SCHOOL MATHEMATICS AND DYSLEXIA: ASPECTS OF THE INTERRELATIONSHIP

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This investigation sought to explore the nature and extent of school mathematical difficulties among the dyslexic population. Anecdotal reports have suggested that many dyslexics may have difficulties in arithmetic, but few systematic studies have previously been undertaken.

The literature pertaining to dyslexia and school mathematics respectively is reviewed. Clues are sought in studies of dyscalculia. These seem inadequate in accounting for dyslexics' reported mathematical difficulties.

Similarities between aspects of language and mathematics are examined for underlying commonalities that may partially account for concomitant problems in mathematics, in individuals with a written language dysfunction. The performance of children taught using different mathematics work-schemes is assessed to ascertain if these are associated with differential levels of achievement, that may be reflected in the dyslexic population - few are found.

Findings from studies designed to assess the relationship between written language failure and achievement in mathematics are reported. Study 1 reveals large correlational differences between subtest scores (Wechsler Intelligence Scale for Children, Wechsler, 1976) and three mathematics tests, for young dyslexics and children without literacy difficulties. However, few differences are found between levels of attainment, at this age (6½ - 9 years).

Further studies indicate that, for dyslexics, achievement in school mathematics, may be independent of measured intelligence, as is the case with their literacy skills. Studies 3 and 4 reveal that dyslexics' performances on a range of school mathematical topics gets relatively worse compared with that of Controls (age range 8 - 17 years), as theyget older.

Extensive item analyses reveal many errors relating strongly to known deficits in the dyslexics' learning style - poor short-term memory, sequencing skills and verbal labelling strategies. Subgroups of dyslexics are identified on the basis of mathematical performance. Tentative explanations, involving alternative neuropsychological approaches, are offered for the measured differences in attainment between these groups.

KEY WORDS
School mathematics
Dyslexia
Interrelationship
Error analysis

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CHAPTER 1

1.1 INTRODUCTION

A syndrome of literacy difficulties independent of intellectual potential is now accepted as one possible learning pattern - dyslexia. When discussing dyslexia, some researchers have mentioned mathematical difficulties in their lists of presenting features. For example, Miles (1974) refers to the inability to learn tables and lack of competence in subtraction as possible characteristics of the dyslexic child's learning profile. In the United States of America, it is an accepted fact that some children with literacy difficulties also have problems related to mathematics. However, at the time that this study was initiated, few systematic and methodologically sound studies had been undertaken, in either the United Kingdom or USA, to determine the nature and extent of mathematical difficulties in the dyslexic population and the possible interrelationship of these problems with literacy failure. An investigation to explore this area was considered important, both to increase our theoretical knowledge of dyslexia (does an underlying cognitive style, which does not favour fluent literacy acquisition, also affect school mathematics in a similar way?) and to provide material which might be useful in improving diagnostic and remedial measures in the interests of the dyslexic child.

Over the past few years there have been an increasing number of individuals referred by parents, teachers and psychologists to the Language Development Unit at the University of Aston in Birmingham for assessment of literacy difficulties. A large proportion of this number have also reported having problems with mathematics. However, until relatively recently, less attention has been paid to the latter since literacy has been considered of paramount importance, whereas failure in mathematics has been socially acceptable. Now, in line with general societal feeling, dyslexics are aware of the need for some degree of mathematical and/or arithmetical competence.

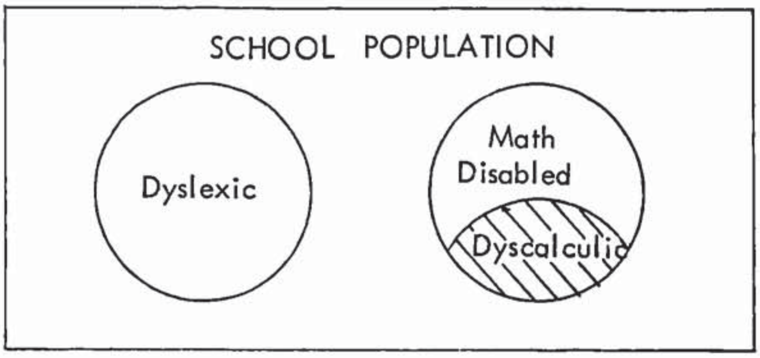
In our day-to-day living, there is an increasing dependence on number-linked technological devices, like computers and various micro-processor-based machines, which require a degree of numeracy for their usage and excellence at both numeracy and mathematics for their design. This development has prompted the commercial and industrial sectors of the community to reflect on the lack of suitably-qualified personnel to fill related positions and to bemoan the large number of innumerate school leavers. They have referred their grievances back to the schools.
The Department of Education and Science (DES) responded to this out-cry by the setting up of the Cockcroft Commission in 1977, to investigate the teaching of mathematics in schools. Further concrete evidence of the Department's concern has been the creation of permanent Assessment of Performance Units, to monitor attainments in Mathematics and English in schools throughout the country.

It seems that to function effectively in society today, people are expected not only to be literate, but to be numerate as well. Failure in arithmetic and mathematics are no longer socially acceptable. This puts at a disadvantage people who have failed to acquire basic literacy, as well as those who are not numerate. Individuals who are both illiterate and innumerate are doubly handicapped. Into this latter category seem to fall that group of dyslexics who seem to have difficulties in both these areas of acquired knowledge. Of course, there are dyslexics who do not seem to have problems with school mathematics.

There also appears to be a little-studied group of people, known as dyscalculics, whose language acquisition and fluency are unimpaired, but who have a specific problem with number. Among the aims of this thesis is that of ascertaining the relationships, if any, amongst dyslexics, dyscalculics and other math-disabled groups. A distinction is made between dyscalculic and math-disabled (see Definitions), the former being a subset of the latter.

The questions posed can be represented using diagrams. In order to illustrate that much maligned aspects of so-called "New Math" (Ballew, 1977; Brody, 1977; Hirschi, 1977) do have practical applications, Venn diagrams and sets will be used to represent the tentative hypotheses under consideration.

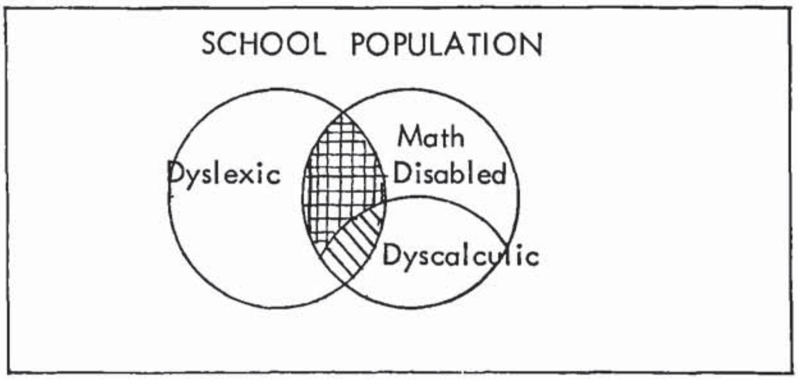
FIGURE 1



Using Figure 1

Is it true to say that Dyslexics and Math-disabled individuals (including Dyscalculics) constitute two separate groups within the school population and that, within the Dyslexic Group, there are individuals who have difficulties with school mathematics, but that these problems are different from those experienced by dyscalculics?

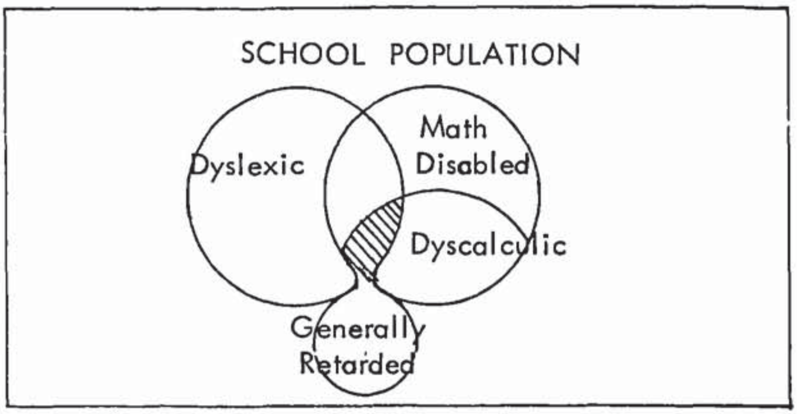
FIGURE 2



Using Figure 2

Are the set of Dyslexics and the set of Math-disabled children intersecting sets, that is, are there some Dyslexics who are Dyscalculic as well? Do some dyslexics share other mathematics-related difficulties? If this is so, what is the size of the intersection and what are the features shared by individuals in this group?

FIGURE 3



Using Figure 3

Are there features of Dyslexics and Math-disabled individuals performance in school mathematics which are also found in pupils who are generally retarded in the acquisition of skills?

The main concern of this thesis is the school mathematical performance of dyslexic children. However, since there was little literature in this area, on which to base research, it was hoped that studies of dyscalculic and other math-disabled children might provide a starting point.

In view of the fact that this is a relatively new field of research, it was considered important to establish, as far as possible, whether reported difficulties in mathematics are part of a dyslexia syndrome, or whether they constitute an independent problem. Could it be that in the same way that some dyslexics have a spelling problem, but are not deficient in reading skills, there is a category in which failure in school mathematics could be similarly included in a model of dyslexia? There is evidence to suggest that dyslexia and poor achievement in arithmetic may be related, but much of this material is anecdotal and/or clinical (Miles, 1974; Svien & Sherlock, 1979). It must be noted that arithmetic is only one aspect of the school mathematics curriculum. The present research sought to broaden the spectrum by the inclusion of other aspects as well - for example, spatial facets - in an attempt to develop a more comprehensive picture.

If aspects of school mathematics failure are found to be part of the dyslexia phenomenon, as is predicted, then this will increase the present body of knowledge about this learning disability, adding another piece to the developing theoretical jigsaw model of "dyslexiology" (Myklebust, 1978). If a relationship is noted, the findings will also have practical implications for assessment procedures and remedial programme planning; these would have to be extended to accommodate school mathematics so that assessment could be more comprehensive.

1.2 Dyslexia and School Mathematics - The Present Situation

Few studies concerning the relationship between dyslexia and school mathematics are to be found in the literature. The reports that have appeared, confine themselves to one aspect of mathematics - arithmetic. However, despite the dearth of published in-depth analyses, aspects of numeracy have been mentioned in some lists of possible presenting features of dyslexia (Vernon, 1970; Critchley & Critchley, 1978). Miles (1974) listing ten descriptive signs of dyslexia includes:

1. Inability to do subtraction, except with concrete aids.
2. Difficulty in memorising arithmetical tables.
3. Losing one's place when reciting tables.

However, a recent appraisal of current knowledge concerning dyslexia makes little mention of arithmetic and none of mathematics (Benton & Pearl, 1979). Other researchers have cited low scores on the arithmetic subtest of the Wechsler Intelligence Scale for Children (WISC) (Wechsler, 1949) as being indicative of poor calculative ability (Levine & Fuller, 1972; Fincham & Meltzer, 1976). But, as Thomson & Grant (1979) point out, the dyslexic child may do poorly on this test, not because of poor arithmetical ability, but because the tasks require fluent sequencing skills and adequate memory for tables and "carrying" of numbers - functions that are particularly problematical for dyslexics (Miles, 1974).

Critchley & Critchley (1978) are of the view that "most dyslexics, whatever their age, seem to acquit themselves better at numeracy than at reading, writing and spelling". This may well prove to be the case; nevertheless, it does not explain anything about the possible links between these skills, especially if the numeracy factor, like the literacy aspects, proves to be an underestimate of potential.

Clues as to the possible nature of the relationship are provided by Klees (1976), who maintains that:

> "Their (dyslexics with problems with mathematics) calculating difficulties could not be compared with those of mentally deficient children; their reasoning faculties were absolutely unimpaired and often provided compensatory mechanisms of surprising complexity."

Additional support for this view is provided by Svien & Sherlock (1979) who maintain that:

> "..... in these cases the underlying disability is not in concept formation but in the language of mathematics and its symbolic code".

This seems to suggest a similar separation of understanding and written symbolism that characterises dyslexics' mastery of language (Thomson, 1977). However, the writer's clinical studies of dyslexics have not always indicated adequate conceptual understanding of mathematical principles, so there seemed to be a need to look further.

As has been mentioned, few studies that have attempted an explanation of dyscalculia (difficulty in dealing with numbers and calculation) as an aspect of dyslexia (Svien & Sherlock, 1979; Fincham & Meltzer, 1976) have been limited to arithmetic. No-one previously has focussed on the other aspects of the school mathematics curriculum, for example, geometry and simple problem solving. The studies reported in this thesis were undertaken to partially redress this imbalance.

There are a number of practical reasons that may contribute to the dyslexics' possible difficulties with school mathematics; although numeracy and competence in basic mathematics are becoming increasingly necessary in society today, literacy is still considered to be of paramount importance. As such, people like dyslexics, who have difficulties with reading and spelling are encouraged to improve these skills, often to the detriment of other school subjects.

Withdrawal from mathematics lessons, to attend remedial language classes, is sometimes unavoidable. The effect of this may be two-fold; firstly mathematics tuition may be missed, and secondly, the implicit assumption (by being withdrawn during mathematics periods), that mathematics is less important than English, is fostered.

To avoid undue stress on the dyslexic, who is already failing in one aspect of education, mathematics is often not emphasised by parents and teachers. Also if the individual is experiencing feelings of failure generally, s/he may not try, believing that the effort would be a waste of time because s/he would be bound to fail again. Aiken (1970) suggests that the circular relationship between academic achievement and attitudes is such that failure of the learning disabled child probably results in an unfavourable attitude towards arithmetic, which has a further detrimental effect on performance. If the individual is anxious or tired, for example, after a remedial English lesson, performance may be poor. Forness & Esveldt (1975) have shown that learning disabled children spend significantly less time than normal achievers in attending during arithmetic classes. Fincham & Meltzer (1976) suggest this might be a consequence of short attention span (Tarver & Hallahan, 1974).

Complacency about failure in mathematics is reinforced by parental statements like "I was never any good at maths either", and "You can always use a calculator". What many people do not seem to realise is that the latter only applies if one has some basic knowledge of the processes involved and an ability to estimate the answer. For example, when multiplying 7 x 6 on a calculator, and the answer yielded is 420, one must be able to distinguish if the answer is incorrect. Ability to estimate is an important prerequisite to the use of calculators, and to calculation in general.

A number of mathematics curricula in schools are workbook based. Pupils are often required to work at their own paces. This assumes the ability to read the instructions; an area of difficulty for the dyslexic. Since the terminology of mathematics and arithmetic is somewhat specific, many words used in these schemes are not likely to have been encountered in reading programmes or in everyday life. Sometimes seemingly familiar words are used that may have specific meaning in the context of a calculation or problem; the word "difference" for example, implies some aspect of subtraction when mentioned in a computational context. So even if the dyslexic is able to read the word, it does not follow that the interpretation thereof will be accurate. However, all these possible reasons for failure do not seem to explain adequately the range of achievements found amongst dyslexics - they do not all fail. Newton (1974a) suggests that some of them excel at geometry, an aspect of mathematics. This latter group seemed worthy of further investigation too.

The present studies were undertaken in order to investigate some of the apparent anomalies in mathematical performance brought to light in the course of clinical diagnosis of dyslexia. It was felt that none of the explanations reported in the relevant literature thus far, was sufficiently detailed to account for these observed differences. More substantive explanations were sought. To this end it was decided to review the literature concerning school mathematics, failure in school mathematics and dyslexia respectively, in a search for possible common underlying features (and differences), which might go some way in explaining the nature of the interaction between written language failure in dyslexic children and their performance in mathematics.

1.3 Hypothesis

The general hypothesis under investigation in this thesis is that a proportion of the dyslexic population does have specific difficulties with aspects of school mathematics.

More specific hypotheses about the nature of these difficulties are presented at the beginning of each study. The main ones are:-

1. That the correlation between measured intelligence and mathematical ability will be lower in dyslexics than in the general population, in which it is expected to be high.

2. That dyslexics will have more difficulty with arithmetic, because of its symbolic code and sequential demands, than with geometry in which they will score highly.

3. That errors made by dyslexics will reflect aspects of their cognitive style. For example, calculation errors are likely to point to sequencing difficulties and limited short-term memory.

1.4 Definition of Terms

Throughout this thesis, unless otherwise stated, when reference is made to "mathematics", it will imply "school mathematics" and should not be confused with mathematics as a scientific discipline, although it may be a forerunner thereof.

For the most part, "school mathematics" will refer to those topics included in the junior school curriculum, although aspects of the secondary school syllabus will be considered in Study 4.

Much of the literature reviewed in this thesis can be criticised on the grounds of lack of clear definition on terms. For example, in many studies, the terms "mathematics", "arithmetic" and "numeracy" are used interchangeably and since this does not always appear to be accurate, inferences are difficult to make and conclusions drawn may be tenuous. In the present thesis "arithmetic" and "numeracy" will be used interchangeably, to refer to the same area of study; that involving calculation. However, it must be stressed that arithmetic is only <u>one aspect</u> of school mathematics. School mathematics encompasses a number of other topics as well - geometry, relationships (bigger/smaller; more/less), measurement, etc.

"Math disability" will be used to describe difficulties related to all aspects of the school mathematics syllabus. People who have such problems are usually of at least average intelligence and have no other scholastic deficiences. They are designated "math-disabled".

"Dyscalculia" will be used to describe a specific difficulty with number and calculation, which is not related to intelligence or attainment in any other scholastic area.

"Dyscalculics" are individuals who exhibit this difficulty.

Unless otherwise stated, Dyscalculia and Math Disability will refer to seemingly congenital dysfunctions as opposed to acquired forms, which may occur as a result of brain trauma, in older children or adults.

"Intelligence" will refer specifically to measured intelligence as assessed using a standardised test.

Written language will refer specifically to English unless otherwise stated.

CHAPTER 2

2. SCHOOL MATHEMATICS

In this chapter, literature will be reviewed concerning the nature of mathematical ability in children and how this might relate to the material included in the school curriculum. Selected studies detailing the development of mathematical concepts will be examined. Other factors, thought to influence achievement, for example, attitudes and gender, will also be presented.

The literature on failure in mathematics will be discussed. Since there are so few studies in this area, it was hoped that the appraisal of research using "normal" subjects might offer some insights, useful in the understanding of individuals deficient in this domain.

THE NATURE OF SCHOOL MATHEMATICAL ABILITY

2.1 Definition

There are many definitions of mathematical ability, but none of them seems to adequately encapsulate the wide range of activities undertaken in the name of "mathematics". A combination of two proposals seems most appropriate to the present investigation, in that they are representative of the findings in this section:-
Hamley (1934) suggests that "mathematical ability is probably a compound of general intelligence, visual imagery, ability to perceive number and space configurations and to retain such configurations as mental patterns".
Erlwanger (1975) alludes to the cumulative aspect of its acquisition when he says that mathematics is "a developing conceptual system of interrelated ideas, beliefs, emotions and views that direct and control how the individual learns and what he understands about the relationship between things".

Instead of seeking an all-encompassing definition it may be more fruitful to examine, in more depth, the nature of school mathematical ability and the features which characterise it. Krutetskii (1976) has highlighted three relevant areas which he regards as warranting further investigation. They are:-

1. the specificity of mathematical ability;
2. the structure of this ability, if it exists;
3. possible topological differences.

Each aspect will be reviewed separately.

2.2 The Specificity of Mathematical Ability

The most important issue under consideration here is whether there is such a thing as "mathematical ability" or whether it is just "a qualitative specialisation of general mental processes ....." (Krutetskii, 1976). Framed in a different way, the question is "is the ability to master mathematics dependent on general intelligence or is it an independent aspect of cognitive functioning?"

Spearman (1927) contended that a general factor "g" was common to all aspects of cognitive functioning. Support for this view was provided by Wrigley (1958) who found that for 13-16 year old boys, intelligence was the single most important factor for success in mathematics, though it is not the only factor. Further support for this view will be provided in the next section. Jones (1977) maintains that, at school level, learning mathematics depends on general intelligence rather than special abilities.

2.3 The Structure of Mathematical Ability

The question posed here is "Is the ability to do mathematics a unitary ability or is it a cluster of different abilities subsumed under one title?" (Krutetskii, 1976).

Examination of the tasks undertaken in the school curriculum suggests that it is unlikely to be a single aptitude that is involved, but many different ones.

Support for this notion derives from studies employing factor analysis, a widely used technique for investigating questions of this nature. The main function of factor analysis is to reveal interdependencies and relationships between test scores, that are not immediately evident.

Wrigley (1958) found a clearly definable mathematics group factor, once the influence of "g" had been minimised. He claimed that the different branches of mathematics are linked together more closely than would be the case if only a general factor were in operation. Verbal (v), Spatial (k) and Numerical (N) group factors were isolated.

Performance in geometry was associated with spatial ability, as measured by the spatial factor. Aptitude in arithmetic (especially mechanical) and, to a lesser extent, algebra, were dependent on numerical ability. Wrigley (op.cit) reports that the factor pattern did not vary with different types of schooling (grammar school or technical college), though Vernon (1950) pointed out that components of mathematical ability do change with increasing age. By High School, though, this Investigator found that non-verbal intelligence "g" and the spatial tests (k) tended to link up with mathematical ability, with the numerical factor (N) becoming detached from the Verbal cluster (v). McCallum et al. (1979), extending the work of Barakat (1951) and Wrigley (1958), agree with Vernon (1950) and Werdelin (1958) that the most important single component for the understanding of mathematical and arithmetical processes is a g/k factor. This factor is said to remain stable over four years of secondary schooling and shows little relationship to language.

In summary, it appears that, in combination with a factor of intellectual potential, the spatial factor has the strongest claim as the essential component of mathematical aptitude. The importance of the numerical factor in junior school mathematics must not be forgotten, though. Caution is advocated when interpreting factorial studies, because the use of "pure" tests in these analyses may conceal the important interrelating processes among them. With this in mind, the relationship between the numerical, spatial and verbal factors and school topics will be discussed.

2.4 Arithmetic

Arithmetic is undoubtedly an important aspect of school mathematics and is related to the factorial "N", discussed above. Rappaport (1966) contends that "Mathematics is the Queen of Sciences and Arithmetic the Queen of Mathematics". Arithmetic is primarily concerned with the relationship between events, which is expressed though a representational system - numbers. Natorp (1910) presented a theory of calculation which still seems relevant today. He believed that counting and calculation have a fundamental starting point - zero. He said that nought was important as a point of reference and that progression from the point contained elements of direction. Calculation involved elements of construction, for example, 2 + 3, that required analysis (keeping count) and synthesis (adding on). Zero was still thought to be fundamental, even if it was not mentioned.

In Reception classes, children are taught to count and to associate each number with a visual representation (see Fletcher et al., 1970). Once numbers have been mastered, algorithms (rules for calculation) are taught. From then on the manipulation of digits forms the basis of arithmetic (Findlay, 1979).

Mental Arithmetic plays a part in these processes. Groen & Parkman (1972) suggest that there are two strategies used in mental arithmetic. The Reproductive Strategy leads to a response based on a direct associational process. For example, when adding 2 and 3, the approach would be to add 1 + 1 + 1. These researchers maintain that this strategy develops with experience into a Reconstructive Strategy. In this form, responses are generated on the basis of stored algorithms; for example, knowledge of tables. Further mention of the role of memory in mathematical performance will be delayed until Chapter 5.

The achievement of numeracy (at least), by all school leavers is a primary aim of teachers. However, the large number of innumerate adolescents seeking employment is testimony to the fact that this goal is not being achieved. Numeracy, in this context, is the capacity for coping numerically with everyday events, like working out the milk bill. Even so, despite its importance and despite the number of individuals failing in this area, little research has been carried out (Hammel & Bartel, 1975*; National Council of Teachers in Mathematics, 1972; Wallace & McLoughlin, 1975*; Bartel, 1975*). (*In Gonyo, 1976)

Otto et al. (1977) suggest that arithmetic has been neglected as a fruitful area of research because it has not been considered as important as reading, say. The research that has taken account of arithmetic is mainly concerned with acquisition of concepts and will be discussed in Chapter 2.10.

Choat (1977) found that number and geometry are interrelated in development. He concluded that, if geometrical development is retarded, the child may develop some number concepts if s/he has the ability to memorise, but that these would be restricted until further elaboration of geometrical concepts could contribute the necessary understanding.

2.5 Spatial Ability

As has been seen from the factorial studies,a spatial factor "k" has emerged as an important aspect of mathematical ability; a finding which is confirmed by McCallum et al. (1979) and Frostig & Maslow (1973). However, its exact role is still unclear, as are its defining characteristics (McDaniel & Guay, 1976). The latter suggest that "the perception of spatial relationships may be the perceptual ability of most consequences in mathematical learning"

Moses (1977) found that individuals with high spatial ability are better at a range of mathematical problems than individuals with low spatial scores. She maintains that the best predictor she used was the Figure Rotations Test.

Smith (1964):

> "We believe that the person with this (spatial) ability, will characteristically reason in a different manner from people who have little of these abilities. Their interests are likely to differ. They are likely to be more successful in solving certain problems. We believe that these abilities can be developed, that they are partially dependent upon innate characteristics, but that they often remain undeveloped because they are not appreciated. We believe that these abilities are much broader in scope than the limited criteria for which they have thus far been shown to be valid .....".

Bruner (1966) and Moses (1977) maintain that instruction in schools has been consistently analytical and that instruction in a spatial mode has been almost non-existent (Kane & Kane, 1979).

2.6 Spatial Visualisation is thought to be the ability to comprehend two- and three-dimensional visual patterns and to mentally manipulate them in space (Gonyo, 1976). This includes recognition of spatial relationships (rotations, symmetry and part/whole analysis) but emphasises construction, manipulation and dissection of images. (See Handler, 1976 for full review). Smith (1964) mentions that this skill is an important part of spatial ability, and problem solving, a view reinforced by many researchers (eg. Kolmogorov, 1959). Handler (1976) presents contradictory evidence to the latter aspect. She found that the spatial problem solving techniques of good and poor visualisers respectively, did not differ significantly. Although the distinction between spatial visualisation and pictorial representation is appreciated, they appear to be related in this particular context; thus Kulm et al.'s finding (1972) that visual presentation of a problem did not facilitate better problem solving, is of note.

Krutetskii (1976) found that superior geometric problem solvers reported a high degree of visuality, which was often not reflected in the working out on paper.

2.7 Geometry

Geometry, related to the factor "k" (Vernon, 1950), when freed of its restricted Euclidean connotation, is the name given to the processes whereby people make sense of space, shape and movement (Glenn, 1979). He stresses that, for the child between five and nine years of age, the fundamental objects of geometry are ordinary three-dimensional (3D) objects, not points, lines and triangles. The school's job is to help the child to make the transition from this practical 3D world to a more organised 2D one, consisting of abstractions - letters, numbers, diagrams, etc.

In primary school, spatial skill seems to be required for the understanding of shapes, symmetry & concepts such as bigger/smaller, more/less. In secondary school, it has been assumed, until recently, that geometry is dependent on spatial analysis (see Franco & Sperry, 1977).

The ontogenetic development of a child's geometrical thought is said to pass through three stages - topological, projective and finally Euclidian, which is said to be mastered at the age of nine or ten (Piaget et al., 1960, 1967; Dodwell, 1968, 1971). Lovell (1962) says that this sequence of stages is not always confirmed. It does seem ironic though that for Piaget, Euclidian geometric topics represent the final stage of development, when in the classroom they often represent the child's introduction to geometry.

Choat (1977) found that numerical development is impaired without a concomitant development of geometrical thinking. This being the case Corso (1977) suggests the introduction of geometry into kindergarten. Rozin (1964) found that the interaction between visuo-spatial and verbal variables were basic to the solution of geometric problems.

2.8 The Verbal Factor

The factorial results discussed, indicated that verbal facility is not necessarily needed in mathematical thinking. In fact, Vernon (1950) suggests that, in the case of numerical and mathematical tests, mathematical reasoning may be hindered when accompanied by language and verbalisation. Wrigley (1958) says there is a possibility that this lack of relationship may be due to the fact that the mathematical tests included a minimum of words.

Whether or not the negative relationship between these variables is supported in further studies, the fact remains that, in schools, mathematics is taught, and the methods used, by and large, are verbal. Thus it seems unlikely that in the school situation at least, the influence of verbal mediation can be ignored.

2.9 Typological Differences in Mathematical Ability

The question begged here is whether there are different types of mathematical ability. History suggests that there are different types of mathematical thinkers; those who seem to adopt a holistic, spatial approach and those who are more linear and sequentially analytical.

Krutetskii (1976) differentiates three types of gifted students:-

1. The analytic type, who attempts to translate the visual image onto an abstract level. This individual finds analysis of a concept an easier task than analysis of geometric diagrams. Any problems involving mental manipulation of figures might be solved by a capable student of the analytic type in a logical/analytical way.

2. The geometric type often lets the visual image replace logical reasoning. Usually when memorising verbal-logical material, s/he attempts to generalise the visual image and keeps this generalisation in memory. Moreover, s/he remembers not the optical image, but the relationship between the parts of the drawing.

3. The harmonic type who possesses equally well-developed verbal-logical and visual-pictorial components. The former are usually slightly stronger.

Satterly (1976) found that 7-11 year olds who showed a preference for an analytic conceptual style scored significantly higher in mechanical arithmetic, than children who did not approach examples in this way.

If there are different types of mathematical thinkers, as these studies suggest, then this may have implications for children who are failing, as well as the high achievers. There is the possibility that a math-disabled person may be taught to apply another strategy if the one s/he is using is not successful. This may relate to specific tasks within the curriculum, rather than to mathematics ability in general.

Investigation of whether dyslexics who are successful or unsuccessful in mathematics respectively, adopt different strategies, will be attempted in a superficial manner, by questioning them as to their methods of solution.

2.10 Acquisition of Mathematical Concepts

The literature detailing the development of mathematical concepts in children is extensive and has been well-catalogued elsewhere (eg. Lovell, 1962; Krutetskii, 1976). Consequently, the studies reported below are only those that may relate directly to other topics to be discussed in this thesis.

Cognitive Developmental Theory

The most influential theory of the acquisition of mathematical concepts is that espoused by Piaget & his co-workers (e.g 1948, 1968, 1969) as part of his general theory of intellectual growth. His ideas have generated much research (eg. Lovell, 1962; Ginsberg & Opper, 1969; Ginsberg, 1975). Piaget (1950) maintained that a combination of motivation and interaction with the environment resulted in an almost spontaneous appreciation of concepts, to which teaching contributed little. Skemp (1972) suggests that a concept is an awareness of something in common between experiences. All aspects of mathematical development are believed to proceed through three well-defined and easily identifiable stages. Taking number concepts as an example, the development would follow in these stages:-

Stage I - The Stage of Global Comparisons/Pre-operational Stage

Children below the age of six years are believed to have a vague notion of "number", which is entirely dependent on configuration. If the configuration changes, the child thinks that the number is different. For example, in one of Piaget's classical experiments (1952) a row of red chips is placed in front of a five-year old child and she is asked to make a similar one. A child of this age typically concentrates on the length of the row, rather than on the number of chips it comprises. So, at this time, the child's concept of number is assumed to be based on perceptual rather than cognitive cues.

Stage II - The Concrete Operational Stage is characterised by the realisation that judgements of quantity and number cannot be made simply in terms of perceived attributes. The child begins to grasp the fact that attributes of quantity and number may remain invariant under different perceptual transformations. Although this realisation is emerging, mistakes in judgement are still present. Piaget (1952) demonstrated this with a six-year old who was able to match his blue chips to Piaget's red ones, in one-to-one correspondence. Although he had the correct number and agreed that this was the same as the investigator's, when one row of chips was extended, the subject maintained there were more in the longer row. So, at this stage, perceptual clues are still exerting some influence.

Stage III - The Stage of Formal Operations in which judgements about number are no longer influenced by perceptual cues like shape, colour or size - the ability to conserve has emerged (Gelman, 1969). Children from about the age of seven years are able to abstract the quality of number (for example, "eightness") and can maintain the concept even though perceptual cues may vary (Pace, 1975).

A concept said to be necessary for the further cognitive development of mathematical thinking emerges at this time; that of reversibility (Copeland, 1970). The qualitative difference between adult and child thought is this ability to decompose problems into component parts and then resynthesize them,to arrive at a solution (Piaget, 1952).
Lovell (1962)maintains that this awareness of the permanent possibility of returning in thought and/or action to one's starting point, is a fundamental skill that underlies all mathematical and logical (internally consistent) thinking (Wong, 1977).

In summary, as the child passes through these stages s/he gains an understanding of number and the principles of conservation, classification and counting. Johnson & Myklebust (1967), based on the work of McSwain (1958) suggest that the thought processes evolve first from direct contact with objects, then to mental perceptions, name, and finally number symbols. These writers add:-

> "A child first assimilates and integrates non-verbal experiences, then he learns to associate numerical symbols with experiences and finally expresses ideas of quantity, space and order using the language of mathematics."

Conservation is a key concept in Piagetian theory. Ginsburg (1975) reports that counting appears to be irrelevant for conservation, although Fincham & Meltzer (1976) found that it was correlated in dyslexic children.

Woodward (1977) studying six-year olds found that conservation of number was the only statistically significant contributor to a child's ability to complete single digit number sentences. Conservation of substance did not appear to be a good predictor of arithmetical ability. Woodward suggests that conservation of number seems to be more significantly related to first grade success in arithemtic than reversibility in general.

Küchemann's results (1978) suggest that the majority of secondary school age children are still at the concrete operational stage. Skemp's warning (1970) may be relevant here. He says that, since the higher order concepts in mathematics are particularly abstract, there is the danger that the child will learn the symbols without the underlying meaning. Support for this concern is offered by Bartel (1975) who found children with virtually no understanding of the principles of arithmetic, hiding behind a facade of rote learning ability in computation.

Lunzer et al. (1976a) have found in their longitudinal study, that the primary school child views symbols as a convenient means of reporting a situation or activity, but only as a means of representing a physical situation, not in terms of the relationship between symbols.

Exponents of Piagetian principles generally assume that an idea of cardinal number (awareness of the constant difference between numerals one, two, three, etc.) develops ahead of ordinal number (classification by order - first, second, etc.) (Henty, 1973). This view is challenged by Brainerd (1973) who maintains that the appreciation of ordinal numbers precedes the development of the cardinal number concept. He maintains that schools are teaching concepts in the wrong order.

Positive support for Piagetian ideas is provided by Dienes (1959) and Zammarelli & Bolton (1977) respectively, who have found that the growth of concepts can be encouraged by teaching and play.

Donaldson (1978) and Fluck & Hewison (1979) suggest that the traditional Piagetian paradigm underestimates children's capacities. They say that a large majority of five-year olds would appear to have developed the logical competence necessary for conservation, but that testing prevents them from showing it. The child is said to be confused by the experimenter's intentions; the experimenter arranges the row of dots behaviourally referring to length, then linguistically refers to number. Scandura & McGee (1972) agree that poor performance on Piagetian conservation tasks is as much due to the lack of the necessary interpretive linguistic abilities as lack of reasoning ability.

Geometry

Geometry, because of its spatial components (Wrigley, 1958) and primarily iconic format (Hunter, 1976) has traditionally been attributed to right hemisphere RH processing.

Franco & Sperry (1977) examined this largely anecdotally based assumption in more detail, using subjects with complete commissurotomies or dominant hemispherectomies. They investigated hemispheric specialisation for the intuitive processing of geometrical relations, using four different types of geometry - Euclidian, affine, projective, and topological (see Figure 1 for examples). These vary characteristically in the number of defining spatial constraints to which each is subject; the greatest number being present in Euclidian forms, with progressively fewer in the other three respectively. The experimental task required intuitive apprehension of geometrical relations, without requiring any formal background knowledge, on the part of the subject.

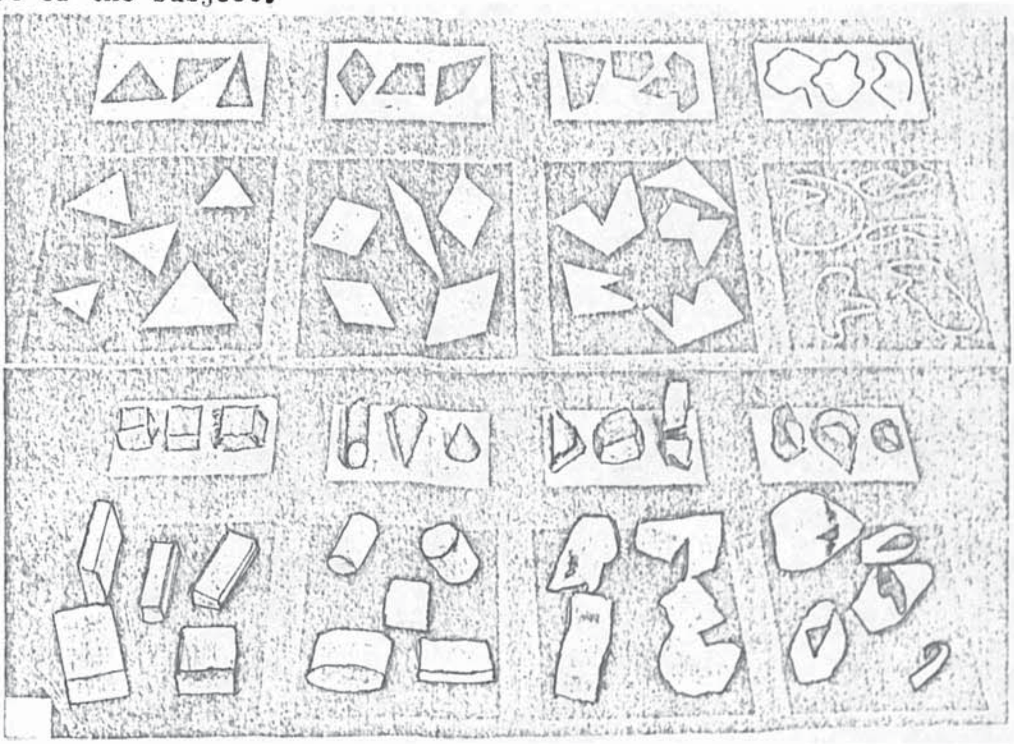


FIG.1: Examples from Franco & Sperry (1977) study. From left to right, examples of Euclidean, affine, projective and topological tasks in 2D (top) and 3D (bottom).

Choat (1977) carried out a longitudinal study of children between the ages of three and seven years. His findings suggested that the development of mathematical ability in children appeared to be partially ordered rather than linear.

It seemed that development of lower order concepts led the individual to reflect on existing knowledge and reorganise related higher order concepts accordingly.

2.11 Attitudes and Sex Differences

Success in mathematics is dependent on a combination of factors and cannot be determined solely by the presence or absence of measured ability (Howlett, 1980). Two such factors, thought to play an important part in school mathematics achievement, are attitudes and gender.

Attitudes are thoughts and feelings about activities and are considered to be an important feature of learning (APU, 1980).

Table 1 lists the findings of studies of the relationship between attitudes and achievement, and self concept and achievement, respectively. Most studies support the view that a positive attitude and satisfactory self-concept are associated with competence at least, and perhaps excellence. Data that do not support this belief are also presented.

Attitudes to mathematics seem to be subject to influence from a number of quarters - society in general, home environment, teachers and school, and, as can be seen from Table 2 , often reflect attitudes about what activities are "appropriate" for males and females respectively. The findings from these studies and those of Table 3, suggest that to a large extent, general attitudes may be contributing to many of the measured sex differences in performance in mathematics.

There seems to be little agreement as to whether "real" sex differences do exist, in this field of study and, if they do, what form they take. If attainment per se is being examined, boys are found to score more highly in many investigations. But, if attempts are made to ascribe these differences to innate ability or superior cognitive specialisation the issues raised are more complex.

TABLE 1. ATTITUDES AND ACHIEVEMENTS

Aiken (1970)	reciprocal relationship
Mager (1968) Brown (1953)	positive relationship between achievement and improved performance in mathematics
Shepps & Shepps (1971)	positive correlation - stronger for boys than girls
Assessment Performance Unit (1980)	attitudes are an important feature of learning
Self Concept and Achievement in Mathematics (See Gordon (1977) for full review)	
Gordon (1977)	review of literature - equivocal results
Enwisle & Mayduck (1973)	positive relationship
Caplin (1969) Hart (1976) Binder et al. (1976) Loguidice (1970)	satisfactory self-esteem is correlated with success in mathematics
Bassham et al. (1964)	if child expects to fail, he works under a serious disadvantage
Katzenmeyer & Stenner (1976)	*complex-self-concept differs for race, IQ.* and scholastic attainment
Marx & Winne (1975)	weak relationship found. Self-concept probably does not lead directly to differences in performance

TABLE 2 FACTORS AFFECTING ATTITUDES

SOCIETAL INFLUENCES		
Michaels Hart	(1978) (1976)	need to strengthen mathematics performance generally.
Aiken Tobias	(1970) (1976)	societal change in attitude to mathematics is needed.
Norman George McAfee Swett	(1977) (1976) (1977) (1978)	our culture believes that mathematics is a male domain.
Ernest	(1976)	role expectation and <u>not</u> mathematical ability leads to higher achievement of men, in this field.
Fennema	(1974)	Play influences development of spatial ability, which develops more in boys, who use building blocks and constructional toys.
Maccoby & Jacklin	(1974)	Sex roles favour independence of thought in boys - superior problem solving ability.
Fennema & Sherman	(1977)	Socio-cultural factors are correlates of mathematics achievement and spatial visualisation.
Sells	(1973)	Mathematics is the critical filter in society. There are less women in engineering and physics in which mathematics is important. Therefore there are fewer female role models, therefore there are fewer women taking mathematics on into science and engineering.
HOME ENVIRONMENT		
Stamp	(1979)	Importance of parental influence
Iams	(1977)	Rationalisation for dislike of mathematics often stems from parental statements like "I don't like maths" and avoidance from involvement - "We did it differently".
Bruner	(1966)	Development of compliance in home leads to a female disadvantage when attempting more complex mathematics.
Maccoby Bernstein	(1966) (1976)	Identification with a male figure (usually father) influences attitudes to mathematics.

Table 2 (cont)

SCHOOL ENVIRONMENT		
Aiken	(1977)	"The classroom teacher exerts a powerful effect on students' attitudes towards mathematics, their ability to express themselves in "mathese" and the motivation and success of their creative efforts in this subject."
Stern Naiman Hart	(1977) (1974) (1976)	Teachers have an important role in improving a child's attitude to arithmetic and mathematics.
Fennema	(1974)	Girls are better at use of symbols. Teachers may move them from concrete to abstract faster than boys. Therefore girls may be deprived of the necessary concrete representations that develop spatial ability.
Department of Education & Science	(1975)	Girls much less likely to choose mathematics at A level in a co-educational school.
Ollerenshaw & Clarke	(1978)	Schools have important role in influencing attitudes to mathematics.
Stevens	(1981)	Tameside Borough has appointed two teachers to tackle the problem of insufficient girls taking courses in mathematics, physics and chemistry.
Gessner reports findings of Lazarus Howson Ernest Haan	(1977) (1974) (1973) (1976) (1961)	Up to 40% of teachers had indifferent or negative attitudes to mathematics.
Gessner	(1977)	**Teacher attitudes towards mathematics is determined significantly by her attitude to women in general (using regression model). More positive view of women will lead to a more positive attitude to mathematics.**

TABLE 3. SEX DIFFERENCES (See also Societal, Home and School Influences)

Maccoby & Jacklin Bernstein	(1974) (1976)	different results depending on populations and measures used.
Fennema McAfee Aiken	(1974) (1977) (1970)	gap in performance first appears at about eleven years of age.
Berglund & Hilton	(1974)	longitudinal study - sex differences in quantitative ability do not appear until adolescence.
Johnson & Myklebust	(1974)	no significant differences in young children in such sex typed aptitudes as mathematical reasoning and spatial relations.
Muscio Jarvis	(1962) (1964)	slight male superiority in arithmetical reasoning after age 12.
Wo zencroft	(1963)	female superiority in arithmetic - 8 and 11 year olds.
Cranford	(1976)	no differences (10-12 year olds) using computer assisted instruction in mathematics.
Stent	(1977)	After age 12, poor performance on a mathematics test was attributed by boys, to insufficient work and by girls to lack of ability.
Norman	(1977)	males superior in arithmetic reasoning (adults)
Hutt	(1972)	innate differences, that favour boys' superiority in mathematics.
Stanes	(1973)	boys are more analytic (6 years old)
Satterly	(1968)	boys more analytic (9-11 year olds) but not at 7-9 years.
Roach Robinson & Gray	(1979) (1974)	Male superiority for conceptual analytic ability (11-12 year olds)
Hawkes reports study by Benbow & Stanley (1980)	(1980)	Boys superior on mathematical tests - (gifted high school students) Equivalent results for males and females on verbal tests.

TABLE 3 CONT'D. SEX DIFFERENCES

Robitaille	(1976)	Females superior in mathematics achievement (9-16 year olds)
Boles	(1980)	Literature on sex differences in spatial ability is beset with problem
McDaniel & Guay	(1976)	Sex differences in favour of boys only for higher level spatial abilities
Isaacs	(1974)	No sex differences amongst Jamaican GCE mathematics candidates.
Johnson & Harley	(1980)	University students - no sex differences for spatial tasks

The influence of possible neurological determinants of mathematical ability are difficult to assess. Rudel (1976) reports findings for differential hemispheric development in boys, that may favour the development of superior spatial abilities. Buffery & Gray (1972) proposed that spatial skills were bilaterally represented in boys and unilaterally localised (in the right hemisphere) in girls. However, Bagnara et al. (1980) do not support this hypothesis. Since sex differences in performance, by and large, do not emerge until the age of twelve, the contribution of neurological differences over and above societal influences would appear to be difficult to detect. Tobias & Weissbrod (1980) report that Sherman's continuing work on sex-related cognitive differences has so far revealed no evidence that supports a biological basis for sex differences in mathematical performance.

In summary, the literature reviewed in this section reflects a lack of consistency in findings, based on conflicting evidence. Further work is needed to isolate the environmental effects before ascriptions of superiority by gender can be made. One general finding, on which there is agreement, is that whatever sex difference there might be for different types of mathematical ability, they do not emerge before the age of 12 years. This has bearing on the selection of samples of children in the present research.

2.12 Summary

It appears that the range of activities, undertaken in the name of school mathematics is extremely varied. All the topics appear to depend to some extent, on adequate intellectual potential, but over and above this, numerical, verbal and spatial factors have been isolated, with the spatial factor being most influential as task complexity increases. It was suggested that the acquisition of relevant concepts developed through stages, similar to those proposed by Piaget (1950), though some modifications were discussed. The effect of attitudes was noted, especially as they are thought to relate to differential attainments in males and females, which result in measurable sex differences in performance.

The literature on disability in mathematics will now be presented.

CHAPTER 3

3.1 Mathematics Disability

School Mathematics in Britain has been the focus of a number of projects aimed at devising more efficient and effective teaching schemes (Nuffield, 1970,1972; Kent, 1977). (See Larcombe, 1977). However, they fall uniformly short in providing for the possibility (and reality) of children, who despite conventional teaching, fail in this particular scholastic area. For the most part, teachers of "non-achievers" in mathematics are advised to provide more concrete aids in the hope that, with sufficient practice and manipulation of objects, the child will move from the concrete to the formal operations stage - a developmental sequence postulated by Piaget (1950) (see Chapter 2.10). This is the approach favoured for the teaching of mentally retarded children (Kiraly & Morishima, 1974a+b)

The idea that there may be individuals with a specific difficulty with school mathematics has been given little airing in the U.K. It seems likely that this lack of attention is a result of the social acceptability of failure in mathematics (Cohn, 1968) and the fact that, until recently, inability to calculate (one facet of mathematics) has not been seen as socially disabling as literacy failure, for example. People will say openly (and often almost proudly) "Oh, I've never had a head for maths", whereas it is exceptionally rare to hear boasts of "I can't read or spell".

In the USA, failure in mathematics has been included under the umbrella of "Learning Disabilities" (Ahn, 1977) and reference is made to the "math-disabled" individual. However, despite recognition of the aforementioned category, reviews of the literature (Austin, 1977; Weinstein, 1978) revealed few in-depth studies of the nature or aetiology of this difficulty, relative to the number of descriptive articles and remedial recommendations.

In the literature that does exist, there is little agreement about descriptive terminology; some writers speak of "dyscalculia" in connection with any type of failure in mathematics (eg. Kosc, 1970a), others limit its use to difficulties in arithmetic and calculation. In this thesis, the terms "math disability" and "math-disabled" will be borrowed from the American texts, to refer to difficulties with all aspects of mathematics. "Dyscalculia" will be used specifically when discussing difficulties with number and calculation that are not associated with other learning problems.

In the next section, research will be presented firstly on math disability in general. It will also include studies of failure in arithmetic which the respective authors do not classify specifically as "dyscalculia".

3.2 Studies of Math Disability

Johnson & Myklebust (1967) report two types of mathematical difficulties. The first type is thought to be secondary to an auditory receptive language disorder. Failure in mathematics in these cases is ascribed to the individual's inability to calculate because s/he has difficulty understanding the teacher's instructions and oral discussions of principles. The second kind of math disability, proposed by these researchers, is "Dyscalculia" which will be discussed in the next section.

Gore (1979) reports that math-disabled individuals, in his samples, were deficient in visual-spatial skills and performed more poorly on intra-modal visual-spatial tasks than a reading disabled group and a non-academically impaired group. Gonyo (1976) found visual-spatial discrimination to be positively related to achievement in arithmetic.

Rourke & Findlayson (1978) studied three groups of 9-14 year olds, equated for age and Full Scale IQ (WISC). Group 1 was performing at below expected grade level in reading, spelling and arithmetic. Group 2 subjects had below expected reading and spelling scores and a relatively higher arithmetic score, though the latter was still below grade level. Group 3 were reading and spelling at grade level but were poor in arithmetic.

The performances of Groups 1 and 2 were superior to those of Group 3 on measures of visual-perceptual and visual-spatial tasks. Group 3 were superior to Groups 1 and 2 on measures of verbal and auditory perceptual tasks. Rourke & Findlayson (1978) suggest that the findings are indicative of a possible Right Hemisphere (RH) dysfunction in subjects in Group 3. Groups 1 and 2 performances are suggestive of Left Hemisphere (LH) dysfunction.

An important finding was that groups who had been equated for deficient arithmetic performance (Groups 2 and 3) exhibited vastly different performances in verbal and visual-spatial tasks. These differences, say these researchers, are clearly related to their patterns of reading, spelling and arithmetic rather than their level of performance in arithmetic per se.

As a sequel to Rourke & Findlayson's (1978) study, Rourke & Strang (1978), using the same groups, found no significant differences in performance on simple motor measures, but the individuals in Group 3 (relatively good reading and spelling, poor arithmetic) were markedly impaired on more complex psychomotor measures and on a composite tactile-perceptual index.

Rourke & Findlayson (op.cit.) and Rourke & Strang (op.cit.) say that there is some evidence consistent with the view that Group 3 was suffering the adverse effects of a relatively dysfunctioning RH. LH performance was found to be satisfactory. Group 2 (poor reading and spelling, relatively good arithmetic) reflected the opposite pattern of hemispheric integrity - an LH dysfunction, with the RH being unaffected.

Rourke & Strang (op.cit.) found no statistical differences between these groups for simple tasks; differences were reflected when the requirements were more involved. This is said, by these researchers, to reinforce the views of Reitan (1966) and Rourke (1975, 1976) that "performance on heterogeneous (complex) tasks is more likely to reflect meaningful aspects of brain behaviour among clinical groups".

Another important finding from these studies is the difference in performance between two groups, equated for level of performance in arithmetical calculation. Had Groups 2 and 3 been combined to form a single group, retarded in arithmetic, these differences may have been averaged out.

Ginsburg (1978) reflects that in general it could be defects in the system of schooling itself which have contributed heavily to current educational problems, like failure in school mathematics. He suggests that schools have failed to exploit pupils' abilities in favour of concentrating on their deficits.

Emotional Factors

Evidence for emotional factors contributing to failure in arithmetic is provided by Rourke (1981). Rourke reports that this group are poor on performance tasks, but may excel verbally. Typically, parental reports mention that the child is clumsy, aloof and has no sense of humour. Their sensory motor development appears to have been impaired. Their social learning is poor; they have difficulty interpreting facial expressions. In adults, lack of intuition is often evident. Rourke (op.cit.) maintains that although these individuals talk and read well, they lack conceptual understanding.

Connolly (1971) uses concepts of Pavlovian and instrumental conditioning in explaining failure in arithmetic. When the child says "I hate arithmetic!" conditioning takes place, with the arithmetic lesson as the conditioned stimulus and anger as the conditioned response. New responses, such as inattention and misbehaviour become associated with arithmetic, leading to further failure. The interaction becomes circular.

Failure in arithmetic (unconditioned stimulus)	→	discouragement and anger (unconditioned response)
Arithmetic Class (conditioned stimulus)	←	Inattention and misbehaviour (conditioned response)

Conditioning of this type often leads to a Broad Block (a negative attitudinal set) on doing anything involving numbers or calculation (Weinstein, 1978). The Broad Block theory predicts that dyscalculics will exhibit many non-systematic errors which produce low levels of performance across all tasks in the mathematics curriculum. The child will not necessarily make the same errors when faced with similar computational problems (Cox, 1975).

Emotional factors as a primary cause of arithmetical difficulties were not found in the present studies. However, during clinical interviews, the Writer has found a number of adults whose dislike of anything associated with mathematics and number, bordered on the phobic. Reactions of this type were consistent with the Broad Block Theory. Characteristically, these individuals report that they had not understood particular topics at school, but had been loath to ask for repeated explanations. New knowledge had been added to rocky foundations and feelings of insecurity are said to have grown. At the time of interview, the mention of the simplest calculation elicited marked negative statements, increased muscular tension (evidenced in pen-grip) and anxiety. When presented with a fairly lengthy computation (for example, 245 x 87) most of those interviewed were able to successfully complete the calculation if they were prompted as they worked. Prompts were as non-directive as possible - "What do you think you do next?" "What is the next step?" etc.

Reactions of this type were not found in younger subjects in these studies. It seems likely that severe anxiety about arithmetic and other aspects of mathematics may be cumulative and only manifest itself after some years of failure, though the possibility of it developing in earlier years is not disputed.

3.3 Dyscalculia

Developmental Dyscalculia is "a disorder of the abilities for dealing with numbers and calculating that is present at an early age and is not accompanied by a concurrent disorder of general mental functions." (Weinstein, 1980) Slade & Russell (1971) make the distinction between developmental and acquired dyscalculia and acalculia when stating that for diagnosis of the former there must be no indicating that the individual's arithmetical ability was formerly at a higher level and subsequently deteriorated. Acquired dyscalculia has been discussed in the medical literature in cases of patients who, through head injuries, have lost the ability to deal with number. Findings concerning acquired dyscalculia and acalculia will be presented in Sections 3 and 6 of this Chapter.

Weinstein (1980) contends that:

> "It is taken for granted that some children will do poorly in arithmetic owing to inadequate instruction, insufficient motivation, or general mental retardation. However, the notion that there are well-motivated children who have normal intelligence and are in good schools, yet evidence disability in arithmetic has gone nearly unrecognised until recently among psychologists and educators."

Kosc (1974) reinforces this view and adds that this is the case, despite the fact that dyscalculia is a nervous system dysfunction which occurs at least as frequently as other disorders, like dyslexia and dysgraphia.

Weinstein's review (1978) of the psychological literature produced only one systematic, empirical investigation which provides evidence for the existence of developmental dyscalculia - that of Kosc (op.cit.). This study, whilst making an important contribution, is limited by the questionable purity of the sample studied; no control seemed to have been made for possible inclusion of dyslexics. As such his assertion that 6% of the general population could be dyscalculic, may be an overestimate. Kosc found that 24 of the 375 ten-year olds he tested (all of whom were in the average range of intelligence) satisfied his criteria for being designated "developmentally dyscalculic", that is, they all exhibited "mathematical" (sic) difficulties presumed to be of a congenital nature without simultaneously being generally retarded.

Kosc reinforces the view that mathematical ability is not simple and compact. He maintains that, in the same way that specific abilities appear to be unevenly developed in "normal" individuals, not all arithmetical functions are equally affected in developmental dyscalculics.

Kosc offers a categorisation of the various manifestations of dyscalculia, stressing that symptoms may occur in isolation or combination.

1. Verbal Dyscalculia - disturbed ability to designate mathematical terms and relations such as naming amounts and numbers of things, digits, numerals and operational symbols, etc.
2. Practognostic Dyscalculia - disturbance of mathematical manipulation with real or pictured objects or in comparing estimates of quantity.
3. Lexical Dyscalculia - disability in reading arithmetical symbols (digits and operational signs in most serious cases; multi-digit numbers, numbers written in horizontal rather than a vertical line, fractions and square roots, decimals, etc. in less serious cases); interchange of similar looking digits; reading of two-digit numbers as reversed.

4. <u>Graphical Dyscalculia</u> - disability in manipulating arithmetic symbols in writing; inability to write numerals as dictated, to write the words for numerals or to copy them.

5. <u>Ideognostic Dyscalculia</u> - disability in understanding "mathematical" ideas and relations and in doing "mental arithmetic" (ie. calculations without using pencil and paper or counting props).

6. <u>Operational Dyscalculia</u> - inability to perform arithmetical operations, for example, interchange of operations (+/x, -/÷) and calculation by counting on fingers where the task could be solved without counting fingers, by the average person).

Subtypes 3 and 4 are also referred to as "numerical dyslexia".

The present writer takes issue with Kosc's interchangeable use of the terms "mathematical" and "arithmetical", as if they represented the same processes. It must be stressed again that the latter is only an aspect of the former.

Johnson & Myklebust (1967) mention dyscalculia as the second type of difficulty allied to arithmetic. It is said to be associated with a neurological dysfunction which interferes with quantitative thinking and impairs the person's ability to understand mathematical principles. The symptoms are said to be related to deficient visual-spatial organisation, non-verbal integration and left/right confusion. In accord with some of Rourke's findings (op.cit.), low social maturity is thought to characterise dyscalculic individuals.

Johnson & Myklebust (op.cit.) describe such children as having difficulty learning to count, mastering cardinal and ordinal systems of number and understanding conservation of quantity. The ability to associate the appropriate auditory and visual symbols also appears to be impaired. These researchers and Rourke (1978a) maintain that pattern of high Verbal IQ - low Performance IQ (WISC) are often a feature of children whose arithmetic proficiency is impaired, relative to their reading and spelling attainments.

Weinstein (1978) found that at least 6% of a sample of 463 children screened seemed to evidence dyscalculia, without concomitant dyslexia. Twenty-nine 9-11 year olds were given a large battery of tests. Having analysed their errors she maintained that their performances supported a Development Lag explanation for dyscalculia in children. The Development Lag hypothesis posits that the difference between a child who is not having difficulty with arithmetic and a dyscalculic is simply due to the slower development of the cognitive structures underlying the acquisition of the arithmetical processes and concepts (Cohn, 1968). It is suggested that using this explanation, the pattern and kind of errors evidenced by dyscalculics should be similar to those of younger students, who do not have a learning problem; so that a 13-year old dyscalculic may perform in a manner more consistent with a nine-year old. Weinstein maintains that the above was true of her sample.

Weinstein rejects two other possible explanations for failure - the Broad Block Theory and the Specific Deficit Hypothesis. The former was eliminated because the subjects did not evidence any motivational difficulties nor did their errors reflect a random pattern of responses. The Specific Deficit Hypothesis was thought to be inappropriate because the level of functioning of the children in dyscalculic group was uniformly below grade level on all tasks, including geometry.

Weinstein proposes that Developmental Lag of this nature could be explained in terms of delay in the shift to hemispheric specialisation for the tasks under investigation. It is well established that before the age of five, the hemispheres of the brain are relatively non-specialised (Newton, 1974a; Rudel, 1976). With increasing maturation of the nervous system, there is a shift to an increased localisation of function. Piaget & Inhelder (1969) recognised that this neurological development was paralleling his stages of cognitive development, but admitted ignorance of the nature of the interaction.

Weinstein suggests that, given the characteristic errors of the dyscalculics and their delay in acquiring Piagetian concepts, a feasible explanation might be a lag in the development of adequate hemispheric specialisation for these tasks. She proposes that these children are still relying on visual cues and immature strategies characteristic of right hemisphere processing. Development of analytic (left hemisphere) skills has not been fully achieved. When forced, these children do shift to analytic processing. As an example, Weinstein cites that when a conservation task was presented and the materials covered before the child was able to respond, subsequent answers were analytic. When visual cues were available, the same child failed to conserve. Weinstein suggests that the fact that when a child is forced to analyse problems, s/he is able to do so, is indicative of potential, which is not yet realised fully, due to a developmental delay in neurological specialisation.

Fisk & Rourke (1978) compared the performances of groups of normal, learning disabled and mentally retarded subjects at different age levels. The Developmental Lag interpretation seemed to fit the performance patterns of mentally retarded children. However, the

Deficit interpretation was found to be more compatible with the performance patterns of learning disabled children.

3.4 Dyslexia and Dyscalculia

Klees (1976), Fincham & Meltzer (1976) and Fisk & Rourke (1978) all provide support for a clinically observed phenomenon which is, that a pupil may be able to conceptualise fully and understand what is being "taught", but be unable to work with concrete aids, or successfully carry out "externally" the required task. This particular phenomenon has, however, been found by the writer to be characteristic of a number of dyslexics' performances in arithmetic.

The following case study serves to illustrate this point:-
Dennis is an 18-year old dyslexic, who will sit his A-level examination in Mathematics this year. He is expected to gain a Grade A pass. However, Dennis is unable to perform arithmetical computations accurately. His scores on Maths Modules 2-5 (NFER, 1978) would identify him as an "average" 11-year old. There is no doubt that he understands fully the underlying concepts of number. He is also able to estimate answers - a good measure of numeracy, in the writer's view. Nevertheless, he makes numerous errors when doing simple sums. Dennis is fortunate in that his aptitude outshone his test attainments and he was recognised as an able student with a specific difficulty. Unfortunately, it seems likely that similarly able (but specifically disabled) students have not been as lucky and have been classified as generally disabled in mathematics and have been hindered by endless calculation exercises, in the hope that practice would improve their performance.

The Developmental Lag theory is not applicable in explaining these findings since performance in general is not delayed. The Specific Deficit hypothesis would appear to be more appropriate, since the poor performance of these individuals seems to be related specifically to one aspect of the task - the manipulation of written numbers and symbols. Further discussion of these explanations will be undertaken in the final chapter of this thesis. Since motivation is often high, the Broad Block theory cannot be invoked.

Kaliski (1967) offers an alternative view. Reviewing cases of dyslexic children, he describes these children as having difficulties with spatial relationships (up/down; left/right) and size relationships, which the writer maintains will cause problems when the child is learning number relation and concepts. Geschwind (1981, personal communication) emphasises that a distinction must be made between an individual being able to follow directional instructions, and a sense of direction. The former seems likely to be a labelling task - a difficulty for dyslexics (see Chapter 4). The latter, however, seems to require intuitive spatial ability, especially if the individual finds left/right discrimination difficult. The present writer feels that an inadequate sense of direction is more likely to be associated with number difficulties, if they are as spatially-dependent as seems to be the case from the evidence presented in Section 2 of this chapter.

Kaliski (op.cit.) also reflects that impulsivity allied to motor disinhibition, which he cites as a concomitant of dyslexia, is likely to interfere with the manipulation of objects and thereby affect mastery of mathematical concepts.

The present writer believes that motor disinhibition is not necessarily a feature of dyslexia. Additionally, Meltzer (1974) has found that dyslexic children do not appear to differ significantly from "normal" individuals on acquisition of mathematical conceptual thought.

It is a well-established fact that dyslexics have a cognitive dysfunction which influences the way they process written language (see Chapter 4). Given this knowledge and dyslexics' variable performances in school mathematics, it was decided to examine the neuropsychological literature to ascertain whether the specific areas of involvement coincide or are directly related.

It was also of interest to determine whether different aspects of mathematics are processed in different parts of the brain. For example, many researchers (eg. Wheatley & Wheatley, 197) assume that geometry is processed in the right hemisphere, but evidence to the contrary is also reported (Franco & Sperry, 1977). A survey of this nature has practical implications for the way mathematics is taught in schools.

Thirdly, it was hoped that information would be brought to light which might go some way to explaining why some dyslexics succeed in all aspects of mathematics, some fail and some perform at a level concomitant with age level and measured intellectual potential.

Finally, discussion will involve the idea of a Development Lag in acquisition of skills appropriate to school mathematics.

3.5 Neuropsychological Findings

The left and right hemispheres of the brain are specialised, to a large extent, for different activities (Sperry, 1968; Luria, 1966; Myslebodsky & Weiner, 1976; Jorgenson et al. 1980). Table 1 lists the findings concerning modes of operation and activities that seem to be implicated in mathematics.

Very broadly, the left hemisphere (LH) is predominantly involved in the mediation of language, symbolic thought, logical analysis and the processing of information serially and sequentially (Bogen & Gazzaniga, 1965; Ornstein, 1972; Nebes, 1974).

The right hemisphere (RH) appears to be less clearly demarcated and more diffuse in its cognitive style than the LH (Semmes et al., 1963). Unlike the LH, the RH processes information holistically and analogically perceiving relationships amongs apparently unrelated concepts and stimuli and is responsible for the synthesis thereof - a generalising ability (Rubenzer, 1979; Nebes, 1974). (See Kane & Kane, 1979; Rubenzer, 1979 for full reviews).

Much of the knowledge about hemispheric speculation has come from pathological studies of individuals who have sustained brain damage. As such, generalisations to the "normal" population must be made with caution. As can be seen from Table 1 findings are equivocal and vary according to the measures used.

Roach (1975) points out that there have been two differing positions with respect to the relationship between hemispheric dominance and arithmetical calculation. The traditional position has been that mathematical skills, like verbal skills, are mediated primarily by

TABLE 1: HEMISPHERIC SPECIALISATION FOR TASKS RELATED TO SCHOOL MATHEMATICS

Left Hemisphere			Right Hemisphere		
Task	Researcher		Task	Researcher	
Arithmetic/Calculation/ Computation	Elliot et al. Wheatley & Wheatley Roach & Rourke Dumas & Morgan Doyle et al. Butler & Glass Galin & Ornstein Lorens & Darrow	(1978) (1979) (1976) (1975) (1974) (1974) (1972) (1962)	Geometry Comparing complex geometric shapes/Geometric figures.	Wheatley & Wheatley Franco & Sperry Kane & Kane Kimura Barakat	(1979) (1977) (1979) (1973) (1951)
Mathematical reasoning	Sperry	(1975)	Problem solving (for which solution is not apparent)	Rubenzer	(1979)
Abstract mathematical computation	Kane & Kane	(1979)	Simple "mathematical" computation	Kreuter et al. Luria Levy-Agresti	(1973) (1970) (1968)
Algebra	Kane & Kane Barakat	(1979) (1951)			
Problem Arithmetic	Barakat	(1951)	Subtraction	Dimond & Beaumont	(1972)
Euclidian Geometry	Franco & Sperry	(1977)	Relative magnitude of digits	Katz	(1980)
			Interpreting iconic presentations of information (graphs, flow charts, etc.)	Rubenzer Wheatley & Wheatley	(1979) (1979)
			Relational Concepts	Ornstein	(1972)
			Positional nature of number	Singer & Low	(1933)
			Arrangement of numerals on a line	Singer & Low	(1933)

Table 1 (cont)

Linear	Ornstein	(1972)	Spatial/Global/Holistic	Dumas & Morgan Butler & Glass Dimond & Beaumont Galin Ornstein Lorens & Darrow	(1975) (1974) (1974) (1973) (1972) (1962)
Process of Information serially/sequentially	Bogen & Gazzaniga Ornstein Sperry	(1965) (1972) (1975)	Processing of stimuli in parallel analogical	Wheatley & Wheatley Nebes Salk Ornstein	(1979) (1974) (1973) (1972)
Sequencing	Nebes	(1974)	Visuo-Spatial	Kinsbourne & Smith Benton	(1974) (1969)
Analytic	Ornstein Sperry	(1972) (1975)	Spatial Orientation	Rubenzer	(1979)
Attention to detail	Wheatley & Wheatley	(1979)	Satisfied with approximate knowledge/diffuse	Prince Ornstein Semmes et al.	(1976) (1972) (1963)
Abstract thought	Bogen & Gazzaniga Levy et al.	(1965) (1972)	Concrete thought	Kane & Kane	(1979)
Symbolic thought	Ornstein	(1972)			
Inductive thought	Kane & Kane	(1979)	Divergent	Samples Kinsbourne & Smith	(1975) (1974)
Formal variables	Wheatley & Wheatley	(1979)	Synthetic - generalisational ability	Rubenzer Nebes Salk	(1979) (1974) (1973)
Rational/Logical	Kane & Kane Ornstein	(1979) (1972)	Intuitive	Kane & Kane Garrett Rennels	(1979) (1976) (1976)
Remembering names	Kane & Kane	(1979)			
Verbal/Language	Wheatley & Wheatley Sperry Ornstein Bogen & Gazzaniga	(1979) (1975) (1972) (1965)	Non-verbal	Buffery Sperry Molfese et al.	(1976) (1975) (1975)
Speech	Elliot et al.	(1978)			
Naming objects	Luria	(1970)	Deductive Thought	Kane & Kane	(1979)
Writing	Elliot et al.	(1978)	Spatial Words Pattern recognition and manipulation	Kane & Kane Dumas & Morgan	(1979) (1975)
Right side of body	Kimura	(1973)	Left side of body	Kimura	(1973)

the Left cerebral hemisphere (Head, 1926; Gazzaniga & Sperry, 1967). Opposing conclusions, based on different data, suggest that the RH may be the predominant influence (Johnson & Myklebust, 1967; Dimond & Beaumont, 1972).

Similar equivocal findings relate to language functions. Lenneberg, (1967) points out that the RH is not totally silent during language mediation and that before the age of above five years, language and other functions are more equally shared between the LH and RH, as seems to be the case for early "mathematical" thinking.

Studies of Hemispheric Mediation in Arithmetic using Normal Subjects

Investigations into hemispheric mediation in arithmetic for subjects without any signs of brain damage or dysfunction also produce equivocal results. Most of the studies can be criticised on methodological grounds.

Dimond & Beaumont (1971) used the Divided Visual Field (DVF) technique to investigate hemispheric preference for digit recognition. Digits appearing in the Right Visual Field (RVF) were found to be more accurately perceived. The limiting factors of this study are that responses were verbal, a mode which could bias results in favour of the LH. Also it is questionable how much simple digit recognition can tell about calculation.

Dimond & Beaumont (1974) using calculation as the experimental task, reported some evidence for RH superiority for subtraction, but not for addition, though there were no differences in latency measures (shorter latencies may have been suggestive of dominance).

Roach (1975) using three modes of data presentation (verbal, numerical and non-verbal (dots)), found an LH superiority for calculation for children without learning difficulties, with the dots condition being the strongest indicator. Using dyscalculic subjects (normal reading-low arithmetic scores) this RVF superiority was not found. Roach (op.cit.) states that, for these children, there is no evidence to suggest a dominant hemisphere for calculation.

Roach (1975) interprets this latter finding as analogous to Witelson's (1977) findings, in the area of reading retardation, ie. subjects indicated an absence of a dominant hemisphere for the task under investigation. This comparison may be too facile given Wilsher & Joffe's (1980) finding that much evidence for lack of hemisphere specialisation in dyslexics is open to an alternative interpretation. Wilsher & Joffe (op.cit) suggests that equivalent reading over both hemispheres, for a particular task does not necessarily mean that neither hemisphere is dominant for that task. It seems that one hemisphere is dominant but is dysfunctioning, thus producing "falsely" equivalent readings.

Simernitskaya et al. (1978) produce some evidence of LH superiority for number perception, but their dubious sampling procedure and interpretation of results, must cast doubt on the validity of their findings.

Katz (1980) has shed new light on this area. He argues that part of the inconsistency in findings could be due to the complexity of arithmetic computations which have been examined. He criticises Dimond & Beaumont's (1974) study because he says their findings could be due to the subsequent matching task, used in the response mode, rather than the computational process. Beaumont (1980, personal communication) accepts these criticisms as valid and says re-evaluation is necessary. Katz (1980) suggests that:

> "Conceivably different hemispheres might mediate the elementary processes involved in various arithmetic tasks, with an overall superiority for one of the hemispheres reflecting the relative contribution of some subset of processes."

Katz, in his study, attempted to eradicate some of the confounding factors in previous research. He used the DVF technique and a motor response mode to compare the subtractive difference between digits. A clear-cut RH superiority was observed for all pairs of digits. Decreases in reaction time were associated with larger subtractive differences between digits, a finding supported by Moyer & Landauer, 1976; Sekuler & Mierkiewicz (1977). Katz contends that subtraction first requires that people identify the larger or smaller digits in the problem. His findings support those of Dimond & Beaumont (1972) that the RH is responsible for this subprocess. Counting may be another subprocess involved.

Comparable results were not found in a comparable task using dots, instead of digits, suggesting that the use of digits per se is an important factor affecting measured visual field differences.

Katz (1981 - personal communication) has suggested that in the light of Pring's (1980) findings there may still be extensive methodological difficulties in studies of this type. Pring (op.cit.) reported differential field effects depending on exposure time and stimulus complexity (including the print size and type).

Thus, at this stage, it does not seem that DVF studies are sufficiently well controlled to allow inferences about arithmetic to be made from measured differences.

3.6 Findings from Pathological Studies

In this section, when reference is made to dyscalculia or acalculia (loss of ability to work with numbers), it will imply dysfunction acquired as a result of brain damage.

From Table 2 it can be seen that there is little agreement as to the area associated with dyscalculia. There are also some anomolous reports. For example, Cohn (1961) points out that Henschen (1926) maintained that the damage to the caudal part of the LH was responsible for the loss of ability to work with numbers, despite his own observations of dyscalculic patients with RH lesions.

Singer & Low (1933) report that acalculia (inability to perform simple arithmetical operations) may occur as a concomitant symptom of an aphasic syndrome or as the only symptom of a localised lesion. The behavioural features mentioned by these researchers are:-

1. Substitution of one operation for another, eg. 2 + 4 = 8.
2. Substitution of counting for calculation 5 + 7 =
   <u>S</u> says 7 + 1 = 8
3. Recapitulation of digits.
4. Reversal of digits.

Single digits can be read promptly. Two-digit numbers cause confusion on first reading, with a tendency to grasp digits on left of number.

The subjects do not grasp the notion of the positional nature of number (eg. 1 in 21 as being different from 1 in 142) but they could identify numbers in columns.

Arrangement of numbers on a line proved problematical but patients did not have an orientation problem - they could read maps.

TABLE 2: FINDINGS CONCERNING ACQUIRED DYSCALCULIA AND ACALCULIA

Hemisphere	Dysfunction	Researcher	
LH	Difficulty with addition and subtraction	Gazzaniga & Sperry Luria	(1967) (1946)
Caudal part of LH	Arithmetic disorders	Henshen	(1926)
Left angular gyrus	"Nominal" aphasia - confusion of numerical sequencing and comprehension of the meaning of number.	Head	(1926)
LH	Impaired use of mathematical symbols	Brain	(1962)
Left parietal lobe (with some occipital involvement)	Dyscalculia	Gerstmann Critchley Luria	(1957) (1953) (1973)
Left temporal lobe	Improved retention of numerical material	Milner	(1971)
RH	Severe calculation difficulties in 4 out of 8 patients	Cohn	(1961)
Right parietal lobe	Calculation deficit	Weisenberg & McBride McFie Hecaen	(1935) (1960) (1962)

Common to all acalculics was found to be the inability to proceed from a given point of reference and remain focussed on it during a calculation; a feature Natorp (1910) mentioned as a characteristic of competent calculative ability.

Singer & Low (op.cit.) also mention lack of appreciation of symmetry as a feature of dyscalculics'and acalculics' performances. Subjects could not compute 9 - 6 = , but carried out this operation, in error, when substituting subtraction for addition: 9 + 6 = 3.

Critchley (1953) asserted that dyscalculia was due to a lesion in the dominant, ie. left, parietal lobe. He classified the symptoms as follows:-

1. <u>Verbal deficiencies</u>
   a. Difficulty in handling numbers as words.
   b. Difficulty in recognising numbers as symbols.
   c. Perseverating tendencies.

2. <u>Constructional or Spatial difficulties</u>
   a. Impairment of the ability to arrange numerals on paper and do calculations. Units are no longer placed below units, etc.
   b. Lack of appreciation that figures must be arranged in a particular way, to facilitate calculation, may be lacking.

3. <u>Ideational deficiencies (anarithmetia)</u>
   a. Loss of understanding of the meaning of numbers.
   b. Slowing down of number operations.
   c. Lessened memory for numbers, the use of separator and operator symbols.

d. Inability to arrange numbers in order of their magnitude.

e. Lack of fundamental concepts of addition, subtraction, multiplication and division, part/whole relationships and place value concepts.

Guttman (1937) found that many dyscalculics could perform mental arithmetic without difficulty, but were unable to order figures on the page. Accordingly, he suggested that dyscalculia is the inability to appreciate positions in space.
Singer & Low (1933) found that many patients who had difficulty in handling spatial elements, were also lacking in calculation skills. Rourke & Findlayson (1974) considered the converse of these findings and found that although the ability to perceive visual-spatial relations is directly related to the ability to reason arithmetically, superior visual-spatial skills do not necessarily lead to outstanding abilities in computation.
Luria (1973) says that the RH need not be involved in arithmetic disorders since a local lesion in the parieto-occipital of the LH would disturb spatial organisation of perception and movement and produce similar effects.

From Table 2 it can be seen that whilst many of the dyscalculic patients had suffered injury to the LH, Weinstein (1978) suggests that some of the manifestations mentioned in Critchley's (op.cit.) classification, for example, Spatial Dyscalculia and some of the ideational difficulties, should have been attributed to RH damage. There is the possibility that RH involvement was not found in some of these studies, because it was not looked for, in the light of the assumption that arithmetic and calculation are LH tasks.

Ahn (1977) reports studies by Weisenberg & McBride (1935), McFie (1960) and Hécaen (1962) which indicate that calculation deficits may be associated with RH parietal lesions, suggesting that arithmetic may involve a spatial element.

In summary, lesion studies have offered support for the involvement of both hemispheres respectively, and suggest that insult in different areas may lead to different types of "dyscalculia".

Gerstmann's Syndrome

Dyscalculia has been mentioned in the medical literature. In this context, it is often discussed in relation to Gerstmann's syndrome, the characteristic features of which are:- (Critchley, 1966; Gerstmann, 1957).

1. Finger agnosia (inability ot identify one's unseen fingers upon verbal or tactile stimulation).
2. Dysgraphia (inability to write letters of the alphabet).
3. Right/left spatial disorientation (inability to distinguish between left and right).
4. Acalculia/Dyscalculia.

Roach (1975) suggests that the implications of the syndrome is that each characteristic is related to the others and that these may in fact be the cause and effect of each other.

Subsequent studies quoted by Roach (1975) suggest that subjects with arithmetical difficulties do not necessarily exhibit any of the other characteristics. Gerstmann suggested that damage to the left parietal or parieto-occipital region of brain was the neurological basis for this cluster of dysfunctions in adult patients.

Despite Gerstmann's conviction that these symptoms formed a well-defined neurological syndrome, other researchers have expressed doubt (Benton et al., 1952; Critchley, 1966; Poeck & Orgass, 1966, 1975; Geschwind & Strub 1975).

Weinstein (1978) points out that fingers and hands seem to have played an essential role in the evolution of the decimal system of numeration. Also young children use their fingers when learning to count and calculate. This being the case, the association of finger agnosia with dyscalculia is of note. The possibility of an underlying organic connection is an interesting area for exploration according to Weinstein (op.cit.)

> "..... between consciousness and fingers ..... and calculation there has existed an intimate functional interdependence and interaction from the earliest period in Man's development."
>
> (p. 867)

In answer to Hermann & Norrie's (1958) question as to whether developmental dyscalculia is a congenital form of Gerstmann's syndrome, Geschwind (1981 - personal communication) suggests that while Gerstmann's syndrome may exist in an acquired form, the existence of a developmental form is doubtful.

Results indicated RH superiority for all four types of presentation, in both plane and solid forms. Orderly differences were found for the LH however, with respect to the different presentations. The LH performed almost as well as the RH for Euclidian geometry, but decreased markedly for the other three types respectively. On topographical tasks LH scoring reached chance level, while the RH achieved almost perfect scores, in this category.

Franco & Sperry (1977) recognise that greater familiarity with Euclidian forms might have played a role, but maintain that this alone would seem to be insufficient in accounting for the striking differences in hemispheric performances on the topological task. It seems that the number of defining constraints governing a task is a crucial feature. Where the restrictive geometric properties are numerous, as in Euclidian geometry, the LH is able to perform relatively well. An individual can follow rules, for example, a triangle has three sides and three angles. When the defining constraints become fewer, as in the projective and topological examples, LH performance approaches chance level. The geometric structure does not seem to affect RH performance.

Franco & Sperry (op.cit) maintain that these findings are in line with other reported observations; children are able to discriminate geometric forms at pre-school age, while still incapable of verbalising their defining features (Piaget & Inhelder, 1948). As people get older and in adult processing geometric properties and theorems can be understood intuitively well before verbal expression is possible.

Franco & Sperry (op.cit) suggest that a possible explanation for the LH results may concern the ease with which a task can be verbalised, and related to a frame of reference, or ordered in terms of class logic. Thus what are referred to as "irregular" figures, can be regarded as "non-verbal" because they convey very little information (as measured in Information Theory), that can be related to a known set of rules. This information is thus not susceptible to decoding, and since this latter is the mechanism by which the LH processes material, this may be the reason for the low LH scores on the topological tests. The LH is specialised for seeking highly structured inputs and is thus able to deal with defined Euclidian structures, seemingly in a similar manner to linguistic structures.

On the other hand, the RH is ideally suited for processing loosely structured shapes, since it is not diverted by the search for detail. It is able to capture the holistic properties of sets, independently of structural constraints, though because of this independence is able to process both structured material equally well, probably by ingoring classifying features. This would accord with the equal success of the RH for both Euclidian and topological tasks.

The implications of these findings will be discussed in Chapter 12.

3.7 Summary

It seems that there are different types of disabilities related to different areas in school mathematics. One such type, dyscalculia, has been found by some researchers to be independent of adequate intellectual potential. Weinstein (1978, 1980) subscribes to the view that dyscalculia, in the light of no measurable brain damage, is attributable to a delay in maturation of hemispheric specialisation. Geschwind (1981 - personal communication) and Rapin (1981 - personal communication) express doubt about the feasibility of a developmental lag explanation for failure in one scholastic area only. Both these neurologists suggest that unless a general retardation is present, a specific deficit hypothesis seems more feasible.

Research on hemispheric specialisation for different aspects of mathematics has yielded equivocal results. Additionally, generalisations from these findings are subject to a number of limitations viz. much of the work has been based on findings from split-brain or brain-lesioned subjects and is perhaps not directly applicable to "normal" subjects. Also, in the writer's view, it seems too simplistic to assume that one area of the brain is solely responsible for a particular function. The interactive effects with other parts of the brain, for example, the frontal lobes, should not be ignored.

Although the findings from pathological studies are useful in providing information about Central Nervous System involvement, they do not offer accounts of the psychological processes involved in dealing with concepts of number, calculation and the understanding of other mathematical relationships. What has become evident, though, is that the traditional view that calculation is an LH task and geometry a RH task, is too simplistic. Both hemispheres appear to have capacities for both these complex skills. The relative contribution of each, and the implications for the way mathematics is taught in schools, needs to be examined.

CHAPTER 4

4. DYSLEXIA

4.1 Definition

> "The term 'dyslexia' describes a specific type of cognitive functioning which is characterised by difficulty in acquiring written language skills. It is independent of intelligence, socio-cultural background and emotional states, and occurs despite conventional instruction."
>
> (Newton, Thomson & Richards, 1979)

Vellutino (1978) contends that:

> "The literature dealing with the problem is uniform in its suggestion that dyslexia is an intrinsic developmental anomaly, the etiology of which is qualitatively different from reading difficulties arising because of extrinsic or environmental factors."

There is much discussion in the relevant literature about the definition of Dyslexia. There is also some lack of agreement as to the critical features which describe this disability. Some writers criticise "definitions by exclusion" in which factors are eliminated and what is left forms the basis of the definition (see Rutter, 1978). It is beyond the scope of this thesis to dwell on this issue; suffice it to say that the controversy has been noted.

Much of the literature about dyslexia concentrates on reading and spelling, however Zangwill (1978) suggests that

> "Dyslexia ..... is better described as a 'syndrome', that is a constellation of associated difficulties, rather than as a difficulty in reading and spelling in the narrow sense."
>
> (In Miles, 1978)

The distinctive feature of dyslexia as opposed to other literacy difficulties is the fact it is found in individuals of adequate intellectual potential, who have had sufficient educational opportunity, are not socially disadvantaged and who do not suffer any gross neurological defects.

"Adequate intellectual potential" in this context refers to at least average intelligence, as measured on a standardised intelligence test, and is one of the defining characteristics about which there is fairly general agreement among researchers (Vellutino, 1978).

Whilst it is recognised that slow learners may not be realising their full potential (Benton, 1978) and may present with characteristic dyslexic features, the interactive factors of their slower potential, and often other perceptual and/or motor difficulties, make it difficult to diagnose them as dyslexic (Johnson & Myklebust, 1967). Certainly, this is a worthwhile area of research. However, it goes beyond the scope of the present investigation. Consequently, to preclude any confounding variables, all subjects described as 'dyslexic' in this thesis, scored 90 or above on the Full-, Verbal- and Performance Scales of the Wechsler Intelligence Scale for Children - Revised Edition (WISC-R) (Wechsler, 1976).

One of the objectives of this thesis is to ascertain whether aspects of Arithmetic and School Mathematics warrant inclusion in a definition of dyslexia. They are only mentioned in a few lists of presenting features (e.g. Miles, 1974). Hughes (1978) & Denckla (1978) include Dyscalculia in their definition of 'dyslexia-plus', along with hyper-activity and lack of motor co-ordination.

4.2 Characteristics of Dyslexia

The specific features, most often mentioned in descriptions of dyslexia are presented in Table 1 along with summarised findings concerning these variables. This list is not exhaustive. The reader is referred to Thomson (1977), Benton & Pearl (1978), Wheeler & Watkins (1979) and Vellutino (1979) for further detail.*

In considering this section, it might be useful to keep in mind that:

> "it is perhaps helpful to regard dyslexia as a family of difficulties. Not every dyslexic sign is present in every case and similar mistakes may occasionally be made by those who are not dyslexic, but a person can be regarded as 'dyslexic' if a sufficient number of these signs occur together."
>
> (Miles, 1978)

Also it must be remembered that the dyslexic child can learn to compensate for some of these difficulties.

*Many researchersrefer to "reading retardation" and poor readers. The studies quoted in this chapter are ones that appear to satisfy the criteria for diagnosis of dyslexia (see Study 1), unless otherwise specified.

TABLE 1 CHARACTERISTICS OF DYSLEXIA

Discrepancy between Intellectual Potential and Scholastic Language Attainments		
Newton	(1974a)	
Newton & Thomson	(1976)	
Miles	(1974; 1978)	
Vellutino	(1978)	Dyslexia precludes measured intelligence scores below 90 on either Verbal or Performance Scales of a test such as the WISC-R.
Familial Incidence		
Newton	(1974)	Other members of the family have been found to have similar literacy difficulties.
Owen	(1978)	
Thomson	(1977)	
Genetic Factors		
Childs et al.	(1978)	No clearly established genetic link.
Birth Trauma		
Newton	(1974a)	"At risk" birth may contribute to the syndrome of dyslexia.
Critchley	(1970)	
de Hirsch et al.	(1966)	
Thomson	(1977)	
Kawi & Pasamanick	(1958)	45% of children with subsequent reading disability had a history of prematurity and birth complications compared with 25% of the Controls.

Delayed Developmental Milestones

Kawi & Pasamanick	(1958)	
Newton	(1974a)	
Miles	(1974)	History of clumsiness, late walking, late talking - often found in dyslexics.

Symbolic Nature of our Language System

Newton	(1974a)	Acquisition of sound/symbol correspondence is particularly difficult for dyslexics.
Thomson	(1977)	

Left/Right Differentiation

Rutter et al.	(1971)	Confusion between L/R is associated with reading difficulties.
Thomson	(1974)	Confusion in dyslexics
Miles	(1974)	
Harris	(1979)	Confusion eight times more common amongst dyslexics than in the "normal" population.
Belmont & Birch	(1965)	Confusion in L/R identification of body parts.

Representational Learning

Vellutino	(1977)	Dyslexics have difficulty with all aspects of representational learning - naming months, seasons, telling time and L/R differentiation.
Blank et al.	(1968)	Dyslexics have a "verbal deficiency in abstract thinking".

Sequencing

Bakker	(1967, 1972)	Dyslexics have difficulties in the perception of temporal or spatial order sequences.
Doehring	(1968)	
Hayes	(1975)	
Bannatyne	(1971)	Difficulties with coding fluency.
Thomson	(1977)	
Thomson et al.	(1979)	
Miles	(1974)	Difficulty in repeating digits in reverse order.
Hayes	(1975)	Sequencing skills vary according to how easily they can be labelled.
Hicks	(1980b)	Difficulties in dyslexics are more marked when test stimuli approximate closely to words and letters. Sequencing strategies can be taught, to some degree, in the test situation.
Naidoo	(1972)	Poor sequencing ability.
Newton	(1974a)	Inability to sequence common events:
Thomson	(1977)	days of week, months of year.
Torgeson & Goldman	(1977)	Dyslexics do not use subvocal mnemonic aids in rehearsal of a sequence to be repeated after a delay.

Irregular Eye Movements

Zangwill & Blakemore (In Pavlidis, 1978)	(1972)	"if he (the dyslexic) is unaware of the direction of his eye movements and simply analyses syllables and words in the order that he inspects them, this may account for some of his odd inversions of words and phrases."

Irregular Eye Movements (Cont'd.)

Pavlidis	(1978, 1980) (a & b)	Dyslexics exhibit erratic eye movements, indicative of oculomotor sequencing disability, which manifests itself when viewing visual, verbal and non-verbal stimuli. May be attributable to central sequencing disability, and exacerbated by the presence of directional confusion. Suggest lights test as "objective" predictor of dyslexia.
Liberman et al.	(1971)	Sequencing difficulty is verbal NOT visual.

Incidence in the Population

Wilsher & Joffe	(1980)	Estimates in the population vary.
Klasen	(1972)	Between 2-25% of Western population
Bannatyne	(1971)	Using "strict criteria", at least 2% of the school population.
Thomson & Newton	(1976)	30% of children have reading and/or spelling difficulties;of these about 10% are dyslexic.
Child (In Newton, 1975)	(1971)	The relatively low incidence of dyslexics in England relative to the USA, reflects recognition of less severe cases in States, of needing special instruction.
Rutter	(1978)	Dyslexia affects 3.5-6% of children of school going age.
Eisenberg	(1966)	Male/female ratio exceeds 4:1.

Importance of Early Screening

Denhoff et al.	(1971)	The importance of early diagnosis is stressed so that appropriate help may be given.
Newton & Thomson	(1976)	
Newton	(1974a)	
Satz et al.	(1978)	

Poor Short-Term Memory

Naidoo	(1972)	
Thomson	(1977)	
Miles	(1974)	
Ellis & Miles	(1978)	
Hicks	(1980a)	
Blank & Bridger	(1966)	
Blank et al.	(1968)	
Rourke	(1978)	
Thomson & Wilsher	(1978)	
Rudel	(1980)	Dyslexics have the inner lexicon, but it is poorly organised and they take a long time to retrieve it, too long apparently to be useful in reading.

Spelling Difficulties

All clinical studies report spelling difficulties, e.g.

Thomson	(1977)	Poor or random sound/symbol correspondence "bizarre" spelling.

Reversals

Newton	(1973)	Persistent reversal and disordering of letters, syllables, words and word order when reading.

Reversals also noted by:-

Pavlidis	(1978)	Hicks	(1980b)	Miles	(1974)
Vellutino	(1977)	Newton	(1975)		

Difficulty in Naming/Verbal Labelling

Denckla & Rudel	(1976a)	Pictured objects - named fewer, slower. (Dyslexics and poor readers, relative to Controls). Auditory definition - poorer performance. (Dyslexics and poor readers relative to Controls). Sentence completion - Dyslexics less accurate than poor readers and Controls. Tactual naming - Dyslexics and poor readers, poor performance than Controls.
Denckla & Rudel	(1976b)	Dyslexics slower than controls and other LD groups on rapid repetitive naming of pictured objects, letters and numbers.
Vellutino et al. Vellutino	(1975) (1978)	, Dyslexics are deficient in verbal labelling.
Ellis & Miles	(1978)	
Hicks	(1980a)	

Word Finding Difficulties

Denckla & Rudel	(1976a)	
Mattis, French & Rapin	(1975)	
Vellutino	(1978)	Difficulty identifying words as wholes and segmenting them into sounds.
Johnson & Myklebust	(1962)	There may be subgroups of the above, as a result of qualitatively different neurological dysfunctions.

Paired Associate Learning

Vellutino et al.	(1975)	Dyslexics - poorer performance for words. - equivalent performance to Controls for pictures.

Abstracting/Generalising

Vellutino	(1978, 1979)	Difficulty abstracting and generalising common constituents of given words.
Newton	(1974a)	Failure to recognise word families.
Shepherd	(1981)	Poor ability at abstracting meaning from stories - poor precis ability.

Perceptual Difficulties

Mattis, French & Rapin	(1975)	Visuo-spatial perceptual disorders reflect one type of dyslexia syndrome.
Satz et al.	(1971)	Poor visuo-motor and auditory-visual integration.
Denckla et al.	(1976c)	Route finding and other visuo-spatial tasks are poorer in dyslexics than "normals" before age 10.
Sobolka et al.	(1977)	By age 10, dyslexics are equal to controls or superior, in route finding ability.
Bakker et al.	(1970)	
Robinson & Schwartz	(1973)	Defects in visual perception and/or visuomotor co-ordination at the age of 5 or 6 years, it NOT seen to relate to subsequent reading difficulties.
Benton	(1975)	Reviewing studies suggesting perceptual deficit theories of dyslexia concludes that "the importance of visuoperceptive and visuomotor difficulties as determinants of reading failure has been overrated by some authors."
Liberman & Shankweiler	(1971)	Some difficulties that appear to be "visuo-spatial" in nature may reflect reliance on language, which is deficient in dyslexics.

Spatial Ability

Newton	(1974b)	Occasional superiority in spatial skills.
Bannatyne	(1971)	Superior performance on Spatial Cluster on WISC.

Arithmetic

Miles	(1974)	Inability to do subtractions without concrete aids.
Joffe	(1980b)	Difficulty in memorising mathematical tables. 'Losing the place' when reciting tables.

Secondary Emotional Factors

Thomson	(1978)
Hicks & Joffe	(1980)

Subtypes of Dyslexia

Johnson & Myklebust	(1967)	There are different sub-types of dyslexia. At the present time no conclusive evidence has been provided as to possible aetiologies for these groups, in fact, if they do exist. The first-named writers suggest that a qualitatively different neurological dysfunction may be involved, in each type.
Vernon	(1979)	
Mattis, French & Rapin	(1975)	

4.3 Theories of Dyslexia

In this section, three main theories of dyslexia will be presented. These three have been singled out for discussion as they may have relevance for subsequent discussions concerning the interrelationships between dyslexia and school mathematics.

Maturational Lag

One of the most influential theories concerning dyslexia was put forward by Orton (1937) who believed that 'strephosymbolia' (twisted symbols), as he referred to dyslexia, was due to a developmental delay in the establishment of consistent cerebral dominance. He believed that both hemispheres of the brain received information simultaneously and that normal perception resulted if images in the non-dominant hemisphere were suppressed. These images were said to have been stored as symmetrical mirror imaged engrams of letters and words. In dyslexics he felt that weak or "mixed" dominance led to competition between the two corresponding visual areas. Failure to suppress one of these images resulted in confusion, resulting in reversals, for example, b/d; was/saw.

Harris (1979) reports Orton's comment:

> "..... if dominance were incomplete, control could alternate between the two hemispheres, and the result would be shifting and inconsistent perception with many reversal errors."

Orton mentioned that a deficiency in visual memory contributed to this difficulty. He also maintained that problems of this nature were specific to symbolic material and not associated with concrete objects and events.

However, as Hiscock & Kinsbourne (1980) state:

> "After 50 years of research, empirical support for Orton's hypothesis is unconvincing."

Satz & Sparrow (1970) and Satz et al. (1978) have also postulated that a disability affecting reading such as dyslexia, reflects a delay in the maturation of the brain which differentially affects the acquisition of the hierarchy of skills necessary for fluent reading. Skills such as visual-perception and cross modal sensory integration are likely to be delayed in children who are maturationally immature. Conversely, say Satz et al. (1978) acquisition of language and formal operational thinking which develop slowly during childhood, are likely to be subject to even slower development in older children who are maturationally immature. The writers say that this theory is compatible with developmental theories such as that postulated by Piaget & Inhelder (1969).

> "It is predicted that these children will eventually "catch up" on these earlier skills which have slower and later autogenetic development ..... If the lag in the later-developing linguistic skills persists beyond puberty, at which time motivation of the Central Nervous System is complete, then a more permanent delay or defect is expected. This formulation thus predicts that the nature of the disorder will vary in part as a function of the chronological age of the child."

The Development Lag theory has been subject to much criticism as has been mentioned in Chapter 3. The proposal that children will "catch up" is criticised by Rourke (1978a). Neurologically, both Geschwind (1981) and Rapin (1981) (personal communications) doubt the feasibility of a lag specific to one area of intellectual functioning. These researchers maintain that a Specific Deficit is more likely to provide an adequate explanation. Hiscock & Kinsbourne (1980) reject delay in maturation of the nervous system as an explanation for dyslexia. However, they maintain that it is still valid in explaining other forms of learning difficulty.

Temporal Order Theory

Bakker (1970) attributes failure in reading to a deficiency in the perception of temporal order. Central to this theory is the fact that sequential memory is seen as a specialised ability distinct from gross memory. Bakker suggests that difficulties in temporal order occur only in the processing of verbal stimuli. The temporal processing of such stimuli is said to take place in the left hemisphere (LH) whereas processing of non-verbal stimuli is apparently supported by the right hemisphere (RH).

Vellutino (1979) points out that Bakker specifically rejects the possibility that dysfunction in ordering meaningful verbal stimuli is due to generalised language deficiencies or disorders in such linguistic functions as labelling and naming. In support of this denial, Bakker points out that poor readers may be able to name letters or numbers but may still find it difficult to remember ordered series of these items.

Groendal & Bakker (1971) found that memory for sequences of meaningless figures did not differ for above- and below-average readers respectively. Other writers have suggested an association between reading disability and temporal sequencing (Senf, 1969; Bannatyne, 1971), however none of them has articulated a theory of reading failure on this basis alone (Vellutino, 1978).
Bakker (1972) maintains that performance on a "mixed" auditory-visual task was a good predictor of reading achievement.
Rourke & Young (1975) found that performance on an auditory sequencing task was faster than on one requiring visual sequencing regardless of

task complexity. Rourke (1978a)rejects Bakker's theory as being too simplistic:

> "It appears that retarded readers as a group exhibit deficiencies in temporal sequencing and serial positioning. However, the fact that there are marked individual differences among normal, as well as retarded, readers on those variables (probably mediational in nature) which appear to affect temporal sequencing ability directly renders the interpretation (and, a fortiori, the applications) of these results rather tenuous."

Verbal Labelling and Acoustic Encoding Theories

This section draws heavily on the work of Vellutino (1978) to whom the reader is referred for further discussion.

The most persuasive theory, at the present time, appears to favour the notion that dyslexia involves a deficit in acoustic encoding of information. As will be seen in Section 2 of this chapter, there is much evidence to suggest that there is a neurological dysfunction underlying dyslexia, but since it is neither desirable, nor economically feasible to subject all children with language difficulties to a neurological examination, most clinicians and educators rely on the behavioural manifestations and psychological correlations of this dysfunction, on which to base their theories.

Vellutino (1978) accepts the notion of an underlying neurological dysfunction. He has suggested that:

> "observed differences between poor and normal readers on a variety of measures involving visual and auditory memory could be attributed to reader-group disparities in verbal encoding ability."

He goes on to say that difficulties in short-term memory in these individuals, is the result of a lack of implicit verbal coding devices which will facilitate efficient storage and retrieval of stimulus input.

It is suggested that verbal information provides a variety of implicit mnemonics as well as a variety of contexts that will allow one to readily symbolise or code stimulus input for efficient processing. The child who lacks the ability to utilise these measures will be at a disadvantage when faced with short-term memory tasks that require rapid coding of information (Vellutino et al., 1975).

Ellis & Miles (1981) also support a "lexical encoding deficiency" explanation for the psychological features of dyslexia.

4.4 Research supporting a Verbal Labelling/Acoustic Encoding Theory

Compatible with Vellutino's (1978, 1979) and others' ideas that the dyslexic failure in written language fluency is in part attributable to failure to translate visual information into an appropriate visual store, are the findings of Hicks (1980_a). In depth reference will be made to Hicks' study as it illustrates well, the main features of a verbal labelling/acoustic encoding deficit as a partial explanation for dyslexia. These experiments also appear to the writer, to have been well designed.

Hicks (op.cit.) carried out four experiments using the Visual Sequential Memory Subtest (VSM) of the Illinois Test of Psycholinguistic Abilities (ITPA) (Kirk et al., 1968).

In Experiment One, Hicks found that 13 of the 20 children (aged 9-10 years), with no learning difficulties reported using a verbal labelling strategy to assist recall. These subjects said that they had associated the symbols presented, with familiar objects and subsequent rehearsal of this association was used to facilitate memory of the symbols. Subjects who used a visual recall strategy said they tried to picture the shape in their minds. The subjects who used a labelling strategy recalled significantly more symbols than those who used a visual strategy.

In Experiment Two, subjects were asked to assign word labels to the visual symbols and attempt to recall the verbal, rather than visual sequence. No significant differences were found when the children who had previously used a visual strategy used a verbal one; their performance improved.

Experiment Three explored these findings further using Dyslexic and Control Groups. Subjects were divided up into a Name Code Group and a Visual Code Group on the basis of the recall strategy they used on the ITPA VSM test. Only one subject in the competent reader group reported using a visual recall strategy compared with nine out of the twelve dyslexics. Children were asked to say the word "the" during the experimental procedure, to test whether a competing verbal response would suppress the tendency to name the visual symbols.

There were no significant differences between the performances of either group under the Verbal-Suppression Condition and no significant differences in the scores achieved by the Visual Code Group. However, the subjects in the Name Code group showed a marked decrease in the number of symbols recalled correctly.

In a further experiment, dyslexics were asked to use a labelling strategy and supplied with labels if none were generated by the individuals themselves. Their performance improved significantly ($p < 0.001$), though they still did worse than good readers.

Hicks (op.cit.) reports that, on the basis of these findings, the ITPA VSM task, does not necessarily measure VSM, but rather verbal coding ability. The finding that a visual strategy is less effective than one using verbal labelling, is in accord with Coltheart (1972) and Neisser (1967) findings that visual memory is limited and subject to quick decay.

The norms of the VSM subtest appear to relate more accurately to verbal labelling scores, rather than visual memory attainments, varying across subjects. This, says Hicks, is further evidence that the test may not be valid for what it is designed to measure.

Implications of this study are that eaching of labelling strategies may improve performance. However, while recall is improved in dyslexics, the amount of information retained is not equivalent to that retained by competent readers. A possible explanation for this is provided by Thomson & Wilsher (1978) in terms of limited short-term memory.

Further support for the verbal labelling/acoustic encoding theory is provided in an alternative examination of reversal errors. Again detailed reference will be made to the work of Hicks (1981).

Reversal errors are often mentioned as one of the signs of dyslexia (Newton, 1975; Thomson, 1977). Hicks (1981) points out though, that they are not specific to dyslexics (Money, 1966; Fischer et al., 1978).

Various proposals have been put forward concerning reversal errors, the most common being that they are visual in origin and attributable to general perceptual immaturity, especially that related to spatial perception and poor directionality (Hicks, 1981). As has been mentioned, Orton (1937) suggested that reversals, such as b/d and was/saw resulted from the inability of the non-dominant hemisphere to suppress the mirror-imaged engrams of symbolic material. Vellutino et al. (1975) refuted this idea and demonstrated that children mislabel letters and words (particularly b/d; was/saw) despite the fact that their perception of these figures was unimpaired.

Hicks (op.cit) provides an alternative explanation for reversal errors in dyslexics, using a search task and auditory and visual inter- and intra-modal stimuli and targets. Four groups of subjects were tested - beginning readers; dyslexics; retarded readers;and normal readers. The beginning, retarded and dyslexic groups showed reversals of letter orientation in both reading and spelling. The normal readers showed no reversals. The results indicated that the underlying cause of reversals varied according to the subject population.

Dyslexics made significantly more errors on the visual to auditory task, than on the auditory to visual, indicating, says the Investigator that:

> "the main area of difficulty for these children lies in transferring visual information into an appropriate acoustic store."

This finding corroborates the findings of Hicks (1980a) and Ellis & Miles (1978) who reported that dyslexics have difficulty in verbally encoding visual information.

Liberman et al. (1971) also noted that dyslexic children's reversals are linguistic rather than visual.

Distinction such as this (modality integration) between dyslexia and other forms of literacy failure give additional support to the views of Rutter, Tizard & Whitmore (1971), Vernon (1979) and many others that dyslexia is unique and qualitatively different from other reading difficulties.

Poor short-term (S-T) memory may also fit into the deficient Acoustic-Encoding model of Dyslexia. Poor short-term memory has often been mentioned as a feature of dyslexics' performances on various linguistic tasks (Naidoo, 1972; Thomson, 1977; Thomson & Wilsher, 1978). At the same time Baddeley & Hitch (1974) suggest that some mechanism for articulatory encoding (an internal speech code) is necessary in situations where the external response is spoken. If this is the case and dyslexics, as has been mentioned, are deficient in auditory encoding, it could be that this is, at least partly, the cause of their short-term memory deficit. A finding of this nature would be consistent with the findings of Vellutino (1979); Hicks (1980a, b); and others.

4.5 Psychometric Assessment

The theories concerning dyslexia are incomplete and can only be used to help interpret information. Still of greatest import is the child and his/her behaviour.

We rely on psychometric techniques and skilled interviewing to get as accurate a picture as possible about each dyslexic individual. One of the instruments most frequently used to measure intellectual potential is the Wechsler Intelligence Scale for Children (WISC-R) (Wechsler, 1976).

Thomson (1980) has suggested that caution and skill in interpretation are necessary when assessing the intelligence of the dyslexic child, because some of the subtests used are known to be areas of weakness in the dyslexic's learning profile. Thomson, Hicks, Joffe & Wilsher (1979) discuss these problems in relation to the British Ability Scales (Elliot et al.,1978). However, since the WISC is the most commonly used test, further discussion will relate to it specifically.

The important feature of the WISC is that it allows both for a general estimate of intellectual potential and an analysis of component skills. Analysis of these will now ensue.

WISC- Subtest Profile

Bannatyne (1968) suggested the recategorisation of WISC scaled scores to identify dyslexic children. On the basis of additional findings by Rugel (1974), Bannatyne (op.cit.) extended his classification. Bannatyne (1974) suggested the following clusters of sub-test scores as useful diagnostic material. Additional annotation is included from Vance & Singer (1979).

<u>Spatial Score</u> was derived from the scaled scores on Object Assembly, Block Design and Picture Completion. These subtests do not seem to involve sequencing, but require the ability to manipulate objects in multidimensional space either symbolically or directly.

<u>The Conceptual Score</u> was obtained from scores on the Vocabulary, Comprehension and Similarities subtests, which together are thought to represent verbal fluency.

<u>The Sequential Category</u> consisted of the Digit Span, Coding and Arithmetic scores. These tests require short-term memory storage and retrieval of sequences of auditory and verbal stimuli.

<u>The Acquired Knowledge Cluster</u> included scores from the Information, Arithmetic and Vocabulary subtests (see Thomson & Grant (1979) for descriptions of individual subtests).

Using this classification, Thomson & Grant (1979) found that 9-11 year old dyslexic boys scored significantly highly compared to same-age Controls on the spatial score and significantly lower on Sequencing Ability and Acquired Knowledge. Thomson & Grant (1979) found that Dyslexics' performance was characterised by higher scores than the Control Group's on Picture Completion, Object Assembly and relatively low scores on Information, Arithmetic, Digit Span and Coding. The Block Design subtest scores were not significantly different, a finding not expected by these researchers who hypothesised that the Dyslexics would do significantly better on this task. The Dyslexics also showed a slight superiority on Picture Arrangement. Thomson & Grant (op.cit.) suggest that this subtest is a complex task and predictions of Dyslexics' poor performance assumes that sequencing ability is a dominant factor. The Picture Arrangement subtest was dropped from Bannatyne's original sequential category, presumably for

for similar reasons. Thomson & Grant (1979) found whilst there were differences between groups based on Bannatyne's clusters, the subtest profile for Dyslexics and Controls was almost identical, the differences being in quantitative rather than qualitative terms, except for the Picture Completion subtest.

Vance & Singer (1979) produced similar results to those reported above. Additionally, they included a Distractibility category composed of the Arithmetic, Digit Span, Coding and Mazes subtest scores (said to require concentration and attention for a specific period). Dyslexics did significantly worse. No significant difference emerged for the Conceptual score, confirming the view that Dyslexics are not retarded in "thinking ability". Vance & Singer (1979) concur:

> "..... this study adds little evidence ..... that indicates the learning disabled child is characterised by a unique pattern of WISC and WISC-R subtest scores."

This does not imply that the WISC profile is not useful in itself, however, as Vance & Singer (1979) point out:

> "We need to approach each individual profile as a specific interpretative challenge, to be understood in the context of the child's particular cultural background and test behaviour."

Thomson & Grant (1979) point out that the Full Scale IQ Score is rather meaningless, when there is a wide scatter of subtest scores. Also, it must be remembered that intelligence tests in general only reflect a small sample of a child's adaptive behaviour and may be a minimum estimate at that.

Attention has focussed in this section on the assessment of intelligence, since it is central to a diagnosis of dyslexia and extensive discussion did not seem appropriate elsewhere. However, further aspects of assessment will be discussed in Study 1.

4.6 Neuropsychological Findings

From the time that dyslexia was first identified, discussion in the relevant literature has focused on its aetiology. Clues as to the cause of this specific learning difficulty were first sought in reports of subjects who had suffered brain damage and subsequently lost, partially or totally, the ability to cope with the lexicon (acquired alexia/dyslexia). However, neurological examination of diagnosed dyslexics revealed no measurable brain damage (Naidoo, 1972; Critchley, 1964, 1978), thus evidence from structurally brain damaged subjects was seen as untenable, in providing an explanation for dyslexia.

In the 1930's an alternative explanation was put forward by Orton, who suggested that dyslexia was due to a failure to establish consistent lateral dominance (see Section 3 of this chapter). Orton (1937) and others assumed that lateral hand-, eye and ear-preference were indicators of cerebral dominance. Hand preference was thought to be of particular importance; if a person was right handed, it was assumed that his/her left hemisphere (LH) was dominant for language, and vice-versa for left handers. If a person was ambidextrous, neither hemisphere was assumed as dominant. Discrepancies between lateral eye and hand preferences were thought to be particularly important in explaining reading failure, especially where these were associated with left handedness or ambidexterity. Subsequent research has cast doubt on this belief (Belmont & Birch, 1965; Critchley, 1970; Beaumont, 1974). Spache (1976) reviewed 34 major studies and found no evidence to support a relationship between preferential hand-eye usage and reading ability.

Other researchers have found that for all but a very small proportion of the population, whether left or right handed, the LH is dominant for language (Penfield & Roberts, 1959; Efron, 1963; Zangwill, 1967; Warrington & Pratt, 1973; Rassmussen & Milner, 1975). Thus, previously held ideas that mediation of language in dyslexics takes place in the RH, or that there is no resolution of dominance for this hierarchy of abilities, proved groundless. Language lateralisation is independent of handedness.

Traditional researchers, in the field of learning disabilities, might claim that there is still the "problem" of mixed laterality to be resolved. As Zangwill (1962) points out:

> "the dilemma is that although there seems to be a relationship between mixed handedness and poor reading, at least in clinical populations, there are disabled readers who are strongly right-handed and many individuals with mixed handedness who read normally."

In incorporating this apparent anomaly in their view of dyslexia, Wilsher & Joffe (1980) support Harris's view (1979), that whilst handedness is not related to cerebral language localisation, it is a correlate of specific reading difficulty, in that the incidence of mixed laterality is five times more common in dyslexics, than in the normal population (see Thomson, 1977).

It must be stressed that mixed laterality should not be confused with difficulty with left/right differentiation. The latter refers to knowledge of left and right, in relation to oneself and others. Harris (1979) reports that this directional confusion is eight times more common in dyslexics, than in the normal population.

Having established that language is localised in the left hemisphere, researchers sought alternative explanations for the failure of dyslexics to acquire literacy skills fluently. In fact, using more sophisticated techniques researchers have come full circle and returned to the earliest findings, like those of Hinshelwood (1917) and Fisher (1910) who implicated the left angular gyrus, as the area of involvement in reading failure (Geschwind, 1978; Rudel, 1978). However, whilst these early investigators spoke of brain damage, more recent research suggests that the nature of the involvement of this area is a dysfunction, rather than any gross brain insult.

Support for specifically located areas of mediation for written language (which are dysfunctioning in dyslexics) is provided by studies using a variety of techniques; evoked potentials in electro-encepholograms (EEGs), divided visual field, dichotic listening and pharmacological intervention.

Using Visually Evoked Potentials (VERs) significantly smaller amplitudes were measured for dyslexics compared to controls, from the electrodes in the left parietal region and the left angular gyrus (Connors, 1971; Preston et al., 1974; Preston et al., 1977; Cohen, 1977). Cohen found that Auditory Evoked Responses (AERs) were similar and normal, for both dyslexic and control groups. Since tones are mediated in the RH (Molfese et al., 1975), it seems that this hemisphere is functioning normally in dyslexics.

Divided Visual Field (DVF) and Dichotic Listening (DL) are "indirect" (non-invasive) methods of assessing hemispheric differences which have been widely used in the study of dyslexics. Superiority of performance of the contralateral visual hemifield and ear respectively have been assumed to indicate the dominant hemisphere for the material presented. Because DVF and DL are indirect assessment techniques, they are subject to extraneous influences. In fact, Kinsbourne (1970) contends that many so-called laterality differences, found with indirect methods, are really attentional effects.

Young & Ellis (1980) pinpoint pitfalls of some of the DVF studies reported in the literature. These include: inadequate control of eye fixation; difficulty with keeping the stimulus constant; and finding equivalent cognitive tasks. Pring (1981) reinforces these views. Experimental groups are often not clearly specified - for example, does a group of poor readers include dyslexics or not?

Criticisms are also levelled against DL studies. Kinsbourne & Hiscock (1978) question their reliability since results for adults do not agree with those from studies using direct methods. In general, mental set and training influence the results of such perceptual tests.

Keeping these points in mind, results from DVF and DL studies should be interpreted with caution. DL experiments have yielded varying results. In dyslexics, a right ear (ie. LH) advantage, for words and digits, has been found by Abigail & Johnson (1976); Leong (1976); McKeever & Van Deventer (1975); Bryden (1970); Witelson (1976, 1977); Yeni-Komshian et al. (1975); Satz et al. (1971); Satz (1976); Bakker et al. (1973); Sparrow & Satz (1970) and Springer & Eisenson (1977). However, Dalby (1979); Thomson (1976); Zurif & Carson (1970) and Taylor (in Kimura, 1967) failed to find a right ear effect. Chasty (1979) reported left ear superiority. Beaumont & Rugg (1978), in reviewing a number of studies, conclude that "dyslexic children do not show abnormal lateralisation for auditory language processing."

In looking at visual field performance of good and poor readers, McKeever et al. (1970, 1975), controlled for the factors mentioned by Young & Ellis (1980). Words directed to the LH were recognised signficantly more often in both groups, though the performance of the poor readers was depressed, relative to the other group. Similar findings are reported by Marcel & Rajan (1973) though their study was subject to the stated criticisms of Young & Ellis (1980).

McKeever & Van Deventer (1978) compared adolescent dyslexics and controls on both DVF and DL tasks. They also compared the results of a group of poor readers from a McKeever & Huling study (1970). Findings revealed that the LH was specialised for language, in all groups and that the dyslexics were underfunctioning compared to the controls. Keefe & Swinney (1979) report similar results, though they report a bi-modal distribution of results, the implications of which warrant further clarification.

Pharmacological intervention studies (Wilsher, Atkins & Manfield, 1979, 1980) indicated that a putative LH drug, Piracetam, facilitated verbal learning in dyslexics, significantly more than for controls. The authors suggest that this improvement is evidence of a previously underfunctioning LH. A similar improvement was found in dyslexic children's reading ability.

To emphasise the specificity of localisation of the dysfunction in dyslexics, it must be remembered that their expressive language is usually unimpaired (Naidoo, 1972; Miles, 1974; Newton, Thomson & Richards, 1979).

Although expressive and written language are linked, damage or dysfunction can affect one, leaving the other unimpaired. Denckla & Bowen (1979) report that surgically lesioned alexics have a similar profile to developmental dyslexics; their expressive language is unaffected, but written language is problematical. Mattis, French & Rapin (1975) found that adequate expressive language was a feature of both acquired and developmental dyslexics. Conversely, Hécaen (1979) lists studies of aphasics who can read and write, but have difficulty expressing themselves orally.

In summary, the abovementioned review of neuropsychological literature seems to support the view that a dysfunction in the left hemisphere, in the region of the angular gyrus, is important in the search for the aetiology of dyslexia. It does seem, however, that other areas are implicated in this cerebral deficiency. The nature and extent of this may account for the range of presenting symptoms and the variations in severity, found amongst dyslexics.

Recent studies by Duffy et al. (1980a, b) have indicated that physiological aberrations in the brains of dyslexics are more widespread that previously suspected. These experimenters maintain that reports of EEG and evoked potential abnormalities in dyslexic children are too non-specific to be useful diagnostically and few have looked beyond the visual (occipital) and classic speech (tempero-parietal) areas.

Duffy et al (1980a) used an analysis of topographic maps of EEG and EP activity formed by Brain Electrical Activity Mapping (BEAM) methodology. They found prominent differences between groups, over the left angular gyrus, however, they also found large between group differences in the frontal regions, bilaterally and accompanied by higher mean alpha for the dyslexic groups.

Geschwind (1981, personal communication) who maintains that the left angular gyrus is the primary area of dysfunction, says that any localised lesion of this type is bound to have secondary effects and that Duffy et al.'s findings are complementary rather than conflicting.

Duffy et al. (1980b) found similar results, using an increased sample. Discriminant analysis and clustering techniques were used. The significance level of the difference between groups reached $p < 0.00001$ establishing these measurements as powerful descriptors of aberrant physiology in dyslexics. However, the researchers do stress that their results do not, as yet, justify the routine clinical application, as they have yet to demonstrate that these neurophysiological measurements are sensitive to differences between different types of LD.

Rapin (1981, personal communication) asserts that whilst localisation of dysfunctions is interesting and necessary for the further development on theory, there is a danger that overemphasis on neurological aspects could hinder the development of appropriate remediations for the individual child.

In summary, Thomson (1977) suggests brain functions influence the individual's cognitive and perceptual skills which make up "learning style". This then interacts with the written language system. Using information from all the studies received in this section, it is the psychologist and educator's task to discover ways of facilitating this interaction. For dyslexics specifically, recent research is providing some promising clues though much more research is needed.

Having briefly reviewed some of the psychological and neurological findings concerning dyslexia, a comparison will now be made between language and mathematics, prior to the presentation of the experimental section of this thesis.

CHAPTER 5

5. WRITTEN LANGUAGE AND SCHOOL MATHEMATICS

5.1 Comparison

Even without having to delve too deeply into cognitive functioning and underlying processes, there appear to be a number of superficial features, shared by language and school mathematics which suggest some common ground (see Table 1). This being the case, it may not be surprising, if it is found that dyslexics, who have difficulties with written language, also have allied problems with those aspects of school mathematics that seem to be reliant on similar premises. Of course, there are differences, and these will be mentioned where appropriate.

Let us examine in some detail, the features that are common to both written language and school mathematics.

To begin with they are both languages (Beilin, 1975; Offner, 1978). The mere fact that mathematics is taught verbally, relates it to language. Some tuition is oral, with the teacher explaining a principle, the rest of the work is textbook based or written on the blackboard. Also, words and numbers form parts of conventional universally accepted representational systems which serve to record knowledge and events and facilitate communication between people (Hickerson, 1952) as both are believed to contain inner receptive and expressive aspects (Johnson & Myklebust, 1967). This representation is symbolically mediated, through ciphers which are arbitrary and do not bear any similarity to that which is being represented. As Newton (1974a) states:-

> "The symbolic function can be defined essentially as the capacity to represent reality through the intermediary of signifiers that are distinct from what they signify."

TABLE 1: SCHOOL MATHEMATICS ACHIEVEMENT AND READING

Pitts Muscio Earp	(1952) (1962) (1970)	high correlation between mathematics achievement and reading.
Erickson	(1958)	relationship between arithmetic achievement and vocabulary and reading comprehension is significant, though there may be other factors which accompany the more complicated task of problem solving.
Gordon	(1977)	review of studies revealed a general finding that reading skills are an important factor in achievement in mathematics (though there is disagreement as to which skills are essential).
*Gordon (1977) quotes the following findings:-		
*Treacy	(1944)	high achievers in problem solving are superior to poor problem solvers in all reading skills.
*Petty	(1952)	concluded, after a review of studies concerned with improving problem solving by improving reading comprehension, that reading comprehension was an important factor in the solution of word problems.
*Hansen	(1944)	when MA and CA are controlled, the relationship between reading ability and successful achievement in problem solving is not significant. Concluded that arithmetic reading skills and vocabulary are specific to this scholastic subject and are separate from general reading skills & vocabulary.
*Fay	(1950)	superior readers are no better than poor readers in arithmetic, when CA and MA are controlled.
*Warncke & Calloway	(1973)	no significant relationship between general reading ability and arithmetical computational ability for subjects of "normal" intelligence.
Lacey & Weil Gilmary	(1977) (1967)	many earlier studies have reported little or no relationship between reading and computational procedures.

The word "elephant" for example, bears no relation to the living object, any more than the number 6, gives any idea of what sixedness is. However, there is universal agreement that the former refers to a large grey animal with a trunk and the latter an event in which there is one more than five and one less than seven (see Table 2).

Both written language and mathematics help to systematise recurring events in the environment and also make the mass of information available to the individual manageable, by helping to impose regularity and predictability on the world, through the limiting structures of language and the various systems of mathematics. Bruner (1964) suggests that literacy is one of the "new technologies to represent the underlying regularities in the environment". Numeracy may be another. Common features of all systems under examination (ie. language, arithmetic, algebra, geometry, etc.) include rules, order, sequence, direction, logic, etc. Each of these will be discussed below.

Language and school mathematics are hierarchical, increasing in complexity as each stage is mastered (Lacey & Weil, 1977). This progression is facilitated by the learning of rules. Smith (1971) suggests that the child has rules for learning further rules and increased verbal sophistication involves discovering the particular rule that applies. Smith (1971) further contends that the development of rules serves to decrease the individual's memory load; being able to make sense of words, through rules, leads to a feeling of relief for the individual. But understanding and ability to interpret are essential too. As Newton (1974a) points out:

TABLE 2: SYMBOLIC AND REPRESENTATIONAL ASPECTS OF SCHOOL MATHEMATICS AND LANGUAGE

Hickerson	(1952)	Linguistic and arithmetical symbols represent things, actions, ideas and relationships.
Gilmary	(1967)	The use of symbols in language will aid the use of symbols in mathematics and vice versa.
Lacey & Weil	(1977)	Symbols such as and should be discussed in terms of English meaning and logic.
Hickerson	(1952)	"The accepted principles underlying the understanding and use of language symbols apply also to the understanding and use of language symbols apply also to the understanding and use of arithmetic symbols."

MATHEMATICS AS A SYMBOLIC LANGUAGE

Gonyo	(1976)	"Numerals are a mechanism for coding spatial relations."
Brown	(1953)	As a symbolic language mathematics is involved in the expression of quantitative and spatial relationships and the theoretical functioning which is necessary to facilitate thinking.
Skemp	(1971)	There are both verbal and visual symbols in mathematics.
Bishop	(1977)	An example of a visual symbol is a cube, which is "a standard and conventional representation which makes little concession to reality". "We have to learn to read this picture as a 'cube'."
Beilin	(1975)	"The physical domains to which these arithmetic operations are applied are irrelevant because the laws implicit in the arithmetic operations are independent of the nature of the magnitudes. It makes little difference if one is dealing with temperatures or lengths if the arithmetic operations apply."

"assimilation of rules externally taught is only part of this learning - a necessary part, but only a part".

An emphasis on meaning allows for some interpretation. For general purposes, for example, reading need not be totally accurate as long as one can "get the gist". In reading, too contextual cues give clues. Spelling and arithmetic seem to be more analytical and more extact - there is no room for interpretation. A greater degree of accuracy is required.

Newton (1974a)maintains that for a language system to work, stable memory engrams of symbols, sequence and direction are required. To ensure this stability, all the symbolic features and rules must be perceived consistently (auditorily and visually), stored, retrieved and reproduced (phonetically and graphically) consistently.

The 26 letters in the alphabet generate a large, but finite system of words. The number system is based on 10 symbols which can be combined in an infinite number of possibilities. The essential mechanisms on which both systems rely are order and sequence.

In English each oral sound (phoneme) can be represented in written form by one or more symbols (graphemes). Individual letters may take different sounds depending on their position, in relation to other letters. For example: the letter 'a' in 'mane', 'alone', 'rain'. A similar arrangement, though more restricted, is central to the system of place value, in numbers. Every event can be represented by a number. Each digit takes on a different value, depending on its relative position in a number, so that '4' although visually constant, reflects different quantities in the numbers 4, 48 and 463.

Because there are no exceptions, as there are in spelling, numbers are arguably more consistent that letters.
In the same way that the sequence of letters has to be constant, in order to ensure communication, so numbers have to be arranged consistently, when representing the same event. In written language, if the order of letters is not maintained, two things may result: firstly, the meaning of the word may be changed, for example, was/saw; on/no, or secondly, the disordering of letters may make the work incomprehensible - a "nonsense" word, eg. swa/aws for saw. The letters also need to be directionally consistent for the same reason. The confusion of digits in a number will always result in another number, thus understanding of the meaning of the representational changes is needed if the error is to be noticed.

Once words and numbers have been mastered initially, they are combined to form sentences, which are temporal and sequential. In English, rules of grammar and syntax indicate the correct placement of different categories of words in a sentence. Similarly, there are rules which govern all aspects of school mathematics. Some rules are axiomatic in both systems. Mathematics is arguably more logical than language, (Lunzer et al. 1976) since the latter only conforms to some sort of logical system when the rules have been learnt.

English language structure also corresponds with modern mathematical concepts in terms of phrases, sentences, compound sentences and conjunctions (Lacey & Weil, 1977). Let us examine the similarities in sentence structure:-

Simple Sentences:	Language	School Mathematics
Active	Anne ate the cake	$2 + 4 = 6$
		$a + b = c$
Passive	The cake was eaten by Anne	$c = a + b$
		$6 = 4 + 2$
		or $b = c - a$
		$2 = 6 - 4$

Compound Sentences:

Anne ate the cake, then drank some tea	$2 + 4 + 5 =$
	$a + b + c =$
	$a > b > c$

The operational signs "+" and "$>$" in this case, are allied to the linguistic verb. So this collection of nouns and verbs, arranged syntactically, in grammatical order, is a basic unit of both systems. Lacey & Weil (op.cit.) mention that most mathematics courses include exercises in changing verbal sentences into mathematical ones, and vice versa.

The algebraic sentence is concise and may be the answer underlying a word problem, in the same way as one sentence may precis the essential elements of a paragraph.

Sentences have different levels of analysis. The surface structure is largely concerned with the phonetic components - actually being able to read the words physically. This is the stage at which the rules, mentioned previously, are important. However, rules are of little help when interpreting what is meant by the words. Ability to cope with the semantic interpretation, the deep structure, forms the basis of linguistic competence. Comparable forms of surface and deep structures can be found in word problems in arithmetic and geometry. For example, Jane has 4 marbles, Fred gives her two more. How many does she have altogether? Perhaps we could say that the actual words comprise the surface structure, whilst recognising the underlying calculation, ie. 4 + 2, requires the understanding of the deep structure.

Nesher & Katriel (1977) suggest that riddles and arithmetical word problems are alike. In both the conventional word problem contains a question leading to a unique logical answer, and the texts are constructed accordingly round a known answer. In both, questions and answer clauses have some referents; in mathematics the listener is required to supply information concerning the identification of the referent, while in arithmetical word problems the individual is asked to use a "mathematical sentence to compute a missing pre-defined quantity attributed in some way to a common referent.

The semantic feature "have" is often important. Analysis of the verbs "having" in arithmetic problems reveals that they can often be disguised: to imply "addition" for example, Nesher & Katriel mention that the child may have to recognise "buy, bring, win,"etc. For "subtraction" it may be necessary to identify the verbs "lose, give, sell, send", etc.

<u>Memory</u> is an important aspect of both language and school mathematics.

> "It is probable that almost any cognitive process requires the storage or retrieval of information in some form or other."
>
> (Baddeley & Hitch, 1978)

In the longer term syntactical rules and underlying patterns have to be remembered. In the shorter term, the holding of information, currently in use, is essential. This latter aspect is referred to as short-term (S-T) memory or working memory. It is said to serve dual functions; that of temporary store, for holding information and as an executive (for carrying out control processes such as rehearsal) (see Baddeley & Hitch, op.cit.). For example, when a child is trying to decode a word phonetically, it is important that s/he concentrates on the phoneme in question (S-T store) and also remembers the previously decoded phonemes (executive). In a similar way, working memory is an essential part of arithmetic. In the example 6 + 4 = , the child has to remember the original number, while adding new digits.

Mental arithmetic is largely dependent on short-term memory. To a lesser extent, word problems also require that relevant information be extracted and retained, intermediately, while the rest of the requirements of the question are carried out.

Lunzer et al. (1976b) found that:

> "Short-term memory for the presentation of visual sequences proved to be a highly significant and independent predictor for success in word recognition and, to a lesser degree, in mathematical understanding."

The learning of spelling rules and arithmetical tables involve rote learning and arguably, engage a long-term store. However S-T memory is required to keep track of what place is reached, especially in the case of tables. Understanding must be an integral part of rote learning. The value of having knowledge which can only be applied mechanically, without understanding, is dubious. Newton(1974a) suggests that between the ages of 6½ and 9 years is the optimum period for rote learning.

<u>Development</u>

There seems to be a critical level of intellectual potential, below which the acquisition of the requisite concepts is unlikely. Terman & Merrill (1937) discuss this in relation to language, whilst Wrigley

(1958) and others provide evidence for a similar relationship for arithmetic and other facets of school mathematics.

Readiness for formal schooling is basic to all subjects. The child has had to reach an appropriate maturational level before s/he will be able to benefit from teaching, in a formal environment.

Concept formation has been proposed as the most likely vehicle for the acquisition of knowledge, in both school subjects. Piaget (1952b) maintained that thoughts have roots in action. As the child interacts with the environment s/he passes through increasingly complex stages of cognitive growth, starting with concrete objects and, through logical reasoning, acquiring increasing sophistication until s/he becomes equipped to deal with abstract linguistic and numerical codes and underlying concepts. Piaget (1952) noted that the understanding of arithmetical operations are achieved at the same time as logical operations. (see Table 3 for further comments).

Although there is some controversy as to the specific stages of its development (Choat, 1977; Bryant, 1974; Beilin, 1975), there is agreement between experts that higher order cognitive processes are called into play, in all the educational areas under consideration, since complex information processing is required for the encoding, decoding and interpretation of information which is an integral part of language fluency and school mathematics.

Learning Style is an aspect which cuts across all educational fields. Some children learn more easily through a visual modality, some an auditory, some prefer a multisensory approach (Johnson & Myklebust, (1967). Krutetskii (1976) has identified different types of "mathematical thinkers (eg. visualiser, analytical thinkers), a finding which may relate to modality preference.

TABLE 3: CONCEPTS

Wilson et al.	(1979)	"It is not immediately apparent that computation of problems in arithmetic requires conceptual activities of the types required in reading."
Choat	(1977)	Development of geometric concepts does not keep pace with numerical development for subjects rated poor in language ability.
Lunzer et al.	(1976)	Measures of operativity (classification, seriation, reflexion and analysis) are superior to language measures in predicting progress in mathematics.

Teaching

The acquisition of written language fluency and basic mathematical principles and techniques are dependent on schooling; they are both areas of acquired knowledge and since they are not self-generated have to be introduced by an external agent, usually a teacher. Newton (1974a) stresses the critical nature of the responsibility of teachers to recognise excellence and failure and provide appropriate tuition in all cases. Gilmary (1967) maintains that excellent teaching of one subject will transfer to the other. Gessner's (1977) review suggests though that many elementary schoolteachers feel competent to teach language, but not school mathematics.

Reading and mathematics are subject to changes in fashion (Glenn, 1978) and innovations in education reflected in the ever increasing number of schemes on the market. It is very rare though that reading and mathematics schemes are ever chosen to complement one another. Glenn (1979) suggests that they be selected on this basis and that reading schemes include vocabulary that children might need for their mathematics studies. This writer maintains that in this way the child's education could be an integrated whole, rather than separate units defined by "subjects". Scheffler (1977) reinforces the latter point and stresses that, in treating each subject as a separate entity, we lose sight of the common bases of many subjects.

Glenn (op.cit.) also recommends that the language of mathematics schemes be examined; children are often capable of doing calculations and experiments but are unable to understand the instructions in the workbooks.

In summary, the seemingly most important similarities between language and school mathematics are listed below. Both written language and school mathematics are:-

universal languages

arbitrary representational systems

symbolically mediated

hierarchically ordered

sequential

logical

governed by rules

systems of acquired knowledge.

<u>They both serve to</u>:

convey information

facilitate communication

impose regularity

<u>They both require</u>:

a minimum level of intellectual potential for their acquisition

recognition of symmetry

analyses and synthesis of information

accurate encoding and decoding of information

memory

development of appropriate concepts

Some of the differences that relate to this list are mentioned in Table 4.

TABLE 4: DIFFERENCES

Directionality	Written language is read from left to right as are horizontally presented number sentences, however as Chalfant & Scheffelin (1969) addition, subtraction and multiplication can be calculated in the opposite direction, from right to left, when the more common vertical presentation is used, eg. 224. "The fact that division x 56 is done from left to right only adds to the confusion."
Symbols	Twenty six letters in written language generate a large but finite system of words. In arithmetic 10 numbers generate an infinite system of numbers. Mathematics has verbal and visual symbols (Skemp, 1971). Written language is limited to verbal symbols.
Language/Mathematics	Factorial results indicate that verbal facility is not necessarily needed in mathematical thinking. "The appearance of negative signs in the case of numerical and mathematical tests indicates that mathematical reasoning may be hindered when accompanied by language and verbalisation." It is possible, though, that the lack of relationship between verbal and mathematical ability was due to the *fact that* the mathematics tests involved a minimum of words. (Wrigley, 1958). Language and verbally-oriented tasks appear to be substantially *more prognostic* of success in geometry than success in algebra. (Leigh Taylor et al., 1976).

So, in summary it seems that there are many common features between written language and school mathematics. However, as little research has been undertaken in this area, many of the comparisons are speculative. The biggest assumption made in the present discussion is that the symbolic codes inherent in these systems are similar in nature and are mediated in the brain in a comparable fashion. This assumption has yet to be tested.

5.2 Difficulties in Written Language and School Mathematics

Given the functional commonalities within written language and school mathematics, mentioned in the previous section, it seems feasible to propose that there may be shared bases for difficulties in both; nor would it seem surprising if a difficulty in one led to a deficiency in the other. This matter will be viewed in the light of the possible relationship between some of the features of dyslexia as they may relate to mathematical difficulties. As Rutter (1978) has pointed out, there are few precedents for evaluations of this type. "Surprisingly little attention has been paid to the similarities and differences between underachievement in different subjects."

Dyslexics are known to have difficulty associating a written symbol with the appropriate sound (sound/symbol correspondence). Could it be that they have a similar problem with number/event correspondence?

Rabinovitch (1968) inferred that deficiencies in language and symbolic learning, characteristic of dyslexics, led to disturbances in acquiring abstract concepts related to number, orientation, time and size.

Sequencing difficulties in dyslexics may affect the ordering of numbers, and thereby affect calculation. Vellutino (1978, 1979) and Hicks (1980) have suggested that sequencing difficulties are associated with deficits in verbal labelling and acoustic encoding strategies. Holmes & McKeever (1979) found that, while series in itself may be a problem, a combination of serial order and name coding may be problematical, as seems likely (in counting, tables, progressions, etc.) then it would not be surprising if the dyslexic performed poorly on these tasks.

Vellutino (1979) mentions that Gerstmann's syndrome is a cluster of dyslexic type problems and number difficulties. These include difficulty with left/right (L/R) differentiation, acalculia and reading and writing difficulties. However, as Geschwind (1981, personal communication) points out, the existence of a developmental form of this syndrome is dubious and, since dyslexics have no gross brain lesions, the acquired form would not be applicable. Further, Benton et al. (1952) maintain that there is no relationship between arithmetical ability and left/right differentiation.

Despite these negative findings, Gerstmann's Syndrome may provide some clues as to neurological implications in this comparison. Gerstmann's Syndrome is associated with acquired lesions in the left parietal lobe, and Head (1926) suggested that damage to the left angular gyrus was the seat of arithmetical difficulties. The left angular gyrus is thought to be a primary area of dysfunction in dyslexics (Geschwind, (1979). If this is the case, it could be that dysfunction in this area is contributing to both language and school mathematical difficulties. Rourke (1981) has suggested that different types of arithmetical difficulties stem from different cerebral dysfunctions. This may account for dyscalculics who are not dyslexic. However, it does not account for dyslexics who have no mathematical or arithmetical difficulties.
Newton (1974b)mentions that dyslexics often have specific abilities in spatial mathematics (eg. geometry and 'set' mathematics).

Poor short-term memory is a feature of dyslexia and, as has been mentioned in the foregoing discussion on similarities between language and mathematics, is an important mediator in both. In calculations, the dyslexic child deficient in S-T memory, may forget to carry; in a word problem, s/he may struggle to read the question and may be concentrating so hard on the words that the basic numerical information and requirements may be forgotten. Abstraction of the essential elements of the question may prove difficult (Shepherd 1981).

To recapitulate, there seems to be a multiplicity of factors involved. Given the deficits characteristic of the dyslexic's performance in written language tasks, and, given the supposed similarity in demands for proficient performance in school mathematics, it would not be surprising to find individuals who have parallel problems in both scholastic fields. However, as has been mentioned, there are dyslexics who do not have apparent difficulties in mathematics, so a theory based on functional commonalities would not be sufficient in itself to explain the nature and extent of a proposed relationship between written language failure and differential attainments in school mathematics.

In order to explore the above phenomenon in more detail, field investigations and experimental studies were designed. These will be presented in the chapters that follow.

CHAPTER 6

6. PILOT STUDY

Aims

1. To make a general assessment of mathematics as it is taught in different schools; to examine the teaching schemes and techniques that are being used and to observe the children's approaches and responses to them.

2. To examine the methods of assessment favoured by different schools.

3. To select schools for more intensive study and to meet the children from amongst whom the experimental samples would be chosen, and the staff whose co-operation would play an important part.

4. To discuss with teachers the teaching and learning of school mathematics.

5. To find out if there were any children who had specific difficulty with the mastery of aspects of the mathematics syllabus.

6. To examine the nature of the system in which the reported failure of some dyslexics was occurring.

6.1 Observation

The pilot study was carried out in fourteen Infant and Junior schools. The schools included in this survey were chosen on the advice of Mr. Brown of the Science and Mathematics Centre, as being a representative cross-section of the schools within the jurisdiction of the Birmingham Education Authority.

The main aim of this initial investigation was to get a general picture of which mathematics topics are covered in different schools, how they are taught, which work schemes and materials are employed and which assessment procedures are used.
The study spanned a period of six weeks, during which time a number of visits were made to each school and every class within each school so that children in the age range 5-12 years were observed.
The investigation took the form of varied periods of participant and non-participant observation, following the guidelines of Bogdan & Taylor (1975). During periods of non-participation the writer merely sat at the back of the classroom observing the types of activities undertaken, the teaching style, classroom organisation, etc. and taking no active part in the ongoing lesson.
Participant observation included walking round the classroom asking children to verbalise (where possible) about what they were doing or how they arrived at a particular answer. If the class teacher offered the opportunity, small groups of children were taught by the Observer. During these periods particular interest was taken in the children's approaches to new subject matter and their modes of problem solving.
Most observations took place when number, arithmetic and mathematical concepts were being taught, though some language and creative activity periods were attended. It was considered important to meet and establish some rapport with the children, from amongst whom sample populations

would be selected for further study, and with their teachers whose co-operation would constitute an essential element in the smooth running of the proposed research programme. To further this end, the Observer attended Assembly, lunched with the children and joined in staffroom conversation.

Besides the above, a number of variables were noted for each school. These included:- socio-economic environment and the attitudes of children, teachers and parents. These variables were noted because they could have a large bearing on the nature of the school and the attitudes and achievements it spawns.

6.2 Geographical Location, Socio-Economic Environment and Parental Attitudes

These variables will be discussed together as they appear to be related.

Cleveland (1961) and Passy (1964) found significant relationships between all aspects of arithmetical achievement and socio-economic status, in 11-12 year olds and 8-9 year olds respectively. Similarly, Gordon (1977) reports that the socio-economic standing and vocational status of a student's parents is positively related to his/her achievement in mathematics. Barakat (1951), however, maintains that differences in achievement of different socio-economic groups only pertain to very extreme groups (very rich or very poor) and that in the middle ranges environmental factors are less influential than had previously been proposed.

In the present survey, great differences in attainment and expectation were found depending on the geographical location and pupil catchment area of the school. In some of the Inner Ring (designated Social Priority Areas) schools, non-English speakers accounted for over 80% of the student population. Consequently the teaching of English was the primary concern. School mathematics attainments in these schools were low.
At the other extreme, in schools on the Outer Ring (ostensibly Middle Class), where parental expectations were high (teachers' reports) and classroom organisation more formal, 6-7 year olds were working with number boards from 1-100. Children of similar age in the rest of the schools visited were concentrating on numbers up to twenty.

From the studies reviewed and the pilot survey, it did seem that there may be a relationship between socio-economic environment and scholastic achievement. While this relationship was not investigated in any detail, it was decided that it could be a confounding factor in any further study, therefore it was decided to control for it. To this end, the schools selected for subsequent studies were situated in seemingly similar environments.

the 5% and 1% levels of significance respectively. Questions involving money (Module 9) prove to be most difficult for Dyslexic Group 1, relative to their Controls ($p < .001$).

Dyslexics in the 11 years - 13 years 11 months age range (Group 2) score poorly relative to their matched Controls, on all aspects tested. Similar findings pertain to Dyslexics and Controls in the oldest age group (14 years - 16 years 11 months).

The performance of the subjects in Dyslexic Group 2 does not differ significantly from the youngest Control Group for Modules 1, 2, 3, 4, 5 and 9. Quantitative differences between the latter groups (Dyslexic 2 and Control 1) are found only for Properties of the 4 Operations, shapes, ratio and proportion and problems (Modules 6, 7, 8 and 10 respectively). Significant differences are found between the scores of Dyslexic Groups 2 and 3 for all Modules ($p < .001$). Similar results are found for Control Groups 1 and 2 and Control Groups 2 and 3 respectively. Control Group 2 does significantly better on subtraction (Module 3, $p < .04$), multiplication (Module 4, $p < .007$) and division (Module 5, $p < .04$) than the oldest Dyslexic Group. There are no significant differences between these two groups' scores for any of the other Modules.

Analysis of Variance

The Analysis of Variance (AOV) (completely randomised) programme available in the Department of Educational Enquiry, University of Aston in Birmingham, was utilised to see if there were significant age and Dyslexic/Control group main effects and whether there was an interaction between these factors. Tables 1M(b) - 10M(b) inclusive list the AOV Summary Tables for Modules 1-10.

Education Authority

Throughout this study, and all the other investigations included in this thesis, the Local Education Authority have been interested and helpful.

6.4 Teaching

The setting up of the Cockcroft Commission of Inquiry into the teaching of mathematics in schools was evidence of the Department of Education and Science's (DES) concern about declining standards in this subject. Niss (1977) and Ollerenshaw and Clarke (1978) report that mathematics teaching is in a critical state.

In the present study, it was found that while most teachers did not mind teaching mathematics, few of them had gone beyond the particular approach adopted by the school, in looking for innovative ways of presenting material or interesting the students. Encouragement of creative thought was not a feature of most mathematics lessons (Hollander, 1977). As Noyce (1979) found, verbal and analytical solutions were most rewarded.

Selection of Materials

Armitage (1977) advocates the selection of materials from many different schemes. This was not a common finding in the schools surveyed. Most schools chose one particular scheme and followed it as recommended by the Authors. Little thought appeared to have been given to the suitability of a particular programme for the school population. This seemed particularly pertinent to schools with a high immigrant population (Segel, 1972 in Dutton,1977). Price,Kelley & Kelley (1977) suggest that inappropriate texts may be the primary source of mathematical difficulties. Larcombe (1977) using the Kent Mathematics Scheme (op.cit.) found that material that was appropriate for brighter pupils was not suitable for children in the lower ability ranges. Little accommodation was in evidence for less able pupils in the schools included in this Pilot Study.

"New Math"

Several teachers expressed doubt as to the efficacy of so-called "New Math" schemes, such as Mathematics for Schools (Fletcher et al., 1970) (often referred to as "Fletcher Maths"). but as can be seen from Table 1, there is substantial evidence to suggest that this approach has been misinterpreted. Most of the teachers who felt insecure about this method, felt that they had not been provided with sufficient training in its implementation (Azzi, 1977). Generally, the Head of the Mathematics Department was the only teacher sent on courses, and feedback to the rest of the staff was often thought to be inadequate. Some teachers felt that situations such as these had contributed to their feelings of unease, when teaching from programmes which included unfamiliar notation.

Linking

One of the criticisms levelled against "Fletcher Math", with which this writer agrees, is that the transition between one stage and another is often too rapid and is not detailed sufficiently.

For example, there is an emphasis on sorting and classifying in the earlier stages (Level 1), which is related to abstract number in later levels, but the transition is not sufficiently graded. The result of this is that many children learn to sort and classify; they also learn to manipulate numbers and calculate; but many of them do not realise that sorting was the concrete event which they are now representing in abstract symbols. Flener (1978) and Williams (1978) both stress the need to relate physical activities to higher order concepts, especially among 5-8 year olds. The emphasis should be on both the process and the product, rather than the product alone.

TABLE 1: "NEW MATH"

Wilby	(1976)	"New Math" is not new, it was known to the ancient Greeks.
Ballew Fletcher et al.	(1977) (1970)	The backbone of the new mathematics movement has been the belief that children should work in a direction from the concrete and familar toward the abstract and unfamiliar.
Binyon Kapur Hirschi Brody Ballew Walker Rappaport	(1977) (1977) (1977) (1977) (1977) (1977) (1977)	"New Math" has been misinterpreted. It was supposed to complement other methods not replace them. It does not do away with the need for drill, for example.
Walton et al.		Pupils do better with "new math" schemes, especially the brighter ones.
Kerr	(1977)	Teachers must understand the educational aims, when new ideas are introduced.
Rouse	(1977)	Even if aims are made clear, schools are extremely resistent to significant changes.
McCutcheon	(1977)	Criticises vocabulary of "new maths" as being verbose and unnecessary.

In general, the Observer noted that links between stages were assumed rather than spelt out. Teachers seemed to feel that if children could sort objects into twos, they would be able to count in twos, and if pupils could add two-digit numbers, they would have no difficulty with three-digit numbers. This does not appear to be the case. See Joffe (1978) for full review of the teaching of mathematics in schools.

Some general points seem worth mentioning:-

1. While most of the more recent teaching schemes try to integrate topics, Glenn (1978) suggests that for children with number difficulties, it may be a good idea to present spatial information separately, to provide an opportunity for a new start. He suggests that the synthesis into mathematics can come later.

2. Teachers reported that they knew of no children with specific school mathematical difficulties, in the age group $6\frac{1}{2}$-$8\frac{1}{2}$ years.

6.5 Assessment of School Mathematical Ability

All of the Head Teachers and Mathematics staff expressed concern about the lack of assessment techniques. Most of the schools had devised their own methods.

At the time that this study was undertaken (early 1977) there were basically two types of tests available:-

1. Those which were designed to provide a single score, a mathematics quotient, similar to an intelligence quotient, for example, Essential Mathematics (NFER,1976).
2. Those which were restricted to examination of performance in one aspect of the mathematics curriculum, for example those devised by Schonell + Schonell (1962) and Vernon & Miller (1976).

Tests in the categories mentioned above, usually sample one or two items from each topic in the syllabus, thus they cannot be used diagnostically. Further opinions on the assessment of school mathematical ability in young children can be found in Table 2.

TABLE 2: ASSESSMENT OF SCHOOL MATHEMATICAL ABILITY OF YOUNG CHILDREN

Burstall	(1977)	Highlights the need for testing mathematical knowledge in practical as well as written modes. He suggests that if this is not done, the mathematical abilities of some children, especially those at the lower end of the ability range and those with reading difficulties could be underestimated.
Fincham & Meltzer	(1976)	Consider that Piagetian tasks be used to assess conceptual thought in mathematics. It is also suggested that tests of this nature may be valuable diagnostic tools, especially for dyslexics.
Harris & Yawkey	(1977)	Stress the need for teachers to assess a child's developmental level. This was not an aspect that seemed to receive any attention in the schools visited in this study.
Jones	(1975)	Suggests that achievement tests may not give an adequate evaluation of a child's work, since they do not include measures of attitude or methods of working.
Burt	(1921)	Stated that formal testing with young children, to obtain measurable criteria is inconclusive.
Wrigley	(1958)	Maintains that if attainment tests are used, then what is measured is greatly dependent upon the teaching which children have received; we measure action rather than ability.
Vernon	(1961)	Gives an opposing viewpoint, when stating that external manifestations constitute reality and that one should not try to persuade oneself that something deeper is being studied.
Bell	(1977)	Advocates the use of different tests to assess various facets of the school mathematics syllabus.
De Bell & Vance	(1977)	Explored the relationship between three arithmetic tests all purporting to measure current academic performance (from the Peabody Individual Achievement Test, Wide Range Achievement test and WISC-R). All three measures yielded different levels of arithmetical achievement. These Writers point out, therefore that scores of this type may not be comparable or useful in psycho-educational assessment.
Krutetskii	(1976)	Condemns Western educators "fetishist treatment" of test results, and the absence of interest in studying the process itself.
Schonell & Schonell	(1962)	"Test performances represent complex resultants for the adequate interpretation of which one needs additional information, particularly on the qualitative side. One should not place too much relevance on an isolated test finding, educators."

6.6 The Development of LJ-1 Linear and LJ2-Spatial

Observation during "maths periods" had revealed that the range of tasks undertaken is enormous and extremely varied. On further examination it seemed unlikely that a unitary ability was involved in the mastery of mathematics, rather, a cluster of different skills seemed to be necessary. This confirmed similar findings by Krutetskii (1976).

At this time, it was decided to focus attention on the Top Infant and First Year Junior classes. This age range was chosen in an attempt to locate possible initial areas of failure. Few difficulties had been observed or reported amongst the younger children in the schools. In the $6\frac{1}{2}$-$8\frac{1}{2}$ year old group however, where more complex ideas were being introduced, different levels of performance were becoming apparent.

Despite the wide variation in presentation of material and subsequent questioning styles used in different schools, there appeared to be two core areas to all the syllabi; the first was concerned with number and arithmetic and seemed to require a linear, sequential, ordered orientation. The second involved knowledge and recognition of shapes and the manipulation of objects and seemed to require a spatial mode of thought. It was decided to concentrate on these aspects.

On a superficial level, it seemed feasible to propose that different types of cognitive processing might be required for the successful mastery of these linear and spatial aspects of the school mathematics curriculum. This proposition was central to the next stage of the investigation in which a comparison was to be made of dyslexics' performances on similar tasks. Research findings had suggested that dyslexics might be poor on sequential tasks (eg. Thomson, 1977) and competent or excellent on spatial items (Newton, 1974b). It was also hoped to relate the performances of the school and dyslexic groups respectively on the linear and spatial tasks, to their written language attainments.

At this time an extremely simplistic notion of hemispheric functioning was invoked and it was of interest to see whether discrepant scores on the two aspects of school mathematics under consideration could be indicative of hemispheric involvement; if a child scored highly on the "spatial" measure, it was proposed that this would suggest competent right hemisphere involvement and conversely, poor scores in arithmetic would point to an underfunctioning left hemisphere. (See Barakat, 1951 and Table 1 Chapter 3).

Since none of the standardised tests on the market at the time (of which the Writer was aware) seemed to provide sufficient detail of these central aspects, it was decided to devise instruments for this purpose, using the data gathered from observation in schools. It was hoped that these tests would be useful for diagnostic assessment.

LJ1-Linear was designed to assess knowledge of arithmetical operations, particularly addition and subtraction, and other aspects of number (relevant to a $6\frac{1}{2}$-$8\frac{1}{2}$ year old age group) which are symbolic and seem to require regular directional steps and an ordered, sequential approach, for their utilisation. (The complete test is included in Appendix 1).

LJ2-Spatial included items related to the identification and labelling of shapes, knowledge of symmetry and recognition of patterns (see Appendix 2).

The tests were a combination of items all of which had appeared in similar form in the most frequently utilised mathematics schemes.

An attempt was made to include as many different presentations of similar questions, to see whether the children's knowledge was adaptable and would generalise to unfamiliar formats.

For example in LJ1-Linear, addition is presented in the following ways:-

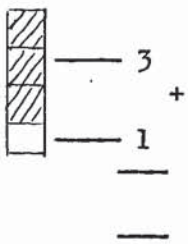
2 + 4 =

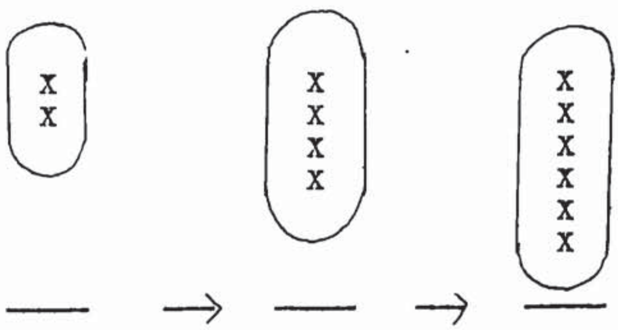
$$\begin{array}{r} 19 \\ \underline{-\ 9} \end{array}$$

What number is 5 more than 5?

X X X X X —— 5

0 0 0 —— ____





I counted on ____ each time

+4

3	9
6	10
5	6
2	7

0
0
0

3 add 2 —— ____

Partition/share these sets

____ + 4 = 6

5, ____ = 6

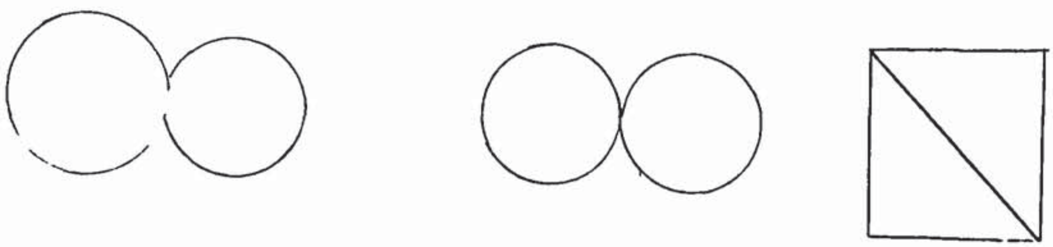
LJ2-Spatial included the following items:-

Continue these patterns:- /\/\/\/\ ______________

1 2 1 2 1 2 ______________

○ ▭ ○ ______________

Are these shapes symmetrical?



The matching of labels to the appropriate shapes was also included as was the identification of shapes, disguised in a picture.

The test items were purposely not graded by difficulty, with all the easier ones at the beginning of the test, in an attempt to prevent a negative "set" if a particular question proved too difficult.

Of course, it was realised that these tests of supposedly super-ordinate features of the school mathematics curriculum are not totally independent. They share aspects of memory and language which are mediating features of both. However, it was hoped that they would provide more insight into pupils' performances than had previously been available and also that some idea of the interrelationship with written language might become apparent.

6.7 Selection of Schools for Further Study

After the six-week period, the data that had been gathered was assessed. What emerged was the enormous variation in the types of schools, the practices used and the attitudes of children, staff and parents. It was decided to attempt to select what might be termed "average" schools (in the light of the available information) from which to draw experimental samples of children, for further study.

To this end, schools were eliminated if it was thought that any of the geographical, socio-economic or other variables were too intrusive. Consequently, schools whose children were achieving exceptionally high or exceptionally low standards, relative to the other schools and to what might be considered satisfactory for those grades, by the Science and Mathematics Centre staff, were eliminated.

Another school was eliminated because the Interviewer was not convinced that the children's poor knowledge of mathematical concepts was a reflection on their abilities. It seemed, rather, to be a result of lack of interest and motivation of the staff in that school. One teacher stated: "I was never much good at number, so I don't do much of it in the classroom."

Lack of sufficient children competent in English usage was another factor in the elimination process.

Having considered all these factors, six schools remained. It was decided to seek the assistance of three of them for further investigation.

The three schools used three basically different methods of teaching number, arithmetic and other mathematical concepts, although there was some overlap on certain topics. It was hoped that in this way, any possibility of a teaching method, as a main effect, would be eliminated. These schools also seemed comparable in terms of pupil population and socio-economic climate. The schools who agreed to co-operate were:-

1. School A, which used Towards Mathematics (Glenn & Sturgess, 1975). The pupils pace themselves using self-instruction booklets. The present Writer felt that this scheme was admirably suited to able students, but seemed a little complicated for slower learners. Children seemed to enjoy using this scheme.

2. School B adopted no one approach. Pupils are taught by the individual teacher's favoured method, though guidelines are given and progress monitored by the Head of the Mathematics Department. Strict progress record forms are kept for each child.

3. School C favoured Mathematics for Schools (Fletcher et al., 1970) (see Section 4). Teachers also teach tables and use some traditional "chalk and talk" techniques.

6.8 Summary and Conclusions

The Writer felt that the Pilot Study had been extremely valuable in emphasising the enormous variations in educational practice, which are often not mentioned when samples of children are selected for investigation of various tasks. The Writer endorses Krutetskii's (1976) view that Field Studies have an important contribution to make to psycho-educational research as they serve to complement more artificially controlled laboratory experiments.

To summarise, fourteen schools were visited over a six-week period, during which observations were made about geographical location, pupil population and attitudes to schooling of children, parents and teachers. Mathematics teaching methods and assessment techniques were reviewed. In the absence of an appropriate standardised format two tests, LJ1-Linear and LJ2-Spatial were devised to assess performance in two major aspects of the primary mathematics syllabus. Three schools, designated as "average" were selected for further study, which will be reported in Chapter 7.

CHAPTER 7

7. STUDY 1

AIMS

1. To select a Control sample for the Dyslexic Group.
2. To assess whether different teaching methods differentially affect attainments in school mathematics, in children between the ages of $6\frac{1}{2}$ and $8\frac{1}{2}$ years.
3. To investigate different areas of strengths and weaknesses within the Dyslexic and Control groups respectively, with respect to performance in school mathematics.
4. To investigate the relationship between measured intelligence and school mathematical performance.
5. To ascertain whether Dyslexics do relatively well at spatial tasks and relatively poorly at sequential aspects of the curriculum.

HYPOTHESIS

1. The attainments of Dyslexic subjects on LJ1-Linear, LJ2-Spatial and Mathematics Attainment A, will be independent of their intellectual potential.
2. Dyslexics will perform better on the spatial mathematics test relative to the Control Group, and relatively worse on those tests involving arithmetic and a large measure of sequencing.

7.1 Introduction

A primary aim of Study 1 was to investigate the relationship between measured intelligence and school mathematical performance, in dyslexic children and those without literacy difficulties. As mentioned in Chapter 2 Wrigley (1958) proposed that general intelligence was the most important component of mathematical ability. Thomson (1977) cites the work of Yule (1973) when stating that there is good evidence to expect that attainment in literacy should match intellectual potential, particularly in the middle ranges of intelligence. However, in the case of dyslexics Thomson (op.cit.) goes on to say:

> "it must be stressed that written language skills can be independent of intelligence."

Given that dyslexics have difficulties with written language, given the similarities between language and school mathematics as discussed in Chapter 5 and given the anecdotal reports of dyslexics' difficulties in aspects of the mathematics curriculum it seemed feasible to suppose that school mathematical attainments might also be independent of intellectual potential in these subjects. This leads to the formulation of the first hypothesis:-

Hypothesis 1: The attainments of dyslexic subjects on LJ1-Linear, LJ2-Spatial, and Mathematics Attainment A, will be independent of their intellectual potential.

It was also proposed that, given the apparent similarities between written language and arithmetic and the findings that dyslexics may excel at spatial mathematics (Newton, 1974b), dyslexics would perform better on the spatial test LJ-1 Spatial, than the Control group, and worse on LJ1-Linear and Mathematics Attainment A, a standardised mathematics test. So the second hypothesis was formulated.

Hypothesis 2: Dyslexics will perform better on the Spatial mathematics test relative to a Control Group and relatively worse on those tests involving arithmetic and a large measure of sequencing.

Before these hypotheses could be tested though, it was necessary to select a Control Group from the School sample. Consequently, the first part of the study is concerned with the examination of the performance of the three school groups. Of interest, is whether different teaching methods differentially affect attainments in this age range.

Method

Subjects:

School Sample

Using random number tables, 20 children were selected from each of the three schools chosen during the Pilot Study. All children met the following criteria; they were between the ages of $6\frac{1}{2}$ and $8\frac{1}{2}$ years of age; English was their home language and, in their teachers' opinions, they had no literacy or mathematical difficulties.
Children were selected from a number of different classes in each school. It was hoped that this would eliminate any teacher main-effect.

Dyslexics

A number of children awaiting assessment at the Language Development Unit of the University of Aston in Birmingham were invited to assist in this study. Of these, 20 children were selected as meeting the criteria for diagnosis as dyslexic, as proposed by Thomson (1977), viz.: all subjects were of average intelligence as measured on a standardised intelligence test; all performed at a level discrepant with their potential on tests of written language; characteristic

errors (omissions, substitutions, reversals, etc.) were a feature of their reading and spelling; and no known neurological defects or primary emotional disorders were present. Some of the children also had difficulty with left/right differentiation and common sequences (days of the week; months of the year).
The children in the dyslexic sample tended to be slightly older than the school group (range 7 years 0 month - 9 years 3 months) since individuals tend to present for diagnosis when they have been failing at school for two years or more.

Sex Differences

The literature review undertaken in Chapter 2 revealed that there is little evidence to suggest sex differences in school mathematical performance in children of this age. Consequently, no control was used for this factor, although it was realised that the ratio of males to females in the dyslexic population is about 3 or 4 to 1 (Rutter, 1978).

Tests used and the rationale for their selection

The psychometric assessment procedure followed for all subjects used to diagnose dyslexia (Thomson, 1977). The tests used supply basal measures of general ability and scholastic attainments in children. Also included were tests of mathematical performance. Each test will be described below.

<u>The Wechsler Intelligence Scale for Children - Revised Version (WISC-R)</u> (Wechsler, 1974) was used because it yields a minimum measure of overall intellectual potential, which is reflected in the Full Scale Score. It also yields a subtest profile, the scatter of which gives some indication of the individual's weaknesses and strengths on the

tasks measured. These are thought to relate to some aspects of school performance. All subtests were administered except the mazes. Any children who scored below 90 on the Full-, Verbal-, or Performance Scales were eliminated from the sample.

The Schonell Graded Word Reading Test (Schonell, 1940) was used as a gross measure of reading ability. Whilst the limitations of word recognition tests as measures of reading ability are noted, this test was considered adequate for the purposes of this study, since reading was not the central issue. Lunzer, Wilkinson & Dolan (1976) report correlations of .954 on this test with the Accuracy Score of the Neale Analysis of Reading Ability (Neale, 1966). Thus the former was adopted because it is quicker to administer.

The Schonell Graded Spelling Test (Schonell, 1942) was used to assess spelling performance.

LJ1-Linear (described in the Pilot Study - see Appendix 1) was used to assess performance in arithmetic and other number-related tasks. Subjects were given a "hundred square" and a number line to assist them (see Appendix 1A).

LJ2-Spatial (see Appendix 2) was administered to assess performance in those aspects of the curriculum involving knowledge of shape, pattern and spatial relationships.

Mathematics Attainment A (NFER, 1970), a standardised test was used as a measure of school mathematical attainment. It was also used as a yardstick against which to compare LJ1-Linear and LJ2-Spatial. The shortcomings of this type of test have been mentioned in the Pilot Study.

Left/Right Differentiation

Subjects were asked to differentiate between left and right in relation to themselves and to the tester, on a number of tasks.

Common Sequences

Subjects were asked to name the days of the week and the months of the year, in order.

Testing

In schools, the tester was allocated a room in which all testing took place. Children were withdrawn from their classrooms to participate in the project. Dyslexics were tested at the Language Development Unit.

The subjects were told that the Experimenter was writing a book about the way children think and very much needed their help. This was also explained to their classmates, so as to avoid any unkind comments as to the reason for their frequent withdrawal from the classroom. The total testing time spent with each child was estimated at 5 hours. However, this comprised a number of short sessions, normally 15-20 minutes, except for the WISC-R, which took 45 minutes to an hour to administer.

The children's attitudes towards the testing situation remained favourable throughout. Only one child out of the school group seemed a bit unhappy at times, though she neither refused to participate nor chose to leave, when offered the opportunity.

The WISC-R, Schonell Reading and Spelling Test were administered individually. Parts of the mathematics tests were administered in groups of up to five children. Questions that required reading were administered individually if a child was thought to be having difficulty. All papers were checked individually with each child to ensure that any questions that had been left out had not been omitted through carelessness or misunderstanding. These sessions were also used to encourage subjects to verbalise how they had arrived at a particular solution.

Scoring of Tests

Tests were scored according to the appropriate manual guidelines. LJ1-Linear and LJ2 Spatial were marked using a schedule devised by the Experimenter.

Four subjects from the Dyslexic Group and seven from the Control Group had to be eliminated at this stage. Some had scored well below 90 on the WISC-R and others had not completed all tests because of absence from school.

7.2 Results and Discussions

The results and discussions for each part of the study will be presented separately.

See Appendix 3A-D.

Results A - Analysis of Variance (AOV)

Mean values were computed for all variables for schools A, B and C. (See Table 1).

Analysis of Variance (AOV) using a completely randomised design was carried out using the PET Commodore terminal and AOV programme available in the Department of Educational Enquiry at the University of Aston in Birmingham. The differences between the following variables were investigated; Full Scale WISC-R Scores, Schonell Reading score and results of LJ1-Linear, LJ2-Spatial and Maths Attainment A. The AOV summary tables are listed in Table 2.

A Tukey Multiple Comparison of Means was carried out on LJ1-Linear:

Comparison	(3,57)	
C with A	5.90	$p < .05$
C with B	5.42	$p < .05$
A with B	0.57	NS

School C yielded significantly higher scores on this test than either Schools A or B, whose means did not differ from one another.

TABLE 1: MEAN SCORES FOR SCHOOLS A, B AND C

VARIABLES	A	B	C
Full Scale	97,2	94,2	102,2
Verbal	95,85	96,5	104,65
Performance	99,6	92,7	99,45
Information	7,9	7,8	9,7
Similarities	8,55	9,35	10,05
Arithmetic	9,0	9,6	11,2
Vocabulary	11,25	10,7	11,25
Comprehension	9,9	10,05	11,9
Digit Span	8,45	8,85	9,1
Picture Completion	9,45	9,0	9,1
Picture Arrangement	9,2	8,7	9,7
Block Design	11,1	9,2	10,05
Object Assembly	10,85	8,85	9,8
Coding	9,25	9,2	10,5
Schonell Reading	7,416	7,96	8,07
Schonell Spelling	7,036	7,988	7,971
Linear	71,525	75,425	91,975*
Spatial	33,075	33,9	35,642
Mathematics Attainment A	94,45	54,55	99,2

TABLE 2: AOV SUMMARY TABLE

Source	Proportion of Variation	df	F	$p < .05$
Explanation by measured IQ	0.07	2	2.23	NS
Residual	0.93	57		
Explanation by Schonell Reading	0.06	2	1.98	NS
Residual	0.94	57		
Explanation by LJ1-Linear	0.28	2	10.91	$p < .001$
Residual	0.72	57		
Explanation by LJ2-Spatial	0.05	2	1.43	NS
Residual	0.95	57		

Discussion A

The finding that most of the test scores were not significantly different, seems to suggest that, for the most part, the teaching method and workschemes used do not influence attainments on the tests used.

Re-examination of LJ-Linear revealed that it did, in fact, include a large proportion of "Fletcher"-type notation. This would bias it toward School C, who were using the "Fletcher Math" scheme and consequently account for their superior performance on this test.

Further discussion about LJ1-Linear and children's test performances will follow in this chapter.

B. Comparison of Dyslexic and Control Groups

The aim of this investigation was to ascertain if there were differences in performance of Dyslexic children and Controls, that might give initial information related to their school mathematics attainments.

Having ascertained that there was only one significant difference among the maths scores of the three school groups, 16 subjects from the joint sample (N = 53) were selected to act as Controls for the Dyslexic Group. Controls were matched for Full Scale Intelligence Quotient. It was decided to include pupils from School C in the Control Group, where appropriate, despite their superior performance on LJ1-Linear because some of the Dyslexic Group were also using the "Fletcher Maths" scheme.

Results B

T-tests were computed using the Statistical Package for the Social Sciences (SPSS) (Nie et al., 1970) in a 1904S (George 3) computer. Few significant differences were found (see Table 3).

Discussion B

From these findings it can be seen that the Dyslexic Group's comprehension score is significantly better at the 5% level of significance. The Dyslexics did worse, though, on both the Schonell Reading Test ($p < .02$) and the Schonell Spelling Test ($p < .001$). This contributes additional support to the general finding that dyslexics' written language attainments are poor relative to similar aged Controls, despite adequate conceptual abilities.

The Dyslexic Group's relatively poor performance on the Arithmetic subtest is also a fairly well-documented feature of their WISC profiles (Fincham & Meltzer, 1976; Thomson & Grant, 1979). No significant differences were found between the mean scores of the two groups for any of the school mathematics measures. Consequently, the second hypothesis must be rejected, for these samples at least, that is, that no support was provided, in this study, to support the notion that Dyslexics perform better on mathematics tests involving spatial elements than similarly aged Controls. No support was found either, for relatively deficient performance in the Dyslexic on ordered, sequential, arithmetical items.

Through observation of subjects while working and analysis of errors, it was found, however, that Dyslexics tended to approach some items in a different way, compared with most of the Control subjects. (This will be discussed further in this chapter).

TABLE 3: t-TEST RESULT FOR DYSLEXICS AND CONTROLS

Group 1 - Controls: N = 16
Group 2 - Dyslexics: N = 16

Variable		Mean	s.d.	t value	2 tailed probability
Age	1 2	7.9 8.2	.5 .6	-1.82	NS (at less than 5% level)
Full Scale (WISC)	1 2	100.6 101.6	13.3 13.3	-0.21	NS
Verbal Scale	1 2	100.9 102.9	11.7 15.5	-0.41	NS
Performance Scale	1 2	100.3 99.8	15.2 12.0	0.10	NS
Information	1 2	8.4 8.0	2.8 2.4	0.48	NS
Similarities	1 2	9.8 11.3	2.0 4.1	-1.26	NS
Arithmetic	1 2	10.1 8.4	2.6 2.1	2.12	$p < 0.04$
Vocabulary	1 2	11.4 11.6	2.6 3.5	-0.17	NS
Comprehension	1 2	11.0 13.1	2.5 3.5	-2.03	$p < 0.05$
Digit Span	1 2	8.3 6.8	2.7 3.2	1.31	NS
Picture Completion	1 2	10.0 10.3	1.9 2.3	-0.42	NS
Picture Arrangement	1 2	9.6 9.0	2.9 2.9	0.60	NS
Block Design	1 2	11.0 11.1	3.0 3.3	-0.11	NS
Object Assembly	1 2	11.1 10.6	3.2 3.0	0.45	NS
Coding	1 2	8.7 8.2	3.7 2.9	0.43	NS
Schonell Reading	1 2	7.9 7.1	1.0 0.8	2.39	$p < 0.02$
Schonell Spelling	1 2	7.8 6.1	1.5 0.8	4.03	$p < 0.001$

TABLE 3 CONT'D.

Variable		Mean	s.d.	t value	2 tailed probability
LJ1-Linear	1	79.7	17.6	0.54	NS
	2	76.5	15.5		
LJ2-Spatial	1	34.8	4.3	-0.99	NS
	2	36.2	3.4		
Mathematics	1	95.7	12.2	1.08	NS
Attainment A	2	91.3	11.1		

As a result of this noted seemingly different approach, it was decided to investigate the correlations between various aspects of the children's performances.

C. Spearman Rank Correlations

In order to investigate whether any qualitative differences could be found, which would explain the observed differential approaches of Dyslexics and Controls to school mathematical items, it was decided to examine the correlations between the data collected initially.

Results C (See Table 4)

Using the SPSS programme (Nie et al., op.cit.) Spearman rank correlation coefficients were computed for all variables, for three subject groups; the full school sample (N = 53), the dyslexics (N = 16) and the matched control group (N = 16). Arguably, the full school sample would be more representative of the general school population than the matched group of 16 Controls, but both were included to see if correlational differences emerged.

For a correlation of this type to reach significance at the .05 and .01 levels, in a sample of 16 subjects, the critical values of the coefficients (^{r}s) must equal or exceed .425 and .6 respectively (Siegel, 1956). If correlations of this magnitude are not found, then there is little or no relationship between those variables being compared. However, in small samples especially, there is the possibility that individual variations could minimise the strength of a relationship that might be significant in a larger population. It seems important that this be kept in mind when interpreting the results in this section.

TABLE 4: SPEARMAN RANK CORRELATION COEFFICIENTS FOR THREE SUBJECT GROUPS

		AGE CON	AGE SIG	SEX CON	SEX SIG	FULL CON	FULL SIG	VERBAL CON	VERBAL SIG	PERFORM CON	PERFORM SIG	INFORMATION CON	INFORMATION SIG	SIMILARITIES CON	SIMILARITIES SIG	ARITHMETIC CON	ARITHMETIC SIG	VOCABULARY CON	VOCABULARY SIG	COMPREHENSION CON	COMPREHENSION SIG	DIGIT SPAN CON	DIGIT SPAN SIG
AGE	F																						
	D																						
	M																						
SEX	F	-0.1	.255																				
	D	-0.18	.315																				
	M	0.15	.337																				
FULL	F	-0.06	.334	0.21	.78																		
	D	0.49	.077	-0.17	.315																		
	M	0.36	.152	-0.08	.416																		
VERBAL	F	-0.06	.341	0.13	.185	0.80	.001																
	D	0.26	.231	-0.30	.195	0.90	.001																
	M	0.14	.346	-0.34	.165	0.78	.004																
PERFORM	F	-0.06	.339	0.21	.073	0.85	.001	0.42	.002														
	D	0.47	.089	-0.09	.405	0.95	.001	0.79	.003														
	M	0.60	.043	0.15	.337	0.86	.001	0.50	.073														
INFORMATION	F	0.06	.339	0.05	.361	0.52	.001	0.64	.001	0.26	.035												
	D	0.13	.363	-0.28	.216	0.67	.017	0.74	.007	0.65	.020												
	M	0.24	.254	-0.23	.260	0.45	.098	0.51	.066	0.51	.066												
SIMILARITIES	F	-0.14	.167	-0.05	.370	0.58	.001	0.72	.001	0.33	.011	0.26	.040										
	D	0.05	.446	-0.18	.313	0.73	.008	0.79	.003	0.56	.048	0.37	.148										
	M	-0.02	.482	-0.45	.097	0.66	.019	0.77	.004	0.26	.237	0.03	.464										
ARITHMETIC	F	-0.09	.278	0.08	.292	0.60	.001	0.70	.001	0.22	.065	0.65	.001	0.27	.032								
	D	0.15	.340	-0.74	.007	-0.08	.409	-0.09	.408	-0.12	.367	-0.22	.269	-0.12	.373								
	M	-0.16	.330	-0.36	.155	0.15	.338	0.65	.021	0.13	.357	0.52	.061	0.45	.095								
VOCABULARY	F	-0.04	.401	0.23	.056	0.63	.001	0.71	.001	0.36	.006	0.29	.025	0.54	.001	0.25	.047						
	D	0.25	.245	0.26	.232	0.29	.003	0.83	.001	0.73	.008	0.66	.019	0.55	.048	0.02	.479						
	M	0.29	.207	-0.20	.292	0.85	.001	0.70	.013	0.60	.033	0.10	.396	0.77	.005	0.05	.446						
COMPREHENSION	F	0.26	.038	0.13	.193	0.56	.001	0.64	.001	0.39	.003	0.25	.044	0.48	.001	0.31	.016	0.42	.001				
	D	0.55	.048	-0.22	.272	0.74	.001	0.75	.006	0.64	.023	0.41	.118	0.54	.055	0.04	.457	0.44	.104				
	M	0.15	.337	-0.19	.296	0.83	.001	0.82	.002	0.55	.049	0.12	.375	0.88	.001	0.28	.213	0.91	.001				
DIGIT SPAN	F	-0.24	.054	0.06	.345	0.13	.189	0.06	.342	0.17	.125	0.06	.338	0.09	.275	0.07	.326	0.09	.267	0.02	.442		
	D	0.26	.284	-0.62	.070	0.90	.003	0.61	.072	0.96	.001	0.53	.109	0.34	.226	0.67	.048	0.44	.0	0.53	.112		
	M	0.13	.360	0.08	.416	0.81	.002	0.68	.025	0.74	.008	0.53	.060	0.52	.060	0.30	.201	0.67	.018	0.74	.007		
PICTURE COMPLETION	F	-0.24	.054	0.06	.339	0.42	.002	0.57	.005	0.38	.004	0.11	.237	0.54	.001	-0.02	.443	0.43	.001	0.23	.062	0.24	.049
	D	0.17	.319	-0.14	.335	0.56	.047	0.56	.047	0.60	.033	0.48	.115	0.44	.100	-0.13	.356	0.28	.213	0.39	.136	0.06	.452
	M	-0.11	.385	0.08	.415	0.59	.037	0.59	.030	0.46	.089	0.00	.500	0.42	.113	-0.61	.493	0.52	.064	0.60	.033	0.44	.100
PICTURE ARRANGEMENT	F	0.03	0.07	.330	0.59	.001	0.25	0.25	.045	0.71	.001	0.54	.241	0.24	.055	0.17	.126	0.24	.050	0.25	.041	-0.01	.472
	D	0.85	.179	-0.21	.292	0.88	.001	0.61	.018	0.86	.002	0.31	.205	0.82	.003	0.09	.406	0.48	.094	0.70	.018	0.81	.025
	M	0.88	.001	0.12	.369	0.69	.035	0.313	.189	0.71	.010	0.36	.157	0.22	.272	-0.90	.489	0.39	.130	0.35	.163	0.34	.171
BLOCK DESIGN	F	-0.02	.439	0.35	.008	0.62	.001	0.36	.007	0.76	.001	0.29	.022	0.24	.050	0.22	.063	0.34	.009	0.23	.059	0.22	.071
	D	0.84	.001	0.09	.404	0.80	.071	0.30	.200	0.51	.066	0.29	.205	0.09	.405	0.01	.493	0.50	.200	0.39	.036	0.14	.230
	M	0.32	.182	0.46	.089	0.18	.308	-0.02	.485	0.46	.092	0.49	.076	-0.25	.243	0.03	.465	-0.12	.372	-0.12	.348	0.43	.080
OBJECT ASSEMBLY	F	-0.09	.205	0.33	.012	0.59	.001	0.32	.014	0.66	.001	0.27	0.32	0.21	.077	0.09	.273	0.32	.012	0.34	.008	0.16	.144
	D	0.56	.047	-0.66	.019	0.53	.057	0.49	.074	0.53	.067	0.80	.013	0.10	.389	0.29	.211	0.46	.093	0.50	.071	0.74	.028
	M	0.41	.123	0.19	.298	0.90	.001	0.59	.036	0.92	.001	0.54	.053	0.28	.216	-0.01	.490	0.62	.028	0.57	.044	0.72	.010
CODING	F	-0.01	.470	-0.18	.106	0.29	.022	0.09	.275	0.40	.002	0.18	.113	-0.02	.436	0.18	.110	-0.14	.172	0.23	.057	0.09	.293
	D	-0.51	.065	0.35	.158	-0.82	.002	-0.71	.011	-0.84	.001	-0.66	.019	-0.45	.094	-0.03	.464	-0.64	.024	-0.70	.012	-0.88	.004
	M	0.55	.050	0.04	.457	0.57	.042	0.16	.332	0.82	.002	0.18	.315	0.10	.391	-0.49	.075	0.41	.122	0.30	.198	0.38	.139
SCHONELL READING	F	0.12	.211	0.12	.203	0.26	.039	0.30	.019	0.14	.169	0.38	.004	0.13	.197	0.23	.054	0.15	.148	0.19	.096	0.14	.167
	D	0.54	.053	0.00	.500	0.37	.147	0.26	.232	0.35	.159	0.42	.112	-0.09	.400	-0.01	.493	0.52	.062	0.07	.420	0.20	.385
	M	0.74	.007	-0.31	.196	0.67	.018	0.46	.093	0.71	.011	0.47	.086	0.30	.200	-0.04	.458	0.51	.065	0.35	.163	0.27	.221
SCHONELL SPELLING	F	0.163	.135	0.01	.475	0.10	.250	0.22	.071	-0.03	.422	0.78	.030	0.04	.399	0.23	.057	0.12	.215	0.14	.467	0.13	.191
	D	0.48	.082	0.22	.272	0.37	.146	0.14	.349	0.44	.100	0.34	.166	-0.17	.323	-0.07	.429	0.36	.153	0.83	.463	0.16	.364
	M	0.71	.011	-0.34	.167	0.46	.090	0.31	.196	0.47	.083	0.35	.160	0.30	.201	0.03	.465	0.33	.173	0.19	.304	0.10	.393
LINEAR	F	0.37	.004	0.27	.031	0.41	.002	0.42	.001	0.31	.015	0.54	.001	0.06	.333	0.59	.001	0.06	.341	0.42	.002	0.01	.468
	D	0.33	.190	-0.10	.396	0.23	.273	0.03	.466	0.38	.159	0.14	.362	-0.42	.132	0.47	.101	0.34	.188	0.11	.390	0.75	.042
	M	0.46	.092	0.27	.229	0.33	.174	0.10	.401	0.56	.046	0.63	.025	-0.08	.415	0.17	.325	0.01	.443	0.04	.460	0.54	.053
SPATIAL	F	0.16	.138	0.18	.105	0.54	.001	0.53	.001	0.40	.002	0.51	.001	0.32	.013	0.42	.002	0.40	.002	0.29	.022	0.15	.154
	D	0.40	.180	-0.48	.079	0.18	.306	0.15	.339	0.28	.218	0.31	.188	0.30	.200	0.42	.112	0.24	.253	0.39	.133	0.98	.137
	M	0.73	.010	0.27	.229	0.78	.004	0.52	.062	0.83	.001	0.35	.179	0.42	.112	0.05	.445	0.64	.024	0.64	0.24	0.73	.009
MATHS ATTAINMENT	F	-0.05	.310	0.32	.014	0.65	.001	0.59	.001	0.53	.001	0.45	.001	0.27	.032	0.80	.001	0.48	.001	0.30	.020	0.18	.113
	D	0.20	.286	-0.57	.060	0.25	.244	0.16	.327	0.38	.143	0.34	.166	-0.23	.263	0.62	.029	0.45	.096	0.07	.423	0.68	.046
	M	0.39	.130	0.12	.376	0.69	.013	0.55	.048	0.57	.042	0.56	.045	0.39	.131	0.35	.164	0.55	.050	0.45	.097	0.70	.03

TABLE 4: SPEARMAN RANK CORRELATION COEFFICIENTS FOR THREE SUBJECT GROUPS

		PICTURE COMPLETION		PICTURE ARRANGEMENT		BLOCK DESIGN		OJECT ASSEMBLY		CODING		SCHONELL READING		SCHONELL SPELLING		LINEAR		SPATIAL		MATHS ATTAINMENT	
		CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG	CON	SIG
AGE	F																				
	D																				
	M																				
SEX	F																				
	D																				
	M																				
FULL	F																				
	D																				
	M																				
VERBAL	F																				
	D																				
	M																				
PERFORM	F																				
	D																				
	M																				
INFORMATION	F																				
	D																				
	M																				
SIMILARITIES	F																				
	D																				
	M																				
ARITHMETIC	F																				
	D																				
	M																				
VOCABULARY	F																				
	D																				
	M																				
COMPREHENSION	F																				
	D																				
	M																				
DIGIT SPAN	F																				
	D																				
	M																				
PICTURE COMPLETION	F																				
	D																				
	M																				
PICTURE ARRANGEMENT	F	0.11	.224																		
	D	0.45	.111																		
	M	-0.04	.456																		
BLOCK DESIGN	F	0.22	.072	0.32	.012																
	D	0.14	.346	0.21	.297																
	M	-0.09	.404	0.32	.187																
OBJECT ASSEMBLY	F	0.33	.011	0.34	.009	0.50	.001														
	D	0.17	.322	0.40	.146	0.48	.079														
	M	0.57	.044	0.60	.034	0.32	.185														
CODING	F	-0.08	.298	0.26	.037	-0.04	.397	-0.08	.302												
	D	-0.26	.230	-0.82	.003	-0.46	.093	-0.80	.003												
	M	0.40	.125	0.55	.049	0.37	.150	0.60	.034												
SCHONELL READING	F	-0.01	.473	0.09	.277	0.07	.322	0.16	.145	0.15	.151										
	D	0.11	.378	-0.18	.323	0.68	.015	0.36	.153	-0.16	.323										
	M	0.19	.299	0.76	.005	0.18	.313	0.62	.028	0.71	.011										
SCHONELL SPELLING	F	-0.10	.246	-0.09	.488	-0.02	.453	0.03	.413	0.10	.256	0.88	.001								
	D	0.21	.282	-0.04	.457	0.71	.011	0.23	.258	-0.15	.395	0.90	.001								
	M	-0.50	.446	0.72	.009	0.22	.269	0.35	.163	0.56	.065	0.92	.001								
LINEAR	F	-0.23	.050	0.27	.032	0.36	.007	0.23	.058	0.26	.040	0.25	.046	0.20	.099						
	D	0.18	.323	0.05	.454	0.56	.058	0.24	.264	-0.18	.323	0.53	.070	0.73	.013						
	M	-0.32	.185	0.62	.027	0.81	.002	0.42	.113	0.31	.190	0.31	.192	0.33	.173						
SPATIAL	F	0.13	.199	0.32	.013	0.41	.002	0.13	.194	0.10	.252	0.51	.001	0.34	.008	0.38	.009				
	D	-0.17	.319	0.28	.234	0.44	.104	0.463	.005	0.62	.027	0.12	.305	0.07	.427	0.46	.106				
	M	0.29	.211	0.82	.002	0.53	.058	0.71	.011	0.63	.027	0.61	.029	0.53	.069	0.62	.027				
MATHS ATTAINMENT	F	0.14	.171	0.43	.001	0.52	.001	0.53	.001	0.002	.494	0.29	.022	0.23	.061	0.52	.001	0.35	.004		
	D	-0.004	.490	0.27	.239	0.28	.213	0.61	.030	-0.46	.091	0.37	.150	0.39	.134	0.77	.008	0.75	.007		
	M	0.12	.368	0.51	.066	0.58	.041	0.63	.025	0.22	.276	0.51	.066	0.50	.073	0.59	.037	0.7	0		

Comparison of the matrices seems to indicate that there are highly significant correlations between the Full Scale WISC scores and the Verbal and Performance scores for all groups respectively ($p < .001$ for all correlations except for the Controls' Full/Verbal correlation which is significant at $p < .004$). There are also many measures which yielded no correlational relationship that seem worthy of further consideration. Correlations that will be mentioned will be those where a similar and sufficiently large amount of the variance seems to have been accounted for and which are statistically significant; and correlations that are different for dyslexics and controls. The 5% level of significance will be the highest acceptable in this discussion and the .001 level will be the lowest probability considered. Most attention will be paid to the correlations involving school mathematics, however, some other general findings will be discussed briefly.

Discussion C

Dyslexics - General Findings

One of the primary features of dyslexia is that literacy attainments are independent of intellectual potential (Thomson, 1977). This finding is borne out again in the present study where no significant correlations were found for Full Scale, Verbal or Performance with Schonell Reading or Spelling respectively. Since subjects were selected using average IQ or above as a criterion, this marks the difference between specific retardation and general reading (and literacy) retardation (see Yule, 1973). In the latter case it would be expected that a lower level of measured intelligence would be associated with poor reading attainments and that these would be significantly correlated.

Thomson & Grant (1979) and others mention that dyslexics score relatively poorly on Information and Arithmetic. The correlation with their Full Scale IQ score for the former was significant at the 2% level for the dyslexics whilst the School Sample yielded a high correlation ($p < .001$). The correlation coefficient for arithmetic was extremely small for dyslexics. The School sample's relationship was highly related to general intelligence ($p < .001$).

Coding, also an area of weakness in the dyslexic's WISC profile, correlated negatively with all the other measures. High negative correlations were recorded against Full Scale IQ ($p < .002$), Performance Scale ($p < .001$), Picture Arrangement and Object Assembly ($p < .003$ for both) and Digit Span ($p < .004$). Lower significant negative relationships were found for Verbal IQ ($p < .01$), Information and Comprehension ($p < .02$), Vocabulary ($p < .03$). No significant negative correlations were found in the Control Groups.

These findings are generally supportive of studies reported in the literature (see Newton et al., 1979). Further implications of these findings are included in the sections that follow.

Correlations Involving School Mathematics

Tables 5, 6 and 7 list the correlation coefficients and significance levels for LJ1-Linear, LJ2-Spatial and Mathematics Attainment A respectively.

TABLE: 5 : LJ1-LINEAR

	School		Control		Dyslexic	
	r_s	p	r_s	p	r_s	p
Full Scale	.4	.002	.3	NS	.2	NS
Verbal Scale	.4	.001	.09	NS	.03	NS
Performance Scale	.3	.02	.6	.05	.4	NS
Information	.5	.001	.6	.03	.1	NS
Similarities	.06	NS	-.08	NS	-.4	NS
Arithmetic	.6	.001	.2	NS	.5	NS
Vocabulary	.06	NS	.4	NS	.006	NS
Comprehension	.4	.002	.04	NS	.1	NS
Digit Span	.01	NS	.5	.05	.8	.04
Picture Completion	-.2	.05	-.3	NS	.2	NS
Picture Arrangement	.3	.03	.6	.03	.05	NS
Block Design	.4	.007	.8	.002	.6	NS*
Object Assembly	.2	NS*	.4	NS	.2	NS
Coding	.3	.04	-.3	NS	-.2	NS
Schonell Reading	.3	.05	.3	NS	.5	NS*
Schonell Spelling	.2	NS*	.3	NS	.7	.01

*Approaching significance at the 5% level.

TABLE 6 : LJ2-SPATIAL

	School		Control		Dyslexic	
	r_s	p	r_s	p	r_s	p
Full Scale	.5	.001	.2	NS	.7	.004
Verbal Scale	.5	.001	.2	NS	.5	NS*
Performance Scale	.4	.002	.3	NS	.8	.001
Information	.5	.001	.3	NS	.3	NS
Similarities	.3	.01	.4	NS	-.3	NS
Arithmetic	.4	.002	.4	NS	.05	NS
Vocabulary	.4	.002	.2	NS	.6	.02
Comprehension	.3	.02	.6	.02	.4	NS
Digit Span	.2	NS	.7	.009	.5	NS
Picture Completion	.1	NS	-.2	NS	.3	NS
Picture Arrangement	.3	.01	.3	NS	.8	.002
Block Design	.4	.002	.4	NS	.5	NS*
Object Assembly	.1	NS	.7	.01	.8	.005
Coding	.1	NS	.6	.03	-.6	.03
Schonell Reading	.5	.001	.6	.03	.1	NS
Schonell Spelling	.3	.008	.5	NS*	.06	NS
Linear	.4	.004	.6	.03	.5	NS

*Approaching significance at the 5% level.

TABLE 7 : MATHEMATICS ATTAINMENT A

	School		Control		Dyslexic	
	r_s	p	r_s	p	r_s	p
Full Scale	.7	$p < .001$	.7	$p < .01$	.3	NS
Verbal Scale	.9	.001	.6	$p < .05$	.2	NS
Performance Scale	.5	.001	.6	$p < .04$	.4	NS
Information	.5	.001	.7	.05	.3	NS
Similarities	.3	.03	.4	NS	-.2	NS
Arithmetic	.6	.001	.4	NS	.6	.03
Vocabulary	.5	.001	.6	.05	.5	NS
Comprehension	.3	.02	.5	NS	.07	NS
Digit Span	.2	NS	.7	.01	.7	.05
Picture Completion	.1	NS	.1	NS	-.009	NS
Picture Arrangement	.4	.001	.5	NS*	.3	NS
Block Design	.5	.001	.6	.04	.3	NS
Object Assembly	.5	.001	.6	.03	.6	.03
Coding	.002	NS	.2	NS	-.5	NS
Schonell Reading	.3	.02	.5	NS*	.4	NS
Schonell Spelling	.2	NS*	.5	NS*	.4	NS
Linear	.5	.001	.6	.04	.7	.008
Spatial	.4	.004	.7	.01	.8	.007

*Approaching significance at the 5% level.

Full-, Verbal- and Performance Scales - WISC-R

Generally, high correlations are found, for the School Sample for all the mathematics tests against Full-, Verbal- and Performance-Scale scores of the WISC-R, with only one correlation (LJ1-Linear with Performance) being less significant than $p < .002$. This suggests that there is an extremely strong relationship between mathematics attainment and measured intellectual potential in a school population with no known learning difficulties.

The Dyslexic Sample yielded a totally different pattern of scores; no relationship was found among Mathematics Attainment A or LJ1-Linear and Full-Scale, Verbal and Performance IQs respectively, suggesting that Dyslexic's performances in mathematics do not relate to their measured intelligence. Since both these tests include large computational components this notion would support the findings of Fincham and Meltzer (1976) and Klees (1976) who reported the relatively poor scoring of dyslexics in tests of arithmetic. However, again it must be stressed in a sample of this size, individual differences could play a large part - the result perhaps of unwittingly biased sample selection.

LJ2-Spatial yielded higher r_s values, for the Dyslexics; with the Full- and Performance Scale scores the relationships were significant at the .004 and .001 levels respectively. Thus, if LJ2-Spatial is measuring a Spatial factor, as was intended in its design, this spatial component seems to be strongly related to that utilised for Performance Scale items, as suggested by Bannatyne (1971), for example. The matched Control sample yielded lower significant relationships than the School sample for Mathematics Attainment A and Performance with LJ1-Linear. Other scores did not reach significance at the 5% level.

<u>The Arithmetic subtest</u> of the WISC was highly correlated with scores on all the mathematics tests, for the School sample, the lowest significance level being $p < .002$. In the Dyslexic group, Arithmetic was found to be related to Mathematics Attainment A only ($p < .03$). This suggests, perhaps, that there is a specific skill that might be needed in both. The Writer contends that, in this case, the specific skill could be short-term memory (S-T memory). The reason for this proposal is that, unlike LJ--Linear and LJ2-Spatial, in which questions and answers are on the same sheet of paper, in the case of Mathematics Attainment A, the child is only given an answer sheet; all questions are presented orally, and although instructions can be repeated, the child does not have written information to which to refer. This would seem to place a load on S-T memory; an area of weakness for Dyslexics (Thomson & Wilsher, 1978). Thomson & Grant (1979) suggest that Dyslexics score poorly on the Arithmetic subtest because of poor S-T recall. Thus it seems reasonable to propose this link, since neither of the other mathematics tests seemed to require as much S-T facility.

<u>Digit Span</u>

The dyslexics' Digit Span scores are significantly related to LJ1-Linear ($p < .04$) and Mathematics Attainment A ($p < .05$). It could be that sequential memory for digits is important in these tests since they both include a large number of calculations and arithmetical sequences. Similar correlational findings for this subtest pertain to the Control group. The School sample coefficients are extremely small. This suggests that Digit Span scores are not related to performance on either LJ1-Linear or Mathematics Attainment A. In the case of LJ1-Linear, the r_s value of .01, may be indicative of the fact that the children wrote down all their working out and did not rely on memory. This explanation would not appear to be sufficient in explaining the lack of relationship with Mathematics Attainment A though. The significance of this finding is unknown.

Coding

The Coding subtest yielded negative coefficients for the Dyslexic Group for all the mathematics tests, though only one reached statistically significant level. Equal but opposite relationships were found between Coding and LJ2-Spatial, for the Dyslexic and Control Groups. For the former $r_s = -.6$, and for the latter $r_s = .6$. This finding suggests that in the Control group, the processes associated with Coding (such as "the ability to recognise and memorise symbols and arbitrary associations at speed, visual and motor co-ordination, and the capacity to sustain a concentrated attentional effort on a routine task" - Thomson & Grant (1979), are being utilised whereas in the case of Dyslexics, they may be hindering performance on LJ2-Spatial. The implication here seems to be that Dyslexics and Controls are using totally different solution strategies.

One possible explanation may relate to neuropsychological findings:-
If one considers Bruner's (1966) report that most teaching in schools is biased toward an analytical mode (a reportedly left hemisphere (LH) skill) together with Franco & Sperry's (1977) finding that spatial tasks (especially those involving familiar Euclidean geometric shapes) can be efficiently mediated by the LH, then it is possible that, given the nature of the Coding task, the Control children are using a predominantly analytical mode to solve spatial problems. This might account for the reasonably high positive relationship between Coding and LJ2-Spatial.

In the case of Dyslexics, whose Coding skills are known to be poor (eg. Thomson, 1977), solution of items included in LJ2-Spatial may have relied on a more spatial approach, a possible area of strength in dyslexics (eg. Bannatyne, 1971). This explanation may be reinforced by the high correlation between the mathematics test and Object Assembly ($p < .005$), though the Block Design score only approaches significance.

Similarities

The Dyslexic group yielded negative (though non-significant) relationships with the Similarities subtest for all three mathematics tests. The implications of this finding are not clear. It could be that these children are using an analytical approach when generalising about verbal concepts, but an alternative, perhaps spatial, approach to the solution of school mathematical problems (see Coding for further speculations about this approach).

D. Bannatyne (1971) Clusters

In an attempt to locate a possible pattern in correlation scores, it was decided to group the r_s values according to the groupings proposed by Bannatyne (1971, 1974).

Results D

See Table 8

TABLE 8 : COMPARISON OF CORRELATIONS WITH SCHOOL MATHEMATICS ATTAINMENT USING BANNATYNE'S (1971) CLUSTERS OF WISC SCORES

	LJ1-Linear			LJ2-Spatial			Mathematics Attainment A		
	Dys.	Full	Control	Dys.	Full	Control	Dys.	Full	Control
SPATIAL CLUSTER									
Object Assembly	NS	NS	NS	.005	-	.01	.03	.001	.03
Block Design	NS	.007	.002	NS	.002	NS	NS	.001	.04
Picture Completion	NS	NS	-	NS	NS	NS	NS	NS	NS
CONCEPTUAL SCORE									
Vocabulary	-	NS	-	NS	.002	.02	NS	.001	.05
Comprehension	-	.002	-	NS	.02	.02	-	.02	NS
Similarities	NS	-	-	NS	.01	NS	NS	.03	NS
SEQUENTIAL SCORE									
Digit Span	.04	-	.05	NS	NS	.01	.05	NS	.01
Coding	NS	.04	NS	.02	-	.03	NS	-	NS
Picture Arrangement	NS	.001	NS	NS	.002	-	.03	.001	NS
ACQUIRED KNOWLEDGE									
Information	NS	.001	.03	NS	.001	NS	NS	.001	.05
Arithmetic	NS	.001	NS	NS	.002	-	.03	.001	NS
Vocabulary	NS	-	-	NS	.002	.02	NS	.001	.05

- indicates a correlation co-efficient $r_s < .15$ and an NS level of probability.

Discussion D

Some interesting patterns emerge from this method of organising the data. There appears to be relationship between the Dyslexic Group's performance on LJ1-Linear and either the Spatial or Acquired Knowledge clusters. It appears that whatever strategies the Dyslexics are adopting they do not involve the same elements that are related to their performance in subtests in these groupings. The correlation patterns for the Full Sample and Control Groups' performance on LJ1-Linear are not as clear, although there are significant differences in the Sequential and Acquired Knowledge clusters for two out of three subtests in each cluster respectively.

Conceptual Scores and Acquired Knowledge Scores are not related to LJ2-Spatial, in this analysis, for the Dyslexics. However, strong relationships are registered for the Controls for these two clusters. This could be indicative of a verbal component in the non-Dyslexic Group's approach, which is not a feature of the Dyslexics correlations. This may relate to an earlier discussion, in which it was suggested that school children, without learning difficulties, may employ an analytic and in this case, verbal mode of analysis in answering questions about spatial relationships.

Mathematics Attainment A is strongly related to the School samples' acquired knowledge cluster as are both of the other mathematics tests. This supports the similar suggestion made in Chapter 5. However, this does not appear to be the case for Dyslexics.

The Bannatyne clusters appear to be useful in relating some aspects of school mathematical performance to aspects of measured intelligence.

Acquired Knowledge is often a weak aspect of a dyslexic child's literacy profile, perhaps because much of each subtest can be related to reading. For example, if a child reads more, s/he is likely to learn more new facts. This may lead to better scoring on Information type tests. The Arithmetic subtest is also problematical for the Dyslexic, as has been discussed. Given these facts it seems that Dyslexics are not acquiring and/or implementing their mathematical knowledge in the same way as the Control children.

7.3 General Findings

The results from the comparison of correlations seem to suggest that the Dyslexic's way of coping with school mathematical data is different from that of Control individuals. Given the differences in Full Scale Intelligence and subtest correlations it seems that this may relate to a difference in processing of information, though the details are not clear.

Again, caution is recommended when interpreting these results, because of the small Dyslexic sample size. Differences in strengths of correlation were found for the Full School sample and Controls matched for the Dyslexic Group. Similar differences may be found between Dyslexic Group and a larger one.

7.4 LJ1-Linear and LJ2-Spatial

Item analyses of each subject's scripts were undertaken. Chi-squared tests (Siegel, 1956) and Tukey Multiple Comparison of Means were computed for all examples. A full table of results will not be given here, since all the errors made are included in the analyses in Study 5. A brief summary of results is given below.

LJ1-Linear

Dyslexics made more errors in horizontally presented addition sums (eg. 27 + 14 =) (χ^2 value 7.29, $p < .01$), word problems ($\chi^2 = 4.41$, $p < .05$) and items involving completion of number sentences ($\chi^2 = 4.3$, $p < .05$).

LJ2-Spatial

Dyslexic children made significantly more errors than Controls when asked to match shapes to their appropriate written labels ($\chi^2 = 3.8$, $p < .05$). This may relate to the previously mentioned verbal labelling deficiency in Dyslexics, or the lack of recognition of the written labels (although they were read to them). The Dyslexics also had more difficulty identifying symmetry ($\chi^2 = 3.8$, $p < .05$.).

LJ1-Linear and LJ2-Spatial had proved useful in this study. However, there were a number of limitations. Firstly, as was seen from the AOV results, LJ1-Linear favoured children who used the "Fletcher Maths" scheme. Also, it appeared on re-examination that some of the questions in LJ1-Linear would be more suitable for LJ2-Spatial.

In general, the Writer felt that a lot more time needed to be devoted to refining these tests, if they were to be diagnostically useful.

At this stage, a decision had to be made as to the central concerns of this thesis. It was decided that revision of these tests would be the subject for a separate dissertation and, if attempted here, would lead away from the central issue - the relationship between dyslexia and school mathematics. At about the same time, The Mathematics Module Programme (Sumner & Bradley, 1978) was being published and the Maths Modules marketed (see Study 4). Since these assessment tests seemed adequate for the needs of this research, it was decided to abandon LJ1-Linear and LJ2-Spatial, at least as they related to work reported in this thesis.

The Dyslexics in Study 1 had employed some interesting strategies in answering the school mathematical questions. It was decided to investigage these further by interviewing children. Study 2 presents the findings.

CHAPTER 8

8. STUDY 2 - CLINICAL INTERVIEWS

AIMS

To investigate further Dyslexics' approaches to the solution of examples from the school mathematics curriculum.

8.1 Introduction

The results from Study 1 had suggested that Dyslexics may approach mathematical questions in a different way to that adopted by children without learning difficulties. It had also been found that certain items appear to be problematical for Dyslexics. It was decided to investigate these findings further. An observational interview approach was adopted to probe areas of difficulty and provide background information on what topics children find easy. It was hoped that some understanding would be obtained as to how Dyslexic subjects regard school mathematics.

Method

Subjects

Thirty children who had been diagnosed as dyslexic at the Language Development Unit at the University of Aston in Birmingham were selected from the available data files.

Diagnosis of dyslexia had followed the procedure suggested by Thomson (1977). All subjects were of average intelligence (WISC-R) and were retarded in reading and spelling by at least 18 months. Little was known about their school mathematical performance.
Dyslexics included in this study were aged between 8 years 6 months and 10 years 2 months.

Interview

The interview situation was structured such that each subject was interviewed in the same relaxed surroundings in the Language Development Unit. General conversation about school and the child's interests was interspersed with questions relevant to arithmetic and other aspects of school mathematics.

Although the sessions were informal, by the end of the meeting every subject had been asked all the questions comprising LJ3 (see Appendix 4). The children were not presented with set question and answer sheets.

By and large, the questions asked concerned items that did not appear in sufficient detail, if at all, in the tests administered in Study 1.

8.2 Results

Attitudes

Children were asked which subjects they liked best at school. Twelve of the thirty subjects mentioned "maths" in their choices; five said they disliked "maths" and the other thirteen did not mention it.

Test Items

Table 1 lists the percentages of correct and incorrect answers to particular questions.

Discussion

Generally, the subjects did not appear to feel threatened when questioned about the solution processes they had adopted. What did happen frequently was that while a child was explaining how a particular answer had been reached, s/he would discover that s/he had made a mistake; often a computational error.

Several common features emerged from an examination of errors compiled from the children's responses.

TABLE 1: RESULTS FROM LJ3-INTERVIEWS

Question	% Correct	% Incorrect	% Not Attempted	Method of Working	Common Incorrect Answer
Numbers given orally to be written as numerals					
Tens, e.g. fifty three	77	6	17		
Hundreds, e.g. two hundred and three	70	23	7		2003
Thousands, e.g. four thousand, two hundred and sixty six	57	20	3		400020066
Shown 107, asked to say number in words	70	27	3		170
Sequences					
1 2 3 1 2 3 ______	63	37		One child labelled sequence as "Twelve, three, Twelve, three. Another said:"Twelve, thirty one....	1 2 3 1 2 3 $\underline{4\ 5\ 6}$ 1 2 3 1 2 3 $\underline{1\ 4\ 3}$
9 8 7 ____	70	30			9 8 7 $\underline{10}$ 9 8 7 $\underline{9\ 8\ 7}$
4 - 2 8 - 2 12 - 2 __ - 2 20 - 2	30	30	40		14
23 - 18 - 13 - __	40	23	37		23 $\underline{24}$ 18 $\underline{19}$ 13 $\underline{14}$ 23 - 18 - 13 - 14

Table 1 (cont)

Counting back from 10 in ones	85	15			
Counting back from 20 in twos	50	17	33		Left out numbers ____ 6, 4, 2, 1, 0
Counting back 8 places from 12	40	23	37		
Counting back 5 places from 21	43	30	27		
x x x + x = x x x x x x x x x x x x x x	57	3	40		
Visualisation - joining dots to form shapes and letters	67	23	7		
Is 5 smaller than 10 or bigger?	80	20			
What number is 5 more than 5?	83	7	10		25
4 more than 0?	67	30	3		0
Calculation					
Knowledge of tables	50	50			
How many lots of 10 in 120?	57	16	27		
10 x 0 (nought)	60	23	17		
4 x 0 (nothing)	73	14	13		
5 x 4	60	20	20		
20 x 1	53	24	23		
Word Problems					
If I earn 8p a day, how much do I earn in a week?	30	43	27	4 x 7 = 28 3 x 7 = 21 Ans. 49	49
				Need 7 eights altogether	41
4 boys have 48p altogether. How much do they each get if they share it?	40	37	23		174p (incorrect 48 x 4) 10p 6p

Counting

Counting forward did not appear to present any difficulty for the subjects interviewed. However, several children were inaccurate when counting backwards. 85% of the subjects could count back from ten in ones. Only 50% were successful in counting back in twos. When asked to count back eight places from 12, only 40% of the sample could supply the correct answer. Miles (1974) and others have found that Dyslexics have particular difficulty remembering digits in reverse order. This may have been an influential factor in the poor scoring on these test items. Poor short-term memory appears to be a limiting factor in this type of exercise. It was found that prompting in the form of "Which number do you start with?", "What is the next step?" increased the number of correct responses. Comments of this type may have helped children to establish points of reference and aided recall of the appropriate steps to apply.

Sequencing

Questions involving sequencing were marked by poor performances. Only 63% of the sample were able to continue the sequence 1 2 3 1 2 3 ___ correctly. Two children adopted unusual labelling techniques; they grouped the sequence numbers in arrays not expected by the interviewer. One child said "Twelve, three, twelve, three ....." It could be that this child had not recognised a relationship between the numbers one, two and three. Another child repeated "Twelve, thirty-one .....". He did not appear to perceive the pattern and was just grouping the numbers in twos.

The sequence 9 8 7 ____ appeared to be less difficult for the Dyslexics, despite the reverse order of digits; 70% of the children continued it correctly. As had been found in LJ2-Spatial, some children tended to continue a second sequence in the way the first one had been completed even if the characteristic pattern was different. In this study, the first sequence was 1 2 3 1 2 3 ______ etc. The second sequence 9 8 7 ____ was then completed by these children in similar fashion. 9 8 7 9 8 7, instead of 9 8 7 6 5 ___ etc.

More complex sequences, involving calculation were mastered by fewer subjects. Only 12 individuals could complete the following:-

4 - 2

8 - 2

12 - 2

__ - 2

20 - 2

This may have been because relatively few of the subjects were familiar with the four times table.

Lack of recognition of the nature of a particular sequence was also evidenced in the example 23 - 18 - 13 - ____. A common finding was that subjects merely examined the last figure. In this case, children frequently completed the sequence with the number 14. When asked why they had selected "14", most subjects said: "Because it comes after 13". Other subjects also did not realise the importance of the intervals between the given numbers. They replied 23 $\underline{24}$ 18 $\underline{19}$ 13 $\underline{14}$. Difficulties in sequencing have been mentioned as a feature of the Dyslexics' performance by most researchers who have described the phenomenon (see Newton, 1974, 1975; Thomson, 1977 for review).

Reversals

Reversal of letters is a frequently mentioned characteristic of Dyslexics' written language (eg. Newton, 1974). In this study only two children were found to reverse numbers and they did so consistently, for example : 7d1/761; Ƨ3/53; 4020dd/4266.

Arithmetical Computation

10% of the subjects were able to calculate using the four arithmetical operations, to a level at least commensurate with chronological age using the guidelines adopted in Schools A, B, and C. For the 10 year olds, for example, multiplication with two digit numbers, including carrying, would be expected.

42% of the children were unable to add two two-digit numbers vertically placed, where no carrying was involved.

30% could not provide the answer to 20 - 13 =

Only 20% could complete ? - 23 = 45. Many incorrect attempts were the result of the use of the incorrect operation. The place holder was often filled by 22, because 22 + 23 = 45.

Methods of Solution

A feature of this group's performance in arithmetic was that they often used long and laborious processes that were potentially more subject to careless errors. It must be pointed out though that in some cases, although long and drawn-out, these methods often resulted in faultless performances. For example:

$$
\begin{array}{r}
505 \\
\times\ 64 \\
\hline
20 \\
00 \\
2000 \\
\hline
300 \\
000 \\
30000 \\
\hline
32320 \\
\hline
\end{array}
$$

In working out examples, at least half of the children used their fingers.

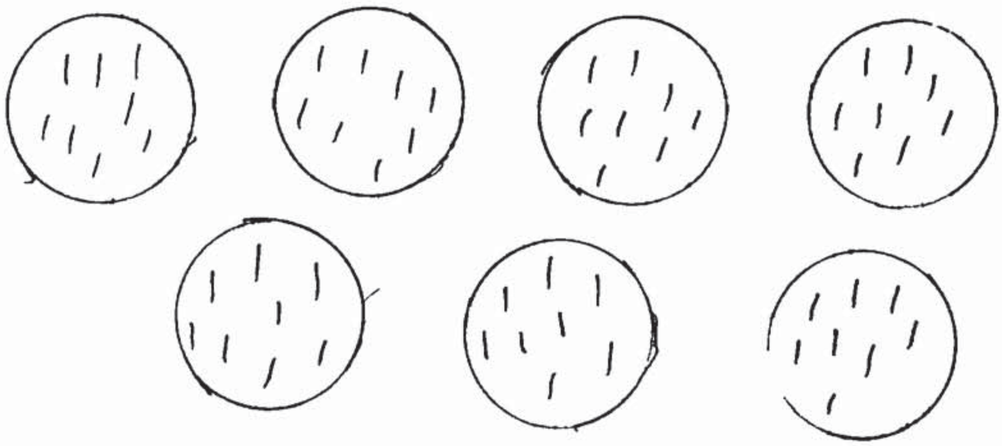
Tallying

Tallying or dots on the page were frequently used when tables were not known. Taking the example: If you save 8p a day, how much do you save in a week?, many children made 8 marks on their papers, 7 times

/ /
/ /

Many errors were made using this method.

Another approach used Venn Diagrams - 7 sets were drawn, 8 marks were made in each and then the marks were counted individually.



Successive addition was employed by five subjects.

8 + 8 + 8 + 8 + 8 + 8 + 8

One child used successive addition on an arithmetical progression:

8 + 8 = 16

16 + 16 = 32

32 + 32 = 64

64 - 8 = 56

Answer: You save 56p in a week.

Tables

All these methods were adopted by children who did not know their tables. The fact that Dyslexic children have difficulty mastering tables has been noted by Miles (1974, 1978). Only 50% of the subjects knew more than 2 arithmetical tables.

In calculation, the most errors appeared to result from a lack of knowledge of place value and the specific positional nature of the number system. These difficulties were also evidenced when children were asked to write down the appropriate numerals representing a number presented in words. For example, when asked to write "two hundred and three" as a number, 23% of the Dyslexics wrote 2003. (Further detailed investigation of all the abovementioned difficulties will be presented in Study 4).

8.3 Summary

In summary, it was found that all but four of the children in this sample were performing at a level below that expected for their age group by the Birmingham Education Authority. Two children appeared to be excelling in the aspects investigated and two appeared to be "average" for their age. Many of the difficulties in the rest of the sample appear to be associated with well-documented features of their learning profile - poor short-term memory, lack of sequencing ability and proficiency at ordering symbols. This study served to highlight the value of the interview technique and item analysis as viable methods of obtaining diagnostically useful information about children's performances in school mathematics, though a more systematic in-depth investigation of this type appeared to be needed. Consequently, it was decided to undertake a larger scale study, the results of which are presented in Study 5.

CHAPTER 9

9. STUDY 3 - BRITISH ABILITY SCALES (BAS) - ARITHMETIC SUBTEST

AIMS

1. To obtain a quantitative assessment of the number of dyslexics, who have arithmetical as well as literacy difficulties.
2. To ascertain the proportion of the normal school population who have specific difficulties in arithmetic.
3. To assess how Dyslexics' arithmetical ability relates to their performance on other tasks.

HYPOTHESES

1. Based on the anecdotal evidence presented by Miles (1974), the data collected in Studies 1 and 2 of the present thesis and the a priori assumptions made about the similarities between language and arithmetic, the following hypothesis was formulated: there will be a greater number of Dyslexics found to exhibit computational difficulties, than will be the case in the Control population.

9.1 Introduction

Studies 1 and 2 (Chapters 7 and 8) of this thesis and other anecdotal evidence (Miles, 1974) have indicated that there are dyslexics who have difficulties with school mathematics. However, nothing was known about the numbers of children who might fall into this category. Kosc (1974) and Weinstein (1978) both reported that 6% of their samples of schoolchildren evidenced a specific difficulty in arithmetic, which was independent of intellectual potential and literacy attainments. They refer to these pupils as dyscalculic. It was of interest to ascertain if similar proportions of dyslexics would evidence arithmetical problems, therefore the following investigation was undertaken.

As part of a larger research programme, the British Abilities Scales (BAS) were administered (see Thomson, Hicks, Joffe & Wilsher, 1980 for results).

Of particular interest, in the present study, is the Basic Arithmetic Scale of the BAS, which takes the form of an untimed, written arithmetic test, designed to evaluate performance in calculation. Examples of the four operations (addition, subtraction, multiplication and division) are presented, graded by difficulty; the easiest, single-digit sums are given first, followed by more complex, multi-digit calculations.

Using Raw Scores and the Ability Ratings, provided in the BAS Manual, Arithmetic Ages can be computed. Although the ceiling age for this subtest is 14 years 5 months, it was administered to all subjects to allow for older subjects, who may not have been achieving at their expected level. This was particularly relevant for the Dyslexics, some of whom were expected to have difficulty with this test.

Subjects

Dyslexic Groups

Fifty-one children between the ages of 8 and 17 years were invited to take part in a research project. The subjects had been previously diagnosed as dyslexic at the Language Development Unit (for criteria see Chapter 4 Section 5), University of Aston and were randomly selected from the available data files.

Subjects were all of average intelligence or above, as measured on the Wechsler Intelligence Scale for Children (WISC-R), or the Ravens' Matrices (1958) and the Stanford-Binet Vocabulary Scale (1937).

Subjects were divided into age groups as specified in the BAS Manual.

Group 1 - Ages ranging from 8 years to 10 years 11 months.

Group 2 - 11 years to 13 years 11 months.

Group 3 - 14 years to 16 years 11 months.

Control Groups

The Control Groups, matched for age and intelligence level (average or above), were randomly selected from schools within the Birmingham area. None of these children had any reading and/or spelling difficulties (based on teachers' reports).

9.2 Results

A difference of 18 months between chronological age (CA) and arithmetic age (Arith Age) was adopted as the measure of severe retardation or excellence respectively (Thomson, 1977). Table 1 lists the proportions of subjects within each of these categories.
Additional data for each group can be found in Appendix 5A-H.

It can be seen that Dyslexic subjects yield Arith Ages which are discrepant from CA's by 19 months or more, more frequently than same-aged Control children. The proportion of Dyslexics failing at this level increases with increasing age. In Group 1, the sample percentage difference is 19%, in Group 2, 42% and in Group 3, 41%. In the Control group, the number of subjects yielding negatively discrepant Arith Ages, relative to the CAs, tends to decrease in the older groups. Conversely, the Arith Ages, in excess of CA by 19 months or more, increase for the Control groups as they get older. In Group 1 only 6% more Controls are excelling in Arithmetic. In Group 2 the margin increases to 64%. In Group 3, all those with an Arithmetic score more than 19 months above CA exceeded the norms of the test.

Table 2 provides a detailed breakdown of the discrepancy between CA and Arith Age and the number of subjects who fell within 6 month categories below or above CA.
A score was designated "average" if an individual's arithmetical and chronological ages coincided (Yule, 1973), though it was realised that this could be an underestimate.

Overall 60% of the total Dyslexic sample yielded arithmetic ages lower than their chronological ages, compared with 19% of the Control population. 40% of the Dyslexics and 81% of the Controls scored at the average level or above.

TABLE 1 : Discrepancies Between Arithmetic Ages (BAS) and Chronological Ages (CA)

	Arithmetic Age below CA by 19 months or more.	Arithmetic Age equal to CA $\pm$ 18 months.	Arithmetic Age above CA by 19 months or more.
Dyslexics 1 N = 16	44%	37%	19%
Controls 1 N = 16	25%	50%	25%
Dyslexics 2 N = 18	61%	28%	11%
Controls 2 N = 16	19%	6%	75%
Dyslexics 3 N = 17	41%	0%	59%*
Controls 3 N = 16	0%	0%	100%*

* - scores above norms for test.

TABLE 2: STUDY 3: DISCREPANCIES BETWEEN CHRONOLOGICAL AGE AND BAS ARITHMETIC AGE

	TOTAL BELOW CA	ARITH AGE < CA					ARITH AGE = CA	ARITH AGE > CA					TOTAL AT CA OR ABOVE
DIFFERENCE IN MONTHS		-30+ over	-24	-18	-12	-6	C.A.	+6	+12	+18	+24	+30+ over	
Dyslexics 1	10 / 62.5%	3 / 18.75%	4 / 25%	1 / 6.25%	1 / 6.25%			2 / 12.5%	1 / 6.25%	1 / 6.25%		2 / 12.5%	6 / 37.5%
Control 1	6 / 37.5%	1 / 6.25%		3 / 18.75%	1 / 6.25%	1 / 6.25%	3 / 18.75%	2 / 12.5%	1 / 6.25%	1 / 6.25%	1 / 6.25%	2 / 12.5%	10 / 62.5%
Dyslexics 2	14 / 78%	8 / 44.2%	1 / 5.6%	2 / 11.1%	2 / 11.1%	1 / 5.6%	1 / 5.6%		1 / 5.6%	1 / 5.6%	1 / 5.6%		4 / 22%
Control 2	3 / 19%		3 / 18.75%				1 / 6.25%					12 / 75%	13 / 81%
Dyslexics 3	7 / 41%	5 / 29.4%	1 / 5.9%	1 / 5.9%								10* / 58.8%	10 / 58.8%
Control 3	0 / 0%											20 / 100%	20 / 100%

*above norms

1 / %

The number in the top left-hand corner, represents the number of subjects from the group sample, who scored within that category.

The percentage given in the bottom right hand corner is a proportional expression of the above-mentioned number, relative to the group.

Analysis by age group revealed the following:-

<u>Dyslexic Group 1</u> (N = 16)

62.5% of this group scored below their chronological ages for arithmetic.

26% were between 18 months and 2 years retarded.

19% were more than 2 years retarded.

31.25% yielded an arithmetic age within 12 months of their chronological ages.

37.5% of the subjects yielded scores above their chronological age.

6.25% were advanced by 14 months.

12.5% scored over 4 years in excess of chronological ages.

<u>Control Group 1</u> (N = 16)

A control sample matched against Dyslexic Group 1 yielded the following results:-

37.5% scored below their chronological ages on the arithmetic subtest.

Of these 12.5% were within 12 months of their chronological ages.

18.75% were retarded by 13-18 months and 6.25% by more than 30 months.

Overall 50% of the Control subjects scored at, or within a year of chronological age.

25% excelled in arithmetic by 18 months or more.

In summary, 62.5% of the Dyslexics in this age group scored below that which would be expected given their chronological age, compared with 37.5% of the Controls. The proportions are reversed for average and above average scores; 37.5% of the Dyslexics fell into this category and 62.5% of the Controls.

Dyslexic Group 2 (N = 18)

78% scored below the level expected, using chronological age as a guide.

50% were more than 18 months retarded.

28% had an arithmetic age within a year of their chronological ages.

11% were 18 months or more advanced of their chronological ages.

Control Group 2 (N = 16)

18.75% of subjects obtained an arithmetic age score between 19 and 24 months below their chronological ages.

6.25% scored at a level commensurate with chronological age.

75% of this group exceeded the norms of the test, ie. they all scored above an arithmetic age of 14 yrs. 5 months, ie. 81% were average or above.

In summary, in Age Group 2, 78% of the Dyslexics and 19% of the Controls yielded below average arithmetic scores, given their CA.
22% of the Dyslexics and 81% of the Controls scored at average level or above.

<u>Dyslexic Group 3</u> (N = 17)

All but two subjects were older than the age limit specified for this Ability Scale. Nevertheless, it was administered in order to ascertain if there were subjects in this group who were retarded in arithmetic.

59% scored above the norms for the test.

41% yielded low scores: 6% were retarded by 14 months.
6% by between 25 and 30 months
29% by more than 30 months.

<u>Control Group 3</u> (N = 16)

All subjects in this group exceeded the arithmetic ceiling age of 14 years 5 months.

So it can be seen that 100% of the Controls and 59% of the Dyslexics scored above the norms of this test. No Controls were retarded; however, 41% of the Dyslexics scored below the average level.

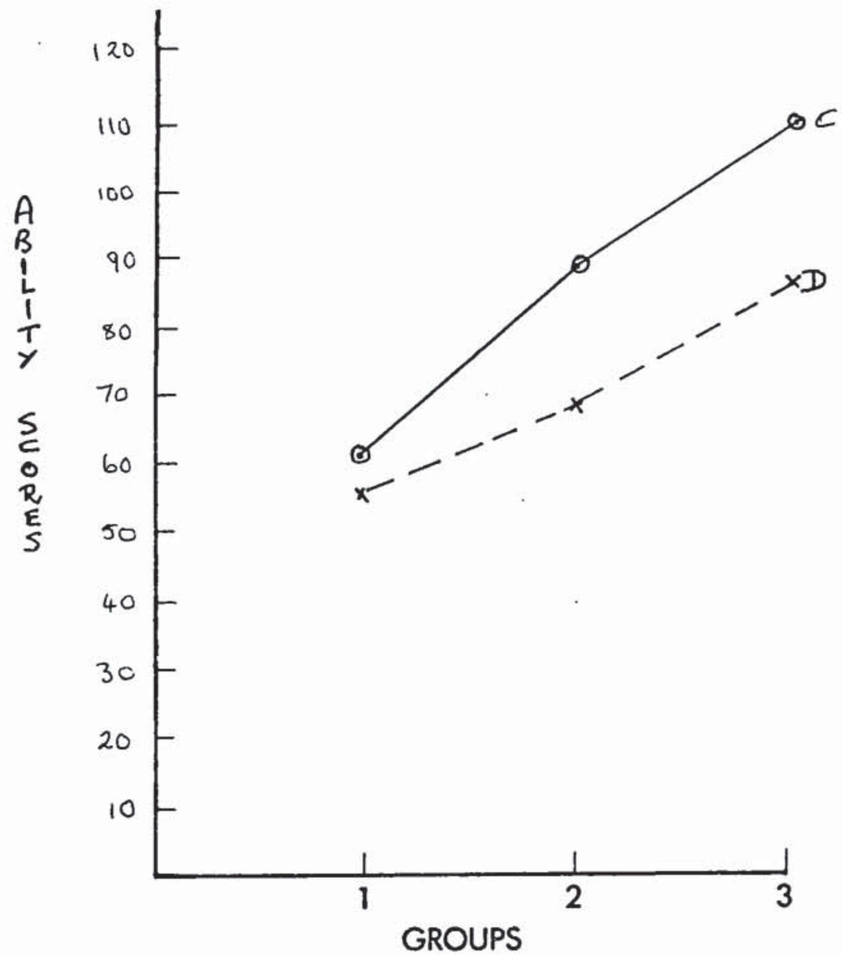


FIG.1 Mean Ability Scores by Group

GROUPS	1	2	3
D	54.7	68.9	87.3
C	61.1	88.9	110.9

TABLE 3: Mean Ability Scores for Dyslexics and Controls

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.12	1	30.64	p<.001
EXPLANATION BY AGE	0.50	2	62.38	.001
EXPLANATION OF READING ABILITY BY AGE	0.02	2	3.00	NS (approaching .05)
RESIDUAL	0.36	90		

TABLE 4: AOV Summary Table

Analysis of Variance (AOV) - Ability Scores

Using Rasch scaling, the BAS scores may be interpreted in, what is thought to be by the Test Constructors, a sample-free, norm-free way of using ability scores.

Ability scores are measures of an individual's abilities, independent of any sample characteristics, like age or sex. The Authors say that this alternative method of interpreting scores should be used cautiously.

The mean ability scores of the Dyslexic and Control Groups are listed in Table 3 and plotted on Figure 1.

Table 4 presents a summary of the AOV findings between these scores, which were computed using the PET Commodore System and the AOV programme available in the Department of Educational Enquiry at the University of Aston in Birmingham. These indicate that all groups show increased ability with increasing age ($p < .001$). There is also a trend towards an interaction effect, at the 5% level, indicating that as Dyslexics get older, their performances tend to become increasingly poor, relative to same-aged Controls.

Expected Arithmetic Ages based on Other Ability Scores

The BAS Manual also provides for the calculation of an expected ability score and age equivalent in one subscale, based on the observed score in another. Table 5 lists some of these findings for the Dyslexics in age groups 1 and 2 using group mean scores. Group 3 was omitted because ages were above the norms for the test. Full BAS profiles were not available for the Control Groups.

TABLE 5: Observed and Expected Arithmetic Ages

	Dyslexics 1	Dyslexics 2
Observed Ages	y. m.	y. m.
C.A.	9.98	12.4
R.A.	7.9	8.4
C.A.	8.10	10.7
Expected Arith Age based on:		
Formal Operational Thinking	10.5	11.11
Block Design Power	9.11	13.4
Recall of Digits	9.8	11.5
Word Reading	8.6	10.1

Using the ability scores on Formal Operational Thinking (thought to involve conceptualising ability), the Dyslexics in Groups 1 and 2 respectively would have been expected to yield mean Arith Ages of 10.5 years and 11.11 years. This represents a difference of 19 months and 16 months respectively between observed and expected arithmetic ages.

Block Design Power is assumed to be a measure of spatial ability. Using this subscale the differences between the expected and observed Arith Ages are 13 months and 33 months respectively.
Given the Formal Operational Thinking and the Block Design Power scores the Dyslexics appear to be underachieving in Arithmetic.

Recall of Digits

The discrepancy between expected and observed scores, using the Recall of Digits ability score is 10 months for both Groups.
Recall of digits is an area of weakness for Dyslexics, yet they appear to do even less well in Arithmetic.

Word Reading

Using Word Reading scores as a guide, Dyslexics in Groups 1 and 2 yield slightly better observed Arith Ages than might be expected from their reading performance. Their observed ages are superior by 4 months and 6 months for Groups 1 and 2 respectively.

9.3 Discussion

The sample chosen was taken to be representative of dyslexic children, as it was randomly selected from amongst 800 diagnosed dyslexics and, as such, the finding that 61% of them are retarded in arithmetic, to some extent, compared with 19% of the Control samples, is noteworthy.

If one takes 18 months as an arbitrary cut-off point suggested by Thomson (1977) and assumes that this amount of retardation (or more) represents a serious deficit, one finds a larger proportion of Dyslexics than Controls in this category. Thus the hypothesis stated at the beginning of this section, must be accepted.

Comparison of Dyslexic Group 1 and the matched Controls reveals that a larger proportion of the Dyslexics are retarded by 18 months or more than the Controls (44% as opposed to 25%) and the number of severely retarded individuals is higher in the former group, as can be seen from Table 2.

The difference in numbers, between those who did well (18 months or more above their chronological age), in the two groups, is less marked - 19% of the Dyslexics and nearly 25% of the Controls. One Dyslexic subject was extremely slow though. She took nearly three times as long as any of the other children to achieve a good score, thus doubt must be cast on her inclusion in this group. Although the test was untimed, it seems reasonable to take excessive time taken into account. The Writer feels that evaluation of ability in tests of this type should include both accuracy factors and a maximum time allowance. If this subject were eliminated from the high attainment group, the margin between Dyslexics and Controls, in this category, would increase.

Approximately 15% of the two younger Dyslexic groups excelled in the Basic Arithmetic Test. They seemed to enjoy "playing" with numbers, and when asked, said that mathematics was their favourite subject.

The skill exhibited by these children and the strategies they employed to work out answers, seemed to indicate a flexibility of approach, not seen in the rest of the Dyslexic sample. (A fuller exploration of these aspects will be undertaken in Chapter 11).

The proportion of those who obtain an arithmetic age 18 months or more below chronological age in the two older age groups, is much greater in the Dyslexic groups relative to their matched controls; in Group 2, 50% of the Dyslexics, as opposed to 19% of the Controls and 35% of the Dyslexics compared with none of the Controls, for Group 3. The AOV results indicate that as dyslexics get older they tend to achieve increasingly lower scores relative to similarly aged controls. All but 25% of the subjects in Control Group 2, scored above the age norms of the test, ie. 14 years 5 months although all of them were younger than this. Only one person in this group yielded an arithmetic age commensurate with his chronological age.

Since it seems unlikely that all of these subjects were excelling at arithmetic, it may be that the age referenced norms, for children without particular difficulties with mechanical computation, could be a little low. However, they do seem useful in identifying children who may be dyscalculic, or have general diffioulties with this aspect of mathematics.

The findings that the total Control Group 3 sample scored above the age norms for the test is not surprising, given that the ceiling score is supposed to be commensurate with an arithmetic age of 14 years 5 months. (Also, most of the subjects in this group are destined for CSE O or A level mathematics groups). However, the BAS Basic Arithmetic Test did prove useful in identifying 42% of subjects, older than 14 years 5 months who are severely retarded in arithmetic.

Thorndike et al.(1925) and Wrigley's (1958) view, that a general intelligence factor "g" is an important aspect of the ability to succeed in school mathematics, is still current today. It seems that a certain basal level of intellectual potential is necessary for the mastery of the variety of prerequisite skills. This finding was borne out for a normal junior school sample ($p < .001$). However, the correlation for a matched dyslexic group was only significant at the 5% level (see Study 1).

The present findings that a large proportion of the dyslexics tested have numeracy difficulties, coupled with the fact that the "g" loading, on school mathematics, is smaller in the dyslexic population (see Study 1) suggests that, in the same way as the relationship between intelligence and reading is not upheld for dyslexics (Newton, 1974a; Thomson, 1977; Yule & Rutter, 1973) the same may apply to arithmetic. Arithmetical ability appears to be independent of measured intellectual potential in these children.

If this is the case, the implication is that there are some dyslexics, who, despite adequate (average or above) intellectual potential, seem to have a specific difficulty with the manipulation and computation of numbers. The influence of the "g" (general intelligence) factor, in these dyslexics, does not appear to be as persuasive as it is in the normal school population. Similar findings pertain to literacy failure in the specifically learning disabled population.

What does emerge from the study is that there are a group of Dyslexics (43% of the samples studied) who seem to fit the criteria for identification of dyscalculia as well.

Additionally, in the Control samples, drawn from the "normal" school population, just over 8% appear to fit Kosc's (1974) and Weinstein's (1978) descriptions of dyscalculics. These individuals seem to have a specific difficulty with number and calculation, which is not accompanied by any literacy difficulties not accounted for by low measured intelligence or motivational factors. This was a surprise finding, since the class teachers had reported that they were not aware of any dyscalculics in their forms.

Whether dyslexia and dyscalculia are independent or part of a common syndrome of difficulty, will be discussed in Chapter 12.

The expected Arith Age based on Formal Operational thinking suggests that the Dyslexics in Groups 1 and 2 are underfunctioning, given their conceptualising ability. These functions appear to be separate, and seem to be relying on different cognitive processes. Similar findings pertain to spatial ability, as measured by Block Design Power.

The expected Arith Age based on the Recall of Digits, suggests that while both these abilities may be weak, the Dyslexics' performance in Basic Arithmetic is still poorer than might be expected given their memory for digits.

Given their observed Reading Ages, these children were doing better than expected in Arithmetic. It seems possible that there is some underlying factor, common to both these skills, which is dysfunctioning in dyslexics and leading to poor performance in both reading and computation. Speculations about this common basis have been made in Chapter 5.

Possible explanations for the failure of many dyslexics and the high scoring of others on a test of arithmetical computation, will be offered in Chapter 12.

An item analysis of errors was carried out on all scripts. However, since the types of mistakes made in this test, closely approximate those found in Modules 2-5 of the next study, they will not be discussed in detail, in this section.

Some general comments about the test format will be made though, since they seemed relevant to some of the errors.

The Basic Arithmetic test question and answer sheet is extremely cramped; items are placed very close together, with little space allowed for working next to the example. Some space <u>is</u> allocated for working out, but it is not near the calculations for which it is most needed. Frequent errors resulted from children miscopying, when transferring answers from the "working out" area to the appropriate section of the answer sheet.

Children in all groups were confused by the setting out notation in division; in the test the format adopted is $6\underline{/96}$, whereas the conventional presentation in Birmingham schools is $6\overline{/96}$.

Since arithmetic is only one aspect of school mathematics, it was decided to investigate whether similar findings to those in this study, pertained to other areas of the curriculum as well. To this end, Study 4 was undertaken, in which other mathematics topics were examined.

CHAPTER 10

10. STUDY 4 - MATHEMATICS MODULES

AIMS

1. To compare the performances of three Dyslexic and three matched Control Groups, on ten aspects of the school mathematics curriculum.

2. To gather data for an extensive error analysis in Study 5.

HYPOTHESES

1. The Dyslexic Groups' performances will be poorer than those of the Control Groups' on the Modules involving numerical calculations.

2. The Dyslexics' scores will be equivalent, if not superior, to those of the Controls, in those aspects tested, which appear to have a largely spatial component.

10.1 Introduction

The results of Studies 2 and 3 indicated that nearly 50% of the Dyslexics tested have particular difficulty with numerical calculation. However, little was known about their performances in other areas of the school mathematics curriculum. The present study was undertaken to investigate some other aspects of the syllabus. Information was also sought for a further study (Study 5), in which it was hoped to analyse children's errors systematically, to gain insight into their approaches to mathematical and arithmetical material.

The Mathematics Module of the Transitional Assessment Programme (Sumner & Bradley, 1978; NFER, 1978) were selected as being most suitable for this purpose.

The Modules cover ten areas of the school mathematics curriculum, which although not exhaustive, appear to include score elements of most school mathematics syllabi.

Modules 2-5 involve numerical calculation. On the basis of the findings from Study 3, the first hypothesis was formulated; that the Dyslexics would perform at a poorer level than similarly aged Controls.

In accordance with the anecdotal evidence of Newton (1974b)and the clusters of abilities put forward by Bannatyne (1971) which suggest differential performance in specific areas, the second hypothesis was formulated; that the Dyslexics would do as well, or better, than Controls on those items which have a largely spatial component. Although this notion had been examined in Study 1, the results had been inconclusive, so further investigation was considered desirable.

Method

Subjects

The same subjects who took part in Study 3 - the BAS Arithmetic Study, agreed to participate in this investigation.

Tests Used and Test Procedure

As has previously been mentioned, the Maths Modules (Sumner & Bradley, op.cit.) were selected as being most appropriate for this Study. "Maths Modules" refers to the actual test scripts. "Mathematics Module" is the name given to the overall study undertaken by the Test Designers, as opposed to the "English Module".

The Maths Modules are written tests. Each module consists of twelve items, graded by difficulty from easiest (question 1) to hardest (question 12).This allows for the collection of systematic, qualitative as well as quantitative data, about each child's performance. Using this Modular system, the child is not given a global assessment in mathematics, rather a number of assessments relating to specified areas, within the subject.

The topics covered are as follows:-

Module 1 Numbers - deals with the translation of numbers given in words to numerals; sequences, equivalence, positional nature of number; odd-, square- and prime numbers and common number-related terms, for example, "greater than".

Modules 2-5 The Four Operations - involve calculations using addition, subtraction, multiplication and division, respectively. Where possible, the setting out format is varied. Though language is kept to a minimum, words commonly associated with particular operations are used in the latter part of the Modules. For example, "difference" in Module 3 (subtraction).

Module 6 Properties of the 4 Operations - tests knowledge of reversibility in addition; equivalence of multiplication and successive additions and translation of word problems into number sentences. Little or no working out is required.

Module 7 Knowledge of shapes, equivalence of measurement, shape, simple construction, spatial visualisation and angles.

Module 8 Ratio, proportion and percentages - graphical and word problem questions.

Module 9 Money - simple addition and subtraction with coins, equivalence, word problems.

Module 10 Problems - devised after Modules 1-9:application of knowledge to simple problems,

Questions were read to children if they were unable to read the examples themselves.

In accordance with Engelhardt's (1977) suggestion, behaviours such as finger counting, and verbalisations while working through problems were noted. No time limit was imposed and subjects were encouraged to complete only as many items as they felt able. The latter two procedures

> "were employed to elicit computational performance which was uncontaminated as much as possible by guessing or the pressure of time."
>
> (Engelhardt, 1977)

The Modules were devised to assist in assessment of performance when children are due to change from junior to secondary school. Thus it was expected that the youngest children might find some of the items too difficult and some of the older ones might find examples too easy. On examining the range of items included, it was decided that there were sufficient which Group 1 children (8 years - 10 years 11 months) could manage. Since many of the older Dyslexics had had difficulty with the BAS Basic Arithmetic test it was decided that many of the seemingly easy items would be suitable.

10.2 Results

Additional data for each group can be found in Appendix 5A-H.

Mean Scores

The mean scores for each module and group were calculated. These are listed in Tables 1M(a) - 10M(a) inclusive. Figures 1 and 2 illustrate the mean scores for the Dyslexic and Control Groups respectively for all ten modules. Both these sets of data are presented together in Figure 3.

It can be seen that overall, the Dyslexic Groups' scores are poorer than those of the Controls, although these differences are not marked

MODULE 1

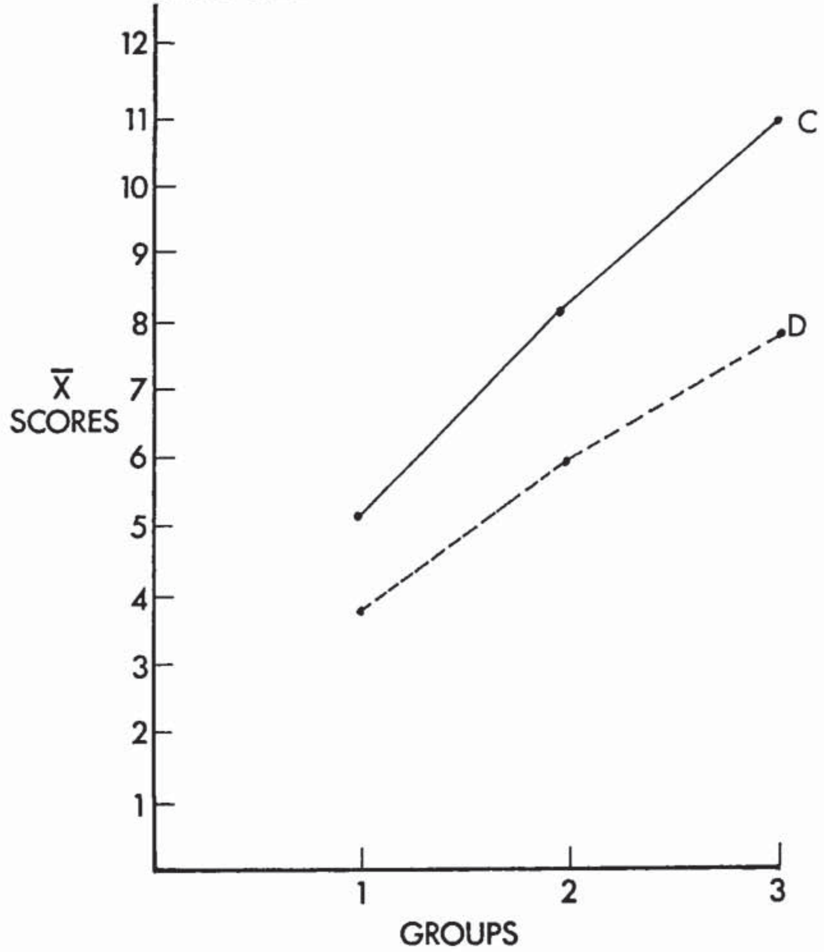


FIG. 1M Mean Scores by Group

GROUPS	1	2	3
D	3.81	5.88	7.88
C	5.19	8.19	11.00

TABLE 1M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.12	1	21.22	.001
EXPLANATION BY AGE	0.37	2	33.45	.001
EXPLANATION BY READING ABILITY X AGE	0.01	2	1.05	NS
RESIDUAL	0.50	90		

TABLE 1M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 2

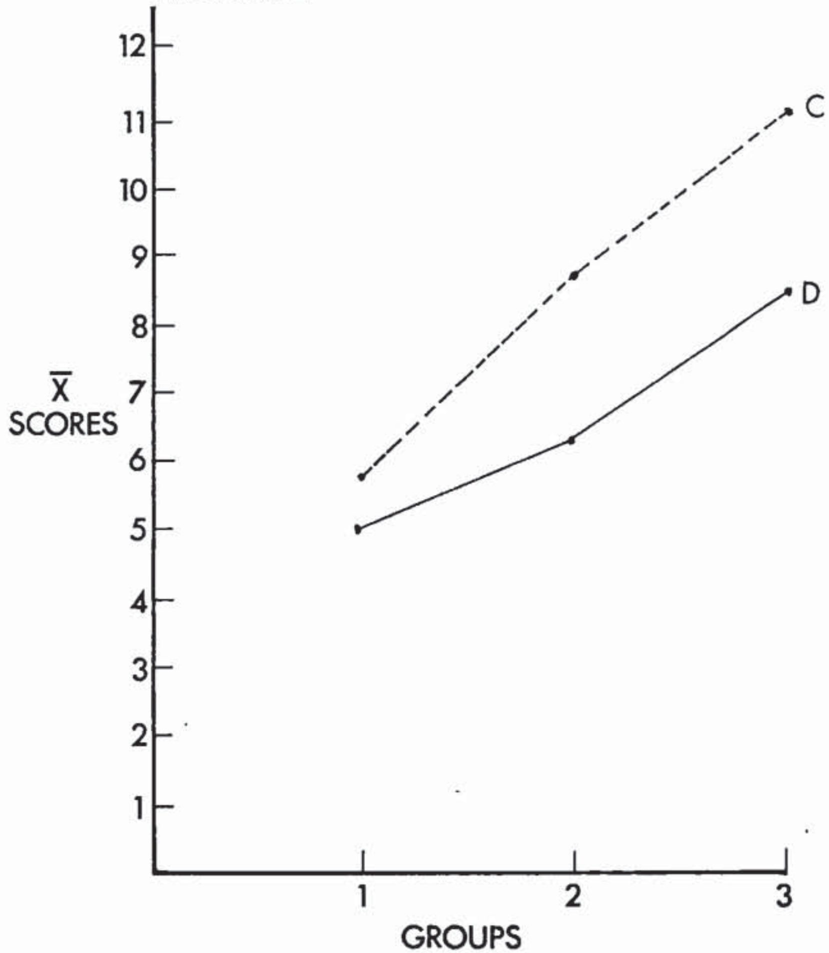


FIG. 2M Mean Scores by Group

GROUPS	1	2	3
D	5.00	6.25	8.50
C	5.81	8.81	11.19

TABLE 2M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.13	1	25.77	.001
EXPLANATION BY AGE	0.41	2	41.44	.001
EXPLANATION BY READING ABILITY X AGE	0.02	2	2.31	NS
RESIDUAL	0.44	90		

TABLE 2M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 3

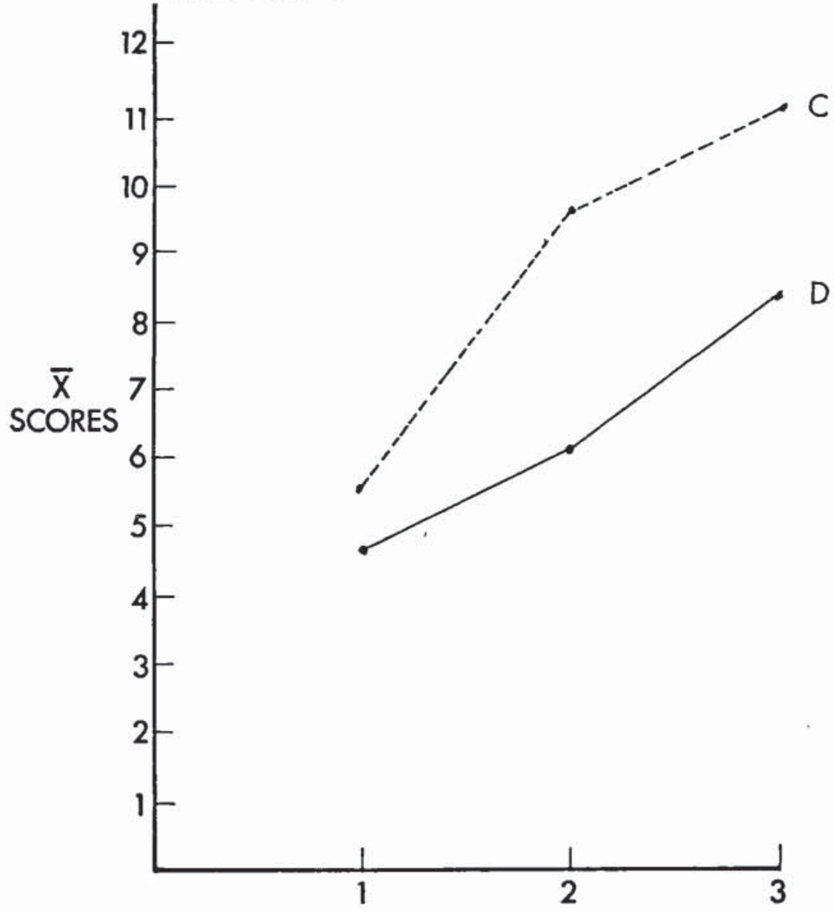


FIG.3M Mean Scores by Group

GROUPS	1	2	3
D	4.75	6.06	8.25
C	5.56	9.63	11.06

TABLE 3M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.14	1	26.63	.001
EXPLANATION BY AGE	0.34	2	31.71	.001
EXPLANATION BY READING ABILITY X AGE	0.03	2	3.13	.05
RESIDUAL	0.48	90		

TABLE 3M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 4

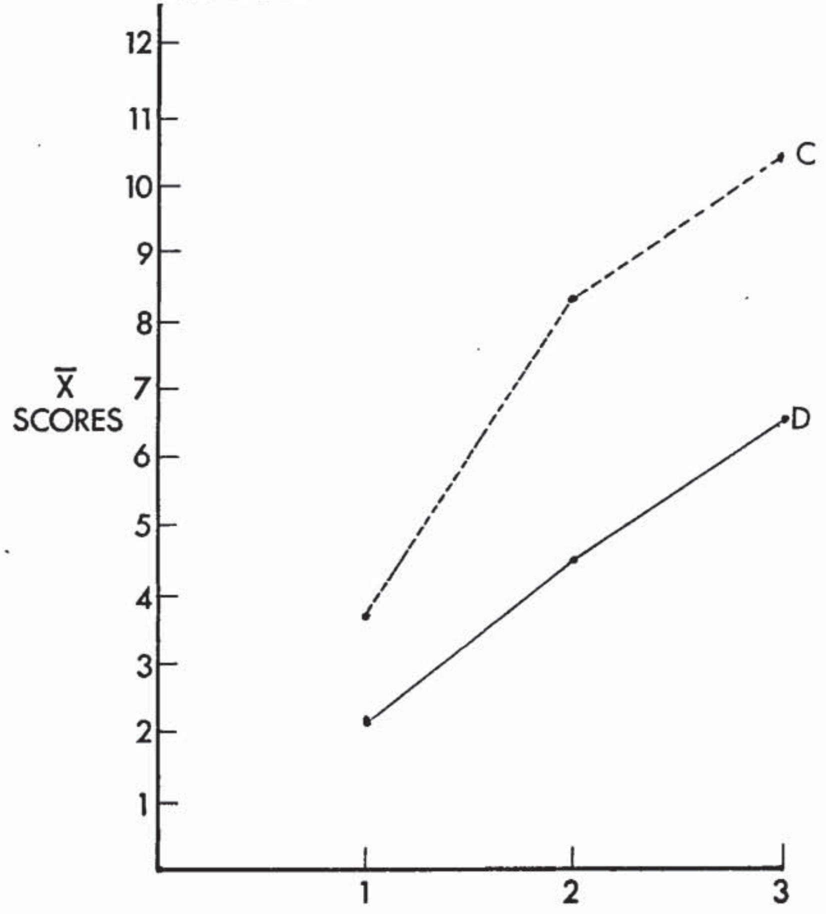


FIG.4M Mean Scores by Group

GROUPS	1	2	3
D	2.13	4.56	6.44
C	3.75	8.25	10.44

TABLE 4M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.21	1	57.25	.001
EXPLANATION BY AGE	0.44	2	61.27	.001
EXPLANATION BY READING ABILITY X AGE	0.02	2	3.30	.05
RESIDUAL	0.33	90		

TABLE 4M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 5

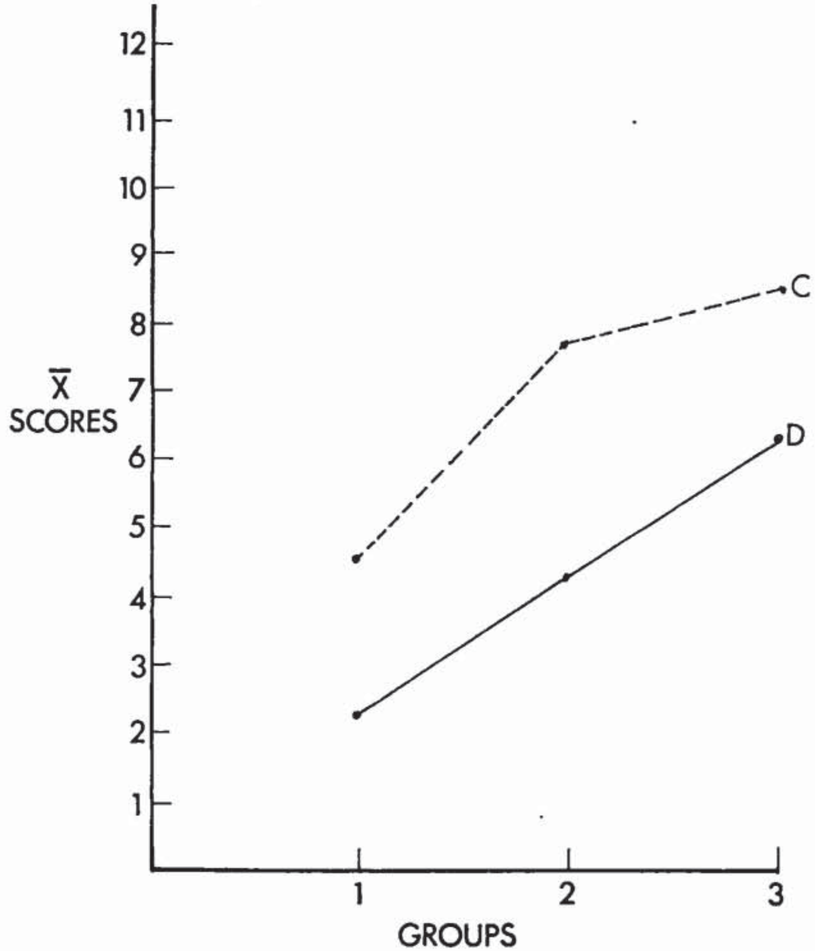


FIG. 5M Mean Scores by Groups

GROUPS	1	2	3
D	2.13	4.31	6.25
C	4.56	7.81	8.56

TABLE 5M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.21	1	36.92	.001
EXPLANATION BY AGE	0.27	2	23.68	.001
EXPLANATION BY READING ABILITY X AGE	0.02	2	1.38	NS
RESIDUAL	0.51	90		

TABLE 5M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 6

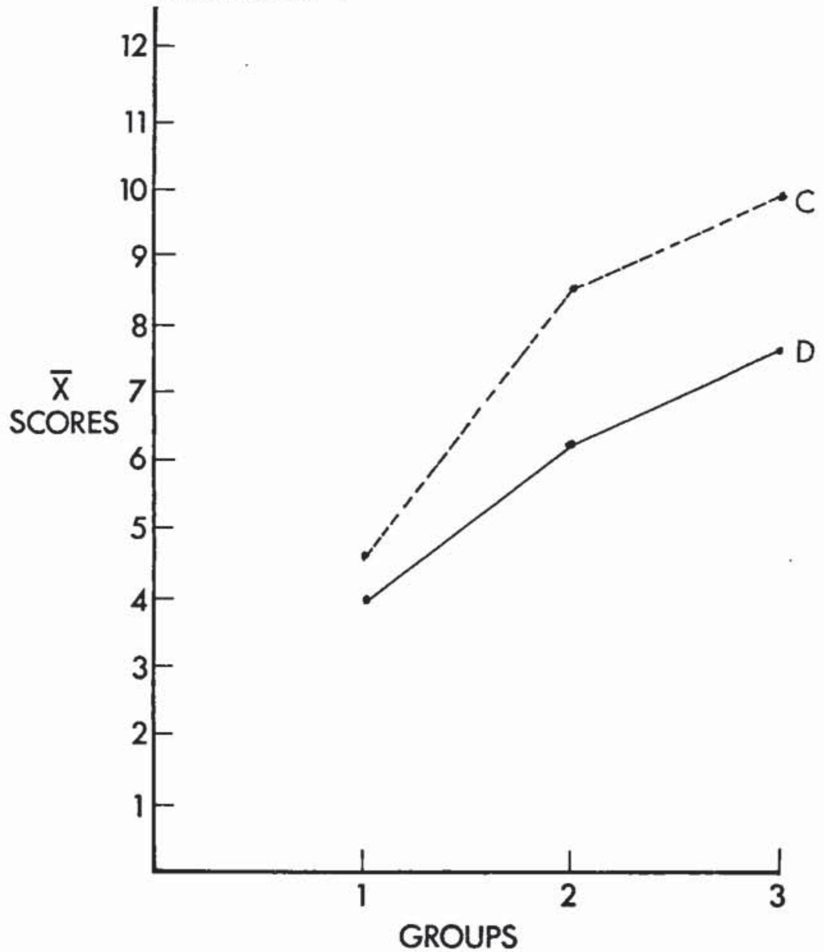


FIG. 6M Mean Scores by Group

GROUPS	1	2	3
D	4.00	6.19	7.81
C	4.63	8.56	9.94

TABLE 6M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.00	1	15.03	.001
EXPLANATION BY AGE	0.41	2	37.12	.001
EXPLANATION BY READING ABILITY X AGE	0.02	2	1.54	NS
RESIDUAL	0.49	90		

TABLE 6M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 7

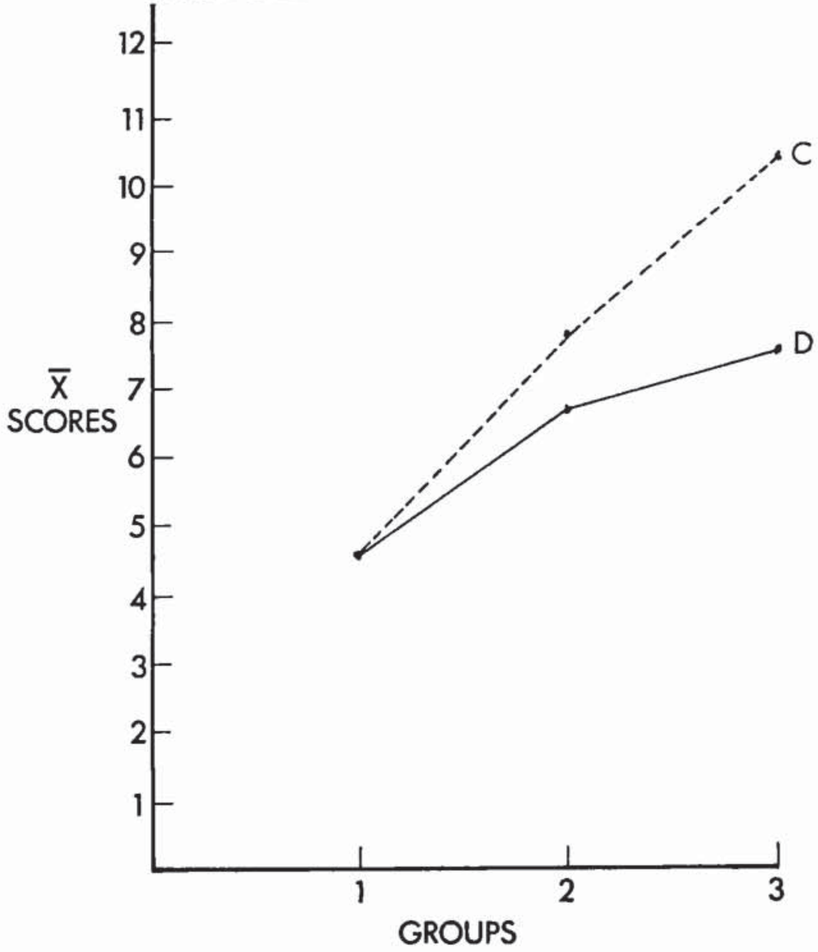


FIG. 7M Mean Scores by Group

GROUPS	1	2	3
D	4.63	6.75	7.63
C	4.63	7.88	10.44

TABLE 7M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.06	1	11.63	.001
EXPLANATION BY AGE	0.45	2	44.40	.001
EXPLANATION BY READING ABILITY X AGE	0.05	2	4.51	.01
RESIDUAL	0.45	90		

TABLE 7M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 8

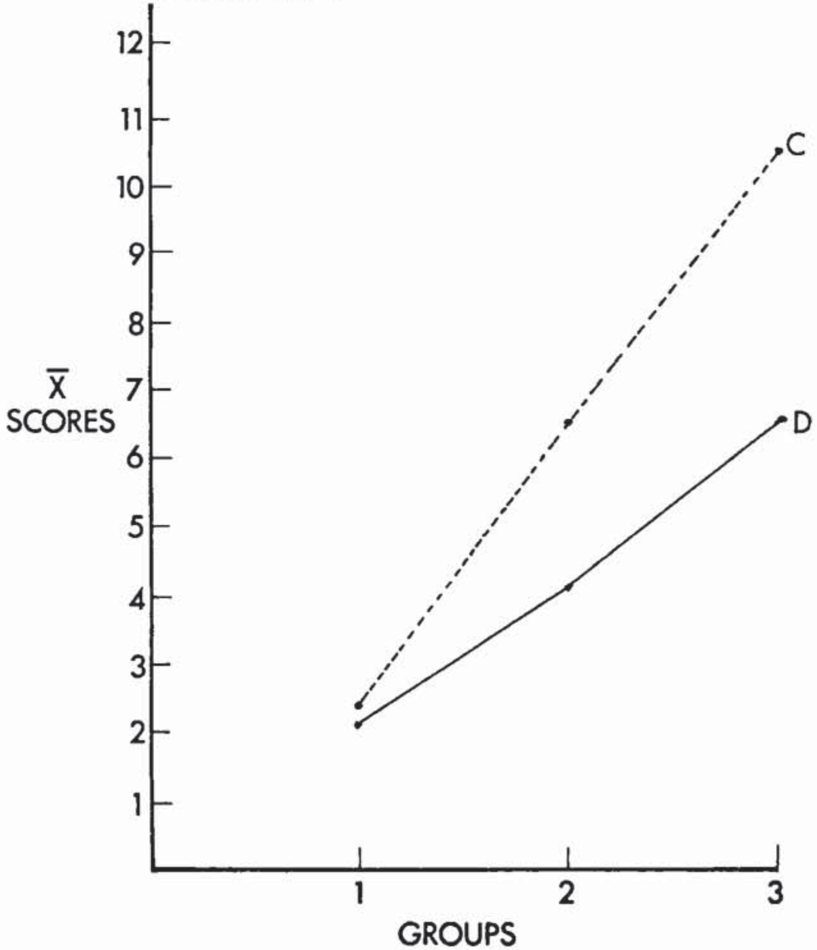


FIG. 8M Mean Scores by Group

GROUPS	1	2	3
D	2.19	4.19	6.63
C	2.38	6.50	10.63

TABLE 8M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.09	1	22.53	.001
EXPLANATION BY AGE	0.51	2	64.40	.001
EXPLANATION BY READING ABILITY X AGE	0.05	2	5.84	.01
RESIDUAL	0.36	90		

TABLE 8M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 9

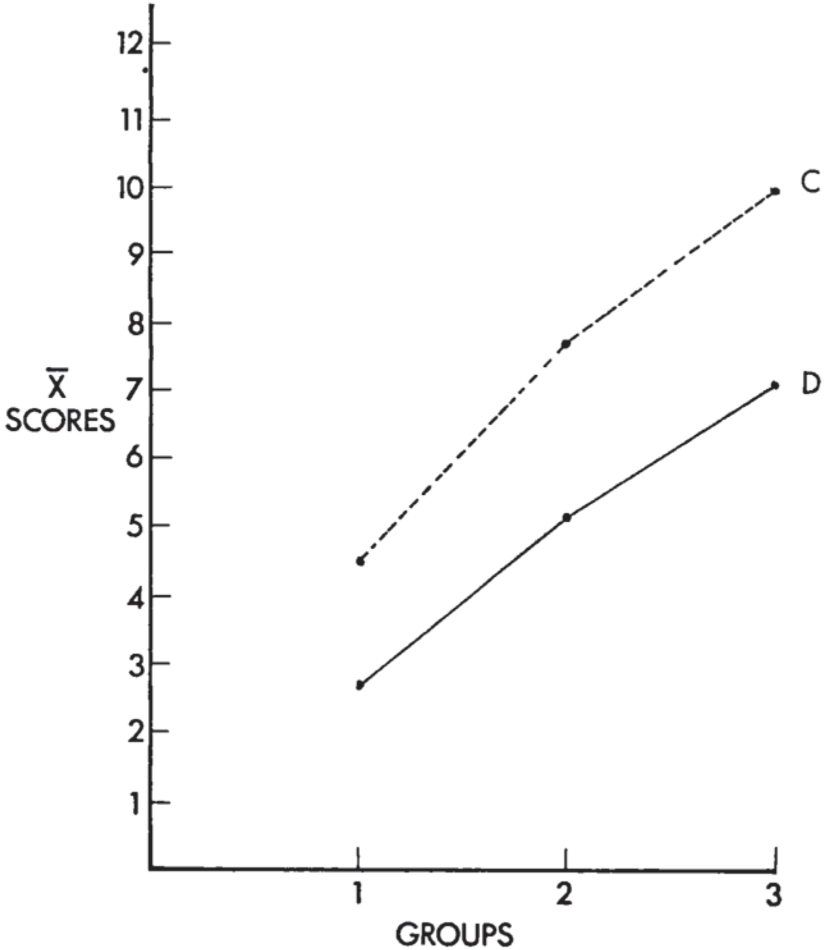


FIG. 9M Mean Scores by Group

GROUPS	1	2	3
D	2.75	5.19	7.13
C	4.44	7.81	10.00

TABLE 9M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.15	1	32.16	.001
EXPLANATION BY AGE	0.43	2	46.55	.001
EXPLANATION BY READING ABILITY X AGE	0.01	2	0.73	NS
RESIDUAL	0.42	90		

TABLE 9M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

MODULE 10

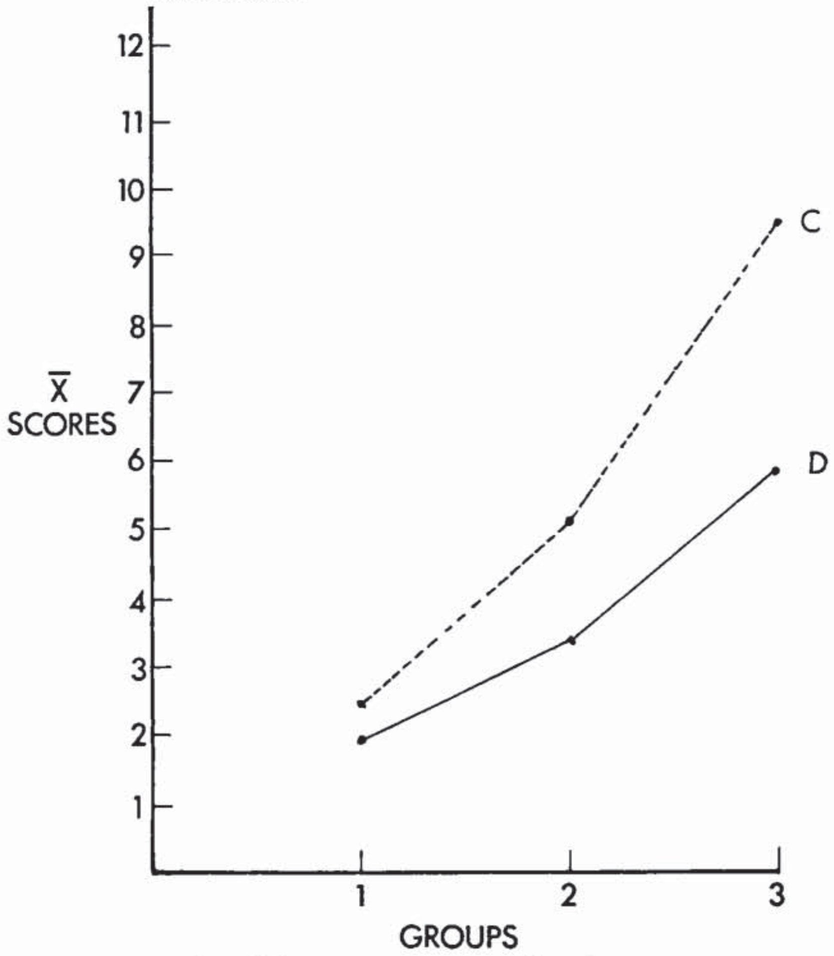


FIG. 10M Mean Scores by Group

GROUPS	1	2	3
D	1.94	3.44	5.94
C	2.44	5.06	9.50

TABLE 10M(a) Mean Scores by Group

SOURCE	Variance	df	F	P
EXPLANATION BY READING ABILITY	0.08	1	19.28	.001
EXPLANATION BY AGE	0.49	2	55.88	.001
EXPLANATION BY READING ABILITY X AGE	0.04	2	4.29	.01
RESIDUAL	0.39	90		

TABLE 10M(b) ANALYSIS OF VARIANCE SUMMARY TABLE

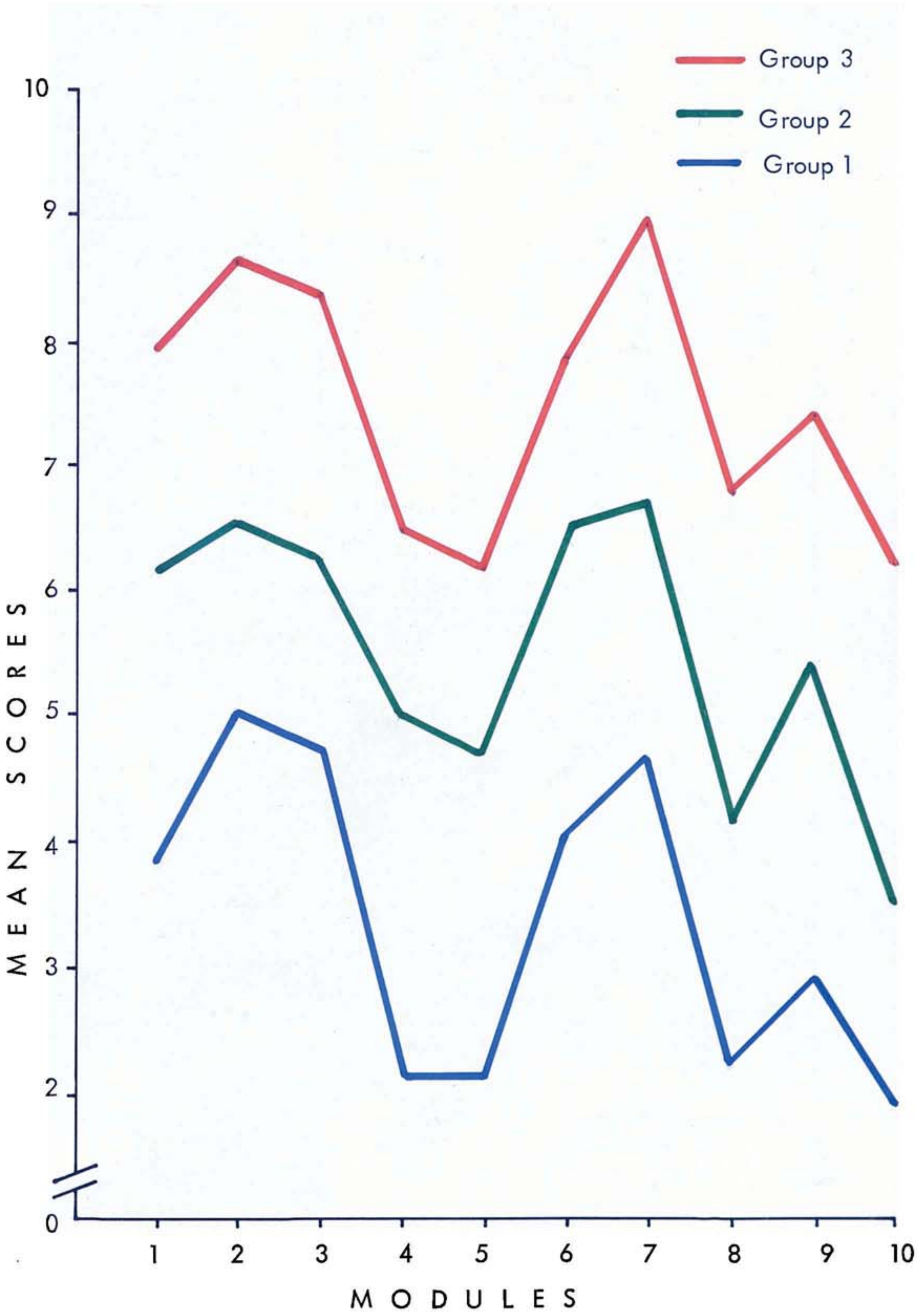


Fig.1 : Maths Modules - Mean Scores for Dyslexic Groups

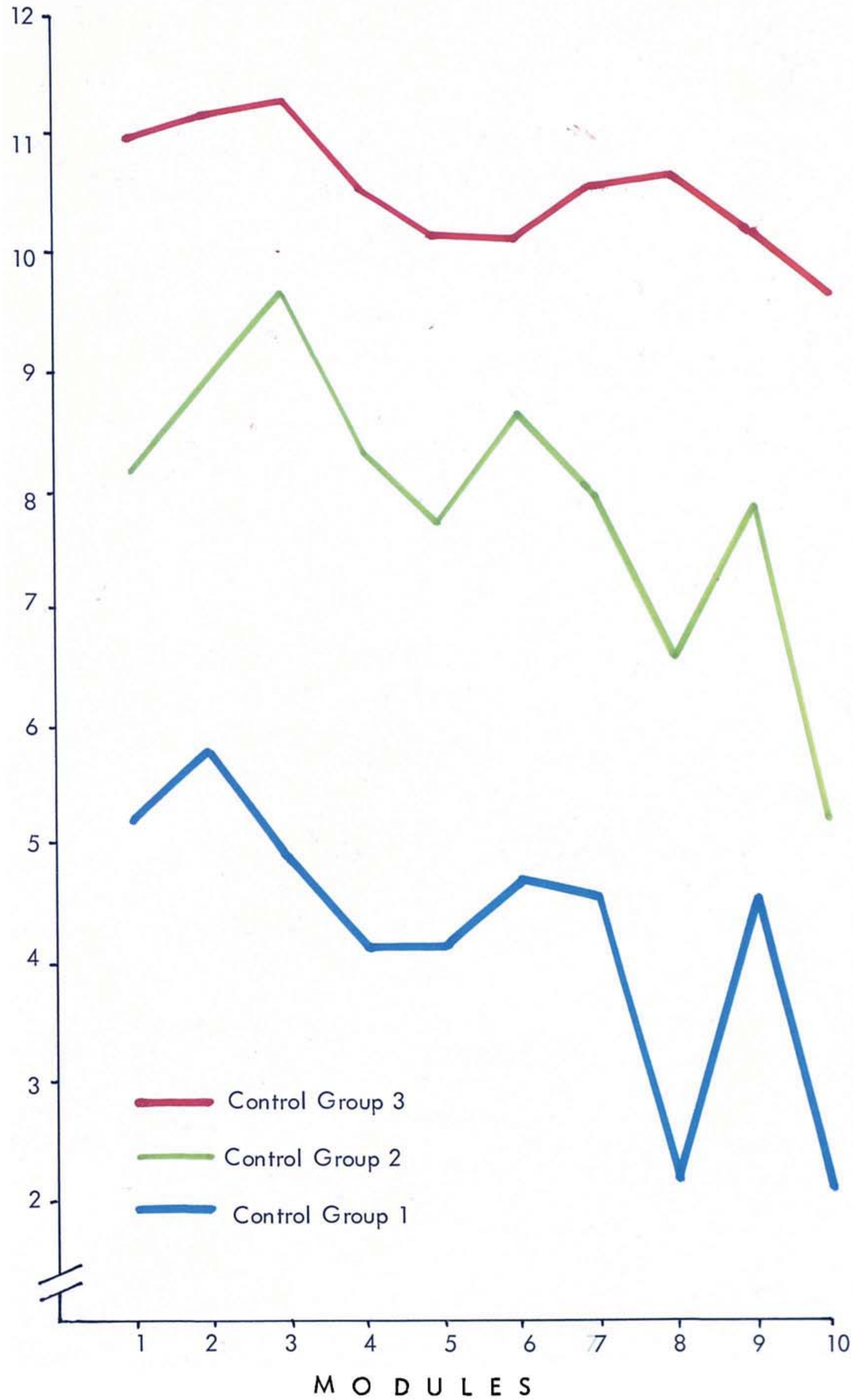


Fig.2 : Maths Modules - Mean Scores for Control Groups.

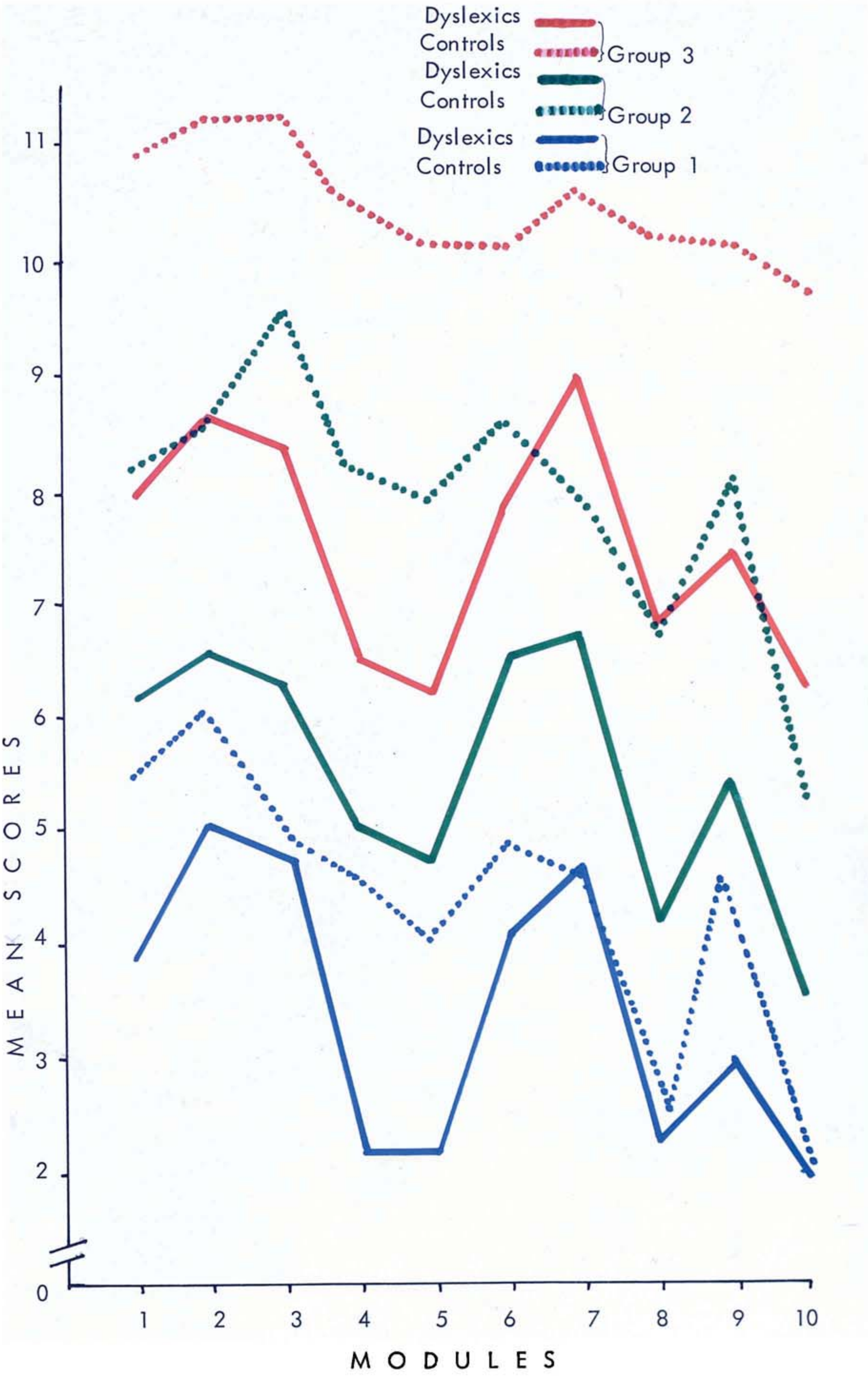


Fig. 3 : Maths Modules - Mean Scores for Dyslexic and Control Groups.

in Group 1, except on Modules 4 and 5 (multiplication and division). With increasing age the relative differences increase. Control Group 3 reaches a ceiling level.

Test for Trend

Because of the marked similarity in the polygram shapes, especially those of the Dyslexics, a Test for Trend (Kirk, 1968) was applied. However, despite the visual appearance, no significant trend emerged. It could be that the joining up of discrete scores, to form the polygram, had led to a false impression of relationship.

Mann-Whitney U Tests

Using the mean scores, Mann Whitney U-Tests (Siegel, 1956) were computed. Table 1 lists the differences in significance levels yielded by this analysis (one-tailed). The lowest probability above which differences are considered significant is the 5% level. The highest level of significance adopted is $p < .001$. Whilst it is recognised that the choice of significance levels is arbitrary, in itself, the fact that the Groups being compared are matched for age and intelligence level, makes comparison permissible. Where sufficient váriance is taken into account, roughly equivalent differences in significance levels seem to be indicative of same quantitative, if not qualitative, difference between Groups.

From Table 1 it can be seen that overall the Dyslexic subjects' performances are poorer than those of the Controls.

Examining each age group individually, it appears that the youngest group of Dyslexics differ from their matched Controls for 3 of the 10 modules; multiplication (Module 4) and division (Module 5) differ at

TABLE 1: STUDY 4: MATHEMATICS MODULES - SIGNIFICANCE LEVELS OF DIFFERENCES BETWEEN GROUPS ON MANN-WHITNEY U TEST (ONE-TAILED)

GROUPS	AGE	MODULES									
		1	2	3	4	5	6	7	8	9	10
Dyslexic 1/Control 1	NS	NS	NS	NS	0.05	0.01	NS	NS	NS	0.001*	NS
Dyslexic 2/Control 2	NS	0.008	0.006	0.002	0.001	0.001	0.02	0.04	0.003	0.002	0.03
Dyslexic 3/Control 3	NS	0.001	0.001	0.001	0.001	0.001	0.004	0.003	0.001	0.004	0.001
Dyslexic 1/Dyslexic 2	0.001	0.01	0.03	NS	0.001	0.001	0.01	0.003	0.005	0.001	0.02
Dyslexic 2/Control 1	0.001	NS	NS	NS	NS	NS	0.05	0.003	0.01	NS	0.02
Dyslexic 2/Dyslexic 3	0.001	0.04	0.007	0.02	0.03	NS	NS	0.03	0.005	0.03	0.005
Dyslexic 3/Control 2	0.001	NS	NS	0.04	0.007	0.04	NS	NS	NS	NS	NS

KEY

* 0.001 has been adopted as the maximum significant level for results.

NS Represents no difference between scores below the .05 level of significance.

the 5% and 1% levels of significance respectively. Questions involving money (Module 9) prove to be most difficult for Dyslexic Group 1, relative to their Controls ($p < .001$).

Dyslexics in the 11 years - 13 years 11 months age range (Group 2) score poorly relative to their matched Controls, on all aspects tested. Similar findings pertain to Dyslexics and Controls in the oldest age group (14 years - 16 years 11 months).

The performance of the subjects in Dyslexic Group 2 does not differ significantly from the youngest Control Group for Modules 1, 2, 3, 4, 5 and 9. Quantitative differences between the latter groups (Dyslexic 2 and Control 1) are found only for Properties of the 4 Operations, shapes, ratio and proportion and problems (Modules 6, 7, 8 and 10 respectively). Significant differences are found between the scores of Dyslexic Groups 2 and 3 for all Modules ($p < .001$). Similar results are found for Control Groups 1 and 2 and Control Groups 2 and 3 respectively. Control Group 2 does significantly better on subtraction (Module 3, $p < .04$), multiplication (Module 4, $p < .007$) and division (Module 5, $p < .04$) than the oldest Dyslexic Group. There are no significant differences between these two groups' scores for any of the other Modules.

Analysis of Variance

The Analysis of Variance (AOV) (completely randomised) programme available in the Department of Educational Enquiry, University of Aston in Birmingham, was utilised to see if there were significant age and Dyslexic/Control group main effects and whether there was an interaction between these factors. Tables 1M(b) - 10M(b) inclusive list the AOV Summary Tables for Modules 1-10.

Significant main effects are found for age and reading ability (ie. Dyslexics - poor reading, Controls - at least average reading) for all modules. This indicates that for all age groups, as children get older, their performance improves. No significant interaction is found between age and reading ability for Modules 1, 2, 5, 6 and 9. In these cases, Dyslexics and Controls appear to improve at a similar rate but at a differential level of performance. The youngest Dyslexics yield lower mean scores than the youngest Controls and though there is an improvement in performance, the differential is maintained.

Significant interactions are observed for Modules 3, 4, 7, 8 and 10 ($p < .05$, .05, .01, .01, .01 respectively). This relationship appears to indicate that in examples involving subtraction, multiplication, knowledge of shape and spatial relations, ratio and proportion and simple problem solving, the Dyslexics do significantly worse relative to their age-matched Controls as they get older; the differences in attainment increase with age.

Individual Profiles

Individual profiles of Maths Modules scores were plotted for all subjects. These can be seen in Appendix 6A-G. From these it can be seen that the variation in test performance is greater in the Dyslexic Groups than in the Controls, though this may not reach statistical significance in all cases.

10.3 Discussion

Overall the results tend to indicate that Dyslexics are poorer at all the aspects of school mathematics tested, than children without learning difficulties. As the Dyslexics get older, the relative differences in their school mathematics performance becomes more marked; the gap between their attainments and those of matched peers widens and the relative deficit grows. This is reflected, particularly by the significant AOV findings for modules 3, 4, 7, 8 and 10.

Figure 3 shows this increasing discrepancy clearly. For all three Dyslexic Groups, the greatest areas of difficulty appear to be those involving calculations, with multiplication and division being functional indicators of difficulty from at least 10 years of age onwards. Attainments in addition and subtraction tend to differentiate Dyslexics from Controls from the age of 11 years upwards. Thus the first hypothesis is accepted; that Dyslexics do do worse on the calculative aspects of arithmetic.

In the youngest age group (8 years - 10 years 11 months) these differences are only significant for multiplication (Module 4) and division (Module 5) and examples involving money (Module 9). The findings of the differences in Modules 4 and 5 may be accounted for by the fact that these operations involve more complex numerical manipulative ability and perhaps short-term memory and these factors may be weak in Dyslexics. The significant difference in Module 9 (Money) for all the Dyslexic Groups is relative to Controls somewhat surprisingly, since it was assumed that calculations involving money would be familiar and relevant and thus account for less errors.

Low scores on this Module seem to have been caused by notation and place value errors. Scripts were scored according to the Mathematics Modules Manual. Marking criteria are strict. For example, if the child writes £1.06p instead of £1.06, the answer is designated in correct. Also, many children knew the answer, but put the decimal point in the wrong place or left out a zero (£1.6/£1.06; £106./£1.06 etc.). More details about these errors will be given in Study 5.

In Groups 2 and 3, the Controls' performances are significantly better for all Modules, though in Group 2, the difference is significant at a lower level for Modules 6, 7 and 10; tests involving understanding of operations, spatial relations and simple problem solving. This finding reflects a general intra group trend for the Dyslexics:

Intra Group Trend - Dyslexics

Scores on addition (Module 2) are relatively high. Maximum exposure and overlearning may have led to mastery of this skill. Although there is a slight decrease in attainments similar findings may apply to subtraction. Multiplication and Division (Modules 4 and 5 respectively) yield the Dyslexics' poorest scores. As mentioned previously this may be a result of the more complex manipulative skills involved, and increased short-term memory load. Understanding of how to utilise the four operations (+, -, x, ÷) is superior to the accuracy of application. It could be that the Dyslexics understand the concepts behind the operations and know when to use the appropriate one, but are unable to carry it out (the mechanical aspects of calculation) successfully. Nevertheless the discrepancy between their understanding and that of the Controls does increase, suggesting that the former group are still operating at a lower level.

Relatively high scores were yielded for all the Dyslexic Groups on Module 7, that of Spatial Knowledge. Thus within the Dyslexic Group it seems that this area of the curriculum is least problematical. However, since differences between mean scores are significant for this Module, in Groups 2 and 3, the second hypothesis has to be rejected, that is, little evidence was found to support Newton's (1974) and Bannatyne's (1971) suggestions of equivalent or superior spatial ability in Dyslexics. It must be noted though this could be the function of the test, so that this finding (and all findings in fact), should not be taken out of context.

Within the Dyslexic Groups' performances, the higher scores on the Spatial Module should also be viewed cautiously. Although Figures 1 and 3 give the impression of superior performance within the Group profile, it could be that it is just the very low scores on many of the other Modules that is creating an artificial appearance of superiority in Module 7.

The shape of the polygram, though not indicative of a statistical trend, seems to be reflecting a pattern of relative areas of strengths and weaknesses, within the topics under investigation, which is established in the early years of schooling and maintained in older Dyslexics. Of course, studies of this nature, which are not longitudinal, cannot make claims to the identification of developmental trends. However, tentative suggestions can be made on the basis of results collected from successively older samples of children selected on similar criteria.

Intra-Group Performance - Controls

The pattern of scores in the Control Groups is also fairly uniform, though again the Trend Analysis suggested that while scores on particular modules may reflect trends, the overall Module profile does not. In the Control Groups the relative difference between scores is less marked than in the Dyslexic Groups, especially those between Modules 2 and 3 and 4 and 5 respectively. Performance in multiplication and division is more closely associated with scoring in addition and subtraction, than is the case in the Dyslexic Group. The Controls do not indicate the relatively high scores on Module 7, as do the Dyslexics. Their calculations with money, though, appear to be successful.

The flattening out effect seen in the polygram of Control Group 3, reflects a ceiling effect. These tests were designed for assessment at the time of transition from primary to secondary school - the tests proved too easy for most of the subjects in Control Group 3. A mean score of 10 or more for any Module is considered as mastered well, according to the Manual, and many subjects in this Group exceeded this score.

Relatively low scores on Module 8 (Ratio and Proportion) for all groups is in keeping with the findings of the Test Designers, who suggest that this Module requires modification.

Individual Score Profile

The mean scores for the Modules reflect Group differences. However the plotting of profiles of Module Scores for all subjects, reveals large individual differences, within Groups. This is especially marked within the Dyslexic samples. Although cluster analysis on results including this data (see Section 5)
of this Chapter) revealed no significant results, it could be that using larger samples, different subgroups of Dyslexics will emerge, based on differential performance in school mathematics. Speculations as to these Groups will be included in the Final Discussion of this thesis.

10.4 Case Studies

Figures 4 and 5 illustrate a few case studies of Dyslexics and Controls Mathematics Module profiles.

Figures 4 and 5 respectively illustrate the profiles of one Dyslexic and one Control subjects in Group 1. Similar profiles are also found in Groups 2 and 3.

A. Glenda (Control 1)

WISC:	Full Scale	99	Chronological Age:	9 years 1 month
	Verbal	102	Reading Age:	10 years 6 months
	Performance	95	Spelling Age:	10 years 1 month

Glenda's performance is marked by superior scores on the Modules involving calculation and money relatively low scores on spatial concepts. This contrasts strongly with the general Dyslexic profile in which this pattern is reversed. Within her profile, Glenda's problem solving scores (Module 10) and application of operations (Module 6) are average.

Glenda is regarded by her teachers as a higher achiever in "mathematics", although her profile suggests to the present writer that she may be good at mechanical arithmetic and relatively poor at understanding more complex mathematical concepts. This latter view was borne out in an interview with Glenda.

B. <u>Helen (Control 1)</u>

WISC:	Full Scale	121	Chronological Age:	9 years 4 months
	Verbal	115	Reading Age:	12 years 0 months
	Performance	123	Spelling Age:	11 years 6 months

Helen's performance is indicative of all round proficiency in school mathematics. There are relatively small discrepancies between scores. Helen's high attainments may be related to her superior intelligence level, as measured on the WISC-R.

Helen's profile contrasts strongly with that of Glenda whose performance is more variable.

C. <u>Chris (Dyslexics 1)</u>

WISC:	Full Scale	113	Chronological Age:	9 years
	Verbal	106	Reading Age:	7 years 1 month
	Performance	110	Spelling Age:	7 years

Chris is almost a non-starter in calculation and knowledge of number. He was able to answer questions orally, but could write very little. Unexpectedly his mental arithmetic was better than might be expected of a Dyslexic. He could identify some shapes, but was unable to compute examples involving spatial relationships.

D. <u>John (Dyslexics 1)</u>

WISC:	Full Scale	107	Chronological Age:	10 years 1 month
	Verbal	103	Reading Age:	7 years 9 months
	Performance	111	Spelling Age:	7 years 10 months

John shows good understanding of the characteristics and properties of number and where it is appropriate to apply arithmetical operations (Modules 1 and 6). His calculative ability is poor though, with

FIG. 4: CASE STUDIES - YOUNG DYSLEXICS AND CONTROLS' PERFORMANCE ON THE MATHEMATICS MODULES

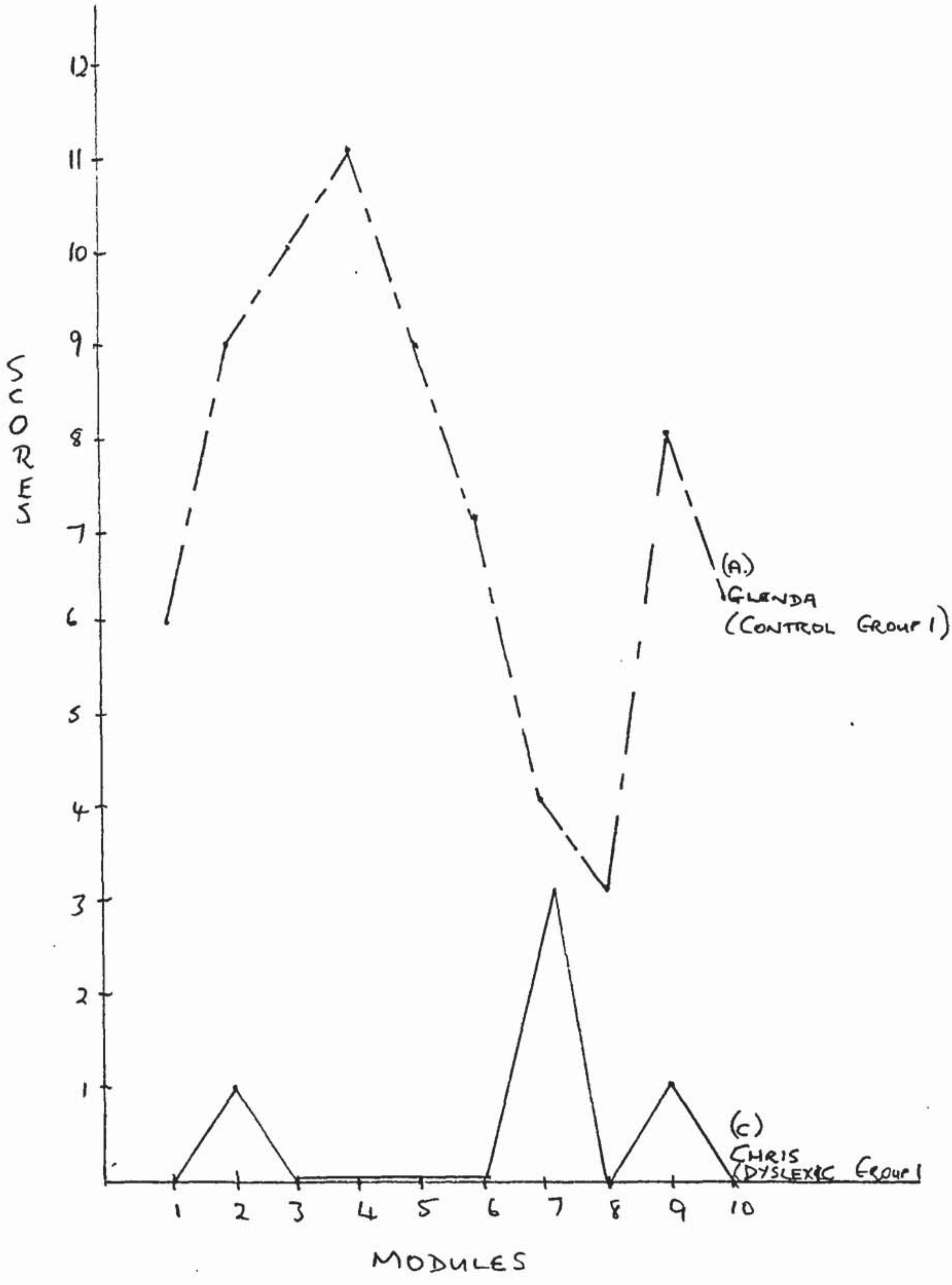
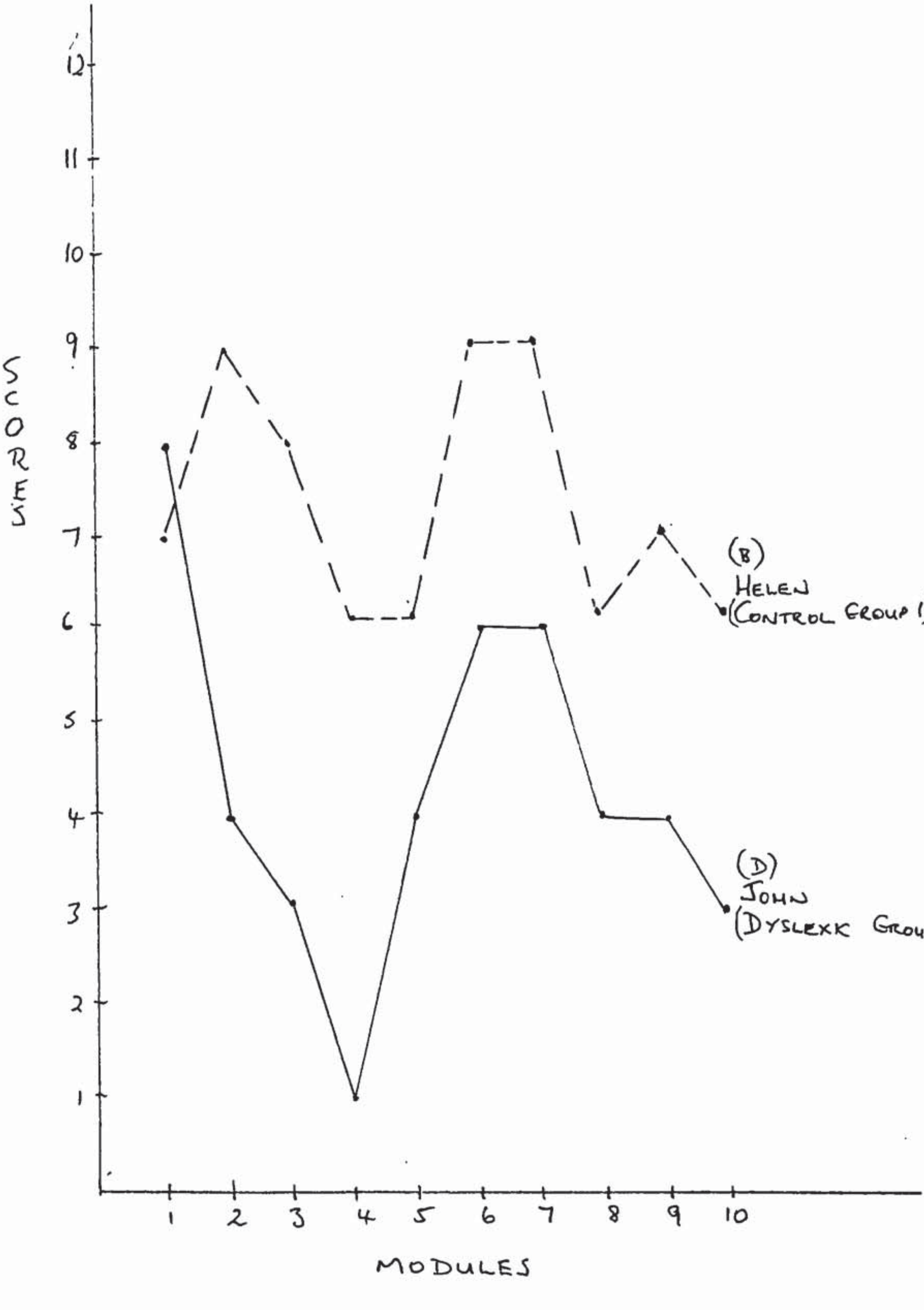


FIGURE 5: CASE STUDIES - YOUNG DYSLEXICS AND CONTROLS PERFORMANCE ON THE MATHEMATICS MODULES



multiplication proving very difficult. He seems to characterise the Dyslexic whose conceptual knowledge is sound, but whose difficulties lie in writing things down. Similar cases have been noted by Klees (1976) and Fincham & Meltzer (1976).

To recapitulate, the findings in this study suggest that, in general, Dyslexics do significantly worse than Controls in all the aspects of school mathematics investigated in this study, and get relatively poorer as they get older. Calculation appears to be a major area of weakness for Dyslexics.

Individual differences are found between performance of children in both groups. These are particularly widespread in the Dyslexic Groups. The possibility of subtypes of Dyslexics has been put forward and will be discussed in Chapter 12.

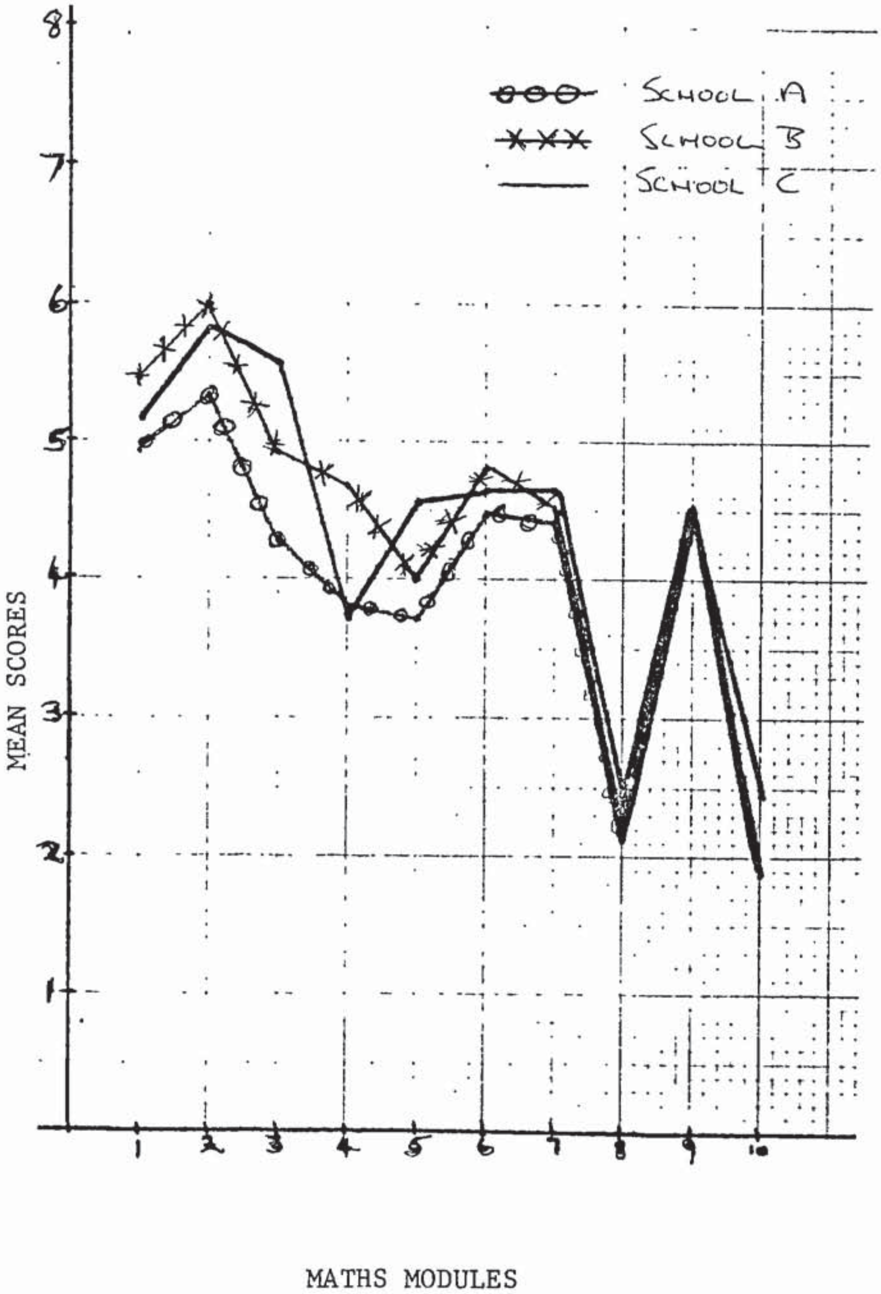
Given the range of topics covered and the relatively low scores for Dyslexics, especially in the older age ranges, it seems that the Mathematics Modules might usefully be maintained as a functional means of diagnosing school mathematical difficulties, especially amongst Dyslexics.

10.5 School Follow Up

(i) Comparisons of Performance of Schools A, B and C

Most of the children from the Control samples in Study 1 also participated in Studies 3 and 4. In Study 1, it had been found that School C performed better on the LJ1-Linear than the other schools. In Study 4, performances for the three schools were compared again (see Figure 6). Mann-Whitney U Tests revealed no significant differ-

FIGURE 6: MATHS MODULES - MEAN SCORES FOR SCHOOLS A, B and C.



ences in attainment. From this, it seems that although there may be a slight initial advantage in using "Fletcher Maths", by the time the top junior classes are reached, teaching scheme advantages appear to have averaged out. Kempa & McGough (1977) found that there were no sixth form subjects who had followed "traditional" or "modern" mathematics schemes.

Where applicable, the data from Studies 1, 3 and 4 were subjected to a Cluster Analysis (Wishart's Mode Analysis - Wishart, 1969) to ascertain whether particular test profiles were associated. No clear clusters emerged. It seems likely that the sample was too small for meaningful results to emerge (Coxhead, 1980 - personal communication). It is hoped to re-run this programme when data from additional subjects has been collected.

(ii) Arithmetic/Mathematics

The Writer was interested in whether teachers distinguish orally between "arithmetic" and "mathematics" when discussing school mathematical topics in the classroom. All the teachers from the schools from which the Control children had been selected were asked whether they make the distinction. Only three of the 15 teachers asked, responded in the affirmative.

Teachers were then asked to rate children's performances in arithmetic and/or mathematics on a scale of 1 to 10. Teachers from two of the three schools involved gave only one rating - "mathematics". These scores tended to correspond more closely with the children's arithmetic scores (in Modules 2-5 for example), than to attainments in Modules 1, 6, 7 and 10.

Teachers in school B gave two ratings - one in mathematics and one in arithmetic. Two of the 16 children received higher "mathematics" than "arithmetic" ratings. Teachers suggested that these children understood more about mathematical concepts than was reflected in their written work, especially their calculation scores. Nine out of sixteen children in this school were given higher arithmetic ratings. One such subject, Glenda, is discussed in the previously presented case studies.

In general, the Headteachers and Staff were keen to know the results of the tests. However, in two of the three schools, the Interviewer felt that interest was centred specifically on test scores, rather than on individual differences in performance. One school was (and still is) particularly interested in utilising the information gathered to improve assessment procedures and teaching. The Head of the Mathematics Department has made use of the error analysis data in devising a diagnostic teaching programme.

The Writer considered the contact with the children in schools and in the Language Development, a rewarding experience which provided great insight into the workings of a child's mind, and led to the development of some interesting relationships. It is hoped that further co-operation with the schools involved in these studies will lead to longer term investigators, in which longitudinal data may be gathered.

CHAPTER 11

11. ERROR ANALYSIS - STUDY 5

AIMS

1. To gain qualitative information about the Dyslexic and Control Groups' performances respectively on the Mathematics Modules.

2. To identify solution strategies which may account partially for the large differences between the Control Groups' total scores and those of the Dyslexic children, found in Study 4.

3. To categorise errors in a manner than may prove diagnostically useful, particularly for Dyslexics.

11.1: Introduction

Having obtained quantitative data on the subjects' performances on the Mathematics Modules, it was decided to qualitatively assess their results, by doing an extensive error analysis. This was considered desirable in that it was hoped that it would provide some clues as to the children's methods of calculation and problem solution and also give some indication of the areas of relative strengths and weakness in their performances, which were not revealed by the total scores. As Hauessermann (1958) (in Krutetskii, 1976) points out, tests show which tasks a person can or cannot do, but they disclose little about how the person arrived at the solution. They also tell us nothing about the reasons for failure. Error analysis seems a viable way of getting around these difficulties. It may provide some understanding about the steps a child is taking when carrying out various school mathematical exercises; what s/he gets right or wrong; whether mistakes are random or consistent and whether they reflect a lack of underlying knowledge.

Information gleaned in this way could have a two-fold purpose for psychologists and teachers. First, some insight might be gained into the cognitive approaches adopted during specific tasks. Secondly, as Hollander (1977) suggests, more effective remediation could be based on specific knowledge of a pupil's relative cognitive and scholastic strengths and weaknesses.

Although the technique of error analysis has been used for many years (Buswell & John, 1926, for example), all of the studies encountered in the literature seemed to limit their investigations to the computational aspects of arithmetic. Among the aims of the present analysis was to extend these classifications to include other aspects of school mathematics as well.

Roberts (1968) in studying errors, classified them according to the pupils' methods of attack, which led to incorrect responses. He called these "failure strategies". He identified four classes of errors.

1. Wrong operation - the pupil attempts to solve a problem with an inappropriate operation, eg. 3 - 2 = 5.
2. Obvious computational error - the pupil attempts to solve a problem using an erroneous basic number fact, like 5 x 3 = 35.
3. Defective algorithm (process/rule for calculation) where a solution is attempted employing other than a basic number fact error or an inappropriate operation error: 23 + 12 + 6 = 14.
4. Random response - the pupil attempts to solve a problem in a way showing no discernible relationship to the given problem.

The fourth response category, Random Response, poses a problem, because it becomes a catch-all for any errors that do not fit into the other three classes. In Roberts' words:

> "In many instances a response might have been classified as random even though the student may have used a perfectly consistent, if incorrect, strategy." (p.446)

Cox (1975) includes Systematic Errors in his classification. The other groups he distinguished are Random Errors and Careless Errors. A similar system is adopted by Blankenship (1978) though this Writer applies it to subtraction only. Whilst this analysis is useful as an initial tool, material included in these categories is thought by the present writer to be too diverse. The same is true of Roberts' classification.

Roberts (1968) does suggest though that his error types have a number of major sub-divisions. Engelhardt (1977) criticises the use of what he sees as "broad, high inference descriptions" like "random" or "careless" and considers the subdivisions within them worthy of consideration as separate error types. He extended Robert's classification, based on results from the Stanford Diagnostic Arithmetic Test (Beatty et al., 1966), given to groups of 8-9 year olds and 11-12 year olds. This expansion was made to avoid the tendency to focus exclusively on the more observable mechanical procedures of computation. A conceptual component was included, that is, a group of errors potentially caused by the same misunderstanding were thought to form a separate error type.

Engelhardt's (1977) analysis of the subjects' errors led to the identification of eight error types.

1. <u>Basic Fact Error</u> - the subject's computation includes an error in recalling a basic number fact. The subject employs a simple number sentence that is untrue, eg. $4 + 3 = 8$; $63 \div 7 = 8$.
These errors are observed mostly within multi-digit and/or multi-stage computations.

$$\begin{array}{r} 27 \times \\ \underline{9} \\ \overline{236} \end{array}$$

(Error: $9 \times 7 = 56$).

2. <u>Defective Algorithm</u> - a systematic but erroneous error is executed. These errors cannot be described as random because the steps are explicable and responses to similar computational tasks are predictable.

$$\begin{array}{r} 123 \times \\ \underline{42} \\ 186 \end{array}$$

Explanation: $2 \times 3 = 6$
$4 \times 2 = 8$
$1 \times 1 = 1$

3. <u>Grouping Error</u> - computation is characterised by a lack of attention to the positional nature of our number system. Errors of this type are especially obvious in computational tasks that require regrouping (carrying).

For example:

$$\begin{array}{r} 57\ + \\ \underline{93} \\ 1410 \end{array}$$

Columns added separately, (no carrying).

Also included are other computational situations not requiring "regrouping" nevertheless suggestive of grouping errors.

For example:

$$\begin{array}{r} \underline{23 \text{ r } 1} \\ 3\overline{)610} \end{array}$$

- the place value of "2" has been ignored.

Sometimes errors which at first appear to be the result of a defective algorithm, could be inferred to be grouping errors. For example, a commonly found multi-digit multiplication error is:

$$\begin{array}{r} 13\ \times \\ \underline{14} \\ 52 \\ \underline{13} \\ \underline{65} \end{array}$$

4. <u>Inappropriate Inversion</u> - a critical aspect of the solution procedure is reversed. Computations classified as inappropriate inversions display reversals of steps in algorithms which often appeared to promote faster responses.

For example:

$$\begin{array}{rl} 43 & \text{- minuend} \\ -\ \underline{19} & \text{- subtrahend} \\ 36 & \end{array}$$

The subject reverses the units in the minuend and subtrahend, thus omitting the "borrowing" step, and deriving a quick response. Another example of this type of error is in a computation involving carrying, in which the place values of the partial sums are reversed.

For example:

$$\begin{array}{r} 23\ \times \\ \underline{7} \\ \underline{152} \end{array}$$

5. Incorrect Operation - the pupil performs an operation other than the appropriate one.

Examples: $\begin{array}{r} 2 \\ \times 3 \\ \hline 5 \end{array}$ $\begin{array}{r} 13 \\ -1 \\ \hline 14 \end{array}$ $4 \div 2 = 8$

6. Incomplete Algorithm - the subject initiates the appropriate operational procedure, but aborts it, or omits critical steps.

7. Zero Errors - the subject computes problems containing zeros in ways suggesting difficulty with the concept of zero.

8. Identity Errors - the subject computes problems containing zero and one in a way suggesting confusion of operation identities.

Pupils who made mistakes included in Error Types 7 and 8, appeared to have inadequate concepts of zero and/or one, or to have confused the roles of 0 and 1, in the various operations.

The Basic Fact and Incorrect Operation error types correspond directly to Roberts' (1968) Obvious Computation Error and Wrong Operation failure strategies respectively.

Engelhardt (1977) points out the inference of error types (ie. conceptual/procedural approaches to incorrect responses) from the subjects' written performance, is a limiting factor, in his own study. The present study sought to rectify this shortcoming by interviewing all subjects and questioning them about their responses on various items. Using this opportunity to investigate a given error further, it was hoped to greatly reduce the possibility of misjudging the origin of the said mistake. Engelhardt also limited his attention to approaches to computation which yielded incorrect responses only. It was of interest in this study to investigate how competent subjects arrived at answers. It was also recognised that erroneous approaches sometimes yield correct responses. If this was suspected, subjects were questioned further.

Engelhardt (1977) intentionally denied (excluded) careless errors. The present study included a category of this type, when it became apparent that a number of errors seemed to fit this description.

Method

Subjects

The same subjects included in Study 4 comprised the sample for the present investigation.

Procedure

Each subject's scripts, comprising 120 items, were individually analysed and commonalities sought amongst the errors made.
The Investigator supported Engelhardt's (1977) contention; it was decided that realistic error descriptors were more important than statistical neatness. Therefore it was accepted that examples might be classified as containing more than one error type.
Consequently, if one item contained two obvious and different errors, both were recorded in the appropriate categories.

As well as subjecting their scripts to in-depth perusal all children were individually interviewed. In this way, the Tester was able to ask the child directly how a particular answer was derived, instead of having to rely solely on their written performances. This was particularly relevant when it seemed that an individual had employed an interesting or unusual strategy to achieve a solution.

Additionally, the Interviewer was aware that, especially in the case of Dyslexics, the inability to produce the correct answer need not necessarily be indicative of a lack of understanding of the underlying processes.

11.2 Results

From the item analyses and the interviews, fourteen different categories of errors were identified. Items were classified in Error Categories 1-12 inclusive if they appeared to be systematic and/or easily identifiable as meeting the criteria for inclusion in that "Error Type". Unsystematic errors, for which there was no obvious reason or precedent in the child's scripts, were designated as "Random". If no attempt at a solution had been made and the subject had been alerted to the example, a "Refusal" was registered.

I. Classification of Errors

From the error analysis, fourteen main classes or types of errors were identified. These included mistakes pertaining to the following:- Properties/Characteristics of Number; Reversals, Sequencing and Direction; Miscalculation; Carrying/Regrouping of Numbers; Arithmetical Operations; Positional Nature of Number/Place Value; Terminology/Misinterpretation of Question; Notation; Setting Out; Reliance on Visual Cues/Spatial Visualisation; General Lack of Knowledge/Bizarre; Abandoned; Random Errors; Refusals. Illustrative examples used below are taken from the Maths Modules (Sumner & Bradley, 1978).

Error Type 1 - Properties and Characteristics of Number

A. Equivalence

(i) Many subjects were not aware that different representations of numbers and facts could yield equivalent answers. For example, that 8 tens are equivalent to 80; or that if 8 x 20 = 160

then 9 x 20 = 160 + 20

(ii) Other instances of equivalence errors related to the Commutative and Associative Laws.

<u>Example</u> (from Maths Module 6)

Tom added 53 and 88.

Pat added 88 and 53.

If they both added correctly, then:

(a) Tom's answer is larger than Pat's.

(b) Pat's answer is larger than Tom's.

(c) Tom's answer is the same as Pat's.

Tick the right answer.

The most frequently given incorrect answer was (b).

B. <u>Identity</u>

Here, the identity properties of 0 and 1 were not known. Subjects lacked knowledge of the following facts:-

$N \times 1 = N$

$N \times 0 = 0$

C. <u>Number Systems</u>

Children were unable to select examples of the following number systems: odd numbers, even numbers, whole numbers, square numbers, prime numbers, etc. For example (from Maths Module 1):

Three of the following are odd numbers. Draw a ring round each of the odd numbers: 30 14 27 41 5

Error Type 2 - Reversals, Sequencing, Directions

A. Reversals

Reversals were identified in answers where the correct digits were present, but in the incorrect order.

For example: 23 + 39 = 26.

If on questioning the child responded that the answer was "sixty-two", the answer was marked as correct, but noted as a reversal.

B. Sequencing

Mistakes were included in this sub-section if the respondent was unable to fill the place-holder with the appropriate number in a sequence.

Example (taken from Maths Module 1):

Which number is next in sequence?
107, 108, 109, ___

Fill in the missing numbers in this series:
284 275 266 ? 248 239

As Mary counted she just wrote down the last figure in each number
...9, ...2, ...5, ...8, ...1

She could be counting forward in (a) twos
(b) threes
(c) fours
(d) fives

Tick the right answer.

C. Direction

Here, pupils were unable to solve simple graphically presented problems because they could not identify the four main compass points: North, South, East and West. This applied, too, to examples where an indication of North was given.

Error Type 3 - Miscalculation

A. General

Most mistakes in this category resulted from the use of an erroneous number fact, often as a result of a lack of knowledge of tables.

Example: $7 \times 8 = 64$

$5 \times 7 = 25$

The same computation, yielding two different answers was sometimes used in one calculation.

For example, one child used $7 \times 8 = 56$

and $6 \times 8 = 56$

in the same sum.

B. Identity Errors

(i) Zero

Mistakes in this group were indicative of a lack of knowledge that any number multiplied by zero is zero. Many subjects who made this mistake in a written calculation, were found to be cognisant of this identity factor when asked orally.

(ii) One

A similar lack of appreciation that multiplication and division by one yields the original figure, despite contrary indications when questioned.

C. Missing by One

Answers in this category were incorrect by one integer, usually through inappropriate inclusion.

For example: In adding $4 + 3$, the child includes 4 in the sum, and gets an answer 6. Similarly, in subtraction, $8 - 2$ yields an answer of 7.

Error Type 4 - Carrying/Regrouping

The most frequently made errors in arithmetic occurred when the subject was required to "carry" numbers. Carrying is also known as regrouping or renaming of numbers.

Here, in accordance with our decimally (ten) based number system, the child is required to regroup numbers in order to carry out an algorithm (computational procedure). The common terminology for this is carrying (for addition and multiplication) and paying back (for subtraction and division).

There were a number of sub-divisions in this category:-

(a) Forgetting to carry/pay back

The child regroups the units but forgets to carry out the requisite next step, that of carrying or paying back.

For example:

$$\begin{array}{r} 12 \\ +19 \\ \hline 21 \\ \hline \end{array} \qquad\qquad \begin{array}{r} 53 \\ -16 \\ \hline 47 \\ \hline \end{array}$$

(b) Carrying but not including the regrouped number

The subject computes and marks down the number to be carried, but fails to include it in the column total.

For example:

$$\begin{array}{r} 29 \\ +59 \\ \hline 75 \\ \hline 1 \end{array}$$

and a similar occurrence in subtraction sums:

$$\begin{array}{r} 1 \\ 31 \\ -\ 9 \\ \hline 32 \\ \hline \end{array}$$

(c) Carrying Inappropriate Number

Here the individual carries one ten or one hundred instead of the calculated number.

For example:

$$\begin{array}{r} 57 \\ \underline{x8} \\ \underline{416} \\ 1 \end{array}$$

The child has remembered to carry, but instead of carrying 50 (5 tens) s/he has only carried one ten.

(d) Confusion of number to be carried

Also common is the confusion of the number to be carried.

For example:

$$\begin{array}{r} 42 \\ \underline{x9} \\ \underline{441} \\ 8 \end{array}$$

Here the multiplication is correct, but the tens and units are reversed when the answer is written down, thus 8 tens are carried, instead of 1 ten.

(e) Carrying the appropriate digit, but ascribing to it the incorrect value

For example: $8\overline{)416}$ 50r7

Here, the child has carried "1", but ascribed to it its unitary value instead of "tens" value, and has therefore added the carried "1" to the 6 making 7, rather than the correct sum of 16.

Error Type 5 - Operations

Mistakes in this category relate to the inappropriate application of the algorithms associated with the arithmetical operations of addition, subtraction, multiplication and division.

(a) Mixed operations

The child starts by executing the appropriate algorithm, but changes to another operation half-way through the calculation.

For example:

$$\begin{array}{r} 236 \\ \underline{\times\ 5} \\ \underline{380} \end{array} \qquad\qquad \begin{array}{r} 357 \\ \underline{-\ 89} \\ \underline{4768} \end{array}$$

In the multiplication example, the units and tens columns are correctly computed. In the hundreds column, however, the child does not multiply 5 x 3, but adds the carried "100" to the 200 in the multiplicand.

In the subtraction example, the subject has added the units, omitted to regroup the ten, then subtracted in the tens columns. He has remembered to pay back, but adds, rather than subtracts, in so doing.

(b) Inappropriate Algorithm

(i) In mechanical arithmetic

Here, an inappropriate algorithm is substituted for the required one, though all the calculations are correct. The most common substitution of operations is addition for subtraction.

For example:

$$\begin{array}{r} 29 \\ \underline{-13} \\ \underline{42} \\ 1 \end{array}$$

(ii) In word problems

In this context, an operation is performed which does not supply the appropriate solution to the problem. For example: in the question "One person earns £10.00 per day, how much does s/he earn in a week?", the child divides instead of multiplies, to get an answer.

(c) Defective algorithm

The child executes a consistent, but erroneous algorithm.

For example:

$$\begin{array}{r} 75 \\ \underline{\times 15} \\ \underline{95} \end{array} \qquad \begin{array}{r} 412 \\ \underline{\times 34} \\ \underline{438} \end{array}$$

(Errors of this type are also indicative of lack of knowledge of place value).

(d) Incomplete operation

Here the pupil fails to complete the operation.

For example:

$$\begin{array}{r} 23 \\ \underline{\times 22} \\ \underline{460} \end{array}$$

(e) Omission of operation

This mistake is most often found in word problems, the child forgets to execute a step necessary to the solution.

For example: Jay has 2/5 left of her salary of £10.

Fred has $\frac{3}{4}$ of his original £12.

How much do they have altogether?

The child correctly calculates 2/5 of £10 (£4) and $\frac{3}{4}$ of £12 (£9) but forgets to add these subtotals together.

Error Type 6 - Positional Nature of Number/Place Value

Errors in this category are indicative of a lack of appreciation of the nature of our decimal number system.

(a) Position of digits

In this sub-grouping were included errors which suggested that the subject did not fully understand that, depending on its relative place in a number, a digit can represent a different quantity.

For example: 3 in 321 represents three hundred, whereas 3 in 439 represents thirty.

Conversely, when asked to translate a number given in words into digits, place value errors were also common.

For example: When asked to write down five hundred and sixty four in numbers, subjects gave answers including 500604, 50064 and 5064. Noughts were included inappropriately.

(b) Inappropriate omission of zero

In other examples, zero was omitted inappropriately, thus changing the number value.

For example: $\begin{array}{r} 23 \\ 3\overline{)609} \end{array}$

Other children gave the answer 2 3 (2 space 3) indicating that they realised that the answer is not equivalent to 23, however, they fail to insert the nought, in the tens column.

(c) Decimal Points

In this category many subjects did not know what to do with a decimal point; they did not know what it meant, nor could they place it correctly.

Some erroneous strategies used to cope with this were:-

(i) <u>Omission of decimal point</u>

Here the decimal point was omitted. So, when asked to add:- 2.6 35 2 743 2.31

the result was:

```
  26
  35
   2
 743
+231
----
1037
```

The addition was often correct, but the place value of the numbers had been ignored.

(ii) <u>Inclusion of the decimal point without regard for its position in relation to other numbers</u>

Using the above-mentioned example, mistakes in this grouping took the following form:

```
   2.6
   3 5
     2
  74 3
  2.3 1
 ------
 10.3.7     or   10.37
```

Sometimes, two decimal places were given inappropriately in answers to computations where no decimal points had originally been included.

(iii) <u>Inappropriate placement of the decimal point</u>

Here, especially in sums involving multiplication and division, the relevant change in the placement of the decimal point was not appreciated.

For example: $.3\overline{)2.16}$ with quotient $.72$

.72 was given as the answer, instead of 7.2

```
   2.4
x   .2
   4.8    (instead of .48)
```

<u>Error Type 7 - Terminology/Misinterpretation of Question</u>

Mistakes were classed in this category if they seemed to result from failure to understand the terminology used in the text. This often resulted in the misinterpretation of the question.

Even terms that appear frequently in exercises, allied to certain operations caused difficulty. For example,-having done 8 addition sums, at least 50% of the subjects were unable to find the "total" of 2 numbers. There appeared to be no association between "adding" and "total".

In subtraction, many children were not familiar with the terms "difference", "reduction" and "minus".

Related to the lack of knowledge of terminology was the failure to recognise clues in simple word problems.

In the following example, many children failed to identify subtraction as the appropriate operation for the solution:
Ian has 9 sweets. Mary has 4 sweets less than Ian.
How many sweets does Mary have?

Similarly, division was not always used in the next example in an exercise containing only division sums.
If Fred, Al and Jim have 33 marbles altogether and each has an equal share, how many does Jim have?

The procedures necessary for the solution of these, and more complex problems were not recognised.

Error Type 8 - Notation

A large proportion of the mistakes made in problems involving money, fractions, ratio and proportion were indicative of a lack of knowledge of the conventional notation associated with these aspects of school mathematics. Errors of this nature were included in this category.

For example, the correct answer of £1.06$\frac{1}{2}$ was given orally by a number of children, whose written attempts included £106$\frac{1}{2}$p, £1.06$\frac{1}{2}$p, £1.6$\frac{1}{2}$ and 1pd$^{2}/_{1}$.

Error Type 9 - Setting Out

Setting out of problems proved particularly difficult for Dyslexics. Some common areas of weakness are listed below.

(a) Horizontal to Vertical Placement

Where numbers were presented horizontally and ease of calculation could be facilitated by the vertical listing of these numbers, errors were frequent. When rewriting them in a vertical form, children often did not place them in their correct place value columns (as described in Error Type 6 - Positional Nature of Number/Place Value.)

A similar lack of adherence to appropriate columns was found in the addition of subtotals in long multiplication. Often the actual multiplication process had been carried out correctly, but confusion was caused by inaccurate listing of subtotals.

For example:

```
   236
 x 142
 23600
9 44 0
 4 7 2
968702
```

(b) Miscopying

Miscopying of facts often occurred when working out had been done separately and the answer was being transferred to the appropriate place on the answer sheet.

(c) Inclusion of an Inappropriate Number

Errors in this group resulted from the inappropriate inclusion of a number from another sum or the previous part of the calculation.

Error Type 10 - Reliance on Visual Cues/Spatial Visualisation

In this class children seemed to be relying exclusively on the "visible" aspects of the problem, to reach a solution.

(a) In Calculation

Subjects making this type of error rely on the visual cues (the numbers listed), rather than employing the appropriate algorithm, in order to complete a computation, or else fail to deduce the correct answer because it is not immediately visible. A common form of this, in subtraction, is to subtract the smallest number from the biggest, regardless of whether it is part of the subtrahend or minuend.

For example:

$$\begin{array}{r} 8\ 4\ 3 \\ -\underline{1\ 6\ 7} \\ \underline{7\ 2\ 4} \end{array}$$

(b) In word problems

For example: Mr. White has £100 in the Bank. He receives interest at a rate of 5% a year. After one year he has £105 in the Bank.

Mr. Gray has £300 in the Bank. He receives interest at a rate of 8% a year.

How much money will he have in the Bank after one year?

(Taken from Maths Module 9).

The most common incorrect answer to this question is £308. It seems that the subjects look at the example and see that the interest accrued is equal to the rate of interest. Without regard for the fact that Mr. Gray's capital is £300 (not £100), the subjects simply added £8, rather than employing the algorithm related to percentages, and simple interest. Both the numbers 300 and 8 are visible, and the subjects rely on these for their solutions.

(c) In geometrical problems

Failure to arrive at the correct solution in this subsection is the result of the appropriate number not being immediately visible. Instead of working out the requirement by deduction, the child relies on the numbers listed in the text.

For example: In a question involving equivalence, pupils were asked to find the length of *, in the diagram, if the large rectangle is an enlargement of the small one (so it is the same shape)

(Taken from Maths Module 7)

The incorrect answer most frequently given is 5 cm. The subjects usually think that since in the smaller rectangle, one side is 1 cm. shorter than the other, the same must apply to the larger one. Thus they subtract 1 cm. from the length of the larger figure (6 cm.) and come up with the answer of 5 cm. Also the sides of the smaller diagram add up to 5, which gives them reinforcement for their answer.

In question 4, Maths Module 10, subjects also rely largely on visual cues when asked to find the <u>shortest</u> route between railways stations. Although the distances between stations are marked, many children ignore the mileages given and maintain that the longest route is shortest because it is direct and looks shorter than the more devious route, which, on calculation, turns out to be shorter by one mile.

<u>Error Type 11 - General Lack of Knowledge/Bizarre</u>

Items were classified in this section if attempted responses were deemed to be due to a general lack of knowledge of how to satisfy the requirements of the question. Categorisation of this type was usually made after the child had been questioned as to the strategy which had been employed in the solution. Answers were often bizarre and bore no relation to the question asked. The child was often unable to provide an explanation for the answer yielded. Sometimes the subject was able to supply a description of the attempted solution and was confident that it was correct, but the interviewer felt that the point of the question had been missed.

Error Type 12 - Abandoned

Included in this category were responses which had been abandoned.

(a) Abandoned

In this subgroup, answers were included if the subject had initiated a response, but had then been unable (usually through lack of knowledge) to complete the problem.

(b) Abandoned as complete

Some answers had been abandoned half-way through, usually in a multi-stage problem, where the final part of the solution had been omitted. If questioning revealed that the subject did know how to continue but had failed to do so because of a lapse in concentration or a distraction, the item was included in this category.

For example: (Taken from Maths Module 9)

> You can buy a fridge in two ways:
>
> (i) Cash £74.00
>
> or
>
> (ii) Hire Purchase £18.50 deposit and 24 monthly payments of £2.65.
>
> How much more does it cost to buy it on Hire Purchase than for Cash?

Here subjects worked out the sum paid by Hire Purchase but failed to carry out the final step; to find the difference between Cash and Hire Purchase payments.

Error Type 13 - Random Errors

A mistake was designated as random if that particular error only appeared once or twice in the individual's scripts and seemed to have been a careless oversight, rather than the result of a systematic fault.

Error Type 14 - Refusals

Responses were included in this category if no attempt at a solution had been made. Refusals usually reflected a lack of knowledge on the part of the subjects; they had no idea of how to approach particular problems and/or what was required for their solution.

See Appendix 6 for mis-spellings of correctly identified shapes from Module 3.

11.3:

II. Occurrence of Error Types over Modules

Table 1 indicates the modules in which each type of error occurred. * is used to denote occurrences of more than 10 errors per module. (*) is used where less than 10 errors per module were scored.

Taking each Error Type individually, it is found that:-

1. Mistakes pertaining to the properties and characteristics of number occur in Modules 6, 8 and 9 particularly, with a small number in Modules 1, 5 and 10 respectively.
   Error scores are highest in Module 6 (notably from Question 5 onwards) with Dyslexic Group 3 making more than three times the number of errors of this nature than Control Group 3.
   In this Module the number of Error Type 1 mistakes made by Dyslexics increases over age, whilst those of the Controls decrease.

2. Reversal, Sequence and Direction errors are found predominantly in Modules 1 and 7, and to a lesser degree in Modules 4, 5, 8 and 10.
   The Dyslexics make many more reversal errors than the Controls (67 as opposed to 40 in Module 1, questions 3, 9 and 12).
   Dyslexic Group 2 produced one subject who consistently reversed numbers.
   All groups except Controls 3, had particular difficulty with Module 7, question 7, which involved compass directions.

TABLE 1: OCCURRENCE OF ERROR TYPES OVER MODULES

ERROR TYPES	MODULES									
	1	2	3	4	5	6	7	8	9	10
1. Properties/Characteristics of Number	(*)				(*)	*		*	*	(*)
2. Reversals, Sequence, Direction	*			(*)	(*)		*	(*)		(*)
3. Miscalculation	(*)	*	*	*	*	*	*	*	*	*
4. Carrying		*	*	*	*				*	*
5. Operations	*	(*)	*	*	*	*		(*)	(*)	*
6. Positional Nature of Number/Place Value	*	*	*	*	*				*	(*)
7. Terminology/Misinterpretation of Question	*	(*)	*				(*)	*	*	*
8. Notation								*	*	
9. Setting-Out		*	*	*	*	(*)			*	*
10. Reliance on Visual Cues/Spatial Visualisation							*			*
11. General Lack of Knowledge/Bizarre	*	(*)	(*)	(*)	*	*	*	*	*	*
12. Abandoned		*	*	*	*		(*)	*	*	*
13. Random Errors	*	*	*	*	*	(*)	*	*	*	*
14. Refusals	*	*	*	*	*	*	*	*	*	*

* represents instances in which more than 10 errors per module occurred.
(*) represents instances in which less than 10 errors per module occurred.

3. Miscalculations were scattered throughout the Modules, the highest concentrations being found in Modules 3, 4, 5 and the items involving computation in Modules 9 and 10. Throughout the Dyslexics made more errors, especially in age group 3. Most mistakes occurred from question 5 onwards and increased in number as the items became more complex.

4. The pattern of "carrying/regrouping errors" is similar to that found with Error Type 3. In this case Modules 3 and 4 produced relatively large preponderances of this type of error especially in Dyslexics 3. Most errors occurred after question 4.

5. Most "Operation" errors are found in Modules 4, 6 and 10, though they are scattered throughout Modules 1, 2, 3, 5, 8 and 9 as well.
   More than half of these mistakes are found in the easier test items (questions 1-4), where many instances of mixed operations occur.

6. Positional Nature of Number and Place Value errors in Modules 1-5 inclusive, and Module 9, with six instances in Module 10. Most mistakes occurred after question 6 in Modules 2-5; those involving computation. Modules 2 and 5 produced the largest number of errors in Dyslexics 3, relative to Controls 3 (24 as opposed to 0), with Dyslexic Group 3's performance being equivalent to that of the younger Dyslexics and younger Controls. Module 9, question 6 caused particular difficulty for the three Dyslexic groups.

7. Errors relating to Terminology and Misinterpretation of the question were found mostly in Modules 1, 3, 8, 9, 10 with some scattered items in Modules 2, 7.

Questions 5, 6 and 8 in Module 1, in which the term "greater" was used caused particular difficulty for Dyslexics 1, 2 and 3 and Controls 1 and 2. More Dyslexics misinterpreted questions in Modules 9 and 10 than did the Controls - 91 errors made by Dyslexics, as opposed to 72 made by Controls. The youngest Control Group made more errors in this category than did the same aged Dyslexics; 42 as opposed to 16.

8. Notation errors occurred in Modules 9 and 10, particularly in questions 6-12 inclusive. All these errors pertained to the conventionally adopted representation for ratio, proportion and money. The oldest Control Group made slightly more errors than did the Dyslexic Group 3.

9. While a few errors arising from inaccurate setting were found in Module 6, most of these type of errors occurred in Modules 2, 3, 4, 5, 9 and 10, in examples in which rewiring of the question in a different format was required. The oldest Dyslexic Group made three times as many errors than the oldest Controls, especially in the more difficult questions 8-12 inclusive.

10. Inaccuracy of spatial visualisation resulted in a large number of errors in all groups in Module 7 and about half that number of mistakes in Module 10. Most of the difficulties arose in the items included in questions 4-12.

11. General lack of knowledge and bizarre responses were evident in Modules 1, 4, 5, 6, 7, 8, 9 and 10, with a few instances in Modules 2 and 3.

In general, the Dyslexic Groups' errors are widely scattered throughout the Modules and questions. The Control Groups tend

to make more responses of this type as the items become more complex.
For example, in the easiest range (questions 1-4) the Dyslexics made 63 errors, compared with the Controls' total of 42.
Both Controls 1 and Dyslexics 1 had particular difficulty in answering questions in Modules 1, 5, 6 and 8. All groups lacked the knowledge to answer questions 4-12 of Module 6, to a large extent. Similar findings pertain to all aspects of Module 8).

12. Besides Modules 1 and 6, items were abandoned in all modules. The number of questions left unfinished increased as the material became more complex. Module 4 (multiplication) yielded the highest number of errors in this category for all groups.

13. Random Errors occurred in all Modules, in all groups, although they were a particular feature of Dyslexic Group 3's performance, making three times as many errors as the Controls, especially in Modules 2-5. The Dyslexic Groups made more random errors on the easier items of all the Modules. The Control Groups' random errors tended to involve more difficult items.

14. Refusals were also represented in all Modules with the Dyslexic Groups' average being extremely high, relative to the Controls. The number of refusals increases with the increasing difficulty of the items, for all groups. However, Dyslexics 1 and 2 refuse to attempt more examples in the easier stages of the Modules than Controls 1 and 2. In questions 1-4 inclusive the number of refusals by Dyslexics relative to age-matched controls was 94 to 55, 42 to 6 and 7, 0 respectively. On Module 8, the

Dyslexic 2's refusal total was 83 compared with Control 2's 16. Similar discrepancies were found for all groups over most modules.

11.4:

III. Distribution of Error Types by Group

The frequency of each error type over the Dyslexic and Control Groups was tallied.

Table 2 gives the relative occurrence of each error type as a percentage of the total errors in each age range. The number in brackets is the absolute number of errors made. The Total represents the combined number of errors made for all the Dyslexic and Control Groups, respectively, taken together.

Each Error Type will be presented individually, (see Figures 1-14). However, there are some general features that are of note.

In 12 out of 14 categories the same pattern of frequency of errors is established; as the Dyslexics get older, their relative share of each of the error types gets larger; that is, they make relatively more errors. The Controls, on the other hand, make less errors as they get older. This applies to all the error types except Notation (Error 8) and Setting Out (Error 9).

In Error Types 1, 3, 4, 5, 6, 10, 12 and 13, the youngest Controls account for the larger share of the percentage of errors in Group 1. In the second age group, however, the dyslexics are making more mistakes in all but three categories: Random Errors and Abandoned, where the Controls' proportion is still larger, and Setting Out where scores are equivalent.

In Group 3, the Controls are making far less errors than the Dyslexics save for Notation (Error 8). The average difference in errors made in Group 3 is 50%, in favour of the Controls.

TABLE 2: DISTRIBUTION OF ERROR TYPES BY GROUP

ERROR TYPE	GROUP 1		GROUP 2		GROUP 3		TOTAL	
1. Properties/Characteristics of Number	45%	(45)	56%	(47)	77%	(41)	56%	(133)
	55%	(54)	44%	(37)	23%	(12)	44%	(103)
2. Reversals, Sequence, Direction	57%	(44)	59%	(44)	75%	(21)	61%	(109)
	43%	(33)	41%	(31)	25%	(7)	39%	(71)
3. Miscalculation	47%	(137)	57%	(176)	74%	(192)	59%	(505)
	53%	(152)	43%	(131)	26%	(66)	41%	(349)
4. Carrying	40%	(24)	50%	(55)	73%	(52)	54%	(131)
	60%	(36)	50%	(56)	27%	(19)	46%	(111)
5. Operations	45%	(30)	63%	(46)	78%	(21)	58%	(97)
	55%	(36)	37%	(27)	22%	(6)	42%	(69)
6. Positional Nature of Number/Place Value	38%	(61)	62%	(97)	86%	(32)	54%	(190)
	62%	(99)	38%	(59)	14%	(5)	46%	(163)
7. Terminology/Misinterpretation of Question	50%	(89)	62%	(129)	84%	(36)	59%	(254)
	50%	(88)	38%	(79)	16%	(7)	41%	(174)
8. Notation	58%	(11)	67%	(10)	41%	(16)	51%	(37)
	42%	(8)	33%	(5)	59%	(23)	49%	(36)
9. Setting-Out	57%	(32)	50%	(33)	76%	(48)	61%	(113)
	43%	(24)	50%	(33)	24%	(15)	37%	(72)
10. Reliance on Visual Cues/Spatial Visualisation	46%	(83)	53%	(104)	69%	(60)	53%	(247)
	54%	(99)	47%	(91)	31%	(27)	47%	(147)
11. General Lack of Knowledge/Bizarre	51%	(152)	63%	(169)	69%	(101)	59%	(422)
	49%	(146)	37%	(99)	31%	(46)	41%	(291)
12. Abandoned	48%	(31)	48%	(28)	54%	(26)	50%	(85)
	52%	(34)	52%	(30)	46%	(22)	50%	(86)
13. Random Errors	38%	(24)	42%	(41)	72%	(84)	54%	(149)
	62%	(40)	58%	(56)	28%	(33)	46%	(129)
14. Refusals	60%	(775)	83%	(480)	86%	(113)	69%	(1368)
	40%	(511)	17%	(99)	14%	(19)	31%	(629)

ERROR TYPE 1: PROPERTIES/CHARACTERISTICS OF NUMBER

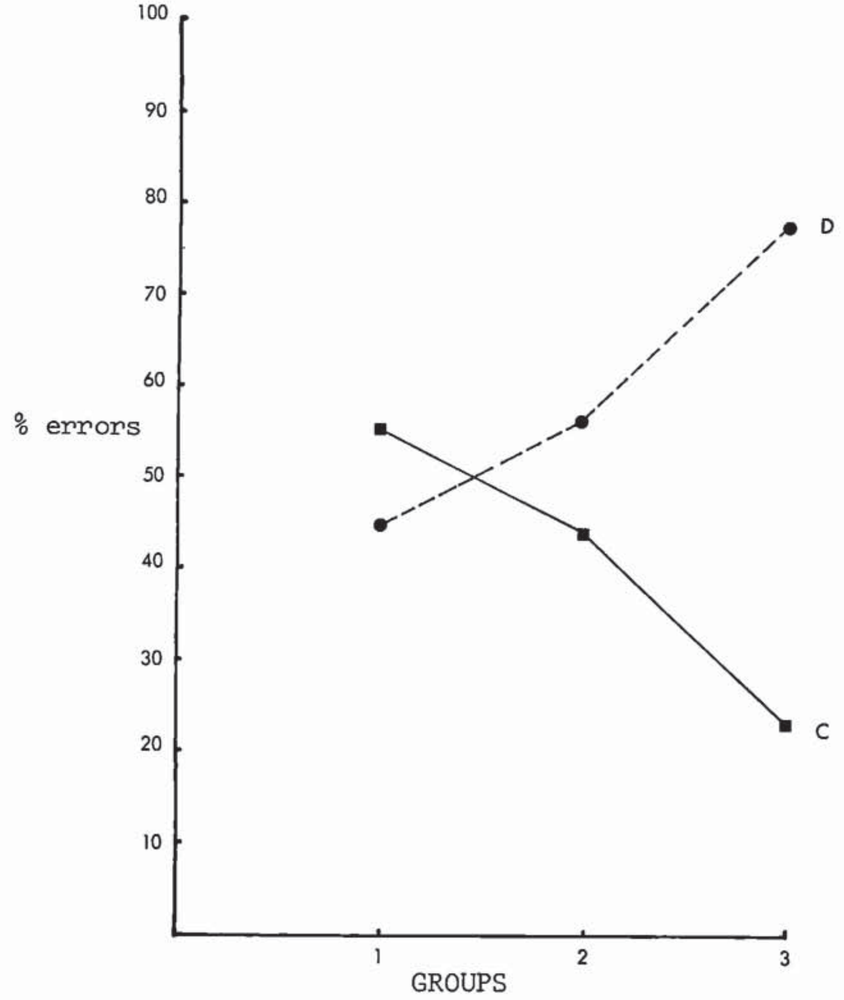


FIG. 1. Percentage errors by group

D	45% (45)	56% (47)	77% (41)	56% (133)
C	55% (54)	44% (37)	23% (12)	44% (103)

From Table 2.

In the youngest age group, the Controls make 10% more errors than the Dyslexics.
In Groups 2 and 3, the Dyslexics' proportion of errors increases relative to the Controls', who make less errors of this type as they get older.
In the oldest age range, the Dyslexics make more than three times as many errors as the Controls. This represents a relative increase in the discrepancy between the Dyslexics and Controls in Groups 2 and 3 respectively of 42%.

ERROR TYPE 2: REVERSALS, SEQUENCE, DIRECTION

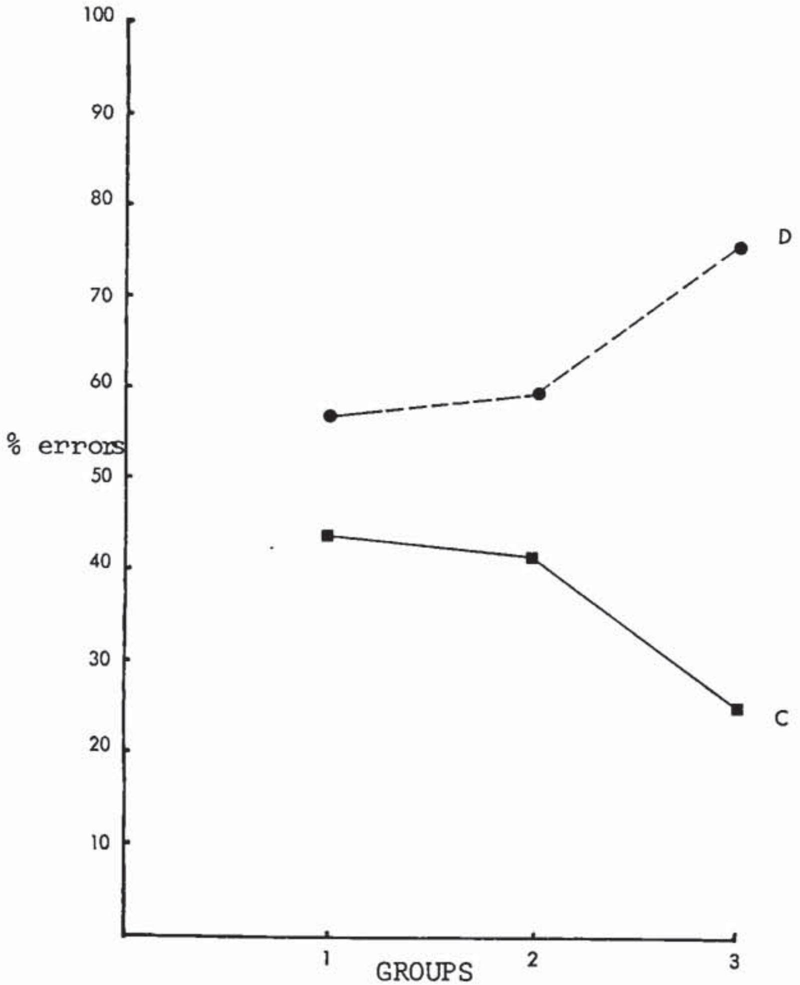


FIG. 2. Percentage errors by group.

D	57% (44)	59% (44)	75% (21)	61% (109)
C	43% (33)	41% (31)	25% (7)	39% (71)

From Table 2.

Overall the Dyslexic Groups make one-third more errors than the Control Groups, with more mistakes being made in all three age ranges. As is widely found amongst the errors, the relative proportion of mistakes increases over age in the Dyslexic Groups. The reverse is true of the Control Groups where the frequency of errors decreases as the subjects get older.

Equivalent percentages of errors for both Dyslexics and Controls are sustained in Groups 1 and 2. In the oldest age range there is a marked decrease in errors in the Control Group, whilst there is an equally marked increase in the Dyslexic Group. Although the absolute number of errors is small, the fact that the Dyslexics make three times the number of errors is of note.

ERROR TYPE 3: MISCALCULATION

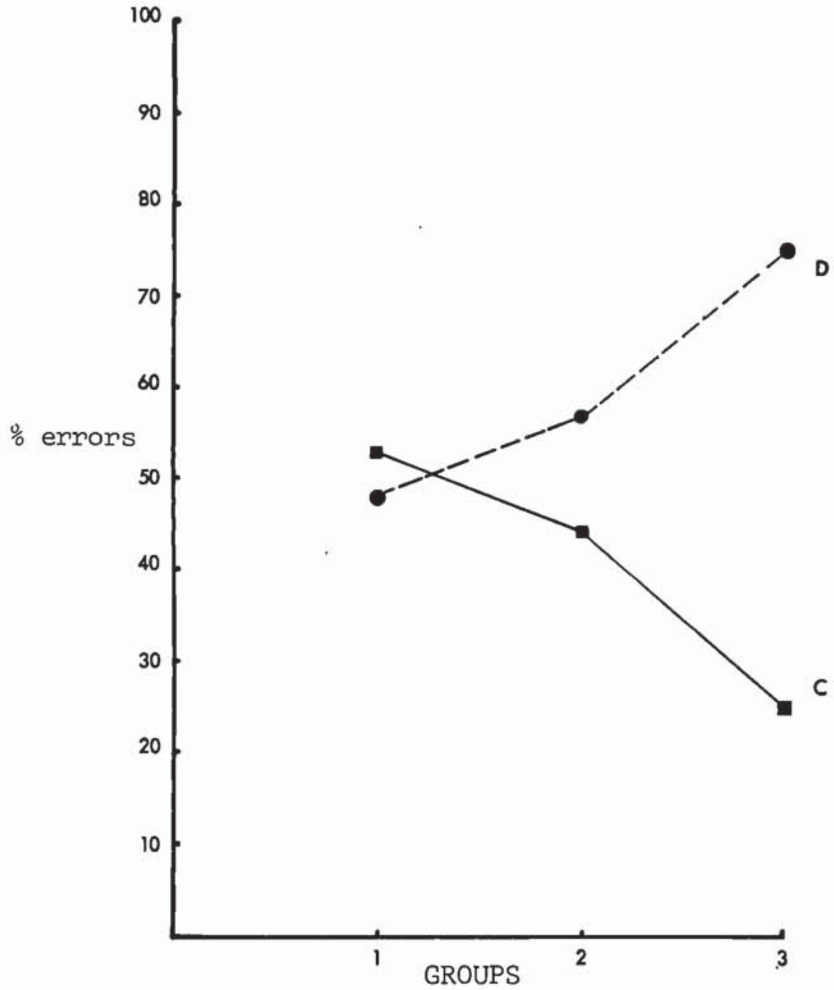


FIG. 3. Percentage errors by group.

D	47% (137)	57% (176)	74% (192)	59% (505)
C	53% (152)	43% (131)	26% (66)	41% (349)

From Table 2.

This category produced amongst the largest number of errors in the present analysis. Control Group 1 make slightly more errors than the similarly aged Dyslexics, but there is a steady decrease in the number of incorrect responses over age in the Control Groups. The Dyslexic Groups, on the other hand, show a steady increase in the number of errors over age. Dyslexic Group 3 make nearly three times as many errors as Control Group 3.

ERROR TYPE 4: CARRYING

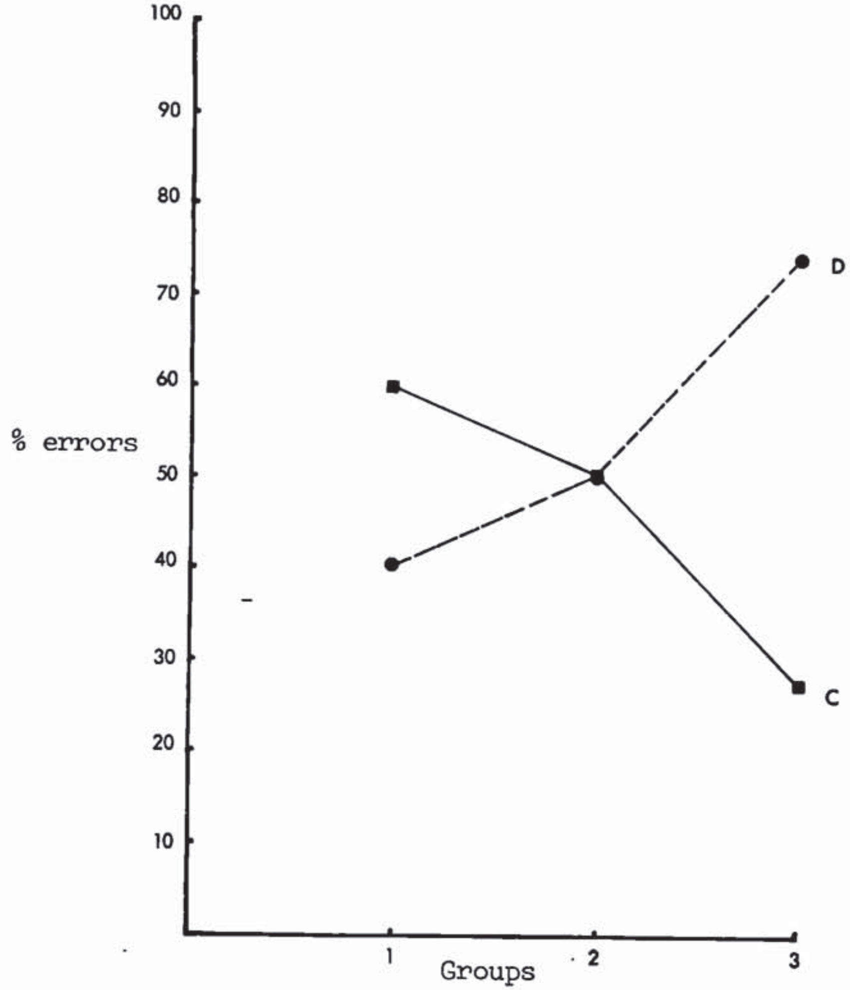


FIG. 4: Percentage errors by group.

D	40% (24)	50% (55)	73% (52)	54% (131)
C	60% (36)	50% (56)	27% (19)	46% (111)

From Table 2.

In general, the Dyslexic Groups show an increase in the number of errors relative to the Controls, whose number of errors decreases over age. Taking each group separately:-

The youngest Controls make 20% more errors than the youngest Dyslexics, though the absolute number of errors is quite small.

In Group 2, performance in the Dyslexic and Control Groups is equivalent.

The Group 3 results indicate a sharp decrease in the number of this type of error in the Control Groups. The Dyslexic Group's performance becomes relatively poor, with an error difference of over 30%.

ERROR TYPE 5: OPERATIONS

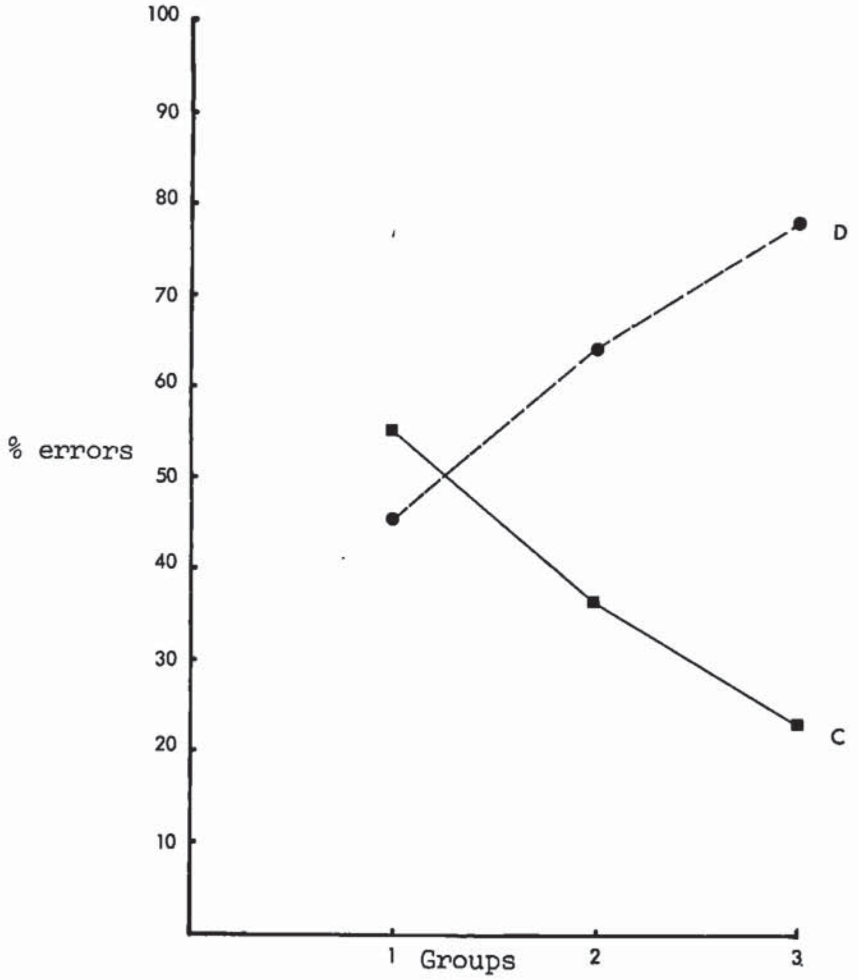


FIG. 5: Percentage errors by group.

D	45% (30)	63% (46)	78% (21)	58% (97)
C	55% (36)	37% (27)	22% (6)	42% (69)

From Table 2.

The absolute numbers in this category are small so that inferences may only be made with caution. Again, the youngest Dyslexic Group make less errors than the same age Controls. However, in Groups 2 and 3 the disparity between group scores increases, with Dyslexics 2 making nearly twice the number of mistakes as Controls 2 and Dyslexics 3 making three times the number of errors, as their age-matched Controls.

ERROR TYPE 6: POSITIONAL NATURE OF NUMBER/PLACE VALUE

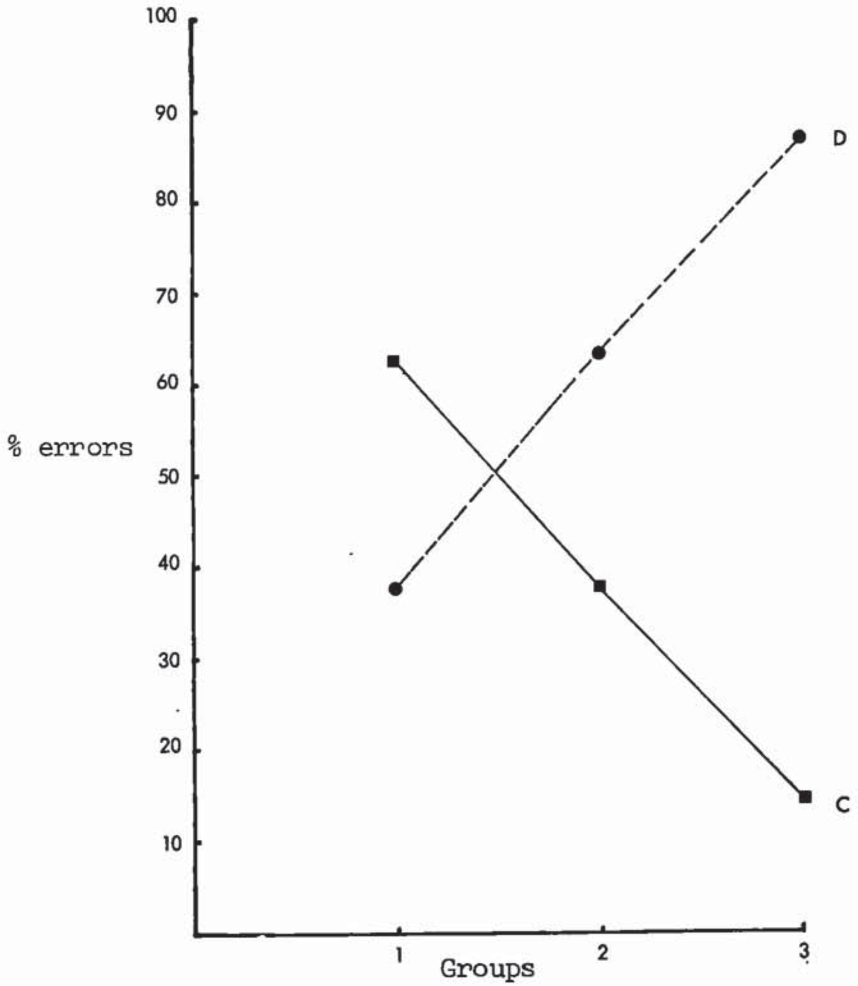


FIG. 6: Percentage Errors by Group.

D	38% (61)	62% (97)	86% (32)	54% (190)
C	62% (99)	38% (59)	14% (5)	46% (163)

From Table 2.

In this category, the Dyslexics in Group 1 make a third less errors than subjects in Control Group 1, but in the second age range, the position is exactly reversed with Dyslexic Group 2 making a third more mistakes than the Controls. Subjects in Dyslexic Group 3 make more than six times more mistakes than their Controls.

ERROR TYPE 7: TERMINOLOGY/MISINTERPRETATION OF QUESTION

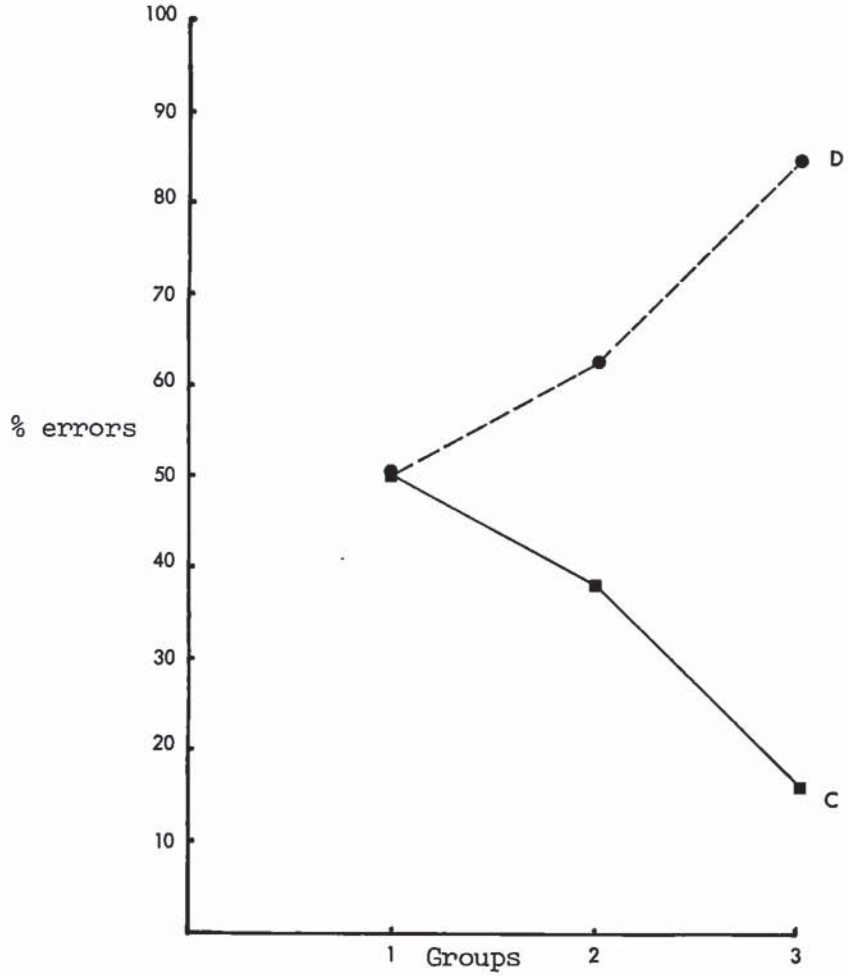


FIG. 7: Percentage Errors by Group

D	50% (89)	62% (129)	84% (36)	59% (254)
C	50% (88)	38% (79)	16% (7)	41% (174)

From Table 2.

This category produced many errors, especially in the first two age ranges. In Group 1, the Dyslexics' and Controls' performances are equivalent. As the Dyslexics get older, however, they do relatively poorly, with Dyslexic Group 2 producing 40% more errors and Dyslexic Group 3 making five times more mistakes than Control Groups 2 and 3 respectively.

ERROR TYPE 8: NOTATION

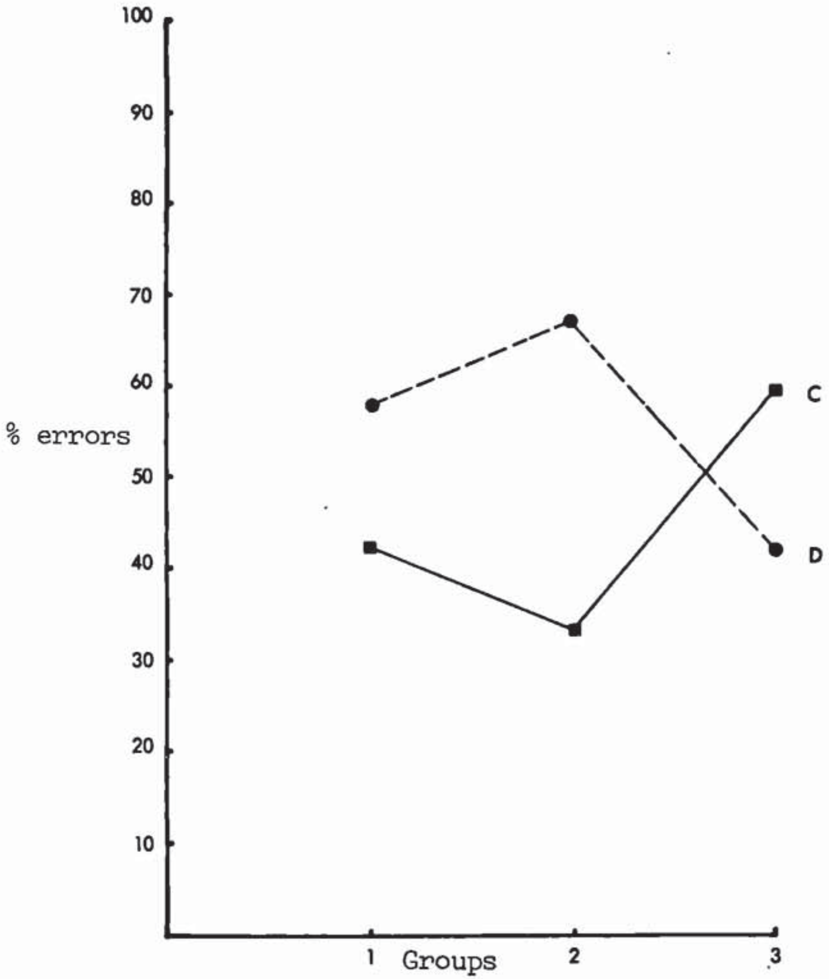


FIG. 8: Percentage Errors by Group.

D	58% (11)	67% (10)	41% (16)	51% (37)
C	42% (8)	33% (5)	59% (23)	49% (36)

From Table 2.

There are a relatively small number of errors in each group in this category, so again, caution must be exercised when interpreting these results.

Taken by group; Dyslexic Groups 1 and 2 make an increasing number of mistakes relative to Control Groups 1 and 2 respectively. Dyslexic Group 3, however, make less errors than Control Group 3.

ERROR TYPE 9: SETTING OUT

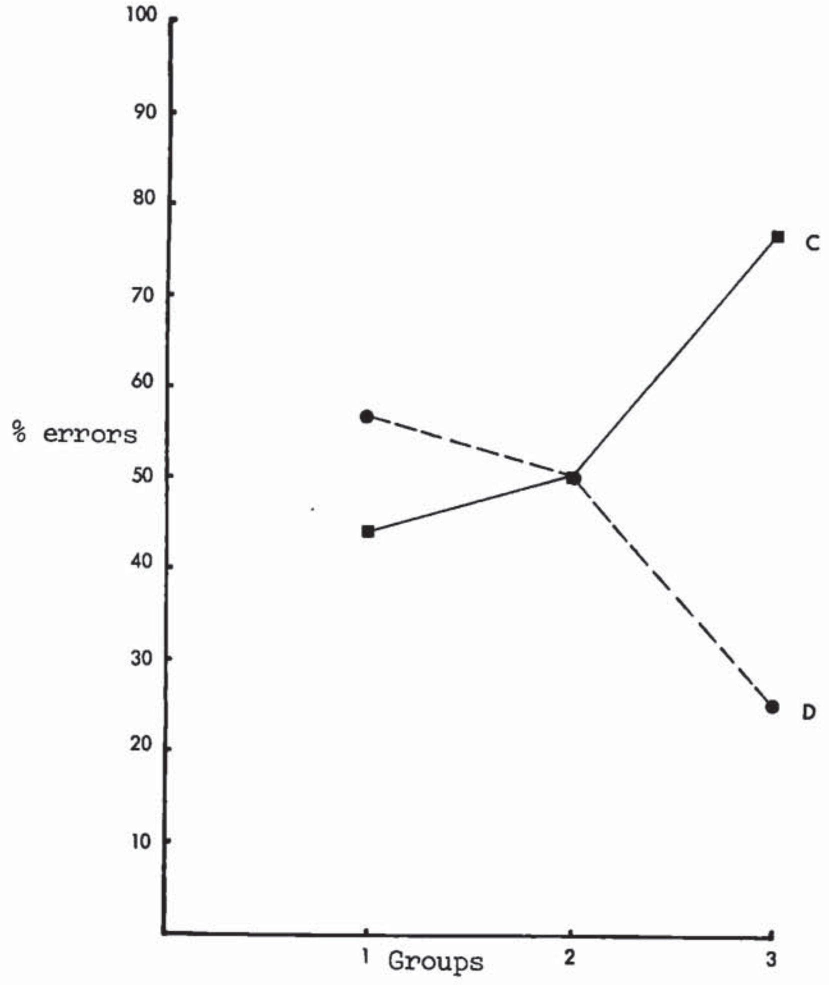


FIG. 9: Percentage Errors by Group

D	57% (32)	50% (33)	76% (48)	61% (113)
C	43% (24)	50% (33)	24% (15)	39% (72)

From Table 2.

Dyslexic Group 1 make proportionally more errors than their age-matched Controls. In Group 2, there is a slight decrease in the number of mistakes made by the Dyslexics, while the Control Groups' share increases. Group 3 sees a sharp increase in the percentage of Dyslexics' errors (1½ times more than the Controls). In Control Group 3 the number of errors is half that of Control Group 2.

ERROR TYPE 10: RELIANCE ON VISUAL CUES/SPATIAL VISUALISATION

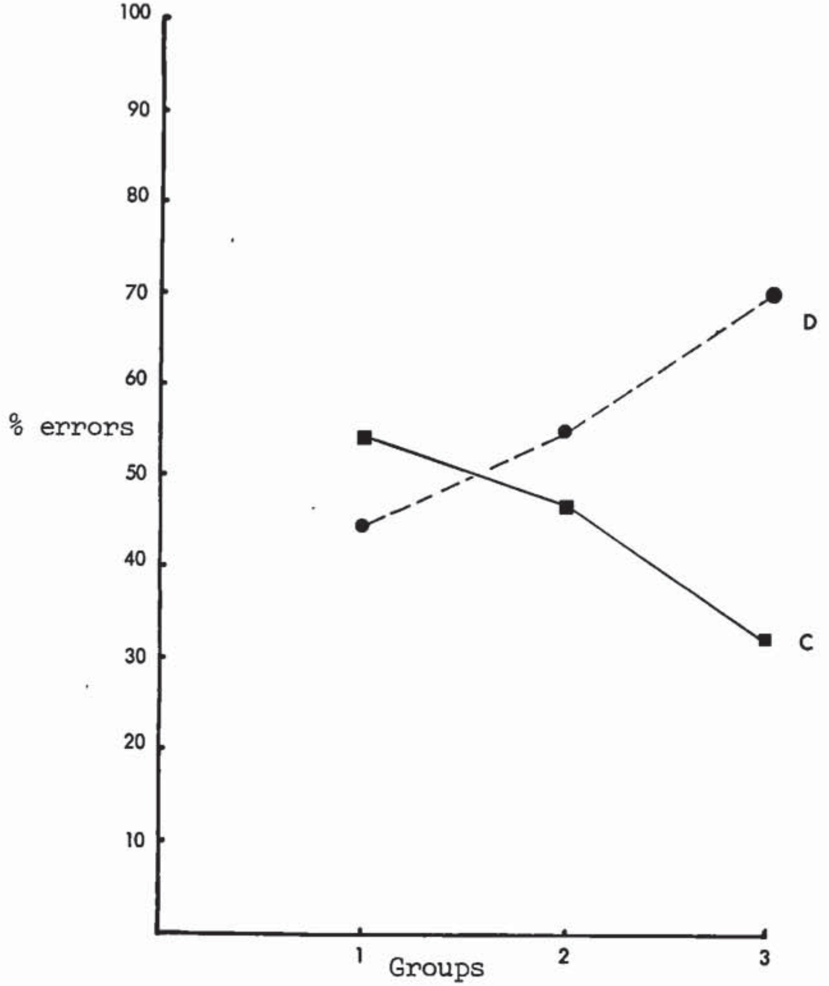


FIG. 10: Percentage Errors by Group

D	46% (83)	53% (104)	69% (60)	53% (247)
C	54% (99)	47% (91)	31% (27)	47% (147)

From Table 2.

The relative percentages reported in this category are similar to those found in Error Type 1.

The Dyslexics account for an increasing proportion of the total errors made, while the Controls' share decreases as they get older.

Between the Dyslexics in Groups 1 and 2 and Groups 2 and 3, the number of errors increases by 10% and 14% respectively. The differences between Control Groups 1 and 2 and Groups 2 and 3 respectively are exactly equal and opposite to those found amongst the Dyslexics.

ERROR TYPE 11: GENERAL LACK OF KNOWLEDGE/BIZARRE

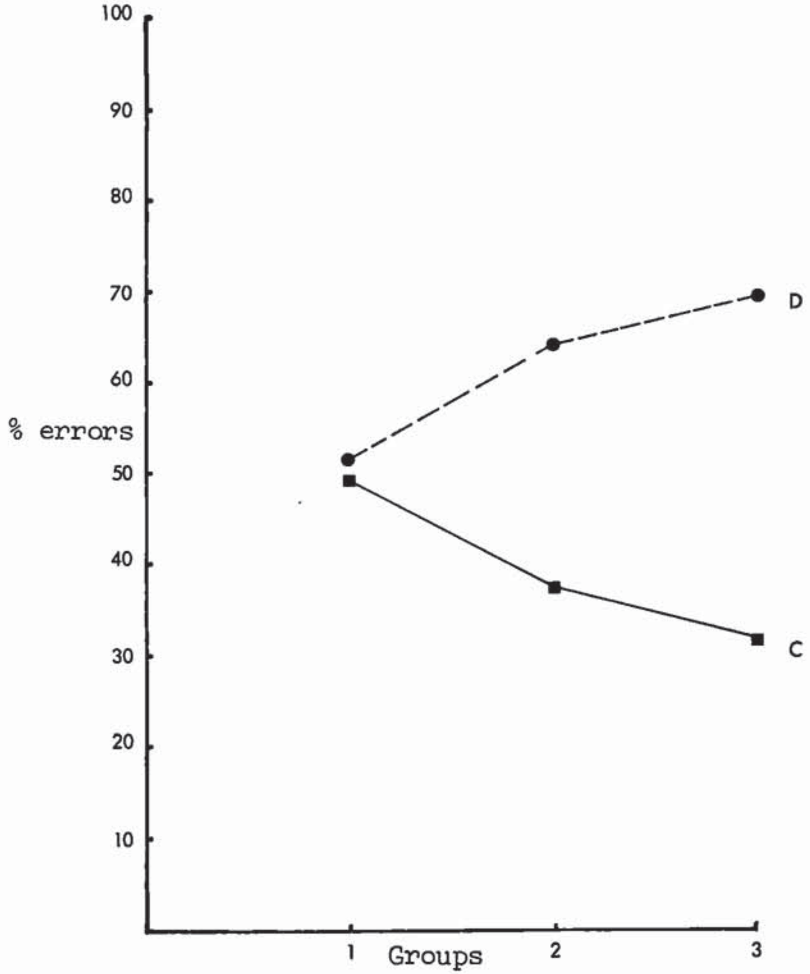


FIG. 11: Percentage Errors by Group.

D	51% (152)	63% (169)	69% (101)	59% (422)
C	49% (146)	37% (99)	31% (46)	41% (291)

From Table 2

In general, numerous errors were made by all groups.

In Group 1, the proportion of mistakes made by Dyslexic and Controls is roughly equivalent. The Dyslexics' share then increases over age. The Controls in Groups 2 and 3 show a concomitant decrease in the number of errors over age.

ERROR TYPE 12: ABANDONED

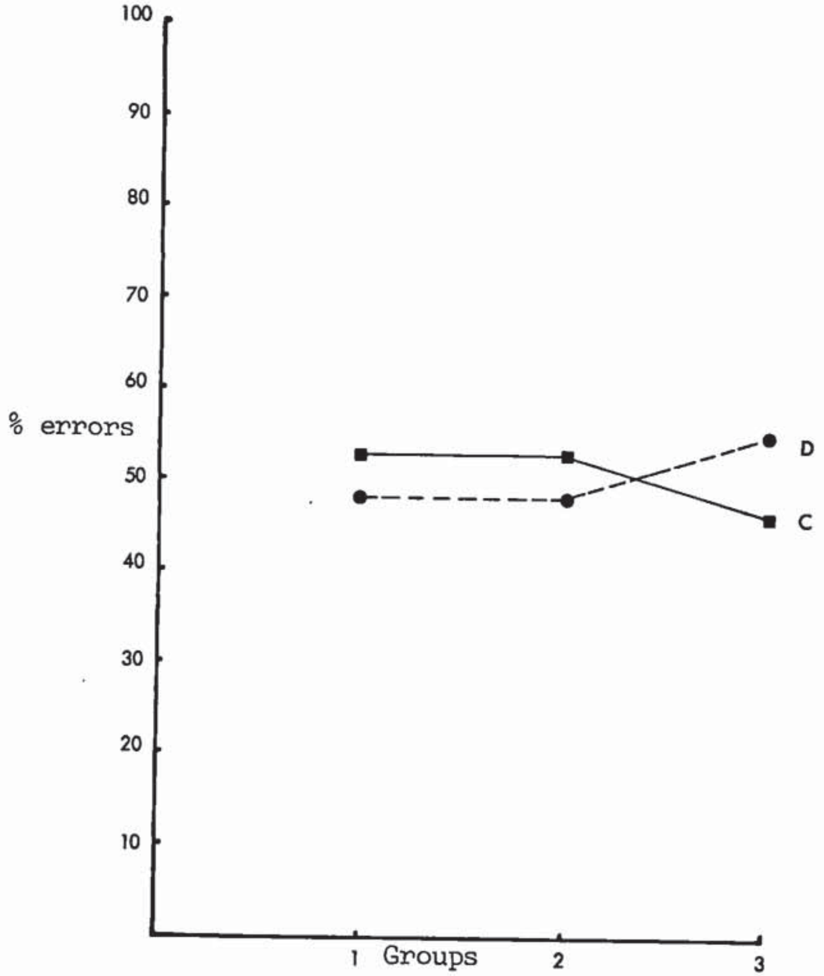


FIG. 12: Percentage Errors by Group.

D	48% (31)	48% (28)	54% (26)	50% (85)
C	52% (34)	52% (30)	46% (22)	50% (86)

From Table 2.

Overall the Total Results in this category are equivalent.

The relative proportion of errors is maintained over the first two age ranges, with the Dyslexics making slightly fewer errors. In Group 3, however, the Controls show a drop of 6% in their number of errors. The Dyslexics' number of errors increases by the same amount, in this age range.

ERROR TYPE 13: RANDOM ERRORS

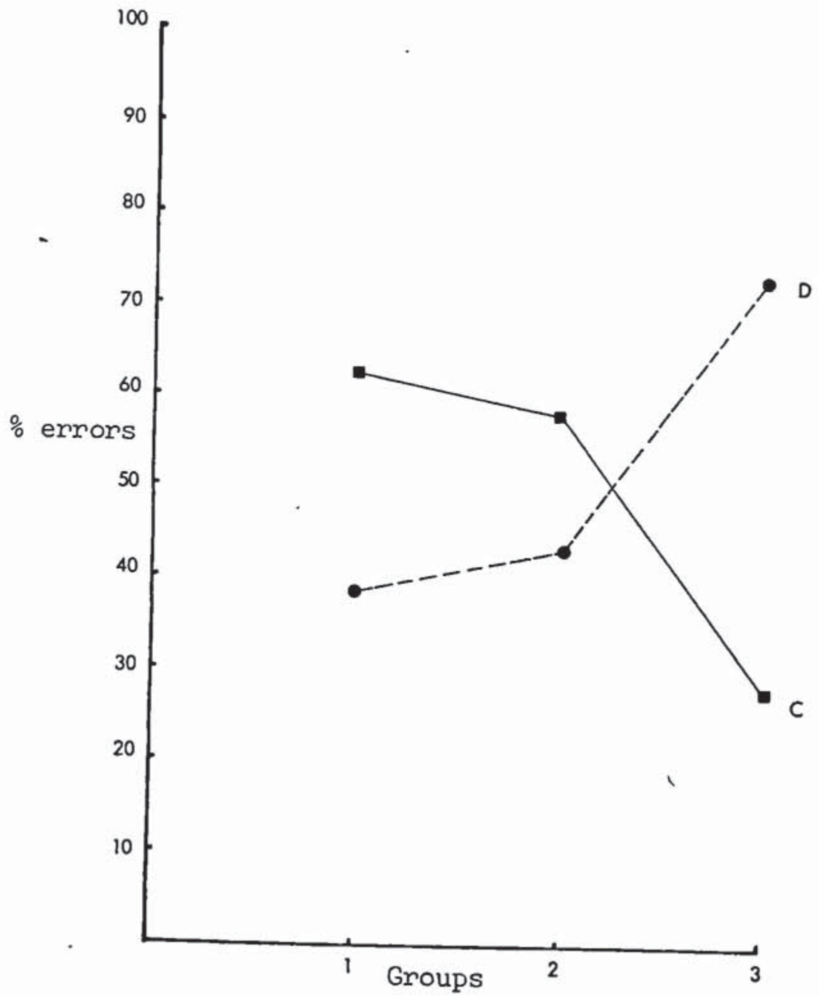


FIG. 13: Percentage Errors by Group.

D	38% (24)	42% (41)	72% (84)	54% (149)
C	62% (40)	58% (56)	28% (33)	46% (129)

From Table 2.

Control Group 1 makes more than a third more errors than Dyslexic Group 1 and maintains a similar relative difference through the second age range. In Group 3, the relative proportion of errors made by the dyslexics increases markedly; they yield more than twice the number of errors made by Controls.

ERROR TYPE 14: REFUSALS

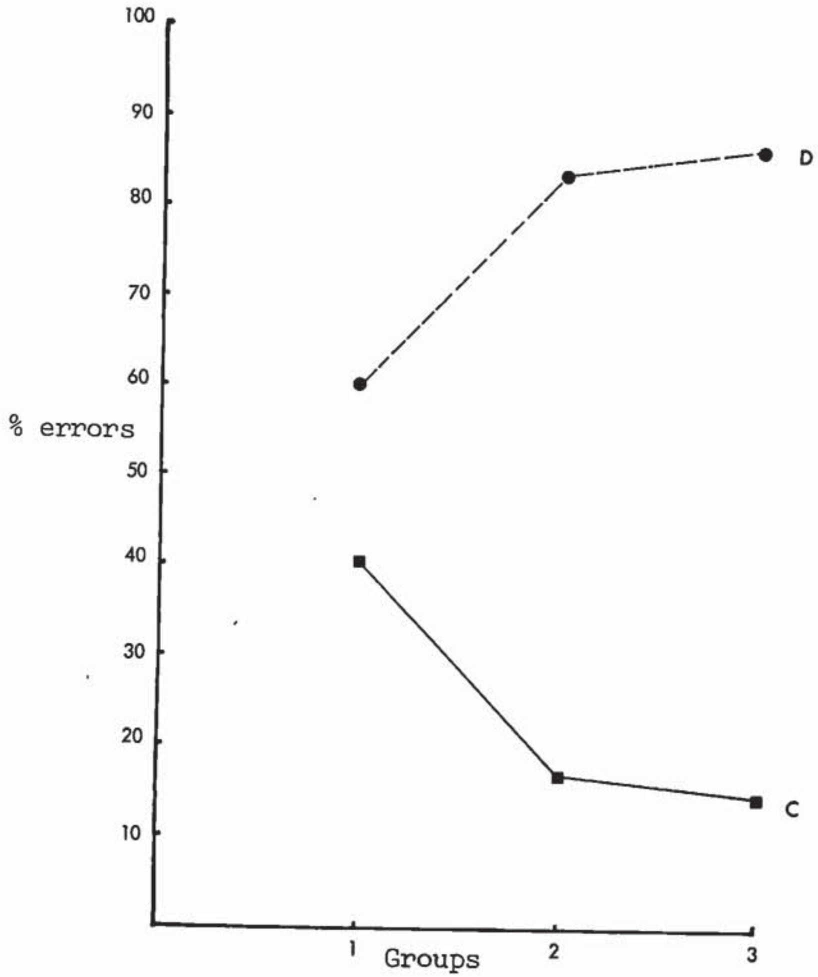


FIG. 14: Percentage Errors by Group.

D	60% (775)	83% (480)	86% (113)	69% (1368)
C	40% (511)	17% (99)	14% (19)	31% (629)

From Table 2.

This category produced the largest number of errors in the present classification. Overall the Dyslexics account for more than double the number of errors than the Controls. The relative proportion of errors accounted for by Dyslexics increases over age, with Dyslexic Groups 2 and 3 making as many errors as Control Groups 2 and 3.

11.5 Discussion

In this error analysis, fourteen categories of errors were identified. However, it must be stressed again that these categories are not necessarily mutually exclusive, nor are they exhaustive. They merely represent an attempt to classify findings into accurate, rather than statistically neat groups, in a way that reflects the demands of the problem and the individual's responses to it.

The error analysis was carried out using the data gathered in Study 4; however the Error types identified do cover all the areas of weakness in school mathematical performance observed in Studies 1, 2 and 3 as well. The occurrence of most of the Error Types in most Modules seems to suggest that lack of understanding may be general in nature, affecting a number of different areas in the curriculum rather than specific to a particular topic.

All error types were found in both Dyslexic and Control Groups. In relation to dyscalculia Weinstein (1978) maintains that if difficulty in calculation were related to a Specific Deficit, it would be expected that errors would be different from those found in other populations. However, given the relatively limited scope of the topics examined in these studies, it seems likely that there are only a limited number of possible errors that could be made. This point will be pursued further in the discussion. Each error type will be examined individually and related to dyslexia where appropriate.

ET1 - Properties/Characteristics of Number

Errors included in this category generally reflected a lack of appreciation of the properties of number and characteristics of the number system. They were differentiated from "General Lack of Knowledge" by the fact that the child thought s/he knew the answer. Error Type (ET1) mistakes were found in the Modules which require understanding rather than rote calculative skills. To take recognition of equivalence as an example, this arguably involves the understanding of symbolic representation and order. In the example, "What number is the same as 8 tens?", the child has to realise that this is equivalent to 80, and distinguish it from among 8, 800, 8000. This number/symbol association may be similar to the sound/symbol relationship that Dyslexics find difficult to master (Newton, 1974a, see Chapter 4). Understanding of order may be required in items like if 8 x 20 = 160 then

9 x 20 = 160 + 20 where an appreciation of successive addition is required. This is another area of weakness for Dyslexics.

Lack of knowledge of number systems could be due to a lack of verbal facility (Critchley, 1953), so the child may not be able to describe or identify whole numbers, odd and even numbers, etc.

ET2 - Reversals, Sequence and Direction are well established areas of weakness for Dyslexics (eg. Miles, 1974; Cohn, 1971) and may affect Dyslexics' general performance in school mathematics. This is one of the categories in which the Dyslexics made more errors from Group 1 onwards.

Naming of compass points, included in this category, seems to involve verbal labelling, in the same way, for example, as seems to be the case with left/right differentiation, so poor scores for Dyslexics would be unsurprising.

Reversals, however, yielded fewer errors than might have been expected, given their often mentioned appearance in the Dyslexic child's work (Newton, 1975; Miles, 1974; Thomson, 1977, etc.). In this study only four children reversed numbers consistently and two of these individuals were in the Control Group. As Hicks (1980b) suggests reversals may have different aetiologies in different populations. This was borne out in Study 1 where Control children were found to reverse digits. A general finding of all the studies from this thesis are that reversals are less common than might be expected, given their prominence in discussions of dyslexia. Even so Wahl (1972) stresses the importance of making children aware of when answers are incorrect as distinct from reversed. This Writer suggests that, in Dyslexics, lack of feedback of this nature (by merely marking answers correct or incorrect) may result in a child not understanding why the answer is wrong and may result in a negative attitude to mathematics in general.

ET3 - Miscalculation

Miscalculation errors were mainly the result of incorrect number facts (eg. 7 x 5 = 25). Many of these related to faulty knowledge of tables. Miles (1974) suggests that dyslexics have difficulty memorising tables and lose their places frequently, when reciting them. This finding was substantiated in this study and Studies 2 and 3. Short-term memory might also have been a factor mediating against Dyslexics, and leading to a number of miscalculation errors, resulting in inaccurate answers. A frequent mistake was the inclusion of the addenda; for example, in the sum 4 + 5, the child might say 4, 5, 6, 7, 8. The answer is eight. Ilg & Ames (1951) suggest that "missing by one" in calculation is part of a developmental stage of mastery of arithmetic, through which most children pass. In Dyslexics, however, errors of this type tend to persist.

ET4 - Carrying Errors

Carrying errors are less frequent in the youngest Dyslexic Group than in Control Group 1. This may be because less examples are attempted or because at this level, the requirements of the question are within their range of ability. In Group 2, Dyslexics and Controls make similar numbers of errors. In the oldest age-group the Dyslexics are making 36% more errors of this type. Cox (1975) suggests that difficulties of this type which relate to the regrouping of digits may be a result of the consequent re-naming that is necessary. The child has to remember that "19" changes to "9 carry one 10" in a calculation. Dyslexics have been found to be poor at verbal labelling (eg. Hicks, 1980a),so this may account for their poor performance. Cohn (1971) found that in dyscalculic populations "carrying" errors account for a large number of inaccuracies.

ET5 - Operations

Mixing of operations may relate to short term memory deficits. The child begins by executing the appropriate operation but forgets some way through. In word-problems, the choice of an inappropriate operation to complete the calculation may be indicative of the inability to abstract the correct elements from the problem. This difficulty has been noted by Shepherd (1981) in dyslexic children.

"Confusion of operation" errors relates to Kosc's (1974) category of "operational dyscalculia", and is also one of the categories noted by Engelhardt (op.cit), who states a truism when saying that the feature which distinguishes competent from incompetent performance in arithmetic, is the ability to execute the correct operation. He goes on to say that these errors occur because subjects do not understand the different procedures; they are not meaningful to them.

ET6 - Positional Nature of Number

There are a number of elements in the positional nature of the number system that might prove difficult for Dyslexics; first, the exactness of numeral and decimal point positions and secondly, the symbol/event correspondence. Both of these aspects have been discussed in Chapter 5. It is therefore not surprising that Dyslexics make many more errors in this category than do the Controls.

Weinstein (1978) and Cohn (1971) mention similar errors associated with dyscalculics' performance in arithmetic. It seems that they too have difficulty with the precise order and sequencing involved.

Kosc (1974) mentions "graphical dyscalculia" (the inability to record dictated numbers, given in words, into numerals). Dyslexics found this a particularly difficult task, as did the youngest Control Group.

ET7 - Terminology/Misinterpretation of Question

Failure to read or identify appropriate terminology appears to be a marked weakness in Dyslexics. The discrepancy between Dyslexics and Control scores, especially in Groups 2 and 3 suggest that the Controls identify operation specific terminology whereas the Dyslexics do not. Of course, much of the poor scoring in the Dyslexic Group may be accounted for by their poor reading ability.

Misinterpretation of questions could also be a result of the lack of ability to abstract the essential nature of the problem. This may be the result of the inability to identify "indicator" words to denote specific operations, like "win", "gain", "get" to denote addition, etc. Glenn (1979) suggests that this "language of mathematics" is specialised and has to be taught specifically.

ET8 - Notation Errors

Notation errors were most prevalent in Module 8 (Ratio and Proportion) where specific conventions are invoked to represent relationships. The finding that Control Group 3 made the largest number of errors in this category is explicable by the fact that they were the group most likely to attempt these examples. Their high error score reflects a higher number of unsuccessful attempts than were made in the other groups, simply because more examples were attempted.

For the most part, notation errors were separated from mistakes in the placing of the decimal point, if it was clear in the former case that the subject knew the answer but could not represent it properly. For example, if the child wrote $1p6\frac{2}{1}$ but knew that this meant "one pound and six and a half pence".

ET9 - Setting Out

Setting out errors were usually noted in long multiplication where children had failed to maintain the correct place value column, even though the subtotal column was correct. These errors were made by both groups, though more were made by Dyslexic Group 3. Again, this is partly a reflection of the fact that more individuals in this group attempted such examples. However, where they did, they still made proportionally more errors than did their matched Controls.

Kosc (1974) and Cohn (1971) mention a similar category of difficulties in their studies of dyscalculics. Critchley (1953) reports that in acquired dyscalculia, individuals who make this type of mistake have constructional and spatial difficulties.

In the present study, it was not apparent whether setting-out mistakes were due to spatial difficulties as such. They seemed to be more closely related to untidy working and a lack of appreciation of place value. It did not appear that the children could not list numbers one under the other, but rather that they did not.

ET10 - Reliance on Visual Cues/Spatial Visualisation

Errors in this category may relate to Bruner & Kenney's (1965) finding concerning the distractibility factor of iconic images. These authors found that the visible features of a problem often retarded children's performances, until they were able to transcend these by symbolic mediation. It seems likely that errors of this type are explicable in these terms. For example, where children had to calculate the length of the fourth side of a rectangle, the fact that they could see the labels on the other three sides may have "fixated" them on these measurements and prevented them from applying the appropriate algorith (the abstract, symbolic aspect which transcends the visible image) which would have led to the correct solution.

Weinstein (1978) and Bullock & Gelman (1977) found that in conservation experiments, questioning after apparatus had been removed, often revealed that subjects who did not appear to conserve volume, length, etc. could do so, but were "confused" when the concrete material could be seen.

ET11 - General Lack of Knowledge/Bizarre

Mistakes of this type appeared to have stemmed from some half-baked notion about a topic, which seemed to have developed along erroneous lines. Often subjects appeared to know what they were doing, ie. actions were systematic, but it did not seem appropriate to any aspect of the question asked, that the Tester could identify. This category appears to resemble Roberts' (1968) "Random Response" class.

ET12 - Abandoned

Examples which were left uncompleted, even though execution of the appropriate procedures had been correct until that point, may have related to a lapse in working memory. In Baddeley & Hitch's terms (1974) the Executive Function may have "switched-off" too soon. The relative number of errors in the Dyslexics and the Controls is roughly equivalent, indicating that this type of mistake is not a particular feature of Dyslexics, but of schoolchildren in general.

"Abandoned" in general, indicated that the child had had an initial thought about what to do but could not go further after an initial step.

ET13 - Random Errors

In Control Groups 1 and 2, these usually meant that children had made a careless mistake that only appeared once (or at least infrequently) in their scripts. In Dyslexic Group 3, these mistakes were found in many calculations, though not in systematic fashion and distinct from "Miscalculations".

ET14 - Refusals

As can be seen from the figures given in Table 2, this category included large numbers of responses in Age Group 1. This was largely a result of many of the items being too difficult. The Reader will recall that the Mathematics Modules are designed for transition between primary and secondary school; thus it was expected that these children would be unfamiliar with some of the items. Nonetheless, 20% more items were refused by the Dyslexics in this age range; the proportion of refusals increases dramatically for Dyslexics and Controls in Groups 2 and 3. This seems to indicate that the relative discrepancies in the other error categories may be an underestimate; if the Dyslexics had attempted more, it seems likely on the basis of the other findings, that they might have got even more wrong.

11.6:

Regrouping of Categories according to known deficits in Dyslexics' Performances

The use of fourteen categories of errors may be feasible in research, but could prove somewhat cumbersome for diagnostic purposes. It seems that there are a number of Error Types which result from similar deficiencies in cognitive processing, though perhaps in varying degrees. If this is so, it may be reasonable to regroup in categories:

Error Types 3-6 inclusive appear to have a number of common features; all of them relate to number and calculation.

Ordering and Sequencing

As has been discussed in Chapter 5, the efficient use of number systems appears to rely on the recognition of the precise order and sequencing of numerals and their positioning in multi-digit numbers to represent different quantities. As such, errors related to these aspects, appear to reflect a deficiency in the ability to order and sequence numbers accurately. This lack of fluent sequencing ability is also a well-documented feature of dyslexics' literacy performances (eg. Newton, 1974a; Thomson, 1977) and appears to be specifically related to verbal and symbolic material (Holmes & McKeever, 1979). As will be discussed below poor sequencing ability seems to relate to the failure to utilise a verbal labelling strategy to aid retention of material.

Verbal Labelling

Verbal Labelling or acoustic encoding is a process whereby labels are given to to-be-remembered-events, and this seems to aid recall, and seems especially important for successful reproduction of sequences.

In Dyslexics, however, there appears to be an insufficient utilisation of this strategy, which leads to poor performance on verbal and symbolic tasks (Vellutino, 1979; Wilsher & Joffe, 1980; Hicks, 1980a; Ellis & Miles, 1981).

Poor acoustic encoding may account for Dyslexics' poor performance in calculations involving the carrying of numbers. Cox (1975) has suggested that carrying or regrouping of numbers involves renaming; ten units become one ten, for example. Since Dyslexics' verbal labelling ability is poor, this may account for the large number of computational errors they make. Deficiencies in verbal labelling strategy could conceivably affect all aspects of school mathematics.

Short Term (S-T) Memory

Poor S-T memory may be partly associated with inefficient labelling strategies (eg. Hicks, 1980a). S-T memory is required in calculations. In addition, for example, a number of steps have to be executed successfully (Findlay, 1979; Groen & Parkman, 1972); the child has to identify the larger addend and remember it, while adding another number (this also involves sequencing of course). Once this has been done, regrouping may be necessary. All these steps require both working memory capacity and the use of executive controls (Baddeley & Hitch, 1974). Dyslexics are known to have a limited short-term memory, which may have an all pervasive influence on the school mathematical performance.

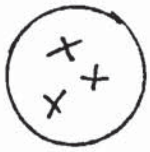
Webster (1980) found a difference in S-T memory between children (11-12 years) who were proficient in mathematics, slightly math disabled and severely math disabled, related to the modality of input and output stimulus. In all cases visual input was more effective than aural presentation of digits and consonant strings. The proficient subjects responded significantly better than the other groups and indicated a preference for graphical/symbolic output. The severely math-disabled group responded best (though more poorly than the other groups) when the response was given verbally. The slightly math-disabled group showed no preference.

The findings presented above are consistent with those of Hicks (1980) for dyslexics, who did as well as other disabled groups when stimulus and response were verbal. The Dyslexics in this study, though, had particular difficulty giving an auditory response to a verbal stimulus. This was said to be due to poor acoustic encoding ability.

These results can by no means be regarded as conclusive; however, it seems that modality preference, as it relates to ease of verbal labelling may be an interesting area of exploration in mathematics. Since these findings were not published until after the data collection for this thesis had been completed, this aspect of functioning was not explored, in the studies reported.

Poor sequencing ability, inadequate verbal labelling and short-term memory deficits appear to account for many of the mistakes associated with Error Types 3-6 inclusive. They also seem to be involved in aspects of Error Types 11 and part of 12 (abandoned, as complete) and arguably influence all aspects of cognitive functioning in Dyslexics.

Symbol/Event Correspondence may also relate to verbal labelling ability. The child has to appropriately name and number a symbol associated with a number. Also involved is the ability to remember alternative representations for the same event. For example, the child has to learn that "8 tens" are equivalent to "80" or that

 is equivalent to "3" and "three".

Weakness in the appreciation of symbol/event correspondence and other specific notions, like that associated with ratios would be part of all Error Types involving symbolic representation. This seems to be related to sound/symbol correspondence which is deficient in Dyslexics (eg. Newton et al., 1979).

Poor Reading Ability

Poor reading ability might cut across most Error Types as most questions relating to school mathematics involve some written material. Obviously though, word problems would be most affected.

Examining these general features, it seems that although mistakes are identifiable in relation to a specific topic area as represented by the Error Types, there are a number of superordinate features which cut across these categorisations and seem to be useful in relating specific mistakes in mathematics and calculation to difficulties in literacy functions in Dyslexics.

Explanations for failure, in terms of these aspects of performance seems an adequate explanation for the failure of Dyslexics in school mathematics. Explanations for failure in arithmetic amongst dyscal-culics have been offered in terms of a Development Lag Hypothesis

(Weinstein, 1978) and will be discussed in the next chapter.

The use of a Piagetian concept model also seems inadequate in explaining some of the Dyslexics' performances. For example, if a child has an adequate conceptual grasp of a concept and knows how to solve a problem, but makes mechanical errors in its solution, can this be attributed to an incomplete concept? This does not seem feasible, unless one separates the mechanical symbolic aspect from the conceptual one. Perhaps the dyslexic child has not developed a complete concept of a symbol. Although many dyslexics make errors related to symbols, it seems more likely that these are explicable in terms of the nature of their neurological style rather than delayed developmental pattern.

11.7 General Findings

Some general findings emerged which appear to be applicable to both Dyslexics and Controls. These will be discussed below.

Representational Aspects of Mathematics

Many, in fact, most children, revealed on questioning that they did not realise that numbers, operator symbols, graphs, etc. serve to represent events in a short-hand form. For most of them, numbers were simply numbers, and are used in calculation. When asked why we use numbers or do mathematics, most younger children said: "'cause it's part of school."

Kent (1978) reports similar findings. Most of the people he tested did not have an equivalent mental image comparable to that conveyed in words. A significant proportion of the adult population he tested did not see the numeral "5", the written "five", the spoken "five" and

x x
 x   as being equivalent. Kent (op.cit.) maintains that a consequent
x x

lack of understanding seems inevitable.

Logic

Hutton (1977) suggests that there is often logic in children's errors. Indeed, the idea of looking for systematic errors is based on this premise. Hutton (1977) gives the following example of a child's work:

$$\begin{array}{r} 42 \\ \underline{\times 24} \\ \underline{844} \end{array}$$

When questioned it appeared that child had been applying the knowledge of "multiplying by 20", which he had been "taught" the day before. Hutton suggests that this inappropriate generalisation of this skill was logical for this child and that the teacher was at fault for going too fast, before checking that the child had a thorough understanding of this exercise.

Another example of a child's logic was found in Module 9, question 6. The individual is told that "Your mother sends you to the Supermarket to buy these five things. How much do they cost altogether?" The items are illustrated and price-tagged. One child, Sally, gave an answer which excluded one item, the joint of meat. When the Examiner asked her about it, she said: "Oh, my mother wouldn't send me to the shops for meat, she has it delivered!"

This example suggests that questions must be considered in terms of the relevance to the child.

Specificity of Knowledge

Wittrock (1974) hypothesises that learning with understanding is a generative process involving structures for storing and retrieving information and processes for relating new information to the stored data. This Writer says that effective instruction causes the learner to generate a relationship between new information and previous experience.

In at least 75% of all the children tested it seemed likely that a system of this nature was not in operation; knowledge was usually context and format specific. For example, in Module 8, many children in age group 3, said that they had "done" ratio and percentages last year, but had forgotten it. For them, it seemed like they had learned it as an independent topic which did not relate to anything else they had learned.

11.7 General Findings

A general finding was that although children use hundreds, tens and units all the time, they did not realise that that meant they were using a decimal system. It seems that teachers need to make these facts

Another illustration of this pertained to the presentation format. In Study 3, for example, children were confused by the setting out of the division items $\underline{/\quad}$, instead of $/\overline{\quad}$.

Similarly, many children who could do two-digit calculations vertically presented, were unable to cope with horizontal presentations, though Cox (1975) suggests that this may be because horizontal presentation is conceptually more complex.

Specificity of knowledge may relate to the teaching a child receives and the amount of flexibility and creativity of thought encouraged. Bruner (1966) & Elliott (1980) suggest that most schools do not nurture these aspects. It may also relate to Bruner's (1964) iconic stage of development in which it is believed that a child can recognise and reproduce material but cannot produce new structures, based on a rule. Bruner suspects that the language the child uses at this age is insufficient as a tool for ordering. This Writer suggests that an increased sophistication in language in terms of invariant symbolism may lead to an improvement in problem solving.

Bruner & Kenney (1965) found that the development of insight into mathematics in a group of 8 year olds (IQ 120-130) depended on the development of abstractions and the realisation that symbolic notation remains invariant across transformations in imagery. It could be that in Dyslexics this development of symbolic notation is impaired. This may account for their relatively poor performance in school mathematics.

Bruner (1964) also suggests;

> "..... it is reasonable to suppose that activation (italics) of language labels that the child has already mastered might improve performance as well ....."

(He advocates getting the child to say his/her description of something before it is dealt with symbolically). If this is equivalent to verbal labelling, then the dyslexic child is at a disadvantage, since as we have noted, Dyslexics have a verbal labelling deficit. One of the aims of the remedial teaching and effective instruction in general, may involve the teaching of this strategy.

Hicks (1980a)has demonstrated that verbal labelling can be taught in the experimental situation. It is possible that this may be extended to general school situation.

There seems to be a need for teachers to encourage the linking of one aspect of the school mathematics curriculum to another and encourage flexibility of thought, so that children do apply previously gained knowledge to new situations. It also seems that there is a need to make explicit that mathematics can be used to describe relationships that children come across in their everyday lives (Flener, 1978) that covers a wider field than just calculating their pocket money.

Verbalisation

Throughout the studies in this thesis, children were encouraged to verbalise what they were doing when working through school mathematical problems.

In the youngest groups, especially in the Pilot Study and Study 1, it seemed that children found it necessary to speak aloud when working through examples. This phenomenon might be explicable in terms of Vygotsky (1962) and Bruner (1964)'s respective theories about thought and language. These Researchers maintain that language not only provides a means for representing experience, but also transforming it. Bruner (op.cit.) suggests that children need language to facilitate the reworking of realities they have encountered, and that seven-year olds, for example, need to talk to themselves. Children of this age though (in the present studies) could not explain their working out to the Interviewer even though they appeared to know what they were doing. This supports Corso's (1977) finding that young children have intuitive perceptions which they found difficult to justify. In the school samples especially, many of the younger subjects assumed they had "got it wrong" if they were questioned. Lunzer et al. (1976a) found:

> "It was sometimes the case that insistence on verbal elaboration of intuitive solutions of problems began to destroy the child's confidence."

Erlwanger (1975) found that children did not consider mathematics to be a subject one could talk about - it was something you <u>did</u>.

<u>Estimation</u>

The Writer believes that ability to estimate is the best indicator of competence. A general finding was that most children did not estimate. When multiplying two numbers, say, 20 x 6, children seemed not to notice that an erroneous answer like 1200 is much too large given the original numbers or that when subtracting 102 - 81 and getting an answer of 181, the difference was bigger than the subtrahend.

Similarly, computations like 4 x 6 = 24 and 6 x 6 = 24, were used in the same example, without any recognition of lack of equivalence. Miles (1978) suggests that inconsistencies of this type characterise the Dyslexics' written work.

During visits to schools, the Writer observed that teachers did not appear to encourage estimation. It seems that there is a need for more emphasis on this area.

11.8 Conclusion

So it seems that poor teaching may contribute to poor performance in mathematics. However, taking that into account, it appears that Error Analysis as a technique is a variable method for prediction of specific areas of difficulty. It may be useful to psychologists and teachers in providing an idea of the procedure a child is adopting in problem solutions (Surany, 1977) so that areas of strength and weakness in cognitive performance and scholastic attainments can be gauged. Insight may be gained into the reasons behind a particular child's mistake. This may help to avoid the teaching of new skills before subsequent ones have been mastered, and also may be useful in the planning of appropriate remedial programmes, based on a knowledge of what skills a child has mastered, or not, as the case may be.

CHAPTER 12

12. GENERAL FINDINGS, SUMMARY, CONCLUSIONS AND IMPLICATIONS

The studies presented in this thesis were undertaken as preliminary investigations into the nature and extent of school mathematical difficulties in dyslexics.

The Pilot Study was undertaken to investigate the tasks presented in junior mathematics curricula, how they were taught and what teaching schemes, if any, were used. Attempts were made to assess the conditions under which success and failure took place. Schools were chosen from which Control Samples were selected.

On the basis of material collected during the Pilot Study, two tests LJ1-Linear and LJ2-Spatial were devised.

Study 1, in which the Wechsler Intellegence Scale for Children - Revised Edition (Wechsler, 1974) and various other tests were administered to Dyslexics and Controls, provided information on the interaction between measured intelligence and measured mathematical ability. For the Control Groups, the traditional finding of Wrigley (1958) and others was confirmed; the correlation between intelligence and performance on mathematics tests was borne out ($p < .001$). However, this relationship was not found in the dyslexic sample; no significant correlations were found between any of the mathematics tests and Full-, Verbal- or Performance Scale scores. Wrigley's assertion that a verbal factor is independent of mathematical ability seems unlikely, given the high correlation between the Controls' measured intelligence scores and school mathematical attainments. Again, no relationship is found for the Dyslexic Group. Only a small sample of dyslexics were included in this study; consequently these findings must be treated as tentative and interpreted cautiously.

LJ-Linear and LJ2-Spatial also provided discrepant correlations with other factors, for Dyslexics and Controls. An analysis of variance indicated that the Dyslexics did not differ significantly from the Controls in terms of total score. However, there did appear to be some differences in solution strategies adopted by the two Groups. Further studies indicated large differences in attainments, as well.

Studies 2 and 4 were carried out in an attempt to identify more specifically than was previously reported, the nature of the mathematical difficulties in the Dyslexic population under investigation.

Findings revealed that in the youngest age group, Dyslexics appear to do almost as well as the Control subjects in school mathematics. However, the relative differences between Dyslexics and Controls increased with age, with the Dyslexics doing significantly worse in arithmetic, simple geometry and simple problem solving. An analysis of errors revealed 14 recurring types of mistakes, many of which are consistent with findings related to dyslexics' literacy difficulties. For example, Miscalculations appear to be largely a function of deficient sequencing and knowledge of arithmetical tables; Carrying errors suggest short-term memory deficit and may involve verbal labelling.

In Study 3 it was found that 60% of Dyslexics, who were of at least average intelligence (IQ of 90 or above) are retarded in arithmetic to some extent. This compares with 19% of the Controls.

Also of importance was the finding that about 7% of Dyslexics excel at arithmetic and other aspects of the school syllabus. It is important that those children be encouraged to maximise on this area of strength, as a boost to their self-esteem. This applies equally to the Dyslexics who, on paper, appear to be severely retarded, but who, when questioned orally, reveal that they have a satisfactory conceptual grasp of the subject matter. This finding is consistent with most of the major work in the field of dyslexia, in which children have been found to have good comprehension skills, but poor ability to express ideas in written form.

The data from these studies supported the general findings that Dyslexics have poor sequencing ability, limited short term memory and deficient name coding skills.

Visuo-spatial skills were mentioned in Chapter 2 as an important concomitant for success in school mathematics. Although no specific tests were administered, results from the WISC (Study 1) and BAS sub-test profiles (Thomson, Hicks, Joffe & Wilsher, 1980) indicated no particular spatial difficulties amongst Dyslexics; seemingly a deficit in this area is not responsible for poor attainments in this Group.
A finding that appeared consistently in all studies was that of a group in the Control sample who appeared to fit the criteria mentioned by Weinstein (1978) as designating developmental dyscalculia. The average finding of 8% of the total sample in this category, is slightly higher than the numbers reported by Weinstein (1978) and Kosc (1974). Both reported 6% of the "normal" school population. Since about 60% of the Dyslexic population exhibit some mathematical difficulties, as opposed to the 19% dyscalculic population, it seems unlikely that they are aetiologically related difficulties, although they may share functional similarities.

Further investigation into the characteristics of dyscalculia is needed, as is early screening in schools to identify dyscalculics (Dunlap et al., 1979; Lansdown, 1978; Thornton & Reuille, 1978).

Teaching

It appears that the teaching of mathematics may be an influential factor in all populations of children. In the present study, few teachers were found who considered the child's developmental pattern when giving instruction. The situation does not appear to have changed since 1932, when Hildreth asserted that

> "..... arithmetic instruction in schools ..... is almost universally inappropriate to the mental maturity of children and will only be improved when the level of instruction is fitted to the actual abilities of the children taught."

Henty (1973) and Jones (1978) maintain that many difficulties in arithmetic are the result of the child not being developmentally ready to learn particular skills. This often results in rote skills being learnt without concomitant understanding. Skemp (1971), Ollerenshaw (1977), Maslow (1977) (cited in Moses, 1977), Price et al. (1977), Bruner (1966), Elliot et al. (1979), Kane & Kane (1979), all call for a revision of teaching methods to encourage more creativity of thought in school mathematics. House et al. (1977) also call for the recognition and nurturing of different types of mathematical ability.

There is still a shortage of mathematics teachers as there was in 1977 (Kerr, 1977) and it seems that approaches to mathematics will not change until this is remedied. This is a pity since, as Dutton (1977) suggests, there is societal investment in good teaching of mathematics and arithmetic.

Attitudes

Much has been written about attitudes and motivational factors in school mathematical performance (see Chapter 2). In the present study few instances of negative attitudes to school mathematics were found. In general, children were keen to co-operate and seemed to enjoy the additional attention they were receiving, despite the fact that they had to work hard during the test sessions.

In the present studies, it seems unlikely that failure in mathematical and arithmetical topics were attributable to affective variables. Many subjects reported liking mathematics, even though their attainments were poor.

Control Groups 2 and 3 were asked about their attitudes to school mathematics. Findings were in keeping with those of Bulton (1956) - different aspects of mathematics were viewed with varying degrees of favour,some children liked arithmetic but not word problems or fractions (Callahan, 1971).

As was found in the APU Report (1980) many children were taking mathematics because it was thought to be useful, rather than because they liked it especially.

Svien & Sherlock (1979) and Klees (1976) report that dyslexics' difficulties with school mathematics are specific to its symbolic aspects and that conceptualising ability is unimpaired. The results from these studies provide a more complex picture.

There appear to be a number of subgroups of dyslexics based on performance in school mathematics:-

1. Dyslexics who excel in all aspects of school mathematics, including arithmetic. Some of these reported favouring visualising modes, while others were unable to explain their strategies. This supports Krutetskii's (1976) finding of different types of mathematical thinkers.

2. Dyslexics who have relatively little difficulty with spatial concepts and general conceptualising ability but appear to be deficient in symbolic skills, especially those required in arithmetic.

3. Dyslexics who score at about the level that might be expected given their age and intellectual potential; that is their school mathematics scores are "average".

4. Dyslexics who are below average in all aspects of the school curriculum measured, particularly arithmetic.

5. Dyslexics who are severely retarded by 4 years or more in school mathematics given their chronological age and measured intellectual level.

Tentative explanations for these findings may be made drawing on the neuropsychological literature. It is necessary to state some findings to explain the conclusion drawn.

The Dyslexic who is poor at all aspects of school mathematics

Weinstein (1978) has suggested that dyscalculics' poor performance in arithmetic may be due to a developmental delay in the development of hemispheric specialisation for calculation. Weinstein contends that calculation is a left hemisphere skill. However, Geschwind (1981) (Personal communication) and Rapin (1981) (Personal communication), both doubt the feasibility of a Developmental Lag explanation for the poor performance of dyslexics in symbolic skills. Geschwind suggests that a dysfunction in the left angular gyrus region is implicated. This area is believed to be involved in translating visual and auditory material. Rourke (1981) and Rourke & Strang (1978) have found that different types of arithmetical difficulties can result from dysfunction in the right and left hemispheres of the brain respectively. Katz (1980) has suggested that both hemispheres may be involved in arithmetic.

Franco & Sperry (1977) found that Euclidian geometry (the type most taught in schools), generally regarded as a right hemisphere task, can be dealt with equally efficiently by the left hemisphere.
Bruner (1966), Kane & Kane (1979) and Elliot et al. (1979) suggest that teaching in schools is geared toward an analytic mode. Analytical thinking is generally regarded as a left hemisphere function (Nebes, 1974).

All these findings taken together may account for the dyslexic who is poor at all aspects of school mathematics. This child may be attempting to use a dysfunctioning area of the brain to solve mathematical problems, in much the same way as s/he might approach symbolic written material.

The Dyslexic who is good at geometry and spatial tasks, but poor on Arithmetic

This child might be using the right hemisphere for spatial tasks, but be engaging a similar area for arithmetic that is involved in the processing of written material.

The Dyslexic who is average at school mathematics

This child may be using some right hemisphere and left hemisphere skills, as suggested by Rourke (1981).

The Dyslexic who excels in all aspects of school mathematics

This child may be adopting a totally right hemisphere approach to calculation.

Of course, a left hemisphere/right hemisphere explanation seems too simplistic. It does not take into account the role of the frontal lobes, or other areas of the brain.

Some of the children in this group reported that they favoured a visualising mode - they saw numbers and problems as pictures. Others were unable to explain their solution strategies. There seems to be some support for Krutetskii's (1976) finding that there are different types of mathematical thinkers.

The findings presented by Duffy et al. (1980a, 1980b) suggest that Dyslexics differ from Controls in a number of areas of neurological functioning and different areas appear to be implicated in each group for different tasks. It could be that intra-group differences will be found which will explain why some Dyslexics do well in all aspects of school mathematics, while some have specific difficulties with arithmetic and others have general difficulties. This seems like an important area for further research.

The use of errors as behavioural measures of a subject's ability, in conjunction with interviewing, appears to be a viable way of assessing performance, in the absence of more direct measures.

Conclusion

The general hypothesis stated at the outset is accepted; that is, there is a proportion of the dyslexic population that does have specific difficulties with aspects of school mathematics. There are many dyslexics (possibly 40%) who do not have difficulties with school mathematics and given that none of the studies supported any notion that failure in this subject was due to lack of schooling, anxiety, negative attitudes, tiredness, withdrawal from the classroom during mathematics lessons, etc., and given the apparent similarities between language and arithmetic, particularly, it does not seem likely that failure in the other 60% of the Dyslexics would be independent of their literacy failure. Rather, whilst anxiety might contribute in some cases, the bulk of evidence tends to support a constitutionally based deficit manifesting itself in parallel forms in mathematics and language. Thus it seems that there is some justification for the inclusion of school mathematical difficulties in the defining characteristics of dyslexia. The fact that not all dyslexics manifest these difficulties can be accounted for in the same way as one accounts for dyslexics who can read adequately but cannot spell; one does not expect to see all possible diagnostic features in every individual.

The finding that about 60% of dyslexics have difficulties in some aspects of school mathematics indicates that these difficulties warrant inclusion in a definition of dyslexia. Until recently, most definitions have featured reading retardation as the primary area of difficulty, but as Miles (1978) states, reading is an important aspect, but not the only one to be considered.

It is suggested that a more comprehensive definition of dyslexia might not refer to reading/spelling/arithmetic and mathematics specifically. There seems to be some evidence to support a more accurate definition in terms of symbolic mediation difficulties and verbal labelling deficits, which cuts across subject boundaries.

Implications for further research

Because of the preliminary investigative nature of the present studies, Dyslexic and Control Groups were treated as homogeneous entities respectively. This broad classification of groups seemed feasible as an initial approach to studies in a relatively new area of research. Findings based on these groupings seem to have provided some interesting general results. However, there now appears to be a need to examine both populations in terms of subgroups. Not all dyslexics manifest the same literacy difficulties and not all dyslexics appear to have similar school mathematical difficulties. It may be that particular literacy difficulties may be associated with differential patterns of success or failure in mathematics. Further studies are planned to investigate these groupings.

Torgeson (1975) says:

> "The greatest usefulness of research may not be in the construction of specific remedial techniques, but in the contribution it makes to the cataloging (sic.) and proper description of the variety of human abilities. Once clinicians and educators are aware of the relevant dimensions along which abilities might vary, they can begin to construct programs that make allowances for the unique problems of each child with learning difficulties."

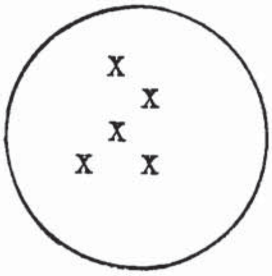
It is hoped that studies undertaken in this thesis have added new data which can be utilised to this end.

APPENDICES

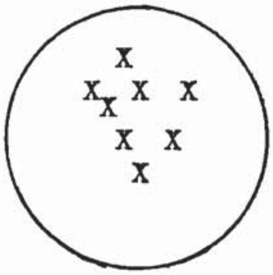
APPENDIX 1

LJ1-LINEAR

How many?



______



______

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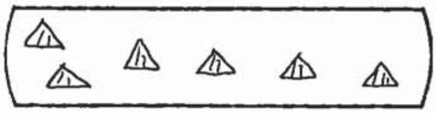
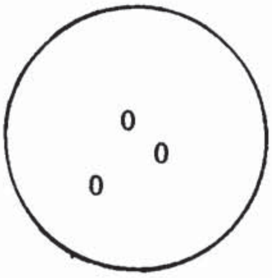
2 + 4 =	9 + 1 =	3 + 4 =
0 + 9 =	125 + 2 =	11 + 11 =
10 + 8 =	10 + 0 =	917 + 83 =
27 + 14 =	12 + 13 =	300 + 20 =

Partition/share these sets

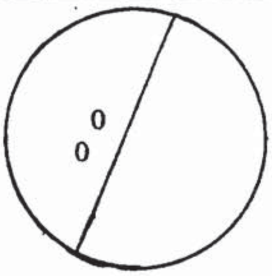


_____ + 4 = 6

5, ______ = 6



3 add 2 ⟶ _____



2 and 0 ⟶ _____

APPENDIX 1 cont'd.

1, 2, 3, 4, ____, ____, ____

2, 4, 6, 8, ____, ____, ____

+4

3	9
6	10
5	6
2	7

An apple costs 2p	1 apple	2p
An orange costs 3p	1 orange	3p
A carrot costs 1p	3 carrots	3p
How many pence altogether?		____

How many?

0 0 0 0 → ____ +

X X X X → ____

____

____

Triangles	△ △ △ △
Squares	□ □ □ □ □ □
Circles	0 0 0
Rectangles	▭ ▭ ▭ ▭ ▭

The number of triangles is ....

The number of circles and rectangles is ....

The number of squares and triangles is ....

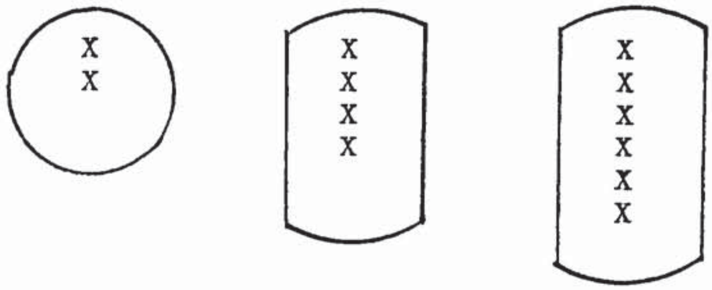
What is the difference between the number of squares and number of circles?

Are there more or less triangles than squares ....

Which set has the least shapes ....

Which set has the most shapes ....

APPENDIX 1 cont'd.



____ → ____ → ____

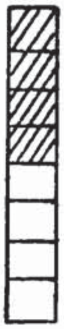
I counted on ____ each time

---

1 + (3 + 4) = 1 + ____ = ____

8 + (5 +6) = 8 + ____ = ____

—— 3
+
—— 1
——
4
——



——
+
——

——
——

X X X X X —— ____

0 0 0 —— ____ +

____

____

If I have 9 chocolate buttons and I eat 4 of them, how many do I have left? ....

---

3 - 1 =	9 - 3 =	0 - 0 =
10 - 4 =	8 - 0 =	7 - 5 =

APPENDIX 1 cont'd.

---

23 ——— 18 ——— 13 ——— ____ ——— ____

I counted back _____ every time

-3

9
7
5

4
6
2

Draw arrows to show your answers

X
X
X
X

0

0

Match these sets.

How many are left over? ______

Count back in two's from 10. Write the numbers here: ________________

_____ - 4 = 6

19 - 10 =

12 - ____ = 9

---

4 - 2 = _____

8 - 2 = _____

12 - 2 = _____

____ - 2 = _____

____ - 2 = _____

Match these sets one to one:

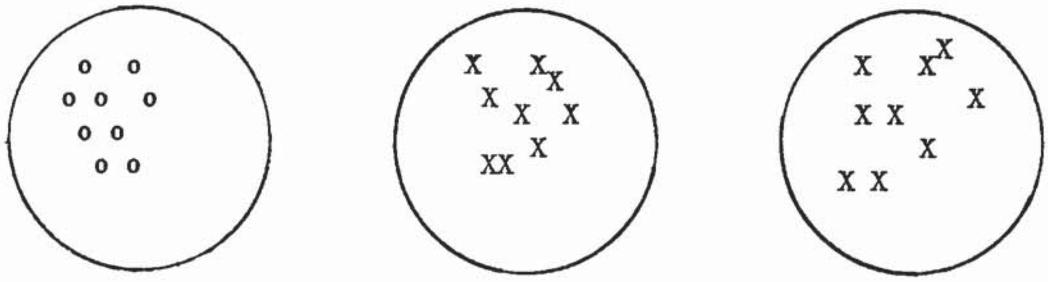
X X
X

X
X X
X
X X

Draw a set of the difference

APPENDIX 1 cont'd.

Partition these sets:



(9, ____)   (6, ____)   (____, 3)

A boy saves 4p every week.

How long does it take him to save 12p? ____ weeks.

I have one pound and I spend 50p, how much do I have left? ____p.

What number do I reach if I count back:-

5 places from 21 ______   8 places from 12 ______

11 - 2 = _____ can be written as 2 + _____ = 11

2 - 1 = _____ can be written as 1 + _____ = 2

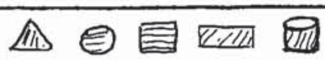
19
-9
—
—

This means that 9 + _____ = 19

X	X	X	X	X	X	X
A	B	C	D	E	F	G

Put a circle around the 4th cross

Which is the 1st cross?



Which shape is 2nd in line? __________

Which shape is last? __________

APPENDIX 1 cont'd.

Which of these is less than 12:

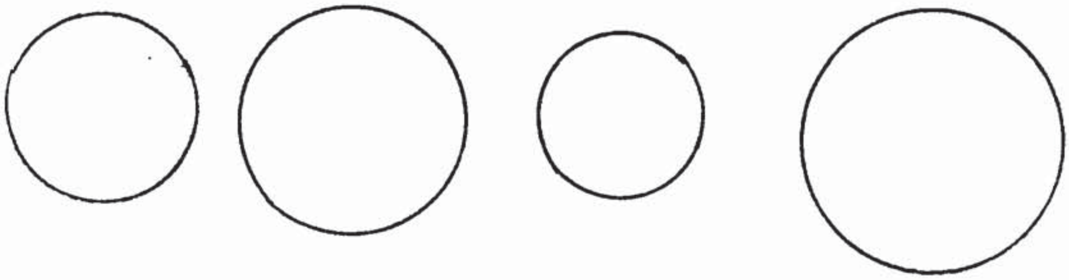
(a) Five twos (c) Three fives

(b) Ten ones (d) Seven twos

Is 4 x 2 the same as 2 x 4? YES/NO

Is 3 x 2 the same as three twos? YES/NO

Start at 5 and count in 3's four times. What number do you reach? ____



Draw arrows to show which circles are bigger than which other ones.

Arrange these numbers from smallest to biggest:

1, 100, 12, 8, 14, 10, 53, 4, 91

What number is 5 more that 5? ____

What number is 4 more than 0? ____

1	2	3	4	5	6	7	8	9	10

6 > ______________ 5 > ______________

4 < ______________

A farmer has 5 fields and he has 10 cows. How many cows would he put in every field so that they all have the same number of cows? ______

Put a ring round all the even numbers:

1, 2, 16, 50, 13, 12, 3, 7, 9, 8

Put a ring round all the odd numbers:

15, 3, 4, 2, 1, 5, 8, 7, 11

APPENDIX 1 cont'd.

HUNDRED SQUARE AND NUMBER LINE HANDED OUT WITH LJ1-LINEAR

1	2	3	4	5	6	7	8	9	10
11	12	13	14	15	16	17	18	19	20
21	22	23	24	25	26	27	28	29	30
31	32	33	34	35	36	37	38	39	40
41	42	43	44	45	46	47	48	49	50
51	52	53	54	55	56	57	58	59	60
61	62	63	64	65	66	67	68	69	70
71	72	73	74	75	76	77	78	79	80
81	82	83	84	85	86	87	88	89	90
91	92	93	94	95	96	97	98	99	100

APPENDIX 2

LJ2-SPATIAL

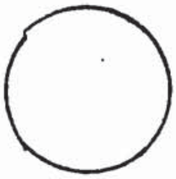
Continue the patterns:

/\ /\ /\ ______________________

1 2 1 2 ______________________

0 □ 0 ______________________

Draw a set of circles



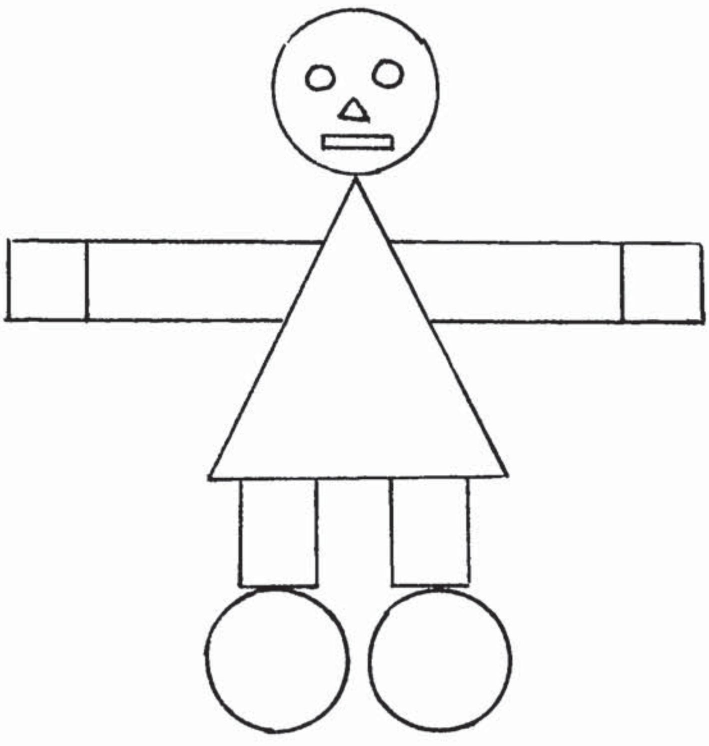
How many sides has a triangle? __________

square? __________

rectangle? __________

hexagon? __________

Match the labels with the shapes



Circle

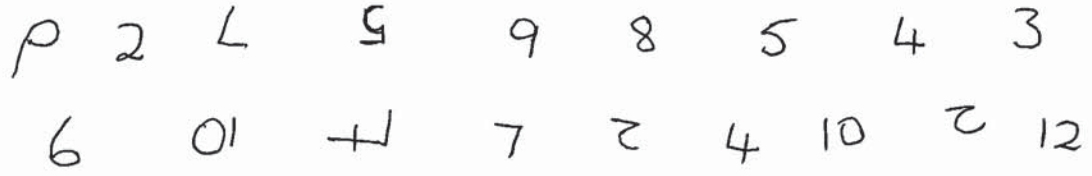
Square

Rectangle

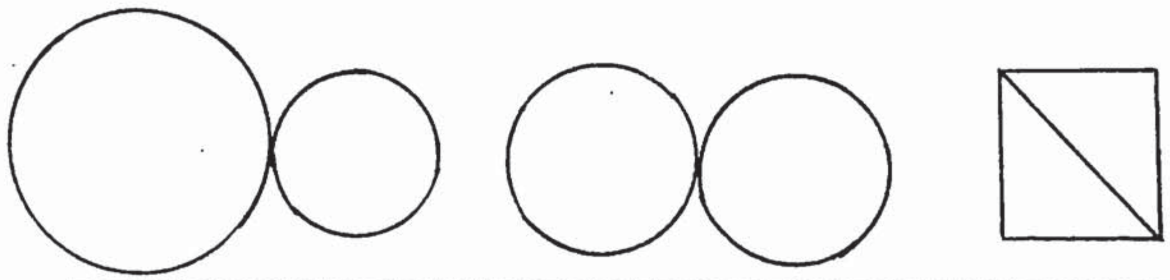
Triangle

APPENDIX 2 cont'd.

Put a ring around the numbers that are correctly written:



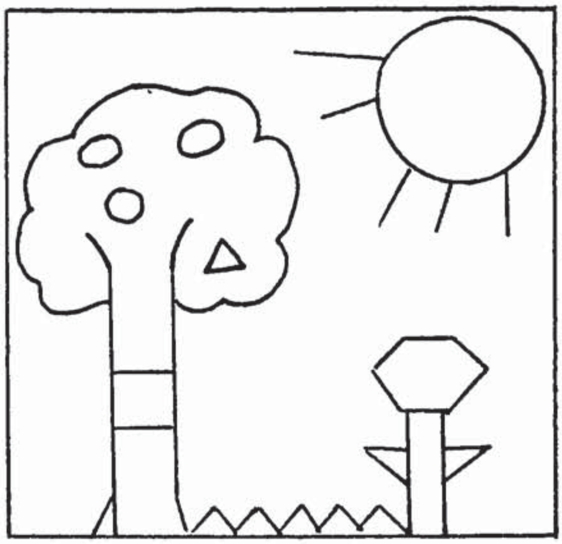
Are these shapes symmetrical?



If things are symmetrical, what do we know about their size and shape?

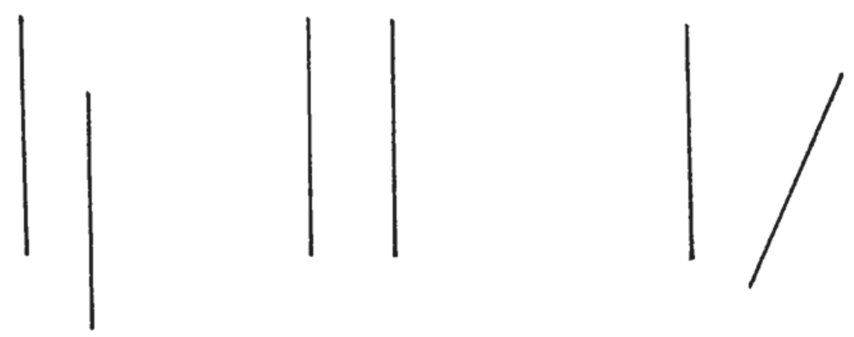
If I fold a piece of paper in half and stick a pin through it, then take the pin away and unfold the paper, how many holes will there be:
______ holes.

If I fold the paper into 4 (quarters) how many holes will be made by the pin?
______ holes.



Write down all the shapes you can see in this picture, and how many of each there are? LOOK CAREFULLY.

APPENDIX 2 cont'd.



Are these pairs of lines the same length or different?

APPENDIX 3 ADDITIONAL DATA FROM STUDY 1

SCHOOL A

subject	Age y	Age m	Sex	WISC Full	Verbal	Perf	Inf	Sim	Arith	Voc	Comp	Digit	Pic Comp	Pic Arr	Block	Object	Coding	Schonell Reading y	Schonell Reading m	Schonell Spelling y	Schonell Spelling m	LJ1-linear /120	LJ2-spatial /50	Maths Attmt
1	7	3	♀	84	85	86	6	3	8	12	9	8	6	6	8	10	10	6	8	6	6	44½	27	84
2	7	10	♂	121	111	128	12	11	11	12	13	12	12	12	16	17	12	9	2	10	3	94½	40½	110
3	7	11	♀	101	102	101	10	7	11	14	10	9	8	8	15	9	11	7	5	7	5	84	40½	101
4	8	1	♀	83	82	86	4	7	6	9	10	8	8	4	8	12	8	7	5	6	2	37	28	79
5	7	4	♂	110	105	115	9	10	10	12	13	7	10	13	14	12	12	7	9	7	5	95½	34½	113
6	8	4	♀	81	82	82	7	6	5	12	6	5	7	9	6	9	6	8	7	9	2	64½	36½	80
7	8	1	♀	121	115	123	11	12	13	14	13	8	15	9	16	14	12	8	8	8	6	88	43½	107
8	8	0	♂	86	79	96	5	6	6	8	8	7	8	11	9	10	10	7	6	6	9	52	23	88
9	6	11	♂	105	106	105	9	11	12	13	10	10	11	12	13	11	7	6	0	5	1	58	35	99
10	8	0	♀	101	101	102	7	11	10	13	10	7	10	12	12	12	6	7	3	7	5	82½	31	98
11	7	3	♂	101	100	104	11	8	10	11	10	10	10	9	13	12	9	7	7	7	2	92	32½	95
12	8	2	♂	102	98	106	8	9	7	15	10	8	11	11	13	12	8	6	0	5	3	68½	35	103
13	7	10	♀	99	95	104	9	9	8	10	10	11	10	10	11	10	12	7	5	6	7	74	33	93
14	7	9	♀	97	85	112	3	7	8	8	12	10	10	9	13	15	12	6	11	6	6	76	30	93
15	7	6	♀	93	96	92	9	8	10	11	9	12	10	8	8	8	11	7	9	7	9	79	33½	96
16	7	0	♂	93	91	98	6	8	10	10	9	11	9	9	8	10	13	7	2	7	0	83½	26	97
17	6	11	♀	109	111	105	12	12	14	11	10	11	8	12	13	11	10	8	2	7	6	96	41	110
18	8	4	♂	73	79	71	4	6	6	10	7	2	9	3	5	6	5	6	7	5	2	37½	31½	70
19	8	1	♂	87	91	85	7	8	7	8	7	6	7	10	11	6	5	6	6	5	2	53½	31½	73
20	8	1	♀	97	103	91	9	12	8	12	12	7	10	7	10	11	6	7	10	8	0	70	28	99

APPENDIX 3 ADDITIONAL DATA FROM STUDY 1

SCHOOL B

subject	Age y	Age m	Sex	WISC Full	Verbal	Perf	Inf	Sim	Arith	Voc	Comp	Digit	Pic Comp	Pic Arr	Block	Object	Coding	Schonell Reading y	m	Schonell Spelling y	m		LJ1-linear /120	LJ2-spatial /50	Maths Attmt
21	6	11	♀	81	86	78	4	9	6	9	11	8	3	8	10	3	10	-6		-5			87	23	87
22	6	11	♀	99	103	93	9	10	10	13	11	10	9	8	8	7	14	8	3	8	9		67	32	90
23	7	8	♀	89	97	82	6	10	13	10	9	9	7	9	11	2	8	7	4	7	0		95	36	98
24	7	5	♀	102	103	101	9	11	9	13	11	8	11	9	9	11	11	8	11	9	0		61	32	95
25	7	11	♂	112	112	109	10	11	11	14	14	10	12	10	10	16	9	8	8	8	2		80	38	107
26	7	6	♀	76	75	80	2	7	7	6	8	4	5	7	8	8	7	7	4	7	0		48½	24½	80
27	7	3	♀	112	112	109	12	12	10	15	11	7	12	12	9	10	14	7	10	8	2		73	38	93
28	7	0	♀	97	100	95	8	10	11	11	10	10	11	10	9	10	7	8	5	8	10		68	34½	82
29	8	7	♀	73	77	73	4	6	9	6	6	10	9	4	5	3	9	8	3	8	8		63	34	82
30	7	6	♀	99	97	101	9	9	9	11	10	7	10	13	10	9	9	8	3	8	1		64	42	96
31	7	7	♀	86	88	86	9	9	9	7	7	7	9	6	11	9	5	8	2	8	10		73	33	95
32	7	3	♀	93	91	98	8	8	8	9	10	8	8	11	7	11	12	8	0	8	5		69	31	93
33	7	9	♂	111	108	112	9	11	9	14	14	13	12	9	14	12	12	8	6	8	0		83	40	100
34	8	5	♂	74	82	70	3	8	7	10	8	10	8	3	5	9	7	6	11	6	8		65	30	72
35	8	1	♀	99	102	95	10	7	14	10	11	12	6	10	7	11	13	8	7	9	8		100½	36	107
36	7	2	♂	102	108	96	5	14	11	13	14	10	11	9	10	10	8	7	4	7	5		81	36	98
37	7	9	♂	97	100	95	10	9	11	11	9	9	7	9	15	8	8	8	2	8	4		91½	35	111
38	8	7	♂	97	95	101	7	9	9	11	10	7	8	12	12	8	11	8	7	8	8		89	37	94
39	7	9	♀	93	98	90	12	9	9	10	9	10	12	8	7	7	9	8	3	7	6		81	36	87
40	7	0	♀	92	96	90	10	8	10	11	8	8	10	7	7	13	6	7	5	7	7		69	30	104

APPENDIX 3 ADDITIONAL DATA FROM STUDY 1

SCHOOL C

subject	Age y	Age m	Sex	WISC Full	Verbal	Perf	Inf	Sim	Arith	Voc	Comp	Digit	Pic Comp	Pic Arr	Block	Object	Coding	Schonell Reading y	Schonell Reading m	Schonell Spelling y	Schonell Spelling m	LJ1-linear /120	LJ2-spatial /50	Maths Attmt
41	7	8	♀	101	98	5	9	14	9	6	11	10	10	10	11	11	12	8	1	7	5	77½	42½	90
42	8	5	♀	97	96	100	8	8	9	10	12	7	9	12	10	10	9	7	7	7	11	88	33½	83
43	8	0	♀	104	108	100	11	10	13	11	12	7	9	10	10	8	13	8	3	8	6	106½	38½	106
44	7	10	♀	93	102	86	11	10	13	6	12	7	9	5	7	4	15	6	11	7	4	85	31	86
45	8	3	♀	128	136	115	14	15	14	17	18	18	10	14	13	13	11	12	6+	11	6	110	44	124
46	8	5	♀	94	96	93	7	9	9	10	12	9	8	9	10	9	8	7	7	7	9	80	29	95
47	8	2	♀	105	108	102	9	12	13	12	11	7	11	10	7	9	15	7	8	7	6	89½	33½	106
48	8	6	♂	92	103	82	9	9	11	12	12	8	9	8	7	6	7	8	5	8	6	96½	38½	97
49	8	9	♀	82	81	86	5	6	6	10	8	11	9	6	9	7	9	6	11	7	1	88	36	92
50	8	0	♂	109	119	96	12	10	12	17	15	6	7	10	7	15	9	8	6	7	9	94	37½	101
51	8	3	♀	100	103	95	9	12	8	13	11	12	11	8	12	12	4	7	2	7	6	86	32	95
52	8	6	♂	99	102	95	12	7	12	10	11	6	8	6	13	11	9	8	1	8	3	111	40½	95
53	7	9	♂	91	94	91	9	9	8	10	9	9	10	7	10	12	5	9	8	9	4	80	34	95
54	7	5	♂	126	127	118	12	13	13	15	15	12	13	12	15	14	9	7	6	7	9	103½	39	115
55	8	6	♀	121	118	120	12	11	16	13	13	11	10	13	14	11	16	9	0	9	7	109½	43½	112
56	7	8	♂	109	98	120	10	7	11	10	11	10	10	12	12	13	17	8	6	8	6	97½	30½	109
57	7	2	♀	97	109	85	10	11	15	11	11	9	11	6	10	4	8	7	7	7	6	78	31½	94
58	8	4	♀	92	95	91	7	8	7	12	12	10	10	11	6	6	11	7	1	6	11	75	33	91
59	8	2	♀	97	97	98	8	11	8	10	11	7	10	10	7	9	13	7	3	6	9	87	32	90
60	8	3	♀	107	103	111	10	9	13	10	11	6	10	15	11	12	10	7	2	6	0	97	33	108

APPENDIX 3 ADDITIONAL DATA FROM STUDY 1

DYSLEXIC GROUP

subject	Age y	Age m	Sex	WISC Full	Verbal	Perf	Inf	Sim	Arith	Voc	Comp	Digit	Pic Comp	Pic Arr	Block	Object	Coding	Schonell Reading y	Schonell Reading m	Schonell Spelling y	Schonell Spelling m	LJ1-linear /120	LJ2-spatial /50	Maths Attmt
1	7	5	♀	76	74	82	5	2	8	7	7	1	10	8	8	8	3	6	9	6	3	42	32½	82
2	9	2	♂	96	91	102	7	8	5	11	12	4	12	10	10	14	6	7	1	5	7	83	35	84
3	7	2	♂	110	113	106	10	16	7	13	14	6	15	10	9	10	10	-6	0	-5	0	46½	32½	81
4	8	7	♂	80	75	88	2	6	5	4	10	3	8	8	10	12	4	6	6	5	11	82	33½	70
5	7	7	♀	101	106	95	10	12	11	11	11	?	9	5	10	13	10	6	8	5	6	69	37½	97
6	7	6	♂	91	100	84	7	11	9	13	10	?	7	4	11	3	13	6	10	5	7	81	36	96
7	8	5	♂	100	114	85	8	13	11	14	16	8	9	8	6	10	6	7	8	6	3	93	36	108
8	8	3	♂	118	121	111	10	19	8	15	15	9	11		14	11	10	9	2	7	0	72	31½	86
9	8	4	♂	106	106	104	8	12	8	10	17	8	8	10	14	12	9	6	6	5	6	63½	41½	86
10	9	4	♀	100	113	85	8	12	10	12	19	9	8	11	5	6	9	7	2	5	8	84½	34	82
11	7	10	♂	102	100	104	7	12	10	8	13	?	11	10	12	9	11	6	4	6	3	84	35½	90
12	8	2	♂	113	112	112	12	11	8	14	15	9	11	8	18	13	9	8	2	8	0	92	42½	106
13	8	7	♀	127	130	118	10	15	12	18	19	12	15	14	14	15	5	7	2	6	6	91	42½	109
14	8	0	♂	114	109	117	10	14	8	15	11	10	10	12	12	12	6	7	0	6	8	79½	36½	101
15	8	3	♂	95	91	101	8	9	8	9	9	3	11	4	13	11	12	7	4	6	9	?	35½	87
16	9	2	♂	96	91	102	6	8	6	11	12	7	10	12	11	11	8	7	11	6	7	84½	36	95

? indicates missing data.

APPENDIX 4

STUDY 2 - CLINICAL INTERVIEWS - LJ3

Subjects were asked the following questions at some time during the session. The items were not necessarily presented in this order; others were worked into the conversation, wherever possible. Questions were modified if they proved too difficult for the individual. No formal answer sheet was used.

1a. What is your favourite subject at school?

b. What is special about it?

2. What is your favourite activity or hobby?

3a. What school subject do you like least?

b. Why?

4. What do you think about maths?

5. Say in words: 107.

6. If you joined the dots, without any lines crossing, what shape would you get? (The subject does not actually join the dots, unless he does not recognise the shape).

7. 20 - 13 =

8. What is another way of saying?

xxx	+	x	=	xxx
xxx		x		xxx
		x		xxx

9. Count back from 20 in twos.

10. Count back 8 places from 12.

11. Count back 5 places from 21.

12. Complete the following sequences:-

1 2 3 1 2 3 ____________

9, 8, 7, ____________

13. Which is the biggest of these numbers?

1100 200 205 453 15 4561

14. What shape is this?

15. 4 - 2 =

8 - 2 =

12 - 2 =

__ - 2 =

16. Write down the number two hundred and three.

17. Is 5 smaller or bigger than 10?

18. ___ - 23 = 45.

19a. 10 x 0 (nought) =

b. 4 x 0 (nothing) =

c. 5 x 4 =

d. 20 x 1 =

20. How many lots of ten are there in 120?

21a. What number is 5 more than 5?

b. What number is 4 more than 0?

22. $\begin{array}{r} 25 \\ +\ 14 \\ \hline \\ \hline \end{array}$

23. Four boys have 48p altogether. How much would each one get if they shared it equally?

24. If you saved 8p per day, how much would you save in one week?

25. Fill in the missing numbers:

23 —— 18 —— 13 ——   ——

26. 11 - 2 = _____ . So 2 + ____ = 11.

27. $\begin{array}{r} 19 \\ -\ 9 \\ \hline \\ \hline \end{array}$ So 9 + ____ = 19.

28. Write down these numbers as I say them: 203

4266

5204

406

53

761

29. Do you do tables at school?

Which ones do you know?

30.
$$\begin{array}{r} 25 \\ \underline{\times\ 63} \\ \underline{} \end{array}$$

APPENDIX 5A - ADDITIONAL DATA FROM STUDIES 3 & 4.

SCHOOL A.

		STUDY 3					STUDY 4									
		BAS BASIC ARITHMETIC					MATHS MODULES									
Subject number	C.A.	Raw Score	Ability score	%ile score	T-score	Arith. Age	1	2	3	4	5	6	7	8	9	10
1	9y 9m	3	25	4	32	7y 4m	1	2	2	1	1	1	2	1	3	0
2	10y 5m	20	87	93	65	above norms	8	7	5	6	7	7	7	6	7	5
3	10y 6m	16	72	56	52	11y 1m	4	7	5	4	1	5	4	2	4	3
4	9y 11m	13	62	53	15	9y 10m	9	8	5	4	4	7	7	3	6	2
5	10y 11m	9	49	11	38	8y 6m	3	6	4	1	6	2	2	0	4	0
6	10y 8m	21	90	94	66	above norms	4	9	8	6	6	9	9	6	7	5
7	9y 5m	8	45	23	43	8y 4m	5	3	3	2	2	4	5	1	4	0
8	10y 8m	17	76	68	55	11y 8m	7	6	8	9	6	5	8	3	6	2
9	9y 10m	12	59	45	49	9y 7m	7	7	5	5	5	6	3	2	5	3
10	10y 5m	13	62	31	45	9y 10m	6	4	5	3	4	3	5	2	4	2
11	10y 5m	11	55	25	43	9y	4	6	5	4	4	2	6	2	5	2
12	10y 1m	6	38	8	36	8y 1m	4	5	3	3	3	4	3	1	4	1
13	10y 11m	4	30	3	31	7y 8m	0	2	1	2	0	4	2	0	0	1
14	10y 8m	4	30	3	31	7y 8m	1	0	0	0	0	2	0	0	4	1
15	10y 7m	18	79	76	56	12y 3m	8	8	5	7	7	6	3	4	5	1

APPENDIX 5B - ADDITIONAL DATA FROM STUDIES 3 & 4

SCHOOL B

		STUDY 3					STUDY 4									
		BAS BASIC-ARITHMETIC					MATHS MODULES									
Subject number	C.A.	Raw Score	Ability score	%ile score	T-score	Arith. Age	1	2	3	4	5	6	7	8	9	10
1	9y5m	7	42	18	41	8y3m	1	4	0	0	1	0	4	0	4	0
2	10y1m	14	65	46	49	10y1m	9	7	4	6	4	7	4	4	6	3
3	9y10m	13	62	53	51	9y10m	6	7	1	4	2	5	4	0	2	1
4	10y5m	13	62	39	55	9y10m	7	8	6	6	5	6	7	3	3	2
5	9y8m	16	72	79	58	11y1m	6	5	3	6	4	3	3	1	4	2
6	9y5m	13	62	65	54	9y10m	5	5	7	3	6	6	4	1	5	4
7	9y11m						0	6	5	3	3	4	3	1	1	1
8	9y11m	15	69	71	56	10y7m	6	7	5	3	4	5	4	2	4	1
9	10y1m	17	76	75	57	11y8m	9	8	8	8	8	6	3	4	4	3
10	10y3m	14	65	46	49	10y1m	10	7	6	6	4	7	7	4	5	1
11	10y10m	6	38	4	32	8y1m	3	2	2	1	0	4	5	1	4	0
12	10y6m	21	90	94	66	above norms	6	9	10	11	9	7	4	3	8	6
13	9y7m	7	42	14	39	8y3m	4	2	4	1	2	3	6	3	4	3
14	10y5m	7	42	10	37	8y3m	3	4	5	3	2	3	4	3	5	0
15	11y0m	20	87	83	60	above norms	7	9	8	9	6	6	6	2	7	2

APPENDIX 5C - ADDITIONAL DATA FROM STUDIES 3 & 4.

SCHOOL C

		STUDY 3					STUDY 4									
		BAS BASIC-ARITHMETIC					MATHS MODULES									
Subject number	C.A.	Raw Score	Ability score	%ile score	T-score	Arith. Age	1	2	3	4	5	6	7	8	9	10
1	10y6m	15	69	48	49	10y7m	5	7	6	2	4	4	4	0	4	4
2	10y2m	16	72	65	54	11y1m	8	5	8	4	6	8	5	1	3	3
3	9y9m	9	49	23	43	8y6m	4	4	4	3	4	3	5	1	4	3
4	10y1m	22	94	97	67	above norm	10	8	10	10	8	8	9	6	10	7
5	10y3m	15	69	57	52	10y7m	2	4	5	4	1	2	4	3	6	2
6	9y6m	11	55	35	46	9y	6	6	5	1	2	5	4	2	4	1
7	10y6m	13	62	31	45	9y10m	4	7	5	3	5	3	6	2	4	2
8	10y3m	13	62	39	47	9y10m	2	6	8	3	5	5	3	1	4	1
9	10y4m	8	45	12	38	8y4m	6	4	4	2	4	4	3	4	4	2
10	9y11m	9	49	23	43	8y6m	5	5	4	2	4	5	4	3	4	1
11	9y7m	15	69	71	56	10y7m	5	7	6	8	6	5	8	3	6	4
12	9y10m	13	62	53	51	9y10m	8	8	4	4	3	4	5	1	4	1
13	9y4m	11	55	46	49	9y	3	6	4	2	4	5	2	2	2	3
14	10y3m	8	45	12	38	8y4m	5	5	6	5	2	4	2	2	4	1
15	10y3m	16	72	65	54	11y0m	4	5	4	5	10	3	4	3	4	1
16	10y3m	13	62	39	47	9y10m	6	6	6	2	5	6	6	4	4	3

APPENDIX 5D - ADDITIONAL DATA FROM STUDIES 3 & 4

CONTROL GROUP 2

			STUDY 3						STUDY 4									
			BAS BASIC ARITHMETIC						MATHS MODULES									
Subject number	C.A.		Raw Score	Ability score	%ile score	T-score	Arith. Age		1	2	3	4	5	6	7	8	9	10
1	12y11m		20	87	65	54			6	10	10	8	8	9	8	5	5	3
2	12y3m		24	102	93	65			7	6	9	7	8	7	5	4	5	3
3	13y1m		16	72	24	43	11y0m		11	8	10	8	9	10	9	10	8	6
4	12y10m		21	90	72	56			8	9	10	9	8	10	8	5	10	7
5	13y8m		19	83	51	50			8	10	9	9	5	9	10	8	7	6
6	12y7m		15	69	25	43	10y6m		8	8	10	6	8	7	7	4	3	4
7	12y9m		22	94	79	58			8	12	12	11	9	8	9	8	11	6
8	12y m		25	107	94	66			10	11	10	10	10	8	9	4	8	5
9	13y9m		21	90	66	54			8	10	9	8	7	9	6	5	9	4
10	13y9m		21	90	66	54			10	12	9	11	7	8	9	9	9	8
11	13y7m		22	94	75	57			10	10	11	9	9	9	8	10	10	6
12	13y4m		22	94	75	57			8	9	12	8	8	11	9	9	11	9
13	12y3m		20	87	71	56			8	7	9	7	11	9	9	8	9	7
14	12y10m		16	72	28	44			4	5	6	5	3	7	5	4	6	3
15	12y3m		24	102	93	65			8	7	9	8	6	7	7	6	7	1
16	12y1m		21	90	77	57			9	7	9	8	9	9	8	5	7	4

APPENDIX 5E - ADDITIONAL DATA FROM STUDIES 3 & 4.

CONTROL GROUP 3

	STUDY 3								STUDY 4									
			BAS BASIC ARITHMETIC						MATHS MODULES									
Subject number	C.A.		Raw Score	Ability score	%ile score	T-score	Arith. Age		1	2	3	4	5	6	7	8	9	10
1	16y2m		26	113					11	12	12	11	9	11	9	12	10	9
2	15y11m		25	107					7	12	11	10	9	9	10	7	6	8
3	15y11m		25	107					11	12	12	12	12	10	11	12	7	11
4	16y0m		26	113					12	8	10	12	10	10	10	10	11	9
5	15y6m		26	113					11	11	10	8	9	11	11	12	11	11
6	15y8m		27	122					11	10	9	10	11	7	10	11	10	10
7	16y0m		20	87					9	10	8	7	5	9	10	9	10	9
8	15y4m		25	107	all	above			10	12	11	10	9	9	12	11	12	7
9	16y0m		25	107	norms	for			11	12	11	11	12	10	10	10	11	11
10	15y10m		26	113		test.			12	12	12	12	11	10	11	11	12	12
11	15y9m		26	113					11	12	12	12	9	10	9	12	12	7
12	15y2m		27	122					12	12	12	11	9	12	11	12	8	11
13	16y5m		27	122					12	12	12	9	9	10	11	10	10	7
14	15y7m		26	113					12	9	12	10	11	10	10	11	10	10
15	15y10m		26	113					12	12	11	12	12	10	10	11	11	11
16	16y6m		28	above norms					12	11	12	10	11	11	12	9	9	9

APPENDIX 5F

ADDITIONAL DATA FROM STUDIES 3 & 4.

DYSLEXIC GROUP 1

			STUDY 3						STUDY 4									
			BAS BASIC-ARITHMETIC						MATHS MODULES									
Subject number	C.A.		Raw Score	Ability score	%ile score	T-score	Arith. Age		1	2	3	4	5	6	7	8	9	10
1	9y9m		7	42	14	39	8y2m		1	4	2	2	1	3	4	1	2	0
2	10y5m		17	76	74	56	11y7m		6	9	9	4	4	5	6	6	5	3
3	8y11m		2	19	5	33	6y10m		0	1	0	0	0	0	3	0	1	0
4	10y6m		16	72	56	52	11y6m		3	6	6	3	2	2	6	2	2	3
5	9y5m		7	42	17	40	8y2m		2	4	4	2	0	1	2	2	2	3
6	10y3m		20	87	93	65	Above norms		6	7	6	5	3	3	6	1	3	2
7	10y8m		6	38	5	33	8y0m		0	4	4	1	3	1	6	2	1	3
8	9y1m		11	55	46	49	8y11m		5	5	6	1	1	4	5	1	3	2
9	10y4m		12	59	31	45	9y6m		6	4	4	3	1	6	4	2	4	1
10	10y2m		9	49	16	40	8y6m		8	4	0	1	4	6	6	4	4	3
11	9y2m		12	59	55	51	9y6m		3	7	7	1	3	4	2	1	4	1
12	10y5m		20	87	93	65	Above norms		9	7	9	2	5	9	5	5	3	7
13	10y2m		8	45	12	38	8y4m		1	2	1	0	0	7	5	0	2	0
14	10y0m		7	42	9	37	8y2m		3	6	6	4	3	3	5	1	2	1
15	9y6m		15	69	71	56	10y6m		3	6	8	3	1	5	5	3	2	2
16	11y11m		5	34	3	31	7y10m		5	4	4	2	3	5	4	2	4	0

APPENDIX 5G

ADDITIONAL DATA FROM STUDIES 3 & 4.

DYSLEXIC GROUP 2.

		STUDY 3					STUDY 4									
		BAS BASIC ARITHMETIC					MATHS MODULES									
Subject number	C.A.	Raw Score	Ability score	%ile score	T-score	Arith. Age	1	2	3	4	5	6	7	8	9	10
1	11y1m	19	83	66	54	13y11m	7	6	8	5	4	8	6	5	3	4
2	11y11m	15	69	31	45	10y6m	6	5	5	5	5	2	7	3	4	0
3	13y6m	25	107	91	63	above norms	10	11	12	11	9	11	10	12	11	7
4	12y3m	11	55	8	36	9y0m	5	6	5	4	3	4	7	4	4	2
5	13y3m	14	65	15	40	10y m	7	8	5	8	5	6	8	5	7	3
6	13y1m	21	90	69	55	above norms	10	7	11	4	8	11	8	7	7	8
7	11y2m	10	52	11	38	8y8m	4	6	3	3	0	4	4	3	6	1
8	12y2m	18	79	50	50	12y2m	5	8	5	4	7	3	5	2	4	3
9	13y4m	12	59	9	37	9y6m	3	3	3	6	3	7	4	2	5	1
10	12y1m	11	55	7	35	9y0m	0	2	1	0	3	2	7	0	3	2
11	12y0m	16	72	32	45	11y0m	10	8	10	5	5	10	9	7	7	6
12	11y11m	17	76	48	49	11y7m	8	7	7	8	7	10	4	3	6	4
13	12y2m	17	76	42	48	11y7m	9	8	11	7	5	9	7	5	4	4
14	13y3m	17	76	34	46	11y7m	7	9	9	8	8	7	9	4	7	4
15	12y10m	14	17	40	65	10y m	5	4	4	4	3	6	6	2	6	3
16	11y2m	13	62	23	43	9y10m	7	8	6	1	3	8	5	3	4	5
17	13y2m	14	65	15	40	10y1m	6	9	5	5	5	6	11	6	6	6
18	11y7m	6	3	31	38	8y0m	0	1	3	1	1	2	4	1	2	0

APPENDIX 5H - ADDITIONAL DATA FROM STUDIES 3 & 4.

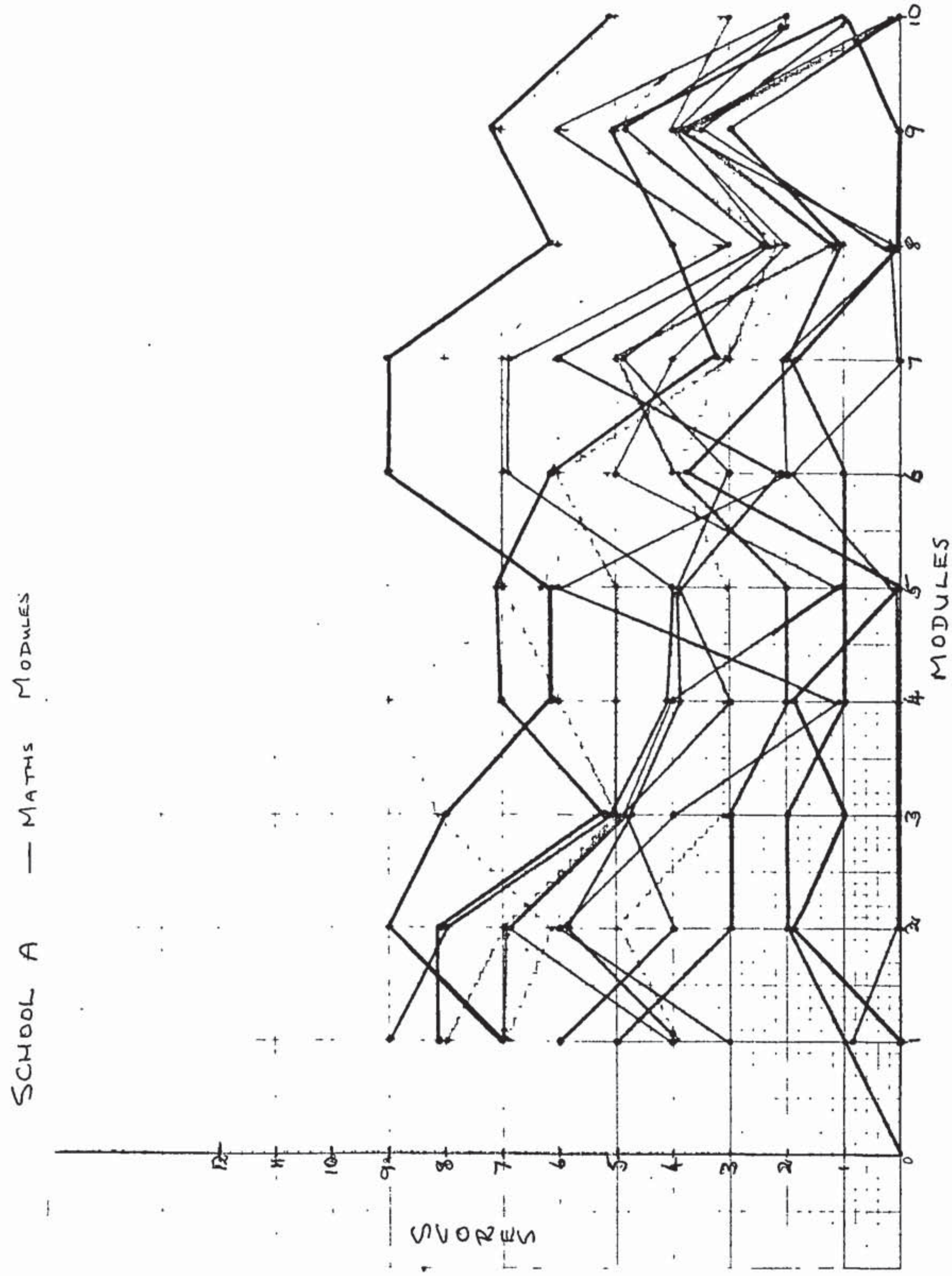
DYSLEXIC GROUP 3.

		STUDY 3					STUDY 4									
		BAS BASIC ARITHMETIC					MATHS MODULES									
Subject number	C.A.	Raw Score	Ability score	%ile score	T-score	Arith. Age	1	2	3	4	5	6	7	8	9	10
1	15y6m	20	87	*	*	Above norms	5	7	7	6	3	5	7	5	4	2
2	14y4m	24	102	86	61		10	8	8	7	9	10	12	10	11	9
3	16y1m	28	Above norms			Above norms	11	9	10	10	7	9	10	10	10	9
4	14y3m	15	69	17	40	10y10m	7	8	8	4	3	8	8	5	4	7
5	15y5m	24	102			Above norms	9	11	12	8	7	9	9	9	11	9
6	14y7m	18	79			12y2m	9	6	8	8	5	9	7	5	7	3
7	14y10m	17	76			[illegible]7m	10	11	10	7	7	11	9	9	10	7
8	14y11m	19	83			13y9m	5	9	6	6	6	8	10	3	6	3
9	14y1m	20	87			Above norms	5	6	7	5	4	6	5	4	6	3
10	15y2m	25	107			Above norms	11	11	9	10	11	11	11	12	10	10
11	15y6m	18	79			12y?m	3	9	9	5	3	4	7	4	6	4
12	14y2m	20	87	57	52	Above norms	10	9	11	6	8	8	5	4	6	8
13	15y7m	26	113			Above norms	11	12	12	8	11	9	12	10	11	8
14	15y9m	21	90			Above norms	9	9	9	6	5	10	7	8	7	8
15	14y8m	12	59			[illegible]	3	6	3	4	4	3	7	3	3	2
16	14y8m	23	98			Above norms	10	10	9	8	10	10	10	9	10	6
17	14y11m	18	79			[illegible]	7	6	6	3	3	4	5	5	3	6

* Blank spaces indicate that scores were above the norms for the test.

APPENDIX 6A - ADDITIONAL DATA FROM STUDY 4

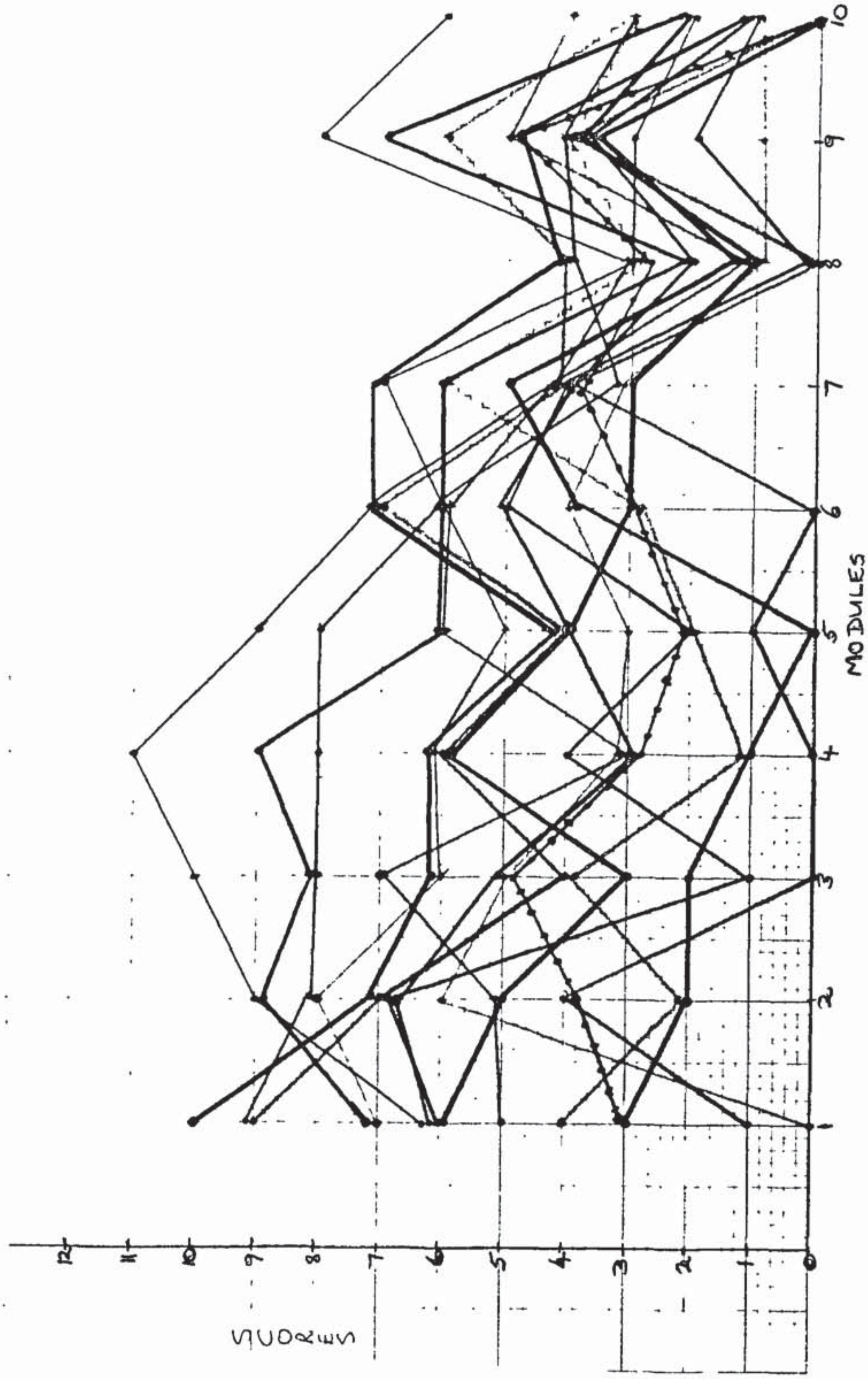
SCHOOL A. — INDIVIDUAL PROFILES — MATHS MODULES



APPENDIX 6B - ADDITIONAL DATA FROM STUDY 4.

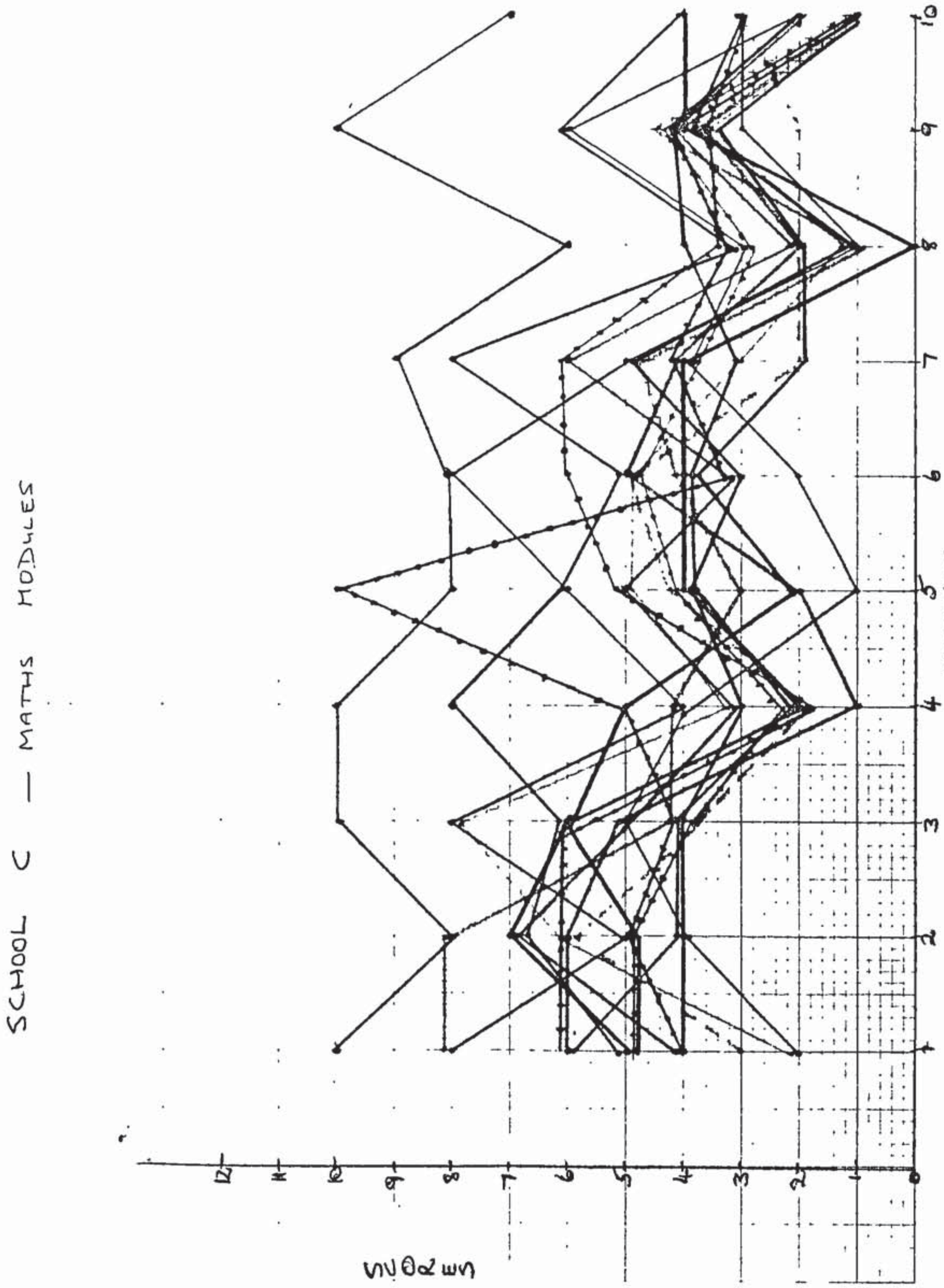
SCHOOL B. — INDIVIDUAL PROFILES — MATHS MODULES

SCHOOL B — MATHS MODULES



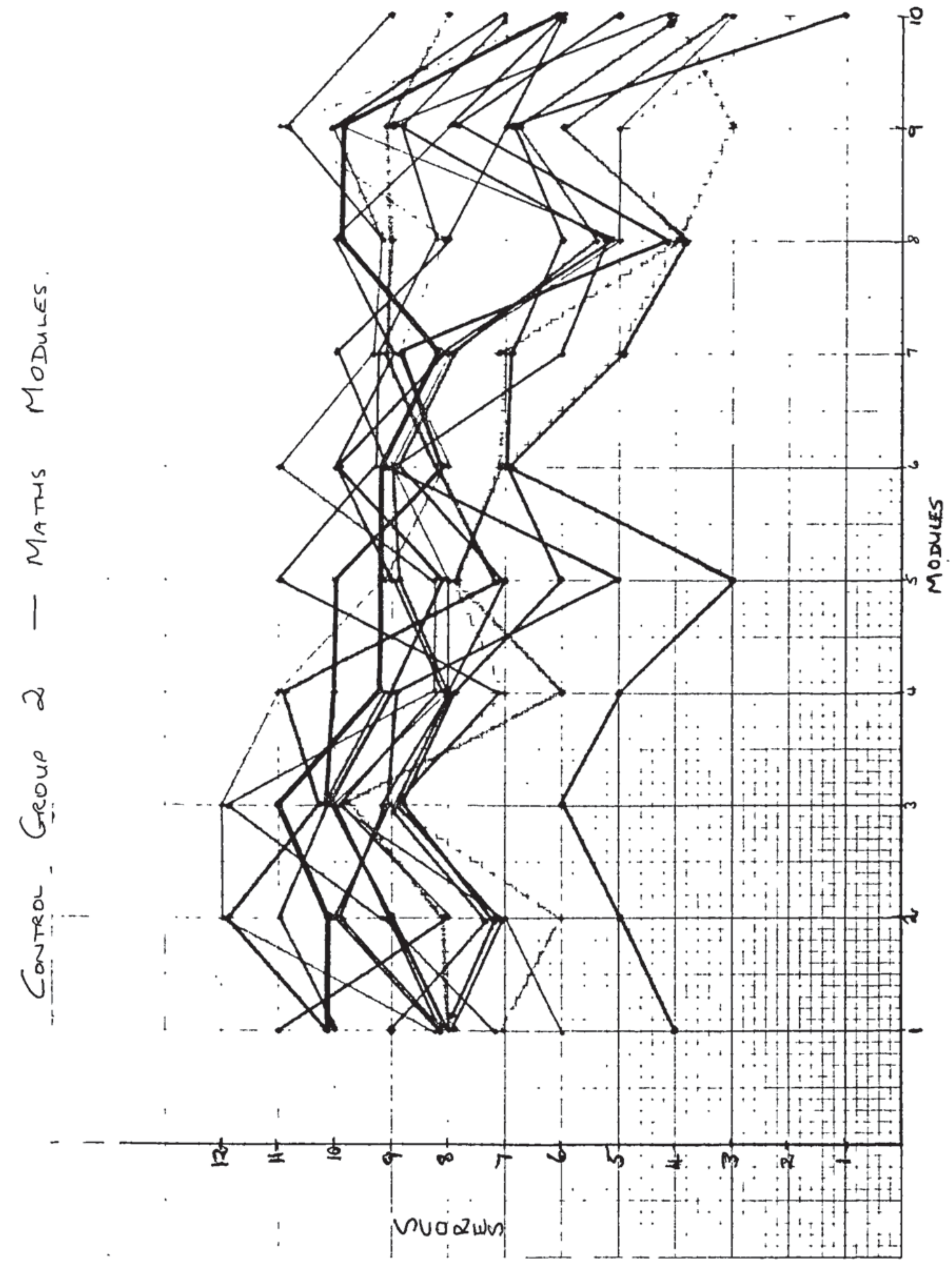
APPENDIX 6C - ADDITIONAL DATA FROM STUDY 4

SCHOOL C — INDIVIDUAL PROFILES — MATHS MODULES



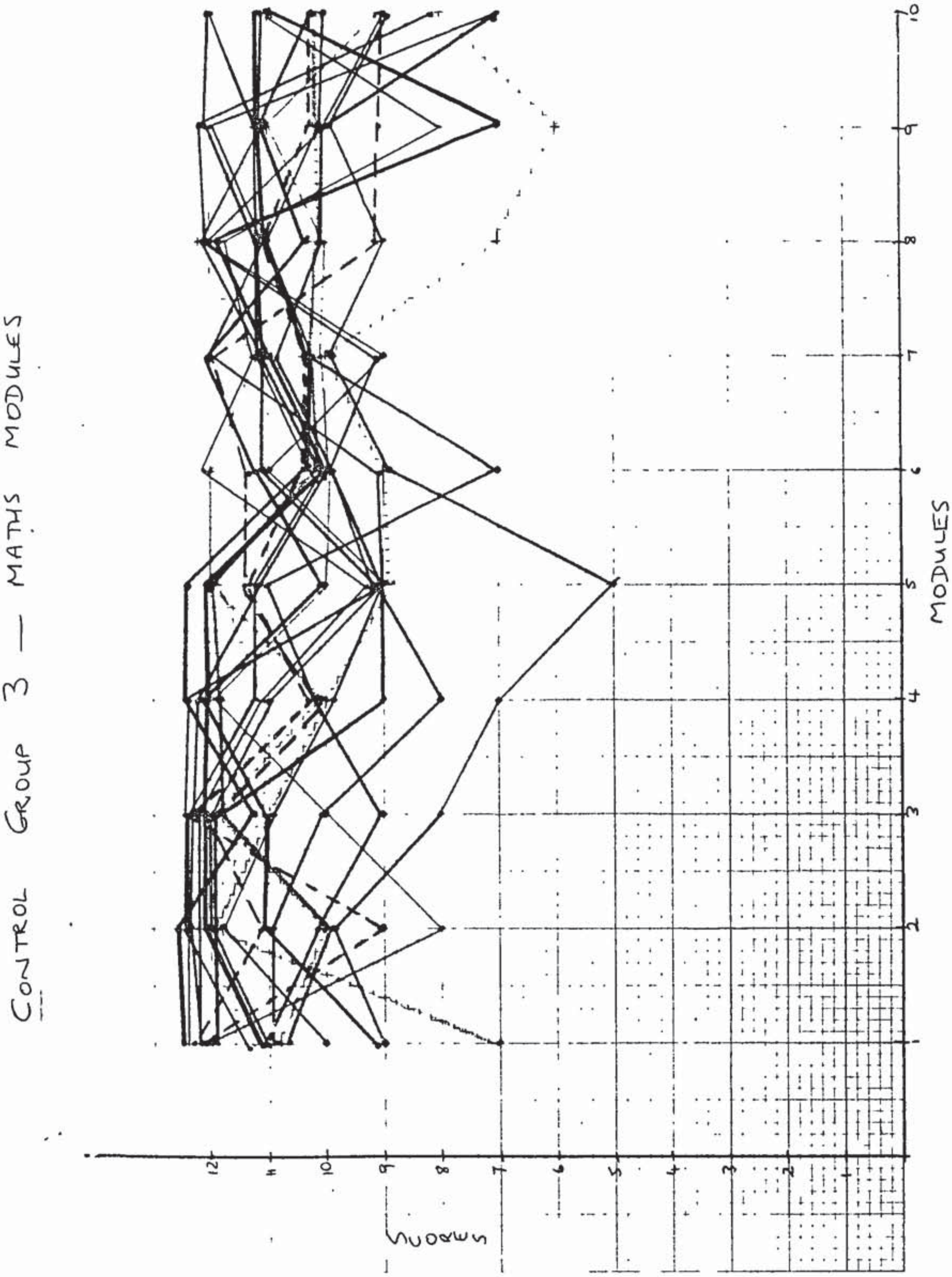
APPENDIX 6D - ADDITIONAL DATA FROM STUDY 4

CONTROL GROUP 2. — INDIVIDUAL PROFILES — MATHS MODULES



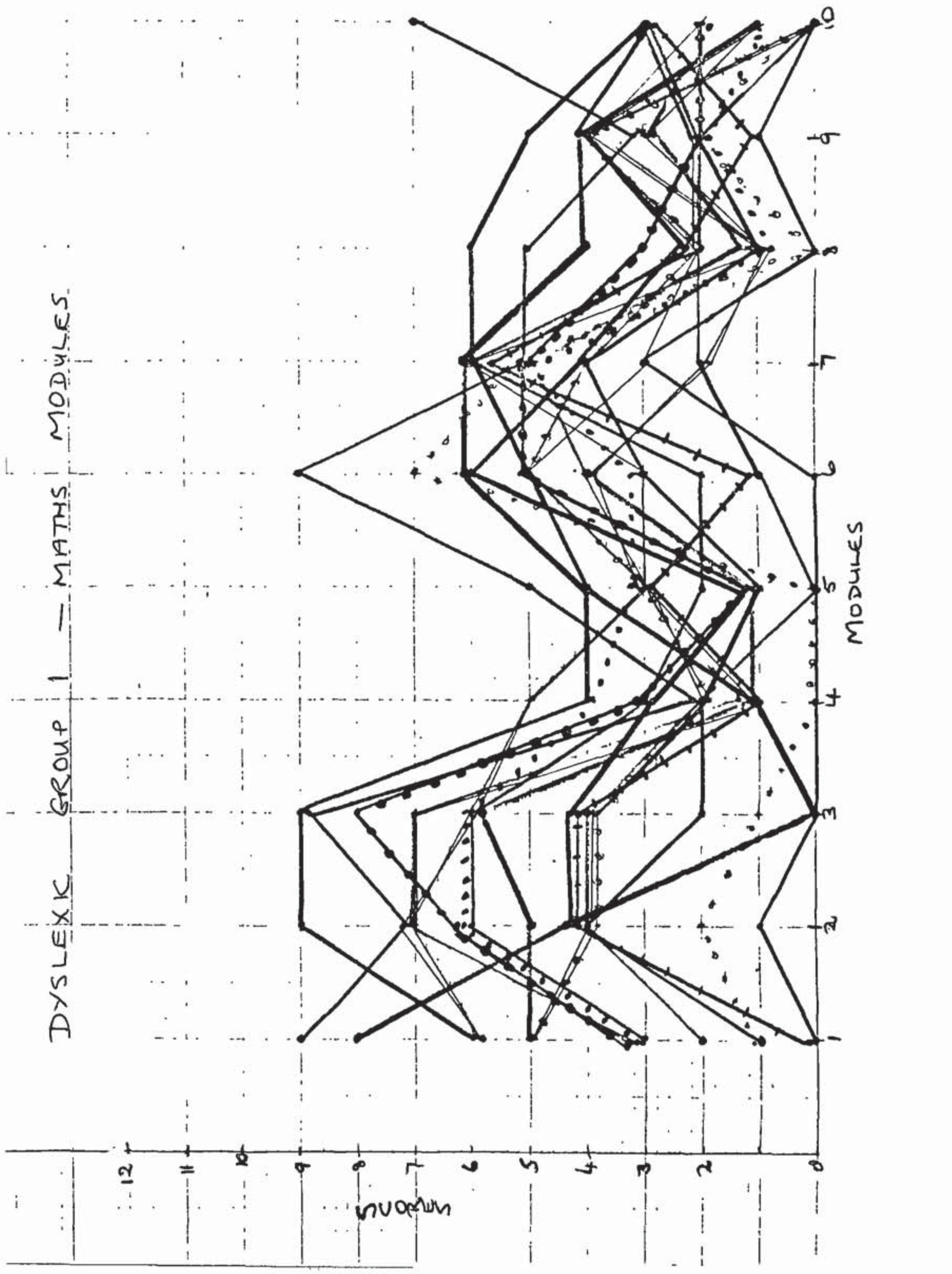
APPENDIX 6E - ADDITIONAL DATA FROM STUDY 4.

CONTROL GROUP 3. ~ INDIVIDUAL PROFILES - MATHS MODULES



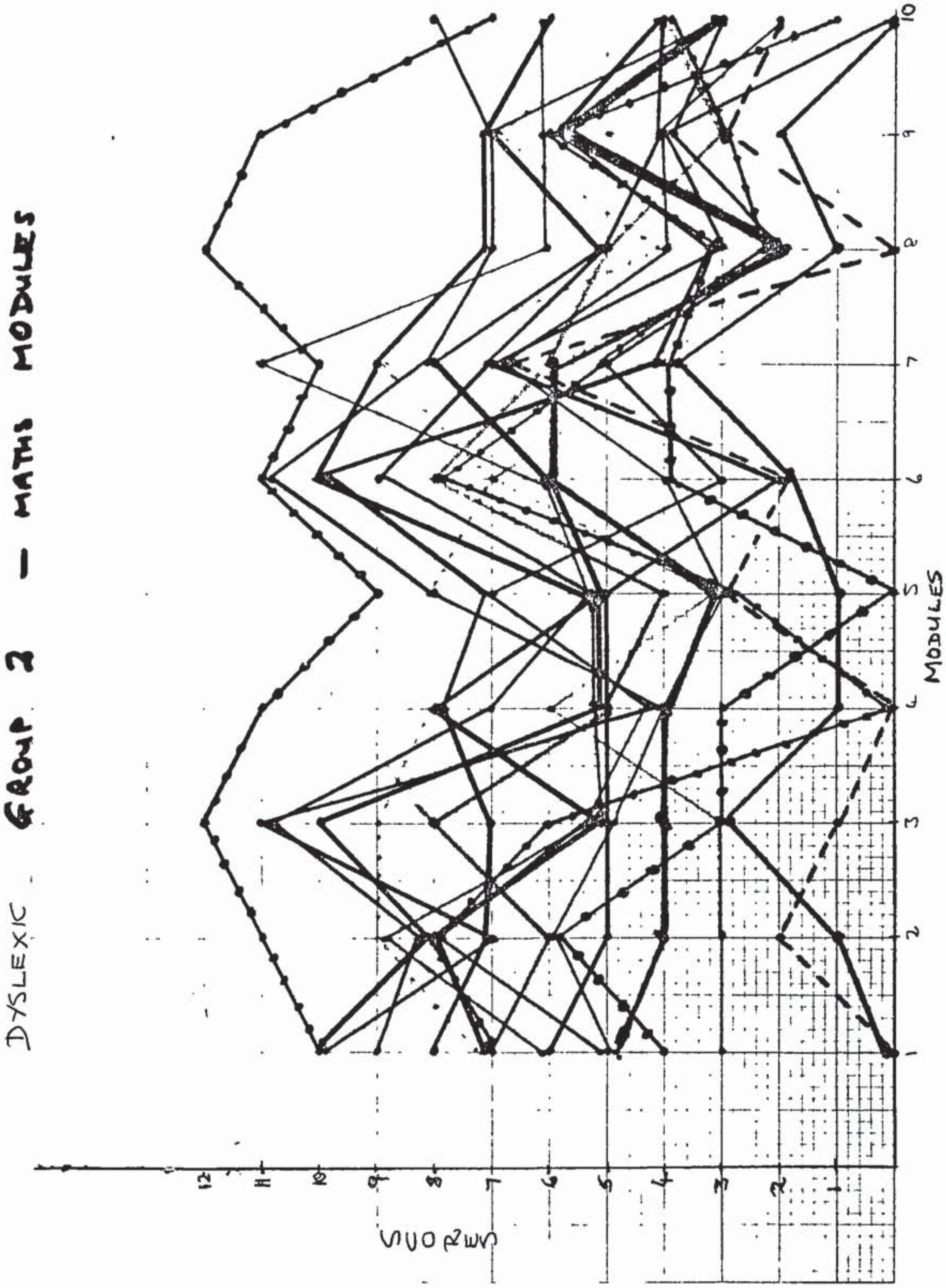
APPENDIX 6F - ADDITIONAL DATA FROM STUDY 4

DYSLEXIC GROUP 1 — INDIVIDUAL PROFILES — MATHS MODULES



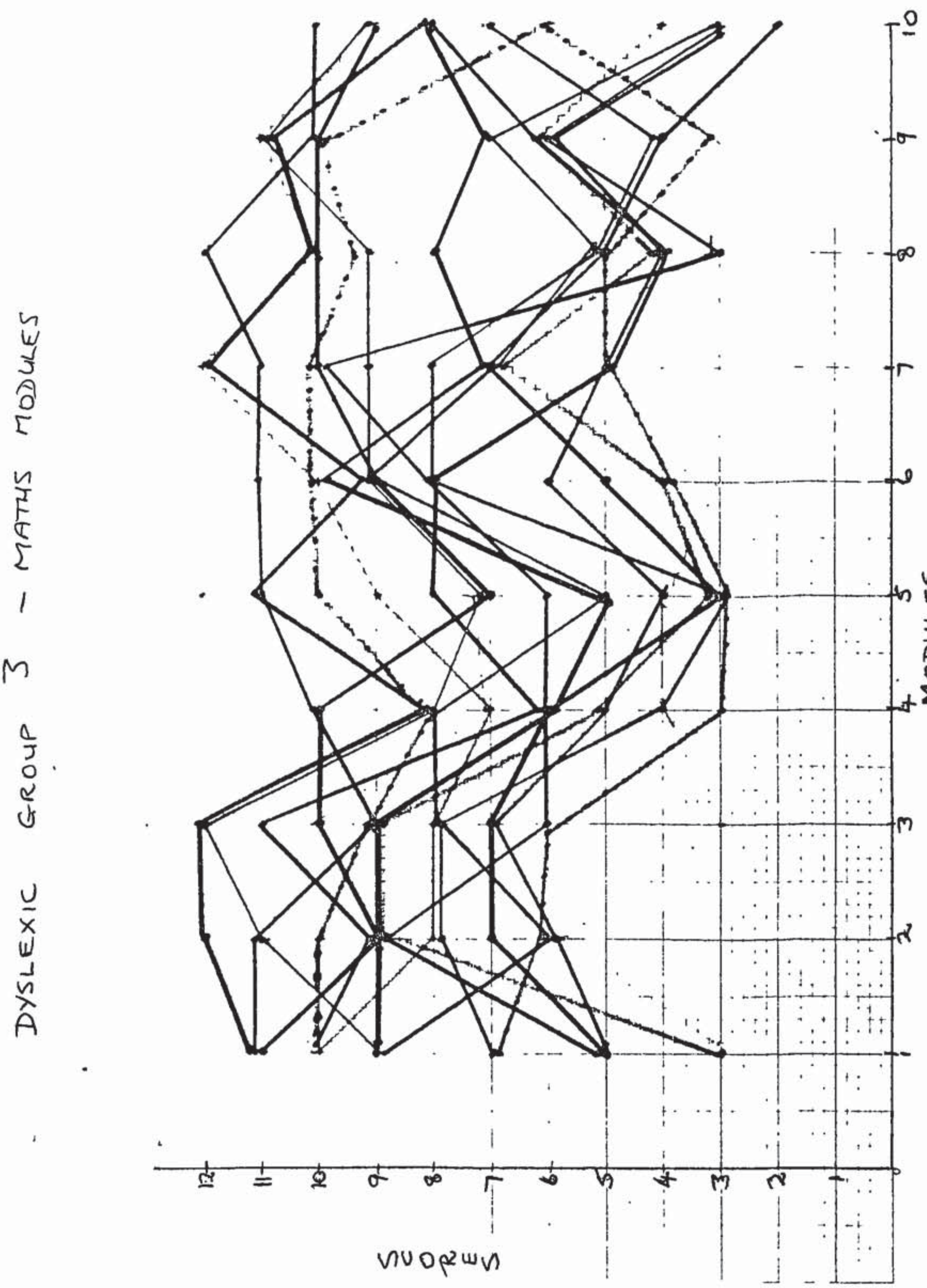
APPENDIX 6G - ADDITIONAL DATA FROM STUDY GROUP 4

DYSLEXIC GROUP 2. — INDIVIDUAL PROFILES - MATHS MODULES



APPENDIX 6H - ADDITIONAL DATA FROM STUDY 4.

DYSLEXIC GROUP 3. — INDIVIDUAL PROFILES — MATHS MODULES



APPENDIX 7

SPELLINGS TAKEN FROM MODULE 7

A.

GROUP 1

CIRCLE	TRIANGLE	SQUARE	OBLONG RECTANGLE	CUBE	CYLINDER or TUBE	CONE	PYRAMID
cicel	triangel	saugurel	regtag	cqub	tub	com	piramid
sculen	tring	surees	retagl		cilinda	con	primant
surcul	triangul	square	rectancgul				pirm
sucull	taragull	squr	obllong				birumid
sullcull	tarangull	scw	oblond				pirumid
circul	trinagal	squar	oblog				peamid
sokl	trin	sare	rectangul				
sik	traingl	squer	rectangool				
suril	triyangul	saw	ogblong				
scucool	triangoll	si	odlong				
cirklel	trangle	scuer					
		sguer					
		squre					
		sgres					

GROUP 2

CIRCLE	TRIANGLE	SQUARE	OBLONG RECTANGLE	CUBE	CYLINDER or TUBE	CONE	PYRAMID
circule	traingle	squore	obulong	qub	chide	kon	piramd
sikl	triacl	saar	oplon	cude	cilinder	coon	pyramide
circl	tringal	scwer	odlong	cub	cilender	cnan	peromed
circel	triancla	saqu	oblonge		silender	con	piramid
surcer	triangel	sqar	retangel				primid
curecl	trangun	sqear	reptangl				
curcel	tring	squer	retangle				
criale	triange	squree	drag				
serkel	triangl	sqwee					
sucl	trangl	squre					
cylel	triagel	squere					
curcl	trainge	sqare					
cercul	trit	sqair					
sucr		sarir					

APPENDIX 7 cont'd.

A.cont'd.

GROUP 3

CIRCLE	TRIANGLE	SQUARE	OBLONG RECTANGLE	CUBE	CYLINDER or TUBE	CONE	PYRAMID
circul cicule cicel cerhell sircle cirle	trinagle tringel trigall trinangle	squeure squar squre	retangle obong oblonge rectangln	qub cudl kueb	tub cilinder cilnder cilendar cinder cylindar cilinde	coan	primide pyrmid pyrimid peramid pinmrid prymid piramid piromid pirimid

B.

	NORTH	SOUTH	EAST	WEST
GROUP 1		Soulf	Eeast Eest Esd Est	Wesd
GROUP 2	Nourth		Eest	Wet
GROUP 3		Soth		Weth

R E F E R E N C E S

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(see also addenda - pg. 380 ⇒)

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