THE UNIVERSITY OF CALGARY

FAMILIAL PATTERNS OF READING DISABILITIES CLASSIFIED BY PRESENCE OR ABSENCE OF MOTOR PROBLEMS

by

SONYA M. REGEHR

A THESIS

SUBMITTED TO THE FACULTY OF GRADUATE STUDIES

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE DEGREE

OF MASTER OF SCIENCE

DEPARTMENT OF PSYCHOLOGY

CALGARY, ALBERTA

JULY, 1987

ISBN 0-315-38058-6

THE UNIVERSITY OF CALGARY

FACULTY OF GRADUATE STUDIES

The undersigned certify that they have read, and recommend to the Faculty of Graduate Studies for acceptance, a thesis entitled "Familial Patterns of Reading Disabilities Classified by Presence or Absence of Motor Problems" submitted by Sonya M. Regehr in partial fulfillment of the requirements for the degree of Master of Science.

Dr. B. J. Kaplan, Supervisor
Department of Psychology

Dr. H. L. Radtke
Department of Psychology

Dr. J. Fagan
Department of Paediatrics

Dr. L. Field
Department of Paediatrics

July 22, 1987

Abstract

There is considerable evidence from a number of studies that various forms of reading disability (RD) are inherited (cf. Regehr, in press). This study examines the familial patterns of one specific type of RD which occurs together with impaired coordination and balance. Ten reading disabled children with these problems (RDMP), 10 children with only reading problems (RDO), and 10 normal control children, matched to the RD children on age, sex, and family socio-economic status, were examined along with their siblings and parents. A high prevalence of reading and motor problems was found in the relatives of the RDMP children, while a high prevalence of only reading problems was found in the relatives of the RDO children. There were no differences among the RDMP, RDO and NC groups of children or their siblings on number of perinatal problems or prevalence of attention deficit disorder. It was concluded that RDMP is an inherited type of RD, distinct from RDO, which is also inherited.

Acknowledgements

I wish to express my sincere appreciation and thanks to Dr. B. Kaplan for her expert supervision, guidance, and support; to Dr. L. Radtke for her assistance with the statistical analysis; and to Dr. J. Fagan for his guidance in designing and presenting the research. I also thank the entire staff of the Behavioural Research Unit, whose support and friendship were invaluable.

In addition, I thank the teachers, administrators, and therapists who referred subjects to me, and all of the families who generously gave of their time as participants in the study.

Finally, I extend special thanks to my husband for his unfailing support and encouragement throughout my studies in graduate school.

Table of Contents

Table of Contents (Cont'd)

List of Tables

List of Figures

Chapter 1

Introduction

Reading disability (RD), or as it is sometimes called, developmental dyslexia, is now recognized as a major social problem, with estimates of its prevalence running as high as 16% (Gaddes, 1976). The World Federation of Neurology has defined it as "a disorder manifested by difficulty in learning to read despite conventional instruction, adequate intelligence, and sociocultural opportunity" (Critchley, 1975). This definition says little about the characteristics and underlying cause of RD, both of which have been the focus of much research. Recent investigations have indicated that there may be more than one type of RD, and perhaps more than one cause (Rourke, 1985). Research has also supplied evidence that much of RD may be genetic, and so the idea that there may be several types of genetic RD has become a popular one. This study attempts to identify one particular subtype of RD and examine its inheritance.

Literature Review

Evidence that RD in General is Inherited

There is considerable evidence that RD in general is genetic. Several twin studies have compared concordance rates of monozygotic and dizygotic twin pairs, and they have all found much higher rates for the monozygotic than for the dizygotic pairs. Pennington and Smith (1983) combined the results of all these studies and calculated that 30 out of 43 (70%) monozygotic twin pairs tested were concordant while only 20 out of 64 (31%) dizygotic twin pairs were. The difference between these two concordance rates is

statistically significant. Thus there is substantial support for the idea that RD at least in part is due to genetic factors.

Further support for the notion that RD is inherited comes from studies examining its familial incidence. In 1950, Hallgren tested 90 families in which one of the parents was RD (Hallgren, 1950). He found that 45.7% of the offspring of these parents were RD as well. Unfortunately, Hallgren (1950) did not test a comparison group of families with non-reading disabled parents to determine how many of their offspring would be RD. Other researchers, however, have tested normal control as well as RD families, and have found that, for instance, the probability that a boy will be RD is .39 if his father is RD, and only .06 if his father is not RD (Vogler, DeFries, & Decker, 1985). They have also found that a child's relative risk of being RD is greater if his father is RD than if his mother is. There is no evidence that RD is an X-linked disorder, however, and so it has been hypothesized that the observed sex differences are due to male/female differences in related abilities such as language development (Pennington & Smith, 1983). Sex differences aside, though, there are a number of studies supporting Hallgren's (1950) initial finding that RD tends to affect more than one member of a family, making the relatives of an RD individual more likely to be RD themselves than relatives of non-RD individuals (cf. Pennington & Smith, 1983).

Family studies such as these have been criticized for assuming the familial patterns are due to genetic factors when environmental factors such as family socio-economic status (SES) or shared attitudes toward reading could also explain the results (Coles,

1980). Many of the family studies on RD, however, have controlled for the effects of SES and education (e.g., Decker & DeFries, 1981), making it especially likely that the observed familial patterns are due to genetic factors.

None of the studies on RD in general, however, has been able to establish the mode of genetic transmission. For instance, Lewitter, DeFries, & Elston (1980) performed segregation analysis on 133 family pedigrees and found no evidence of a single dominant or recessive gene responsible for the disorder. They concluded that RD is heterogeneous, and that any further attempts at genetic analysis will require prior classification of the RD families into subtypes.

Inheritance of Subtypes of RD

In accordance with this research indicating that RD may be heterogeneous, many investigators have attempted to study the inheritance of distinct subtypes of RD (cf. Regehr, 1987). Two major subtypes of RD have been suggested: RD associated with verbal/language problems, and RD associated with visual/spatial problems. RD individuals with verbal/language deficits are characterized by a low verbal IQ score and an inability to sound out words, spell phonetically, and learn easily from orally presented material, but have no impairment of spatial, visual or reasoning skills. It has been speculated that underlying these specific disabilities is left hemispheric dysfunction or underdevelopment, but this claim has yet to be satisfactorily substantiated. The second type of RD, associated with visual/spatial deficits, is characterized by an inability to remember what letters and words look like, and difficulties in learning from visually presented

material.

There is research indicating that the verbal/language subtype of RD is inherited. It tends to occur frequently within only certain families, making a relative of an RD individual of this subtype not only more likely to be RD but also more likely to be of this particular subtype (Owen, Adams, Forrest, Stolz, & Fisher, 1971; Naidoo, 1972; Gordon, 1980; Decker & DeFries, 1980; Decker & DeFries, 1981; DeFries & Decker, 1982; DeFries, Singer, Foch, & Lewitter, 1978; Lewitter et al., 1980; Boder, 1973; Childs & Finucci, 1979; Smith, Kimberling, Pennington, & Lubs, 1983; Omenn & Weber, 1978). One group of researchers even found evidence indicating that a gene on chromosome 15 may be responsible for the transmission of this subtype of RD (Smith et al., 1983). Thus there is considerable evidence for the existence of a subtype of RD involving verbal and language deficiencies which is genetically transmitted.

A number of investigators have also found that the visual/spatial type of RD is inherited. It too occurs only within certain families, such that the RD relative of an RD individual of this subtype is likely to be of this subtype as well (Boder, 1973; Childs & Finucci, 1979; Omenn & Weber, 1978). No one has yet isolated a gene which may be responsible for this subtype, but the studies of familial incidence do provide some evidence that this visual and spatial subtype of RD is inherited.

The two subtypes of RD discussed so far are by no means the only subtypes of RD which have been postulated (cf. Rourke, 1985). They are, however, the only ones which have been examined for

genetic etiology. This genetic analysis has been of considerable value, both in terms of clarifying their etiology and in terms of validating the notion that they are indeed distinct subtypes of RD. If it can be shown that other hypothesized subtypes of RD occur frequently within certain RD families and not others, and are in fact associated with specific genes, then it appears much more likely that such subtypes do indeed exist. It is for this reason that the author proposed to examine the inheritance of an hypothesized subtype of RD which has not yet been genetically analyzed. This subtype of RD is characterized by the co-occurrence of reading problems and impaired balance and coordination.

A Subtype of RD Associated With Motor Problems

A number of researchers examining the motor problems which often accompany RD have concluded that both the motor and reading difficulties are due to dysfunction of the cerebello-vestibular (C-V) system (Levinson, 1980). This is in contrast to most theories of RD which posit cerebral cortical factors as being the cause of the reading and even certain motor problems (e.g., Denckla, 1973 and Denckla, 1974). There is, however, evidence that at least some RD individuals do indeed show signs of C-V impairment. The vestibular system together with the cerebellum serves to regulate posture, muscle tone, body equilibrium, spatial orientation, and eye-head coordination (Nauton, 1975). Many RD individuals show problems in these very areas: they have been found to perform abnormally on tests of balance, coordination, posture, body equilibrium, spatial visualization, oculomotor control and postrotary nystagmus (e.g., Ayres, 1969; de Quiros, 1976; deQuiros & Schrager, 1978;

Ottenbacher, 1980; Ottenbacher, 1978; Steinberg & Rendle-Short, 1980; Steinberg & Rendle-Short, 1977; Younes, Rosner & Webb, 1983). It has been postulated that the reason these children have trouble reading, however, is because of their impaired ocular fixation and scanning abilities, as well as their limited cerebellar capacity to regulate the order and speed of sensory input to the cortex (Ottenbacher, 1980; Levinson, 1980). It is easy to see how an inability to precisely control eye-head movements in the gathering of sensory information, and then to accurately relay this information from the retina to the cortex, could result in reading difficulties. Zangwill and Blakemore (1972) and Pavlidis (1981) have observed that many RD individuals do exhibit abnormal and erratic eye movements when reading, although one cannot be sure that the erratic eye movements are the immediate cause of the reading difficulties these children experience. Frank and Levinson (1976) have also shown that when presented with visual displays with either the background or the foreground moving at different speeds, RD children reported that the picture became blurred at a much slower speed than did normal control children. It was hypothesized that this was because the maximum C-V tracking capacity was reached much sooner with the RD than with the normal control children. Again, however, there is no evidence that this deficit is the immediate cause of the reading problems these children experience. Nevertheless, there is fairly strong evidence that many RD individuals do display motor problems which could be signs of C-V dysfunction, and the notion that such dysfunction impairs reading ability by means of an inability to accurately gather and transmit

sensory information during reading seems reasonable.

While there is clearly an association between RD and impaired balance and coordination indicative of C-V dysfunction, it is unlikely that all RD children suffer from these motor problems. Doehring (1985) has suggested that there may be many subtypes of RD, and that only one of them is characterized by these particular motor problems. He has actually found evidence of one subtype of children with oral reading problems, who also have great difficulty with motor planning and coordination. It is interesting to note that he has also found no evidence that these motor problems are due to right or left hemispheric dysfunction. It appears, then, that motor problems more characteristic of C-V than cortical dysfunction are associated with some cases of RD, and may even be the markers of a unique subtype of RD.

The Inheritance of RD Associated with Motor Problems

There have been only three published studies examining the inheritance of RD associated with problems of balance and coordination. Owen et al. (1971) examined 76 RD children and their siblings and 76 normal control children and their siblings. Seventeen of the RD children were identified as showing abnormalities on medical-neurological tests, and so were subtyped as medical-neurological. These children were then found to be different from their normal controls on such variables as right-left discrimination, performance on a balance beam, fast alternating finger and hand movements, coordination, and auditory tapping. The authors also tested the siblings of the medical-neurological children on these variables, but they could not test the siblings of

the normal control children. Thus the crucial test of whether the siblings of the medical-neurological children differed on the average from their controls on these variables was not done. It was found, however, that the siblings of the medical-neurological children did not differ from the medical-neurological children on these variables, providing limited support for the notion that the C-V dysfunction is inherited.

Kripke, Lynn, Madsen, and Gay (1982) provided further evidence that RD which occurs together with motor problems is inherited. These authors examined 6 adults with difficulties in reading, writing, and spelling, irregularities and eyestrain in ocular tracking, impaired gross and fine motor coordination, a poor sense of balance, hypotonia, and a tendency to fatigue easily. The purpose of the study was to determine the efficacy of treatment with mono-sodium glutamate in these patients. The authors did informally assess the inheritance of the disorder, however, and found that all 6 of their RD subjects reported that one of their parents exhibited the same symptoms they did. The authors were able to interview some of these parents themselves to confirm these reports. This research is limited as a genetic study, however, because of the informal methods used to assess subjects, and the small number of subjects tested.

Rasmussen, Gustavson, and Bille (1984) examined the inheritance of minor neurological disorder (MND), which was characterized by deficits in coordination of the extremities, posture, balance, fine manipulative skill, design copying, and gross motor functioning. Although the presence of a reading disability was not part of the

definition of MND, many of the subjects with MND in this experiment also had developmental language disorders and learning disabilities, while still having average or better IQ scores. In total the authors identified 7 families with several MND members each, and found that in 4 of them no brain damaging factors could be traced in the prenatal, perinatal or postnatal periods, making genetic factors the most likely cause of the problems. Thus a disorder characterized by impaired balance and coordination, and associated with learning and language problems, appeared to be inherited in at least some families.

Justification for the Current Study

There is, then, a considerable amount of research suggesting that RD associated with motor problems is inherited. The evidence is weak, however, since few of the tests used in the studies were standardized and consistently applied to all family members. Furthermore, none of the studies compared the families of the diagnosed RD individuals to the families of normal control individuals matched to the RD individuals on SES and education. Certainly it is important to control for the effects of these variables when examining family patterns of a variable like reading ability which is so easily affected by social factors. Finally, the studies by Rasmussen et al. (1984) and Kripke et al. (1982) used very small samples and did no statistical analyses to test their main hypotheses.

The aim of this research was to study further the question of whether the subtype of RD characterized by the motor signs of C-V dysfunction may be inherited. Efforts were made to use formal

standardized tests when assessing all family members, to use a sufficiently large sample, to include a normal control group matched to the RD groups on SES and education, and to analyze the results statistically. In the study, 10 RD children with motor problems (RDMP), 10 RD only children (RDO), and 10 normal control (NC) children with no problems in either area, plus the siblings and parents of each type, were compared on a variety of motor and reading tests to see if (a) the relatives of one type of child were more likely than normal to be of that type as well and (b) RDMP appeared to be a genetically separate disorder from RDO.

It was also decided to examine the relationship between attention deficit disorder (ADD) and the genetic aspects of the two types of RD. In his large study on families with a history of RD, Hallgren (1950) found an increased incidence of oppositional, aggressive, restless, childish, labile behaviour and concentration difficulties among the family members. This suggested that RD and certain behaviour problems may be linked genetically. Further support for this argument comes from a clinical observation by Wender (1978) of an increased incidence of pure RD among the siblings of children with behaviour problems. Since it has been suggested that RDMP children are more likely to have ADD than RDO children (Denckla, Rudel, Chapman, & Krieger, 1985), it was decided that it would be especially important in this study to compare the incidence of ADD among the relatives of the RDO, RDMP and NC children.

It is possible that any C-V dysfunction underlying RD may be caused at least in part by perinatal problems and not genetic

factors. To control for this, the mothers of all children in the study were asked to fill out a questionnaire listing any problems or abnormalities which occurred during their pregnancies and deliveries.

Hypotheses

Hypothesis 1: The siblings and parents of the RDO children will be more likely to be RDO as well and the siblings and parents of the RDMP children will be more likely to be RDMP. Specifically, on the average, the relatives of the RDO children will be impaired on the reading tests, but not on the motor tests, relative to the NC relatives, while the relatives of the RDMP children will be impaired on both the reading and the motor tests, relative to the NC relatives.

Hypothesis 2: RDMP is a separate disorder from RDO. Specifically, only the RD relatives of the RDMP children will have motor problems; the relatives of the RDO children will score normally on the motor tests. This hypothesis is very similar to hypothesis 1, but the two hypotheses differ in that while one is concerned with assessing the inheritance of the two types of RD, the other determines whether the familial patterns of the two types are different enough to confirm the idea that the two types of RD are indeed qualitatively different from each other.

Hypothesis 3: ADD is associated with RD, and in particular, RDMP. Specifically, the affected relatives of the RDMP children, and perhaps also the RDO children, will have more symptoms of ADD than the NC relatives.

Chapter 2

Method

Subjects

Thirty children and their families were involved in the study. Ten RDMP children, 10 RDO children, and 10 NC children were selected from referrals to the School Age Developmental Clinic at the Alberta Children's Hospital and from the public and private school systems. The NC children were matched as closely as possible to the RDMP children on gender, age, and family socioeconomic status (Table 1). Family socioeconomic status was determined from the parents' occupations using the socioeconomic index for occupations in Canada (Blishen & McRoberts, 1976). This index considers typical salary range and educational requirements for each occupation.

Most families consisted of the child initially referred to the study (the proband), a sibling of that child, and the child's parents. In three cases, however, the father was unwilling to be tested, and so only the proband and his or her sibling and mother participated. When more than one sibling was available for the study, the one closest in age to the proband was chosen. Analysis of variance revealed no significant differences between the RDMP, RDO, and NC children or their siblings on age, sex, or socio-economic status (Tables 1 & 2). A power analysis had indicated that with the given sample size there was adequate power ($\beta < .95$) to detect a difference among the groups of at least one socio-economic level.

Table 1

Age, Family Socioeconomic Status, and Gender of Probands

		RDMP Probands (n = 10)	NC Probands (n = 10)	RDO Probands (n = 10)
Age	Mean	9.1	9.2	11.2
	Standard Deviation	1.3	1.8	2.0
	Range	7.3 - 12.8	7.1 - 13.1	7.5 - 13.9
Family[a] Socio-Economic Status	Mean	2.8	2.7	2.3
	Standard Deviation	1.3	0.8	1.1
Gender	Number of Females	1	2	1
	Number of Males	9	8	9

[a]Family socioeconomic status scores are on a scale from 1 to 6, with 1 indicating a high status and 6, a low one.

Table 2

Age and Gender of Siblings

		RDMP Siblings	NC Siblings	RDO Siblings
Age	Mean	11.5	11.8	11.3
	Standard Deviation	1.7	2.2	2.7
	Range	8.6 - 13.8	7.8 - 14.1	7.8 - 14.0
Sex	Number of Females	5	6	4
	Number of Males	5	4	6

Procedure

Families initially referred to the study were screened before being invited to participate in the research. The criteria for admission into the study were as follows: (a) the family had to have two children, the proband and a sibling, between the ages of 7 and 14, (b) where possible, both parents had to be willing to participate in the study, and (c) the children had to be the biological offspring of the parent or parents in the study. There also had to be evidence that the reading problems of the RDO and RDMP probands were not due to a below average IQ. All of the RDMP and RDO probands admitted into the study had been given the Wechsler Intelligence Scale for Children - Revised (WISC-R) (Wechsler, 1974) on a previous occasion, and had obtained a performance or a verbal scale score of at least 90, and a full scale score of at least 85 (Table 3). The children who were reading at an age-appropriate level were assumed to be of normal intelligence and were not given the WISC-R specifically for this study.

Families meeting the above listed criteria were sent a letter inviting them to participate in the study (Appendix A). This letter was followed up with a phone call, and if at that time the family agreed to become involved in the study, an appointment was made for them to come to the Alberta Children's Hospital Research Centre to be tested. In total, 74 families were called, and 44 declined to participate. The most typical reasons for declining were that parents were embarrassed about their own reading disabilities and that families were too busy or felt that their child had been overtested already. Three of the families who were too busy to come

Table 3

Intelligence Test Scores for RDMP and RDO Probands

		RDMP Probands	RDO Probands
Full Scale Score	Mean	101.4	106.0
	Standard Deviation	9.2	12.7
Performance Scale Score	Mean	102.0	110.0
	Standard Deviation	10.2	15.1
Verbal Scale Score	Mean	101.2	101.9
	Standard Deviation	10.7	9.8

to the Research Centre to be tested, consented to being tested in a quiet room in their homes.

Each family member was tested individually by the author after signing a consent form (Appendix B). The tests of motor performance were administered first, followed by the reading and spelling tests. Total testing time ranged from 30 to 60 minutes per subject.

Following the administration of the motor and reading tests, both parents were given a reading questionnaire, and the mothers were also given questionnaires on pregnancy and birth complications and ADD (described below). If the parents had demonstrated adequate reading ability on the PIAT, they were simply given the written questionnaires and asked to fill them out on their own. If, however, their performance on the PIAT indicated a reading disability, the questionnaires were read aloud to them and their verbal answers were recorded.

Tests

Measures of Reading and Spelling

The reading recognition, reading comprehension, and spelling subtests of the Peabody Individual Achievement Test (PIAT) (Dunn & Markwardt, 1970) were administered to all adults and children. This test correlates highly with other standardized tests of reading and spelling ability such as the Wide Range Achievement Test (r = .83-.95), and has test-retest reliability coefficients of .89 for reading recognition, .64 for reading comprehension, and .65 for spelling (Dunn & Markwardt, 1970).

The parents were also asked to fill out a self report inventory of their reading ability (Finucci, Whitehouse, Isaacs, & Childs,

1984). Questions such as "How would you rate your reading ability today? Below average, average or above average" comprise the questionnaire (Appendix C).

Measures of Coordination and Balance

The balance, bilateral coordination and upper limb coordination subtests of the Bruininks-Oseretsky Motor Proficiency Test (BOMPT) (Bruininks, 1978) were administered to all subjects. These tests assess a subject's balance and coordination in a variety of tasks, such as walking on a balance beam, throwing and catching a ball, and coordinating simultaneous foot and hand movements.

The motor accuracy (MAC-R) and design copy (DC) subtests of the Southern California Sensory Integration Test (SCSIT) (Ayres, 1972) were administered to assess fine motor ability and coordination. The MAC-R test requires the subject to trace along a curving line as accurately as possible, while the DC test requires the subject to reproduce different geometric designs by connecting certain dots on a grid.

The subjects' ability to perform fast movements with their feet and hands was assessed by timing their performance of a number of successive and alternating finger, hand and foot movements. These tests are part of a standard neurological exam, and they were scored according to age norms provided by Denckla (Denckla, 1973; Denckla, 1974).

The BOMPT, SCSIT, and fast movements tests are all routinely used to test RD children, and have been shown to discriminate significantly between RD and normal control children (Bruininks, 1978; Ayres, 1972; Denckla, Rudel, Chapman, & Krieger, 1985). The

test-retest reliability coefficients for the BOMPT subtests are .56 for balance, .80 for bilateral limb coordination, and .61 for upper limb coordination (Bruininks, 1978). For the SCSIT tests, the reliability coefficients are .81 for motor accuracy, and .71 for design copy (Ayres, 1972). Finally, the fast movements tests have an average test-retest reliability of .66 (Denckla et al., 1985).

Measure of Pregnancy and Birth Complications

The mothers of all subjects were asked to fill out the Anser questionnaire (Levine, 1980) about problems or abnormalities which occurred during their pregnancies and deliveries (Appendix C). A risk score was calculated for each proband and sibling based on the number of problems which were reported to have occurred. There were no reliability and validity data available on this test, but it is widely used in the assessment of learning disabled and ADD children.

Measure of ADD

The ten item version of the Conners' Abbreviated Symptom Questionnaire (ASQ) for parents (Goyette, Conners & Ulrich, 1978) was also filled out by the mothers for both of their children in the study (Appendix C). The questionnaire requires parents to rate items such as "Excitable, impulsive" on a scale from "Not at all" to "Very much". The results of this questionnaire provided an indication of the number of symptoms of ADD and hyperactivity each child had. The ASQ is commonly used in assessing ADD, and estimates of its test retest reliability range from .70 to .90 (Goyette et al., 1978).

Group Assignment

When the probands were initially referred to the study, they

were temporarily diagnosed as RDMP, RDO, or NC based on their school and hospital records. Before final assignment to one of the three groups, however, their scores on the reading and motor tests given during this experiment were considered. In order to be classified as RD, a child had to have a reading quotient (RQ) score of less than 0.90. Reading quotients were calculated as the ratio of observed age to expected age. Observed age was defined as the average age score on the three PIAT tests: reading recognition (RR), reading comprehension (RC) and spelling (SP). Expected age was defined as the average of a child's chronological age (CA), mental age (MA) as indicated on the WISC-R, and age for grade (GA). Thus the formula for calculating a reading quotient score was as follows:

$$RQ = \frac{\text{observed age}}{\text{expected age}} = \frac{(RR + RC + SP) / 3}{(GA + MA + CA) / 3}$$

This formula is similar to one used by Finucci, Isaacs, Whitehouse, and Childs (1982). These authors suggest that an RQ score of less than .80 indicates a definitely disabled reader; a score between .80 and .90, a borderline reader; and a score above .90, a normal reader. It was decided in this study to consider all children with a score less than .90 to be reading disabled. A cut-off point of .90 was chosen rather than one of .80 because it was found that while most of the RDO and RDMP children referred to the study were experiencing serious reading difficulties at school, they still obtained RQ scores in the .80 to .90 range. The inflation of the RQ scores seemed to be due to the PIAT, which overestimated their actual ability. This also appeared to be the case for the normal control children, whose average percentile

scores were 78.20 on reading recognition, 81.20 on reading comprehension, and 74.40 on spelling. Most of these control children, however, were reported by parents to be average readers at school.

It appeared, then, that the test norms for the PIAT did not apply very well to the children in this study. There are a number of possible reasons for this. First, the test is American, and this study was done in Canada. Unfortunately, there is no Canadian test comparable to the PIAT. Second, most of the RD and normal children were from urban, middle class families (Table 1) and went to schools with middle class expectations. Thus the RD children may have been doing poorly relative to their urban Canadian middle class peers and were thus diagnosed as RD, but they were not seen as so severely disabled when compared to test norms based on a random sample of American children. Whatever the reason, however, it was decided that in this study, the children's abilities were being overestimated by the PIAT, and that this justified requiring an RQ score of .90 instead of .80 for a diagnosis of RD. When all the probands had been diagnosed in this way, a plot of their reading scores was generated, which revealed a bimodal distribution with all the children referred to study with a reading disability scoring below .90 and all of the NC children scoring above 1.0.

To be classified as having motor problems, a child had to score at least one standard deviation below the test mean in two of the following four areas: (a) balance, as assessed by the BOMPT, (b) bilateral coordination, as assessed by the BOMPT, (c) upper limb coordination, as assessed by the BOMPT, and (d) fine motor

coordination, as indicated by the child's average score on the SCSIT and the fast movements tests. As with the reading tests, some of the balance and coordination tests appeared to overestimate the children's ability relative to their own peers. Specifically, while the normal control probands were an average of 0.19 standard deviations below the test mean on balance, they were 1.21 standard deviations above the mean on bilateral coordination, 0.83 standard deviations above the mean on upper limb coordination, and 1.01 standard deviations above the mean on fine motor coordination. Because of this apparent overestimation of the children's motor ability, a somewhat liberal diagnostic criterion was adopted in this study: more than one standard deviation below the mean on two of the four tests was required. It is important to note that none of the NC children referred to the study met these somewhat liberal diagnostic criteria for motor impairment.

Chapter 3

Results

To confirm that the groups of probands did indeed differ from each other as desired, a multivariate analysis of variance (MANOVA) was done with the probands' diagnoses as the grouping variable and their performance on the tests of balance, bilateral coordination, upper limb coordination, fine motor coordination, reading recognition, reading comprehension, and spelling as the dependent variables. Pregnancy and birth complications and ADD were also examined as dependent variables, although they had not been considered when diagnostic decisions were made. The overall effect for diagnosis was significant (Appendix D), and so the univariate F values for each dependent variable were examined. To control for experiment-wise error rate, these effects were tested at the .05/9 = .006 level. There were no significant effects for ADD or pregnancy and birth complications, but there were significant effects for each of the motor and reading/spelling variables. These significant effects were followed up with Newman-Keuls multiple comparisons at the .05 level, and it was found that the NC and RDO groups scored higher than the RDMP group, but did not differ from each other, on balance, bilateral coordination, upper limb coordination, and fine motor coordination. It was also found that the RDO and RDMP groups scored lower than the NC group, but did not differ from each other, on reading recognition, reading comprehension, and spelling (Appendix E). Thus the groups did differ from each other in the expected directions.

The siblings and parents were then divided into three groups

according to the diagnosis of the proband they were related to. There were 10 siblings, 10 mothers, and 9 fathers in the RDMP group, 10 siblings, 10 mothers, and 10 fathers in the NC group, and 10 siblings, 10 mothers, and 8 fathers in the RDO group.

To compare the three groups of siblings and parents, three types of analyses were done. A MANOVA was done first, to test simultaneously the differences among the groups on the multiple dependent variables. If this analysis revealed significant differences, it was followed up by both univariate analyses of variance (ANOVAs) and discriminant function analyses. The univariate analyses tested for group differences on each variable individually, and if significant differences emerged, Newman-Keuls post-hoc multiple comparisons were performed to determine where the differences lay. This allowed for all three groups to be compared with each other on a single dependent variable. The conclusions from these tests had to be made carefully, however, since the use of multiple univariate tests on the same data elevates the chance of making a type 1 error. For this reason, and also in order to study the multivariate nature of the disorder, discriminant function analyses were also performed. In these analyses, functions were generated from linear combinations of the dependent variables, and were tested on their ability to discriminate between the groups. If a function did significantly differentiate between the groups, it was examined to see which variables appeared to contribute significantly to its discriminatory power. This allowed for a more multivariate interpretation of the data, in addition to the univariate interpretation achieved by performing the ANOVA's.

Siblings

MANOVA and ANOVAs

To begin these analyses, then, a MANOVA was performed on the three groups of siblings as classified by diagnosis of proband. The dependent variables were balance, bilateral coordination, upper limb coordination, fine motor coordination, reading recognition, reading comprehension, and spelling. The results indicated a significant overall effect for diagnosis (Appendix D), which was followed up by ANOVAs for each of the 7 dependent variables. Again, to control for experiment-wise error rate, these effects were tested at the .05/7 = .007 level. Significant effects for diagnosis emerged on the following variables: bilateral coordination, upper limb coordination, fine motor coordination, and reading comprehension (Appendix D). These results were followed up with Newman-Keuls multiple comparisons at the .05 level, which indicated that (a) for bilateral coordination and upper limb coordination, the NC and RDO groups scored higher than the RDMP group, but did not differ from each other, and (b) for fine motor coordination and reading comprehension, the RDMP and RDO groups scored lower than the NC group, but did not differ from each other (Figure 1). There had also been a marginally significant effect of diagnosis on reading recognition ($p=.0078$), and when this was followed up with Newman-Keuls multiple comparisons, it was found that the RDMP and RDO groups scored lower than the NC group, but did not differ from each other. There were even more marginal effects on balance ($p = .038$) and spelling ($p = .070$), but the means for these variables did lie in the expected directions (Appendix E).

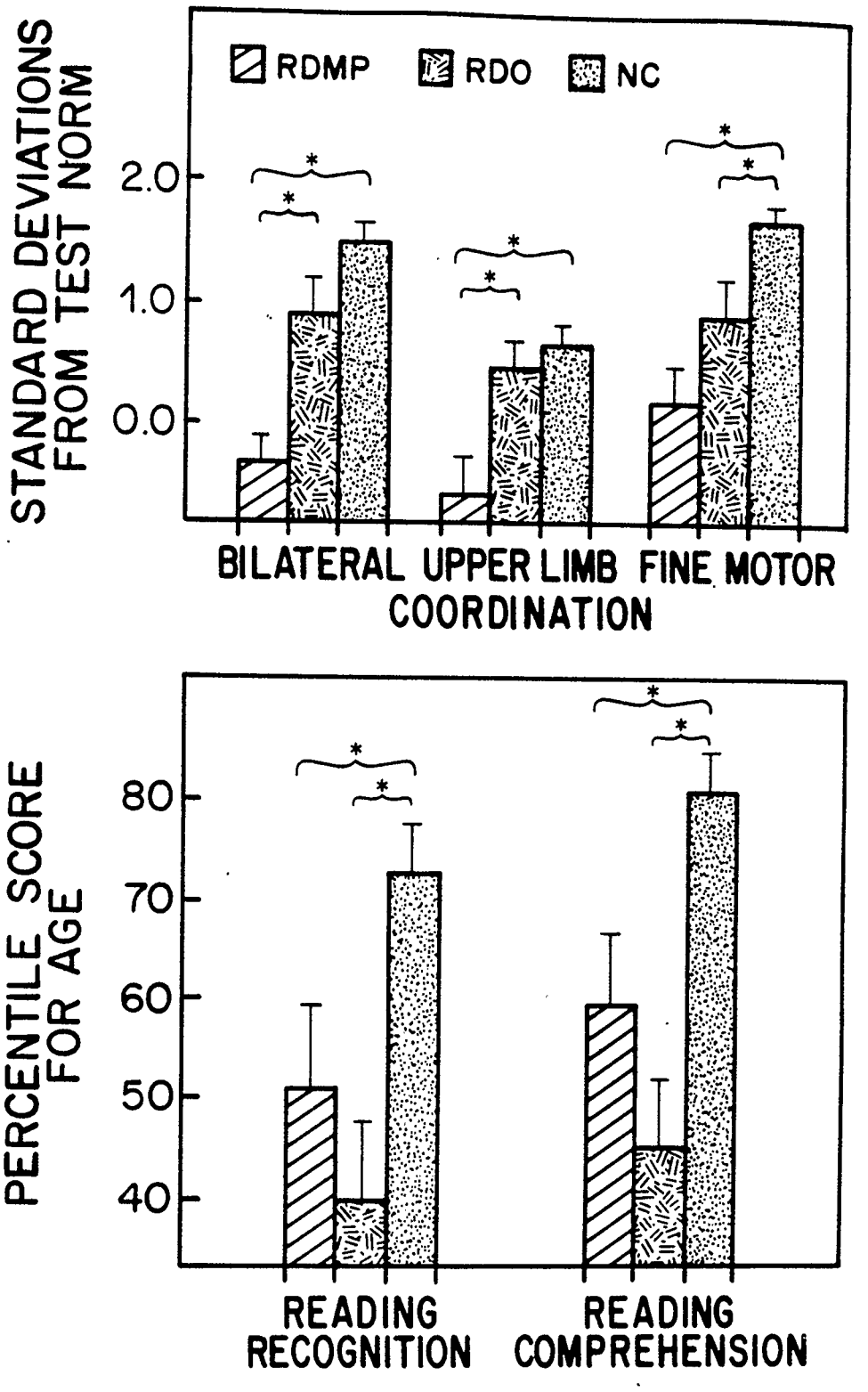

Figure 1. Sibling means and standard errors

* $p < .05$

It was also found that, as with the probands, the three groups of siblings did not differ from each other on number of symptoms of ADD or on reports of pregnancy and birth complications (Appendix D).

Discriminant Function Analysis

The data on the three groups of siblings were then subjected to discriminant function analysis. The following dependent variables were entered simultaneously: balance, bilateral coordination, upper limb coordination, fine motor coordination, reading recognition, reading comprehension, and spelling. Function 1 significantly discriminated between the groups of siblings (Λ (14)=.18, $p<.0005$), and there was a marginally significant effect for function 2 to discriminate between them as well (Λ (16)=.63, $p=.08$). Function 1 obtained a squared canonical correlation of .72 while function 2 obtained one of .37. The structure coefficients and standardized canonical discriminant function coefficients for each variable were then examined on both functions (Table 4). It was found that the four motor variables all had high structure coefficients (>.30) on function 1. Bilateral coordination and upper limb coordination also had high discriminant function coefficients on this function. Balance and fine motor coordination did not have as high discriminant function coefficients, but this was likely due to the large correlations between the four motor variables (Appendix F). The three reading and spelling variables had very low structure coefficients on function 1. Reading comprehension and spelling did have fairly large negative discriminant function coefficients, which suggests that they acted as supressor variables. Both also had fairly high zero order correlations with a number of the motor

Table 4

Results of Discriminant Function Analysis of Siblings' Data

	Standardized Discriminant Function Coefficient		Structure Coefficient	
	function 1	function 2	function 1	function 2
Balance	.30	.05	.32	.14
Bilateral Coordination	.99	-.20	.65	.40
Upper Limb Coordination	.48	-.15	.45	.11
Fine Motor Coordination	.28	.26	.44	.51
Reading Recognition	.37	.63	.08	.83
Reading Comprehension	-.47	.62	.06	.92
Spelling	-.88	-.24	.09	.57

variables. It appeared, then, that function 1 reflected the motor ability of the siblings and not their reading/spelling ability, and that this motor ability significantly discriminated between the groups. The group centroids for this function were -2.13 for the RDMP group, 0.99 for the RDO group, and 1.14 for the NC group. Thus the differences between the groups did lie in the predicted directions.

In examining function 2, it was found that two of the motor variables, bilateral coordination and fine motor coordination, had fairly large structure coefficients. One of these variables, bilateral coordination, had a rather small discriminant function coefficient, but this was likely due to redundancy among the variables. The other motor variable with a high structure coefficient, fine motor coordination, had a moderately sized positive discriminant function coefficient, indicating it was an important variable to the function. The three reading and spelling variables had large structure coefficients on function 2, and reading comprehension and reading recognition also had large discriminant function coefficients. Spelling, however, had a small discriminant function coefficient, probably because of redundancy among the variables. In general, it appeared that reading and spelling ability was a major component of this function, but that fine motor coordination was important as well. The ability of the function to discriminate between the groups was only marginally significant, but this was likely because the rather small sample reduced the power of the test. The group centroids for this function were .04 for the RDMP group, -.92 for the RDO group, and

.88 for the NC group. Thus while the discriminatory power of the function was somewhat less than statistically significant, the differences between the groups were in the predicted directions.

Generally, the results of the discriminant analysis supported the results of the ANOVA's in showing that on the average, the three groups of siblings did differ on motor performance in the expected directions. Both types of analyses also indicated differences between the groups on reading and spelling ability, but in particular the discriminant analysis pointed to stronger group differences on motor performance than on reading ability.

Parents

MANOVAs and ANOVAs

A mixed model MANOVA was then performed on the combined parent data, with proband diagnosis as the between groups factor and sex of parent as the within groups factor. The dependent variables were balance, bilateral coordination, upper limb coordination, reading recognition, reading comprehension, and spelling, as well as scores on the motor accuracy test and the fast movements tests. The motor accuracy and fast movements scores could not be averaged together to get an overall index of fine motor coordination as they were for the probands and siblings, because standard scores on these tests were not available for adults. The raw scores had to be used instead, which meant that the tests were no longer on the same metric and so could not be averaged together. Results of the analysis revealed significant overall effects for diagnosis, sex, and sex by diagnosis (Appendix D). Since the interaction of sex and diagnosis was significant, the univariate F values for this interaction were

examined at the .05/9 = .006 level for each of the 9 dependent variables. Only the effect on spelling even approached significance (Appendix D). This effect was followed up by tests for simple main effects, which revealed a significant effect of diagnosis on fathers, but not on mothers. This effect on fathers was followed up with Newman-Keuls multiple comparisons at the .05 level, and it was found that the NC group scored higher than the RDMP group but was not significantly different from the RDO group (Appendix E). There was also a significant simple main effect for sex on the RDMP group, with the fathers scoring lower than the mothers.

Because the interaction between sex and diagnosis was significant on only one of the dependent variables, spelling, the main effects for diagnosis and sex were examined on the other dependent variables. There was a significant main effect for sex on upper limb coordination (Appendix D), with fathers scoring higher than mothers (Appendix E). There was also a marginally significant effect ($p = .026$) for fathers to perform the fast movements more quickly than mothers.

There was a significant main effect at the .006 level for diagnosis on the following variables: balance, bilateral coordination, upper limb coordination, motor accuracy, and reading recognition (Appendix D). These effects were followed up with Newman-Keuls multiple comparisons at the .05 level, which revealed that the RDO and NC groups scored higher than the RDMP group, but did not differ from each other, on balance, bilateral coordination, upper limb coordination, and motor accuracy. In addition, the RDO and RDMP groups scored lower than the NC group, but did not differ

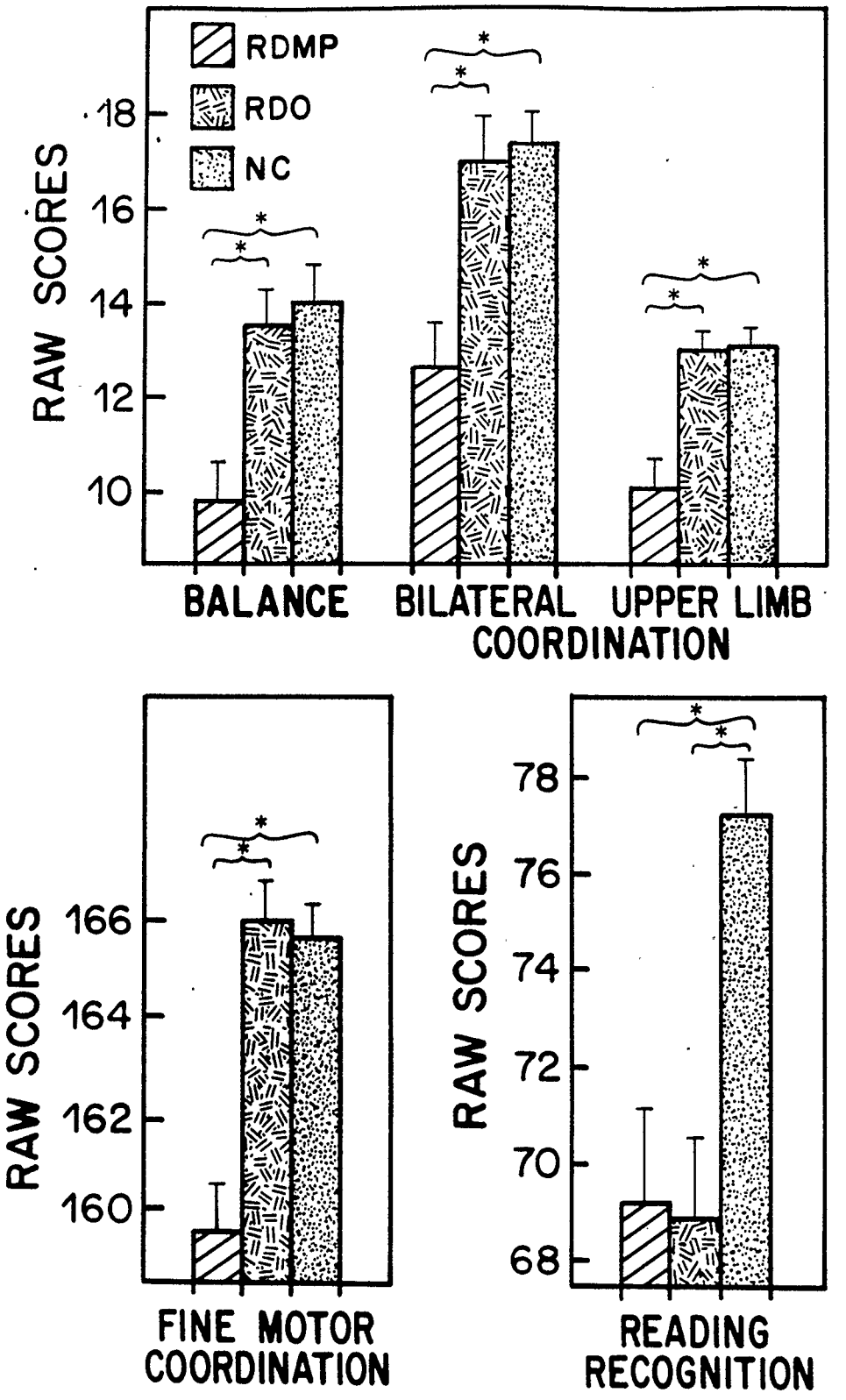

Figure 2. Parent means and standard errors
* $p < .05$

from each other, on reading recognition (Figure 2). There was also a marginally significant effect of diagnosis on the performance of fast movements ($p = .011$), and the group means for this variable lay in the predicted directions (Appendix E).

Discriminant Function Analyses

A discriminant function analysis was then performed on the three groups of parents. Because there had been an overall significant effect for sex and for sex by diagnosis on the MANOVA, the data on the mothers and the fathers were not combined for the discriminant analysis. Instead, two separate discriminant analyses were performed, one for the mothers and one for the fathers. In both of these analyses, the following variables were entered simultaneously: balance, bilateral coordination, upper limb coordination, fast movements, motor accuracy, reading recognition, reading comprehension, and spelling.

In the discriminant analysis for mothers the first function generated was highly significant (Λ (16)=.19, $p<.001$), while the second function was only very marginally so (Λ (7)=.61, $p=.11$). Function 1 obtained a squared canonical correlation of .68, while function 2 obtained one of .39. The motor variables balance, bilateral coordination, upper limb coordination, and motor accuracy all obtained structure coefficients on function 1 greater than .30 (Table 5). Three of these variables, bilateral coordination, upper limb coordination, and motor accuracy, also had high discriminant function coefficients, indicating they were important contributors to the function. Balance did not have as high a discriminant function coefficient, but this was likely due to the substantial

Table 5

Results of Discriminant Analysis of Mothers' Data

	Standardized Discriminant Function Coefficient		Structure Coefficient	
	function 1	function 2	function 1	function 2
Balance	.13	.37	.33	.09
Bilateral Coordination	.42	-.43	.53	-.17
Upper Limb Coordination	.46	-.06	.55	.01
Motor Accuracy	.35	-.25	.48	-.17
Fast Movements	-.09	.28	-.28	-.05
Reading Recognition	.85	2.17	.37	.63
Reading Comprehension	-.23	-1.39	.35	.32
Spelling	-.93	-.14	-.05	.38

correlations between the motor variables (Appendix F). The other motor variable, fast movements, obtained a moderately sized structure coefficient, but its discriminant function coefficient was small, likely because of redundancy among the variables. The values of the coefficients were negative, but this was because for the adults, the fast movement scores were time scores, and so a lower score indicated better performance. For the other variables, a higher score indicated better performance. The two reading variables also obtained structure coefficients greater than .30 on function 1. One of these variables, reading recognition, also had a high large function coefficient, indicating it was an important variable to the function. The other reading variable, reading comprehension, had a small discriminant function coefficient, but this was likely due to redundancy among the variables. Spelling had a large negative discriminant function coefficient and a low structure coefficient, indicating it may have been functioning as a suppressor variable. It did have high zero order correlations with the motor variables (Appendix F), and in particular with upper limb coordination. In conclusion, function 1 appeared to be discriminating between the groups on the basis of both motor performance and reading recognition ability. The group centroids were -1.86 for the RDMP group, .42 for the RDO group, and 1.44 for the NC group, which is the pattern of means one would expect from a function reflecting both reading and motor ability.

Function 2 appeared to reflect exclusively reading and spelling ability, since only reading recognition, reading comprehension, and spelling obtained structure coefficients greater than .30. Reading

recognition also obtained a large discriminant function coefficient, indicating it was an important variable in the function. Spelling obtained a small discriminant function coefficient, but this was likely due to redundancy among the reading and spelling variables. Reading comprehension, however, had a large positive structure coefficient and a large negative discriminant function coefficient. The correlation between reading recognition and reading comprehension was very high (r = .87), though, which makes interpretation of the discriminant function coefficient for reading comprehension rather meaningless. What is important to note, then, is that both reading recognition and reading comprehension obtained structure coefficients greater than .30. The motor variables appeared fairly unimportant in this function, with none of them achieving very high discriminant function or structure coefficients. It appeared, then, that this function generally reflected the differences between the groups on reading recognition. The function was only a very marginally significant (p=.11) discriminator between the groups, however, and so any interpretations about it must be made with great caution. The group centroids for this function were -.19 for the RDMP group, -.72 for the RDO group, and .75 for the NC group, and so the marginally significant group differences did lie in the predicted directions.

In conclusion, the results of the discriminant analysis performed on mothers' scores did agree with the results of the ANOVA's performed on the parents' scores. The ANOVA's indicated that the groups differed on certain motor variables and on reading recognition, and function 1 of the discriminant analysis for

mothers, which reflected motor and reading recognition ability, significantly discriminated between the groups.

The results of the discriminant analysis performed on the three groups of fathers were similar to those for the mothers. The first function generated was significant (Λ (16)=.20, $p<.01$), while the second was not. The first function obtained a squared canonical correlation of .72 while the second function obtained one of only .29. The five motor variables all had structure coefficients greater than .30 on function 1 (Table 6). The fast movements variable had a negative structure coefficient, but as discussed earlier, this was because the fast movement scores were time scores, and so a lower score indicated better performance. While all of the motor variables had large structure coefficients, only four of them, bilateral coordination, upper limb coordination, motor accuracy, and fast movements, had relatively large discriminant function coefficients. Balance had a discriminant function coefficient of only -.01, but this was likely due to redundancy among the motor variables. Thus it appeared that the motor variables were very important in this function. One non-motor variable, spelling, obtained large structure and discriminant function coefficients on this function as well. Reading recognition had a low structure coefficient and a large negative discriminant function coefficient, indicating it was a supressor variable. Generally, then, it appeared that function 1 discriminated between the groups on the basis of both motor and spelling ability. The group centroids were -2.06 for the RDMP group, 1.49 for the RDO group, and .66 for the NC group. These scores are what would be predicted from a function

Table 6

Results of Discriminant Analysis of Fathers' Data

	Standardized Discriminant Function Coefficient		Structure Coefficient	
	function 1	function 2	function 1	function 2
Balance	-.01	.15	.49	.25
Bilateral Coordination	.32	.36	.34	.24
Upper Limb Coordination	.33	-.13	.56	-.02
Motor Accuracy	.54	-.09	.59	.14
Fast Movements	-.39	.46	-.46	-.11
Reading Recognition	-1.44	1.13	.12	.65
Reading Comprehension	.98	-1.08	.16	.22
Spelling	.69	.58	.33	.77

mainly reflecting motor ability.

Function 2 appeared to reflect both reading recognition and spelling ability, since both variables obtained large structure and discriminant function coefficients. The motor variables appeared relatively unimportant, while reading comprehension may have been a supressor variable since it had a small structure coefficient and a large negative discriminant function coefficient. Function 2 did not, however, discriminate significantly between the groups of fathers.

In conclusion the results of the discriminant analyses and the ANOVA's indicated that on the average, the three groups of mothers and fathers did differ as expected on the motor variables. The ANOVA's also indicated that the three groups of parents (mothers and fathers combined) differed on reading recognition, and that the RDMP fathers and the NC fathers differed from each other on spelling ability. The discriminant analysis for mothers revealed significant differences between the groups on a function reflecting in part reading recognition, while the discriminant analysis for fathers revealed significant differences on a function reflecting in part spelling ability. Thus the results of the two analyses together can be interpreted to mean that the three groups of mothers and the three groups of fathers did differ as expected on motor performance. Also, the groups of mothers tended to differ on reading recognition, while the groups of fathers differed on spelling ability.

The data on mothers and fathers was then combined to examine the differences between the three groups on reading questionnaire scores. These data were not included in the above analyses in order

to make those analyses as analogous as possible to the analyses of the sibling and proband data. Results of the analysis of the reading questionnaire data indicated no effects of sex by diagnosis or sex alone, but they did indicate an effect of proband diagnosis ($F(2,24)=4.49$, $p=.022$); but it was not significant at the .01 level. The means of the three groups as classified by proband diagnosis did, however, lie in the predicted directions, with the RDMP group obtaining a mean of 16.33, the NC group obtaining one of 9.85, and the RDO group obtaining one of 15.06. It is important to note that on this variable a higher score indicated a greater degree of impairment.

One of the questions on the reading questionnaire for parents was "How often do (did) you read to your children?". It was thought that it would be of interest to examine the parents' responses to this question alone, to see if the three groups of parents differed on this index of parenting and family attitudes to reading. The results of this analysis, however, revealed no significant differences among the three groups.

Pedigrees

Next, for the purposes of drawing up pedigrees, diagnostic criteria were established for diagnosing each parent and sibling. For the siblings, an average age-normed reading and spelling score below the 50th percentile was required for a diagnosis of RD. For a diagnosis of motor problems to be made, scores more than 0.5 standard deviations below the test means in two of the four motor areas were required. These criteria are somewhat liberal, but this seemed justified because (a) there was evidence that both the

reading and the motor tests were overestimating the children's ability, as discussed earlier, and (b) Pennington (1986) has suggested that in family studies of continuous variables like reading ability, some family members may have milder forms of the disorder that do not meet standard diagnostic criteria, but that to diagnose such individuals as normal would be misleading.

To diagnose the parents required referring to the reading and motor test means of the NC adults in this study, since many of the tests used did not provide norms for adults. For a parent to be diagnosed as RD, then, he or she had to obtain an average reading and spelling score at least 2 grade levels below the average score for the NC group. For a diagnosis of motor problems, a parent had to score more than 1.5 standard deviations below the NC means in two of the four motor areas.

No parents or siblings in the NC group met the diagnostic criteria for RD, but one NC father met the criteria for a diagnosis of motor problems. Many of the relatives of the RDO and RDMP probands were diagnosed as having problems, and so pedigrees of both groups were drawn up (Figure 3). Two of the families in the study had more than two children between the ages of 7 and 14, and these additional children were tested by the experimenter. Their data was not included in the statistical analyses, but these children were diagnosed and included in the pedigrees that were drawn up. Examination of the pedigrees revealed definite familial patterns to the disorders, as was also suggested by the statistical analyses. There was also evidence that the two disorders, RDO and RDMP, were relatively distinct, with motor problems being fairly unique to the

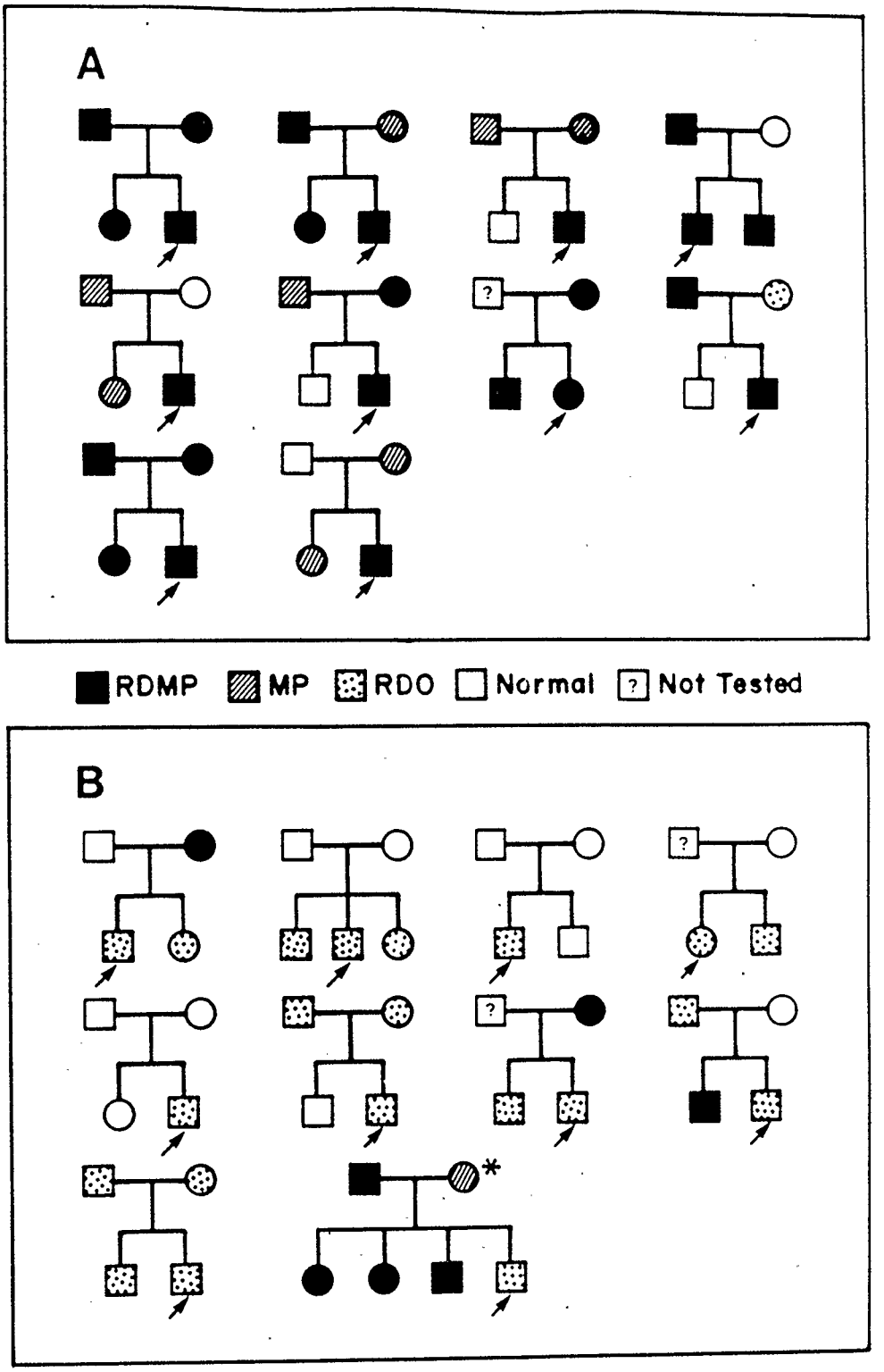

Figure 3. Pedigrees. The arrows refer to the proband in the family, and the asterisk indicates the RDO family showing an RDMP familial pattern.

families with RDMP probands. There was one exception to this pattern; one family with an RDO proband had four RDMP members and one member with only motor problems. The proband had been given a number of the motor tests previously, however, and perhaps his familiarity with the tests inflated his scores on them. In any case, the strong pattern of motor problems in most of the family members suggests that the family is best characterized as RDMP and not RDO, even though the proband originally referred to the study was diagnosed as RDO.

Finally, in order to see if the reading and motor problems were related or associated in the RDMP families, a χ^2 analysis was performed on the sibling data. Only the siblings in the RDMP families were included in the sample for this analysis (Figure 3). The χ^2 test of association was used to see if diagnosis of RD was associated with diagnosis of motor problems in this group. A Pearson χ^2 value of 6.24 was obtained, and Fisher's exact test determined that the effect was significant at the .035 level. Thus there was evidence that among the siblings of the RDMP probands, the reading and motor problems were not two separate problems, both showing a familial pattern, but were two related problems, possibly sharing one common genetic etiology.

Chapter 4

Discussion

Hypotheses

The first hypothesis of this study was that the relatives of the RDO children would be more likely to be RDO as well, and that the relatives of the RDMP children would be more likely to be RDMP. This hypothesis was confirmed by the results of the study. Both the univariate and the discriminant function analyses showed that on the average, the siblings and parents of the RDMP children did worse than the relatives of the RDO or the NC children on the tests of motor ability. Furthermore, the univariate analyses showed that on the average, the siblings and parents of the RDO and the RDMP children were impaired relative to the relatives of the NC children on reading and in some cases on spelling as well. The discriminant function analyses also indicated differences among the three groups of siblings and mothers on reading ability, and differences among the three groups of fathers on spelling ability, but these differences were not as striking as the differences on motor ability. Perhaps this was because in our society more emphasis is placed on remediating reading difficulties than on correcting poor coordination and balance. Thus a strong environmental effect could have diminished the expected familial patterns on reading, while having little effect on the patterns of motor ability. In general, though, it did appear that taken together, the results of the two types of analyses done in this study did confirm the hypothesis that the siblings and parents of the RDO probands were more likely to be RDO as well, and the siblings and parents of the RDMP probands were

more likely to be RDMP.

The second hypothesis was that RDMP is a separate disorder from RDO. This hypothesis was also confirmed by the results of this study. Specifically, the post-hoc multiple comparisons used to follow up the univariate analyses indicated that on the average, the siblings of the RDMP probands showed deficits on bilateral coordination and upper limb coordination relative to the NC siblings, but that the relatives of the RDO probands did not. Similarly, the parents of the RDMP probands showed deficits on balance, bilateral coordination, upper limb coordination, and motor accuracy relative to the NC group, while the parents of the RDO probands did not. Thus it appeared that among the siblings and parents, motor problems were relatively unique to the relatives of the RDMP probands. Examination of the family pedigrees (Figure 3) confirms this idea. There were certain families with a history of both reading and motor problems, and others with a history of only reading problems.

One finding, however, did contradict this hypothesis that motor problems were unique to the relatives of RDMP probands. The siblings of the RDO probands, while scoring significantly better than the siblings of the RDMP probands, scored significantly worse than the NC siblings on fine motor coordination. This could mean that while balance and gross motor coordination problems are specific to families with a history of RDMP, deficits in fine motor coordination can occur in the children of families with a history of RDO. It should be noted, however, that the tests of fine motor coordination often resembled academic tests, requiring children to

draw or trace using a pen or pencil. The tests of gross motor coordination and balance involved tasks like walking on a balance beam or throwing a ball, which are less like academic tests than tasks involving drawing and tracing. Perhaps, then, the RDO children, who had already experienced a considerable amount of failure on traditional academic tasks, became more nervous and unsure on the tests of fine motor coordination than on the other motor tests, and as a result performed more poorly.

In general, however, the results of this study did confirm the hypothesis that RDO and RDMP are two separate disorders, with motor problems being relatively unique to families with an RDMP proband. A χ^2 analysis of the siblings of the RDMP probands also indicated that the two problems, reading disability and motor deficits, are associated. Whether the two problems share the same immediate etiology, perhaps C-V dysfunction, remains to be seen. Nevertheless, it does appear that there is a unique disorder, characterized by related reading and motor problems, which occurs with considerable frequency among certain families.

The third hypothesis was that ADD would be related to RD, and in particular, RDMP. There was no support for this hypothesis in the data. Neither the probands nor the siblings showed any group differences on tests of ADD. This is in contrast to the findings of Hallgren (1950) who found an increased incidence of ADD in his families with a history of RD. It also contradicts the finding of Denckla et al. (1985) that RDMP children are especially likely to have ADD. Perhaps these contradictory findings are due to differences between the studies in sample size. Hallgren (1950)

tested 90 RD families, whereas in this study only 10 RDO and 10 RDMP families were examined. Denckla et al. (1985) also used a much larger sample (N = 75) than was used in this study. Perhaps, then, had a larger sample been used in this study, the predicted differences among the groups on ADD would have emerged.

To summarize, then, this study did find evidence of two types of reading disability, RDO and RDMP. Both forms of disability showed strong familial patterns, with the groups of RDO and RDMP families differing from the group of NC families in the predicted directions on motor and reading ability. There was, however, no evidence that the three groups of families differed in any way in the prevalence of ADD.

Nongenetic Factors

Familial patterns of any disorder, and in particular a reading disorder, do not necessarily indicate that the disorder is genetic. A number of nongenetic factors can cause the types of family patterns seen in this study. Efforts were made in this research, however, to control for a number of these nongenetic factors. For instance, it was found that the RDO and RDMP groups did not differ from the NC group on SES or reports of pregnancy and birth complications. Also, the parents of the RDO and RDMP probands did not differ from the parents of the NC probands on their responses to the question "How often do (did) you read to your children?". Indeed, the parents of the RDO and RDMP children placed great emphasis on the importance of being able to read well, and many were paying considerable tuition fees to have their children educated in special schools for the learning disabled. Thus it appears

relatively unlikely that the observed familial patterns of RD were due to nongenetic factors such as family SES or negative attitudes toward reading shared in certain families. Of course it is still possible that nongenetic factors which were not controlled for in this study caused the familial patterns, but in view of the extent to which the 3 groups of families were equated on important social variables, it seems quite likely that at least in part, the familial patterns were genetically based.

Limitations to the Study

There were a number of limitations to this study. First, it was very difficult to diagnose the subjects as RDO or RDMP. The American test norms did not apply to this sample, and so approximate diagnoses had to be made. It was especially difficult to diagnose subjects as RD. The current preferred method for diagnosing RD is to develop a regression equation applicable to one's sample, including predictors such as intelligence and level of education (Pennington, 1986). This study did not involve preliminary testing of a large sample of families comparable to those involved in the actual genetic study in order to develop an appropriate regression equation. Furthermore, the amount of time required of families volunteering in the study was already so large, that it would have been unreasonable to expect each sibling and parent to also take an intelligence test for the purposes of diagnosing them as RD or not. As a result, however, the diagnoses were not made according to the best current method for detecting such a disorder.

A second problem with the study was that the sample may have been biased. Biological families willing to volunteer a

considerable amount of time for research were required. Many families who were called about the study refused to participate, partly because of the time commitment involved and partly because many parents were embarrassed about their inability to read and did not want to be tested. Embarrassment about a reading disability was particularly common among the fathers; 44 out of 74 families who were called regarding the study declined to participate, and of these 44 families who declined, 15 did so because the father was unwilling to be tested. Eventually some families were tested without the father in order to keep the sample from becoming too biased. Even so, the final sample of RDO and RDMP families was predominantly middle to upper class, with numerous parents being very well educated. This is probably not typical of many families with RD children. The existence of such a biased sample could in part explain the fact that the observed familial patterns of RD were not as strong as those of motor problems. The severely RD parents, and in particular the fathers, may have simply refused to participate in the study, being unwilling to admit a weakness in an ability so important in our society. While the biased sample could have affected the strength of the observed familial patterns of RD, it could also have affected the finding that the RDO and RDMP families did not differ from the NC families on their responses to the question "How often do (did) you read to your children?". Perhaps had the sample been less biased, there would have been significant differences among the groups on this index of family attitudes to reading. Certainly, then, the results of this study must be interpreted with caution, keeping in mind the nature of the

sample of families involved. Broad generalizations of the results to the total population of reading disabled families may not be appropriate.

A third limitation of this study was the relatively small sample. Only 10 families of each type were tested. This limited sample size prevented the author from using segregation analysis to investigate the possible modes of inheritance of RDO or RDMP in the families. Segregation analysis allows one to detect whether the familial distribution of a variable such as reading ability is consistent with the involvement of a major gene. A variety of possibilities can be tested, such as Mendelian segregation at a single autosomal dominant locus with two alleles or Mendelian segregation at a single autosomal recessive locus with two alleles. To do this segregation analysis, however, requires a sample much larger than 10 nuclear families, as was the case in this study.

Conclusion

In conclusion, this study has shown that two types of reading disability, RDO and RDMP, do show strong familial patterns, with some families showing a history of RDO, and others, one of RDMP. Furthermore, in the families with a history of RDMP, it appears that the reading and motor problems are related, maybe as part of one genetic disorder characterized by underlying C-V dysfunction.

Perhaps the information from this study can be used to expedite the diagnosis of RDO or RDMP in young children showing some initial weaknesses in these areas. Knowledge of a positive family history for either disorder could help in the diagnostic process if it is known that having such a history increases the child's chance of

also having the disorder. Certainly in diagnosing many other problems, and in particular medical problems, taking a family history is considered an important diagnostic tool. If young children showing beginning signs of reading or motor problems can be identified early as RDO or RDMP on the basis of their family history, remediation can begin immediately, and hopefully avert the development of more serious problems. Furthermore, remediation can be made specific to the type of reading disability identified. For instance, RDMP children could be given extra help in developing skills such as handwriting which require good motor ability.

References

Ayres, A.J. (1969). Deficits in sensory integration in educationally handicapped children. Journal of Learning Disabilities, 2, 160-168.

Ayres, A. J. (1972). Southern California Sensory Integration Test Battery. Los Angeles, California: Western Psychological Services.

Blishen, B. R. & McRoberts, H. A. (1976). A revised socioeconomic index for occupations in Canada. Canadian Review of Sociology and Anthropology, 13, 71-79.

Boder, E. (1973). Developmental dyslexia: a diagnostic approach based on three atypical reading-spelling patterns. Developmental Medicine and Child Neurology, 15, 663-687.

Bruininks, R. H. (1978). Bruininks-Oseretsky Test of Motor Proficiency. Circle Pines, Minnesota: American Guidance Services.

Coles, G.S. (1980). Evaluation of genetic explanations of reading and learning problems. Journal of Special Education, 14, 365-383.

Childs, B. & Finucci, J. M. (1979). The genetics of learning disabilities. In Human Genetics: Possibilities and Realities. (Ciba Foundation Symposium 66). New York: Excerpta Medica.

Critchley, M. (1975). Specific developmental dyslexia. In Foundations of Language Development. E.H. Lenneberg & E.H. Lenneberg, Eds. New York: Academic Press.

Decker, S. N. & DeFries, J. C. (1980). Cognitive abilities in families with reading disabled children. Journal of Learning Disabilities, 13, 517-522.

Decker, S. N. & DeFries, J. C. (1981). Cognitive ability profiles in families of reading-disabled children. Developmental Medicine and Child Neurology, 23, 217-227.

DeFries, J. C. & Decker, S. N. (1982). Genetic aspects of reading disability: a family study. In Malatesha, R. H. & Aaron, P. G.(Eds.). Reading Disorders: Varieties and Treatments. New York: Academic Press.

DeFries, J. C., Singer, S. M., Foch, T. T. & Lewitter, F. I. (1978). Familial nature of reading disability. British Journal of Psychiatry, 132, 361-367.

Denckla, M. B., (1973). Development of speed in repetitive and successive finger-movements in normal children. Developmental Medicine and Child Neurology, 15, 635-645.

Denckla, M. B., (1974). Development of motor co-ordination in normal children Developmental Medicine and Child Neurology, 16, 729-741.

Denckla, M. B., Rudel, R. G., Chapman, C., & Krieger, J. (1985). Motor proficiency in dyslexic children with and without attentional disorders. Archives of Neurology, 42, 228-231.

Doehring, D. G. (1985). Reading disability subtypes: Interaction of reading and nonreading deficits. In Neuropsychology of Learning Disabilities: Essentials of Subtype Analysis. B.P. Rourke, Ed. New York: The Guilford Press, pp. 133-146.

Dunn, L., & Markwardt, F. (1970). Peabody Individual Achievement Test. Circle Pines, Minnesota: American Guidance Services.

Finucci, J. M., Isaacs, S. D., Whitehouse, C. C., & Childs, B. (1982). Empirical validation of reading and spelling quotients. Developmental Medicine and Child Neurology, 24, 733-744.

Finucci, J. M., Whitehouse, C. C., Isaacs, S. D., & Childs, B. (1984). Derivation and validation of a quantitative definition of specific reading disability for adults. Developmental Medicine and Child Neurology, 26, 143-153.

Frank, J., & Levinson, H. N. (1976). Dysmetric Dyslexia and Dyspraxia. Academic Therapy, 11, 133-143.

Gaddes (1976). Prevalence estimates and the need for a definition of learning disabilities. In The Neuropsychology of Learning Disabilities. R.M. Knights & D.J. Bakker, Eds. Baltimore: University Park Press.

Gordon, H. W. (1980). Cognitive asymmetry in dyslexic families. Neuropsychology, 18, 645-656.

Goyette, C. H., Conners, C. K., & Ulrich, R. F. (1978). Normative data on revised Conners parent and teacher rating scales. Journal of Abnormal Child Psychology, 6, 221-236.

Hallgren, M. (1950). Specific dyslexia ("congenital word blindness"): A clinical and genetic study. Acta Psychiatrica et Neurologica Scandinavica. Supplement 65.

Kripke, B., Lynn, R., Madsen, J., & Gay, P. (1982). Familial learning disability, easy fatigue and maladroitness: Preliminary trial of monosodium glutamate in adults. Developmental Medicine and Child Neurology, 24, 745-751.

Lewitter, F. I., DeFries, J. C., & Elston, R. C. (1980). Genetic models of reading disability. Behavior Genetics, 10, 9-30.

Levine, M. D. (1980). The Anser System Parent Questionnaire, Form 2P. Cambridge: Educators Publishing Service Incorporated.

Levinson, H. N. (1980). A Solution to the Riddle Dyslexia. New York: Springer-Verlag.

Naidoo, S. (1972). Specific Dyslexia. London: Pitman.

Nauton, R. (1975). The Vestibular System. New York: Academic Press.

Omenn, G. S. & Weber, B. A. (1978). Dyslexia: search for phenotypic and genetic heterogeneity. American Journal of Medical Genetics, 1, 333-342.

Ottenbacher, K. (1978). Identifying vestibular processing dysfunction in learning disabled children. The American Journal of Occupational Therapy, 32, 217-221.

Ottenbacher, K. (1980). Excessive postrotary nystagmus duration in learning disabled children. The American Journal of Occupational Therapy, 34, 40-44.

Owen, F. W., Adams, P. A., Forrest, T., Stolz, L. M. & Fisher, S. (1971). Learning disorders in children: sibling studies. Monographs of the Society for Research in Child Development, (Vol 36). Chicago: University of Chicago Press, 1971.

Pavlidis, G. Th. (1981). Do eye movements hold the key to dyslexia? Neuropsychologia, 19, 57-64.

Pennington, B. F. (1986). Issues in the diagnosis and phenotypic analysis of dyslexia: Implications for family studies. In The Genetics of Learning Disabilities: Genotypic Studies, S. D. Smith, Ed. San Diego: College Hill Press.

Pennington, B. F. & Smith, S. D. (1983). Genetic influences on learning disabilities and speech and language disorders. Child Development, 54, 369-387.

de Quiros, J. B. (1976). Diagnosis of vestibular disorders in the learning disabled. Journal of Learning Disabilities, 9, 50-58.

de Quiros, J. B. & Schrager, O. L. (1978). Neuropsychological Fundamentals in Learning Disabilities. Novato: Academic Therapy Publications.

Rasmussen, F., Gustavson, K., & Bille, B. (1984). Familial minor neurodevelopmental disorders. Clinical Genetics, 25, 148-154.

Regehr, S. (1987). The genetic aspects of developmental dyslexia. Canadian Journal of Behavioural Science, in press.

Rourke, B. P. (1985). Overview of learning disability subtypes. In Neuropsychology of Learning Disabilities: Essentials of Subtype Analysis, B.P. Rourke, Ed. New York: The Guilford Press.

Smith, S. D., Kimberling, W. J., Pennington, B. F. & Lubs, H. A. (1983). Specific reading disability: identification of an inherited form through linkage analysis. Science, 219, 1345-1347.

Steinberg, M. A. & Rendle-Short, J. (1977). Vestibular dysfunction in young children with minor neurological impairment. Developmental Medicine and Child Neurology, 19, 639-651.

Steinberg, M. A. & Rendle-Short, J. (1980). Neuro-sensori-motor dysfunction in young children with educational and behavioural problems and controls. The Exceptional Child, 27, 107-114.

Vogler, G. P., DeFries, J. C., & Decker, S. N. (1985). Family history as an indicator of risk for reading disabilities. Journal of Learning Disabilities, 18, 419-421.

Wechsler, D. (1974). Manual for the Wechsler Intelligence Scale for Children - Revised. New York: Psychological Corporation.

Wender, P. (1976). Hypothesis for a possible biochemical basis of minimal brain dysfunction. In Knights, R.M., & Bakker D. J. (Eds.) The Neuropsychology of Learning Disorders. Baltimore: University Park Press, pp. 111-122.

Younes, R. P., Rosner, B., & Webb, G. (1983). Neuroimmaturity of learning-disabled children: a controlled study. Developmental Medicine and Child Neurology, 25,574-579.

Zangwill, O. L., & Blakemore, C. (1972). Dyslexia: Reversal of eye-movements during reading. Neuropsychologia, 10, 371-373.

Appendix A

Correspondence with Teachers and Parents

Letter Sent to Parents of Children Referred
Through Alberta Children's Hospital

August 25, 1986

Dear :

Sonya Regehr is a graduate student in the Psychology Department at the University of Calgary and, as part of the requirements for her graduate program, she is conducting a research project on school age children with learning problems. She is investigating children with reading problems as well as assessing their balance and coordination. These children are ages 7 to 14 years and it appears that your child may be eligible for participation in her project.

Ms. Regehr will be telephoning you within the next two weeks to ask whether you would like to hear about the project. If you agree to listen to the description of the project, you will be asked, after hearing the description, whether you would be willing to have your child participate. Your decision will not affect you child's status on the waiting list nor will it have any implication for your child's care at the Alberta Children's Hospital. You are under no obligation to have your child participate in this study. Thank you for your consideration.

Sincerely,

Pat Petrie, Ph.D.
Director, School Age Developmental Clinic
DAT Centre

PP:ms

Letter Sent to Teachers, Requesting Referrals

October, 1986

Dear Teacher:

I am writing to you in regard to a research study which is underway at Alberta Children's Hospital. The purpose of this study is to assess the heritability of reading disabilities and in particular reading disabilities which occur together with problems of balance and coordination. I would like to see if there are families in which more than one member shows both these types of disabilities. For this reason, children showing both of these deficits, and their families, are being invited to participate in this study. For comparison, children who show only a reading disability, and children who show no reading or balance/coordination problems, are also being invited to participate in the study with their families.

I am currently looking for children with both reading and balance/coordination problems. Such children could be described as follows:

a) 7-14 years of age
b) either male or female
c) of at least average intelligence
d) not currently on medication for symptomatology associated with learning or behaviour problems
e) have trouble with reading
f) have difficulty with balance, coordination, and motor skills. These problems could manifest themselves in:
   -a poor sense of balance
   -clumsiness and trouble using both hands or both feet together
   -a tendency to be confused by unfamiliar tasks, requiring the child to think about each movement of a new task
   -difficulty learning to print or problems keeping up with peers in the playground

In addition to meeting the above criteria for participation in the study, a child would have to have a biological sibling, age 7 to 14, and both biological parents willing to participate in the study.

If you think you know a child who may meet these criteria, I would appreciate it very much if you would send a copy of the attached "Letter to Parents" home with that child, and then call me at 229-7365 to let me know who you have sent letters to. I will then contact each of those families. If you have any questions about the study or possible referrals, please do not hesitate to give me a call.

Thank you very much for your interest and cooperation.

Sincerely,

Sonya M. Regehr, Graduate Student
Psychology Department, University of Calgary

Letter Sent to Parents Of Children Referred
Through the School System

January, 1987

Dear Parents:

I am writing to you in regard to a research study which is underway at Alberta Children's Hospital. The purpose of this study is to assess the heritability of reading disabilities, both when they occur alone and when they occur together with balance and coordination problems. I would like to see if any family patterns to these disabilities can be detected. For this reason, reading disabled children and their families are being invited to participate in this study.

Everyone who participates in the study will be assessed by me for 35 to 60 minutes. They will be asked to do some reading and some simple tasks like throwing and catching a ball. In addition, mothers will be asked to fill out a short questionnaire indicating how hyperactive, restless and irritable they feel their children are. They will also fill out a questionnaire indicating any problems they had with the pregnancies and births of their children. Later, the results of the tests and the overall study will be made available to the families if requested.

I will be calling you soon to discuss this study with you more fully. If you are interested then and are eligible for the study, we will arrange for you to participate in this research.

Sincerely,

Sonya M. Regehr
Graduate Student, Psychology Department
The University of Calgary
(Dr. B. J. Kaplan, supervisor)

Appendix B

Consent Forms

Consent Form

I have been asked to participate in a study to assess whether or not reading disability which occurs together with certain problems of balance/coordination tends to occur frequently within certain families, perhaps indicating a genetic predisposition. To find this out, this study will compare children with this type of reading disability, children with a reading disability but no sign of balance/coordination problems, and children with no problems in either area. The study will also examine the parents and one sibling of these children to see if their reading ability, balance, and coordination are about the same as the child they are related to.

I understand that each person involved in the study will be given a reading test and a number of tests of balance and coordination. Some children's school records will also be examined to see the results of any intelligence tests given, and if the children have not been tested formally for intelligence, they will be given an intelligence test for the purposes of this study. Any information obtained regarding a child's intelligence will be kept strictly confidential. I understand that each parent in the study will also be asked to fill out a questionnaire on which they will estimate their own reading ability. Furthermore, each mother in the study will be asked to complete two questionnaires for each of her children involved in the study. One questionnaire involves indicating the tendency of the child to be hyperactive, restless, and irritable. The other involves indicating any problems the mother had with the pregnancy or delivery of the child. If the child was born in a Calgary hospital, his or her birth record at that hospital will be examined as well for further information on the birth.

I have been told that all medical, school, and other records used in this study will be kept in total confidence. The results of any tests or questionnaires given in this study will also be kept strictly confidential. I understand that I may refuse to participate and that I may withdraw from the study at any time without prejudice to the treatment my child might receive at the Alberta Children's Hospital or at his or her school.

I agree to participate in this study.

_____ _____

Father Mother

Children's Consent Form

I have been asked to be in an experiment. In the experiment I will do some reading, play some games, and do some drawing. I agree to do this.

Student _____ Student's brother or sister _____

I, the undersigned, have defined and fully explained the study to the above volunteers.

_____ Date _____

Appendix C

Questionnaires

Completed by Parents

Conners Abbreviated Symptom Questionnaire (ASQ)*

INSTRUCTIONS: Listed below are items concerning children's behaviour or the problems they sometimes have. Read each item carefully and decide how much you think your child has been bothered by (characterized by) this problem at this time.

OBSERVATIONS	Not at all	Just a little	Pretty much	Very much
1. Restless or overactive				
2. Excitable, impulsive				
3. Disturbs other children				
4. Fails to finish things he starts; short attention span				
5. Constantly fidgeting				
6. Inattentive, easily distracted				
7. Demands must be met immediatly; easily frustrated				
8. Cries often and easily				
9. Mood changes quickly and drastically				
10. Temper outbursts; explosive and unpredictable behaviour				
Subtotal:				

Total: _____

An individual's total score was calculated by adding up the checkmarks in each column, giving checkmarks in the "very much" column a weight of 3, those in the "pretty much" column a weight of 2, those in the "just a little" column a weight of 1, and those in the "not at all" column a weight of 0.

*From Goyette, C.H., Conners, C.K., & Ulrich, R.F. (1978). Normative data on revised Conners parent and teacher rating scales. Journal of Abnormal Child Psychology, 6, 221-236.

Pregnancy and Birth Complications Questionnaire

The following checklists help us to decide whether there are any early medical factors that might be important. The checklist entitled "Possible Pregnancy Problems" concerns the pregnancy with this student, except for items 1.12 and 1.13 which refer to previous pregnancies. The "Newborn Infant Problems" checklist is about the baby's first month of life. Please read each list, and then put an X in the appropriate column following each item.

1.0	Possible Pregnancy Problems	True	Not True	Cannot Say
1.1	Had bleeding during first three months			
1.2	Had bleeding during second three months			
1.3	Had bleeding during last three months			
1.4	Gained 30 or more pounds (Specify:)			
1.5	Had toxemia			
1.6	Had to take medications*			
1.7	Vomited often			
1.8	Got hurt or injured			
1.9	Gained less than 15 pounds (Specify:)			
1.10	Took narcotic drugs			
1.11	Drank much alcohol			
1.12	Had previous miscarriages			
1.13	Had previous premature babies			
1.14	Had an infection			
1.15	Smoked one pack (or more) of cigarettes a day			
1.16	Labor lasted longer than 12 hours			
1.17	Had a caesarean section			
1.18	Had a difficult delivery			
1.19	Was put to sleep for delivery			
1.20	Labor lasted less than two hours			
1.21	Length of pregnancy ( ) months			

*Specify any medications:

1. _____

2. _____

3. _____

Other pregnancy problems/illnesses:

1. _____

2. _____

3. _____

Pregnancy and Birth Complications Questionnaire (Cont'd)

2.0	Newborn Infant Problems	True	Not True	Cannot Say
2.1	Born with cord around neck			
2.2	Injured during birth			
2.3	Had trouble breathing			
2.4	Got yellow (jaundice)			
2.5	Turned blue (cyanosis)			
2.6	Was a twin or triplet			
2.7	Had an infection			
2.8	Was given medications			
2.9	Had seizures (fits, convulsions)			
2.10	Had diarrhea			
2.11	Needed oxygen			
2.12	Was in hospital more than 7 days			
2.13	Gagged often			
2.14	Vomited often			
2.15	Born with heart defect			
2.16	Born with other defect(s)			
2.17	Had trouble sucking			
2.18	Had skin problems			
2.19	Was very jittery			
2.20	Baby's birth weight (lbs.)			

Please list any other problems:

1._____

2._____

3._____

An individual's risk score was calculated by adding up all the true responses on both the possible pregnancy problems and the newborn infant problems scales. The responses were weighted equally.

This questionnaire is taken from: Levine, M.D. (1980). The Anser System Parent Questionnaire, Form 2P. Cambridge: Educators Publishing Service Incorporated.

Reading Questionnaire for Parents*

1. Did you have difficulty with reading in school?
   No (0) Yes (2)

2. How much tutoring in reading did you receive?
   None (0) Little (1) Moderate (2) Great deal (3)

3. How many, if any, grades did you repeat?
   None (0) One (1) Two or more (2) School drop-out (3)

4. Did you fail any courses? If so, which ones?
   None (0) Math/Science only (1) Eng./Hist/Lang (2)

5. How would you rate your ability in English?
   Very good (0) Average (1) Some difficulty (2) Great difficulty (3)

6. How often do you read the newspaper?
   Daily (0) Usually (1) Irregularly (2) Rarely or never (3)

7. How often do you read the Sunday newspaper?
   Avid/weekly (0) Usually (1) Irregularly (2) Rarely or never (3)

8. How many magazines do you read per month?
   Five or more (0) Two to four (1) One (2) None (3)

9. How many books do you read per year?
   More than ten (0) Six to ten (1) One (2) None (3)

10. How do you feel about word-game playing?
    Enthusiastic (0) Sometimes play (1) Indifferent (2) Detest (3)

11. How often did you read to your children when they were young?
    Enthusiastic (0) Yes (1) Rarely (2) Never (3)

12. Do you have trouble remembering the names for things?
    Never (0) Rarely (1) Sometimes (2) Often (3)

13. Do you have trouble remembering addresses and phone numbers?
    Never (0) Rarely (1) Sometimes (2) Often (3)

14. How would you describe your attitude toward reading?
    Very positive (0) Enjoys/pleasurable (1) Indifferent (2)
    Difficult/chore (3)

15. How would you rate your spelling ability?
    Above average (0) Average (1) Below Average (2) Poor/terrible (3)

(An individual's score was determined by adding up his or her responses using the weightings indicated in brackets on the questionnaire.)

*From Finucci, J.M., Whitehouse, C.C., Isaacs, S.D., & Childs, B. (1984). Derivation and validation of a quantitative definition of specific reading disability for adults. Developmental Medicine and Child Neurology, 26, 143-153.

Appendix D

MANOVA and ANOVA

Summary Tables

Multivariate and Univariate Summary Table for Probands

Variable	SS	DF	MS	F
All (MANOVA)		24,32		12.14*
balance	36.36	2,27	18.18	16.29*
bilateral coordination	23.91	2,27	11.96	23.66*
upper limb coordination	28.66	2,27	14.33	17.77*
fine motor coordination	32.56	2,27	16.28	28.72*
reading recognition	24534.5	2,27	12267.2	95.02*
reading comprehension	21554.5	2,27	10777.2	30.28*
spelling	22922.5	2,27	11461.2	85.90*
ADD	13.4	2,27	6.7	4.86
pregnancy and birth problems	22.9	2,27	11.4	1.10

*$p < .006$

Multivariate and Univariate Summary Table for Siblings

Variable	SS	DF	MS	F
All (MANOVA)		16,40		3.63*
balance	9.54	2,27	4.77	3.69
bilateral coordination	16.11	2,27	8.06	15.75*
upper limb coordination	8.67	2,27	4.34	6.95*
fine motor coordination	12.00	2,27	6.00	8.62*
reading recognition	6008.27	2,27	3004.13	5.84
reading comprehension	6843.80	2,27	3421.90	7.07*
spelling	3373.07	2,27	1686.53	2.94
ADD	0.17	2,27	0.08	0.06
pregnancy and birth problems	0.08	2,27	0.04	0.15

*$p < .007$

Multivariate and Univariate Summary Table Examining
Sex by Diagnosis Interaction in Parents

Factor	Variable	SS	DF	MS	F
Sex by Diagnosis	All (Manova)		18,32		2.50*
	Balance	21.17	2,24	10.58	1.36
	Bilateral Coordination	12.27	2,24	6.14	0.79
	Upper Limb Coordination	12.51	2,24	6.26	2.88
	Motor Accuracy	8.17	2,24	4.08	0.41
	Fast Movements	1.28	2,24	0.64	2.25
	Reading Recognition	40.73	2,24	20.37	0.73
	Reading Comprehension	114.36	2,24	57.18	2.65
	Spelling	748.80	2,24	374.40	6.10*

**$p < .006$

*$p < .01$

Univariate Summary Table Examining Simple Main Effects on Spelling in Parents

Factor	Variable	SS	DF	MS	F
Diagnosis (on Mothers)	Spelling	116.74	2,24	58.37	1.06
Diagnosis (on Fathers)	Spelling	1414.3	2,24	707.15	6.15*
Sex (on RDMP)	Spelling	953.39	1,24	953.39	15.53*
Sex (on NC)	Spelling	39.20	1,24	39.20	0.64
Sex (on RD)	Spelling	14.06	1,24	14.06	0.23

*$p < .01$

Multivariate and Univariate Summary Table Examining Effect of Sex in Parents

Factor	Variable	SS	DF	MS	F
Sex	All (MANOVA)		9,16		3.94*
	Balance	7.61	1,24	7.61	0.98
	Bilateral Coordination	0.74	1,24	0.74	0.10
	Upper Limb Coordination	42.80	1,24	42.80	19.72**
	Motor Accuracy	5.44	1,24	5.44	0.54
	Fast Movements	1.61	1,24	1.61	5.65
	Reading Recognition	0.51	1,24	0.51	0.02
	Reading Comprehension	8.77	1,24	8.77	0.41
	Spelling	276.39	1,24	276.39	4.50

*$p < .01$

**$p < .006$

Multivariate and Univariate Summary Table Examining Effect of Proband Diagnosis in Parents

Factor	Variable	SS	DF	MS	F
Diagnosis	All (MANOVA)		18,32		4.38**
	Balance	197.37	2,24	98.68	8.41**
	Bilateral Coordination	262.76	2,24	131.38	7.50**
	Upper Limb Coordination	106.02	2,24	53.01	17.42**
	Motor Accuracy	457.71	2,24	228.86	17.24**
	Fast Movements	4.92	2,24	2.46	5.48
	Reading Recognition	854.28	2,24	427.14	5.98*
	Reading Comprehension	611.34	2,24	305.67	2.51
	Spelling	782.24	2,24	391.12	3.60

** $p < .006$

* $p < .01$

Appendix E

Tables of Means

and Standard Deviations

Means and Standard Deviations for Probands

Variable	Mean			Standard Deviation		
	RDMP	NC	RDO	RDMP	NC	RDO
balance	-2.4	-0.19	-0.09	1.65	0.40	0.68
bilateral coordination	-0.92	1.21	0.57	0.67	0.60	0.84
upper limb coordination	-1.39	0.82	0.50	1.26	0.72	0.57
fine motor coordination	-1.32	1.01	0.76	0.66	0.67	0.90
reading recognition	19.80	78.20	15.50	10.27	9.61	13.76
reading comprehension	22.40	81.20	26.50	20.96	15.05	20.04
spelling	17.70	74.40	14.00	13.52	10.06	10.78
ADD	1.52	-0.09	0.44	1.17	0.81	1.46
pregnancy and birth problems	5.20	4.50	3.10	4.26	2.22	2.85

Means and Standard Deviations for Siblings

Variable	Mean			Standard Deviation		
	RDMP	NC	RDO	RDMP	NC	RDO
balance	-1.27	0.05	-0.28	1.48	1.06	0.76
bilateral coordination	-0.26	1.50	0.91	0.64	0.51	0.93
upper limb coordination	-0.59	0.64	0.44	1.03	0.45	0.78
fine motor coordination	0.17	1.72	0.90	0.93	0.36	1.04
reading recognition	50.80	72.80	38.60	25.35	16.22	25.24
reading comprehension	59.10	80.80	44.00	25.30	12.54	25.60
spelling	48.90	67.50	42.50	27.02	12.55	28.91
ADD	-0.21	-0.21	-0.37	1.18	1.23	1.10
pregnancy and birth problems	6.10	4.90	2.40	4.51	1.97	1.78

Means and Standard Deviations of
RDMP Mothers and Fathers

Group	Type	Variable	Mean	Standard Deviation
RDMP	Mother	balance	10.22	2.991
		bilateral coordination	11.78	4.790
		upper limb coordination	8.667	2.500
		motor accuracy	160.3	3.640
		fast movements	5.646	.6593
		reading recognition	69.00	9.394
		reading comprehension	67.44	13.28
		spelling	73.11	9.413
	Father	balance	9.333	4.000
		bilateral coordination	13.33	3.500
		upper limb coordination	11.56	1.667
		motor accuracy	158.8	3.841
		fast movements	5.569	.8003
		reading recognition	69.33	7.280
		reading comprehension	69.22	10.66
		spelling	58.56	14.13

Means and Standard Deviations of
NC Mothers and Fathers

Group	Type	Variable	Mean	Standard Deviation
NC	Mother	balance	13.60	3.273
		bilateral coordination	17.70	2.710
		upper limb coordination	12.80	1.476
		motor accuracy	166.0	3.109
		fast movements	4.987	.5413
		reading recognition	78.20	3.120
		reading comprehension	77.80	2.898
		spelling	73.00	5.270
	Father	balance	14.50	3.136
		bilateral coordination	17.10	2.998
		upper limb coordination	13.40	1.075
		motor accuracy	165.1	3.275
		fast movements	4.819	.4051
		reading recognition	76.20	6.630
		reading comprehension	74.70	5.736
		spelling	75.80	6.529

Means and Standard Deviations of
RDO Mothers and Fathers

Group	Type	Variable	Mean	Standard Deviation
RDO	Mother	balance	12.37	2.446
		bilateral coordination	17.13	3.758
		upper limb coordination	12.12	1.642
		motor accuracy	165.8	2.550
		fast movements	5.494	.7871
		reading recognition	67.63	5.999
		reading comprehension	69.37	6.186
		spelling	68.50	7.231
	Father	balance	14.62	2.446
		bilateral coordination	16.88	3.357
		upper limb coordination	14.00	.7559
		motor accuracy	166.2	3.909
		fast movements	4.699	.2834
		reading recognition	69.87	8.593
		reading comprehension	73.12	8.323
		spelling	66.63	10.54

Means and Standard Deviations of
Mothers and Fathers

Group	Variable	Mean	Standard Deviation
Mothers	balance	12.11	3.191
	bilateral coordination	15.56	4.569
	upper limb coordination	11.22	2.621
	motor accuracy	164.0	4.038
	fast movements	5.357	.6995
	reading recognition	72.00	8.000
	reading comprehension	71.85	9.469
	spelling	71.70	7.446
Fathers	balance	12.81	4.029
	bilateral coordination	15.78	3.609
	upper limb coordination	12.96	1.581
	motor accuracy	163.4	4.811
	fast movements	5.033	.6533
	reading recognition	72.04	7.876
	reading comprehension	72.41	8.409
	spelling	67.33	12.67

Means and Standard Deviations for
The Three Groups of Parents

Group	Variable	Mean	Standard Deviation
RDMP	balance	9.778	3.457
	bilateral coordination	12.56	4.148
	upper limb coordination	10.11	2.541
	motor accuracy	159.6	3.711
	fast movements	5.607	.7124
	reading recognition	69.17	8.155
	reading comprehension	68.33	11.72
	spelling	65.83	13.84
NC	balance	14.05	3.154
	bilateral coordination	17.40	2.798
	upper limb coordination	13.10	1.294
	motor accuracy	165.6	3.138
	fast movements	4.903	.4732
	reading recognition	77.20	5.146
	reading comprehension	76.25	4.700
	spelling	74.40	5.951
RDO	balance	13.50	2.633
	bilateral coordination	17.00	3.445
	upper limb coordination	13.06	1.569
	motor accuracy	166.0	3.196
	fast movements	5.096	.7036
	reading recognition	68.75	7.253
	reading comprehension	71.25	7.344
	spelling	67.56	8.786

Appendix F

Correlation Matrices

Correlations between the Variables
Using the Sibling Data

	Balance	Bilat. Coord.	Upper Limb Coord.	Fine Motor Coord.	Reading Recog- nition	Reading Compre- hension	Spel- ling
Balance	1.00						
Bilat. Coord.	.03	1.00					
Upper Limb Coord.	.17	.28	1.00				
Fine Motor Coord.	.20	.53	.27	1.00			
Reading Recog- nition	-.06	.55	.27	.29	1.00		
Reading Compre- hension	.18	.52	.29	.52	.75	1.00	
Spel- ling	.03	.66	.45	.47	.75	.67	1.00

Correlations between the Variables
Using the Mothers' Data

	Balance	Bilat. Coord.	Upper Limb Coord.	Motor Accuracy	Fast Movements	Read Recognition	Read Comprehen.	Spelling
Balance	1.00							
Bilat. Coord.	.20	1.00						
Upper Limb Coord.	.61	.18	1.00					
Motor Accuracy	-.14	.08	.24	1.00				
Fast Movements	-.07	-.26	-.24	-.16	1.00			
Read Recognition	.17	.29	.33	.17	-.41	1.00		
Read Comprehen.	.37	.23	.44	.09	-.27	.87	1.00	
Spelling	.20	.26	.37	.15	-.41	.72	.61	1.00

Correlations between the Variables
Using the Fathers' Data

	Balance	Bilat. Coord.	Upper Limb Coord.	Motor Accuracy	Fast Movements	Read Recognition	Read Comprehen.	Spelling
Balance	1.00							
Bilat. Coord.	.19	1.00						
Upper Limb Coord.	.10	-.16	1.00					
Motor Accuracy	.43	.01	.20	1.00				
Fast Movements	-.00	-.04	-.42	-.33	1.00			
Read Recognition	.24	-.09	.38	.21	-.10	1.00		
Read Comprehen.	.33	-.01	.27	.03	.32	.77	1.00	
Spelling	.29	-.10	.40	.21	-.31	.80	.47	1.00