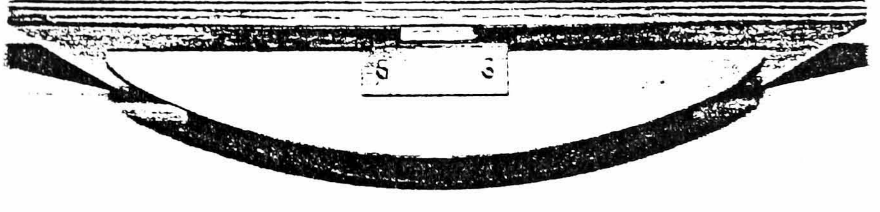
Balance Board



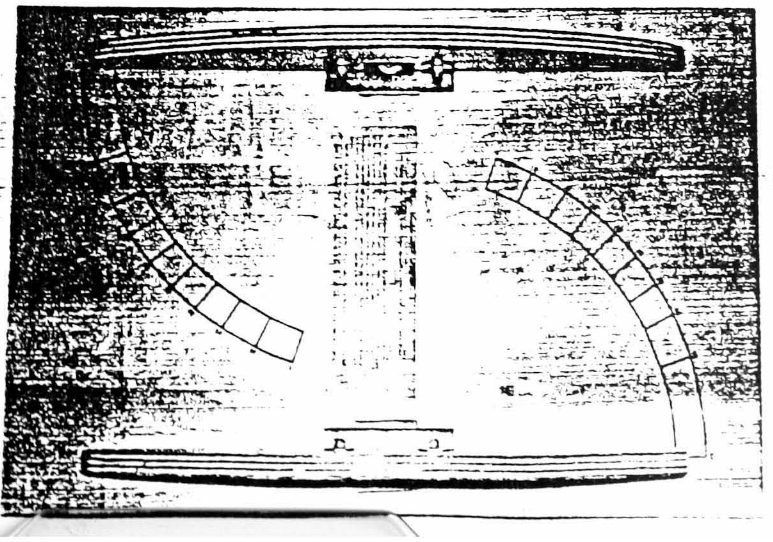
Top Position (a)



(b)



Side Position (c)



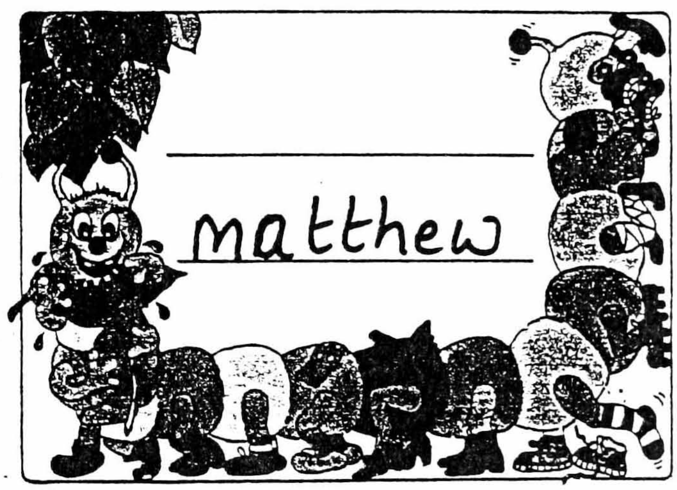
Underneath Position (d)

Appendix 5

An example 'Balance Training Workbook' from the parental intervention study.

(See Chapter Five – Page 190)

BALANCE TRAINING STUDY



BALANCE TRAINING WORKBOOK

-Please Spend 10 minutes training daily-

Please tick off each day as the training is completed:

NAME: Matthew, [redacted]

CLASS: 5

DOB: 20.10.89

Day 1 27.3.95.	Day 9 5.4.95	Day 17 "	Day 25 24 20 mins	Day 33
Day 2 28.3.95.	Day 10 7.4.95	Day 18 "	Day 26 25 10 minutes	Day 34
Day 3 " 29	Day 11 8.4.95. AWAY	Day 19 "	Day 27	Day 35
Day 4 " 30	Day 12 "	Day 20 "	Day 28	Day 36
Day 5 " 31	Day 13 "	Day 21	Day 29	Day 37
Day 6 " 1	Day 14 "	Day 22 14 10 mins	Day 30	Day 38
Day 7 3.4.95	Day 15 "	Day 23 19 10 mins	Day 31	Day 39
Day 8 4.4.95	Day 16 "	Day 24 20.	Day 32	Day 40

BALANCE BOARD TRAINING STUDY

Thank you for volunteering to help in this Training study!! The purpose of these balance based activities, is to try and increase the efficiency of the basic brain functions that underpin many basic skills such as memory, concentration, coordination, speech, vision, reading etc etc.

By carrying out the 'before and after' tests on your children, I hope to observe significant improvements in their performance in many of these areas as a result of your 8 week's training with them on the balance board.

For there to be any hope of a training effect being observed, I need you to work with the children for a daily session of 10 minutes on the board throughout the 40 day duration of the training period.

The main point of this training is firstly that you and your child have fun and enjoy yourselves with the board, and secondly that the training challenges your child for there to be resulting improvements. An activity done in a sloppy, disorganised manner is not going to result in much brain tuning. An activity done in a routine and rigid manner maintains the function, but an activity performed with an eye to perfection, or one that challenges ability should build on and refine your child's performance efficiency.

To enable the 'challenging' aspect of the programme to be maintained and so maximising the likelihood of skill improvement, a certain amount of flexibility will be necessary in your approach to the training. On the following pages, I have outlined 4 different training sequences to be followed which each last approximately 10 minutes. The study allows for each sequence to gradually be made more demanding as the training progresses and as your child's skill develops. I have stated as clearly as possible the degree of performance required before moving on to the next sequence. Obviously a fair amount of discretion will be necessary on your part in this respect, which will be difficult for me to control. However one of the ideas behind the 'Learning Breakthrough Programme' is that the training routines are meant to be personally monitored and developed in a flexible manner. Guidelines are meant to be just that, and not a set of rigid and inflexible instructions engraved in tablets of stone!!
Thank you again for offering to do this for me. Below is my contact number again should there be a problem at any stage;

Miss Fiona Maclagan
Daytime: Room 2:43 Psychology Bldg-Tel: 826558
Evenings/weekends - 14 Burns Rd S6-Tel: 668146

General Practical Considerations

The best way for the training to be done is with the parent standing in front of the child performing the sequence themselves with the child imitating. (Parent should stand close but not too close to the board. approx. 3-4 feet which is close enough to catch them should they over-balance!) To make the training more fun, a 'Simon says' format could work well.

Remember!

- **Be flexible**
- **Be creative**
- **Be challenging**
- **Be enthusiastic**

- **Encourage concentration and control**
- **Keep unnecessary chatter to a minimum**
- **The further apart the feet are, the harder it is to balance**
- **Try to keep board level and still throughout the sequence**
- **Aim to get your child to flow continuously from one movement to the next, so try to introduce the next movement before the previous one is finished.**

- **Don't push your child too far, movements should be fluid, smooth and relaxed,** NOT JERKY AND EFFORTFUL.

HAVE FUN !!

Prior to training:

- shoes and socks off!!

- **Very important** - centralise child on board (feet equidistant from centre of platform and toes lined up on same horizontal grid line)
- general familiarisation with balancing on board, e.g. pretending to ski on board, gentle rocking from side to side etc. until child comfortable on board and relaxed.
- get all chattering and possible distractions out of the way at this stage!
- alter distance between feet until child can balance with arms by side without jerky reactions, but still feels the drive to balance themselves.
- try to ensure board is level and child can remain still for a few moments before starting. (both these requirements may be difficult at first but will improve with practise. Some children will have a slightly inaccurate perception of what is level. This perception should become more accurate as the training proceeds)

Training Sequences

What follows are 4 separate example training sequences, each revolving around one activity:

- bean-bag -
- shapes -
- skittles and bucket -
- general movement and coordination -

• I suggest that at the beginning, you rotate between the different activities on a day to day basis.

• It is impossible to judge accurately how long each sequence lasts, probably much longer than 10 minutes! So just reduce or increase the repetitions, omit or invent your own similar movements as required.

• Remember, these sequences are only meant as a guideline, and so strict adherence to their steps is not obligatory. Obviously, don't be overly innovative! So long as you concur to the general considerations mentioned earlier and maintain the focus of the movements on the particular activity for that sequence, you can't go far wrong.

• Eventually, as your experience increases, you may like to create your own training sequences based on a combination of the 4 activities, or even using your own apparatus! This would be great as it will help maintain your interest and enthusiasm, but can I ask that we get through the first four weeks sticking to stricter guidelines first. We can discuss new ideas etc. at the mid-session meeting.

Methods of increasing and decreasing difficulty

• The fundamental method of increasing difficulty in this programme is by increasing the distance of both feet from the central vertical grid line and so making the maintenance of a level state of balance more difficult.

• Generally insisting on more fluency and accuracy in execution of instructions, increasing concentration levels etc. will all increase the mental demands of the training.

• Other methods are pretty obvious. For instance, increasing the number of repetitions of a particular movement, or by the following methods:-

e.g.: bean bag activity sequence:	-throwing bean bag higher -throwing and catching from a greater distance
e.g.: shapes:	-progressing from circle to square to triangle to diamond drawing -forcing more repetitions in the 'weak' drawing direction
e.g.: bucket and skittles:	-increase distance of target from balance board -move slowly whilst holding target bucket rather than standing stationary
e.g.: general movement:	-provide a moving rather than a stationary target -increasing the difficulty of aiming accurately by more challenging movement patterns -increase the complexity of Simon's commands!!

Activities which are 'boxed' should only be attempted when an increase in difficulty is required.

- Obviously, to <u>decrease</u> difficulty, reverse the above changes -

Criteria for increasing and decreasing difficulty

- A general 'rule of thumb' in terms of increasing difficulty in any area of the training is only increase the difficulty:

- when the activity is consistently being executed smoothly and in a relaxed manner, and
- when a steady level of balance in equilibrium is being maintained, and
- when the child is no longer being challenged by the activity i.e. concentration not needed, mind beginning to wander, boredom beginning

- Look for 'non challenging' behaviour in two of the same consecutive training sessions before increasing difficulty.

- When increasing the distance between feet on the board, increases should be small i.e. no more than 2 cm's in each foot. Little and often is best!

- If increases obviously make balancing too demanding, then don't hesitate to backtrack for a while.

- Likewise, with specific increases within sequences, apply the 'little and often' rule. Again don't overstretch your child, or force it if they're obviously struggling and their balance is being affected. Return to an easier level or lessen the increase, alternatively increase in another area first.

Sequence 1 - BEAN BAG

- 1) Stand balanced on the board arms by side with bean bag resting on head for a count of ten.
- 2) Repeat whilst counting slowly to ten out loud.
- 3) Repeat counting backwards from ten to one.
- 4) Repeat with hands on top of head, holding on to bean bag.
- 5) Stand balanced on the board for the count of ten with bean bag balanced on back of hand.
- 6) Repeat with the other hand.
- 7) Balance for the count of ten with bean bag balanced on one finger.
- 8) Repeat with the other hand.
- 9) Stand balanced on the board and pass the bean bag around your body three times.
- 10) Repeat in the opposite direction.
- 11) Stand balanced on the board and throw the bean bag gently and accurately to your parent! Repeat three times.
- 12) Try and catch it when it is thrown back to you. Repeat.
- 13) Throw the bean bag a little way into the air and catch it with both hands when it comes back down. (Don't throw bean bag high) Repeat three times.
- 14) Throw and catch the bean bag with both hands, trying to throw it a little higher as you improve. Make the two sides of your body move symmetrically. Follow the bean bag with your eyes as it moves through space.
- 15) Throw and catch the bean bag with both hands. Make the bean bag just touch the ceiling. Point the tip of your nose at the bean bag and follow it as it moves through space.
- 16) Throw and catch the bean bag with both hands. Try to make the two sides of your body move symmetrically. Throw the bean bag up and try to make it come as close to the ceiling as you can without touching the ceiling. Point the tip of your nose at the bean bag and follow its movement.
- 17) Throw and catch the bean bag with both hands. Move symmetrically. Throw the bean bag up and try to make it come one foot from the ceiling, then two feet from the ceiling, and then three feet from the ceiling. Continue this sequence. (NB **increased difficulty only**)
- 18) Throw the bean bag with the left hand to your parent. Repeat three times.
- 19) Throw the bean bag with the right hand to your parent and repeat.
- 20) Invent your own way to throw and catch the bean bag to complete the ten minutes. Aim to maintain balance at all times.

Sequence 2 - SHAPES

- 1) Standing on the board, keeping left hand by your side and your right elbow by your side, point with your right hand and then draw a spiral starting close at the chest and growing outwards and away until arm fully extended. Pause and then spiral in reverse until hand by chest again. Repeat three times.
- 2) Repeat with opposite hands.
- 3) Draw a circle in the air with your right hand. Draw a small circle three times, them a medium circle and then a big circle three times. Repeat whole process three times.
- 4) Repeat with left hand.
- 5) Do not look at a specific point, just let your eyes relax and draw a big clockwise circle in the air with the tip of your nose. Draw the circle very slowly and try to keep the circle centred with your body.
- 6) Repeat in an anti-clockwise direction.
  (if one direction is easier than the other to do, then work on the weak direction until both directions are of equal difficulty.)
- 7) Repeat all the above with a square, then a triangle and then a star if shapes are known.
- 8) Very carefully repeat with your eyes closed! Start with a circle first and go in both directions.
- 9) Starting in the centre, draw a series of circles in the air with the tip of your nose. Begin with a very small circle and keep making it a little bit bigger until you can't draw the circle any bigger. Repeat three times.
- 10) Repeat with the other shapes. Try to repeat all the shapes with your eyes closed.
- 11) Turn your body (but not your feet) about 45 degrees (1/8 turn) to the left and draw the circle in the air with the tip of your nose.
- 12) Turn back to the centre position and draw the circle.
- 13) Turn 45 degrees to the right and draw the figure in the air with the tip of your nose.
- 14) Turn back to the centre position and draw the circle again.
- 15) Repeat 11) to 14) with the other shapes.
- 16) Draw the circle in the air with your right hand. Hold your pointing finger so that you can follow the finger nail on your pointing finger with your eyes as you draw.
- 17) Repeat with the other hand.
- 18) Repeat nos 16) drawing a big a circle as possible. Then repeat with the other hand.
- 19) Repeat 16) to 18) with the other shapes.
- 20) Now draw the circle in the air with your right hand and instead of following the finger nail, look straight at your parent while you draw the shape.
- 21) Repeat with the other hand, (and other shapes).

Sequence 3 - SKITTLES AND BUCKET

- 1) Standing on the board, throw the bean bag with preferred hand and try to knock over two skittles placed beside each other (touching) approx 5 feet in front of the board, whilst keeping as level as possible on the board. Repeat five times trying to increase number of 'strikes' each day!
- 2) Repeat the above but using only one target skittle.
- 3) Repeat 1) and 2) using non-preferred hand. (work on the non-preferred hand until ability in each more evenly matched)
- 4) Repeat 1) and 2) throwing bean bag with two hands together.
- 5) Vary distances and number of targets as ability requires.
- 6) Standing on board holding bucket, catch bean bag thrown by parent from varying distances. directions and heights. Repeat as desired.
- 7) Standing on the board, try to throw bean bag into bucket held by parent at varying distances and heights. Repeat as desired. (Parents can help success here to maintain motivation!!)
- 8) Standing on the board, throw the bean bag into the bucket placed on the floor at varying distances and in different directions.
- 9) Standing on board and holding a skittle in preferred hand, hit the bean bag when thrown by parent from varying distances, directions and at different heights. Repeat as desired.
- 10) Repeat with non-preferred hand. (work on the hand that is found to be the most difficult until both hands are more equal)
- 11) Repeat holding a skittle in each hand and alternating the hands used each time. Repeat as desired.
- 12) Try and throw the bean bag into the bucket held by parent walking very slowly but smoothly in a semi-circle in front of the board. Repeat at varying distances and walking at varying speeds.
- 13) Invent your own ways to use the skittles, bean bag and bucket until 10 minutes elapsed.

Sequence 4 - GENERAL MOVEMENT AND BODY TEAMING

(all activities in this section performed off the board)

- 1) March slowly and smoothly in a circle around the room lifting knees high and keeping arms straight. On the command from the Sergeant Major (parent!) sharply turn and repeat in the other direction. Repeat as desired.
- 2) Repeat the above skipping and then galloping. Try and keep movements fluid and smooth and respond as quickly as possible to commands.
- 3) Repeat 1) and 2) moving in a square shape and then a triangle and diamond. Try to define clearly where the corners are.
- 4) Place approx five 'throwable' objects randomly around the room with the parent standing in the middle holding the bucket. Walk, run, skip, hop, crawl, creep, roll or otherwise move about the room from object to object. When you reach an object, pick it up and try to throw it in the bucket and then carry on to the next.
  (The important thing here is to eventually aim to throw without stopping your movement or changing pace).
- 5) Invent a simple 'Simon says' game for the duration of the 10 minutes.
  i.e. stand in front of child and say "Simon says 'Pat your head',"
  "Simon says 'Rub your tummy in this direction and now this direction', and now do it while you pat your head"
  "Simon says 'Balance on one leg and count out loud to ten forwards and then backwards' and now with your eyes closed." etc. etc.!!
  (in case you don't know the rules, the idea is that the child copies every command so long as Simon says to do it! If no 'Simon says' is added then the child should carry on with the instruction they were doing until Simon says to do something again. Try and get the child to perform each action as accurately as possible. Stretch the coordination and complexity involved as necessary.)

Notes

On the following pages, please note down anything you feel like noting!! If you have any suggested improvements for the study, complaints or queries, then please note them here. This research is very new so I really would like all the feed-back possible.

If your child has any comments to make on what I'm putting them through, then please jot these down too.

If you create your own successful moves and sequences, then I'd be grateful if you would note these down too, to help me improve future studies.

Appendix 6

Excerpt from: 'The Learning Breakthrough Programme'. (Belgau and Belgau, 1982)

(See Chapter Five – Page 190)

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Excerpts from: LEARNING BREAKTHROUGH PROGRAMME (Belgau & Belgau, 1982)

THE PENDULUM BALL

INTRODUCTION

In these activities you will work with the PENDULUM BALL.

The Pendulum Ball is one of the most valuable of all the perceptual development tools. It helps you to develop and refine some important basic brain processes. The Pendulum Ball is a solid rubber ball attached to the ceiling by a string. There is an adjustment on the string so that the length of the string can be changed. The period of the pendulum, or the time it takes the ball to swing back and forth, is a function of the length of the string. The longer the string, the longer the period, the shorter the string, the shorter the period. A long period means a slow swing,a short period means a fast swing. Since the period is constant at any given length, activities using the Pendulum Ball aid the brain in sensing time and in developing and refining the sense of timing.

The ball will swing through space under the direct influence of two basic natural forces - inertia and gravity. The oscillations of the ball, or the swings of the ball back and forth or around in a circle, are the result of the interaction of gravity and inertia. When the ball is pulled back and released, gravity carries it from the high point down to the lowest point of the swing. As the ball swings down, the gravitational component decreases, and the inertial component increases. When it reaches the lowest point in the swing, inertia carries it up the other side. As it swings up the force of gravity counteracts the inertia. The gravitational component increases as the inertial component decreases. When the ball reaches the uppermost limit of the swing, the energy begins to change from gravitational to inertial. As the ball swings back, its speed increases. The increase is a function of the acceleration of gravity.

Because of this inertial-gravitational relationship, the ball will follow a consistent trajectory until it is acted upon by an outside force. When an outside force is introduced, the trajectory changes, reflecting the force applied.

For a person to control the movement of the Pendulum Ball and change the trajectory in order to move the ball to a point or target in space, his brain must sample the motion of the Pendulum Ball, calculate the inertial and gravitational components of the Pendulum Ball's trajectory, and generate a movement with the desired thrust in exactly the proper direction timed to intercept the ball at exactly the proper point in space. If the calculations are correct and the motor output matches the calculations, the ball will move through space along the predetermined trajectory and strike the target or swing along the planned path. The actual doing of this tremendously complex activity is so much within the capabilities of the human intellect, that, with the proper opportunities, a preschool child will become proficient enough at controlling the ball that he or she can be successful at playing fun games with it. The Pendulum Ball challenges a great range of abilities. Though it is a good game for a preschooler, its value is not limited to children. The Pendulum Ball can challenge and develop the intellects of first class professional athletes, creative mathematicians, test pilots of high performance aircraft, and astronauts.

Since the movement of the ball through space is always relative to how a force is applied to it, the ball is a valuable feedback device for developing brain structures that process visual space, and the motor control of objects in visual space.

If the activities controlling the motion of the Pendulum

Ball in space are done on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM, a more precise integration is required. This means that a much finer integrated circuit between the two hemispheres of the brain, and the tactile, visual, vestibular, and motor systems is constructed.

The motion of the Pendulum Ball is consistent, and follows precise mathematical laws. For this reason, it is possible for the brain to develop computing structures and programs to take a small sample of the motion of the Pendulum Ball's trajectory and then compute and predict where the ball will be at a future time or predict the exact time it will reach any point in its trajectory.

Activities with the Pendulum Ball refine the brain's abilities in spatial relations, temporal relations and temporal-spatial relations, all of which are foundational structures for high level intellectual functions.

SET UP:

Stand centered and balanced on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM. Make sure your two feet are the same distance from the center of the platform and your toes are touching the same horizontal grid line. The vertical center line of the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM should be pointing at a point directly under the point where the Pendulum Ball attaches to the ceiling. You want to be centered on the swing of the Pendulum Ball.

ACTIVITIES:

1. Swing and catch the ball with both hands. Try to make the ball go where you want it to go. Breathe deeply and try to relax as you swing and catch the ball, and make it move through space just as you want it to move.

Swinging and catching the ball with both hands requires the two hemispheres of the brain to work together. Controlling the ball and visually tracking it as it moves through space develop visual-motor integration. Doing these activities on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM helps restore the ability to posture the body so that the visual axis, the vestibular axis, the motor or kinesthetic axis, and the auditory axis of the body are aligned with the gravitational reference.

2. Catch the ball. Swing and catch the ball with your right hand. Make the ball go where you want it to go.

3. Throw and catch it with your left hand. Throw the ball and swing it around in a clockwise direction.

4. Swing and catch the ball with your right hand and make it swing around in a counterclockwise direction. Each time you swing the ball plan to make the circle a little larger, a little smaller, or the same size as it was the time before. Then swing it and notice if the ball is swinging as you planned.

5. Swing and catch the ball with your left hand. Try to make it swing back and forth in a straight line.

6. Swing it in a clockwise direction with your left hand. Make it swing in a little larger, a little smaller or the same size circle each time you swing it. Check and see that you are properly aligned on the balance platform. Feel your balance.

7. Swing it in a counterclockwise direction. Again, make it swing in a circle that is a little larger, a little smaller, or the same size as the one before. Keep your eyes on the ball and notice the path it takes as it swings through space. Try to be aware of all the space in the room as you swing and catch the Pendulum Ball.

Swinging the ball with one hand and then with the other hand helps separate or differentiate the left from the right. Developing control and organization on each side separately is important. It is easier to develop integration and cooperation between two well organized sides than it is to develop it when one side, or both sides are poorly organized.

Trying to swing the ball so the path it follows is the same size, a little larger, or a little smaller than before requires a little more attention to the task both visully and motorically. It requires more visual memory, it involves evaluation and it involves a more precise visual-motor integration. It prevents boredom since it requires a concious awareness of, and decision about, each swing.

8. Swing the ball in a clockwise direction with your right hand and catch it with your left hand. Then swing it in a clockwise direction with your left hand and catch it with your right. Try to swing it with your left hand along the same path it followed when you swung it with your right hand.

9. Swing the ball in a clockwise direction with your left hand. When it comes back catch it with your right hand. Then swing it with your right hand so that it follows the same path and moves in the same direction as it did when you did it with your left hand.

10. Now swing the ball with the right hand in a counterclockwise direction. When it swings back to you, catch it with your left hand. Then swing it with your left hand so that it follows the same path and moves in the same direction as it did when you swung it with your right hand.

11. Swing the ball in a counterclockwise direction with your left hand. When it comes back to you catch it with your right hand. Then swing the ball with your right hand so it follows the same path and moves in the same direction as it did when you swung it with your left hand. Feel your balance and make sure you are standing properly on the balance platform.

12. Swing the ball in a clockwise direction with your right hand. When it comes back to you catch it with your left hand. Then swing the ball with your left hand so that it moves in the same path but in the opposite direction from what it did when you swung it with your right hand.

13. Swing the ball in a clockwise direction with your left hand. When it comes back to you catch it with your right hand, then swing it in a counterclockwise direction with your right hand. Try to make the ball follow the same path, but move in the opposite direction to what it did when you swung it with your left hand.

To do these activities successfully your right hand must literaly know what your left hand is doing and vice versa. If the two hemispheres are properly balanced, a right side motion can be transferred to the left side and a left side motion can be transferred to the right side. The Pendulum Ball provides feedback to the brain through the visual modality relative to the activity of each side. Through this feedback, corrections and modifications will be made that will result in helping to balance out the two systems.

14. Hit the Pendulum Ball with your right fist. Hit it gently and make it go where you want it to go.

15. Hit it with your left fist. Hit it gently and make it go where you want it to go.

16. Hit it first with the right fist and then with the left fist. Alternate each time the ball swings back. Keep the ball under control. Try to make it follow the same path each time you hit it.

17. Hit the ball with the back of your right hand. Keep hitting it with your right hand and keeping it under control.

18. Hit it with the back of your left hand and try to make it go where you want it to go.

19. Hit it with the side of your right hand karate style. Keep the ball under control.

20. Hit it with the side of your left hand karate style.

21. Keep hitting it karate style but alternate right hand

and left hand. Change the trajectory of the path the ball follows each time you hit the ball. Make it follow a different path each time. Do not hit it haphazardly. Plan each new trajectory and notice if the ball goes exactly where you plan for it to go.

22. Hit the ball with the palm of your right hand. Keep it under control.

23. Hit the ball with the palm of your left hand.

24. Hit it alternately, first with the palm of your right hand and then with the palm of your left hand. Choose a different path for it to follow each time you hit it. Notice if it is going where you want it to go or not.

In activities 14 - 24, your hands were used in a lot of ways to hit and control the movement of the Pendulum Ball through space. Each change in the way the hands were held to hit the ball required a different program to be generated and executed in the brain. All of the activities had a lot in common, but each one was unique in some way. The advantage of this kind of activity is that a much more elaborate structure must be constructed in the brain to control the motion of the Pendulum Ball while hitting it in all the different ways. This principle is a very important one in developing activities that organize the brain, in developing higher levels of operation, and in building the Structure of the Intellect. In many athletic games and sports a limited number of movement patterns is all that is needed. If there are problems in the coordination and integration of the two hemispheres of the brain or problems in sensory integration, the systems that do not function properly are partially or totally suppressed. Then the systems that do function properly are not disturbed by the less well organized systems, and they are able to meet the demands of the game or sport. It would be better in the long run, though, if this process were recognized, and the poorly organized systems were developed so that they could be integrated. It might take longer to reach the point of excellence, but the ultimate level of performance would be much higher, and would be built on a much firmer base.

25. Clasp the two hands together and hit the Pendulum Ball and make it go where you want it to go.

26. With the two hands clasped together hit the Pendulum Ball with the sides of your hands karate style. Make the ball swing around in a clockwise direction for three revolutions, then make it swing in a counterclockwise direction for three revolutions, then make it swing straight out in front of you.

27. Keep your hands clasped together. Hit the Pendulum Ball first with the back of your right hand and then with the back of your left hand. Keep it under control and make it go where you want it to go.

These activities tie the two sides together externally. To make the ball swing many different ways - clockwise, counterclockwise, and straight - requires modifying the basic movement for each change.

In these activities, the two sides of the body are tied together in the brain by the integrated circuits that are programming the activities. They are tied together externally by the two hands being clasped together. The motion of the ball provides feedback relative to the level of efficiency of this cooperative or integrated control relationship. If part of the brain control mechanism for one side is not performing properly, the side that is working provides a structure in which the weaker side can function. The external structure of moving and performing with the other side sends a correcting signal through the brain structures that are not operating efficiently, and helps develop the proper efficient integration. There is an added demand in this activity for precision in the integration of all the systems because of the added balance factor that results from standing and balancing on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM.

PENDULUM BALL WITH TARGET STAND AND TARGET PINS

INTRODUCTION:

In the following activities there is an added factor - the target stand and target pins. The position of the target pin stand is important. If it is too far away the ball will swing over the top of the pins. (Sometimes this is the position you want.) If it is too close the ball will swing and the string will hit the cross bar that the pins sit on and everything will turn over. The stand must be set in accordance with the specific exercises you are performing so the ball either strikes the pins and knocks them over or so that it just misses the tops of the pins if that is what you want it to do.

Since the string on the Pendulum Ball can be let out or taken up to make it longer or shorter, the target stand should be placed and set up after the length of the string has been set. If the string is let out and made longer, the stand must be set back farther. If the string is shortened, the target stand must be moved closer.

The difficulty of hitting the target pins on the stand is relative to their distance from the balance platform on which you are standing. It is easier if the target pins are close, and more difficult if they are farther away, since a slight error in control is amplified by distance.

The manner in which the target pins are knocked over is also involved in determining the difficulty of the task. The easiest and most efficient way to knock the target pin over is to swing the Pendulum Ball and strike it from the front. It is more difficult to swing the ball around so it strikes the target pin from the side. More depth perception is involved in striking the target from the side. The most difficult trajectory to program is to swing the ball so that it goes around behind the target pin and knocks it over by striking it from the rear.

The target pins can be utilized in four ways to structure the Pendulum Ball activity. The first way is to swing the ball and knock the targets over. The second is to swing the ball and purposely miss the target pins. The third way is to use them to set limits. For example, two target pins can be set, one on each end of the target stand with the target stand centered. The target stand cross member is 24" long. With the 1 1/2" wide target pins sitting one on each end of the crossbar, a space of 21" will separate them. Various activities can be carried out swinging the ball so that it will swing between the two target pins. The difficulty level can be increased by bringing the two target pins closer and closer together. You can keep track of the number of times you swing the ball between the pins, the number of times the ball swings outside the pins, and the number of times the pins are knocked down. You can then chart your improvement in ball control.

For example, the target stand can be placed ten feet from the CALIBRATED-VARIABLE DIFFICULTY BALANCE PLATFORM. The target pins can be placed 21, 18, 12, or 6 inches apart on the target stand. You can hit the ball in various ways making it swing between the target pins, then score the task by counting the number of swings between the targets and counting how many times the ball either did not swing within the limits or hit the pins. To get a score that is valid for evaluating control development the ball should be hit or swung at least 100 times and the number of misses should be subtracted from 100. After you have been on the program for several weeks you can repeat this activity and chart your improvement.

The fourth way the target stand and target pins can be utilized to structure the activity is to set the target stand back so that the ball swings over the tops of the pins and misses the pins by about 1/4" as it swings. As the ball swings it does not knock the pins over, but it is easy enough to see whether the ball would have knocked the pin over if it had been swinging at the right height. (The advantage of the 2nd, 3rd, and 4th ways of using the target pins over the 1st way is that you do not have to keep setting the pins back up. There is, however, a certain emotional satisfaction to knocking over the target. You may want to use different set up systems at different times.) Swinging the Pendulum Ball over the targets allows you to see how close the ball is to being perfectly centered on the target pin. To hit the target pin you do not have to be as precise. The ball will knock the pin over if any part of it touches any part of the pin.

SET UP - I:

Set up the target stand with the target pins equal distances apart and in this order from left to right: circle, cross, square, triangle, and diamond. The center line of the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM should point in the direction of the target pin at the center of the target stand. A straight line drawn from the center of the target stand to the center of the balance platform should pass directly under the point on the ceiling where the ball attaches. Everything should be lined up.

Hold on to the ball. Stand on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM with your feet an equal distance from the center line of the platform and your toes lined up to the same horizontal grid line.

ACTIVITIES - I:

1. Locate the target pin that is in the center of the target stand. Plan carefully, then swing the ball and knock over the centerpin. Catch the ball when it swings

back. Locate the target pin that is just to the left of the center pin. It should be the pin with the cross on it. Now swing the ball and knock it over. Catch the ball. If you did not knock over the pin that was just to the right of the center pin with your return swing, swing the ball again and knock it over. Catch the ball.

2. Swing and catch the ball with your right hand. Try to swing it between the target pins that are still on the target stand as you continue to swing and catch the ball with your right hand.

3. Now switch and swing and catch the ball with your left hand. Try to make the ball swing between the two target pins left on the stand without hitting them.

4. Swing and catch the ball with both hands. Try to swing the ball between the two pins without hitting them.

5. Try to get as close to the pins as you can without hitting them.

6. Swing and catch the ball with both hands. Try to make the ball swing out around the target stand and the target pins.

7. Plan carefully. Visualize the trajectory of the Pendulum Ball, then swing the ball with both hands and try to knock the target pin on the right side of the target stand over by striking the target pin from the rear.

SET UP - II:

Put two pins on the target stand crossbar. Put one about 4 inches to the left of the center. Put the other target pin on the far left end of the crossbar. Move the target stand back so that the ball swings 1/4" over the top of the target pins and does not hit them. Hold onto the ball and get back onto the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM.

ACTIVITIES - II:

1. Swing and catch the ball any way you like, with either hand. Make it swing around between the target pins. Follow the motion of the ball carefully with your eyes as it swings. Plan the trajectory. Visualize it carefully before you swing the ball, then follow the ball after you swing it and check how accurately the ball follows the path you planned for it to travel.

2. Hit the ball with the palm of your right hand and make it swing around between the targets. Keep hitting the ball with the palm of your hand.

3. Hit the ball with the palm of your left hand and keep it swinging so it swings between the two target pins. Follow the motion of the ball carefully with your eyes.

4. Alternate left palm, then right palm, and make the ball swing between the two target pins. As the ball swings, point the tip of your nose at the ball and follow the motion the ball makes as it swings. Keep the tip of your nose pointed at the ball.

5. Make a fist and hit the ball with your left fist, then with your right fist and control the motion of the ball so that it swings between the two target pins. Plan the ball's trajectory carefully and try to make the ball follow the path that you want it to follow.

6. Clasp both hands together and hit the ball and make it swing around between the pins. First make it swing in one direction, and then make it swing back around in the other direction. Catch the ball.

7. Swing the ball with your right hand. Make the ball swing around both targets and catch it. Then make it swing around the target that is nearest the center of the stand, between the two targets, and back to you. Catch it and start over again. Continue this sequence.

8. Swing the ball with your left hand around both targets, then just around the target that is nearest to the center.

9. Swing the ball so that if it were low enough it would hit the target pin that is closest to the center. Swing it so that it would hit the target pin on the side.

10. Swing the ball so that if it were low enough it would hit the target pin that is on the left end of the target stand. Swing it so that it would hit the target pin from the side.

11. Swing the ball with both hands and catch it with your left hand. Swing it again and then catch it with your right hand. Keep swinging and catching the ball in this sequence.

12. Imagine that there are target pins on the far right and in the middle of the right side of the crossbar. Swing the ball as if to knock over your imaginary targets.

13. Swing the ball and hit it two times with your right hand, then three times with your left hand, then one time with both hands clasped together. Keep this sequence going.

14. Swing the ball with both hands. While it is swinging out, twist your body as far as you can to the right. As the ball swings back to you, twist your body back to the center and catch the ball.

15. Swing the ball with both hands. As it swings out, twist your body as far as you can to the left. As the ball swings back, twist back to center and then catch it.

16. Swing the ball out with both hands. As the ball swings out, twist your body as far to the right and then as far to the left as you can, then swing back to the center and catch the ball.

BEAN BAGS

INTRODUCTION:

Bean bag activities can play an important role in developing right hemisphere functions. They can be valuable in developing, refining and extending the integration of the two brain hemispheres and of the various brain components that deal with spatial relations, temporal relations, vision, movement, and balance. Bean bag activities can provide a means of exploring the potentials of your senses. They can be a means for developing an understanding of how this marvelous person called you operates, moves, and learns, in this fascinating universe we live in. Bean bag activities provide the same potential as does art or music for you to exercise and develop your creative abilities. Bean bag activities can provide a world of fun for young and old.

Man is unique in his ability to pick up an object while he is walking, running, or otherwise moving through space, throw that object at another moving object, and hit it. This ability to throw and hit moving objects, and the perceptual functions that go with this ability, are fundamental to the development of the Structure of Man's Intellect. A great deal of complex mental calculation is involved in the process of throwing an object and hitting another moving object. The human brain is so geared to this kind of processing that a preschool child who has had the opportunity to run free, to throw sticks and stones, and to manipulate toys, can do a pretty fair job of throwing and hitting a moving target. The child would have to develop quite a bit more to hunt tigers, however, the brain ability to perform this type of data processing is the same ability which has allowed the human race to put a man on the moon and to fly by the planets in our solar system, and it is the ability which will someday allow us to set foot on planets that orbit nearby stars.

To throw an object while you are running appears to be a simple task, but in reality it is not. You must know your own velocity and the direction of your movement through space. Knowing your velocity and direction requires you to process data from the tactile, kinesthetic or motor, vestibular, and visual sensory modalities. The bottoms of the feet furnish tactile data that is created by the changing pressures that result from running and balancing the body as it moves through space. The tactile data has a velocity component and a directional component. The muscles and joints that are producing the motion, and at the same time keeping the body balanced and aligned properly, provide kinesthetic data relative to the velocity and direction of movement as well as to the balance state of the body. The vestibular sense or equilibrium is providing data that is utilized in stabilizing the head so that it is held perfectly level and moving in an almost straight line through space. The vestibular sense is also providing inertial data that has a directional component and also a velocity component. The visual sensory modality, depending very much on the work of the other systems, is providing a great deal of very accurate data relative to the rate and direction of motion. The visual modality is also providing data relative to the inertial state of the target and of the other objects in the visual field, that is, other objects that are either moving or standing still.

As the body moves through space the visual field expands, both horizontally and vertically away from the point that the body is moving toward, or the center of motion. The farther you are away from the center of motion, the more rapidly the field expands. (When you are driving your car, the center of the part of the road you are driving on appears to be moving much more slowly than the objects at the side of the road. When you turn, the visual field on one side appears to move faster than that on the other. In fact, you guage your rate of turn using this phenomenon. When you land an airplane, the point on the ground you are moving directly toward is the only point that remains stable - the rest of the visual field expands around it.) With the vestibular processes stabilizing the eyes,the brain can compute the motion of numerous reference points on the retinas of the two eyes. The brain utilizes this data to refne the control of the body so it can move efficiently and respond to objects in the visual field. Since the visual field expands away from the center of motion the brain has a precise reference for centering visually.

When you reach down to pick up an object to throw, the brain has to superimpose the program to change body posture, body balance, and body movement required to allow you to reach down and pick up the object, over the present program of body posture, balance and movement through space. As you pick up the object to throw, the tactile sensors in the tips of the fingers and palm of the hand, and the tactile sensors on the bottoms of the feet are activated. (The object changes the body balance and pressure distribution on the bottoms of feet.) The kinesthetic sense in the muscles and joints is activated by the mass of the object in the hand. The brain processes the data from these systems and determines the mass of the object. (The brain has already estimated the weight from visual clues before you picked it up. The tactile and kinesthetic data refines that estimate.) The body posture and dynamic movement are realigned to compensate for the changes. Using visual information, the position of the intended target is determined, a sample of its movement through space is taken, and from this sample, its future position is calculated. A movement pattern to throw the projectile to the intended target is generated taking into consideration the body's velocity and direction of movement through space, the intended target's velocity and direction of movement through space and the mass of the projectile.

The movement of the body through space has to be included in the calculation. The throwing movement is superimposed on the body's movement. At just the right moment the series of body actions necessary to throw the projectile, and to counter balance the force of throwing and the change in dynamic body balance resulting from the throwing of the object is executed. As the projectile moves toward the target, the visual system monitors the motion of the projectile. If the projectile hits the target, the brain sends an OK throughout the system; if the projectile misses the target the brain automatically reviews the program to try to locate the errors in it. Either way, anything unique in the program is held in memory for future reference and for use in refining the system.

To perform this type of activity properly, a great deal of the brain is involved. The over all command and control is a right hemisphere function. In doing this type of activity you must always be on guard to keep the left hemisphere from grabbing control. Right hemisphere control results in a global integration of all the systems. Left hemisphere control results in a rigid linear program of specific movements with limited, even suppressed, sensory inputs organized to perform in a very specific way. If parts of the movement system, or of the visual system, or of the vestibular or tactile systems are not refined enough to perform properly, the left hemisphere will suppress them to get a specific activity done. The left hemisphere is interested in the here and now.

For example, if you are going to throw the bean bag and hit a target, the left hemisphere will let you throw it under handed, or maybe over handed. It will want a specific distance that you are going to throw. It will not want to vary the distance. It will want bean bags of a specific weight. It likes rules and laws and formula type operations.

The right hemisphere likes complex systems. It likes to deal with all of the space. It likes targets to be all over - above, below, moving and still. It even likes to imagine targets. It likes you to look at a number of targets, close your eyes, then throw the bean bags with your eyes closed. The right hemisphere likes to have different weight bean bags because the weight of the bean bag is a factor in determining the amount of energy necessary to throw the bean bag through a given distance. Speaking of distance, the right hemisphere likes the targets to be near, far, and at different distances. When you throw the bean bag, the right brain hemisphere prefers that you throw it many different ways, over handed, under handed, side armed, both hands together, right handed, left handed,- there have to be ten thousand different ways. The left hemisphere likes its complex language structures and games with words. The right brain hemisphere likes its varied and complex movements, varied and complex visual structures, and varied and complex spatial relations. The right brain hemisphere knows that if you do not sort out your body's internal space and sort out the space around yourself by utilizing your movement structures in many different ways and observing their effect on the external world, you will never really comprehend the marvelous space that we exist in, the space that exists in an atom, the space a quark occupies, or the space that separates us from the farthest star in the universe.

(Ed. note: The left hemisphere realizes that if you consistently operate on this global plane, you will never get anything done. It is necessary to develop a balance between the two hemispheres.)

The right brain hemisphere does not even like these activities to be limited to bean bags. It likes balls - round ones, bouncy ones, soft ones, hard ones. It loves rocks of all kinds. It likes sticks, rockets, cars, boats, airplanes, anything that the mind of man can move. Even mountains. It recognizes though that a great deal can be done with bean bags, so it is happy to begin with them so long as you recognize the global applications of the ideas.

The right brain hemisphere also recognizes your great potential for elaborating these ideas and creating your own activities once you really turn on both sides of your brain.

SET UP - I:

We will begin the activities with a complex and difficult one. There is no failure in this. It is just a challenge. We will not even utilize the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM directly for this one. You will see that we will utilize the platform indirectly after you have done this program for a while. You will need the bean bags, target pins, target stand, and Pendulum Ball.

ACTIVITIES - I:

1. Clear out a good sized space. Locate a point in the middle of the space. Place the target pins randomly around the space. Get your three different weight bean bags. Stand in the middle of the space and look at and locate the different target pins. The target pins are marked with a circle, a cross, a square, a triangle, and a diamond, to make them easy to identify. Make a mental note of the position of each pin. Now close your eyes, and keeping in mind the position of the target pins and your position relative to them, turn around, move to the right a few steps and move backward a step. Keep your eyes closed. Throw one of your bean bags at the target pin with the square on it. Notice which bean bag you have thrown - the heaviest, the lightest, or the one in between. Keep your eyes closed. Now, turn around again and throw another bean bag at the target pin with the triangle on it. Listen as the bean bag hits the floor to see if you threw it where you intended to throw it. Keep your eyes closed, step two steps forward and throw the last bean bag at any target you choose.

As soon as the last bean bag leaves your hand and before it can reach the target, open your eyes and watch it. Notice how far off target you were. As soon as you have checked the accuracy of the third bean bag thrown, cast your eyes toward the second bean bag. Try to see how quickly you can direct your eyes to the second bean bag thrown. This will give you an idea of how well you have kept the organization of the space around you in your mind, while you moved with your eyes closed. Did the second bean bag go where you thought it would go? Cast your eyes immediately to the first bean bag. How well did it follow the path you planned for it, and how well were you able to remember its position in the spatial arrangement?

This would be an excellent game to build a television show around. The person who did the best and won the prize would surely deserve it.

This activity forces you to use your brain and your senses differently from the way you use them in just throwing the bean bags at targets. When you first looked at the target pins that were around you, and then closed your eyes, you had to remember where the various target pins were relative to your position. Since they were all around you and at different distances from you, you had to see them as part of the over all space structure. You can zero in on a single target with your eyes open and perceive it without really seeing it in the context of the overall space structure, but to perform the activities in the previous sequence, you have to organize, and then maintain, the overall space structure.

When you moved your body with your eyes closed, you had to utilize your inertial guidance system. You had to process data that was generated by the vestibular modality, the kinesthetic modality, and the tactile modality. The vestibular modality picked up changes in the acceleration and the direction of the change as your head moved through space. The kinesthetic modality picked up data generated by your muscles and joints as they moved and caused your body to move through space. The tactile modality picked up data generated by pressure changes on the bottoms of your feet as your body moved and turned through space. Your brain processed the vestibular, kinesthetic and tactile data and modified the visual structure it was holding in memory. It transformed the structure mentally to adapt to the movement of your body through space and your changed position in the structure.

Throwing the bean bags at the mental image of the target pin involved gathering data relative to the mass of the bean bag by sensing the pressure on the hands and fingers created by the force of gravity acting on the bean bag. This force of gravity acting on the bean bag is also sensed kinesthetically from the sensors in the muscles and joints.

To refine the data that is created by sensing the force of gravity on the bean bag, the arm, hand, and bean bag were probably moved up and down. This motion introduced an inertial component which allowed a finer determination of the mass. When the mass of the bean bag had been determined, your brain computed the relative distance and direction of the mental image of the target.

It takes a specific amount of energy to change the inertial state of the bean bag, to cause it to move through a specific distance in the gravitational field. The brain computes this, then selects the specific muscle units and the sequence in which the muscle units will be employed to cause the arm to move in the proper direction with the proper amount of force to change the inertial state of the bean bag to move it to the target.

For every action, there is an opposite and equal reaction. If all the brain computed was the movement to cause the bean bag to move to the target, the reaction to that movement would upset the body balance and throw it to the floor. The brain generates a counter balancing movement sequence to counteract the opposite and equal reaction to the throwing activity. Moving again and throwing the second bean bag involved the same factors as previously. There was another element in this second sequence. You were instructed to listen to where the bean bag landed. Listening to where the bean bag landed required perception of auditory spatial relations which involved auditory depth perception and auditory perception of direction.

Thowing the bean bag through space requires energy to change the bean bag's inertial state. The brain processes space in terms of differences in inertial states, therefore spatial relations are inertial relations. A specific amount of energy to change the inertial state of the bean bag from a state of being at rest to the proper state of motion in the gravitational field is required to move the bean bag from one point in space (Point A) to another point in space (Point B). If point A or point B is in motion, or if they are both in motion, their inertial states must also be accounted for. The brain processes space, and motion of objects in space, in terms of the dynamic inertial state. The brain's ability to determine the inertial state of the body's motion and its ability to determine the inertial state of objects in space, whether they are at rest or in motion is the fundamental base for spatial perceptions.

2. Place the bean bags randomly around the room. Swing the Pendulum Ball. Walk, run, skip, hop, crawl, creep, roll, or otherwise move about the room from bean bag to bean bag. Without stopping your movement or changing your pace, when you reach a bean bag pick it up with the hand that is closest to it, then throw it at the swinging Pendulum Ball and try to hit the ball. Keep moving from bean bag to bean bag untl you get tired. As you throw the bean bags they will go to another place in the room so this becomes a never ending activity. Throw the bean bag with right hand, left hand and both hands.

3. Set up the target stand with the targets placed on it. Set the Pendulum Ball so that it will hit the target pins. Do the previous activity again, only try to hit the Pendulum Ball with a bean bag in such a way that the ball will knock over one of the targets. You can hit the Pendulum Ball and make it go straight to the target, or you can hit it so that it will swing out around and back to the target. If you are behind the target stand when

you throw the bean bag, you are going to have to plan an indirect trajectory to reach the target.

Throwing bean bags at moving targets while walking, running, skipping, hopping on left foot, hopping on right foot, hopping on both feet, or while rolling, creeping or crawling, requires you to superimpose the throwing movement over many different movement patterns. How well the movements are integrated will be reflected in whether you hit the target, or how close you come to hitting the target, and in how smoothly you move. As you move your body in different ways under visual control, you are establishing visual motor relationhips in a more divergent way than if you only moved your body through space in the conventional manner of walking or running. It is also more difficult to maintain a suppression pattern in the motor functions of the trunk, neck and arms if you are creeping, crawling or rolling through space in different ways as you throw the bean bag at the targets.

SET UP - II:

The following bean bag activities can be done standing on the ground or they can be done while balancing on the CALIBRATED VARIABLE-DIFFICULTY BALANCE PLATFORM. They can also be done while walking up and down on the VARIABLE-DIFFICULTY BALANCE BEAM.

ACTIVITIES - II:

1. Throw the bean bag up in the air with both hands and catch it when it comes back down. Make the two sides of your body move symmetrically or exactly the same way.

2. Throw and catch the bean bag with both hands. Make the two sides of your body move symmetrically. Follow the bean bag with your eyes as it moves through space.

3. Throw and catch the bean bag with both hands. Make the bean bag just touch the ceiling.Point the tip of your nose at the bean bag and follow it as it moves through

4. Throw and catch the bean bag with both hands. Try to make the two sides of your body move symmetrically. Throw the bean bag up and try to make it come as close to the ceiling as you can without touching the ceiling. Point the tip of your nose at the bean bag and follow its movement.

5. Throw and catch the bean bag with both hands. Move symmetrically. Throw the bean bag up and try to make it come one foot from the ceiling, then two feet from the ceiling, and then three feet from the ceiling. Continue this sequence.

Activities 1 - 5 involve symmetrical motion of the two sides of the body. This type of motion requires that the two sides of the body work harmoniously, and helps to integrate the two brain hemispheres. Throwing the bean bag up and making it come as close to the ceiling as possible requires more precision and finer control of the movement. The brain's calculations and the visual motor relationship must be more accurate to do this. This activity also stimulates precise depth perception. The ceiling lacks a lot of the depth clues that you have when you look out in front of yourself. You really have to depend more on stereopsis to judge depth looking up at the ceiling. Throwing the bean bag to a point 1 foot, then 2 feet, then 3 feet from the ceiling forces finer control and depth evaluation.

6. Throw and catch the bean bag with the left hand.

7. Throw and catch the bean bag with the right hand.

8. Throw and catch the bean bag with the right hand and follow the motion of the bean bag with your eyes. Keep your eyes on the bean bag throughout its trajectory.

9. Throw and catch the bean bag with your left hand. Follow the motion of the bean bag with your eyes. Keep your eyes on the bean bag throughout its trajectory.

10. Throw and catch the bean bag with your right hand. Point the tip of your nose at the bean bag and follow the bean bag with the tip of your nose throughout its trajectory. (You could put on a miner's light, a light that straps on your head, and keep the light centered on the bean bag to do this activity.

11. Throw and catch the bean bag with your left hand. Point the tip of your nose at the bean bag and follow its motion throughout its trajectory.

12. Throw and catch the bean bag with your right hand. Make the bean bag just touch the ceiling as you throw it. Do not hit the ceiling hard.

13. Throw and catch the bean bag with your left hand. Make the bean bag just touch the ceiling when you throw it.

14. Throw and catch the bean bag with your right hand. Make the bean bag come as close to the ceiling as you can make it without touching the ceiling.

15. Throw and catch the bean bag with your left hand. Make the bean bag come as close to the ceiling as you possibly can without touching the ceiling.

16. Throw and catch the bean bag with your right hand. Make the bean bag come to within 1 foot of the ceiling, the next time make it come to within 2 feet of the ceiling, and the next time make it come to within 3 feet of the ceiling.

17. Throw and catch the bean bag with your left hand. Make the bean bag come to within 1 foot of the ceiling, then make it come to within 2 feet of the ceiling, then to within 3 feet of the ceiling. Continue this sequence.

18. Throw and catch the bean bag with both hands. Make the bean bag get as close to the ceiling as possible when you throw it up and let it get as close to the floor as possible before you catch it.

19. Throw the bean bag with your left hand. Make it come as close to the ceiling as you possibly can when you throw it up. Let the bean bag get as close to the floor as you possibly can before you catch it. Catch it with your left hand.

20. Throw the bean bag up with your right hand. Make the bean bag get as close to the ceiling as you possibly can when you throw it up. Then when the bean bag comes back down, let it come as close to the floor as you possibly can before you catch it. Catch it with your right hand.

21. Invent your own way to throw and catch the bean bag.

22. Throw the bean bag up in the air with your right hand. Catch it with both hands when it comes back down. The first time you throw it up let it get as close to the ceiling as you can, the second time throw it to within 1 foot of the ceiling, the third time throw it to within 2 feet of the ceiling.

23. Throw the bean bag up in the air with your left hand. When it comes back down catch it with both hands. The first time you throw it let it come as close to the ceiling as you possibly can without touching the ceiling. The next time you throw it let it get to within one foot of the ceiling and the third time you throw it let it get to within 2 feet of the ceiling.

24. Throw the bean bag up in the air with your right hand. Catch it with your left hand when it comes back down. Catch it as high in the air as you can.

25. Throw the bean bag up in the air with your left hand. Catch it with your right hand when it comes back down. Catch it as high up in the air as you can.

26. The second time you throw it let it get as close to the floor as you can before you catch it. Throw it with your right hand and catch it with your left hand.

27. Throw it with your left hand and catch it with your

right hand. Let it get as close to the floor as possible before you catch it.

28. The third time you throw it try to catch it at a point that is exactly midway between the point at which you caught it the first time and the point at which you caught it the second time. Throw it with your right hand and catch it with your left hand.

29. Throw it with your left hand and catch it with your right hand. Catch it at the midway point.

30. Throw the bean bag up with both hands and catch it on the back of your right hand.

31. Throw the bean bag up with both hands and catch it on the back of your left hand when it comes back down.

32. Put the bean bag on the backs of both hands. Throw the bean bag up in the air and catch it.

33. Pick up another bean bag. Throw and catch two bean bags simultaneously. Throw and catch the lightest bean bag with your right hand, and the heaviest bean bag with your left hand.

34. Throw and catch two bean bags simultaneously. Throw and catch the heaviest bean bag with your right hand and the lightest bean bag with your left hand.

35. Throw and catch two bean bags simultaneously. Throw the heaviest one with your left hand and the lightest one with your right hand. Throw them as high up in the air as you can and keep them under control. Try to throw them up and just touch the ceiling. Try to make both of them go up the same distance when you throw them.

Appendix 7

Excerpt from: 'Sound Linkage' An Integrated Programme for Overcoming Reading Difficulties – Sections 1-2 (Hatcher, 1994)

(See Chapter Five - Page 195)

Excerpt from: 'Sound Linkage' - An Integrated Programme for Overcoming Reading Difficulties (Hatcher, 1994)

SECTION 1

IDENTIFICATION OF WORDS AS UNITS WITHIN SENTENCES

ACTIVITY 1

INTRODUCTION TO THE CONCEPTS OF 'BEGINNING', 'MIDDLE' AND 'END'

Materials needed: picture sheets 1 and 2.

Instructions
Present the pictures, giving help as necessary. Say:

Look at this train. Can you show me the beginning *of the train? Can you show me the* end *of the train? Where is the* middle *of the train?*

If no difficulty is encountered with those questions, begin Activity 2.

Say:

> *The next picture is about a line of people, at a bus stop. Look. This lady is at the* beginning *of the line [point]. Who's at the* end*? Can you find somebody in the* middle *of the line?*

If no difficulty is encountered with those questions, move to Activity 2.

Say:

> *Now we've got a line of traffic waiting at the lights. Can you show me what's at the* beginning *of the line? What's at the* end*? And what's in the* middle*?*

Again, if a child has no difficulty, move to Activity 2.

Say:

> *Here's a boy going along the road. There's a row of houses with numbers 1, 2, 3, 4, 5. Which house is at the* end *of the road? Which house is at the* beginning *of the road? Which house is in the* middle*?*

ACTIVITY 2

COMPREHENSION OF THE CONCEPTS 'BEGINNING', 'MIDDLE' AND 'END' IN SENTENCES

Materials needed: picture sheets 1 and 2 and photocopiable record sheet.

Instructions
Set out the two worksheets. Record the answers to the following questions:

Who's at the *end* of the line at the bus stop?	[ ]
Where's the *middle* house in the road?	[ ]
Show me the *end* of the train	[ ]
Find the house at the *beginning* of the road	[ ]
Who's at the *beginning* of the line at the bus stop?	[ ]
What's waiting in the *middle* of the line at the traffic lights?	[ ]
Total	[ ]/6

ACTIVITY 3

TRANSFERRING THE CONCEPTS 'BEGINNING', 'MIDDLE' AND 'END' TO AN AURAL ACTIVITY

Materials needed: photocopiable record sheet

Instructions
Explain that this time there will be no pictures but you will be listening for things at the beginning, middle and end.

Say:

> *Your name is* [say child's name]
> *Tell me the names of two of your friends.*
> *Now, I am going to say the three names. Let's see which one comes at the* end. *You tell me what it was.*
> *I'll say the names again* [use the same order]. *You see if you can hear the* middle *name this time.*
> *What was it?*
> *I'll say the names again* [use the same order]. *You see if you can find the name at the* beginning.
> *What was it?*

If the children show difficulty in answering these questions, get them to give you three other names and list them. Then discuss the positions of the names. For example:

> *(– –) was at the* end. *I said (– –) at the* beginning *and (– –) came in the* middle.

The same procedure can be followed using names of foods, places, etc.

Record the responses to the following, using the format:

> *I'll tell you three* [say class of things]. *You tell me the one at the* [say position].

Class	Position				
Colours	Beginning	**Red**	Yellow	Green	[✓]
Animals	End	Monkey	Pig	**Elephant**	[✓]
Numbers	Middle	Two	**Six**	Eight	[✓]
Drinks	Middle	Lemonade	**Milk-shake**	Cola	[✓]
Insects	End	Beetle	Caterpillar	**Spider**	[✓]
Scary things	Beginning	**Giant**	Dragon	Ghost	[✓]
Total					[ ]/6

PRODUCTION OF INITIAL, FINAL AND MEDIAL WORDS IN SENTENCES OF TWO TO FOUR WORDS

Materials needed: photocopiable record sheet

Instructions

Explain that you are going to say some words. You want the children to tell you one of the words. The word you want might be at the beginning, the end or the middle.

Ask them to say:

My name is [child's name].

Ask:

What was the word at the beginning? [**my**] ✓
What was the word at the end? [**child's name**] ✓
What was one of the middle words? [**name** or **is**] ✓

Say:

Now listen to this and tell me the word at the beginning. Wake up [**wake**] ✓

Use a similar format for the following:

Middle	It is snowing (**is**)	[✓]
End	Shall we go out? (**out**)	[✓]
End	Stop shouting (**shouting**)	[ ]
Middle	Here comes mum (**comes**)	[ ]
Beginning	Now you've done it (**Now**)	[ ]
Beginning	Good morning (**Good**)	[ ]
Middle	How are you? (**are**)	[ ]
End	Breakfast is nearly ready (**ready**)	[ ]
Total		[ ]/6
Beginning	Hello Fred (**Hello**)	[ ]
Middle	Are you better? (**you**)	[ ]
End	You seem to be (**be**)	[ ]
End	Daffy duck (**duck**)	[ ]
Middle	Laid an egg (**an**)	[ ]
Beginning	'Quack, Quack', she said (**Quack**)	[ ]
Beginning	Saturday morning (**Saturday**)	[ ]
Middle	Time to play (**to**)	[ ]
End	Let's feed the horse (**horse**)	[ ]
End	Stop thief! (**thief**)	[ ]
Middle	Catch that man! (**that**)	[ ]
Beginning	He's stolen my radio (**He's**)	[ ]
Total		[ ]/12

ACTIVITY 5

MATCHING COUNTERS TO WORDS IN SENTENCES OF TWO TO FIVE WORDS

Materials needed: packet of counters, board with six boxes (picture sheet 53) and photocopiable record sheet.

Instructions

Put out the plastic counters and the card with six boxes.

Ask the children to tell you any word that they can think of. If they can't think of a word, give an example and ask them to furnish further examples.

Explain that you are going to say some words. You want them to repeat each word and to push a counter into a box as they do so.

For each of the following, give the children the number of counters necessary to complete the task. Show them what to do if they don't understand. If children have difficulty in remembering the sentences, practise that aspect of the task before going on to ask them to push the counters.

Sentence	Number of counters	
Help me	2	[ ]
She shouted	2	[ ]
I can't get down	4	[ ]
It is scary	3	[ ]
The horse is frightened	4	[ ]
It is nearly free	4	[ ]
Please help me	3	[ ]
The horse jumped the fence	5	[ ]
It galloped down the road	5	[ ]
Total		[ ]/6
Helen held on tightly	4	[ ]
'Slow boy, slow', she shouted	5	[ ]
'Slow boy, slow'	3	[ ]
She pulled the reins	4	[ ]
The horse began to slow	5	[ ]
They came to a stream	5	[ ]
The horse skidded	3	[ ]
Helen slipped forward	3	[ ]
But she didn't fall	4	[ ]
The horse stooped to drink	5	[ ]
Helen sat up straight	4	[ ]
Phew, that was scary	4	[ ]
Total		[ ]/12

SECTION 2

IDENTIFICATION AND MANIPULATION OF SYLLABLES

ACTIVITY 1

INTRODUCTION TO SYLLABIC RHYTHM IN POEMS (A)

Materials needed: none

Instructions

Ask the children if they can remember the nursery rhyme 'Polly put the kettle on'. If they can, get them to recite it; otherwise, refresh their memory by reciting it:

Polly put the kettle on,
Polly put the kettle on,
Polly put the kettle on,
We'll all have tea.

Sukie take it off again,
Sukie take it off again,
Sukie take it off again,
They've all gone away.

Explain that you want them to say the rhyme with you and to tap their knees as they do so.

You may need to vary the speed and the amount of support you give. Children might also find it easier to tap alternately with their left and right hands rather than to use one hand all the time. Ideally, by the end of this activity, children should be able to tap their leg(s) while they, or you, recite the rhyme.

Repeat the procedure with one or more of the verses given below.

You may need to divide some of the verses into units of one or two lines and to get the children to repeat each unit after you before beginning the knee-tapping exercise.

Mrs Down
Went to town
With her face
Painted brown.

Mrs Jack,
She came back,
with her husband
in a sack.

Mrs Green
Was last seen
Getting in
A space machine.

Mrs White
Got a fright
When she met
A ghost last night.

Finally, try the same procedure with the following verse:

Piggy on the railway picking up stones,
Along came an engine and broke piggy's bones.
'Oi,' said the piggy, 'that's not fair.'
'Pooh,' said the engine driver, 'I don't care.'

ACTIVITY 2

INTRODUCTION TO SYLLABIC RHYTHM IN POEMS (B)

Materials needed: none.

Instructions
Ask the children if they can remember this rhyme:

One, two, three, four, five,
Once I caught a fish alive,
Six, seven, eight, nine, ten,
Then I let it go again.

Why did you let it go?
Because it bit my finger so.
Which finger did it bite?
This little finger on my right.

Explain that you want them to say the rhyme with you and to tap their knees while they do so.

As before, you may have to vary the speed and the amount of support you give. For example, before asking the children to say the rhyme and tap their knees, dividing the verses into units of one or two lines, and getting the children to repeat each unit after you may be helpful.

Repeat this procedure with the following poem, which is from 'Seeing and Doing', Thames Television, 1982. Before asking children to complete the task, it may be helpful to discuss the poem with them.

I lie in the grass
And see in the sky
A moving spark,
Ever so high.

Hard to believe
That away up there,
Are ordinary people
Flying where?

Perhaps to Bangkok,
Perhaps to Rome:
Some for a holiday,
Some going home.

Funny to think
That none of them know
That away down here,
I'm watching them go.

ACTIVITY 3

SYLLABLE BLENDING (2–4 SYLLABLES)

Materials needed: photocopiable record sheet.

Instructions
Explain that you are going to pretend to be a robot. As a result, you can only say words in a funny kind of way. The child has to guess what you are saying. Start with the child's name. Break it into syllables, and pronounce each syllable with a 1-second interval between them. For example:

Night – mare
Croc – o – dile
Tel – e – vi – sion

Say:

I am now going to say some more sounds. See if you can make them into words.

Speak the following words, keeping a 1-second interval between each syllable:

Pop – eye	[ ]
Tea – pot	[ ]
Di – no – saur	[ ]
Vid – e – o	[ ]
Un – der – stand – ing	[ ]
Pa – ra – chu – ting	[ ]
Total	[ ]/6

Prin – cess	[ ]
Doc – tor	[ ]
Car – pet	[ ]
Bis – cuit	[ ]
To – ma – to	[ ]
Cho – co – late	[ ]
Tel – e – scope	[ ]
Ex – plo – sion	[ ]
Tram – po – li – ning	[ ]
Re – mem – ber – ing	[ ]
Tel – e – pho – ning	[ ]
Ra – di – a – tor	[ ]
Total	[ ]/12

ACTIVITY 4

INTRODUCTION TO SYLLABLE SEGMENTATION

Materials needed: picture sheets 3 and 4 and photocopiable record sheet.

Instructions
Explain that we can split up words like the robot did. Using words that are familiar to children, such as their name, demonstrate that we can split words into pieces. For example, we could split:

Jason into Ja – son (two pieces).
Andrew into An – drew' (two pieces).
Jennifer into Jenn – i – fer (three pieces).

Suggest that this can be done with other words.

Say:

What about 'Carlisle'? You could say 'Car – lisle'.
Then there's 'Liverpool'. That would be 'Liv – er – pool'.
And the word 'Eden', as in the River Eden, could be split up into 'E – den'.

Present the eight pictures on the picture sheets, and ensure that the children can name them all.

Go back to the first picture and take turns in saying the syllables.

Do this by pointing at yourself, or the child, to indicate whose turn it is. For example:

Teacher	*Po –*
Child	*– ta –*
Teacher	*– to*

If a child says too much of the word, exclaim

That was a bit too much. Leave some for me!

Then demonstrate the correct version.

If a child says too little, exclaim

I think you need to say a bit more!'

Then demonstrate the correct version.

Say:

Let's see if we can work out how to split up these words.

Potato	*Po – ta – . Can you finish it?*
Scissors	*I'll start this one and you finish it. Sci – .*
Cupboard	*I'll start this one and you finish it. Cu – .*
Table	*You begin this one and I'll finish it.*
Radio	*I'll start this one and you do the next bit. Ra – .*
Flower	*You begin this one and I'll finish it.*
Television	*This one has four pieces in it, so remember to leave some for me! I'll start. Tel – .*
Cat	*Can we split that one into parts?*

Name the animals on the animal sheet. Explain that you are going to take turns with these words, for example:

Zebra	Teacher to start	
Monkey	Child to start	
		Number of syllables given correctly
Elephant (3 syllables)	Teacher starts	[ ]
Camel (2 syllables)	Child to start	[ ]
Alligator (4 syllables)	Teacher starts	[ ]
Hippopotamus (5 syllables)	Child to start	[ ]
Penguin (2 syllables)	Teacher starts	[ ]
Tiger (2 syllables)	Child to start	[ ]
Total		[ ]/9

ACTIVITY 5

SEGMENTATION OF WORDS INTO SYLLABLES (TWO TO FOUR)

Materials needed: picture sheets 5–7, counters, card with six boxes (picture sheet 53) and photocopiable record sheet.

Instructions

Explain to children that you are going to show them a picture, which they have to name.

They must say the word slowly, and for each part of the word push a counter into one of the boxes, for example:

Rainbow	Rain – bow (2)
Aeroplane	Aer – o – plane (3)
Helicopter	Hel – i – cop – ter (4)

For each of the following words, give the children the correct number of counters to complete the task. If necessary, demonstrate the task.

Scarecrow (2)	[✓]
Boomerang (3)	[✓]
Butterfly (3)	[✓]
Postman (2)	[✓]
Rhinoceros (4)	[ ]
Thermometer (4)	[✓]
Total	[ ]/6

Elephant (3)	[✓]	Spider (2)	[ ]
Window (2)	[✓]	Cinderella (4)	[ ]
Television (4)	[✓]	Money (2)	[✓]
Dragon (2)	[ ]	Alligator (4)	[ ]
Caterpillar (4)	[ ]	Kangaroo (3)	[ ]
Submarine (3)	[ ]	Camera (3)	[ ]
		Total	[ ]/12

ACTIVITY 6

SYLLABLE COUNTING IN WORDS OF TWO TO FOUR SYLLABLES

Materials needed: Counters, card with six boxes (picture sheet 53) and photocopiable record sheet.

Instructions

Explain that you are going to say a word. You want the children to listen to it carefully. They have to say the word slowly, and for each part of the word push a counter into one of the boxes, for example:

Freezer	Free – zer (2)
Blackberry	Black – be – ry (3)
Supermarket	Su – per – mar – ket (4)

For each of the following, give the correct number of counters to complete the task. If necessary, demonstrate the task first.

Beanstalk (2)	[✓]
Houdini (3)	[✓]
Hoovering (3)	[✓]
Breakfast (2)	[✓]
Cauliflower (4)	[✓]
Operation (4)	[✓]
Total	[6]/6

Pantomime (3)	[✓]	Children (2)	[✓]
Gremlins (2)	[✓]	Exterminate (4)	[✓]
Photographer (4)	[✓]	Brookside (2)	[✓]
Neighbours (2)	[✓]	Fingermouse (3)	[✓]
Bananaman (4)	[✓]	Television (4)	[✓]
Eastenders (3)	[ ]	Mexican (3)	[✓]
		Total	[12]/12

ACTIVITY 7

SYLLABLE DELETION

Materials needed: photocopiable record sheet.

Instructions

Explain that you are going to say a word. You want the children to say the word without the first part. For example, say:

Say 'football'. Now say it without saying 'foot'.
Now say 'farmhouse' without the first part.
Say 'Sunday without the first part.

Present the following using the same format.

He-man	[ ]
Playtime	[ ]
Fairground	[ ]
Hillwoman	[ ]
Lookaround	[ ]
Ghostbusters	[ ]
Total	[ ]/6

Inside	[ ]
Gasbag	[ ]
Headlines	[ ]
Sportsworld	[ ]
Allsorts	[ ]
Network	[ ]
Oilskin	[ ]
Landowner	[ ]
Newspaper	[ ]
Roundabout	[ ]
Blackbird	[ ]
Blackberry	[ ]
Total	[ ]/12

Appendix 8

Excerpt from: A 'Letterland' Activity Book – Red Book One (Letterland Publications Limited).

(See Chapter Five - Page 197)

LETTERLAND

ACTIVITY BOOK

RED BOOK ONE

FREE LETTERLAND BADGE!

Just send your name and address to the Hairy Hat Man:
Letterland Direct
P.O. Box 161,
Leatherhead, Surrey
KT 22 8HY

Introducing the letters with fun activities, games and puzzles

HOW TO USE THIS BOOK

As you start each page, take time to read the directions to your child and answer any questions he or she might have.

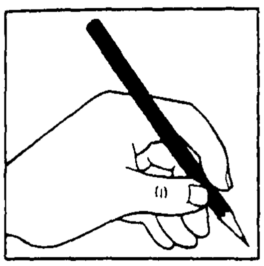
Approach each page with enthusiasm and build your child's confidence with encouragement and praise. Continue only for as long as your child is interested. This book is fun. Never let it feel like hard work!

Look for opportunities to talk about the letters and words you meet. On each new letter page, you could draw your child's attention to other words beginning with that letter, leading to a simple I Spy game. "Clever Cat went shopping and bought a cabbage, a camera, a ..." is another game you can enjoy together.

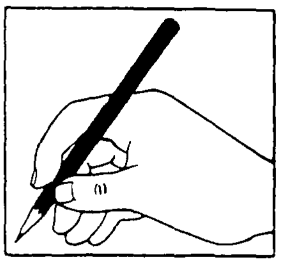
How to Pronounce the Letters

Don't use the alphabet names "aee, bee, cee". These *names* are no help to a child learning to read. You can hear the correct letter *sound* as soon as you start to say the Letterland character's name, i.e. **C**lever **C**at. Don't add "uh" to the sound.

How to Hold the Pencil



Check that your child is holding the pencil correctly. It should be held lightly between the thumb and forefinger, about 2cms from the point. The pencil rests on the middle finger.



RED BOOK 1

This book will help develop your child's pre-school skills, including pencil control, co-ordination and concentration.

Many of the activities feature movement from left to right. You can help by pointing with your finger as you read the directions on each page, reinforcing the reading and writing direction.

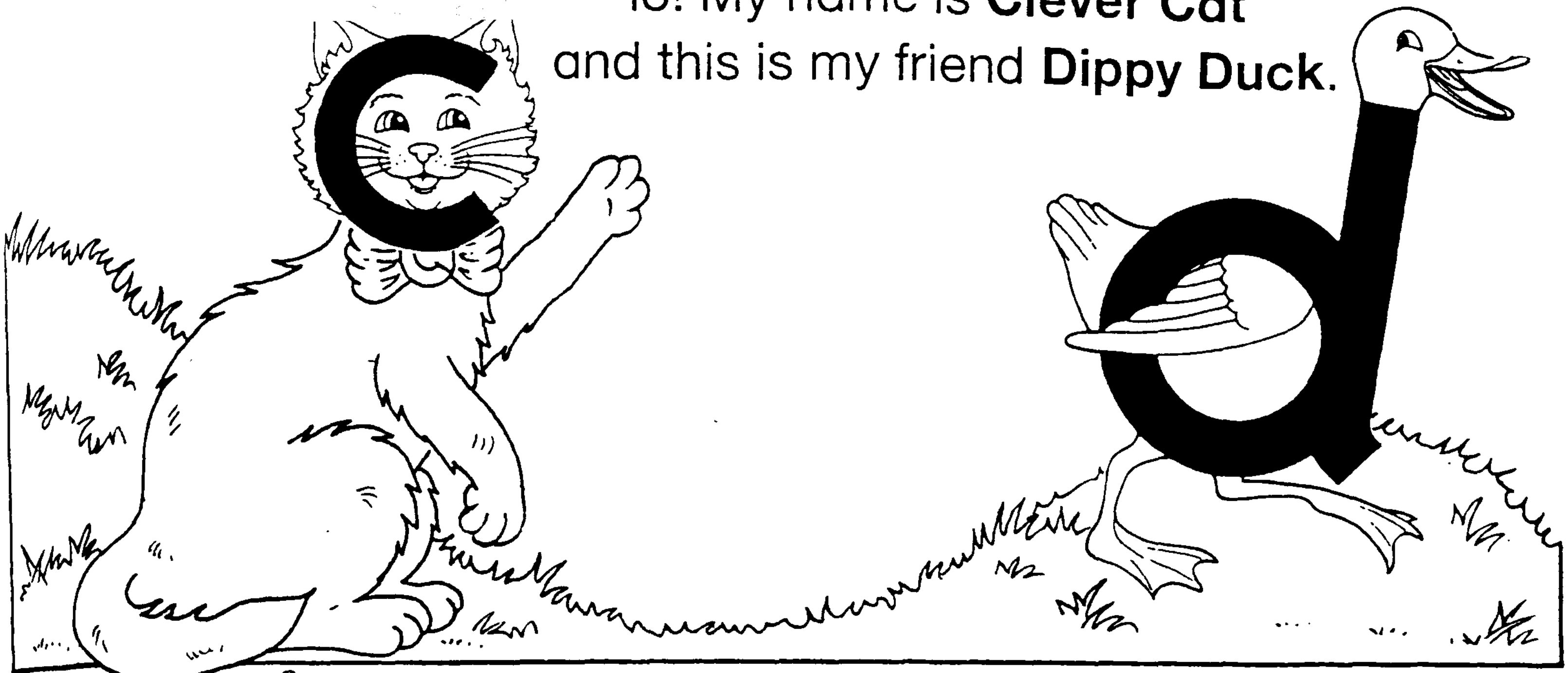
All the activities in these books are in line with the National Curriculum and complement school work carried out in the classroom.

Written by Stephanie Laslett
Designed and Illustrated by Arkadia
Design Production by FdK
With Consultant Advice from Lyn Wendon

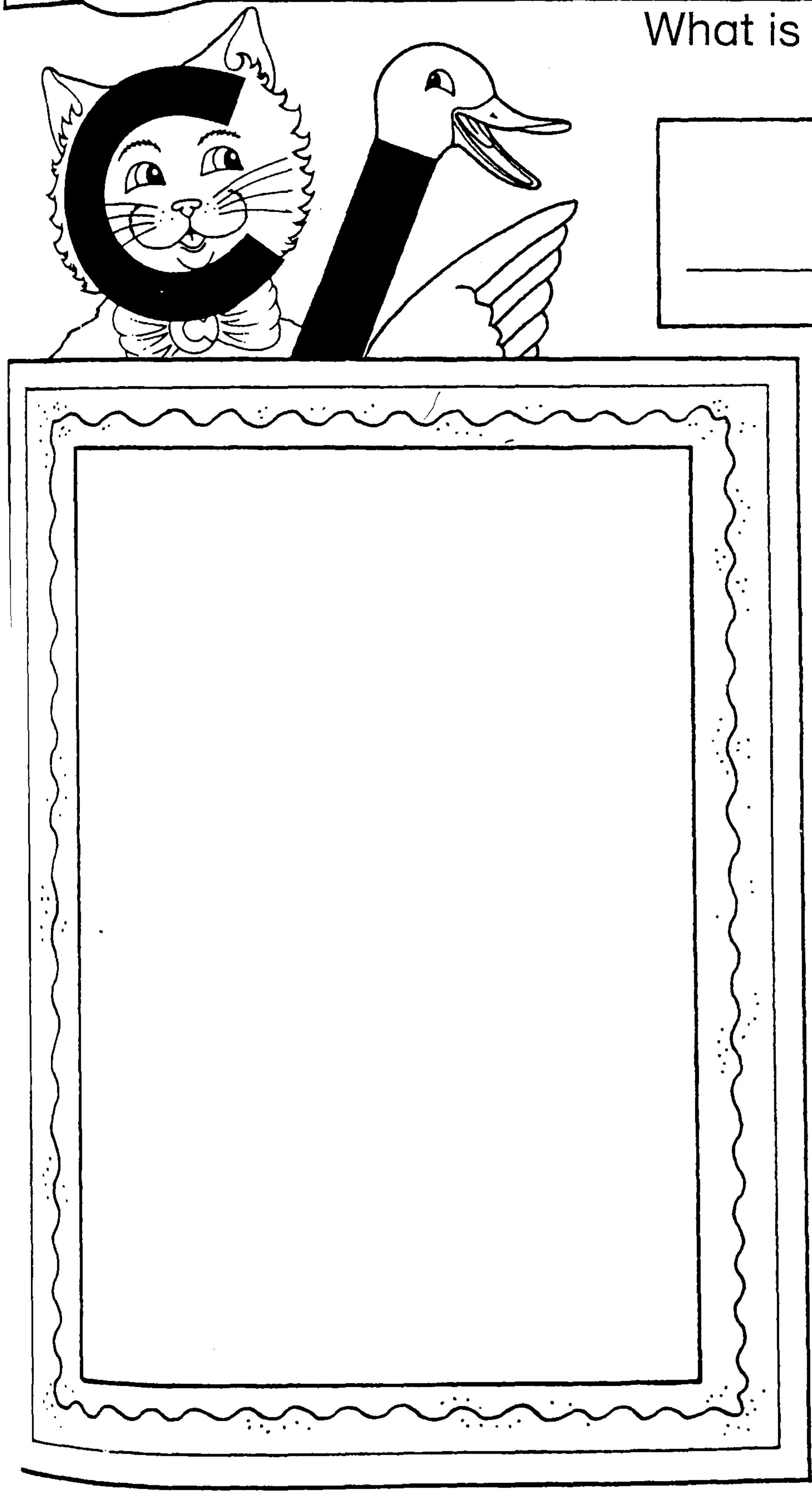
Published by
Letterland Direct Limited
PO Box 161, Leatherhead, Surrey, KT23 3YB

ISBN 1 85834 000 4
Printed and bound in the United Kingdom

lo! My name is **Clever Cat**
and this is my friend **Dippy Duck**.



What is your name? Write it here.

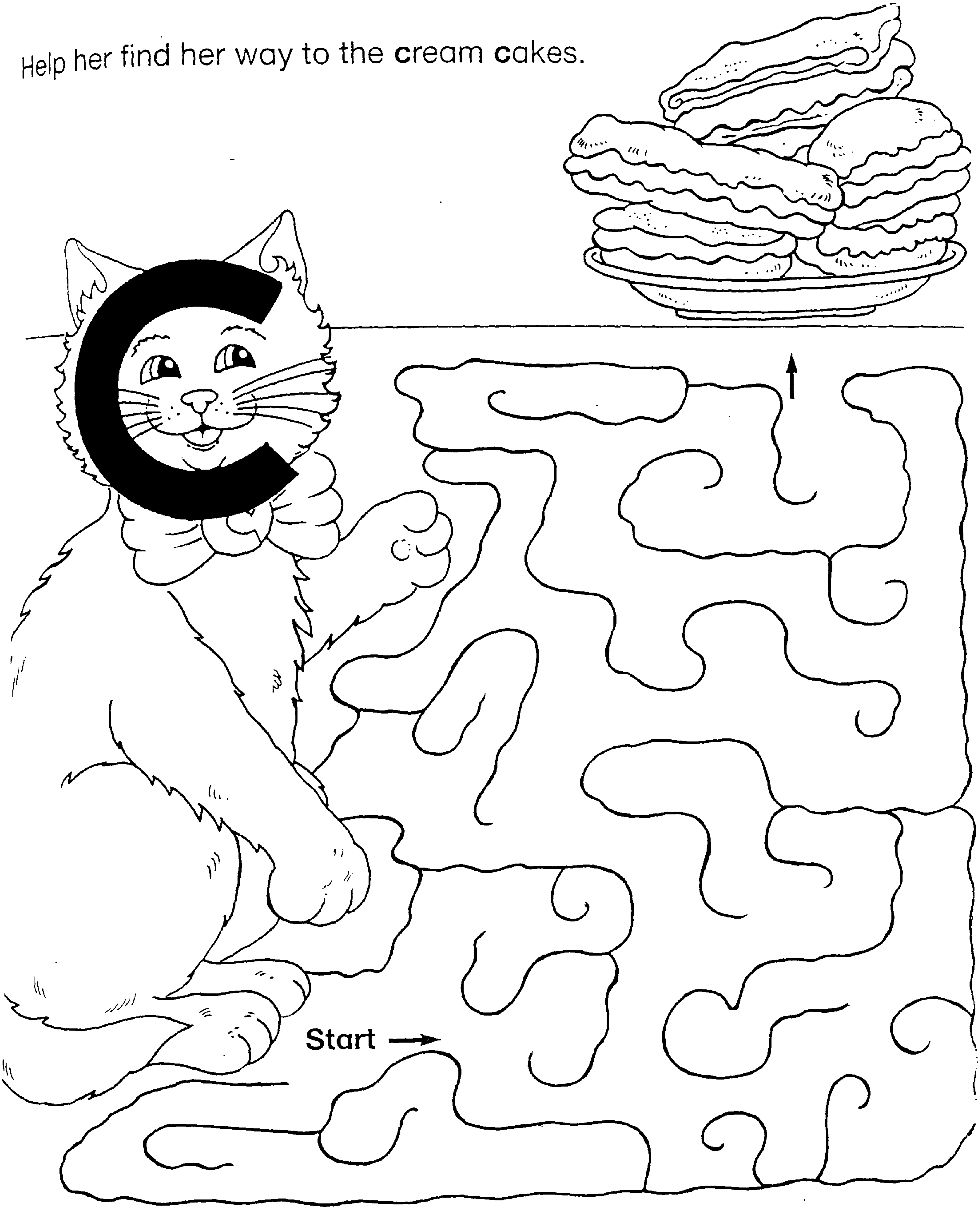


Clever Cat and **Dippy Duck** want to know what you look like.

Can you draw a picture of your face here and colour it in?

Clever Cat is hungry.

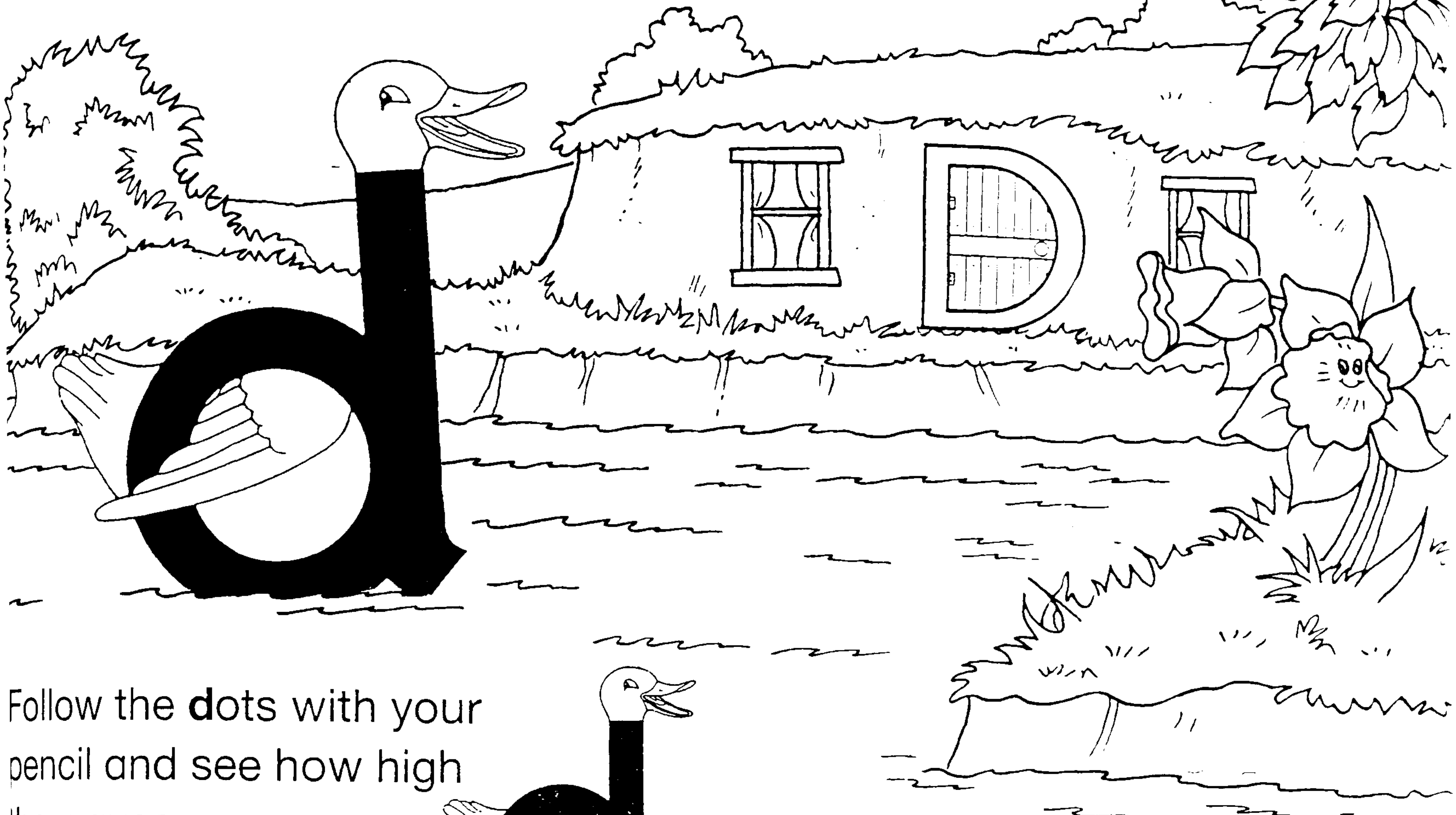
Help her find her way to the **c**ream **c**akes.



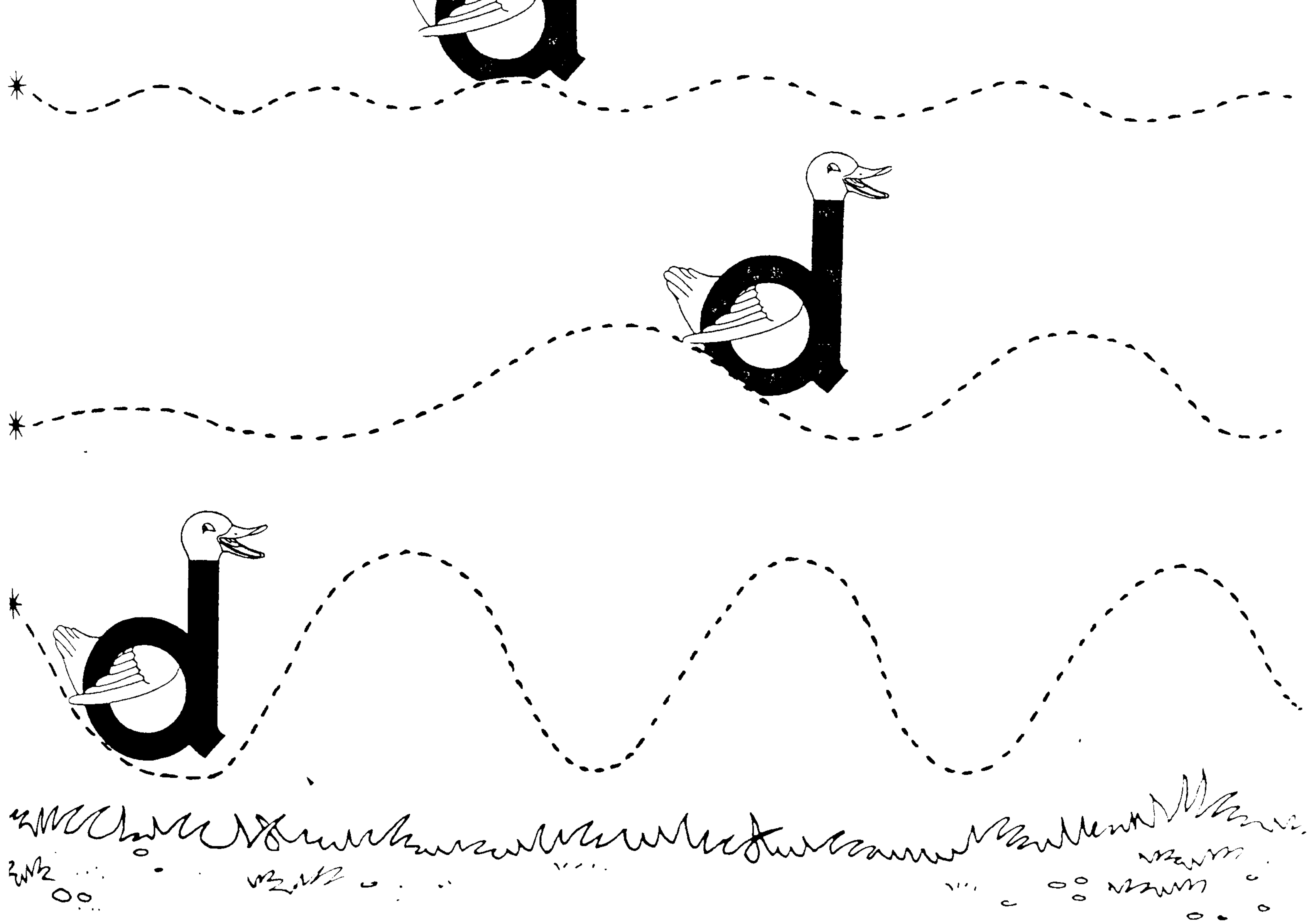
Now colour her in.

Give her a blue bow-tie and yellow fur.

It is a windy **d**ay and **Dippy Duck** is having fun with her friends on the pond.



Follow the **d**ots with your pencil and see how high the waves are.



raw some more **d**ucks, just like **Dippy**, riding on the waves.

low colour in the picture.

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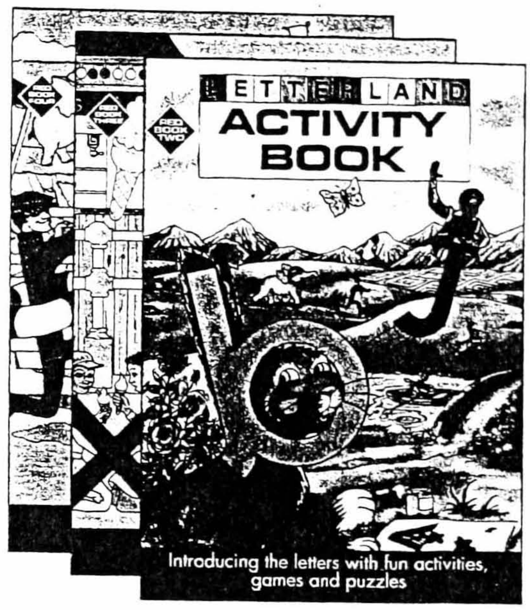

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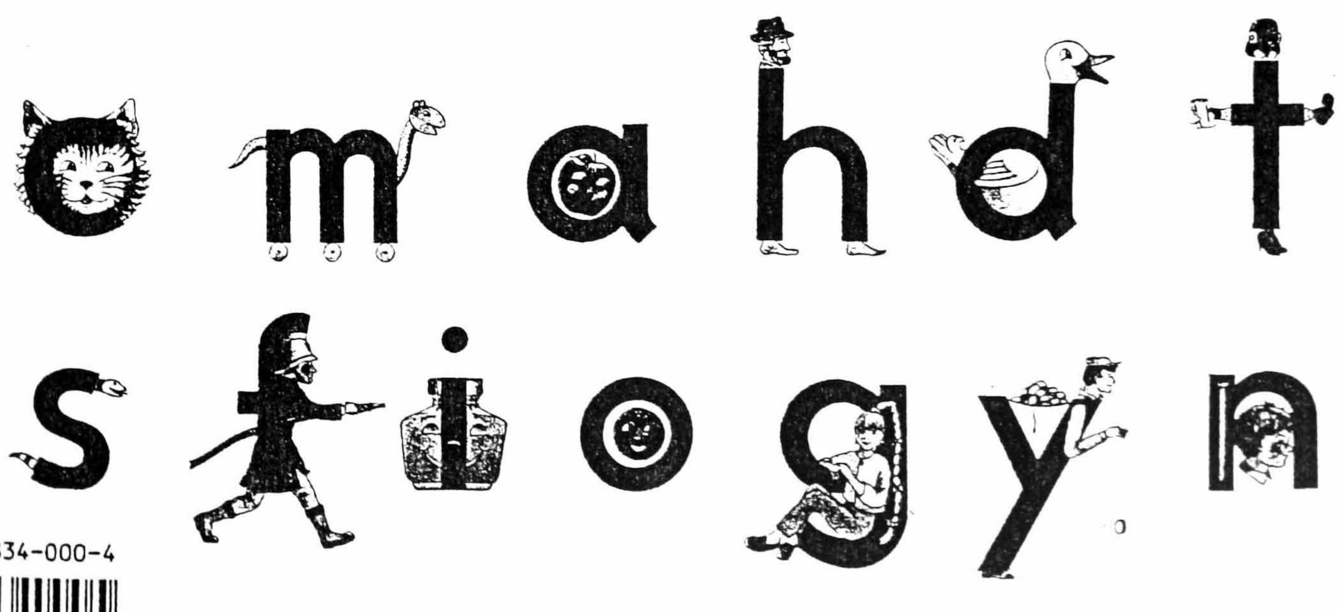

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Appendix 9

Summary of parental feedback and comments from the parental intervention study, chapter five.

(See Chapter Five - Page 215)

Feedback from parents in the intervention programmes

This information was gained in a number of ways. Entries made by parents at random during the balance training period in the general comments section of the workbooks, (some parents chose to note down observations on a daily basis, resulting in a progressive diary of performance changes during the training period). The author visited all parent and child volunteers involved in the balance training at their homes mid way through the training programme to elicit from parents any informal comments on the training to date. Furthermore, as part of this visit the author videoed all subjects performing a section of one balance training sequences (chosen by the child and parent) to enable a qualitative record to be made of performance to compare with the quantitative measures taken at this mid training stage. At the end of the training session, the author telephoned the parents involved in all three studies, balance, phonology and maths. The purpose of this was to ask about the parent's opinions as to the success of the programme and whether they had any particular comments to make or observations to bring to the attention of the author. What follows below is a summary of qualitative observations made from mid-sessional interviews in the balance group and end of session telephone interviews in all groups.

Mid and end of session interviews and diary comments for balance group

At the mid sessional home visit, all nine children were extremely keen to show what they had learnt to 'an audience' and all seemed to be greatly enjoying 'performing'. All parents were already noting observable improvements in their children's balancing ability on the board. There was evidence of the balancing ability transfering to other coordinational activities outside of the training regime, One particularly 'clumsy' child was noted for improved general throwing and catching ability, and another parent specifically commented on improved general coordination in her child, with the child now spending hours kicking a football from foot to foot in the garden since the training had begun. However, four of the nine parents reported that boredom, poor motivation and resistence was already beginning for their children during training. From interview and observation, it was felt that two of these parents were themselves lacking committment and interest in the training and that this attitude was being picked up their children. Practical difficulties including space for training and disturbance by siblings were the significant cause of the problems rather than the inherent nature of the training task. It is interesting to note that at the end of session, those parents who had reported problems at the mid-sessional, reported that problems had continued to the end of the training programme. For those reporting boredom and/or over-familiarity, recommendations on varying activities and/or methods of increasing difficulty were discussed. *All* parents reported at the end of session that they had managed to complete the majority of the training sessions and that there was an improvement in general balance and throwing and catching ability in the children by the end of training.

End of session interviews and diary comments for Maths group

All nine parents were contacted. No problems were reported for any of the parents. All parents reported that interest and enjoyment levels remained good throughout the training. Furthermore and of particular interest was the fact that all parents reported direct and indirect improvements in maths ability, 5 parents specifically and unprompted reported children having improved recognition and writing of their basic numbers as a result of the training. It seems likely that this was the easiest of the training as standard text books were used for working through and both parents and chidren were familiar with maths workbooks from mathes classes at school.

End of session interviews and diary comments for Phonological group

Eight parents were contacted. As with the balance group there was more variation in results possibly caused by the fact the training was quite challenging and more unfamiliar for the children and parents, particularly the Sound Linkage regime which is typically administered by trained teachers. 5 parents reported that the childen loved the training and that it had improved their recognition of letters/sounds and reading skills. 3 parents reported unprompted on their own sense of personal satisfaction and reward in being involved with their children's learning aftr school hours for the first time and their intention to maintain this imput after the training programme had finished. 3 parents reported difficulties in using