# MOTOR SKILL ACQUISITION IN CHILDREN WITH LEARNING DIFFICULTIES AND THEIR CHRONOLOGICAL AND MENTAL AGE COUNTERPARTS

by

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ABSTRACT

The physical abilities and motor performance of children with learning difficulties and children of the same chronological age and mental age is reviewed, together with information relating to their learning of motor skills. It is noted that although children with learning difficulties perform at a level lower than that of their peers, this is not consistently the case, and it is hypothesised that the anomalies may be at least partly due to the different types of tasks employed. On the basis of this, a task classification scheme is proposed, based on the mobility or otherwise of the environment, the whole body and the body parts, and five tasks are selected as representative of categories within one scheme. For each task, a group of children with learning difficulties is matched with two groups, on chronological and mental age, and all three groups given practice at the task; the experimental design used differs according to the task.

On two of the tasks, in which the environment is stationary, the whole body is stationary and only body parts are moving, the group with learning difficulties performs at a level equal to that of their chronological age matched peers, and above the group matched on mental age. On the two tasks in which the environment is moving, the whole body is stationary, but body parts are moving, the group with learning difficulties performs at a level below that of the chronological age matched group, equal to that of the group matched on mental age, and on occasions below it. On the fifth task, in which the environment and whole body are moving, and the body parts stationary, the group with learning difficulties performs consistently at a level lower than that of either the chronological or mental age matched groups.

It is concluded that whilst there may be tasks which children with learning difficulties experience problems in learning, there are other tasks with which they are able to cope well, these tasks being distinguishable at least on the basis of the temporal demands imposed by the environment and the degree of bodily involvement.

Furthermore, on the tasks in which the children with learning difficulties,as a group, perform behind their chronological and mental age matched counterparts, there are certain individuals within the group who are able to perform at a level such that they would be indistinguishable from their chronological age matched peers.

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# INTRODUCTION

Human abilities are many and varied; in all walks of life people vary in their ability to execute tasks. In areas as broad as sport, management, art, science and linguistics, and more specifically within these fields, a great discrepancy is apparent between levels of achievement. Within a particular sport for instance, individuals differ in their ability to perform certain skills. In the game of tennis for example, players differ in their style of play, their ability to execute the various strokes, and their ability to anticipate the movements of the opponent. However, these various factors come together to create one measure, the ability of the person, in this instance, to beat the opponent. In this way, we assess individuals' abilities in many different fields. One aspect of ability which has perhaps attracted the greatest amount of attention is that of cognitive ability. In past years, measures of cognitive ability or intelligence have been the basis, at least in England, of allocation to type of school. In taking a measure of cognitive ability such as an Intelligence Quotient (IQ) and using it in this way, there lies the assumption that this measure is indicative of the total ability of the person concerned. The approach is organismic in its nature, in that all abilities or aspects of the person are seen to develop in the same way and at the same rate; that physical, motor and cognitive abilities for instance, go hand in hand; the more advanced the cognitive factor, the more advanced is the motor element; conversely, the more retarded is the cognitive development, the more retarded will be the motor development. The question that arises, however, is how strong are these relationships, if they exist at all, and whether or not they are tenable in all instances.

Correlations between IQ and motor abilities have generally been found to be low. Singer and Brunk (1967), using elementary school children, found high correlations between all intellectual factors of the Pinter Elementary Test and Stamford Achievement Test, but low correlations between these and achievement on a perceptual - motor figure - ground reproduction test. The highest correlation of .29, although significant, only accounted for .08 of the variance. Other researchers have found similar correlations between IQ and motor tasks (e.g. Dingman and Silverstein, 1964). Some research has suggested that, although within the normal population low correlations exist, at the extremes of the population, and the area most studied is the lower end in terms of achievement, the strength of the relationship between the two increases markedly. Comparisons between children of low IQ (50-75) with children of normal IQ have been made, using a variety of tasks ranging from highly physical tasks, such as grip strength, to more cognitive reaction time and discrimination tests. In many cases there is support for a relationship between IQ and motor performance, with the mentally retarded performing at a lower level (e.g. Berk, 1957; Ellis and Sloan 1957, Frances and Rarick 1959, Rarick, Dobbins and Broadhead, 1976). However, in studies where a battery of tests have been used, the superiority of the "normal" population is not 100%. It appears that in certain isolated instances, the retarded can perform on a level equivalent to the normal intelligence group (Rarick, Dobbins & Broadhead, 1976). There would, therefore, appear to be somewhat of a paradox; whilst for children within the range of normal intelligence, there appear to be low correlations between intellectual and motor abilities, for children with an IQ at the lower end of the scale and as such, classified as mentally retarded, there appears to be general support for the idea that they perform at a lower level in motor tasks.

One of the problems in collating research and making generalisations in this way about motor performance of both normal and retarded persons is that the research has employed widely differing populations, ranging from young children to adults, intellectually gifted to severely mentally handicapped and physically normal to physically handicapped. To generalise from one population to another could be inherently wrong and for this reason it is necessary to standardise the population tested, and make statements referring to that population only. In order to overcome this problem, this dissertation is concerned with the population of children known as 'children with learning difficulties'. These children, when the research commenced, were classified as "educationally subnormal (Moderate)" or ESN(M), in England, having an IQ between 50 and 75. The term used in the United States of America is "educable mentally retarded" or EMR, with the IQ lying betwen 50 and 70. Recent legislation has abolished the use of these terms and children with an IQ of roughly 50 to 75 are now known as children with learning difficulties. At the time of testing, all children were being educated in special schools, and whilst there does exist some transfer between these schools and the normal state system, the population within the schools used remained fairly constant. All children had been assessed as in need of a specialised form of education, part of this assessment being a measure of intelligence.

A second problem in examining the research in this area is that any discrepancy in results could be due to certain procedural variables. No single means of measuring has been used, and the number and type of tasks used in comparing normal with retarded populations have varied greatly. It may be that abilities are very task specific. Singer (1968) lends support to this idea; he postulated that interrelationships between physical, perceptual-motor and academic achievement would be higher in younger age groups (3rd grade as opposed to 6th grade) and that tasks requiring perceptual and intellectual skills (such as a choice reaction time task) would correlate more highly with academic achievement than simple motor tasks such as stabilometer balancing tasks. However, on the basis of a battery of tests, he was forced to conclude that abilities are relatively task specific, even at 3rd grade level and that factors in the cognitive domain are only slightly related to factors in the physical and the motor domains. It may be, therefore, that discrepancies in the research findings can be attributed to the differing nature of the tasks used; that superior motor performance on one task does not necessarily indicate superiority in all motor tasks. Tasks differ widely in their demands on the individual, and in view of this fact, this dissertation has employed a task classification scheme which reflects the diverse nature of tasks. This will be detailed at a later stage. In brief, tasks were selected which were representative of a certain task classification.

A third discrepancy that exists between research is the way in which comparisons have been made between retarded and normal populations. Some research (e.g., Berk, 1957; Widdop, 1967) has matched the retarded group with a normal group of equivalent chronological age, whereas other research (eg., Ellis & Sloan, 1957; Baumeister, 1966) has employed a mental age matched group. In order to overcome this anomaly, this research has employed both chronological and mental age matched groups in all studies.

Using a task classification scheme to categorise tasks and testing children with learning difficulties and normal children of both mental and chronological age match, this dissertation proposes to examine any differences in learning and performance that lie between the groups over a series of tasks differing in their demands on the individual. Until the task demands and the resources of the individual are considered it is difficult to make any meaningful statements about motor learning and performance both in children with learning difficulties, and in children of normal intelligence.

# CHAPTER ONE

Interest in children with learning difficulties has provoked research into various aspects of their development and performance, amongst them language, social, physical and perceptual-motor performance. Children are described as having learning difficulties if in some way they fail to match up to the level achieved by their peers, particularly in terms of academic achievement. However, academic achievement is only one element of their development. Researchers have also considered the question of whether such children differ from their peers of normal intelligence in terms of physical development, and performance on physical and motor tasks. The research into these questions can be broadly divided into two major classes, which are characterised by a different approach to the question and an attempt to answer different questions. Both classes can be subdivided into smaller areas of concern.

## I PHYSICAL AND PERFORMANCE MEASURES

In this area of research, the focus has been on the physical characteristics of children with learning difficulties, their level of performance on a particular test or a battery of tests, and the way in which this might differ from that of children of normal intelligence. Some of the research covers all these issues, but in general, three main areas of concern can be identified.

### (i) Anthropometric Measures

The concern here is with the physical development and maturity of the children under study. Measures used include height, weight and skinfold thickness.

(ii) Performance on tests of physical ability

This includes measures such as grip and leg strength, knee flexion and spinal extension. The experimental work is often conducted alongside the anthropometric measures.

(iii) Performance on tests of fine and gross motor skill

Researchers have taken performance on equipment such as the stabilometer and the Minnesota Rate of Manipulation Board as an indicative of fine and gross motor skill, and used them to assess the level of performance of children with learning difficulties.

## II CONSIDERATION OF THE PROCESSES INVOLVED IN PERFORMING A MOTOR SKILL

In the light of research into motor performance by children and adults of normal intelligence, researchers have investigated motor performance by children with learning difficulties in terms of the underlying process involved, and the way in which these may or may not differ from those of children of normal intelligence. This includes research into areas such as attention, reaction time and memory. The question under consideration is how performance is brought about, and attention to this question has given rise to an information processing approach to motor skill performance. This approach enables the researcher to analyse the processes involved between the onset of a stimulus and a response to that stimulus. Models of performance have been proposed which highlight the processes thought to be involved in motor skill performance, such as those of Whiting (1969) and Welford (1968). These models propose that information is taken from the environment via the senses; on the basis of this information, some decision is made about what to do, and the response is then initiated. This entire process involved several smaller processes, aspects of which can be considered in isolation.

(i) Attention

The performer needs to attend to the environment in order to take in the appropriate information.

(ii) Decision-making

The question here is how quickly the performer can initiate a response to the situation.

(iii) Effector Efficiency

The speed of a movement is the point at issue here.

(iv) Memory

The question here is how movement information is stored and recalled.

### (v) Feedback

Feedback refers to information which arises out of the response and enables the performer to evaluate the success of that response, and make any alterations either to the present or the future responses, where possible.

Whilst these processes do not operate in isolation, it is possible to focus on the various processes independently in order to gain some insight into the role that they play in performance. The information processing approach provided the framework within which this is possible.

The distinction made here between the various areas of concern is similar to that made by other researchers, such as Schmidt (1982). It provides a framework of reference which the research done can be collated, although evidently some research covers more than one area. Each of these areas will be considered in turn.

## I PHYSICAL AND PERFORMANCE MEASURES

### (i) Anthropometric Measures

Much of the earlier interest in children with learning difficulties of all kinds focussed on the question of physical differences between such children and persons of normal intelligence, and between boys and girls within these populations. The research is largely of a descriptive nature and in many cases derived from extensive surveys of children classified as educationaly subnormal (ESN), educable mentally retarded (EMR) or having learning difficulties, and using a large battery of measures. Early work done by Judelsohn (1924) found mentally backward boys to be shorter and lighter than normal boys, aged 9-12 years, and about the same for those aged 13 and 15 years. Rarick and Dobbins (1972) took almost 50 measures from normal boys and those with learning difficulties. This included measures of body size, skinfold thickness and flexibility, such as height, weight, bi-acromial and bi-iliac width, abdominal, subscapular and triceps skinfolds, and spinal extension and rotation. Overall, the children with learning difficulties tended to be smaller, fatter, and less flexible than children of the same age, but of normal intelligence. Rarick and McQuillan (1977) compared trainable mentally retarded children (TMR) with EMR children and found the TMR to be smaller and fatter than the EMR. Consideration of anthropometric measures of children with learning difficulties versus normal children formed part of a study by Rarick, Dobbins and Broadhead (1976), which also compared boys and girls. They found no significant sex differences on four measures of body size (height, weight, bi-acromial and bi-iliac width), but in terms of comparisons between normal and those children with learning difficulties, the height of the normal children was significantly greater than that of those with learning difficulties. No weight differences between the groups led Rarick, Dobbins and Broadhead (1976) to conclude that the children with learning difficulties were relatively heavy. Furthermore, the skinfold thickness of these children was significantly greater than the normal children, again an indication of the overweight of the children with learning difficulties. In terms of flexibility, the normal children were found to be significantly superior on all tests relating to the ability (spinal rotation and extension, lateral spinal extension and toe touch). Measures from the two age groups (with a mean of 8 years 4.1m and 11 years 5.6m) revealed no age differences for the measures of flexibility, although the boys evidenced greater flexibility than the girls at both ages. Skinfold measures were greater in the older children and greater for the girls than the boys. Rarick, Dobbins and Broadhead (1976) comment on one further interesting point, the variability within the EMR group studied. In general the children with learning difficulties were much more variable as a group than the normal children. Using a coefficient of variation to compare the groups they found the group with learning difficulties exhibited 50% greater variability than normal children of the same age. This variability factor is common not only in anthropometric measures but can be seen throughout the whole range of measures of physical and motor performance.

(ii) <u>Performance on tests of physical ability</u>

Research in this area falls into two areas; research which employs one test or a battery of tests of various physical capabilities and measures the performance of children with learning difficulties often in comparison with normal children, and secondly, research concerned with the extent to which performance on tests of physical ability can be improved by training or practice. This area has received less attention.

(a) Measures of performance on physical tests

Early work by Francis and Rarick (1959) employed a battery of tests designed to measure static strength, running speed, dynamic strength, balance and agility in children with learning difficulties, in order to determine any age and sex trends in these gross motor abilities. Their findings revealed age trends in strength for each sex that followed approximately the same pattern as those for normal children, although the absolute level of performance was lower. On measures of power, the age and sex differences of the children with learning difficulties were similar to those of children of normal intelligence, although for one of the tests, the standing broad jump, the improvement with age did not follow the steady developmental pattern of the normal children, whose gains were made with each chronological year. Performance by retardates on tests of running speed, agility and balance were found to follow the same developmental pattern as those of normal children, but again at a significantly lower level when compared with normative data available for children of average intelligence. On the majority of measures, the children with learning difficulties were 2-4 years behind the published normative data, and furthermore, the deficit increased with age. Correlations between measures of performance on the various tests used tended to suggest that the interrelationships between the gross motor functions are structurally similar in children with learning difficulties and children of normal intelligence.

Subsequent work by Rarick (1968), using factor analysis on this data, pointed to three factors common to both sexes at each of three age levels - explosive muscular force, static strength, and a coordination factor. These factors have also emerged in studies of persons of normal intelligence, which would support the idea of structural similarity of motor components between the two groups. Fait and Kupferer (1956) found that on a simple motor task (vertical jump) children with learning difficulties performed equally well as normal children. On a more complex, burpee task, however, the children of normal intelligence were considerably superior. Judelsohn (1924) found 'mentally backward' boys to fall 2-3 years and girls 2-7 years behind their peers on track and field events. Rarick and Dobbins (1972), as part of their test battery, took various measures of strength and muscular endurance, such as grip strength and performance on a bicycle ergometer. They found that in almost all cases, the children with learning difficulties operated at a lower level than the normal children and girls less efficiently than boys. When compared with TMR children, Rarick and McQuillan (1977) found the higher IQ children to be superior overall.

The American Association for Health, Physical Education and Recreation (AAHPER) Youth Fitness Test, or a selection or subtests from it, has been used extensively to measure the fitness of both children of normal intelligence and those with learning difficulties. Research by Widdop (1967), using an adaptation of the original AAHPER Youth Fitness Test serves to support the findings of Francis and Rarick (1959) and Rarick and Dobbins (1972). Using seven tests comprising a 300 yard run/walk, 50 yard dash, standing broad jump, shuttle run, situps, flexed arm hang and soft ball throw, he found at all ages boys and girls with learning difficulties significantly retarded in terms of mean performance on almost all subtests when compared with children of normal intelligence, the deficit being in the order of 2 to 4 years. Again, the age and sex trends are comparable to those of children with normal intelligence. The findings also revealed a positive relationship between intelligence and performance, the only anomalies being in the 50 yard dash, where 15 year old boys with learning difficulties performed significantly better than boys of normal intelligence of the same chronological age, and the softball throw, where 18 year old girls with learning difficulties were more successful than their chronological age matched counterparts.

Rarick, Widdop & Broadhead (1970) used the AAHPER Youth Fitness Test, again with slight modifications, to test children with learning difficulties aged 8 to 18 years. In all cases, where normative data was available for children of average intelligence of the same age, the retardates performed at a lower level than the given norms. The characteristic change by age found in normal children was in many cases duplicated by those with learning difficulties. The research supported previous findings that there existed low but positive relationships between measures of physical ability and intelligence. Similar work by Brace (1961) cited by Campbell (1973), again using the AAHPER Youth Fitness Test, confirmed that boys with learning difficulties scored below the national norms at each age level, with 80% of all scores falling below the median.

Rarick, Dobbins and Broadhead (1976) used items from the AAHPER Youth and Fitness Test as part of their battery of tests with two age groups of children with learning difficulties approximately 8 and 11 years of age, and one group of children of normal intelligence approximately 8 years of age. Again, the children with learning difficulties performed at a lower level when matched on chronological age with children of normal intelligence, but evidence of an improvement with age by the children with learning difficulties was found. Overall, the relationship between intelligence as measured (IQ) and motor performance was low but positive. There was one anomaly in the results in that in terms of explosive muscular force, the children with learning difficulties, although poorer than the children of normal intelligence were not as poor to the extent that they were on tests requiring a degree of perseverance. Rarick, Dobbins and Broadhead (1976) make the point that

> It would seem that EMR children either do not have the muscular endurance of normal children or they are not as willing as normal children to accept the discomfort that accompanies tasks of this kind. This, of course, raises the question of validity. Do such tests assess the retarded child's muscular endurance, his attention span or his willingness to endure physical discomfort.
>
> (page 112)

It would appear from the research cited that children with learning difficulties do perform at a lower level on almost all tests of physical performance. In the light of the differences in the anthropometric measures already discussed between such children and those of normal intelligence, Dobbins, Garron and Rarick (1981) questioned whether the poorer performance on physical tasks was in fact due to a deficit in intelligence or rather to the differences in body size. Using a battery of anthropometric tests and twelve tests of motor performance, including grip strength, knee flexion, sit-ups and 150 yard dash, they controlled for the differences in body size between normal and regarded boys. The results demonstrated that whereas without adjustment the normal boys were superior in all twelve tests, with adjustment, no difference between the groups was found for five of the twelve tests. Furthermore, in relating motor performance differences to differences in intelligence, they point out that whereas the mean IQ of the children with learning difficulties fell 2.27 standard deviations (SD) below the mean of the normal boys, in no case did their performance on the physical tests fall more than 2SD below the mean of the normal boys. This would indicate that the relative IQ deficiency of the boys with learning difficulties is greater than their motor deficit.

Dawson & Edwards (1965), on the same principle, tested grip and leg strength, controlling for physical development. They found significant differences for grip strength between children of low (IQ 50-84) and high (IQ 85-149) intelligence when matched on chronological age only. However, after matching for height and weight, these differences were no longer apparent. It may be that poor physical and motor performance is not attributable to a deficit in intelligence only.

(b) Improvement of Physical Performance

If one accepts that there is a difference between normal children and children with learning difficulties on tests of physical performance, the question then arises as to whether it is possible to improve the physical fitness of those evidencing poor performances. Rarick (1980) suggests that the disparity in performance between such children and those of normal intelligence, which is known to increase with age, may be due largely to the limited learning capabilities of children with learning difficulties. He cites work by Kirby (1969) which found that retarded children made significantly less progress in learning a stabilometer task than normal children and younger retardates less progress than those aged 13-14 years. Certainly, in an experimental situation, and within the school, many of the problems for the child with learning difficulties would appear to lie in a lack of appreciation of the requirements of the task and its demands on the individual.

Research has demonstrated, however, that if the demands are largely physical rather than cognitive, gains in performance can be made through practice or training on the part of children with learning difficulties. Solomon and Pangle (1967) noted significant improvement in performance on selected items of the AAHPER Youth Fitness Test (chins, situps and 50 yard dash) following an eight week training programme of 45 minutes per day of planned and progressive physical educational activities. Furthermore, the improvement was maintained over the six weeks following the termination of the programme. The improvement was such that the children with learning difficulties performed as well as normal subjects on the chins and 50 yard dash, and superior to them on the situps and overall achievement. Campbell (1973) cites work by Giles (1968) which supports this view. A structured programme of physical education (in this case, softball, dodgeball, relays, tumbling and calisthenics) resulted in improvements in performance on the AAHPER Youth Fitness Test, the most significant gains being made in situps, softball throw and 600 yard run/walk. Burwitz, Harrison, Davies, Daggett and Montgomery (1977) conducted similar research, which supports the hypothesis that the physical fitness of children with learning difficulties can be improved with practice.

Horvat (1982), working with children aged 7-9 years, classified as learning disabled, found that a 12 week home learning programme involving exercises and practice at tasks of static and dynamic balance resulted in better static and dynamic balance performance. Similar improvement by children with an IQ of 48-79 as a result of a training programme on tests of basic skills was found by Ross (1969).

(iii) <u>Performance on tests of fine and gross motor skill</u>

Research into the performance of children with learning difficulties on tasks involving fine and gross motor skill can be drawn from three areas; firstly, that which forms part of a battery of tests including anthropometric measures and measures of physical performance; secondly, research employing established test batteries, primarily the Oseretsky Motor Development Scale, to give, in many cases, an indication of overall ability on fine and gross motor tasks; and thirdly, research concerned with performance by such children on specific motor tasks, such as the stabilometer.

(a) <u>Motor Skill performance as part of a battery of tests</u>

Rarick, Dobbins and Broadhead (1976) included in their battery of tests, tests of fine visual-motor coordination and balance. With regard to fine visual-motor coordination, measured by performances on tasks such as ring stacking, Minnesota manipulation, and golfball placement, the performance deficit of the EMR was slightly greater than on the gross motor tasks, particularly on the tasks requiring manipulative skills. Improvement with age was evident, however.

Tests of balance, such as stabilometer balancing and railwalk tests revealed significant differences berween children with learning difficulties and those of normal intelligence, the children with learning difficulties again proving less competent. Changes with age were again in line with normative data available for children of normal intelligence, although at a lower level; improvement was apparent with increasing age, although the differences were not as dramatic as for the fine visual motor coordination factor. There were virtually no sex differences, the only exception being stabilometer balancing, in which the girls were superior to the boys, and backwards and sideways railwalk, in which this trend was reversed. Rarick and Dobbins (1972) found similar changes by age on tests of fine and gross motor skill.

Earlier research into the motor proficiency of children with learning difficulties includes that of Howe (1959), who incorporated into his battery of tests, ball throwing for accuracy, tapping tracing and dotting speed, and paper and pencil tracing. The children with learning difficulties were matched with children of normal intelligence on the basis of sex and age. The normal boys were significantly better than the boys with learning difficulties on all tests, the same pattern being reflected by the girls, with the exception of ball throwing, for which no differences were found. Distefano, Ellis and Sloan (1958) included the Minnesota Rate of Manipulation Test within their battery of tests and found the placing and turning subtests to correlate more highly with mental rather than chronological age. Kulcinski (1945) compared the ability of superior, normal and subnormal children to learn 22 fundamental skills of a stunt or tumbling nature, and found the children with learning difficulties to perform significantly below the other two groups.

Liemohn and Knapczyk (1974) attempted to analyse factorially the structure of fine and gross motor skills, using a battery of tests derived from various sources, including Cratty's Six Category Gross Motor Test, a selection of tests from the Lincoln-Oseretsky Motor Developmental Scale, the standing broad jump, and hopping tests taken from Ismail and Gruber (1967). They identified eight factor areas - upper extremity coordination, gross motor functioning, praxis, dynamic balance, general muscular coordination, rhythmic ability, maturation and sex. No attempt was made to generalise this to a population of normal intelligence, although work with normal subjects has evidenced similar factors (e.g. Fleishman 1964).

(b) The Oseretsky Motor Development Scale

The Oseretsky Motor Development Scale has been widely used to assess the level of performance of both normal and children with learning difficulties aged 6-14 years. It was originally developed in Russia in 1931 by Oseretsky, and was used extensively in Europe in the 1930s and 1940s before being translated into English (Doll 1946). The original scale comprised 85 items, but since then several adjustments have been made; Sloan (1955) conducted one revision, providing separate norms for boys and girls, known as the Lincoln-Oseretsky Scale. The Vineland-Oseretsky (Cassel 1949) and the Berk-Oseretsky (Berk 1957) scales are also adaptations. Apart from these overall revisions, individual researchers have also extracted items or adapted the scale for their own use. Sloan (1951) used the Oseretsky scale to compare the performance of children with an IQ of 49-70 with the normative data available for children of normal intelligence. The results indicated a positive relationship between motor proficiency and intelligence, the poorest performance by those of lower intelligence being on tests involving simultaneous movements. Other early work using the Lincoln-Oseretsky scale includes that of Turnquist and Marzolf (1954), who compared two groups of 13 year olds, with a mean IQ of 69 and 102. The superiority of the latter group was not complete, in that they were only significantly better on 20 of the 65 test items, the children with lower IQ being superior on 5 and there being no difference on the remaining 40 items. However, the clear distinction between the groups arises on those items classified as representing synkinesia, simultaneous movement, and balance, on which the higher IQ group performed significantly better. In no category did the lower intelligence group come out as significantly superior overall, in this way. Pyfer and Carson (1972) using the Lincoln-Oseretsky Motor Development Scale with children aged 5 to 13 years who had been referred by school psychologists because of learning disabilities, found poor performance on items of general static coordination. However, it must be noted that the IQ of the group ranged from 85 to 128, so that the children cannot be seen strictly within the category of those with learning difficulties.

Berk (1957) used his adaptation of the Oseretsky scale with three groups of subjects, designated subnormal (IQ of 50-90), normal (IQ of 90-110) and gifted (IQ over 130), to examine the relationship between intelligence and motor performance. He found significant differences between the subnormal and other two groups on all test items except asynkinesia, the intellectually subnormal always performing at a lower level. Further research using the Oseretsky scale includes that of Bruininks and Bruininks (1977), who used their adaptation of the test to assess the motor proficiency of children at least one and a half grades below that expected on the basis of chronological age but with no learning difficulties. Taking the tests to represent eight areas (running speed, balance, bilateral coordination, strength, upper-limb coordination, response speed, visual-motor control, and upper limb speed and dexterity), they found the learning disabled group to perform significantly worse than the non-disabled group in overall motor performance, the deficit being greatest in the areas of balance, simultaneous or sequential bilateral coordination of movements involving arms and legs (pattern making), and visual-motor coordination (drawing designs or tracing images). The children ranged from 6 to 15 years in chronological age and in general the older children performed better than the younger ones.

Lewis, Bell and Anderson (1970) used the Lincoln-Oskeretsky scale in addition to other tests to investigate any correlation between motor performance and poor reading ability. They found the poor readers performed significantly worse on the Oseretsky tests than the reading able group, although they advise caution in the interpretation of the results in view of the wide IQ range. Hollingsworth (1972) used the Lincoln-Oseretsky Test as an indicator of motor performance for children with learning difficulties in comparison with children matched with them on the basis of mental and chronological age. The children with learning difficulties performed significantly better than the group matched on mental age, but considerably worse than those matched on chronological age. In addition, Hollingsworth (1972) found a low but positive correlation between IQ and motor performance for the children with learning difficulties; however, no correlation between the two was evident for the children of normal intelligence.

Research by Rabin (1957) revealed no significant differences between moderately and severely subnormal children aged 10 to 14 years on the Lincoln-Oseretsky scale. The results did however approach significance and Rabin (1957) argues that they would have done so but for confounding foster/institution variables. The moderately subnormal tended to perform better overall.

Hofmeister (1969) used the Lincoln-Oseretsky scale in a broader study to investigate any relationships between academic achievement, behavioural disturbance, sociometric rating, mental age (intelligence) and motor proficiency. He found positive relationships between level of arithmetic achievement and motor proficiency, intelligence and motor proficiency and sociometric status within the class and motor proficiency.

Overall, research using the Oseretsky Motor Development scale and its various adaptations reveals a lower level of performances in general by children with learning difficulties when compared with children of normal intelligence. However, it must be conceded that the superiority of the normal children is not complete and there would appear to be certain instances in which children with learning difficulties are equally capable. Furthermore, it would appear from the findings of Lillie (1968) that performance on the Lincoln-Oseretsky Motor Development Scale by children with learning difficulties can be improved as a result of lessons or training programmes.

### (c) Performance on specific tasks of Fine and Gross Motor Skill

Using specific tasks, researchers have examined the performance of children with learning difficulties, either in isolation or in comparison with children of normal intelligence. This is often done in the belief that skills are task specific and that the test battery to give an indication of overall ability is the wrong way to approach the question. Seashore (1942), for example, found that gross and fine motor abilities functioned independently of each other. Eckert and Rarick (1976) used a stabilometer task to examine the performance of children with learning difficulties and normal children aged 9-13 years, and 6-9 years respectively. They found, in the case of the children with learning difficulties that the older children were less proficient than the younger group, whereas for the normal children performance improved with age. It must be noted however, that there were no 13-15 year olds in the normal group, which might have reflected different trends. In all cases, however, the performance of the children of normal intelligence was superior to that of the children with learning difficulties.

Dobbins and Rarick (1977) used an overarm throwing task in which children with learning difficulties and normal children aimed a tennis ball at the centre of a target six feet square. Errors in the vertical and horizontal planes were recorded. Variable and absolute error scores were greater for the children with learning difficulties than the normal group but using 'E', a composite of variable and constant error, the relative contribution of the two elements to the total error score was the same for the two groups, implying the performance of the children with learning difficulties to be no more variable than that of the normal group.

Cantor and Stacey (1951) measured the manipulative dexterity of teenage boys within an IQ ranging from 42-82 and compared it with data available for two groups of normal intelligence, using the Purdue Pegboard, which measures both gross arm and 'tip of the finger' dexterity. Again, the normal subjects performed at a significantly higher level on all tests. However, they reported considerable overlapping of scores between the low and normal intelligence groups, many of those of lower intelligence being able to at least equal if not surpass the performance of some of the intellectually superior subjects. This is again indicative of the variability of the population with learning difficulties that whilst some children areable to perform on a par with their peers, on some tasks at least, others fall well behind.

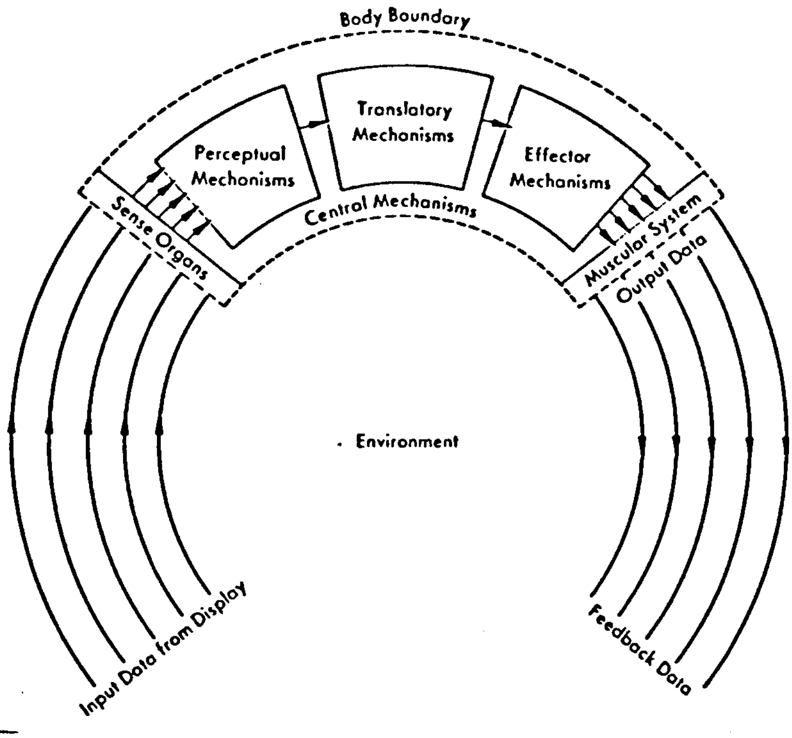
Keogh and Keogh (1967) tested boys aged 9 and 10 years with learning difficulties and compared their performance with that of normal boys aged 6 to 9 years on tests of pattern copying (drawing) and pattern walking. They found no difference between drawing and walking for the normal boys, but the boys with learning difficulties were significantly poorer in their ability to walk than to draw the patterns. Furthermore, the low intelligence group scored lowest of all the groups at both walking and drawing, although the difference between them and the normal 6 year olds did not reach significance. Keogh and Keogh (1967) remark that in walking, the majority of the children with learning difficulties seemed to have difficulty in planning their movements and organising their actions. The translation of the visually perceived pattern into a much larger, physically based, spatial-temporal activity seemed to present problems for them. They do however, remark that a few of the children with learning difficulties were able to cope with the task quite well, and acted with confidence and speed, a further indication of the variability within this population.

## II CONSIDERATION OF THE PROCESSES INVOLVED IN PERFORMING A MOTOR SKILL

Research into the area of motor skill performance in general has focused more recently on the question of how performance is brought about. Consideration of this question gave rise to an information processing approach to motor skill performance, in an acknowledgement of the fact that cognitive processes are operating within the performer between the onset of the stimulus and the response to it; the strict S-R interpretation was conceded to be an oversimplification of the case. Researchers adopted a more process orientated approach, focussing on the underlying mental and neural processes that aid in bringing about performance. The performer is considered to be a processor of information; the way in which he does this is the focus of attention. This approach gave rise to the postulation of models of performance, which hypothesise about the processes involved in making a response to a situation. Models proposed include those of Whiting (1969) and Welford (1968), shown in figures 1.1 and 1.2

Whiting (1969) explains the component processes of the model in the following way:-

Figure 1.1: Systems analysis of perceptual motor performance (Whiting, 1969)



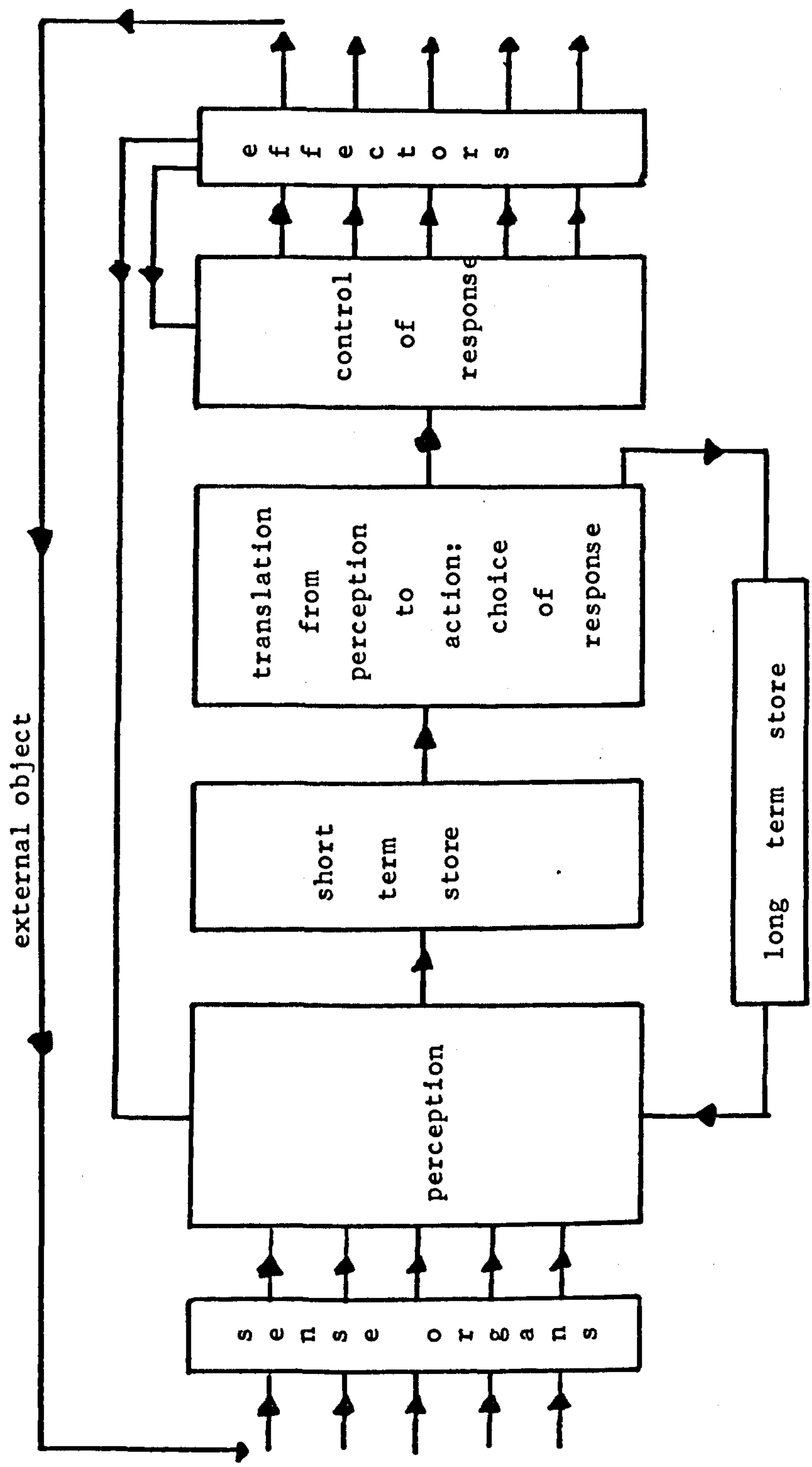



Figure 1.2: Hypothetical block diagram of the human sensory-motor system (Welford, 1968)

> Information about the display....or about the internal environment (Proprioceptive information) is relayed to the central mechanisms of the brain via the sense organs. Since the performer of a skill cannot utilise all the information available in the display at any one instant, selective attention determines both the area of the display which is scanned and the particular information which is abstracted. Sensory data from the external and internal environment is interpreted (the process of perception) in the central perceptual mechanisms. On the basis of such perceptions, decisions are made with regard to newresponses or adjustments to ongoing responses. If a response is to be made, the translatory mechanism selects the appropriate response pattern and the effector system gives the executive command to appropriate muscular response systems. The carrying out of an effector response brings about a change in the display giving rise to 'feedback' information about the effectiveness of the response. Such information together with other information from the display and the internal environment can then be monitored by the sensory systems and used in the control of ongoing responses or utilised in initiating future responses.
>
> (page 3)

Welford's (1968) model, shown in figure 1.2, demonstrates similar constructs and processes, but incorporates within it memory, in terms of both long and short term stores. He further states that only some of the many feedback loops that exist are shown.

Both these models incorporate within them the fact that certain processes must operate for performance of a response to occur - the information is taken in, some decision is made about what to do, the response is initiated and feedback is produced. In terms of the research done to examine these hypothetical constructs and processes, attention has tended to focus on one element, such as attention and whilst manipulating that element and holding all others constant, examine the performer's execution of that process and his ability to do so. Research into motor performance generally has concentrated on the following areas of the operation:-

(i) Attention

(ii) Reaction Time

(iii) Movement Time

(iv) Memory

(v) Simultaneous versus sequential processing

(vi) Feedback

This is also true of the study of motor performance by children with learning difficulties, although the amount of research conducted with such children is considerably less than that with adults and children of normal intelligence. Whilst this information processing approach to the analysis of performance has a tendency to result in the total process being seen as comprising several discrete and unrelated operations, it provides a useful structure of reference, if the reader bears in mind the place of the operation under study within the total framework. The only area that has not been considered with specific reference to children with learning difficulties is that of feedback. Feedback is known to be essential to effective performance and learning of skills over time, in addition to the correction of any ongoing movement response that it facilitates. There is no reason to suggest that this will be any different for children with learning difficulties, only that they may fail to use the information adequately, and that the provision of augmented knowledge of results might therefore be even more important for such children, both from a motivational and an informational point of view. For the purpose of the present study, research into the underlying processes involved in the performance of motor skill responses by children with learning difficulties will be considered under the headings listed, with the exception of feedback.

(i) Attention

Posner and Boies (1971) identify three components of attention - alertness, selectivity and processing capacity. Alertness, usually studied experimentally in terms of vigilance, refers to the person's ability to develop and maintain an

> ... Optional sensitivity to external stimulation ...
>
> (page 391)

particularly over long periods of time. Selectivity refers to the individual's ability to

> ... select information from one source or of one kind rather than another ...
>
> (page 391)

Posner and Boies (1971) third sense of attention is related to the idea of

> ... a limited central processing capacity ...
>
> (page 391)

the result of which would be impaired performance if more than one operation were to require the full capacity at the same time. The concept of capacity has been studied largely within the area of reaction time.

(a) Alertness

The attention span of children with learning difficulties has often been said to be short, particularly by those involved in teaching such children. Researchers have postulated that, for example, poor reaction times on the part of such individuals may be attributable to their inability to attend to the stimulus for an appropriate length of time.

Kirby, Nettelbeck and Thomas (1979) examined the vigilance performance of children with an average IQ of 68, comparing their performance with that of two control groups, one matched by chronological age, and the other by mental age. The task involved the detection of the presence or absence of a red circular patch of light embedded in a display. Little difference was found between the low IQ group and the group matched by mental age, but both performed at a lower level than the group matched by chronological age. Furthermore, the performance of the first two groups declined more rapidly over trials. A significant group x time interaction was found; although there was virtually no difference between the groups on the first test block, the performance of the low IQ group declined even faster over time resulting in increasingly great group differences. The percentage of false alarms recorded by the low IQ group was greater than for the mental age match, which was in turn greater than that recorded by the group matched on chronological age. Kirby, Nettelbeck and Thomas

(1979) suggest that this poor vigilance is largely due to retarded developmental factors, and that by adulthood, those with learning difficulties might catch up. However, they do acknowledge that the poor discriminative ability of the retardates must be due, at least in part, to a genuine intellectual deficiency and cannot be totally attributed to retarded development. Previous work with adults on vigilance performance (Kirby, Nettelbeck and Bullock, 1978) revealed little difference in terms of hit rate between a group with a mean IQ of 70, aged 18-19 years and a group of normal intelligence of the same age. In addition, in terms of decline in hit rate over time, the performance of the low IQ group did not deteriorate any faster than that of the normal group. The low IQ group recorded a very low false alarm rate at the beginning, resulting in a group x time interaction, with no difference between the groups in the later stages of testing. This would appear to support the hypothesis of Kirby, Nettelbeck and Thomas (1979) that poor vigilance in children with learning difficulties can be attributed at least in part, to overall retarded development. Krupski (1977) examined attention within reaction time experiments. She compared the reaction time and off-task glancing during the preparatory interval of a group of adolescents with a mean IQ of 64.8 and a group of normal intelligence matched on chronological age (15.6 years). The low IQ group exhibited not only slower reaction times, but also a greater incidence of off-task glancing than the group matched with them on chronological age. The frequent off-task glancing was interpreted as being indicative of inattention to the reaction time task, which would account, at least in part, for the slower reaction times.

(b) Selective Attention

The developmental research suggests that in normal children the ability to selectively attend increased with age; research by Smirnor & Zinchenko (1969) supports this. Brown, Campione & Gilliard (1974) found that young children failed to appreciate the value or importance of ignoring irrelevant information. Hagen, Meacham & Mesibov (1970) found a negative correlation between recall of a central (desired) object and a second background or incidental object, with increasing age.

The paradigm most commonly used to investigate this is one established by Maccoby & Hagen (1965) and later modified by Hagen (1967), involving the recall of the serial position of pictures of animals presented on cards, each of which was also accompanied by a picture of a household object. The attention of the child is focussed on the animal. Central recall is measured as the number of times the child is able to recall the serial position of the animals, and following the central recall trials, measurement of 'incidental recall' is done by asking the child to pair the animal and household object on the cards. Maccoby and Hagen (1965) found that the central recall increased with age, whereas incidental recall increases only slightly, if at all. Deikel & Friedman (1976), working with children of normal IQ but having learning disabilities and a group with no such disability, on a test of incidental recall, found greater incidental recall of items related to the primary task by the latter group, and greater incidental recall of irrelevant information by the group with learning disabilities.

In terms of children with learning difficulties, the research findings are, in part, contradictory. Early work by Werner & Strauss (1940) found children thought to be brain damaged to be more likely to respond to the background than to the central figure of visually presented cards. Zeaman and House (1963) investigated the discrimination learning of children with mental ages of 2-6 years, and found that once the children had learned to attend to the relevant dimension (e.g. colour size) that differentiates two objects, they learned as quickly as children of normal intelligence.

McLeskey (1982) working with children having an IQ of 55-70, found that written and verbal labelling of visual materials resulted in the children locating the item more quickly, looking at it longer, and recognised more items on later recall. This was also the case for children from within the range of normal intelligence.

Hagen & Huntsman (1971) found that the selective attention ability of institutionalised retardates was inferior to that of normal controls matched on mental age, but found no difference between non-institutionalised retardates and their normal peers. Hagen, Streeter and Raker (1974), however, found no difference in selective attention ability between low IQ and normal groups matched on mental age, when the sociometric background of the groups was also taken into consideration.

Mosley (1980) investigated the selective attention of subjects with learning difficulties (mean chronological age 21.5 years, mean IQ 66.2, mean mental age 9.85 years), and groups matched on chronological age and mental age. The design incorporated both recall and recognition of letters and Chinese characters. Mosley (1980) argued that recall requires orientation to the visual input, transfer of this input into the short term memory store and the concurrent search and match of previous input; recognition, however, requires orientation to the features or characteristics of the novel stimulus and this information then needs to be encoded in such a way as to facilitate keeping it active in the short term memory store since a search and match analysis for the character per se would be difficult. In terms of recall (stating what the familiar letter presented was), differences lay between the group with learning difficulties and the group matched on chronological age, the former being much slower to repeat the name of the letter. With regard to recognition of a Chinese character previously presented and subsequently located within a group of four characters, the retardates performed significantly worse than both other groups. They appeared unable to extract salient features of the character originally presented to act as cues for encoding and use at a future time. A card sorting task, in which the subjects classified cards of characters into three groups in their own way revealed that the classification by those with learning difficulties was more or less random. Overall, this would appear to be indicative of poor selective attention, an ability to extract salient features.

Anwar (1981) suggests that added information which might be thought by a teacher or experimenter to be useful in aiding performance might prove interfering in some instances for children with learning difficulties. She took groups of children with learning difficulties with chronological ages of 8, 10 and 12 years and mental ages ranging from 4 to 10 years, and measured performance on tasks of visually guided target localisations in which the subject could see both his hand and the target, and visually directed localisations in which only the target was visible. Minimum information meant that only the top of the target was visible, and this was then hidden from view as the response was made; augmented visual knowledge of results indicated whether or not the attempt had been correct. Presentation of knowledge of results in this way had no effect on performance by those with learning difficulties, whereas for normal subjects it assisted in improving performance significantly. For those with learning difficulties there was very little difference between minimum information and knowledge of results conditions; some of the low mental age subjects (4 years) did worse on the visual knowledge of results condition than the minimum information condition, suggesting that increasing the amount of information presented is in some way interfering with performance. Possibly, this is a reflection of the inability of children with learning difficulties to attend to the appropriate information.

### (c) Limited Central Processing Capacity

The reason for the necessity of selective attention is that the human system is unable to process all the information that impinges on the senses. The fact that children with learning difficulties seem to be less efficient in terms of selectivity means that the system is attempting to cope either with a greater amount of information than someone of normal intelligence in the same situation, or with information that is irrelevant in terms of making a successful response. Some researchers have also suggested that possibility that the upper limit of the processing capacity of children with learning difficulties is in fact lower than that of children with normal intelligence of the same age.

Sugden (1980) found a developmental increase in the capacity of the motor system with age for normal boys and girls aged 6-12 years. Sugden and Gray (1981) investigated the capacity and strategies of boys with learning difficulties on serial and discrete tasks involving movement speed. Measures of capacity placed the boys with learning difficulties at least five years behind the capacity expected on the basis of chronological age. The precise location or locations of the limited capacity within the human system is not totally understood. However, evidence of there being, at some stage, a limited capacity for operation, can be seen through the studies of the various processes. 1

A further issue related to the question of allocation and attention is the question of whether the human 'machine' processes information sequentially (that is, one item after another) or simultaneously (more than one item at a time) is an issue of debate. Research by McLeod (1977) would seem to suggest that humans have the ability and do in fact on occasions process more than one item of information at one time.

Das and Cummins (1978) examined the question of preferred mode of processing on the part of children with learning difficulties, and the way in which this might differ from children of normal intelligence. Using various tests, they measured simultaneous processing, successive processing and also performance on the Wechster Intelligence Scale for Children (WISC). They found that simultaneous processing positively correlated with IQ and arithmetic ability, and successive processing positively correlated with spelling and oral reading, but negatively correlated with WISC performance IQ. This would suggest that successive strategies are less efficient for solving spatial tasks such as those identified by the WISC performance IQ. Das and Cummins (1978) argue that simultaneous processing is especially important for the development of elementary decoding skills, and this is the level at which development on the part of children with learning difficulties stops.

(ii) Decision Making

A commonly used index of the efficiency of decision making is reaction time. Reaction time has attracted a great deal of attention both in the study of the behaviour of persons of normal intelligence and that of those with learning difficulties. Reaction time is interpreted to mean the time between the onset of a stimulus and the initiation of a response to it; movement time, which is often studied in conjunction with reaction time, is said to be the time taken from the initiation of the response until the completion of it. Various aspects of reaction time have been studied, including the absolute measure of simple reaction time (one stimulus, one response) and choice reaction time (more than one stimulus, one or more responses) and its correlation with intelligence, the question of probabilities of stimuli appearing within the display, and the effect on reaction time of the complexity of the required response.

(a) Decision making & Intelligence

Studies of reaction time and its relationship with intelligence would appear to suggest that children and adults of low intelligence exhibit a comparatively slow reaction time. Krupski (1977) found children with learning difficulties to have a slower reaction time than normal children of the same age. Ellis and Sloan (1957), using an auditory stimulus and a push button response, reported a significant correlation between mental age and simple reaction time, the effects of chronological age being negligible. Comparisons with normal groups revealed not only a slower reaction time for retardates but also the fact that subjects with a low mental age are also more variable in their performance on task. This slower reaction time of children and adults with learning difficulties is well documented (e.g. Lally and Nettelbeck 1977; Brewer and Nettelbeck 1979) although the underlying reasons for it are perhaps less well understood.

Groden (1969) examined the possibility that a complex perceptual motor disability might be the reason for a slower reaction time on the part of the persons of low intelligence, by determining the effects on the relationship between reaction time and intelligence of holding constant relatively simple motor abilities on one hand, and complex perceptual-motor abilities on the other. He took certain tasks as being representative of these abilities. Using finger oscillation and grip strength as measures of simple motor abilities and a task involving a sequence of finger presses as representative of complex motor abilities, Groden (1969) found all three measures correlated with mental age. Further analysis revealed complex motor abilities to be more highly related to mental age than either reaction time or simple motor abilities, and reaction time more so than simple motor abilities. When complex motor abilities and chronological age were held constant, the correlation between mental age and simple motor abilities disappeared. Groden (1969) suggests that reaction time and complex motor tasks both require something more than is required of the individual when performing simple motor tasks. He hypothesises that this might be increased vigilance, or greater visuo-motor guidance, which are more cognitive processes and therefore more influenced by intelligence.

Lally and Nettelbeck (1977) suggested that the longer reaction time of those below average intelligence was due to them taking longer to accumulate evidence as a basis for decision, a longer 'inspection time'. They measured the minimum stimulus duration time at which subjects attained a prescribed degree of accuracy, and found this to be significantly longer for a group aged 17-26 years, with a mean IQ of 69 than for persons of normal intelligence of the same chronological age. This resulted in a high correlation between inspection time and IQ, for both two and eight choice reaction time. As the amount of information increased, the difference in inspection time between the intelligence groups also increased, suggesting that the lower intelligence group found the high information load differentially more difficult.

In a second experiment, Lally and Nettelbeck (1977) used a single response, regardless of the number of stimuli presented, unlike the first experiment in which each stimulus required a different response. This was done in order to control for the possible effects on reaction time of increasing response complexity.

Again, the reaction times of both groups increased with the increase in number of stimulus alternatives and, as before, the reaction times for those with low intelligence were significantly slower than those of the normal children. The group x number of stimulus alternatives interaction was even more marked than in the first study, the reaction times of the low intelligence group slowing up much more than those of the normal group with the increase in number of stimuli. They concluded that the reason for the slower reaction times by persons with learning difficulties was in fact the longer inspection time required, and this was the limiting factor in performance.

Research by Brewer and Nettelbeck (1979) revealed slower eight choice reaction times for subjects of low intelligence when vision of the hands was allowed than when a wooden block over the hands prevented visual monitoring; for a group of normal intelligence however, the vision/non-vision effects were virtually zero. However, whereas subjects of normal intelligence recorded a 3% error rate for both conditions, the error rates for the subjects of low intelligence increased from 6% with visual monitoring to 10% without. They suggest that preventing visual monitoring forced the subjects with learning difficulties to forego a cognitive element of the process essential to them for effective performance. Further experimentation allowed for the comparison of errors when the response keys were close to and far from the stimulus lights. The subjects of low intelligence were found to make more errors on the 'distant' task than the 'near' task, a trend not reflected by those subjects of normal intelligence.

Brewer (1978) found a greater error rate for subjects with learning difficulties than a group of normal intelligence when the number of alternative responses increased and when responses were required to be made using the inside fingers. This was the case even when the stimulus-response translation process was reduced to a minimum by generating direct stimulation of the finger to respond by means of a vibrating key under the finger. Although significant reaction time differences were found between subjects of low and normal intelligence, this mean difference was reduced from 170 msec to 40 msec when the vibrotactile stimulation was used. This would suggest that perhaps the slower reaction times in persons with learning difficulties could be accounted for in terms of less efficient perceptual and translational processes.

(b) Probabilities and decision making

Varying the probability of the appearance of the various stimuli within the display has been shown experimentally to affect reaction time to them. Fitts, Peterson and Wolpe (1963) recorded faster reaction times to highly probable events at the expense of slower reaction times to the less probable events. Maisto and Sipe (1980) found that persons of low intelligence, in addition to having a slower reaction time overall, exhibited less improvement in performance with increased probability than did normal subjects; the effect of establishing probabilities was much less marked in the group with low intelligence. It would appear that these subjects did not use the information in an appropriate way during the encoding process, such that they did not develop stimulus expectancies in the same way as persons of normal intelligence.

(c) Response Complexity and decision making

Reaction time has been found to increase in response to complexity in certain situations. Henry and Rogers (1960) used a simple reaction time paradigm with three differing degrees of response complexity, the subjects knowing in advance which of these was required. They found no increase in reaction time with increased movement complexity; however, since 1960 the results of similar experiments have, in part, been contradictory. Klapp (1974) suggests that this is partly because in a simple reaction time task, the subject knows the response to be made and effectively 'preprograms' the response, whereas in a choice reaction time task, the response cannot be programmed or instigated until after the presentation of the stimulus. Research with simple reaction time tasks supports this hypothesis; Klapp, Wyatt and MacLingo (1974) found no differences in simple reaction time tasks requiring different complexities of response, whereas research designs incorporating choice reaction time tasks would suggest effects on reaction time of increasing response complexity, such that reaction time would increase (Klapp 1974).

Sugden and Gray (1981) found simple reaction time unaffected by movement complexity in boys with learning difficulties on a discrete reaction time task. Distefano and Brunt (1982) manipulated response complexity for eight year old boys and girls with learning difficulties. The three responses involved running 4.6 metres as fast as possible and breaking a light beam, running to this point and then veering towards one of two lights illuminated at the time of reaching the beam, or running as before and veering to one of three possible lights. They found no change in the reaction time of normal boys with an increase in response complexity; the reaction time of the children with learning difficulties, however, increased significantly with each increased complexity. Furthermore, a sex difference emerged for the subjects with learning difficulties, boys being faster than girls, a trend not reflected by the children of normal intelligence. Whilst the issue is not yet resolved it would appear possible that children with learning difficulties are at a disadvantage in certain reaction time situations when a complex response is required.

(iii) Effector Efficiency

A common index of effector efficiency is the measure of movement time. Movement time has been defined as the time taken to complete a response, and is measured from the initiation of the movement until its completion. It is generally studied experimentally within reaction time paradigms. Distefano and Brunt (1982) in the experiments already cited, measured the movement time for the subjects until the movement of breaking the light beam at the end of the 4.6 metre run. They found that for the two more complex tasks, the children with learning difficulties exhibited longer movement times than for the simple task, whereas the normal subjects evidenced no differences in movement time over the three tasks. The former group seemed unable to attend to the environmental stimuli and simultaneously perform a running task, whereas for the children of normal intelligence, the running task required so little attention that they were easily able to cope with the second task. Sugden and Gray (1981) using a serial dotting task and a discrete reaction time task, investigated movement speed in boys with learning difficulties. Different movement complexities were presented; on the serial task, this was done by varying the size of the targets to be hit and the distance between them, and on the discrete task, by varying the target size and the distance from the base starting point to it. They found a linear relationship between movement time and information load, as computed using Fitt's formula for index of difficulty (1954). The slope for the serial task was steeper than for the discrete task, which would suggest that the boys found the task differentially more difficult. On the serial task, at a relatively easy level, the boys seemed to adopt strategies similar to those used by normal subjects, such as visually focussing on one target and moving to and from it, but as the task difficulty increased, they appeared to need to focus all their attention on the moving hand.

(iv) Memory

Motor memory is an area of concern that has received considerable attention, particularly over the last decade. Traditionally, it has been compartmentalised into sensory storage, short term memory and long term memory. Motor information in long term memory appears to be extremely resilient to decay, as witnessed by people's ability to swim or ride a bicycle after many years of not having done so. Furthermore, the capacity of long term memory would seem to be very large, a fact which is not true for short term memory. Short term memory would not only appear to have a limited capacity, but items and information held in the store are very susceptible to decay, particularly when the person does not pay conscious attention to them. Various strategies, such as 'chunking' (Miller 1956), can be adopted whereby the absolute amount of information held in short term memory can be increased. In terms of research into motor memory of children with learning difficulties, it is short term memory that has received most attention.

Reid (1980a) used a linear positioning task to investigate rehearsal in a group of adolescents with a mean IQ of 65.8, and their counterparts matched on mental and chronological age. He used five retentive conditions (immediate, 20 second filled with an interpolated activity, 20 second unfilled, 20 second overt rehearsal, and 20 second overt rehearsal during a filled interval), and found the low IQ group to perform significantly worse in general than the other two groups. When the opportunity for rehearsal was prevented or not required, as an immediate recall, the task was insensitive to normal low intelligenc differences, whereas when rehearsal was necessary and possible, as during the 20 second unfilled interval, chronological and mental age matched normal subjects recalled much better than the low intelligence group. This would support the hypothesis that the deficit in motor short term memory by children with learning difficulties is due to a lack of spontaneous use of strategies.

Reid (1980b) went on to assess the value and effectiveness of teaching rehearsal strategies. With a taught group and a control group, and retention intervals of 0 and 15 seconds, he found significant effects for instruction over the 15 second interval, but no effect for immediate recall. He argues that immediate recall depends more on sensory storage and is not amenable to cognitive strategies. It is, however, evident that it is the use of strategies which is important, and that although persons of lower intelligence are apparently capable of using strategies, they do not do so spontaneously.

Reid's (1980a) findings on the short term memory of children with learning difficulties are supported by Sugden (1978) who again found no difference between normal children and children with learning difficulties on a visual-motor short term memory task when central processing, and therefore rehearsal was prevented. Furthermore, when comparing three age groups (6, 9 and 12 years) of children with learning difficulties and normal children, the developmental trends in terms of an increase in recall evidenced by the normal children was not reflected to the same degree by the children with learning difficulties, the only significant difference in recall for them being between the 6 and 12 year olds. Kelso, Goodman, Stamm and Hayes (1979) also posed the question of how efficiently children with learning difficulties recall motoric information, and whether there are any developmental trends associated with this. They used a linear positioning task with two groups of children with learning difficulties, with a mean age 12-2 years and 9-4 years respectively. In the first task, the location to be recalled was presented as a constrained stop, and in this they found a significant difference between immediate recall and recall after 15 seconds, which is in contrast to the findings of research with which suggests that location information can be retained accurately over time. In order to increase the codability of the information, the second task allowed the children to preselect the location themselves. Recall of this location was then compared with recall of constrained locations. No differences were found between the age groups, although the preselected location resulted in less error for immediate and 7 second recall than 15 second recall, overall.

From this, it would appear that children with learning difficulties are able to code movement information in the same way as persons of normal intelligence. In a third task, Kelso, Goodman, Stamm and Hayes (1979) prevented rehearsal by filling the retention interval with an interpolated motor task, and compared this with recall following an unfilled interval. No difference was found between the 7 and 15 second filled intervals, whereas there was a difference for the unfilled interval, recall after 7 seconds being superior. This would again suggest the ability of children with learning difficulties to rehearse information.

The use of rehearsal and strategies to assist recall has received particular attention in the realm of verbal behaviour, in which considerable differences between persons of average intelligence and those of below average intelligence have been found, the retardates generally performing at a lower level. Clark and Detterman (1981) argued that research in this area resulted in differences between the tasks used, often of a discriminative nature, used materials which had differences in terms of meaning for the two groups. For this reason, Clark and Detterman (1981) used a lifted weight task, whereby subjects were presented with five weights, and then asked which of these weights equalled a probe weight subsequently presented. Subjects were also asked what strategy or plan they had used, if any. The actual weights used were different for the normal and low intelligence groups, but were considered on the basis of previous research to be equal in terms of discrimination for both groups. The group of normal intelligence performed significantly better than those of low intelligence, and those who reported using a strategy significantly better than those who did not. By increasing the number of weights from five to nine, they then hoped to make the use of strategies virtually impossible. The normal intelligence group again performed better than the below average intelligence group, but in all cases, performance was worse, particularly for those who had earlier reported using a strategy or plan. This would tend to support the argument that the lack of use of strategies will result in poor performance, and that retardates do not adopt the use of strategies spontaneously.

From the research cited, it would appear that children with learning difficulties suffer from problems in executing efficiently the various processes involved in making an appropriate and successful response to a situation. In terms of attention, speed of decision making, speed of movement and motor short term memory,the evidence would appear that, as a group, their performances fall behind that of their peers. This poorer performance is also reflected in poorer scores on tests of strength, flexion and other physical measures, although it would appear that some of these at least can be attributed to differences in physical and physiological development. However, much of the research cites instances where the performance of individuals within the low intelligence groups studied compares favourably with that of children of normal intelligence, or at least acknowledges the greater variability of performance both within the group and within the subject. Furthermore, there is some evidence to suggest that in certain areas of operation at least, such children can be taught to work more efficiently, and, given time, on some tasks, match the performance of their peers of normal intelligence. The differences that exist between children with learning difficulties and those of normal intelligence may not be as clear cut as the research might at first suggest.

# CHAPTER TWO

Learning, both in humans and animals, has been widely researched. This is the case not only within the field of motor skill learning, but in all aspects of human life. The diversity of human experience raises the question of whether there is one kind of learning common to all aspects of experience, or whether there are several types of learning specific to these different aspects of experience; it is this question which, in part, makes the definition and understanding of learning difficult. Melton (1964) proposed seven categories of human learning, of which perceptual-motor skill learning is one. Gagné (1965) argued the case for eight types of learning, structured in a hierarchical fashion. Fitts (1964) states

> Processes which underly skilled perceptual-motor performance are basically very similar to those processes which underly language behaviour as well as processes involved in problem solving, concept formation etc. If so, then laws of learning should be similar ... distinctions between verbal and motor processes serve no special purpose.
>
> (page 243)

However, whilst this may be the case, since the present study is concerned with perceptual-motor learning, it is from this area of research that an understanding of learning will be sought, as far as possible.

Further problems in attempting to define learning lie in the need to differentiate between learning and performance and the difficulties that arise in attempting to do so. The issue is only confused by the fact that early definitions of learning tended to explain the phenomenon in terms of changes in performance. Differences between learning and performance will be considered as a separate issue.

## I DEFINITION OF LEARNING

Early researchers tended to define learning in terms of changes in performance. Partly because of the problems that arise in doing so, more recent definitions have tended to focus on the processes and internal changes involved in learning. Schmidt (1975a) defines learning as

> ... a change, as a result of practice (experience), in a relatively stable internal state turned habit, which is a necessary, but not a sufficient, condition for performance to occur.
>
> (page 32)

More recently (Schmidt, 1982), he redefines learning, shifting the emphasis more to the processes involved; he defines it as

> ... a set of processes associated with practice or experience leading to relatively permanent changes in skilled behaviour.
>
> (page 438)

Singer (1980) defines learning in the following way

> ... Learning is reflected or inferred by a relatively permanent change in performance or behavioral potential resulting from practice or experience in the situation.
>
> (page 9).

Although these definitions and many others have slightly different emphases, they do have certain elements in common, each of which may be examined independently:-

(i) Learning is the result of practice.

(ii) Any change must be relatively permanent, for learning to be said to have occurred.

(iii) Learning cannot be measured directly; it can only be inferred from observations of performance over time.

(i) Learning is the result of practice

This element of the definitions eliminates any change in performance as indicative of learning that can be attributable to the processes of growth or maturation. The strength, for example, of a young child is much less than an adult, but it would be incorrect to attribute this change to learning; it arises directly out of growth processes.

Given that this is the case, attention has also focussed on the question of how much practice is necessary for learning to occur. The precise amount will naturally depend upon the nature and complexity of the task and upon the resources of the individual performer. There would, however, appear to be some benefit in continuing practice after the skill has been initially mastered; this is known as overlearning.

Melnick (1971) used a stabilometer task to evaluate the effects of varying degrees of overlearning. The learning criterion was set at 28 seconds in balance out of a 30 second trial, and following achievement of this criterion, groups of subjects were given differing degrees of overlearning (0%, 50%, 100% and 200%). They were then retested after one week or one month. After both these time periods, those groups experiencing overlearning recalled the task much better than the zero overlearning group. In terms of 'savings scores' (the minimum time taken to reach the criterion again), the 200% overlearning group recorded by far the best, a saving of 97.5%. From this it would appear that there is a significant advantage in overlearning a task, but probably only if the aim in learning it is its repeated use over extended retention intervals. The optimum level of overlearning is difficult to determine, but perhaps as Singer (1980) remarks

> ... 50 per cent overlearning is advantageous, but practice beyond this does not afford a proportional gain for the extended effort.
>
> (page 382)

In general, however, the statement that practice is an essential part of learning is true. The precise amount of practice to master the skill will depend on the task and the performer, and the degree of an overlearning advisable will probably depend on the original purpose in learning the skill.

(ii) <u>Any change must be relatively permanent</u>

The implication here is that learning is a permanent influence; that having learned something, the process cannot be totally reversed, although of course, forgetting does occur. One can argue that even if the actual skill originally learned has been 'forgotten' something can and will remain, perhaps in the form of approach or orientation to the task. In attempting a task, once mastered and then forgotten, one is never a real novice again. In this sense, the person is changed 'relatively permanently' as a result of learning.

When measuring learning, if learning is considered to be relatively permanent, it is necessary to examine behaviour on more than one instance or trial. In the same way as 'one swallow does not make a fine summer', one skilled performance does not indicate permanent change and therefore learning. It may be the result of luck, chance or some temporary influence, such as drugs. To demonstrate that learning has occurred, the change in behaviour must be relatively permanent and therefore must be demonstrable consistently over time. 'Relatively permanent' is a vague term. There is no attempt to define just how permanent the change must be, or just how lasting the effects of the practice must be, for learning to be said to have occured. Nevertheless, the implication is that the behavioural changes must be lasting, and not fleeting in nature.

(iii) Learning cannot be measured directly

Earlier definitions tended to explain motor learning in terms of changes in performance. There lies a logical error here, in that if one defines learning in this way, and no changes in performance are observed, one is forced to conclude that no learning has taken place. The underlying processes involved in learning are, no doubt, extremely complex, and changes in the organisation and efficiency of these processes may well be taking place, which is not observable through performance. Latent learning, where learning is taking place although not demonstrated, has been verified in experiments using rats, where maze learning is apparent only when reinforcement is given. Until this point the rats had obviously been learning the maze, although there had been no motivation to demonstrate the fact.

The definitions used here emphasise that the learning changes take place within the body and because of this are not directly measurable. The medium through which the researcher or observer can infer learning, is performance, although caution must be exercised in doing so, since performance is not always reflective of learning.

## II LEARNING AND PERFORMANCE

It is necessary, because of the interrelationships between learning and performance, and the dependence of the observer on performance as a measure of learning, to clarify the differences between the two concepts. Whereas learning has been defined as being a change in an internal state and therefore not directly observable, performance is the perceivable action or response that is made: it may or may not be a manifestation of a degree of learning or expertise. Furthermore, certain factors or influences will affect learning and performance disproportionately and it is necessary to consider these in turn.

(i) Temporary influences on performance

Singer (1980) states

> ... performance may fluctuate from time to time because of the potential for many variables to operate...
>
> (page 11)

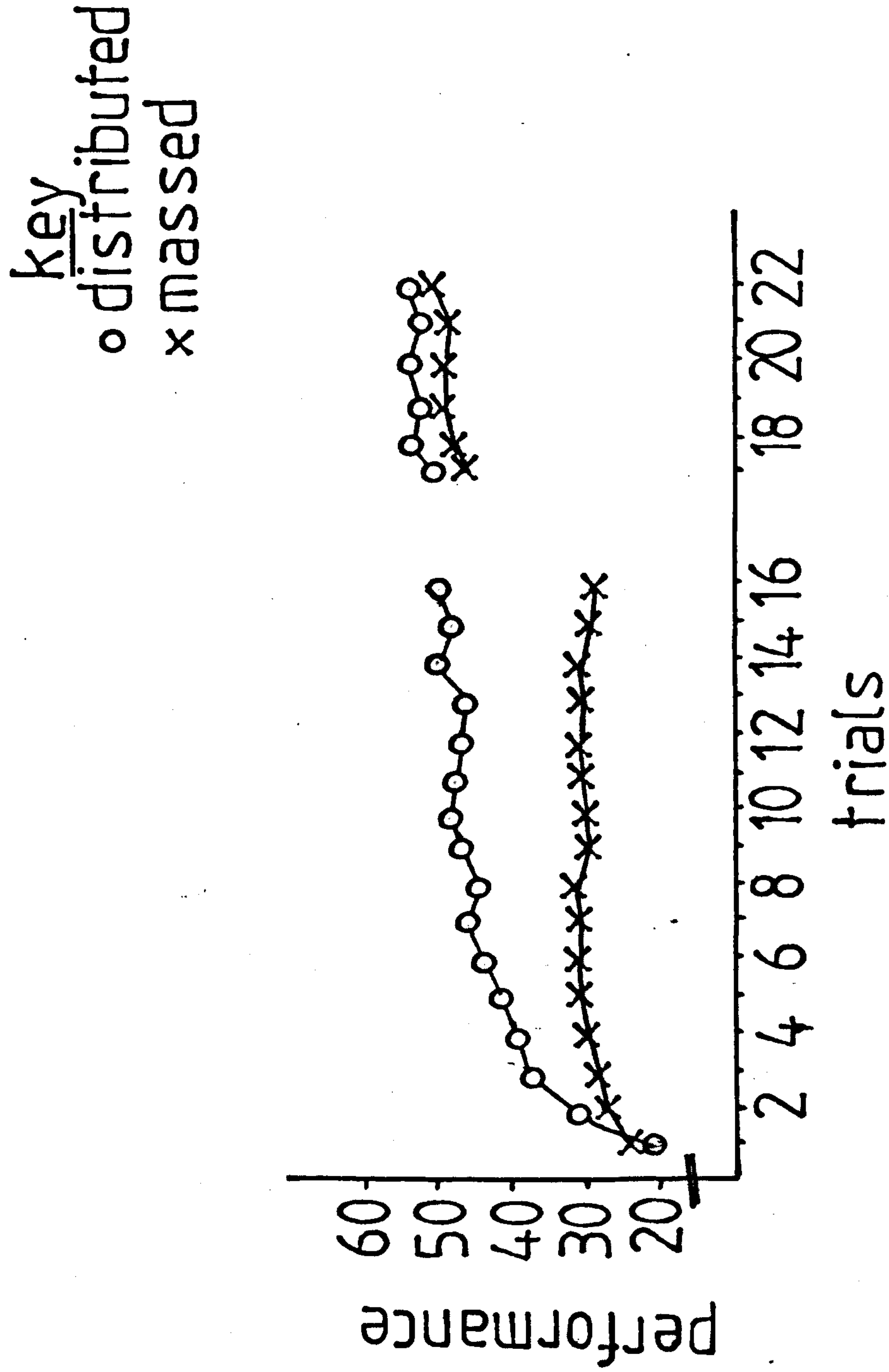
whereas this is untrue of learning. Performance may be influenced by such factors as drugs, boredom or fatigue, and whether the effect is dperessing or stimulating, it disappears once the cause is removed. Furthermore, it has virtually no influence on the overall learning process. Godwin & Schmidt (1971) studied the effects on the learning and performance of a discrete motor task of artificially induced physical fatigue. The task was the 'Sigma' task, which involved rotating a handle clockwise and anticlockwise, then moving the arm straight to knock over a barrier, in the minimum time possible. During the learning trials, the performance of a fatigued group was significantly worse than that of the non-fatigued group, although both groups demonstrated overall improvement. After three days rest, performance was again measured under non-fatigued conditions. Initially the fatigued group were inferior to the non-fatigued group, but the difference between the two groups disappeared over the ten trials. Fatigue, on the basis of these results, would not appear to be a crucial factor in learning.

In the same way as physical fatigue has been examined, the effects of a kind of 'mental fatigue' on learning and performance have also been studied. This kind of fatigue is induced by varying the practice schedules through which the performer will learn the task. 'Massed' practice schedules in which the learner has little or no rest, are compared with 'distributed' practice schedules, which give the performer ample rest between trials. Following practice on one of the schedules, the subjects then transfer to a more sympathetic, distributed schedule. The results tend to indicate that massing practice has a depressing influence on performance at the time of practice, but after rest and on transfer to a more sympathetic schedule, the effects of the massed practice disappear almost entirely; performance is equal to that by subjects having continuously experienced distributed practice schedules. This is exemplified by work done by Adams and Reynolds (1954) and Stelmach (1969) amongst others.

Adams and Reynolds (1964) used a pursuit motor task with varying amounts of massed practice (30 second practice, 5 seconds rest) before the transfer to distributed practice (30 seconds practice, 30 seconds rest). In all cases, on transfer to the distributed schedule, performance improved dramatically (known as remeniscence), and after three or four trials equalled that of the group which had continuously experienced distributed practice. Stelmach (1969) used Bachman ladder and stabilometer tasks, and found significant differences between groups characterised by practice schedule, massed or distributed, during the practice phase. On transfer to the distributed schedule, the difference between the groups was almost entirely eliminated. This is shown in figure 2.1.

In both these cases, the practice schedule is, in effect, a temporary influence on performance, and has no effect on the learning process.

Figure 2.1: The performance curves for the distributed and massed practice groups on the stabilometer (Reproduced from Stelmach, 1969, page 200)



(ii) Ceiling and Floor Effects

Ceiling and floor effects are artefacts imposed on performance either by the task or by the measuring process.

In terms of ceiling and floor effects setby the task, the implication is that a ceiling effect is present if the task is too easy for the performer and he achieves the maximum immediately; in this way, no learning can occur. At the other end of the continuum, a floor effect is present if the task is far too difficult and he cannot begin to master it, even after several trials. This problem is particularly apparent in developmental studies, in which various age groups are required to perform the same task, and their relative performance compared. If the task is too easy, the older children will reach the maximum quickly, if not immediately, and not then evidence any improvement; conversely, if the task is too difficult, the younger children will not evidence any improvement, since they are unable to begin to master the task.

Ceiling and floor effects as artefacts set by the measuring process are due to the fact that certain types of scoring set limits which performance cannot exceed. Measuring in percentage scores results in 0% and 100% as the limits; although performance would not appear to change after the 100% mark, learning may still continue after the performer has reached this maximum. Similarly, measuring the time taken to execute a movement can never result in a score of zero seconds (provided anticipation is prevented). However, despite these impositions, once the maximum is achieved, it is possible that learning is still occurring in that fluency or consistency may be improving, the task may be becoming less attention demanding, or the performer may be improving in 'unmeasured' aspects of the task.

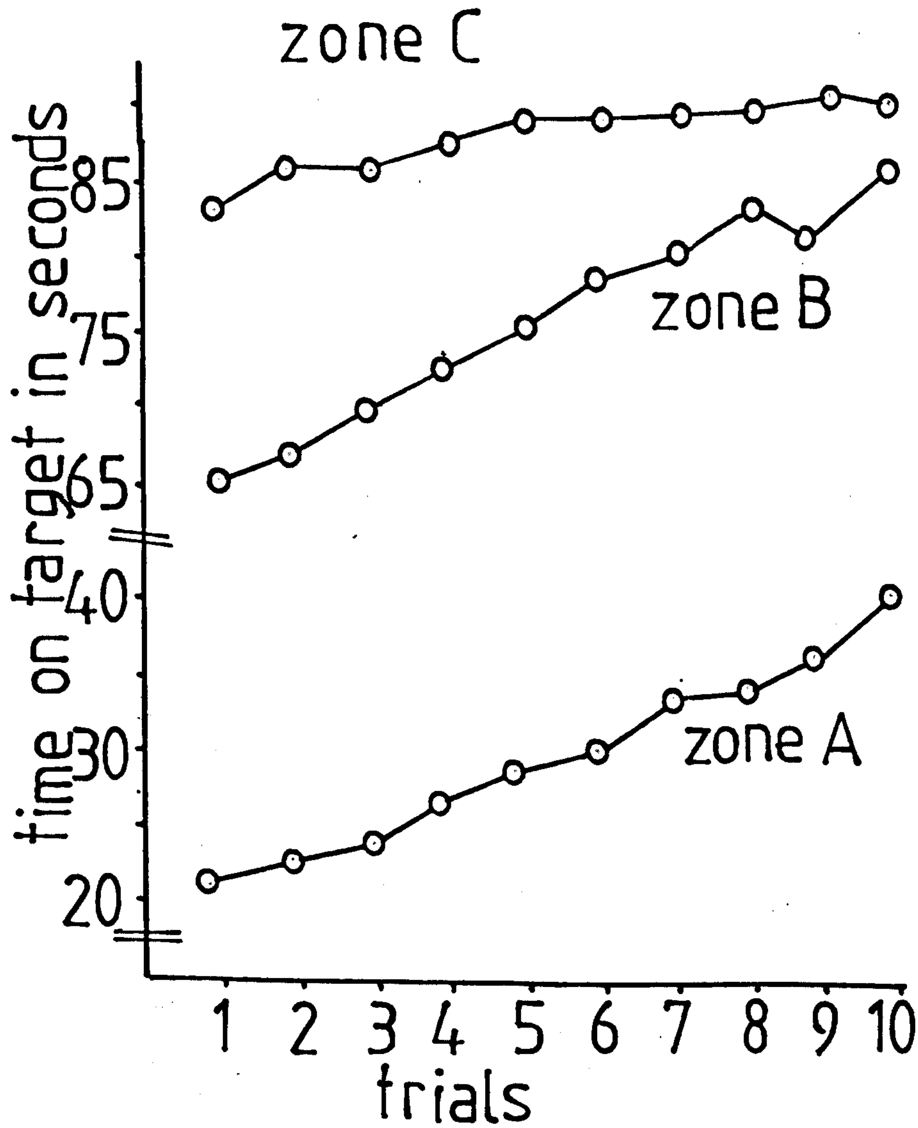
A further, related issue is that the way in which performance is measured may influence the nature of the inference made about the learning process. Bahrick, Fitts and Briggs (1957) demonstrate this quite clearly. They used a tracking test and as their measure of performance, time on target, setting a tolerance band of correctness around the target of three different widths. Using the same data of subjects, but with three tolerance bands, they plotted the 'learning' or 'performance' curves. The resulting curves might well lend themselves to different inferences regarding the learning process. This is shown in Figure 2.2.

However, given the problems both in measurement of learning and performance, and the differentiation of the two, at present, the measurement of learning is undertaken through the examination of performance over time. The experimental design used generally adopts one or both of two strategies:-

(i) Acquisition of skill and retention of that skill over varying periods of time, ranging from a few seconds to a year or more.

(ii) Acquisition of a skill and transfer to a novel but related task that incorporates the same elements, or requires the use of the same strategies, as the learned task.

Figure 2.2: Time on target of 25 male subjects on a simple tracking task (From Bahrick, Fitts and Briggs, 1957, p.260)



Whilst this situation is not ideal, as Singer (1980) states

> Nevertheless, a true measure of learning has yet to be devised, and performance scores reflect the best means available at the present time.
>
> (page 11)

## III PRODUCT VERSUS PROCESS ORIENTATED RESEARCH

The way in which the emphasis of the definitions of learning have shifted from the observable product, performance, to the internal process, is also reflected in the way in which researchers have approached the whole question of the learning of motor skills. Research specifically related to the area has a long history; in the early 19th century, Bessel began by investigating the differences between recorded transit times of stars by colleagues, and by the turn of the century, Bryan & Harter (1897) had begun to study the learning of telegraphy and Morse Code. Examining the research done since then, one can classify the work done as adopting one of two approaches in general. These approaches can be termed product orientated and process orientated.

In the case of product orientated research, the focus of attention here is the end result of learning, performance. Questions raised include optimal learning conditions, whole versus part learning and practice scheduling.

Similar to the shift in emphasis demonstrated by the definitions, research adopting a process orientated approach has focussed on the underlying processes involved in learning. The difference between this approach and the product orientated approach lies in the nature of the questions asked. Rather than 'What we have learned?' the question is now 'How do we learn?' This approach has given use to some degree of understanding of the capabilities and limitations of human beings and furthermore, it has given rise to theories of motor learning such as those of Adams (1971) and Schmidt (1975b).

Origins of learning theory go back to Thorndike's (1927) Law of Effect. The second world war generated interest in motor skill and with it, an interest in theories of motor learning. The most notable of these is that of Hull (1943), which provided a basis and a starting point for much experimental research. A similar springboard has been provided more recently by the theories of Adams (1971) and Schmidt (1975b). The focus on learning in children has developed only recently, with an increasing realisation that if one is examining the learning of novel motor tasks, the processes are probably more easily identifiable in children, since they are less accomplished motorically than adults, and the tasks used will effectively hold more novelty for them.

Learning is an extremely complex phenomenon, not yet fully understood. Learning by children of perceptual-motor skills is an area of research that has attracted attention more recently, but which requires a greater understanding also.

# CHAPTER THREE

# LEARNING BY CHILDREN WITH LEARNING DIFFICULTIES

Research into the area of learning in children with learning difficulties is less complete than research into learning in normal children and adults. This is particularly true of perceptual-motor skill learning, where there is a paucity of information. For this reason, study of the research done into motor learning by such children would provide an unsatisfactory understanding, and it is necessary to turn to the research into verbal learning and verbal behaviour by such children. Fitts (1964) argues that the processes underlying may be common to all learning experiences. Whilst one might not agree with this statement in its entirety, research into an area of human behaviour is not conducted in a vacuum, and very often draws on theory, terminology and evidence from another area. The origins of 'schema', for example, now a common feature of discussion in the area of motor skills, lie in language, the term there referring to abstract memory representations for events and stories(Head, 1926), which lack many of the details of the events, but acts as a concept or rule. Similarly, the MacNeilage target hypothesis (1970) has made a contribution to the understanding of body control, although concerned primarily with speech production. Since there is a paucity of information regarding motor skill learning in children with learning difficulties, it will be beneficial to consider the research findings in the realm of verbal learning and behaviour in such children.

## I VERBAL LEARNING IN CHILDREN WITH LEARNING DIFFICULTIES

Borkowski and Wanschura (1974) state

> ... rote learning, which is the strengthening of the direct association between the internal representation of two events (e.g., a stimulus and a response in a paired-associate task), does not adequately describe the adult learning process... Cognitive structured learning occurs when a direct association occurs between two events, together with some additional, indirect association... These indirect associations are commonly referred to as mediators.
>
> (page 1)

Empirical and anecdotal evidence can be cited to substantiate the statement that, given time, even children and adults of severely subnormal intelligence can be trained to make certain responses or perform certain tasks (e.g., those working in special sheltered workshop environments). However, this is only indicative of 'rote' learning, and demonstrates no cognitive element, which Borkowski and Wanschura (1974) argue is characteristic of mature adult learning. In the study of learning in children with learning difficulties, the focus of attention is on the differences between such children and their peers who will generally exhibit 'cognitive structured learning'. Numerous studies can be cited in which learning in children with learning difficulties is found to be less competent than that of their peers (e.g. Butterfield, 1968; Gerjuoy and Spitz, 1966, Gerjuoy, Winters, Pullen and Spitz, 1969), although the reasons for this decrement are less clear. Since the differences between rote learning and mature adult learning lie in the use of mediational processes, and children with learning difficulties are known to be capable of rote learning but experience difficulty in mature adult learning, it is in the area of the use of mediational processes and strategies that the research has centred.

In an attempt to understand the reasons underlying poor learning by children with learning difficulties, the research has considered possible sources of this limitation:-

(i) Structural features and control processes.

(ii) Mediational and production deficiencies.

(iii) Use of active and passive strategies.

(i) Structural features and control processes

The question at issue here is whether poor learning in children with learning difficulties can be attributed to a limitation in structural features, which Brown (1974) defines as

> ...those aspects of the system which are not 'programmable', i.e. cannot be varied or changed due to some "structural" limitation of the organism.
>
> (page 60)

or whether it is through use of the control processes, which can be seen as those aspects of the system that can be altered and maximised through training. The structural limitations may increase with maturity, but at any given time cannot be increased and have a fixed capacity which cannot be altered. In analysing the extent to which poor learning by children with learning difficulties can be attributed to these two aspects, problems arise in that a failure to train successfully an individual to, for example, memorise information, does not necessarily imply a structural limitation, since the training programme could be ineffective. Until all possible programmes have been exhausted, which is surely an impossible task, one cannot genuinely infer a structural deficit. Furthermore, whilst it is possible to train children to, for example, rehearse, there may be an upper limit to the effects of the training, fixed by the structural capacity.

(ii) Mediational and production deficiencies

Brown (1974) used the term 'mediational' in the same sense as Borkowski and Wanschura (1974) use the term 'control'. Borkowski and Wanschura (1974) explain the distinction between the two deficiencies in the following way

> A process analysis of mediation separates the associative chain (S→r→s→R) into two distinct parts: S - r and s - R. A production deficiency is said to occur when the implicit mediator, r, is not evoked by event S, even though the mediator is a part of the language repertoire of the learner ... A control deficiency is assumed present when the internal mediator, r, is present and elicits the internal stimulus event, s, but fails to influence the behavior under study, R.
>
> (page 4)

(iii) Active and passive strategies

The distinction drawn here is between passive acceptance of a task, with no attempt by the individual to impose any mediational strategy or organisation in order to facilitate recall, and the imposition, actively on the part of the learner, of strategies or plans for effective memorization.

Brown (1974) summarises the plight of the children with learning difficulties stating that

> ... the general consensus of opinion is that a characteristic feature of the immature memorizer should be an inadequacy in the spontaneous use of control processes, acute mediational devices, and strategic transformations of the input.
>
> (page 66)

This would appear to be the case for children with learning difficulties, as research into the use of mediational strategies in learning in many cases demonstrates. Research into the ways in which such children employ strategies to facilitate learning and recall has focussed on the following areas:-

(a) Rehearsal Mechanisms

(b) Organisational Strategies.

(a) <u>Rehearsal Mechanisms</u>

The fact that children with learning difficulties do not spontaneously rehearse information to be recalled has been extensively researched and supported. Belmont and Butterfield (1971) tested both normal and mildly retarded teenagers on a serial recall of letters task. During free recall of items, adults generally exhibit a typical pause pattern, indicative of the fact that they are taking time to mentally rehearse the items presented. This is known as the 'cumulative rehearsal, fast finish' strategy (Pinkus and Laughery, 1970), and is characterized by increasingly long pauses as the subject goes deeper into the list, but with the final few items run off quickly and not rehearsed.

Under a 'free strategy' condition, Belmont and Butterfield (1971) assessed rehearsal by measuring the mean pause time between letters. This increased over the six letters for the normal subjects, but decreased with the children with learning difficulties, which would suggest that the latter group of children was not rehearsing the information. Using a similar paradigm, but with seven items, Belmont and Butterfield (1969) found a similar absence of rehearsal in children with learning difficulties. This is supported by Kellas, Ashcraft and Johnson (1973), who found a similar lack of spontaneous rehearsal, with a resulting low level of accuracy on recall, on serial and free recall of photographs by adolescents of low intelligence. Other research has documented similar findings (Ellis, 1970; Brown, 1972).

Given that children with learning difficulties do not spontaneously rehearse, the question arises as to whether they can be trained or taught to do so, and if so, whether the learned rehearsal strategy will generalise to tasks for which it has not been specifically trained. Belmont and Butterfield (1971) found that when the adolescents were compelled to rehearse their accuracy of recall of the early letters increased significantly ('primacy' effect); similarly, prevention of rehearsal on the part of the normal subjects, produced poor recall of early letters. There is considerable evidence to support the view that rehearsal can be trained.

Butterfield, Wambold and Belmont (1973) found that training adolescents with learning difficulties in the use of such strategies improved their serial recall of letters. Brown, Campione and Murphy (1974) found that training in the use of rehearsal strategies improved performance on a 'keeping track' task; furthermore, the majority of those maintained the strategy over six months, without prior instructions to do so. Similarly, Brown, Campione, Bray and Wilcox (1973) found beneficial effects of training adolescents with learning difficulties in cumulative rehearsal, the result being a significantly increased primacy effect as well as a general increase in accuracy of recall. Kellas, Ashcraft and Johnson (1973) found beneficial effects of rehearsal training, although the evidence of such was greater when the subjects were retested using the same material rather than a new set.

Conroy (1978) used an interesting experimental paradigm with two groups of children and two types of 'cumulative' rehearsal, fast finish' strategies; the children either repeated verbally the names of objects on cards, or traced them on the table. He found that the rehearsal taught groups recalled the items significantly better than those not taught, with no differences for the type of rehearsal, verbal or kinaesthetic. This again supports the view that children with learning difficulties are capable of rehearsal, but do not do so spontaneously. Furthermore, they would appear to be able to make the transitions between the senses, since both modes of rehearsal proved equally effective.

The question that has remained largely unanswered is the extent to which rehearsal strategies taught can be generalised to new situations. However, there does appear to be evidence to suggest that children with learning difficulties can be taught to use rehearsal.

(b) Organisational Strategies

Research into the use of organisational strategies by children with learning difficulties has focussed on the use or otherwise of the three main ones:-

(b1) associative clustering

(b2) mnemonic elaboration

(b3) redundancy.

(b1) Associative Clustering

Experimental designs of research into associative clustering generally consists of the presentation of a list of words drawn from various conceptual categories, the subject being required to recall as many of the items as possible. Mature adults will tend to recall the items in conceptual categories even when the items are presented randomly, which is uncharacteristic of young children and children with learning difficulties. The fact that associative clustering increases with chronological age in children of normal intelligence was evidenced by Bousfield (1953), who compared 3rd grade, 4th grade and college students.

Rossi (1963) matched normal children and children with learning difficulties on mental age, and found both groups to cluster equally well over five training/test trials. Gerjuoy and Spitz (1966) matched normal children and those with learning difficulties on both mental age and chronological age; using this experimental paradigm, they found that the children with learning difficulties and those matched on mental age clustered well, but significantly less so than those of equal chronological age. Evans (1964) found no statistically significant differences between low and higher IQ subjects with learning difficulties in terms of clustering, although the trend suggested that those children with learning difficulties having a low IQ exhibit less clustering. The overall consensus would appear to be that children with learning difficulties do not spontaneously employ associative clustering techniques to facilitate recall.

Various methods have been adopted to improve clustering and facilitate recall of the items used during training and of other lists that are structurally similar, but different in content. The method of originally presenting the material to be recalled is one approach used. Gerjuoy, Winters, Pullen and Spitz (1969) found that clustered presentation of paired stimuli facilitated recall by children with learning difficulties, although subjects matched with these children on mental age recalled significantly better, even so. These findings are supported by Bilsky and Evans (1970); they found that organisation of the lists proved beneficial for subjects with learning difficulties in that organising the lists on the first two trials had beneficial effects on recall of two subsequent randomly presented lists, although it must be noted that they were using the same twenty word list throughout. Gerjuoy and Alvarez (1969), however, found no evidence of clustering of a randomly presented list one week after training either by subjects who had previously experienced a clustered list or those who had experienced a randomised list.

The question of whether or not induced clustering by children with learning difficulties will transfer to new material has been investigated by Bilsky, Evans and Gilbert (1972). They presented two lists of words under two conditions - random, whereby the words from the various categories were ordered randomly, or blocked, whereby all the words from each category were presented together. Subjects were assigned to three levels of list novelty for two trials, all with random presentation, following the two 'learning' trials. The conditions were, firstly, same words, same categories; secondly, same categories, different words; and thirdly, different words, different categories. The effects of original presentation and degree of list novelty on recall were then assessed. The results indicated that experience with organised lists facilitated clustering on later trials only when the same verbal materials were used for all trials. There was no transfer to novel lists and the strategy appears to have remained specific to the situation in which it was learned. Bilsky (1976) used three training schedules with adolescents having learning difficulties and examined their relative effects on clustering and recall of a transfer list that for half the subjects contained the same categories, and for half categories were different to the training list. The three schedules were firstly, blocked presentation with instruction to try and work out how the words went together; secondly, blocked presentation with labels (e.g., the next words will be colours); and, thirdly, blocked presentation but with no further instructions or assistance. The results indicated that receiving labels assisted performance during the training programme, their recall being superior to the other two conditions. This trend was also evident during the transfer phase, for both types of lists, although in each case the 'same category' list recall was superior to the 'different category' list. Burger, Blackman and Tan (1980) examined the ability of normal subjects and those with learning difficulties to maintain and generalise a learned strategy over six months. They found no difference between subgroups having had practice on training after six months, recall apparent for both. On tasks of near generalisation (recall of words generated by the subject) and far generalisation (a word elicitation task; the generalisation of words in response to a given taxonomic category or in response to a stimulus word) no differences between groups were found and both normal subjects and those with learning difficulties who had received training and practice performed better than those who had not. A recent study by Hamre-Nietupski, Nietupski, Vincent and Wambold (1982) found training in clustering visually presented objects to assist in recall by children with a mean IQ of 55-81 one week after training. Both recall of the objects used during training, and performance on a task of sorting other objects into groups was improved by training.

In general, the conclusions can be drawn that spontaneous use of associative clustering techniques is uncharacteristic of children with learning difficulties. However, it is a strategy which appears trainable, at least to the extent of it facilitating recall of materials used during the training period. Research into the question of spontaneous generalisation of this strategy to structurally similar tasks, and the ability to train this generalisation suggests little evidence of transfer overall.

(b2) Mnemonic Elaboration

Mnemonic elaboration as an aid to information recall has been studied most widely in terms of paired associate learning. An example of the way in which one might use mnemonic elaboration in this way to assist recall of two words, is to embed them within a meaningful sentence. 'Book' and 'table' to be recalled in this way, as a pair, can be linked through the sentence 'She put the book on the table.', thus more easily associating the words together. Immature young children with learning difficulties do not spontaneously adopt such a strategy, and researchers have focussed on the question of how this can be enhanced.

Shif (1969) suggests that children with learning difficulties require specific instructions in the identification and utilisation of such elaboration strategies. Taylor, Josberger and Knowlton (1972) found that through training, it was possible to induce children with learning difficulties to construct elaborative sentences, and this in turn resulted in improved performance. Turnure and Walsh (1971) found that the provision of sentences in which the words have already been embedded enhanced the performance of persons with learning difficulties on a paired-associate learning task. However, once again, relatively little transfer of the strategies to a novel but related task was apparent. Turnure and Thurlow (1973), however, did find some transfer to new lists; their training programme comprised experience with more than one set of stimuli. Generalisations would appear to be the key issue, and the value of a training programme which facilitates only maintenance, with the same stimuli, of the strategy is questionable.

(b3) The use of redundancy

The recognition of recurring and redundant patterns in material to be recalled is another strategy employed by mature adults, and yet again uncharacteristic of persons with learning difficulties. Adults tend to recognise quickly patterns such as the repetition of letters and numbers, and by manipulating the material, so reduce the demands on the information processing system in general and on short term memory in particular.

Spitz (1972) used lists of digits containing varying degrees of redundancy, and found that children with learning difficulties did not recognise the redundant elements on initial presentation. Spitz, Goettler and Webreck (1972) found that making the redundancy cues more salient improved the performance of such children dramatically. Presentation in the sequence 2, 5, 8, 2, 5, 8, facilitated recall more than 2, 2, 5, 5, 8, 8. In the same way, repeated presentations of 50% redundant digit lists (e.g. 1, 2, 3, 1, 2, 3) enhanced the use of redundancy and improved recall. Baumeister and Kellas (1971) found, however, that children with learning difficulties did not make use of the redundancy cues in a paired-associate task (such as when the two words were the same). Again, the question arises as to whether the induced use of redundancy cues is material or task specific.

In all cases, the research suggests that what is lacking in children with learning difficulties is the spontaneous use of mediational strategies, regardless of the nature of the desired strategy. Induced use of strategies of all kinds would appear possible, implying that the defect is not one of structure but of control, and in the past the research has suggested that training in the use of strategies will only be specific to the task used during training, although some more recent literature now suggests that some generalisation to novel situations is possible. Ross and Ross (1978) found effective generalisation on a multiple associatelearning task following a training programme involving imagery instruction; Borkowski and Cavanaugh (1979) cite an experiment by Kendall, Borkowski and Cavanaugh (1978) who successfully effected the generalisation of a strategy during paired associate learning, and report similar results by Belmont and Borkowski (1978), and Kahn (1977). Burger, Blackman and Clark (1981) considered the value of three types of instruction on generalisation of a verbal abstraction strategy and found all to be more successful than no training at all (surprisingly, perhaps, the group who were instructed to point out 'relevant attributes' only were equally good on generalisation as groups receiving self-management programmes whereby they asked and answered questions themselves; the view that generalisation can only be mediated by superordinate process training is questioned by this.

The difference, perhaps, comes back to the question raised earlier, in that it may be the nature of the training programme that is facilitating learning. It was argued that attribution of poor performance to structural limitations was logically impossible until all possible training programmes have been exhausted. An increasing awareness of the processes underlying verbal learning is perhaps enabling the structure of more effective training programmes. This, in turn, may improve the learning of children with learning difficulties to the point imposed by the structure of the system, which one could argue is equal to that of children with the same age, but of normal intelligence. Kramer, Nagle and Engle (1980) conclude

> The results are encouraging: however, the paucity of data makes it impossible to make conclusions with any degree of certainty about the conditions that facilitate generalisation.
>
> (Page 308).

## III MOTOR LEARNING IN CHILDREN WITH LEARNING DIFFICULTIES

Motor learning in children with learning difficulties has not been studied extensively. The approach to the issue has been less systematic than that to learning in children and adults of normal intelligence, and there would appear to be a general dearth of literature on this subject. As with the research into the area of verbal learning in such children, the design employed often compares the performance on a learning task of a group of children with learning difficulties with that of children matched on chronological and/or mental age from within the range of normal intelligence. Tasks used are often the same as those used in investigating motor learning in persons from within the range of normal intelligence, and as with such research, the focus of attention is generally directed to answering of what is learned ('product') or how one learns ('process').

If one accepts that the research into learning in persons of normal intelligence should be utilised to as great an extent as possible in order to increase our understanding of motor learning in children with learning difficulties, then one can pose certain questions regarding children with learning difficulties. On issues about which the research into subjects of normal intelligence has something to offer, it then remains to examine whether or not the research done with children with learning difficulties has anything to contribute to the issue. Questions that might be posed are the level to which children with learning difficulties are able to learn motor tasks, the way in which such children learn motor skills, and the extent to which this learning is influenced or affected by those variables known to influence learning in children from within the range of normal intelligence.

(i) Do children with learning difficulties learn to the same extent as children from within the range of normal intelligence?

The research into performance suggests that children with learning difficulties generally perform at a significantly lower absolute level than their peers matched on chronological age. In general, correlations between IQ and motor performance are also greater for children of below average intelligence than for those within the normal range.

With regard to motor learning, early work by Brace (1948) investigating the ability of girls with a mean IQ of 52.98 to learn gross motor skills such as bouncing a ball on a tennis racquet, indicate that for such subjects the relationship between IQ and motor learning is more significant than for girls of normal intelligence. Baumeister, Hawkins & Holland (1966) using a rotary pursuit task, with boys having a mean IQ of 79.3 and boys from within the range of normal intelligence, found this group was initially superior, although with practice, the group with learning difficulties eradicated the differences, coming up to the level of those of normal intelligence. Similar results were found by Ramella (1982) working with high and low achievers on a task involving pulling a yard stick 16" out of a sheath whilst blindfolded; these subjects were not strictly with learning difficulties but the trend remains constant. Porretta (1972), using a schema paradigm on a tracking task, found children with learning difficulties to perform at a lower absolute level than those matched with them on chronological age.

In general, it can be tentatively suggested that children with learning difficulties, as a group, may well perform at a lower absolute level in initially attempting the task. Dependent on the type of task, the amount of schedule of practice given, and any ceiling or floor effects that might be present, many if not all children may well be able to reach the level of performance achieved by children of equal chronological age but from within the range of normal intelligence.

(ii) Do children with learning difficulties learn motor tasks in the same way as children from within the range of normal intelligence?

This question reflects a shift in emphasis characteristic of research into motor performance and learning in children and adults of normal intelligence. The focus here is the way in which learning is brought about rather than whether or not it occurred or what was learned, and the processes involved are the issues of interest.

Schmidt (1975b) argues on the basis of research with persons from within the range of normal intelligence, that in learning a motor skill, it is necessary to extract elements of information from several experiences within a particular response class, to form a "schema" or rule for use in making future responses within that class. This would appear to be an essentially cognitive exercise, and the question remains as to whether children with learning difficulties are able to form cognitively these relationships necessary as the basis for schema and, according to Schmidt (1975b), learning.

Porretta (1982) hypothesised that in fact children with learning difficulties would in fact be unable to do this. To test the hypothesis, he used a kicking task with children with learning difficulties and those matched with them on mental and chronological age. They practised kicking for accuracy on four different surfaces or on one surface only, and a control group for each of the groups had no kicking practice, but participated in a throwing and catching task instead. All boys then attempted ten kicking trials on a new terrain. During practice, the group matched on chronological age proved superior to the group with learning difficulties and to the group matched on mental age, and with regard to the type of practice, variable practice proved less accurate than constant practice on one surface only. On transfer to the new surface, the group matched on chronological age again proved superior, but for all the groups the effect of practice schedule was such that variable practice resulted in greater accuracy than either constant practice or no relevant practice at all. These findings are comparable to those found using children and adults from within the range of normal intelligence as subjects (e.g. Moxley 1979),and it is possible to conclude, on the basis of the results that children with learning difficulties are, in fact, able to perform cognitive operations resulting in the formation of schema and the learning of multi-skills in the same way as persons of normal intelligence, although at a lower absolute level, and not as efficiently.

A feature arguably essential to learning is the ability to use feedback and knowledge of results to influence successive performances or attempts. Without an awareness of the degree of success of a response, certainly in the early stages of learning, the individual has nothing on which to base future responses.

Baumeister, Hawkins & Holland (1966) compared the learning of a rotary pursuit task by boys with learning difficulties (with a mean IQ of 79.3) with that of boys of normal intelligence and the same age, as a function of supplementary knowledge of results and practice schedule. For those with supplementary knowledge of results, a buzzer sounded whenever the stylus was in contact with the target, and the practice schedules varied according to the amount of rest between practice and test (0, 2 or 30 minutes). The results showed that supplementary knowledge of results benefitted both groups equally. Furthermore, although the boys of normal intelligence were initially superior in terms of performance, boys with learning difficulties equalled their level with practice.

Horgan (1980) also used a pursuit rotor task to investigate learning by children with IQ ranging from 60 to 75 under supplementary feedback conditions. Seven types of feedback conditions were employed - illuminated light on stylus when on target, illuminated light when off target, buzzer when on target, buzzer when off target, vibrations through the stylus when on target, vibrations through the stylus when off target, and no supplementary knowledge of results. Fifteen trials over three sessions were given. The auditory and tactile on target information proved superior during learning and all three on target types of information proved superior to those indicating the stylus to be off target. The "no supplementary knowledge of results groups" also improved over trials, their final performance being superior to the 'off target' information group. Overall, however, auditory on target information would appear to be most advantageous for this group of people.

It would appear however, that whilst one can argue in general that children with learning difficulties will benefit from supplementary knowledge of results in learning a motor task, the precise nature of that information may well be task specific. In the case of the pursuit rotor task, auditory on-target information was most advantageous, whereas Horgan (1977) found visual information to provide the greater enhancement of learning on a stabilometer task.

Ramella (1982) proposed that differences between learning by children of low and high intelligence arises because those with the higher IQ are actually coming to terms quicker with the meaning of the knowledge of results. He used a task involving pulling a yardstick 16" out of a sheath whilst blindfolded, with knowledge of results given in the form of "units" of error. High academic achievers demonstrated superiority of performance over low achievers during the early phase of learning although this difference disappeared over nine trials. Although the children involved here were not strictly children with learning difficulties, and only identified by having low grade averages, it can be seen that the hypothesis could have relevance to such children.

The incomplete picture of the way in which children with learning difficulties actually learn serves to emphasise the need for research into the area. Some insight may be gained by examination of verbal skills, but this is less than satisfactory, since the underlying processes are not necessarily the same.

(iii) Is learning by children with learning difficulties influenced by the same variables as those affecting learning by children from within the range of normal intelligence?

Once again, research that might attempt to answer this question is not as prolific as is desirable. However, two areas which have received attention are the areas of overlearning and practice scheduling. Both these factors are shown to influence learning and performance when subjects from within the range of normal intelligence are studied. Consequent on these findings, some researchers have considered their effect using children of below average intelligence as subjects.

With regard to the effects of overlearning, Melnick (1971) for example, found overlearning on a stabilometer task (50%, 100%, 200%) to be advantageous for future recall using subjects of normal intelligence. Chasey (1971) allocated teenagers with an IQ ranging from 15-94 to one of two groups who learned a diagonal hop and a double hop (two feet together). One group practised until they had completed the task once without error, and the other group until they had completed three successive performances without error. Retesting took place 4 weeks later whereupon the overlearning group recalled the task significantly better than those who had only achieved one performance without error.

Using a similar group of adolescents, with IQ ranging from 12 - 69, Chasey & Knowles (1973) examined the effects of overlearning a beanbag throwing task. However, they also divided the adolescents into three groups labelled mildly retarded (IQ 50 - 69), moderately retarded (IQ 35 - 49) and severely retarded (IQ 12 - 34). Subjects attempted to hit the centre of a circular target and scored according to proximity to the centre. Two throwing distances of 8 ft and 16 ft were used. At 8 ft learning was deemed to have occurred when the subject accumulated 10 points in 3 consecutive throws, and at 16 ft when he achieved 6 points in 3 consecutive throws. The learning group stopped practising when this criterion was reached, whereas the overlearning group continued until they had achieved the criterion on three successive occasions. After five weeks, retention of the task was measured as well as the number of trials required to reach the criterion again. Chasey & Knowles (1973) found a significant effect for level of retardation at 8 ft, the mildly retarded group performed better than the moderately retarded and the moderately retarded better than the severely retarded. At 16 ft the mildly and moderately retarded groups performed equally well and in both cases better than the severely retarded. An effect for degree of learning was found at 16 ft in favour of overlearning. The level of retardation and degree of learning interaction revealed overlearning to be even more important for the severely retarded group than the other two groups. Chasey (1976) subsequently used a stabilometer task to investigate degree of learning required but with a narrower IQ band of 36-54. Using 0%, 50%, 100% and 200% overlearning, he found degree of overlearning significant on retest eight weeks later.

On the question of overlearning, the research suggests that as with children of normal intelligence, the amount of original learning of a task is an important factor in its recall over long periods of time. Chasey & Knowles (1973) suggest that the greater the degree of retardation, the more important it becomes.

With regard to the effects of massed and distributed practice scheduling on learning and performance, the research using subjects from within the range of normal intelligence would suggest that massing practice may have a detrimental effect on performance at the time, but not on the overall learning process since the decrement in performance tends to disappear after test and on transfer to a more sympathetic regime (e.g. Stelmach 1969).

Bassin & Webster (1973) used a pursuit rotor task to determine the type of practice schedule that would most facilitate learning by children with IQ ranging from 36 to 67. Using two practice schedules of 20 seconds practice, 20 seconds rest and 20 seconds practice, 0 seconds rest, they found that the group operating under the first schedule were superior during the 20 pre-test trials. However, after the 5 minute rest, the massed practice group demonstrated a significantly higher reminiscence score, with the result that there was no difference between the groups. This would indicate that children with low IQ exhibit learning profiles comparable with children of normal intelligence when practice schedule is the variable manipulated.

Chasey (1976) using a stabilometer task to study the effects of practice scheduling on performance and learning by boys with IQ ranging from 27 to 48, aged 11 years. He found distributed practice scheduling to be superior to massed scheduling both in terms of initial acquisition and retention, but found no significant difference between the two groups for relearning, which he took to indicate the scheduling of practice to be a performance rather than a learning variable.

Auxter (1971) used a stabilometer task to compare reminiscence in children with learning difficulties with that of children of normal intelligence, as it relates to age. The practice schedule was standardised for all, and he compared two groups of children of normal intelligence aged 9-11 years, 15 - 17 years, with two groups of similar chronological age but with IQ ranging from 50 and 74. He found that the older group of normal intelligence was significantly superior in terms of reminiscence effect than the other three groups, there being no difference between the two low IQ age groups, which would would indicate that whereas reminiscence is age related in children of normal intelligence, this is not true of children with learning difficulties. In their case, rest would not appear to facilitate improvement in performance, but perhaps enhance forgetting. This finding is supported by research by Ellis, Pryer & Barnett (1960), using a pursuit rotor task.

One further issue that had received attention relative to children with learning difficulties, is the question of the effects of praise, encouragement and incentives. Holland, Friedrich & Hawkins (1974), using a pursuit rotor task, found children from within the range of normal intelligence to increase their superiority over those with a mean IQ of 72.5 as trials progressed, but for both groups, those subjects given incentives in the form of a penny each time they passed their previous time on target score, improved their performance beyond that of those not receiving incentives. This was particularly the case for the children with learning difficulties. Ellis & Distefano (1959) found similar beneficial effects of urging and praise on subjects with an IQ of approximately 52 attempting to perform a pursuit rotor task. Heitman, Justen & Gilley (1980) however, found high MA subjects (MA ranging from 8 to 12 years, IQ ranging from 55 - 75) to benefit more than low MA subjects MA ranging from 4 to 7 years, IQ ranging from 55 - 75) on a marble placing task from verbal praise. They suggest that the effect of the verbal was to sensitise the subjects to attend to knowledge of results. Fueyo, Saudargas & Bushell (1975) found that in the teaching of two swimming skills, task specific praise plus corrections resulted in faster learning than non-specific praise, with two boys and two girls attending special classes for the educable mentally retarded.

In general, the research here would suggest that praise and encouragement have a beneficial effect on learning in children with learning difficulties. This is true also of children from within the range of normal intelligence.

The research into learning by children with learning difficulties is very incomplete, serving to emphasise the need for such. Experimental paradigms etc. may be 'borrowed' from the research with children from within the range of normal intelligence, but since it is a relatively new area of interest by comparison, it should be possible to make the investigation into learning by such children more systematic and thorough. It would appear, however, that there may be certain rules regarding learning that are generalisable to persons with learning difficulties, although great care should be taken in doing so.

# CHAPTER FOUR

# THE CLASSIFICATION OF TASKS

The need for a task classification scheme in the study of skilled behaviour is self-evident. If one is to attempt to understand the processes involved in learning and performing skills, it is necessary also to understand the nature of the skills concerned. Certain taks have features in common and identification of these features and commonalities has value insofar as it allows certain generalisations to be made and facilitates the study of skilled behaviour in general.

In performing a task, the individual brings to the task certain resources and certain limitations imposed both by his personal ability in the sphere of operation, and by the natural limitations of the human body. A task will also impose limitations and demands on the individual, the precise nature of the demands being task specific, although tasks of a given kind will impose demands similar in certain respects. Task classification schemes attempt to extract these distinguishing features or commonalities, to provide a framework for analysis of the performance and learning of motor tasks.

The precise form taken by skill and task classifications has varied considerably, as have the dimensions used. One dimension along which skills have been classified is the discrete - continuous dimension. Discrete tasks are those which have a definite beginning and end, such as throwing a ball or picking up a pen. At the other end of the continuum lies tasks classified as continuous which have no recognizable beginning or end and which will proceed until arbitrarily stopped. Driving a car along a road and tracking tasks, such as the pursuit rotor, are typical continuous tasks. Between these two extremes lie serial tasks which fundamentally are a series of discrete tasks put together sequentially to form a whole unit, such as when starting up a car, the important feature being the sequential organisation.

A second dimension along which skills can be classified is that originated by Poulton (1957). He classified skills into open and closed skills dependent upon the nature of the prediction required for successful execution. Closed skills were so termed because

> ... the performance can be carried out without reference to the environment.
>
> (page 472)

Poulton (1957) defined an open skill as one

> ... which has to fit either an unpredictable series of environmental requirements or a very exacting series, whether predictable or unpredictable.
>
> (page 474)

Poulton (1957) distinguishes further between five types of skill.

(i) Open skill without advance information. This is the least predictable of all and the response must be made to a constantly changing environment such as in returning a shot during a game of tennis when the ball has caught the top of the net on its way over.

(ii) Open skill with advance information such as in catching a ball thrown.

(iii) Closed skill with predictable requirements. Poulton (1957) cites the example of dealing cards into four piles around the table.

(iv) Closed skill without external requirements, such as writing one's name in the air.

(v) Open skill with exacting positional requirements, such as negotiating one's way through very narrow streets in the car, or through bollards in rally competitions.

Knapp (1963), extrapolating from the work of Poulton (1957), postulates that the classification is more of a continuum, with skills that are predominantly 'habitual' at one end (closed) and those which are predominatly 'perceptual' (open) at the other. She states that for the habitual skills

> ... 'conformity to a prescribed standard sequence of motor acts' is all-important...
>
> (page 152)

whereas, at the perceptual end of the continuum are skills in which

> ... 'at every instant the motor activity must be regulated by and appropriate to the external situation' ...
>
> (page 152)

A classification of tasks along lines similar to open and closed, is the characterisation of tasks as externally paced or self paced. In a self paced task, the object or environment is stationary and the performer is able to commence the movement in his own time, such as in serving in tennis. For tasks classified as externally paced, the temporal execution of the task is dictated by the environment or object in motion, such as in returning the service of the opponent. This classification can again be seen as a continuum, with self-paced and externally paced tasks at opposite ends, along which particular tasks can be placed dependent on the degree of control on the individual exercised by the environment. Tasks lying somewhere between the two extremes are termed mixed paced; either the person or the environment is stationary, but not both. Externally paced and open skills are probably very similar, as would be self-paced and closed skills.

These continua, both separately and together, have been widely used in the study of learning and performance to understand the way in which different task demands affect performance. The concept of continua is particularly useful in that it allows tasks to be classified relative to one another rather than in separate 'boxes' into which particular tasks do not necessarily fit exactly.

Gentile, Higgins, Miller and Rosen (1975) expanded the open-closed concept of classification, and include in their classification the nature of the movement required by the task, along with the classification of open or closed dependant on the nature of the environmental control. (See Figure 4.1).

The nature of the movement is broken down into total body stability and total body transport, which is then subdivided into

Figure 4.1: <u>Taxonomy of Skill</u> (Gentile, Higgins, Miller and Rosen, 1975)

| Nature of Environmental Control | Nature of Movement Required by Task | | | |
|---|---|---|---|---|
| | Total Body Stability | | Total Body Transport | |
| | No LT/M* | LT/M | No LT/M | LT/M* |
| Closed (Spatial control: stationary environment) | Sitting<br>Standing | Typing<br>Writing | Walking<br>Running | Carrying or handling objects during locomotion<br>javelin throw |
| Open (Temporal/spatial control: moving environment) | Standing on a moving train<br>Log rolling<br>Riding an escalator | Reading a newspaper on a moving train<br>Skeet shooting<br>Batting in baseball | Dodging a moving object<br>Walking in a moving train<br>Dancing with a partner | Run and catch a moving object<br>Throwing on the run<br>Dribbling in basketball |

*LT/M = Independent limb transport and manipulation, usually involving maintaining or changing the position of objects in space.

independent limb transport and manipulation, usually involving the maintenance or change of the position of objects in space, and no such limb movement. This results in eight types of tasks or skills, as which tasks under study may be classified and placed within the framework. The only problem with the classification of Gentile, Higgins, Miller & Rosen (1975) is that it fails to account for differing amounts of limb transport and manipulation.

Spaeth-Arnold (1981) elaborated the work of Gentile, Higgins, Miller and Rosen (1975) further, to allow for an understanding of the way in which children's activities could be accommodated within the scheme.

The original work in task taxonomy which related the issues of body involvement and environmental control was by Fitts (1965). He admits it to be a gross classification, but it formed the basis of future work, such as that of Gentile, Higgins, Miller & Rosen (1975) and Merrill (1972). In the same way as Fitts ' (1965) classification, Merrill (1972) viewed the degree of difficulty to be fundamental. He depicts Fitts' classification graphically, as can be seen in Figure 4.2, with examples of typical tasks. Merrill (1972) however, argues that the Fitts ' (1965) taxonomy focuses on only one of three possible areas of psychmotor skill, that of complex skill, and excludes stimulus response learning and chaining.

The classification by Fitts (1965) fails to acknowledge the way in which part body movement contributes to overall task performance in the same way as is possible with the Gentile, Higgins, Miller and

Figure 4.2: Task constancies relating conditions of the body and an environmental object during the interval prior to initiation of response

| | | |
|---|---|---|
| BODY AT REST | TYPE 1<br>e.g. Drive golf ball<br>Pick up pencil<br>Thread a needle | TYPE II<br>e.g. Hitting a baseball<br>Aiming gun at duck<br>Following rotary pursuit |
| BODY IN MOTION | TYPE III<br>e.g. Shooting a layup (basketball)<br>Throw to first base (shortstop) | TYPE IV<br>e.g. Aiming at aircraft from pitching ship<br>Throwing a running pass to moving receiver (football) |

Rosen (1975) scheme. It is perhaps more limited in its application, since there would not appear to be a place within the framework for activities such as sitting and standing. These would presumably be classified as Type 1 tasks, although they would appear fundamentally different to the examples given.

Quite a different approach has been adopted to the classification of tasks by Smith and Smith (1966) and Frohlich (1983). Smith and Smith (1966) identify three types of task, postural, locomotive and manipulative. To these three, and using the term 'motor goals' rather than types, Frohlich(1983) adds to the three postulated by Smith and Smith (1966) one more, environmental goals. This is shown in Figure 4.3.

Frohlich (1983) argues that the four goals are hierarchical in nature, with postural at the lowest end and environmental at the top. He suggests that tasks are characterised by their highest level goal since the higher levels will automatically involve lower level goals. He gives the example of threading a needle, which he states is an environmental goal, but which will involve postural changes (preparatory alterations of limb positions) and manipulation (picking up the objects). Frohlich (1983) further recognises the importance of internal and external contextual constraints placed on the person, such as the configuration and dynamic condition of the limb system (internal) and the environment (external), as well as the constraints imposed on the individual, including developmental and experimentail constraints.

Widdop (1981) expands the concept of open and closed skills, relating it to the teaching and coaching of the skills. She argues

Figure 4.3: Four types of motor goals (Frohlich 1983)

| NAME | DEFINITION | EXAMPLES |
|---|---|---|
| POSTURAL | Those requiring a change in the relation between limb segments. | Facial expression/self-grooming |
| LOCOMOTIVE | Those requiring a non-manipulative change in the relation between actor and environment | Walking/running/jumping/climbing |
| MANIPULATIVE | Those requiring a manipulative change in the relation between actor and environment | Feeding/examining objects |
| ENVIRONMENTAL | Those requiring a manipulation of one part of the environment relative to another | Construction/target acquisition |

that however small the temporal demand of the environment or task is, it becomes 'open', until such time as the temporal consideration no longer influences the performance, such as when a skating routine is mastered. She adopts the concept of a 'Y' analysis stating that all skills should be taught initially in a closed environment, which she designates as the top left point of the 'Y'. Practice is given over a period, and then at the intersection of the 'Y' if the skill is closed practice continues down the stem, as it were, and if it is potentially open, then practice continues up the right side. She argues that the 'Y' could even be seen as being diamond shaped with progression from the 'open' point to the closed point at the end of the inverted 'Y', when temporal influences are no longer significant. Although this concept may be useful in the teaching of some skills, it does not differentiate between the tasks in the way in which a formal classification (e.g. Merrill 1972) does.

The development and learning features are also recognised in the task classification by Singer and Gerson (1981). They argue the case for a three factor task classification mode, which recognizes the importance of environmental or pacing considerations, and the potential use of ongoing or terminal feedback as distinguishing features of tasks. The third factor in the scheme

> ... reflects the processing mechanisms within the human behaving system that have the greatest impact on the learner's use of information inherent in a motor learning situation ....
>
> (page 103)

These mechanisms are identified as sensory - perceptual mechanisms, short and long term memory mechanisms, and the movement generator -

effector mechanism. The classification scheme results in eighteen cells into which tasks can be placed

> ... depending on their characteristics and the demands placed on learners. Some tasks are relatively easy to classify, others not. As to the dominant processing mechanism, much will depend on the person's skill level and the context in which the task objectives are to be realized.
>
> (page 103)

This is shown in Figure 4.4.

In the same way as Singer and Gerson (1981) recognise the importance of the level of learning and development, Keogh and Sugden (in press) also consider the resources of the individual learner or performer. Whilst not a strict task classification scheme, it is a different approach to movement and movement difficulty. They state that

> the interplay of <u>mover</u> and <u>environment(s)</u> creates a movement problem and a related <u>movement task</u>. <u>Environmental conditions</u> and task <u>requirements</u> are balanced against the <u>resources of the mover</u> to establish <u>level of individual demand</u> for a movement situation.

The concept of 'level of demand' is further exemplified by the diagram in Figure 4.5 reflecting the effects of these factors on it.

The level of demand placed on the individual will depend largely on his stage of development; a task such as tying shoelaces is very difficult for a young child, but simple to an adult, the same task resulting in high demand for the child, but low demand for the

Figure 4.4: Task classification scheme (Singer & Gerson, 1981)

| | FEEDBACK UTILIZATION | | | | | |
|---|---|---|---|---|---|---|
| | Continual (closed, ongoing) | | | Terminal (open, subsequent) | | |
| | DOMINANT PROCESSING MECHANISM | | | | | |
| | Sensory-perceptual Mechanisms (input operations) | Short & Long Term Storages (central operations) | Movement Generator & Generation (output operations) | Sensory-Perceptual Mechanisms (input operations) | Short & Long Term Storages (central operations) | Movement Generator & Generation (output operations) |
| Externally-Paced | | | | | | |
| Mixed-Paced | | | | | | |
| Self-Paced | | | | | | |

adult. Keogh and Sugden (in press) go on to state

> If movers have more personal resources, they can function more adequately in a movement situation. Changes in mover resources, therefore, become the key to understanding changes in movement development.

Examination of the various skill classification schemes would appear to highlight certain features as being important, and which it would be necessary to include in any complete skill classification scheme.

(i) The dynamism of the environment.

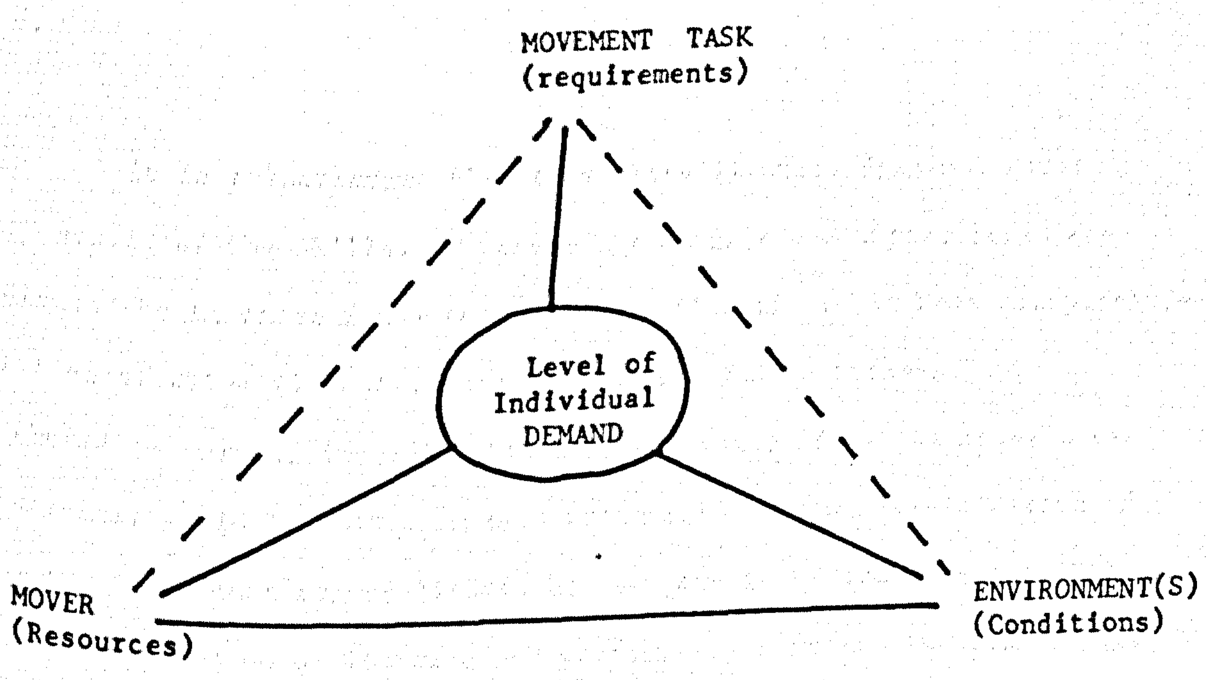
(ii) The dynamism of the total person.

(iii) The dynamism of the body parts.

For the purposes of this study, the classification that will be used considers these three elements. Whilst it is conceded that there are disadvantages to classifications that attempt to allocate tasks to "boxes", it is considered that when three elements are involved, the concept of a continuum is difficult to employ to advantage. The classification to be used is shown in Figure 4.6.

The only way in which the continuum is useful within the proposed classification scheme is to relate the degree of body part involvement of one task to another, from maximum to minimum. This is the fundamental difference between the classification scheme proposed here, and that of such as Gentile, Higgins, Miller & Rosen (1975).

Figure 4.5: A general representation of a movement situation
(Keogh & Sugden, in press)



Tasks can be placed into the category thought to be the most suitable, although it is acknowledged that within each category, differences in terms of degree, of for example, body part movement, will exist. Movement of two or three parts of the body, for example, particularly in some coordinated sequence, will be more demanding than one part only. However, the nature of the demands will be of the same kind.

It is acknowledged that this classification does not cover every aspect of the skills. However, the three elements postulated are considered to be those fundamental to classification. It does not preclude inclusion of other elements, such as discrete and continuous, but one should be wary of including too many elements, since the result, taken to extremes, would be that each task woüld fall into a classification of its own. In essence.commonalities between the tasks are more important to the student of motor learning and performance than are the differences between them, once the fundamental differences have been established.

Figure 4.6: Proposed task classification scheme

| ENVIRONMENT STATIONARY | | | | ENVIRONMENT MOVING | | | |
|---|---|---|---|---|---|---|---|
| WHOLE BODY STATIONARY | | WHOLE BODY MOVING | | WHOLE BODY STATIONARY | | WHOLE BODY MOVING | |
| BODY PART(S) STATIONARY | BODY PART(S) MOVING | BODY PART(S) STATIONARY | BODY PART(S) MOVING | BODY PART(S) STATIONARY | BODY PART(S) MOVING | BODY PART(S) STATIONARY | BODY PART(S) MOVING |
| | min ⟷ max | | min ⟷ max | | min ⟷ max | | min ⟷ max |

# CHAPTER FIVE

# PURPOSE AND RATIONALE OF THE THESIS

Several features of the motor learning of children with learning difficulties become salient and are of interest when the research surveyed and cited here is considered. The primary focus of concern is motor learning by children with learning difficulties, how this is brought about, and the way in which it may or may not differ from motor learning in children from within the range of normal intelligence. Much of the research cited regarding children with learning difficulties makes comparisons between them and children matched with them on chronological or mental age. However, use of one of these matched groups only fails to give an understanding of how the processes involved change with age for children from within the range of normal intelligence.

Comparisons are therefore necessary of children with learning difficulties with children matched on both chronological age and mental age in order to assess whether learning and performance is more closely correlated with chronological or mental age, and to consider the issue of whether any decrement in level of performance is atrributable to a developmental lag or to the existence and use of different underlying processes. Mental age is assessed using the formula $MA = \frac{CA}{100} \times IQ$. Interest in the motor learning of children with learning difficulties also focusses attention on their relative performance at the various stages of learning, including during practice, on recall and on transfer to a novel version of the task, since any differences between the level of performance of the groups may occur at one, two or all of these stages, with different inferences accordingly. The performance of the groups at each of these stages must, therefore, be analysed, in order that a full picture be established.

With regard to the way in which learning is brought about, Schmidt (1975b) postulates a 'schema' theory of learning. This will be considered in fuller detail in Chapter Six, but the fundamental tenet is the development of 'schema', sets of rules or abstractions as a basis for responses of a given class. These are developed through cognitive processes, extracting elements and relationships between experiences. The question that is posed is whether or not children with learning difficulties are able to perform these cognitive exercises in the same way and to the same extent as are children from within the range of normal intelligence. Variability of practice is hypothesised as fundamental to the development of schema. Practice of different types, therefore, needs to be given to examine the relative effects of such on each of the three groups of children.

One feature of the research cited is the anomalies that exist between findings, in several cases. It is possible that this is the result in part of the different tasks used making different demands on the resources of the individual, some of which children with learning difficulties, for example, are more able to cope with than others. The task classification scheme wasproposed in order to give some structure to the research. Examination could then be made into the question of whether differences and similarities between groups are consistent at all types of tasks, or whether the different types of tasks would result in different patterns of learning for the three groups, since the different types of tasks make different demands on the resources of the individual. If the task classification scheme is sound, one would also anticipate similarities in the patterns of behaviour for tasks from the same category. The five tasks employed here are representative of three categories from the scheme.

Bearing all these features in mind, the following design was established for the thesis. As has been stated, five tasks were chosen, representative of three of the categories within the task classification scheme proposed. In all cases, a group of children with learning difficulties aged approximately 12-13 years is matched with two groups on mental and chronological age. The children are then exposed to practice at the task, subgroups being established within the three groups for whom the practice required or task demands vary. Recall of the task and transfer to a novel version of the task are also considered in most cases. Comparisons are then made between the three groups and the practice regimes for each study at all stages of learning, with discussion of the implications of the results in all cases. Some consideration of the relative performance of individuals within the group is also undertaken in view of suggestions regarding greater variability within groups of children with learning difficulties in particular. A final summary and discussion with respect to the performance of the three groups over the five tasks relative to the task classification scheme is presented. Using this overall design, it is hoped that some insight into motor learning by children with learning difficulties and their counterparts matched on chronological and mental age, will be achieved.

# CHAPTER SIX

## AN INVESTIGATION INTO THE EFFECTS OF DIFFERENT TYPES OF PRACTICE ON LEARNING TWO DISCRETE BALLISTIC TASKS BY CHILDREN WITH LEARNING DIFFICULTIES AND CHILDREN MATCHED WITH THEM ON CHRONOLOGICAL AGE AND MENTAL AGE

# I INTRODUCTION

The question of how one learns to perform skills has been the focus of attention of many researchers since the turn of the century. Interest in this issue has given rise to various theories of learning, such as those of Thorndike (1927) & Hull (1943). More recently, two theories specifically related to motor learning have emerged, those of Adams (1971) and Schmidt (1975b).

## (i) Theories of motor learning

On the basis of experimental evidence from slow positioning tasks, Adams (1971) postulated a closed loop theory of motor learning, which stated that learning is largely error based, in that it occurs through comparison of the feedback from the present response or movement with a reference of correctness that is built up as a function of practice at the task. Subsequent responses are then organised in the light of the previous ones. Adams (1971) proposes two states of memory, termed the memory trace and the perceptual trace. The role of the memory trace is

> ... to select and initiate the response, preceding the use of the perceptual trace. The memory trace must be cued to action, and the strength of it grows as a function of practice trials.
>
> (Page 125)

As such, the memory trace is analogous to recall memory in verbal learning. The perceptual trace is the template against which the movement response, once initiated, is compared. It is the internalised ideal or image of the movement, up to which the response will be matched. Adams (1971) defines the perceptual trace as

> ... the construct which fundamentally determines the extent of movement and it is what S uses as the reference to adjust his next movement on the basis of KR he has received. Beginning the movement brings an anticipatory arousal of the trace and the feedback from the onging movement is compared with it.
>
> (Page 123)

Adams (1971) was the first to attempt to separate the selection of a movement response from the performance of it; this separation can be seen to be acknowledged, although in modified forms, in theory and research a decade later.

Fundamental to the development of these two traces is practice, which Adams (1971) views as the repetition of the actual movement to be learned. He states

> ... there is nothing to contradict the assumption that acquiring the perceptual trace is by stimulus contiguity.
>
> (Page 123)

and of memory trace,

> Strength is a function of stimulus - response contiguity
>
> (Page 125)

This was partially supported by early work by Adams (1954) who found single instance practice in general superior to multiple instance practice on a problem solving task requiring deductive inference.

On transfer to a novel, but related problem, although the multiple instance practice group was initially superior, the single instance practice group was more effective overall. Adams (1954) states that although varied practice may make for smoother initial transfer, the single instance is the better for permanent learning. The Adams (1971) closed loop theory of motor learning was the first occasion on which a theory had been based on sound experimental evidence. Furthermore, it provoked a great deal of experimental research following the exposition of the theory, both confirming and negating various features. Amongst this was the research by Schmidt.

Schmidt (1975b) criticizes the Adams (1971) theory on several counts:-

(a) Limitation to positioning responses. Schmidt (1975b) questions whether this narrow task is representative of all skills and whether generalisations can be made from this task to others, fundamentally different. He argues that it fails to account, for example, for fast ballistic skills, such as throwing, in which continuous feedback is not available, nor is ongoing correction possible.

(b) The error detection mechanism. Since the perceptual trace is used to guide the movement until it is correct, at the termination of the response the difference between the perceptual trace and incoming feedback is necessarily zero. Schmidt (1975b) argues that because of this no information about the actual success or error of the response is produced or is available for future reference, although Adams (1971) argues that this is the precise type of information required.

(c) Learning without knowledge of results. Adams (1971) argues that during the latter stages of learning, when the perceptual trace is well established, the absence of knowledge of results will not prevent the continuation of learning. Schmidt (1975b), however, argues that since the perceptual trace on the first trial without knowledge of results will be the basis for the initiation of future response, and this is necessarily zero, improvement in performance would seem logically impossible.

(d) Perceptual and memory trace development and the novelty problem. Adams (1971) states that the cornerstone of trace development is repetition practice. However Bartlett (1932) states

> When I make a stroke I do not, as a matter of fact, produce something absolutely new, and I never repeat something old.
>
> (Page 202)

Bartlett (1932) argues that the learning and performance of skills, certain elements will inevitably vary from trial to trial, such as the precise starting point of the limb, the body position and the environmental conditions. The fact that one is able to cope with this suggests that the performer does not have to have executed the response before in order to do so successfully. Schmidt (1975b) argues that the Adams (1971) theory does not account for this. Consequent on this fact, constant practice at a task may not be the best way of learning since in the novel or transfer condition variable practice in a series of related skills may engender better transfer to the new situation.

(e) The storage problem. Adams (1971) theory implies a stored reference of correctness for every movement response and whilst there is no evidence that this is not possible, the demands made on the storage system would seem very large, and as such, unlikely.

On the basis of these criticisms and in an attempt to account for many of the problems raised, Schmidt (1975b) postulated a schema theory of discrete motor skill learning. He restricts the theory to discrete tasks because, he argues, continuous tasks have a

> ... rather complex simultaneous interaction between sensory input and motor output ...
>
> (Page 230)

although he does not preclude the possibility that the theory may have a role to play in understanding such tasks.

(ii) <u>The Notion of Schema</u>

The notion of 'schema' itself originates with Head (1926) and Bartlett (1932). Schmidt (1975b) uses Evans' (1967) definition:

> A schema is a characteristic of some population of objects, and consists of a set of rules serving as instructions for producing a population prototype (the concept).
>
> (Page 233)

Similarly, Attneave (1957) explains the concept in the following way

> ... the schema consists, at least in part, of some representation of the central tendency or commonality of the class of subjects in question ...

(iii) Schmidt's (1975b) schema theory of discrete motor learning

Schmidt (1975b) takes the concept of schema, and relates it specifically to motor learning. He views the schema as a relatively stable and permanent construct, although to a certain extent dynamic in that it is subject to modification, which is representative of a class abstractions or rules about those events. It is built up as a result of practice and experience within the particular class of response, on the basis of four types of information available after a response is made - initial conditions, response specifications, sensory consequences and response outcome. It is not actual experiences that are stored in the memory, but rather the interrelationships between elements of the experiences (thus reducing the amount of material actually stored). It is argued that the schema strengthens as a result of practice within the response class, although one can only conjecture at the size and properties of a response class.

Miller and Krantz (1981) found significant covariation on 6 of 10 isomorphically related fine and gross skills, arguing that the schema may be responsible for the integration of some skills in this way. Others would argue that the response class is very much smaller than this.

Since it is the relationships between the experiences that form the basis of schema, variability of practice becomes the cornerstone of learning, in direct opposition to Adams (1971) theory, which advocates constant practice of the specific movement response.

In this way, three factors become fundamental to schema theory:-

(a) the generalised motor program

(b) the separation of recognition and recall memory

(c) the amount and variability of practice,

each of which will be considered in turn.

(a) The generalised motor program

Keele (1968) defines a motor program as a sequence of stored commands that is

> ... structured before the movement begins and allows the entire sequence to be carried out uninfluenced by peripheral feedback.
>
> (p.387)

Evidence for centrally controlled movement goes back to Lashley (1917), who found that a patient with gunshot wounds in the back preventing any afferent information, was able to perform positioning movements accurately. More recent research, using cuff techniques to generate temporary absence of afferent information, such as that by Laszlo (1967), confirms that this is the case. Evidence for motor programming is also drawn from research into the limitation in the use of feedback. Since feedback information cannot be utilised to advantage in correcting movement in less than one reaction time (approximately 120-200msecs) movements lasting less than this period of time must be under central as opposed to peripheral control. Research with birds and animals also suggests the existence of motor programing. Wilson (1961) for example, deafferented the wings of locusts, but found that when they were stimulated electrically they exhibited wing movements resembling flying, albeit the amplitude of the movements was reduced; Taub, Perrella and Barro (1973) found monkeys able to perform accurate and coordinated movements following deafferentation and without vision. Although, as Pew (1974) points out, there is no direct human evidence for a motor program, and the argument is largely a default one, the weight of evidence appears to come down on the side of the existence of motor programs.

Schmidt (1975b) argues the case for a slight modification to the original concept of the motor program, in that whereas previous definitions have indicated the existence of a motor program for every movement, he argues the case for a generalised motor program for a given class of movements. The actual size of the class is a matter of debate, but Schmidt (1975b) argues that it is the generalised concept that is important. This generalised motor program is then adapted to suit present needs. Schmidt (1975b) states:-

> These generalised motor programs are assumed to be able to present the prestructured commands for a number of movements if specific response specifications are provided.
>
> (Page 232)

(b) Recognition and recall memory

Schmidt (1975b), like Adams (1971), argues the case for two states of memory, although they differ significantly from the Adams (1971) concept, in the role that they play. Recall memory is responsible for the production of the movement and recognition memory is responsible for the evaluation of the response and any corrections possible to the ongoing movement. In this way, schema theory overcomes the problems faced by the Adams (1971) closed loop theory of having two processes executed by the same mechanism. It is hypothesised that in order to make a response, the performer requires information about the present state of himself and the environment in relation to the overall goal (initial conditions). Drawing on the appropriate schema, he generates response specifications which are the parameters for the motor program, and with this, a series of sensory consequences expected as a result of the response, which is then initiated. This is entirely the role of the recall schema. Recognition memory then comes into play in that it evaluates the success of the response made and in the case of slow positioning movements enables corrections to be made to the ongoing movement response. The sensory consequences of the movement are then compared with those expected, and the actual outcome response examined in relation to the intended goal and the response specifications made. This information is then fed back into the schema, which is strengthened further by the added experience, and future responses are made on the basis of the 'modified' schema. Since the performer is drawing on a schema, and not a particular stored response, he does not need to have experienced a movement previously in order to execute it successfully. In this way, the schema theory (Schmidt 1975b) overcomes the problem of novelty faced by the Adams (1971) theory.

### (c) Amount and Variability of practice

Fundamental to the development of schema is the concept of variability of practice, which Schmidt (1975b) views as the cornerstone of learning. Learning by definition cannot occur without practice; an amount of practice is therefore necessary to the development of a schema. The actual amount of practice necessary will vary from task to task, and from individual to individual, but nevertheless, it is fundamental to the development of any schema. The hypothesis that variability of practice is essential to learning has provoked a great deal of research, although the greatest part of it has been done using adults as subjects.

The experimental paradigm generally used to test the variability hypothesis employs at least two groups, one of which practices a single version of the task over a given number of trials, whilst the other group(s) experiences an equal number of trials in total, but at two or more versions of the task. One element, such as distance, angle, weight of object etc., is manipulated throughout. Following the practice or acquisition phase, all subjects are then tested, usually without knowledge of results, at the task practised by the single instance group and/or a variation of the task, novel to all groups. This paradigm has been used to test both recall and recognition schema.

(i) Recall Schema

(ia) Constant vs. Variable Practice

Research with Adults

The results of research with adults suggest limited support for the superiority of a variable practice regime over a constant practice regime. McCracken and Stelmach (1977), using a task requiring execution of a movement in 200 msec exactly, found limited support for schema theory on transfer when absolute error (AE) alone was considered. Margolis & Christina (1981) had adult subjects wear prism glasses and perform a rapid aiming task, and found that groups with variable target practice had less error both on initial transfer to the novel target and throughout the twenty transfer trials, than groups with single instance target practice.

Zelaznik (1977) also used a rapid timing task with variable practice at three distances or constant practice at one distance, and found no difference between the groups on transfer. The significant point, however, is that on examination of the means, the variable practice group appears inferior to the constant practice group in terms of accuracy of performance. In this case, however, the transfer target was closer to the constant practice target than those practised by the variable practice group; the fact that proximity may be more influential than type of practice needs consideration.

Wrisberg & Ragsdale (1979), using a coincident timing task, required subjects to either watch a stimulus moving or to respond to it with the nonpreferred hand. Subgroups were established whereby the stimulus moved either at a constant velocity over trials, or at different velocities, varying from trial to trial, the high stimulus variability and the high response requirements contributed to significantly lower AE on a criterion transfer task.

Research with Children

Research into the effects of variable practice on recall schema with children includes that of Kerr & Booth (1977), who used a beanbag throwing task with children aged 7 to 9 years. Varying the distance thrown, they found significantly less AE, CE (constant error) and VE (variable error) on the part of those having experienced variable practice than those having experienced the criterion distance only, when all children attempted the criterion. Carson & Wiegand (1979) varied the weight of beanbags thrown, and found that on transfer to a weight novel to all group trained at four weights record significantly less error than a group trained at a single weight only. Similar results were obtained by Kelso & Norman (1978) who used a linear slide task with children aged three years. The variable practice group, who had practised at four different target locations, were superior in terms of AE, CE and VE to the constant practice group, who had practised at one target location only, on transfer to novel criterion distances both inside and outside the range of the practice targets. Reservation must be expressed, however, about this work; working with children so young, on a relatively complex task in this way must surely have met with problems of attention, motivation etc. such that the experiment could not have been strictly controlled.

Kerr (1982a) working with blindfolded children aged 12-14 years, on an angular positioning task, varied the number of target positions (1 or 6) and the way in which the movement was made during practice (fixed, whereby they moved the stylus along the edge of a metre rule to the stop; limited in which the subjects were free to move the rule to the position they desired, but then had to move the stylus along it; free, with no rule, so that they moved freely to the target). Two test targets were then presented with four trials to each. Distance and degree of error were measured. In terms of AE, no differences between the specific and varied groups emerged, giving some support to schema theory, but for VE, the constant practice group evidenced less variability. This supports work done by Kerr (1982b) with adults on the same task, in which constant and varied practice proved superior to a control group in terms of distance, although little difference was found in terms of errors of direction.

Moxley (1979) investigated variability of practice with children aged 6 to 8 years on a shuttlecock throwing task, under three practice regimes. The variable manipulated was angle of throw, and one group practised from one of the four angles only (low variability group), whilst the other group (the high variability group) practised from all four angle locations. On transfer by all groups to a fifth angle location, the high variability group exhibited significantly lower AE and VE than the low variability group, giving some support for the variability of practice hypothesis.

Dummer (1978) used a linear slide task with children having a mean IQ of 40.36, and a mean mental age of 4.29 years. She found no support for the superiority of variable practice over constant practice on transfer to novel target distances both inside and outside the practice range. It is often argued that one of the main problems in learning by such children is the problem of generalisation to a novel task of strategies or information previously acquired. This experiment would appear to confirm the argument. Porretta (1982) used a ball kicking task with children with learning difficulties, varying the slope of the surface along which the ball travelled to the target. He found that during practice, variable practice resulted in lower accuracy than constant practice, although both groups evidenced some degree of learning. However, on transfer to kicking a novel surface, the variable practice group performed significantly better than the constant practice group. These subjects had a higher IQ than those of Dummer (1978), and were perhaps more able to make the generalisations necessary.

Research by Moore, Reeve and Pissanos (1981) investigated the effects of two types of teaching method on overarm throwing. The exploratory method employed variable practice in that two types of balls were used, whereas the direct method employed one type of ball only. No differences were found berween the groups on transfer to the novel task, with a different ball and target. The absence of any difference might give some support to schema theory, but it is compounded by the teaching method factor.

(ib) Amount of variability

Research with adults

Shapiro & Schmidt (1982) cite work by Hogan (1977), Hunter (1977) and Allen (1978), all of whom questioned the optimum variability of practice necessary for learning. Hogan (1977), using a ballistic timing task, found that the group experiencing four distances was superior to the group experiencing two distances, when both groups transferred to a novel criterion distance. Hunter (1977) used a ballistic linear slide task and found an eight target location group superior to a two target location group, although the results did not reach significance.

Research with children

Allen (1978) used the same task as Hunter (1977) but with children and found similar results, again indicating the superiority of the eight target location group, but with no statistical significance.

Gerson & Thomas (1977) compared two groups of children on a task requiring them to locate a mid point position between two pegs, after moving either to those two pegs, or after moving to three pegs, and then locating the mid point between the last two. Perhaps surprisingly, the group experiencing three locations proved more accurate in locating the mid point, although as each trial consisted of movement to peg one, peg two and mid point, or movement to peg one, peg two, peg three and mid point, it could be argued that the latter group in fact received more practice.

(ic) Order of Presentation

Order of presentation of practice is a facet of learning that warrants consideration, since it is possible that it might confound results. Newell and Shapiro (1976), using adults as subjects on a rapid timing task, found that the variable practice group working in the order 70 msec, 130msec, were superior on transfer to 180msec, than the group experiencing the same degree of variability, but working in the reverse order. On transfer to the 100 msec target, however, there was no difference between the two variable practice groups. Shapiro and Schmidt (1982) cite work by Piggott (1979) who found blocked presentation of 3 trials superior to both blocked presentation of 6 trials and random presentation, on a bean bag throwing task in which the weight of the bean bag was varied.

In general, the research cited would appear to support the argument that variability of practice is superior to constant practice in learning motor skills. However, one must also consider such factors as proximity of targets and type of practice schedule presentation, since the variability factor is not the only one operating.

(ii) Recognition Schema

The recognition schema is thought to be responsible for error detection, both in terms of evaluation at the conclusion of the task and as part of the ongoing correction process involved in slow, linear positioning type movements. The research was focussed on both of these types of tasks in order to evaluate the optimal type of practice for the development of the recognition schema; however, the experimental work done has been conducted using adults as subjects.

(iia) Constant vs. Variable Practice

Newell & Shapiro (1976), as part of their experiment using a rapid linear timing task, asked subjects to estimate the time they had taken to move through the required distance immediately after the completion of a task. One group experienced two different required times (70 msec and 130 msec), and the other group one time only (170 msec or 130 msec). Superiority in terms of accuracy of estimation was apparent only for the variable practice group working in the order 70 msec, 130 msec, and only transfer to 180 msec; no differences were evident on transfer to 100 msec target.

Magill & Reeve (1978) used a linear positioning task in which subjects were required to attempt to move either to one distance (54 'units' long), or to a series of distances within the range 33-57 units or 0-90 units. Following 12 trials with knowledge of results they were given 10 attempts at 45 units, 3 trials with knowledge of results and 7 without. No difference between the groups on initial accuracy of production of the novel distance was apparent although when knowledge of results was no longer available, the group that had practised within the range 33-57 units maintained the degree of accuracy much better than the other two groups, both of which demonstrated a decrement in performance without knowledge of results.

Williams & Rodney (1978) also used a linear positioning task in which blindfolded subjects practised the criterion task only or a range of distances surrounding the criterion. On transfer to the criterion, the variable practice group performed equally well as the group having previously experienced the criterion continually during practice. Similarly, Williams (1975) found that experience of the criterion task during practice of a linear positioning task did not produce superior reproduction of that criterion when knowledge of results was withdrawn, in comparison to practice regime allowing for experience of distances around the criterion target. Similar results were also found by Zelaznik, Shapiro and Newell (1978) in a task in which subjects listened to movements made on a linear positioner. The group having listened to several movement speeds performed equally well when asked to produce the criterion as those subjects who had listened to the production of the criterion only.

Reeve (1977), using a linear positioning task, presented four different types of practice. One group attempted to produce a criterion distance; they were unaware of the actual distance, but moved and stopped themselves, and were then given instructions to reduce the error to zero in each occasion. The second group attempted to produce previously selected distances and were told their errors, but not permitted to correct them. The third group again moved to previously selected distances, and were given information as to the distances moved without reference to the criterion. The fourth group experienced the criterion target only. On transfer to the criterion, the third group was significantly poorer than the other three groups, with no difference apparent between groups one, two and four. Reeve (1977) argues, on the basis of this, that it is difficult to resolve the issue of how an internal standard is influenced by correct responses and errors, but that the variability of response is not as important to the development of recognition schema as is the labelling of the response in terms of correctness, giving an indication of the relationship between the response outcome and the criterion goal.

(iib) Amount of Variability

In terms of the amount of variability advantageous to recognition schema, Newell & Shapiro (1976), as part of the work already cited, found that increasing the variability from 20 trials at three targets to one trial at each of the 60 targets, organised sequentially or randomly, had no effect on performance on the transfer task; no difference between the groups was found.

It must be acknowledged that the work done in the area of recognition schema has employed adults and not children as subjects. The generalisation of the research to recognition schema development in children is not necessarily accurate, although it would appear from the research into recall schema that trends evidenced by adults are exemplified by children, and in general, to much greater extent.

Whilst Schmidt's (1975b) schema theory has overcome many of the questions raised of the Adams' (1971) closed loop theory of motor learning, the research conducted, particularly since 1975, has indicated areas of concern for the theory. Issues such as the alteration and modification of the schema trial by trial, if it is considered to be a relatively stable construct, is debatable. Further questions are raised as to whether initial conditions information is essential to initiation of a successful response, in view of the evidence that would suggest that accurate movement responses are possible in the absence of such information. Early work by Lashley (1917) with patients suffering from gunshot wounds and subsequent absence of afferent information, and more recent work by such as Polit and Bizzi (1978, 1979) suggests that this is the case.

However, a great deal of research has been generated as a result of the schema theory of discrete motor learning (Schmidt 1975b). Certain features at least remain intact, and the theory goes some way towards explaining the process of learning motor skills.

## II PURPOSE OF THE TWO EXPERIMENTS

The central focus of the present thesis is motor learning in children with learning difficulties and their counterparts matched on chronological and mental age. The first two experiments are concerned with the learning by such children of two skills, both of them examples of a specific type of task. All three groups follow the same programme, and through this, it is proposed to investigate whether all are equally capable of learning the tasks, or whether any differences between the groups emerge in terms of the way in which they learn or the amount learned.

The two tasks used, the linear slide and the ball throwing task, are both discrete tasks, ballistic in nature; there is a clear beginning and a clear end to the tasks, and once the action has been executed, the performer can only observe the result, and do nothing to correct it. Both tasks could be designated relatively 'closed' skills, since the environment, the targets, remain stationary throughout each trial and the performer is able to work in his own time, beginning the response when he wishes, because no temporal imposition is made by the task itself. Within the classification postulated for use here, both tasks would fall into the category of environment stationary, whole person stationary, body part(s) moving.

In terms of experimental paradigm, both tasks employ the same design. Acquisition of this skill over 40 trials is measured, followed by measurement of performance on two transfer tasks, which are essentially similar to the acquired skills, but different versions. The reason for this paradigm is that it is considered that performance on a transfer task is a true measure of learning. Acquisition of a single task is important, but the ability to generalise skill acquired to novel tasks is essential for successful operation in all walks of life. Furthermore, within this paradigm, it will be possible to examine whether the three groups of children are able to generalise skills acquired in the same way, and to the same degree, on whether differences between the groups emerge.

Within the three groups, four different practice schedules are employed, in both tasks. Two questions regarding the nature of a schema are investigated. The first is the size of a response class, and this is considered by examining the effect of different width practice bands. The second issue is whether a schema is in fact represented topographically within the brain; if variability of practice is the cornerstone of learning, how should this practice be varied? Variability of practice in terms of varied distance through which to project a missile is given here, and the question asked is whether this is the appropriate dimension along which to vary the practice.

A further point regarding the development of schema through variability of practice warrants consideration. Both tasks here will fall under the responsibility of the recall schema; the response specifications are issued and the motor program executed, with the result that no correction of the ongoing response is possible, which would be the responsibility of the recognition schema. The research done in the area of development of recall schema in children of normal intelligence tends to suggest that variability is advantageous in learning motor skills (e.g. Kerr & Booth, 1977; Moxley, 1979). Dummer (1978), however, suggests that this is not the case for children with an IQ of approximately 40. Between these two groups of children lie those with learning difficulties, with an IQ ranging from 50 to 75. The question arises whether such children are able to perform the cognitive exercises required to build up a recall schema in the way postulated by Schmidt (1975b) which would form the basis of production of responses within the particular schema developed.

## III STUDY I: THE LINEAR SLIDE TASK

### (i) Method

#### (a) Subjects

48 boys and girls were drawn from two local schools for children with learning difficulties, with a mean chronological age of 12 years 10 months, and ranging from 11 years 7 months to 13 years 7 months, and a mean IQ of 64.77, ranging from 48 to 77. Mental age was calculated using the formula

$$MA = \frac{CA \times IQ}{100}$$

resulting in a mean mental age of 8 years 5 months.

48 boys and girls were drawn from two local junior schools, as a mental age match for the children with learning difficulties. All were considered to be within the range of normal intelligence and the mean chronological age was 8 years 7 months, ranging from 8 years 4 months to 9 years 4 months.

48 boys and girls were drawn from two local middle schools as a chronological age match for the children with learning difficulties. The mean chronological age of these children was 13 years 0 months, ranging from 12 years 6 months to 13 years 6 months. Again, all were considered to be within the range of normal intelligence.

In all cases, the teacher in the school who arranged for the children to be released was asked to exclude any children considered to have any physical or behavioural problems that might influence performance on the tasks.

(b) Apparatus

The apparatus consisted of a wooden base, at each end of which was mounted a wooden block 5 cm high, with an indentation in the top on which rested a stainless steel rod 2.30 m long, which provided the horizontal linear trackway. On the rod was placed a ball bushing 4 cm in length, 2 cm in internal diameter, 3 cm in external diameter, which travelled along the rod with near frictionless movement. Along the wooden base were placed two metre rules adjacent to each other lengthways, and graduated in centimetres, with zero located at the front end of the bushing when it rested against the wooden block. This is shown in Figure 6.1.

A removable bridge was also constructed consisting of a piece of wood, 4.9 m by 0.16 m in size, mounted on four legs 11 cm in height. This could be placed over the trackway without inhibiting the movement made by the subject in making the response, or the movement of the bushing along the trackway, yet preventing vision of the bushing once the response had been made. This is shown in Figure 6.2.

The target distances were indicated by placing a model traffic lights sign at the side of the trackway. The apparatus was placed on tables at a height for the children being tested.

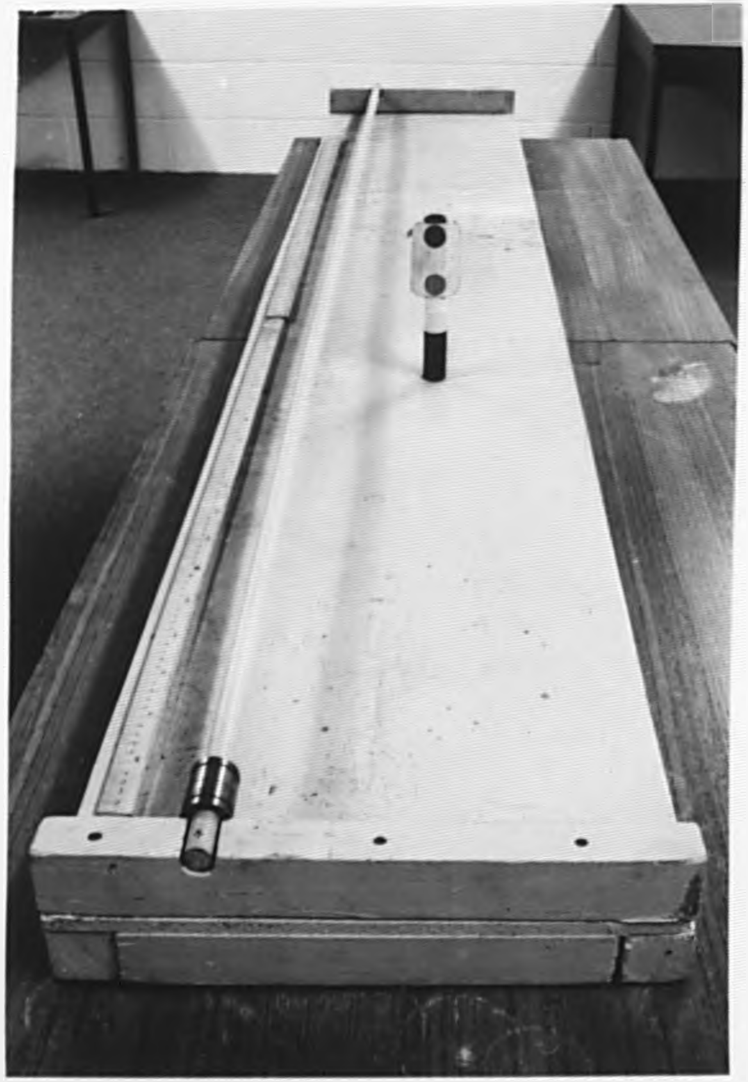


Figure 6.1: The linear slide apparatus (i)

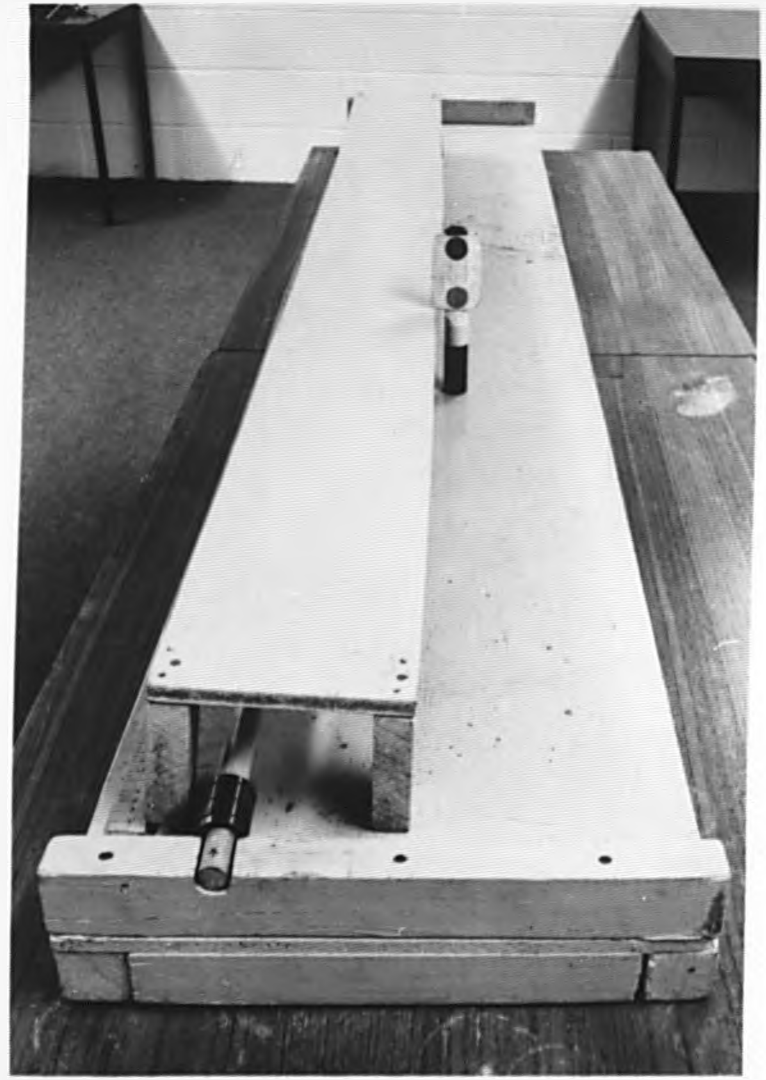


Fig. 6.2: The linear slide apparatus (ii)

(c) Design

For all three groups of children with learning difficulties (CLD), the mental age match (MA) and the chronological age match (CA), the 48 subjects were randomly allocated to one of the four practice conditions, resulting in four groups of twelve subjects in each case. All subjects were told to attempt to make the bushing stop at previously defined distances, by propelling the bushing to that point. The variable manipulated was the target distance(s) practised. Table 6.1 shows the target distances attempted by the four practice condition groups.

Table 6.1: Target distances attempted during practice (linear slide)

| Practice | Target Distance | Number of Trials | Number of Subjects |
|---|---|---|---|
| 1 | 30 cm | 20 | 12 |
| | 120 cm | 20 | |
| 2 | 45 cm | 20 | 12 |
| | 105 cm | 20 | |
| 3 | 60 cm | 20 | 12 |
| | 90 cm | 20 | |
| 4 | 75 cm | 40 | 12 |

In the case of the variable practice conditions 1, 2 and 3, the two distances were attempted alternately: half the group began with the shorter distance and half with the longer distance. Vision was available throughout the acquisition phase. All subjects received forty acquisition trials in total, 4 blocks of 10 trials with a rest of 1 minute between blocks. Following the forty acquisition trials, the bridge was placed over the trackway and all subjects received 10 attempts at 75 cms, followed by 10 attempts at 140 cms, with a rest of 1 minute between the two blocks of 10 trials. The target distances during practice were selected so that the total distance attempted was equal for all subjects. The transfer phase was conducted in the order stated for all subjects, since the reverse order might have resulted effectively in variable practice for group 4 on transfer to 75 cm, without vision, as they would have previously attempted 140 cms. The second transfer distance, 140 cms, was selected because it was considered that the logical choice of 150 cms might result in some kind of direct transfer from the 75 cms distance, since the latter distance is exactly half the former. The use of 140 cms as the second transfer target overcame this problem.

All testing was conducted within the school environment familiar to the subjects, in a room allocated by the teacher in charge.

(d) Procedure

The subjects were tested individually. In cases where it was necessary to take two children together, the second child was employed at the other side of the room on a drawing task and situated such that he could not watch the testing of the first child. On entry into the testing room, the apparatus was shown to the child, and the way in which the bushing moved along the trackway explained. The child was told that the experimenter would place the traffic lights at the side of the trackway in various places, and that he, the child, should attempt to make the bushing, or "car" stop with its front end level with the near side of the traffic lights. The child then stood at the end of the apparatus and using the preferred hand, placed his thumb and forefinger on the bushing. The child was told that he should push the bushing and let go, in one movement, not attempting to hold onto it in any way. The child was then asked if he understood what he was trying to do, and any questions the child asked were answered. The subject was told that he would have forty attempts altogether, in order to see how much he improved and that there was no hurry, he should begin when he was ready. After each trial, the bushing was returned to the starting point by the experimenter and the child told his error in centimetres, too far (+) or too short (-). This score is then recorded on the child's individual score sheet (See Appendix 7, Sheet 1).

Following the 40 practice trials, the experimenter explained that she was going to place the bridge over the trackway, so that the child could not see how far the bushing went. It was explained that essentially the task remained the same, to make the bushing stop at the traffic lights. The traffic lights were placed at the 75 cm target and the subject given 10 attempts, followed by 10 attempts at 140 cm.

Following each trial, the bushing was returned to the starting point by the experimenter as before, but using a ruler. The experimenter placed the ruler under the bridge on the trackway at the far end of the rod, and moved it along from the end point to the starting point, at a constant speed, regardless of the moment of contact with the bushing, until the bushing was replaced at the starting point. This was done in order to prevent the subject from estimating where the bushing had stopped by watching the hand of the experimeter as she went to push it back. No verbal knowledge of results was given during the transfer phase.

(ii) Results

Absolute error (AE), constant error (CE) and variable error (VE) for each subject werecomputed in all cases. However, some consideration of the relative merits of these three measures is necessary.

Differences of opinion exist on the relative merits of AE, CE and VE. Whilst Schmidt (1975b) argues that schema 'prefers' AE, Schutz and Roy (1973) argue that AE is 'the devil in disguise', in so far as it is statistically dependent on CE and VE, and confounded by the two. Since CE and VE are independent measures and contribute to AE, they argue that only consideration of the first two measures is necessary for accurate analysis of data. They do admit, however, that the relationship between the three measures is increasingly reduced as the distribution of the data deviates from normal.

Newell (1976) argues the case in favour of AE; he points out that in group data, if half the group performs consistently on each side of the criterion, it is possible for groups to have equal CE and VE means, leaving AE as the only discriminating feature. Newell (1976) demonstrates this graphically (Figure 6.3) using some of his own data.

Furthermore, a low CE score does not necessarily reflect greater accuracy, since large positive and negative error deviations can effectively cancel each other out: only if all scores are either positive or negative (i.e. CE = AE) does mean CE reflects accuracy on each block of trials. In addition, use of CE in analysis of variance will only provide information about differences between means, not relative accuracy.

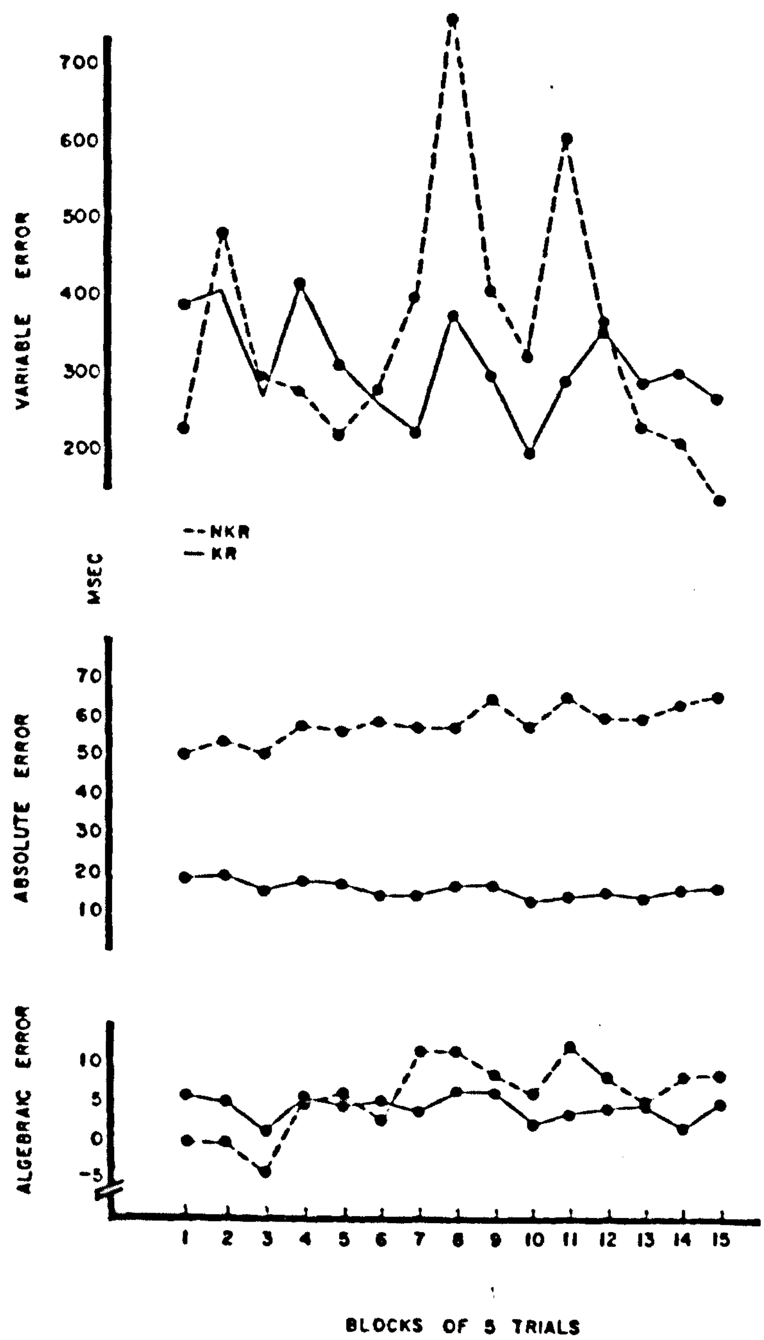



Figure 6.3: Mean absolute error, algebraic error, and variable error as a function of knowledge of results (reproduced from Newell, 1976).

Consideration of the task being used is also necessary. In the case of this task, and many others, when the individual is learning, he is being told to aim for a criterion (effectively zero), on repeated occasions. He is not being told to reduce his CE, (i.e. if he has just scored - 10, to aim for +10 and so reduce his mean CE to zero), nor to reduce his VE (i.e. if he has just scored -10, to aim for that point again, resulting in a VE of zero). Newell (1976) further states

> Although variable error and constant error may help explain how the subject attempted to reduce absolute error, it seems unreasonable to evaluate the effect of an independent variable primarily through criteria different from that originally stressed to the subject. The implication is that changing the subject's goal in the experiment to reducing constant error and/or variable error may induce an entirely different strategy on the part of the subject and hence a different relationship between the three error scores.
>
> (page 141)

Henry (1974) advocates the use of E, the total variability of the individual's scores as a variable measure, arguing that it represents overall accuracy. Schmidt (1975b) states that when CE is close to zero, E is probably highly associated with AE and VE.

Schmidt (1975b) argues that AE is the measure preferred, since having two dependent measures of performance can lead to opposite conclusions about the processes involved, and also because of its sound history of use and the point taken by Newell (1976) stated above. Schmidt (1975b) concludes

> For these reasons, the use of absolute error as a measure of recall-schema strength seems justifiable.
>
> (page 243)

On the basis of the arguments presented for and against the use of AE, CE and VE all three have been calculated, although it is probably towards AE in general that most concern is focussed, in this experiment at least.

The effects of group (children with learning difficulties, MA matched and CA matched) and practice condition (variable 1, 2 and 3 and constant 4) on the following were examined.

(a) 4 blocks of 10 practice trials.

(b) Transfer target 1, trials 1-5 and 6-10.

(c) Transfer target 1, trial 1.

(d) Transfer target 2, 1-5 and 6-10.

(e) Transfer target 2, trial 1.

With the exception of (c) and (e) for which VE is not a viable statistic, analysis of variance for all three measures, AE, CE and VE, were conducted, each of which will be considered in turn.

(a) <u>4 blocks of 10 practice trials</u>

The mean score (AE, CE and VE) for each block of 10 trials was calculated for each subject. The results were then subjected to a 3 (group) x 4 (practice conditions) x 4 (trial blocks) analyses of variance (ANOVA), with repeated measures on the last factor.

(a1) <u>AE</u>

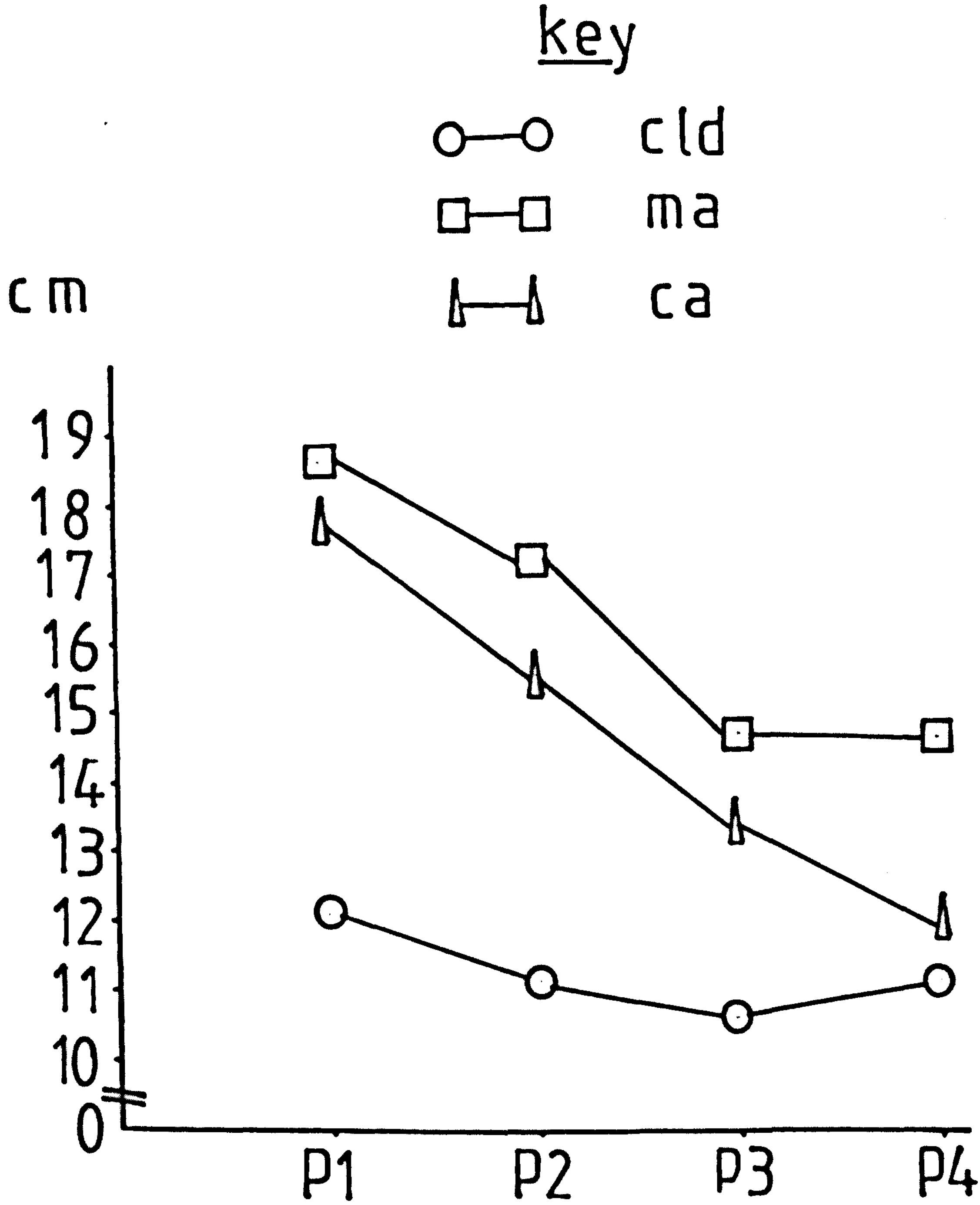
The 3 (group) x 4 (practice condition) x (trial blocks) anova for AE revealed significant main effects for group ($F(3, 132), = 44.50$ $p < .01$), practice condition $F(3, 132) = 12.31$, $p < .01$) and trial blocks ($F(3, 396) = 39.83$, $p < .01$) and a trial blocks x group interaction ($F(6,396), = 3.40$, $p < .01$) (See Appendix 1, Table 1).

With regard to the differences between the practice conditions over the 4 trial blocks, with all 3 groups and a 4 trial blocks combined, the posthoc test (Tukey HSD) revealed a significant difference to lie between condition 1, (wide practice band), and 2 (medium practice band) ($p < .05$), condition 1 and condition 3 (narrow practice band)($p < .01$), and condition 1 and condition 4 (constant practice)($p < .01$), the wide practice band demonstrating the greater error, and between conditions 2 and 3 ($p < .05$), and 2 and 4 ($p < .01$), the medium width practice band recording greater error than the other two groups. (See Appendix 1, Table 2). The group means for the practice conditions are shown in Table 6.2 and demonstrated in Figure 6.4.

Table 6.2 <u>Mean error for the 4 practice conditions during practice trials (AE), linear slide task</u>

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 16.01 | 14.65 | 13.02 | 12.62 |

Figure 6.4: Performance under the four practice conditions for the three groups, during practice trials (AE), linear slide task



The trial block x group interaction indicates significant differences between groups on certain trial blocks, and also reflects differences in the form of learning between the groups. Tests for simple main effects were carried out (see Appendix 1, Table 3), and overall significance was found between groups for all trial blocks (trial block 1, $F(2, 132) = 42.65$, $p < .01$; trial block 2, $F(2, 132) = 7.69$, $p < .01$; trial block 3, $F(2, 132) = 12.64$, $p < .01$; trial block 4, $F(2, 132) = 12.47$, $p < .01$) and between trial blocks for all groups (CLD, $F(3, 396) = 5.51$, $p < .01$; MA, $F(3, 396) = 23.85$, $p < .01$; CA, $F(3, 396) = 17.32$ $p < .01$).

Subsequent posthoc testing (Tukey HSD) revealed the following differences:-

(a) On trial block 1, between CLD and MA ($p < .01$)
CLD and CA ($p < .01$)
MA and CA ($p < .05$)

(b) On trial block 2, between CLD and MA ($p < .01$)
CLD and CA ($p < .05$)

(c) On trial block 3, between CLD and MA ($p < .01$)
CLD and CA ($p < .05$)

(d) On trial block 4 between CLD and MA ($p < .01$)
CLD and CA ($p < .01$)

In all cases, the means were in the order of MA, CA, CLD, the MA exhibiting the greatest error.

(e) For the group with learning difficulties, between trial blocks

1 and 4 ($p < .01$)

2 and 4 ($p < .01$)

(f) For the mental age matched group between trial blocks

1 and 2 ($p < .01$)

1 and 3 ($p < .01$)

1 and 4 ($p < .01$)

(g) For the chronological age matched group, between trial blocks

1 and 2 ($p < .01$)

1 and 3 ($p < .01$)

1 and 4 ($p < .01$)

2 and 4 ($p < .05$)

The trend was for reduction in error over trial blocks. (See Appendix 1, Tables 4-10). This can also be seen in Fig. 6.5.

(aii) <u>CE</u>

The 3 (group) x 4 (practice condition) x 4 (trial blocks) anova for CE revealed a significant main effect for group ($F(2, 132) = 4.57$, $p < .01$) and for practice condition ($F(3, 132) = 4.05$, $p < .01$) and a trial block x group interaction ($F(6, 396) = 2.40$, $p < .01$) (See Appendix 1, Table 11).

Performance under the four practice conditions when the three groups are combined is shown in Figure 6.6 and the means for the four conditions are shown in Table 6.3.

Figure 6.5: Performance of the three groups over 4 practice blocks (AE), linear slide task

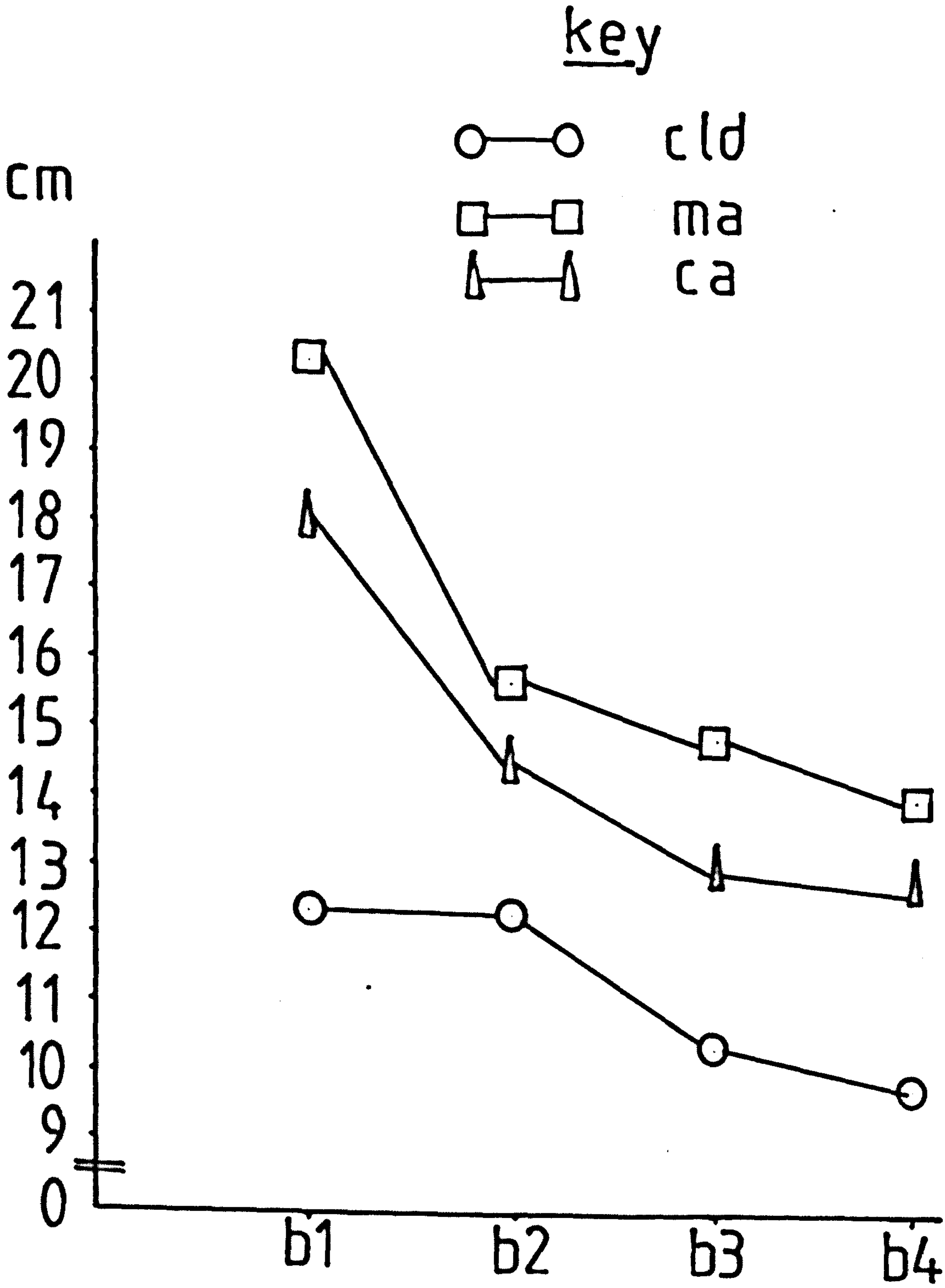


Figure 6.6: Performance under the four practice conditions for the three groups during practice trials (CE), linear slide task

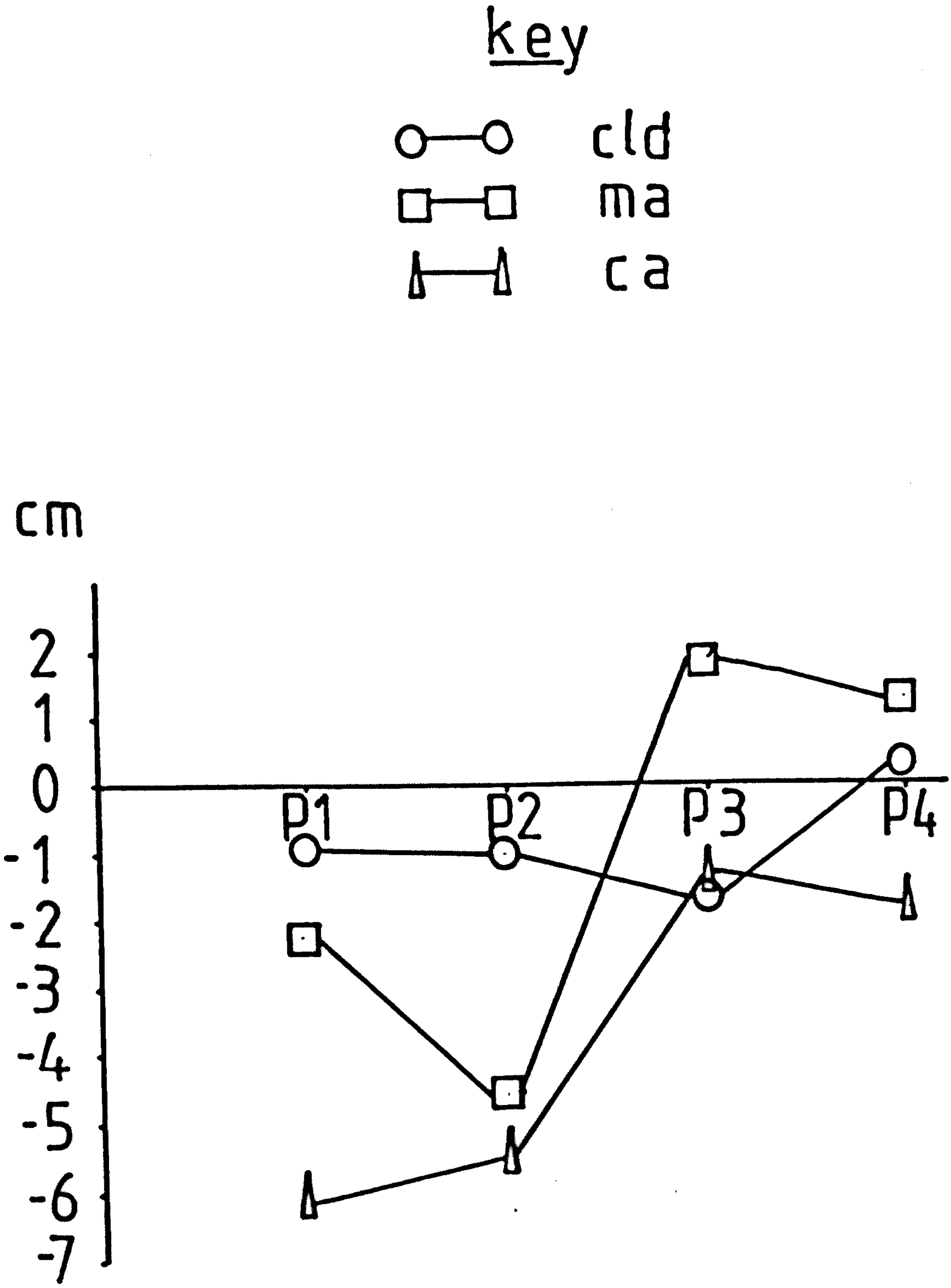


Table 6.3: Mean error for performance under the 4 practice conditions (CE) linear slide task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| -3.10 | -3.67 | -0.48 | -0.12 |

Posthoc testing (Tukey HSD) proved the difference to lie between condition 4 (constant) and 2 (Medium band) ($p < .05$) (See Appendix 1, Table 12).

Tests for simple main effects on the significant trial blocks x group interaction demonstrated significant differences between groups on trial block 2 ($F (2, 132) = 4.38$, $p < .05$) and between trial blocks for the MA matched group ($F (3, 396) = 2.98$ $p < .05$). (See Appendix 1, Table 13). With regard to the differences between groups on trial block 2, posthoc testing (Tukey HSD) revealed the difference to lie between the group with learning difficulties and the chronological age matched group ($p < .05$), the latter group exhibiting the greater CE (See Appendix 1, Table 14). The means for the three groups, with practice conditions combined, are shown in Table 6.4 below.

Table 6.4: Mean error for the three groups on trial block 2 (CE) linear slide task

| CLD | MA | CA |
|---|---|---|
| 0.02 | -2.84 | -4.29 |

The difference between the trial blocks for the MA match was found to lie between blocks 1 and 2 ($p < .05$), following posthoc testing (Tukey HSD) (See Appendix 1, Table 15). The means for the four blocks are shown in Table 6.5 below:

Table 6.5: Mean error for the four trial blocks by the MA matched group (CE) linear slide task

| Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|
| 0.55 | -2.84 | -0.75 | -0.69 |

The greatest difference lies between blocks 1 and 2 ($p < .05$), block 2 recording greater CE. The performance of the three groups over the four trial blocks is shown in Figure 6.7.

(aiii) VE

The 3 (group) x 4 (practice condition) x 4 (trial blocks) anova for VE scores of subjects revealed a significant main effect for group ($F(2, 132) = 56.24$ $p < .01$), practice condition ($F(3, 132) = 17.20$, $p < .01$), and trial blocks ($F(3, 396) = 28.65$, $p < .01$), and in addition a significant trial block x group interaction ($F(6, 396) = 2.42$, $p < .01$). (See Appendix 1, Table 16).

The group mean error scores for performance under the four practice conditions are shown in Table 6.6.

Figure 6.7: Performance of the three groups over the four practice trial blocks (CE), linear slide task

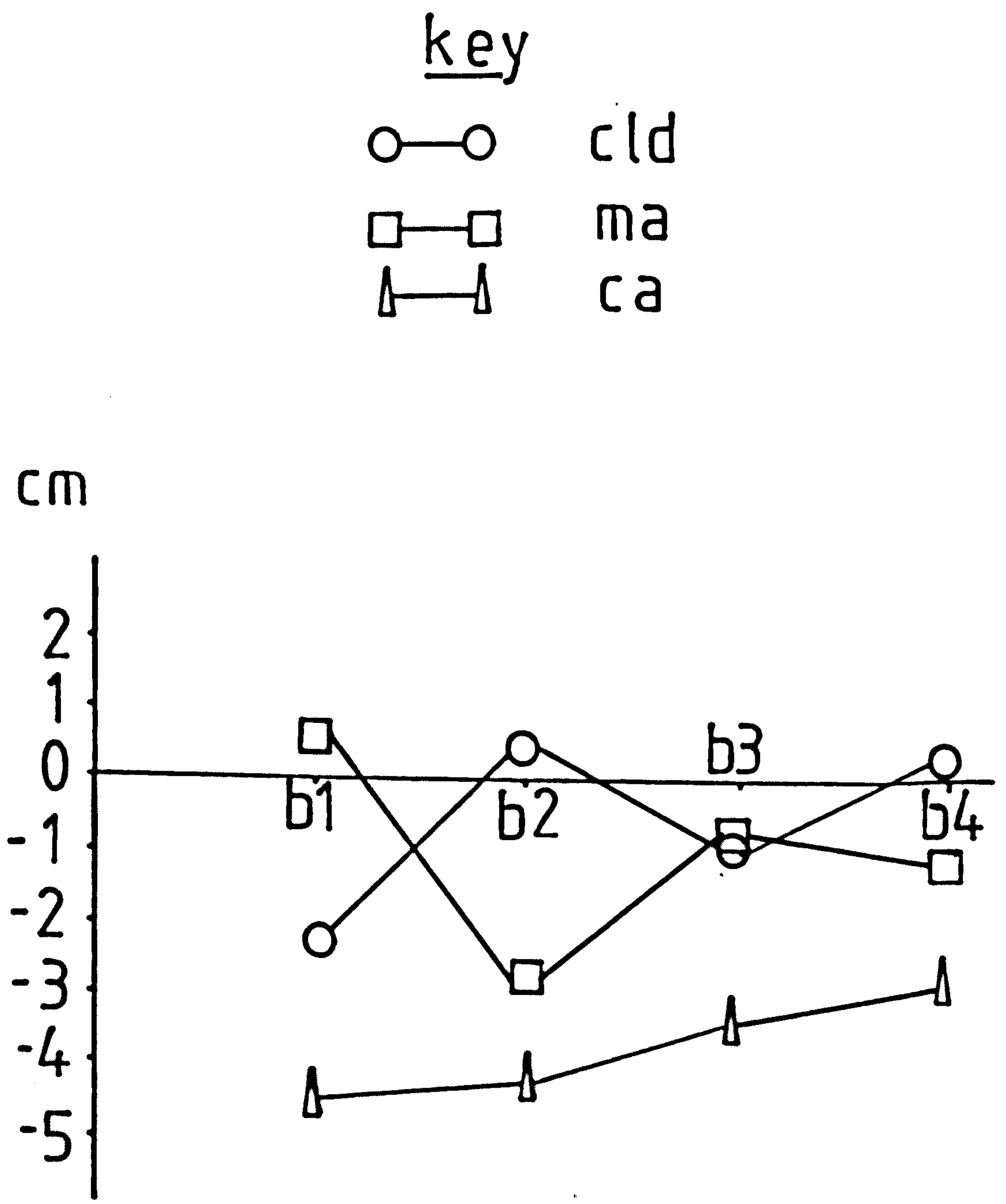


Table 6.6: Mean error scores under the four practice conditions during practice trial blocks, (VE), linear slide task

| Practice Condition 1 (Wide) | Practice Condition 2 (Medium) | Practice Condition 3 (Narrow) | Practice Condition 4 (Constant) |
|---|---|---|---|
| 18.79 | 16.69 | 14.46 | 14.46 |

Subsequent posthoc testing (Tukey HSD) revealed differences to lie between conditions 1 and 2 ($p < .05$), 1 and 3 ($p < .01$) and 1 and 4 ($p < .01$), 2 and 3 ($p < .05$) and 2 and 4 ($p < .05$). (See Appendix 1, Table 17).

Tests for simple main effects on the significant trial block x group interaction revealed significant differences between groups on all trial blocks (trial blocks 1, $F\ (2, 132) = 41.88$, $p < .01$; trial block 2, $F\ (2, 132) = 11.45$, $p < .01$; trial block 3, $F(2, 132) = 19.53$, $p < .01$; trial block 4, $F(2, 132) = 16.12$, $p < .01$), and between trial blocks for all groups (CLD, $F(3, 396) = 3.69$, $p < .05$; MA match $F(3, 396) = 16.04$, $p < .01$; CA match, $F(3, 396) = 13.75$ $p < .01$). (See Appendix 1, Table 18). Figure 6.8 demonstrates the performance of the three groups over the 4 trial blocks, practice conditions combined, and the means are shown in Table 6.7.

Figure 6.8: Performance of the 3 groups over 4 practice trial blocks (VE), linear slide task

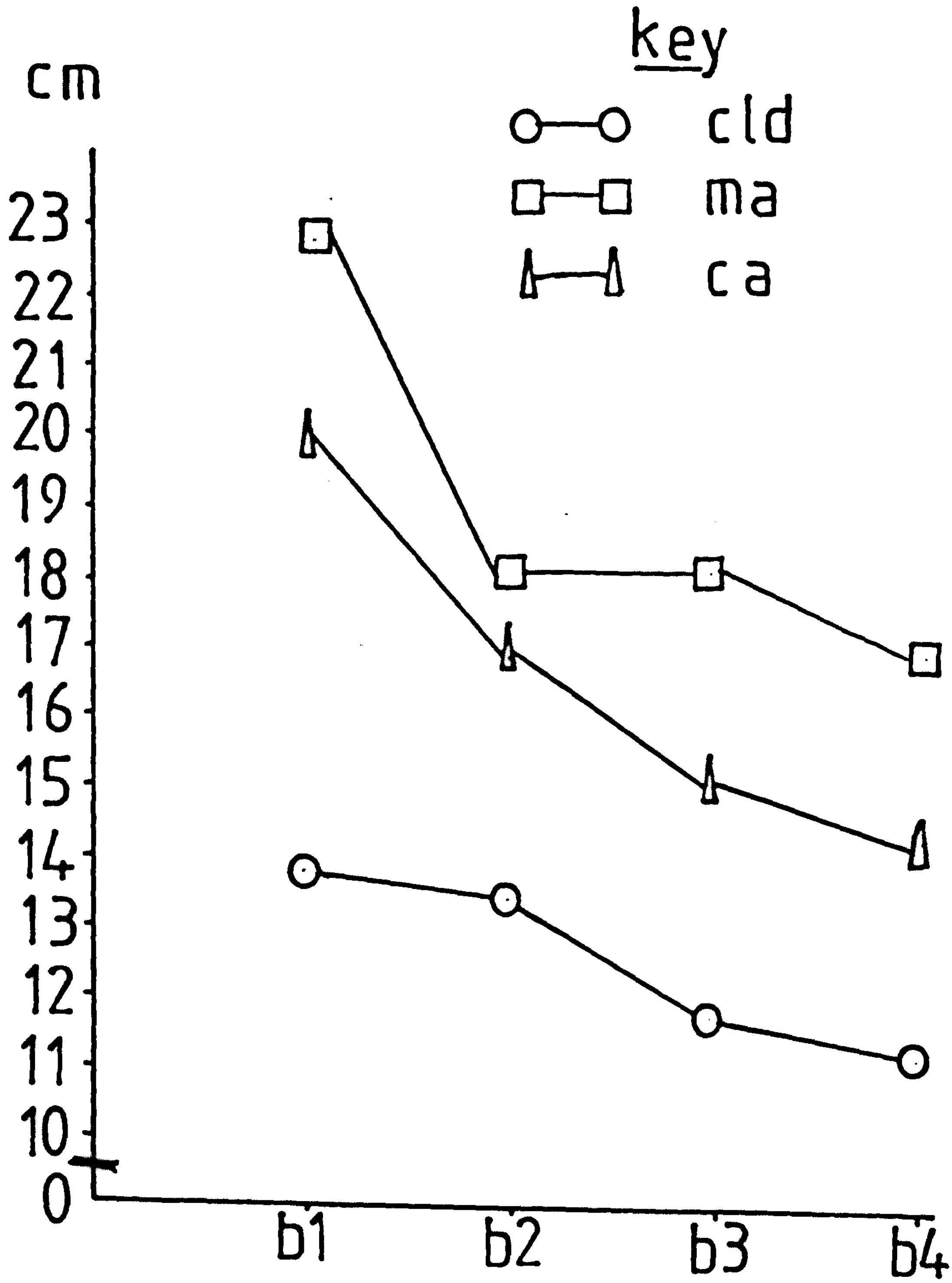


Table 6.7: Mean error for the 3 groups over the 4 practice trial blocks (VE), linear slide task

| Group | Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|---|
| CLD | 13.82 | 13.54 | 11.82 | 11.26 |
| MA | 22.92 | 18.21 | 18.18 | 16.99 |
| CA | 19.88 | 17.00 | 15.12 | 14.44 |

Subsequent to the test for simple main effects, posthoc testing (Tukey HSD) revealed the following specific differences:-

a. On trial block 1 between CLD and CA ($p < .01$)
CLD and MA ($p < .01$)
MA and CA ($p < .01$)

b. On trial block 2, between CLD and MA ($p < .01$)
CLD and CA ($p < .01$)

c. On trial block 3, between CLD and CA ($p < .01$)
CLD and MA ($p < .01$)
CA and MA ($p < .01$)

d. On trial block 4, between CLD and CA ($p < .01$)
CLD and MA ($p < .01$)
CA and MA ($p < .05$)

In all cases the mental age matched group exhibited the greatest VE and the group with learning difficulties the least.

e. For children with learning difficulties between blocks 1 and 4 ($p < .05$).

f. For the mental age match between blocks 1 and 2 ($p < .01$)

1 and 3 ($p < .01$)

1 and 4 ($p < .01$)

g. For the chronological age match between

blocks 1 and 2 ($p < .05$)

1 and 3 ($p < .01$)

1 and 4 ($p < .01$)

2 and 4 ($p < .05$)

In all cases the trend was from high variability on the first trial block, decreasing over successive blocks (See Appendix 1, Tables 19-25).

(b) <u>Transfer Target 1, Trials 1-5 and 6-10</u>

The ten trials at transfer target one (75 cms) were divided into two blocks of five, for purposes of analysis, to determine any changes in performance over time. During the transfer phase, the bridge over the steel rod prevented vision of the bushing and also of the result of the attempt. Since no knowledge of results was given by the experimenter it might be expected that some change in performance over trials might occur. The means for each of these two blocks of five trials were calculated for each subject, for AE, CE and VE and the results subjected to a 3 (group) x 4 (practice condition) x 2 (blocks) analysis of variance with repeated measures on the last factor in all cases. Each of these analyses will be considered in turn.

(bi) AE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova for AE revealed a significant main effect for practice condition ($F (3, 132) = 3.43$, $p < .05$), and a group x practice condition interaction ($F (6, 132) = 3.12$, $p < .01$) was also found. No differences between trial blocks were found (See Appendix 1, Table 26).

The group x practice interaction was subjected to tests for simple main effects, which revealed differences to lie between groups for practice condition 4 ($F(2, 132) = 3.93$, $p < .05$) and between practice conditions for the group with learning difficulties ($F(3, 132) = 9.07$, $p < .01$) and the mental age matched group ($F(3, 132) = 3.07$, $p < .05$). (See Appendix 1, Table 27). Posthoc testing (Tukey HSD) revealed the following specific differences.

(a) For practice condition 4 (constant) between the group with learning difficulties and MA match ($p < .05$).

(b) For the group with learning difficulties, practice condition 4 (constant) and 3 (narrow) ($p < .01$).

(c) For the mental age matched group, between no specific practice conditions (See Appendix 1,Tables 28 to 30).

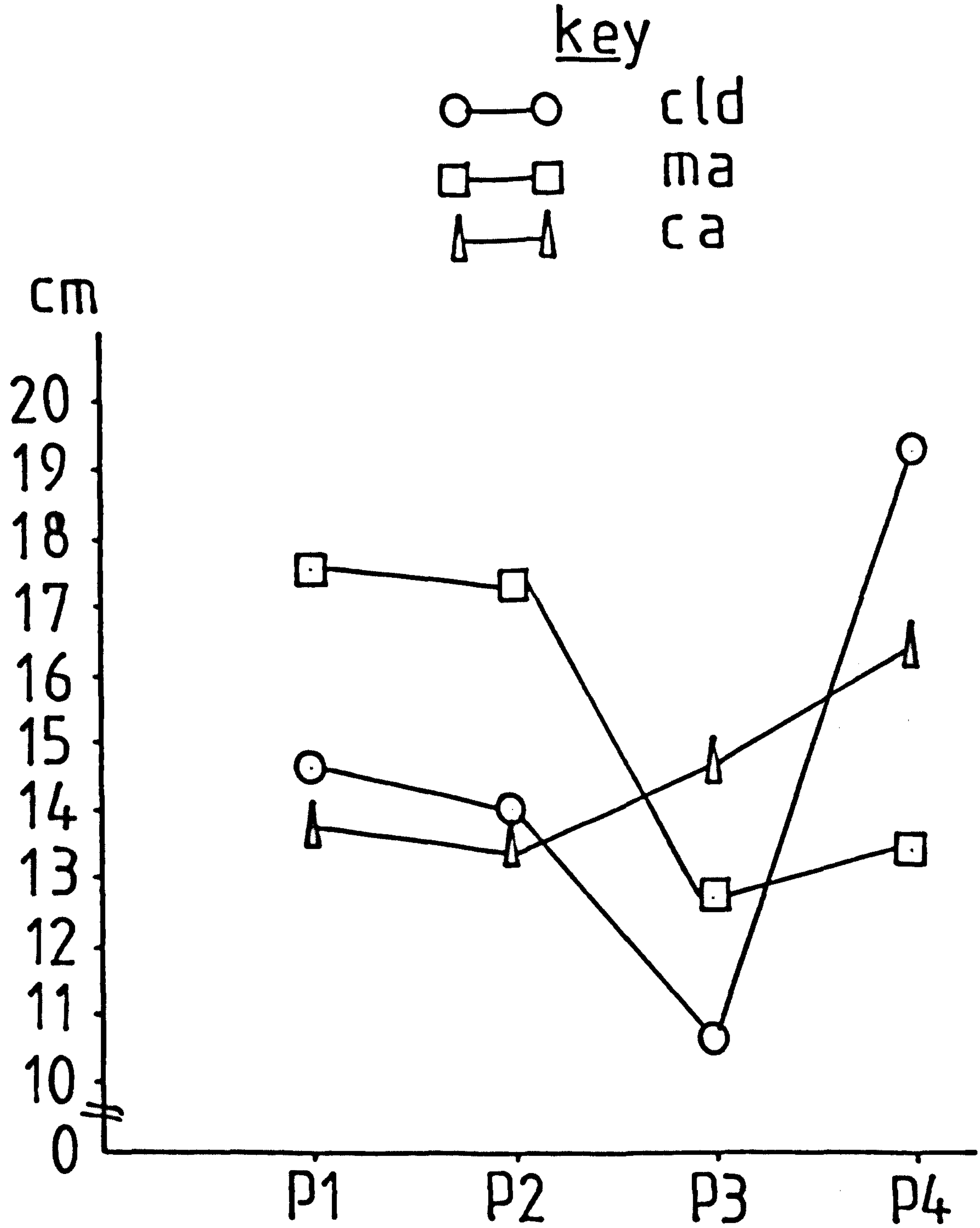
In the case of the apparent absence of differences between practice conditions for the mental age matched group using the Tukey HSD test, Fisher's least significant difference test (LSD) was used to find any trends. The LSD test is a less conservative test and as such is more likely to generate a Type I error, rejecting the null hypothesis when it is actually true. The results, therefore, should be interpreted with caution. However, use of the LSD test in the case of differences between practice conditions for the mental age matched group resulted in differences between conditions 1 and 4 ($p < .05$), 1 and 3 ($p < .05$), and 2 and 3 ($p < .05$) (See Appendix 1, Table 31).

The performance of the 3 groups as a function of practice conditions is shown in Figure 6.9, and the means shown in Table 6.8:-

Table 6.8: Error Performance of the 3 groups under the four practice conditions, transfer target 1 (AE), linear slide task

| Group | Practice condition 1 | Practice condition 2 | Practice condition 3 | Practice condition 4 |
|---|---|---|---|---|
| CLD | 14.67 | 14.08 | 10.71 | 19.30 |
| MA | 17.65 | 17.38 | 12.72 | 13.50 |
| CA | 13.94 | 13.75 | 14.81 | 16.55 |

Figure 6.9: Performance of the three groups as a function of practice condition on transfer target 1 (AE), linear slide task



(bii) CE

On transfer to the 75 cm target, the 3 (group) x 4 (practice condition) x 2 (blocks) anova for CE evidenced a significant effect for group only ($F(2,132) = 4.21$, $p < .05$. No effect for practice condition or blocks was apparent, nor was any interaction. (See Appendix 1, Table 32). The means for the 3 groups are set out in Table 6.9, with practice conditions and blocks combined.

Table 6.9: Error performance of the 3 groups on transfer target 1 (CE) linear slide task

| CLD | MA | CA |
|---|---|---|
| -7.78 | -4.77 | -9.38 |

Posthoc testing (Tukey HSD) revealed the differences between the groups to lie between the chronological and mental age matched groups ($p < .05$). (See Appendix 1, Table 33).

(biii) VE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova on the VE scores at transfer target 1 revealed a significant main effect for group only ($F(2,132) = 5.58$, $p < .01$), and no significant interactions (See Appendix 1, Table 34). Subsequent posthoc testing (Tukey HSD) revealed the differences to lie between the group with learning difficulties and the mental age matched group ($P < .01$). (See Appendix 1, Table 35). The groups mean, with practice conditions and blocks combined are shown in Table 6.10.

Table 6.10: Mean error scores of the 3 groups at transfer target 1 (VE) linear slide task

| CLD | MA | CA |
|---|---|---|
| 10.89 | 13.91 | 12.23 |

(c) Transfer Target 1, trial 1

The error score on the first attempt at transfer target 1 (75 cm) was taken, and a 3 (group) by 4 (practice condition) anova conducted, for both AE and CE.

(ci) AE

The 3 (group) x 4 (practice condition) anova for AE revealed no significant main effects for either group or condition and no interaction between them. (See Appendix 1, Table 36). The group means are shown in Table 6.11.

Table 6.11: Performance of the 3 groups as a function of the 4 practice conditions on the first attempt at transfer target 1 (AE) linear slide task

| Group | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| CLD | 15.00 | 16.25 | 15.25 | 15.83 |
| MA | 17.75 | 16.50 | 13.08 | 20.92 |
| CA | 15.67 | 18.25 | 17.75 | 16.83 |

(cii) CE

The 3 (group) x 4 (practice condition) anova for CE revealed no significant main effect for practice condition, but a main effect for group was evident ($F(2, 132) = 4.98$, $p < .01$). No interaction between group and practice condition was apparent (See Appendix 1, Table 37). Posthoc testing (Tukey HSD) revealed the differences between groups to lie between theCA and MA matched groups ($p < .01$). (See Appendix 1, Table 38). The means for the groups are set out in Table 6.12.

Table 6.12: Group mean error on the first attempt at transfer target 1 (CE) linear slide task

| CLD | MA | CA |
|---|---|---|
| -7.96 | -1.60 | -13.33 |

(d) Transfer Target 2, Trials 1-5, 6-10

In the same way as for the analysis of results at transfer target 1, the 10 trials at the second transfer target (140 cms) were divided into two blocks of 5 (1-5 and 6-10), again in order to determine any change in performance over trials. The means of each of these two blocks for each subject were then calculated, for AE, CE and VE and the results subjected to a 3 (group) x 4 (practice condition) x 2 (blocks) analysis of variance with repeated measures on the last factor in all cases.

(di) AE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova for AE revealed significant main effects for group ($F (2, 132) = 3.07$, $p < .05$) and trial blocks ($F (1, 32) = 4.37$, $p < .05$). No effect for practice conditions was evident nor any interaction (See Appendix 1, Table 39).

With regard to the differences between the groups, posthoc testing using Tukey HSD test revealed no specific differences (See Appendix 1, Table 40). Subsequent use of the LSD test revealed differences to lie between MA and CLD ($p < .05$), MA and CA ($p < .05$). (See Appendix 1, Table 41). Again, these results must be interpreted with caution, due to the nature of the test. The mental age matched group however, does show the largest AE as can be seen from the means in Table 6.13.

Table 6.13: Group mean error scores on transfer target 2 (AE), linear slide task

| CLD | MA | CA |
|---|---|---|
| 30.25 | 34.63 | 30.06 |

Examination of the difference between blocks 1 (trials 1-5)and 2 (trials 6-10) demonstrates an overall reduction in error over blocks as can be seen from Table 6.14.

Table 6.14: Performance over trial blocks 1 and 2 at Transfer Target 2, all groups and practice conditions combined (AE) linear slide task

| Trials 1 - 5 | Trials 6 - 10 |
|---|---|
| 32.71 | 30.66 |

The cell means for Transfer Target 2 are shown in Appendix 1, Table 42.

(dii) CE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova for CE revealed no significant main effects for group or practice condition, but a significant difference between blocks ($F(1, 132) = 11.57$, $p < .01$). (See Appendix 1, Table 43). Examination of the means for trial blocks, with practice conditions and groups combined shows a reduction in CE over trial blocks as can be seen in Table 6.15.

Table 6.15: Performance over trial blocks at Transfer Target 2, groups and practice conditions combined (CE) linear slide task

| Block 1 | Block 2 |
|---|---|
| -26.81 | -22.59 |

Examination of the cell means shows that this reduction is characteristic of all groups and practice conditions with the exception of the MA matched group, condition 2 (See Appendix 1, Table 44).

(diii) VE

The 3 (group) x 4 (practice condition) x 2 (trial blocks) anova revealed no significant main effects or interactions (See Appendix 1, Table 45). Examination of the cell means gives no indication of any consistent trends (See Appendix 1, Table 46).

(e) Transfer Target 2, trial 1

As for transfer target 1, the first attempt by each subject at Transfer Target 2 was taken, and for both AE and CE, a 3 (group) x 4 (practice condition) anova, was conducted.

(ei) AE

No significant main effect for group or practice condition was found, nor was any interaction between the two (See Appendix 1, Table 47). Examination of the cell means suggests no consistent trends, although the group with learning difficulties has marginally the least error overall (see Appendix 1, Table 48) (eii) CE

The 3 (group) x 4 (practice condition) anova for CE revealed no significant main effects for group or practice condition and no interaction between them (See Appendix 1, Table 49). Examination of the cell means shows no consistent trends (See Appendix 1, Table 50).

(iii) Discussion

In the same way as in the previous section, the discussion of the results will be considered under the various headings, but with a general discussion in conclusion.

(a) 4 blocks of 10 practice trials

Both AE and VE reveal that learning has taken place over the four blocks of ten trials for all children. The learning and group interaction for AE and VE are interesting in that in both cases, for children with learning difficulties, there is no improvement between blocks 1 and 2 and the improvement would appear to occur at a later stage, whereas for both the other groups of children, the difference between trial blocks 1 and 2 is significant ($p < .01$) for MA matched group, $p < .05$ for CA matched group). Furthermore, this improvement is maintained over the next two blocks since the difference between blocks 1 and 3 and 1 and 4 is also significant for both mental and chronological age matched groups ($p < .01$). It could be argued that the children with learning difficulties need to spend a longer period of time sorting out the requirements of this task, and the approach necessary for the task; those aspects of learning characteristic of Fitts' (1965) cognitive stage of learning. Fitts (1965) states -

> Evidence from many sources indicates the cognitive processes are heavily involved early in the learning of most complex skills ... Students and instructors attempt to analyse tasks and to verbalize about what is being learned. What to expect and what to do is emphasized, procedures are described, and information is provided about errors, which often are frequent.
>
> (page 187)

The cognitive operations involved may well be expected to take children of low intelligence longer, resulting possibly in positively accelerated learning or performance curves, whereas for children of normal intelligence on the same task, the resulting curves may well be negatively accelerated. However, that they are able to sort out the task requirements is apparent, since improvement takes place later. Furthermore, the mean error (AE) of the group with learning difficulties is actually less than that of other groups. They would appear, however, to require more time to sort out the task requirements and so bring about improvement. The fact that all groups exhibit some degree of learning would indicate no ceiling or floor effect to the task.

The difference apparent between the three groups, evident to varying degrees for each of the statistics, is not immediately explicable. AE demonstrates overall superiority by the group with learning difficulties, as does VE, both measures also indicating the MA group to perform least well. The latter fact might be expected, since older children may well be more competent at a task of this nature, but the superiority of the group with learning difficulties is less straightforward. It can only be reported that at the time of testing this group was highly motivated, perhaps more so than the others.

Differences in performance under the four practice conditions had also been experienced by other researchers. McCracken and Stelmach (1977) found higher variability to produce greater error scores, and similar trends during practice were found by Williams (1975), who found different practice conditions to result in differing degrees of error. The linear slide experiment used here revealed a trend for the constant and narrow band of practice to result in greater accuracy than the wider practice bands. Schmidt (1975b) makes no suggestion for schema as to what might be happening during practice. It is conceivable that in this experiment, the wide practice band (30 cm and the 120 cm) is the most difficult task to master, the relationship between the experiences more difficult to perceive, than for the narrow and constant practice condition. For both AE and VE, although not all are significant, the trend of the scores is for constant practice (75 cm) showing least error, then the narrow practice band (60 and 90 cm), middle practice band (45 and 105 cm) and finally the widest practice band (30 and 120 cm). AE appears to reflect VE throughout. This can be seen from Table 6.16.

Table 6.16: Mean AE and VE scores for the 4 practice conditions during practice trials. Linear Slide Task

| Error Score | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| AE | 16.01 | 14.65 | 13.02 | 12.62 |
| VE | 18.79 | 16.69 | 14.46 | 14.46 |

The fact that CE would appear to indicate no learning has taken place could reflect an apparent cancelling out of positive and negative scores. The fact that VE decreases systematically over trial blocks would appear to confirm this. This would appear to be a factor in consideration of the differences between groups for CE; the CA matched group exhibits greatest CE but considerably less VE than the MA group, for instance.

(b) Transfer 1, Trials 1-5, 6-10

For all these statistics used, no difference emerged between trials 1-5 and 6-10. Examination of the group means reveals no trend in any particular direction. (See Appendix 1, Tables 49, 50 and 51). Consideration of the AE scores, for example, demonstrates that for children with learning difficulties, for three of the four practice conditions, performance improves over trials, the wide practice band being the exception; for the MA matched group, three of the four practice band conditions results in a deterioration in accuracy over trials, the wide band in this instance demonstrating the opposite trend; for the CA matched group, improvement in performance over trials is evidenced by three of the four practice conditions, the constant practice group showing a small decrement in performance. As can be seen, no consistent pattern emerges that would either support or reject the hypothesis that learning can continue in the absence of knowledge of results, following constant or variable practice.

The differences that emerge between the groups and practice conditions at this stage are interesting. With regard to group analysis, AE demonstrates no differences, which is interesting when the margin between the groups during practice is taken into consideration. The superiority of the group with learning difficulties during practice disappears, for AE, although consideration of the means for all 10 trials at Transfer Target 1 shows the trend is for the MA matched group to perform at a lower level of accuracy than the two chronologically older groups. This is shown in Table 6.17.

Table 6.17: Mean Performance at Transfer Target 1, 3 groups and 4 practice conditions (AE) linear slide task

| Group | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 | Mean |
|---|---|---|---|---|---|
| CLD | 14.67 | 14.08 | 10.71 | 19.30 | 14.69 |
| MA | 17.65 | 17.38 | 12.72 | 13.50 | 15.31 |
| CA | 13.94 | 13.75 | 14.81 | 16.55 | 14.76 |
| Mean | 15.42 | 15.07 | 12.75 | 16.45 | |

From this it could be argued that children with learning difficulties are unable to transfer skills learned to novel but related tasks, since performance originally superior to 2 other groups is now equal to it. However, two factors warrant consideration; firstly, that VE scores show superior performance maintained by the children with learning difficulties (See Table 6.10), and secondly that although perhaps they may not be able to transfer to the same extent as children of the same chronological age, of normal intelligence, the fact that they are able to transfer at least to some degree, is evidenced by the fact that the error scores for children with learning difficulties having received variable practice, are less than those for the constant practice (See Table 6.17). They are able to make the extrapolations necessary for schema and to use this in the execution of novel responses, albeit perhaps not to the same extent as their peers of normal intelligence.

It is possible, therefore, to tentatively argue that children with learning difficulties are able to perform the cognitive exercises required to build up and use schema. A further related point emerges in that for such children on transfer to the novel condition without knowledge of results, the best performance is exhibited by the narrow practice band group. Possibly the novel task has to be seen to be very closely related to the practised task for such children to make the generalisations necessary; certainly the error scores of the wider practice bands as considerably greater. This trend is reflected by the MA matched group, although not significant, but not by the CA matched group, who appear to perform better after the wider practice band; again, however, this is not significant, the significant differences found between practice conditions 3 and 4 for all groups is a trend reflected largely by the group with learning difficulties and the MA matched group.

(c) <u>Transfer Target 1, Trial 1</u>

This analysis was carried out in order to determine any effect for group or practice condition on the first attempt at a novel task. Performance at the first attempt will inevitably draw on experiences during practice. For the constant practice group, this is a continuation of previous practice; the fact that knowledge of results is absent will not affect the first trial, since this has not previously been available until the completion of the response and ongoing correction is impossible for a ballistic task of this nature. One might expect therefore, that this group has an advantage, which would result in more accurate performance when compared to the variable practice groups.

However, this is not the case; for AE, for no group does the constant practice generate least error and in the case of the mental age matched groups it generates most error, although these are not significant statistically (see Table 6.11). This would indicate that variable practice is as effective as constant practice in this case which offers limited support for schema theory (Schmidt 1975b). This is also reflected by the CE analysis (See Appendix 1, Tables 37 and 52).

The results regarding the differences between groups are similar to those emerging from the 3 (group) x 4 (practice condition) x 2 (blocks) anova on the transfer 1, trials 1-5, 6-10 data which were considered in the previous section. The results here can be interpreted in the same light.

(d) Transfer Target 2, Trials 1-5, 6-10

The significant difference that exists between the two blocks of five trials would appear to demonstrate some degree of learning in the absence of knowledge of results, although there are isolated instances in which this trend is not apparent, such as for the MA matched group, practice condition 2. Schmidt (1975b) argues that learning can take place without knowledge of results since the schema forms the basis of each response; Adams (1971) argues that it can take place only after constant practice at the task, since the perceptual trace forms the basis of the response, and this is developed through repetition. The results here would perhaps give more support to the Schmidt (1975b) viewpoint, although not entirely since the constant practice group also evidenced improvement.

The differences shown between the three groups for AE are interesting since it appears that at this stage, the chronologically younger group is beginning to fall behind the older groups. The means show the MA matched group to exhibit greater error, with the group with learning difficulties and CA matched group, very much the same (see Table 6.13).Subjectively the tester observed that the MA matched group in particular appeared to view the second transfer task as being very much more difficult. Possibly the task difficulty is such that it is more CA related than MA dependent, in that to physically smaller individuals, the increased distance (75 cm to 140 cm) appears relatively large, is viewed as being more difficult and undertaken with less confidence.

No differences between the four practice conditions at this stage suggests that all four conditions enable subjects to cope equally well with the novel task. Schema theory (Schmidt 1975b) would predict that the constant practice group would perform at a lower level of accuracy than those having experienced variable practice. This is not the case, however; only in the case of the CA matched group does the constant practice group exhibit the greatest error (AE) (See Table 6.18), and in no case are the differences significant (see Appendix 1, Table 39). The overall mean also reflects greater error for the constant practice group, although marginal and not significant.

Table 6.18: Mean error for all groups and practice conditions on Transfer Target 2, (AE) linear slide task

| Group | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| CLD | 28.64 | 33.17 | 27.75 | 31.85 |
| MA | 36.83 | 35.92 | 32.07 | 33.69 |
| CA | 26.97 | 27.67 | 32.22 | 33.39 |
| Mean | 30.81 | 32.25 | 30.68 | 32.98 |

One point of interest is that again, although not significant, the narrow practice band results in least error both overall and for the group with learning difficulties and the MA matched group, a reflection of the trend for transfer target 1. It was suggested at that stage that less mature individuals might not see relationships as easily between targets relatively disparate, and may require smaller units as a basis for schema development.

(e) Transfer Target 2, 1st Trial

The non-significant differences between groups and practice conditions for both AE and CE permit little interpretation (See Appendix 1, Tables53 and 55). Examination of the means shows some differences between the groups (See Appendix 1, Tables 46 and 48), but the standard deviations are extremely large (See Appendix 1, Tables 53 and 54) which would obviously affect analyses of variance.

(f) General Discussions and Conclusions

The apparent superiority of the children with learning difficulties during learning is difficult to explain. They were randomly selected subjects, the sole grounds for elimination being the existence of any physical or behavioural problems that might adversely affect performance. The tester can only report high motivation on the part of these subjects to do well. Whilst this superiority tends to disappear during transfer, at no time does the performance of these subjects fall significantly behind that of the other two groups. During transfer, the trend is for the greater differences to lie between the group with learning difficulties and the CA match, rather than the group with learning difficulties and the other two groups, as during learning.

It can be tentatively suggested that children with learning difficulties are capable of the cognitive exercises proposed by Schmidt (1975b) for the development of schema, in the same way as children of normal intelligence. Furthermore, one can suggest that on a task of this nature, which is discrete, ballistic and in which no temporal demands by the environment are made, children with learning difficulties appear to be able to perform at a level comparable to their peers of normal intelligence, and above that of children matched with them on mental age.

## IV STUDY II: THE BALL THROWING TASK

The ball throwing task has several features in common with the linear slide task; it is discrete, relatively 'closed', and falls into the same category of environment stationary, whole body stationary, body part(s) moving. However, in many respects, it is also a contrast to the linear slide task. The linear slide task was completely novel, whereas all the children must have had some experience with ball games; the linear slide task involved fine finger movements, whereas the ball throwing task required a full arm movement and some body involvement; in the case of the changes in distance through which the bushing was to move, these were achieved by altering the position of the target, whereas in the ball throwing task, the target remains stationary throughout and the subject moves backwards and forwards. However, regardless of these features, it is hypothesised that fundamentally the tasks are similar, and the demands on the individual will be relatively similar for both tasks.

### (i) Method

#### (a) Subjects

40 boys and girls were drawn from a school for children with learning difficulties, having a mean chronological age of 12 years 8 months, ranging from 11 years 8 months to 13 years 11 months, and a mean IQ of 67.72, ranging from 46 to 73, resulting in a mean mental age of 8 years 7 months.

40 boys and girls were drawn from two local junior schools, as a mental age match for the children with learing difficulties. The

mean chronological age of these children was 8 years 7 months, and ranged from 8 years 4 months to 9 years 2 months. All were considered to be within the normal range of intelligence.

40 boys and girls were drawn from a local middle school, as a chronological age match for the children with learning difficulties, with a mean chronological age of 12 years 5 months, and ranging from 11 years 8 months to 12 years 8 months. Again, all children were considered to be from within the range of normal intelligence.

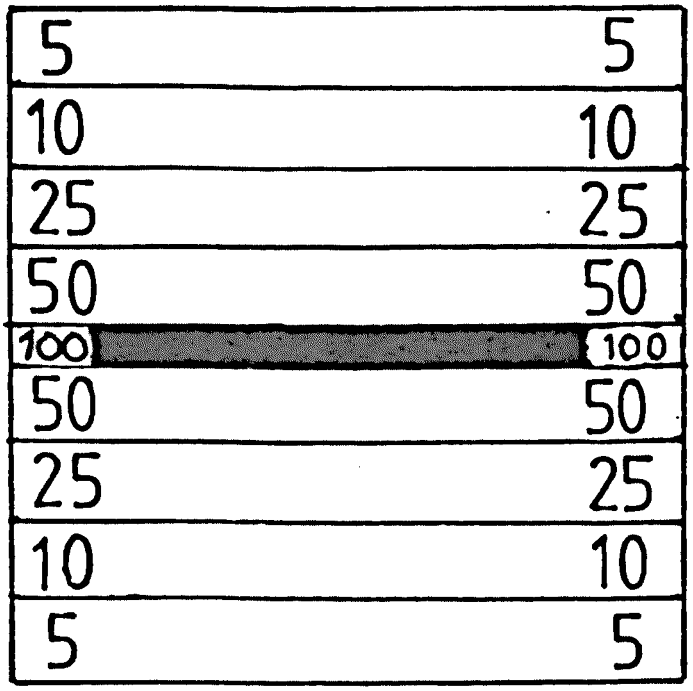
In all cases, the teacher in the school who arranged for the children to be released was asked to exclude any children considered to have any physical or behavioural problems that might affect performance at the task.

(b) Apparatus

A foam backed nylon carpet, 1.25 metres square was used as a target and placed on the floor, with plenty of room around it. It was placed reverse side up, so that the tufted side would prevent the target sliding on the floor.

On the foam side, across the centre was painted a black line, 2 cm in width. On each side of the line were painted four bands of colour, approximately 15 cm in width. At the sides of the target, on the bands of colour, numbers were painted in black, in order to give the carpet a 'target' or 'dartboard' appearance. This is shown in Figure 6.10.

Figure 6.10: Plan of the target for the ball throwing task (not drawn to scale)



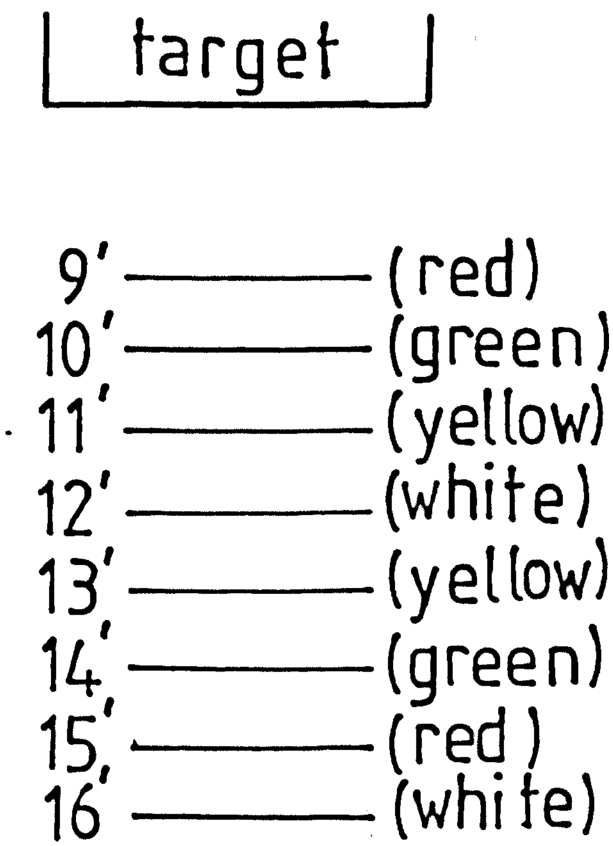




Figure 6.11: Plan of the throwing distances on the ball throwing task (not drawn to scale)

Having placed the target on the floor, distances of 9 ft, 10 ft, 11 ft, 12 ft, 13 ft, 14 ft, 15 ft and 16 ft from the centre of the black line were marked on the floor, by a line 2 ft long, using a tape or chalk, such that the numbers could be read from these lines. The 9 ft and 15 ft distances were marked in red, the 10 ft and 14 ft distances in green, the 11 ft and 13 ft distances in yellow, and the 12 ft and 16 ft distances in white. The plan of this is shown in Figure 6.11. Coloured plastic air-flo balls were used, and kept in a canvas bag. A metre rule, marked in centimetres, was used by the tester to measure the error distances.

(c) Design

For all three groups, the children with learning difficulties, the mental and chronological age matches, the children were randomly assigned to one of four practice conditions, resulting in 4 groups of 10 subjects in each case, each operating under a different practice regime. The aim throughout was to throw the ball in such a way as to make it land on the black line. Group 1 threw from 9 ft and 15 ft, alternately; group 2 from 10 feet and 14 ft, alternately; group 3 from 11 ft and 13 ft, alternately; and group 4 from 12 ft only. This is shown in Table 6.19.

All subjects received 40 trials in total, 4 blocks of 10 trials from their allocated throwing distances with a rest between the blocks to collect the D balls thrown. For groups 1, 2 and 3, where two throwing distances are involved, half of each group began with the shorter distance and half with the longer distance.

Following the practice trials, all groups attempted ten throws from 12 ft followed by ten throws from 16 ft. Vision was available throughout. All testing was conducted in a room in the school familiar to the children and allocated by the teacher in charge.

The effects of group and practice conditions on performance over four blocks of trials and at the two transfer distances were analysed.

Table 6.19: Throwing distances and trials of the 4 groups

| Group | Throwing distance | Number of trials |
|---|---|---|
| 1 | 9 ft | 20 |
| | 15 ft | 20 |
| 2 | 10 ft | 20 |
| | 14 ft | 20 |
| 3 | 11 ft | 20 |
| | 13 ft | 20 |
| 4 | 12 ft | 40 |

(d) Procedure

The children were tested individually. The apparatus was shown to the subject on entry into the room and the task explained. The subject was given the bag containing ten air-flo balls and told that he was to try to "score 100" by throwing the ball underarm with his preferred hand and make it land on the black line. It was explained that the important point was where the ball landed on the first bounce, not where it came to rest. The subject was then told from which line(s) to throw the balls and that on each occasion one foot at least had to be up to, but not touching, the line behind which he was standing. Any questions that the subject asked were answered and the tester then asked the subject if he understood what he was trying to do. If he did, the subject then placed the bag of balls close to his starting lines, on the floor, and was told to throw the first one when he was ready, but on all subsequent throws to wait until the tester told him she was ready before beginning his throw.

All ten balls were thrown, then collected and replaced in the bag by the subject before commencing the next block of trials. The tester watched the subject throw the ball and, observing where it landed, measured the shortest distance from that point to the centre of the 2 cm black line, using the metric rule. The subject was then told his "score" (100, 50, 25, 5 or 0) and the error score in centimetres too far (+) or too short (-). Vision of the flight of the ball and the target were available throughout. Following the practice trials, the subject was then told to throw 10 balls from 12 ft, followed by ten throws from 16 ft, the aim remaining the same, to make the ball land on the black line. No knowledge of results in terms of score or distance from the line was given, but the target and the flight of the ball remained visible throughout. In all cases, the error score (+ or - ) was recorded on the subjects' individual score sheet (See Appendix 7, Sheet 2).

In cases where it was necessary to take two children together, the second child was employed on a drawing task at the other side of the room, positioned such that view of the child working and of the target was not possible.

(ii) Results

The relative merits of AE, CE and VE were discussed in the results section of the experiment using the linear slide. The same holds true here. AE, CE and VE were computed in all cases. The effects of group (children with learning difficulties, mental age match and chronological age match)and practice condition (variable 1, 2 and 3 and constant 4) on the results for the following were examined:

(a) 4 blocks of 10 trials.

(b) Transfer distance 1, Trials 1-5 and 6-10.

(c) Transfer Distance 1, trial 1.

(d) Transfer Distance 2, trials 1-5 and 6-10.

(e) Transfer Distance 2, trial 1.

With the exception of Transfer Targets 1 and 2, first attempt, for which VE is not a viable statistic, analyses of variance were conducted for AE, CE and VE in all cases, each of which will be considered in turn.

(a) 4 blocks of 10 trials

The mean error score (AE, CE and VE) for the four practice trial blocks was computed for each subject and a 3 (group) x 4 (practice condition) x 4 (Trial Blocks) anova with repeated measures on the last factor was conducted in each case.

(ai) AE

The 3 (group) x 4 (practice condition) x 4 (Trial Blocks) anova for AE revealed significant main effects for group ($F$ (2, 108) = 11.46, $p < .01$), practice condition ($F$ (3, 108) = 4.14, $p < .01$), and trial blocks ($F$ (3, 324) = 17.69, $p < .001$), with no interactions between the three factors (See Appendix 2, Table 1).

With regard to the differences between the three groups, post-hoc testing (Tukey HSD) revealed the differences to lie between the CA and MA matched groups ($p < .01$) and children with learning difficulties and MA matched group ($p < .01$), the MA matched group exhibiting the greater error. No differences between the children with learning difficulties and the CA match were apparent. (See Appendix 2, Table 2). The group means are shown in Table 6.20.

Table 6.20: Mean error for the three groups during practice trials, (AE) ball throwing task

| CLD | MA | CA |
|---|---|---|
| 24.89 | 30.92 | 22.36 |

The effect of practice condition during the trial blocks was such that posthoc testing (Tukey HSD) revealed differences to lie between conditions 1 (wide practice band) and 3 (narrow practice band) ($p < .05$) and 1 and 4 (constant practice) ($p < .05$), the widest practice band resulting in the greatest error (See Appendix 2, Table 3). The means for the 4 practice conditions, groups and trial blocks combined, are shown in Table 6.21.

Table 6.21: Mean error scores for the four practice conditions, during practice trials (AE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 30.37 | 26.08 | 23.77 | 24.01 |

With regard to the significant main effect for trial blocks, posthoc testing (Tukey HSD) revealed the differences to lie specifically between blocks 1 and 2 ($p < .01$), 1 and 3 ($p < .01$) and 1 and 4 ($p < .01$) (See Appendix 2, Table 4), with no difference between blocks 2, 3 and 4. The trend is for a reduction in error over trial blocks. The means for the four blocks with groups and practice conditions combined are shown in Table 6.22.

Table 6.22: Mean Error Scores over the four Trial Blocks,(AE) ball throwing task

| Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|
| 30.86 | 24.74 | 24.68 | 23.96 |

(aiii) CE

The 3 (group) x 4 (practice condition) x 4 (trial blocks) anova for CE revealed a significant main effect for trial blocks ($F (3, 324) = 14.05$ ($p < .001$), but no effect for group or practice condition and no interaction between the three factors (See Appendix 2,

Table 5). With regard to the significant effects for trial blocks, the means for the blocks with practice conditions and groups combined are shown in Table 6.23.

Table 6.23: Mean Error Scores for the 4 trial blocks (CE) ball throwing task

| Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|
| - 17.82 | -10.65 | -10.58 | -11.16 |

Subsequent posthoc testing (Tukey HSD) revealed the differences to lie between 1 and 2 ($p < .01$), 1 and 3 ($p < .01$), and 1 and 4 ($p < .01$) (See Appendix 2, Table 6). Block 1 exhibited the greatest error. Although not significantly different, the means for the three groups, practice conditions and practice blocks combined, are shown in Table 6.24.

Table 6.24: Mean error Scores for the 3 groups during trial blocks (CE) ball throwing task

| CLD | MA | CA |
|---|---|---|
| -11.19 | -14.49 | -11.98 |

The trend would appear to be for the children with learning difficulties and the chronological age match to perform on a par, the mental age match exhibiting greater CE. The means for the 4 practice conditions are shown in Table 6.25, although, again, they are not significantly different.

Table 6.25: Mean Error Scores for the 4 practice conditions, during practice trials (CE) ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| -15.07 | -13.00 | -11.53 | -10.62 |

No steady trends are apparent, although condition 1 has the greatest error and condition 4 the least.

(aiii) VE

The 3 (group) x 4 (practice condition) x 4 (Trial Blocks) anova for VE revealed significant main effect for group ($F\ (2, 108) = 26.50$, ($p < .001$), Practice Condition ($F\ (3, 108) = 4.09$, ($p < .01$) and trial blocks ($F\ (3, 324) = 6.26$, $p < .001$). No significant interactions between the three factors were apparent (See Appendix 2, Table 7). The means for the three groups, with practice conditions and trial blocks combined are shown in Table 6.26.

Table 6.26: Mean Error Scores for the 3 groups during trial blocks (VE) ball throwing task

| CLD | MA | CA |
|---|---|---|
| 24.37 | 32.41 | 23.46 |

Subsequent posthoc testing (Tukey HSD) revealed the difference to lie between the MA and CA matched groups ($p < .01$) and the MA matched group and the children with learning difficulties ($p < .01$) (See Appendix 2, Table 8), with no difference between the two chronologically older groups. With regard to the differences between practice conditions, the means are shown in Table 6.27.

Table 6.27: Mean error scores for the four practice conditions during practice trials (VE), Ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 29.11 | 28.17 | 24.48 | 25.26 |

Subsequent posthoc testing (Tukey HSD) revealed a significant difference between practice conditions 1 and 3 ($p < .05$), the wide practice band resulting in the greatest variability and the narrow band, the least (See Appendix 2, Table 9). The means for the 4 trial blocks with groups and practice conditions combined are shown in Table 6.28.

Table 6.28: Mean error scores for the 4 trial blocks, (VE) ball throwing task

| Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|
| 29.39 | 26.13 | 25.96 | 25.54 |

Subsequent posthoc testing revealed the differences to lie between blocks 1 and 2 ($p < .01$), 1 and 3 ($p < .01$) and 1 and 4 ($p < .01$), with no difference between blocks 2, 3 and 4. (See Appendix 2, Table 10), the greatest error demonstrated on the first trial block, decreasing progressively over blocks.

(b) Transfer distance 1, trials 1 -5 and 6 -10

The 10 trials from transfer distance 1 were divided into two blocks of 5 trials (1 to 5, 6 to 10) for purposes of analysis, in order to determine any change in performance over time. The mean of each block was calculated for each subject, (AE, CE and VE), and the results subjected to a 3 (group) x 4 (practice condition) x 2 (blocks) anova with repeated measures on the last factor in all cases.

(bi) AE

The 3 (group)x 4 (practice condition) x 2 (blocks) anova for AE revealed a significant main effect for group only ($F (2, 108) = 13.31$, ($p < .001$) and no interactions between the three factors (See Appendix 2, Table 11). The means for the three groups with practice conditions and blocks combined are shown in Table 6.29.

Table 6.29: Mean error scores for the three groups at transfer distance 1 (AE) Ball throwing task

| CLD | MA | CA |
|---|---|---|
| 20.68 | 26.42 | 18.42 |

Subsequent posthoc testing (Tukey HSD) revealed significant differences between the MA matched group and the group with learning difficulties ($p < .01$) and the MA and CA matched groups ($p < .01$) (See Appendix 2, Table 12).

With regard to performance at transfer distance 1, trials 1-5, 6-10, as a function of practice condition, no significant differences were found. The means, however, for the 4 conditions can be seen in Table 6.30.

Table 6.30: Mean error for the 4 practice conditions at transfer distance 1, (AE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 23.50 | 22.07 | 20.90 | 20.89 |

The trend is for the wider bands to result in marginally greater error.

The means for performance over the two blocks of trials, 1-5, and 6-10, with groups and practice conditions combined, are shown in Table 6.31. Again, the difference was not significant, but the trend is for error to increase marginally over trials.

Table 6.31: Mean error scores for the two blocks of trials (1-5, 6-10) at Transfer Distance 1, ball throwing task

| Trials 1 - 5 | Trials 6 - 10 |
|---|---|
| 21.03 | 22.65 |

(bii) CE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova for CE revealed a significant main effect for group only ($F(2, 108) = 5.21$, ($p < .01$), and no interactions between the three factors (See Appendix 2, Table 13).

The mean error scores for the 3 groups are shown in Table 6.32.

Table 6.32: Mean error scores for the 3 groups, at transfer distance 1, (CE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| -13.59 | -14.56 | -8.23 |

Subsequent posthoc analysis (Tukey HSD) revealed the difference to lie between the CA and MA matched groups ($p < .01$) and the CA matched group and the children with learning difficulties ($p < .05$). (See Appendix 2, Table 14). The CA matched group exhibits the least error.

The means for the 4 practice conditions are shown in Table 6.33. No significant differences were found and the differences are only small.

Table 6.33: Mean error scores for the 4 practice conditions at transfer distance 1, (CE), ball throwing task

| Practice condition 1 | Practice condition 2 | Practice condition 3 | Practice condition 4 |
|---|---|---|---|
| -10.13 | -12.25 | -9.56 | -10.83 |

The effect for blocks approaches significance (F (1, 108) = 3.71, ($p < .0566$) and the means are shown in Table 6.34. The trend is for error to increase over trials.

Table 6.34: Mean error scores of the 2 blocks of trials 1 -5 and 6 -10 at transfer distance 1, (CE) ball throwing task

| Trials 1 - 5 | Trials 6 - 10 |
|---|---|
| - 9.18 | - 12.21 |

(biii) VE

The 3 (group) x 4 (practice condition) x 2 (block) anova for VE at transfer distance 1, trials 1-5, 6-10 revealed a significant main effect for group only (F (2, 108) = 11.78 ($p < .001$) and no significant interactions between the three factors. (See Appendix 2, Table 15). The means for the three groups, with practice conditions and blocks combined, are shown in Table 6.35.

Table 6.35: Mean error scores for the 3 groups at transfer distance 1, (VE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| 19.88 | 26.29 | 18.93 |

Subsequent posthoc testing (Tukey HSD) revealed significant differences between the MA matched group and the group with learning difficulties ($p < .01$) and the MA and CA matched groups ($p < .01$), there being no difference between the chronologically older groups. (See Appendix 2, Table 16).

The means for the 4 practice conditions, groups and blocks combined are shown in Table 6.36, although no significant differences were found.

Table 6.36: Mean error scores for the 4 practice conditions at transfer distance 1, (VE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 23.83 | 20.68 | 26.41 | 21.56 |

The cell means for the 2 blocks of 5 trials, with groups and practice conditions combined are shown in Table 6.37. Again, no other significance was evident.

Table 6.37: Mean error scores for the two blocks of 5 trials at transfer distance 1, (VE) ball throwing task

| Trials 1-5 | Trials 6-10 |
|---|---|
| 21.40 | 22.00 |

(c) Transfer distance 1, trial 1

The error score of each subject on the first attempt at transfer distance 1 was taken and using as both AE and CE. A 3 (group) x 4 (practice condition) anova was conducted in both cases.

(ci) AE

The 3 (group) x 4 (practice condition) anova for AE revealed a significant main effect for group only ($F(2, 108) = 6.61$, ($p < .01$), and no interaction between the 2 factors. (See Appendix 2, Table 17).

The group means, with practice conditions combined, are shown in Table 6.38.

Table 6.38: Mean error scores for the 3 groups at transfer distance 1, (AE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| 14.95 | 28.02 | 16.77 |

Subsequent posthoc testing (Tukey HSD) revealed significant differences between the MA and CA matched groups ($p < .01$)and MA matched group and group with learning difficulties ($p < .01$), with no difference between the group with learning difficulties and their chronological age match (See Appendix 2, Table 18).

The means for the 4 practice conditions are shown in Table 6.39. No overall significant differences were evident, although condition 2 has the lowest mean.

Table 6.39: Mean error scores for the 4 practice conditions at transfer distance 1, trial 1, (AE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 22.60 | 16.13 | 20.97 | 19.97 |

(cii) CE

The 3 (group) x 4 (practice condition) anova for CE revealed no significant main effects nor any interaction between the two factors. (See Appendix 2, Table 19). The means for the 3 groups are shown in Table 6.40, although they are not significantly different.

Table 6.40: Mean error scores for the 3 groups at transfer distance 1, trial 1, (CE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| -0.45 | -7.87 | -0.02 |

The means for the 4 practice conditions, again not significantly different, are shown in Table 6.41.

Table 6.41: Mean error scores for the 4 practice conditions at transfer distance 1, trial 1 (CE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| - 3.00 | - 8.53 | - 0.50 | - 0.10 |

(d) Transfer Distance 2, Trials 1-5, 6-10

As for the Transfer Distance 1, the ten attempts from Transfer Distance 2 were divided into two blocks of 5 trials (1-5, 6-10), in an attempt to evaluate any changes in performance over trials. The mean AE, CE and VE of each block of trials was calculated for each subject and the results subjected to a 3 (group) x 4 (practice condition) x 2 (blocks) anova with repeated measures on the last factor in all cases.

(di) AE

The 3 (group) x 4 ( practice condition) x 2 (blocks) anova, with repeated measures on the last factor for AE at Transfer Distance 2 revealed significant main effects for group ($F$ (2, 108) = 19.01, $p < .001$) practice condition ($F$ (3, 108) = 2.89, $p < .05$) and blocks ($F$ (1, 108) = 14.54, ($p < .001$), but no interactions between the 3 factors. (See Appendix 2, Table 20).

The mean error scores for the 3 groups, with practice conditions and blocks combined, are shown in Table 6.42:

Table 6.42: Mean error scores of the groups at Transfer Distance 2, (AE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| 31.93 | 42.56 | 27.73 |

Subsequent posthoc testing (Tukey HSD) revealed the significant differences to lie between the MA matched group and the group with learning difficulties ($p < .01$) and the MA and CA matched groups ($p < .01$), with no differences between the group with learning difficulties and their chronological age match (See Appendix 2, Table 21).

With regard to the differences between practice conditions, the cell means are shown in Table 6.43, with groups and blocks combined.

Table 6.43: Mean error scores for the 4 practice conditions at Transfer Distance 2, (AE) ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 31.00 | 37.80 | 31.30 | 36.20 |

Subsequent posthoc testing (using Tukey HSD) revealed no significant differences between the means (see Appendix 2, Table 22). Use of the LSD test revealed differences to lie between conditions 2 and 3 ($p < .05$) and 2 and 1 ($p < .05$). (See Appendix 2, Table 23), although these results should be treated with caution, as the test is not conservative and more likely than the Tukey HSD test to result in the making of a Type 1 error. Examination of the means suggests a trend for a natural division between conditions 1 and 3 together and 2 and 4 together, the latter resulting in greater error.

The differences between the two blocks of 5 trials (1-5, 6-10) is shown in Table 6.44.

Table 6.44: Mean error scores for the two blocks of trials at Transfer Distance 2, (AE), ball throwing task

| Trials 1 - 5 | Trials 6 - 10 |
|---|---|
| 36.69 | 31.46 |

There would appear to be a general reduction in error over trials.

(dii) CE

Using the BMDP computer program package, analysis of the CE scores was not possible. The differences were virtually nonexistent such that using 5 decimal places resulted in zeros.

(diii) VE

The 3 (group) x 4 (practice condition) x 2 (blocks) anova for VE, with repeated measures on the last factor, at Transfer Distance 2, Trials 1-5, 6-10, revealed a significant main effect for group only ($F(2, 108) = 15.15$, $p < .001$), and no significant interactions between the 3 factors (see Appendix 2, Table 24).

The means for the 3 groups, with practice conditions and blocks combined are shown in Table 6.45.

Table 6.45: Mean error scores for the 3 groups at Transfer Distance 2, (VE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| 25.20 | 33.09 | 23.14 |

Posthoc testing (Tukey HSD) revealed the differences to lie between the MA matched group and the children with learning difficulties ($p < .01$) and the MA and CA matched groups ($p < .01$), with no difference between the chronologically older groups (See Appendix 2 Table 25).

The means for the 4 practice conditions, although not significant, are shown in Table 6.46.

Table 6.46: Mean error scores for the 4 practice conditions at Transfer Distance 2, ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 26.73 | 29.68 | 24.71 | 27.44 |

Examination of the above means reveals no particular trends.

With regard to any changes in performance over trials, although not significant,VE seems to reduce over the blocks. The means are shown in Table 6.47, groups and practice conditions combined.

Table 6.47: Mean error scores for the 2 blocks of trials (1-5, 6-10) at Transfer Distance 2, (VE) ball throwing task

| Trials 1 - 5 | Trials 6 - 10 |
|---|---|
| 28.39 | 25.90 |

(e) Transfer Distance 2, Trial 1

In the same way as the first trial at Transfer Distance 1, the error score for the first attempt at Transfer Distance 2, was taken as both an absolute and constant error score. 3 (group) x 4 (practice condition) anovas for both AE and CE were then conducted. VE is not a viable statistic.

(ei) AE

The 3 (group) x 4 (practice condition) anova for AE revealed a significant main effect for practice condition ($F\ (3,\ 108) = 3.57$, $p < .05$) but no effect for group nor any interactions between the two factors (see Appendix 2, Table 26).

Wtih regard to the differences between practice conditions, the mean error scores, groups combined, are shown in Table 6.48.

Table 6.48: Mean error scores for 4 practice conditions at Transfer Distance 2, Trial 1 (AE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| 24.30 | 43.60 | 29.70 | 33.27 |

Subsequent posthoc testing (Tukey HSD) revealed significant differences between conditions 2 and 1 ($p < .05$) only. (See Appendix 2, Table 27).

The mean error scores for the 3 groups, not significantly different, are shown in Table 6.49.

Table 6.49: Mean error scores for the 3 groups at Transfer Distance 2, Trial 1, (AE) ball throwing task

| CLD | MA | CA |
|---|---|---|
| 30.37 | 38.42 | 29.35 |

The trend is for the children with learning difficulties and the CA match to show almost equal error, but with the error for the MA match somewhat greater.

(eii) CE

The 3 (group) x 4 (practice condition) anova for CE at Transfer Distance 2, trial 1 revealed no significant main effects, nor any interaction between the two. (See Appendix 2, Table 28).

The mean error scores, although not significantly different, for the 3 groups can be seen in Table 6.50. Again, the trend is for the MA matched group to exhibit greater error than both other groups.

Table 6.50: Mean error scores for the 3 groups, at Transfer Distance 2 Trial 1 (CE), ball throwing task

| CLD | MA | CA |
|---|---|---|
| -14.92 | -21.97 | -12.15 |

With regard to the performance at Transfer Distance 2, Trial 1 as a function of practice condition, the mean error scores can be seen in Table 6.51. Again, no overall significance was apparent.

Table 6.51: Mean error scores for the 4 practice conditions at Transfer Distance 2, Trial 1 (CE), ball throwing task

| Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|
| -29.11 | -22.47 | -14.10 | -13.73 |

(iii) Discussion

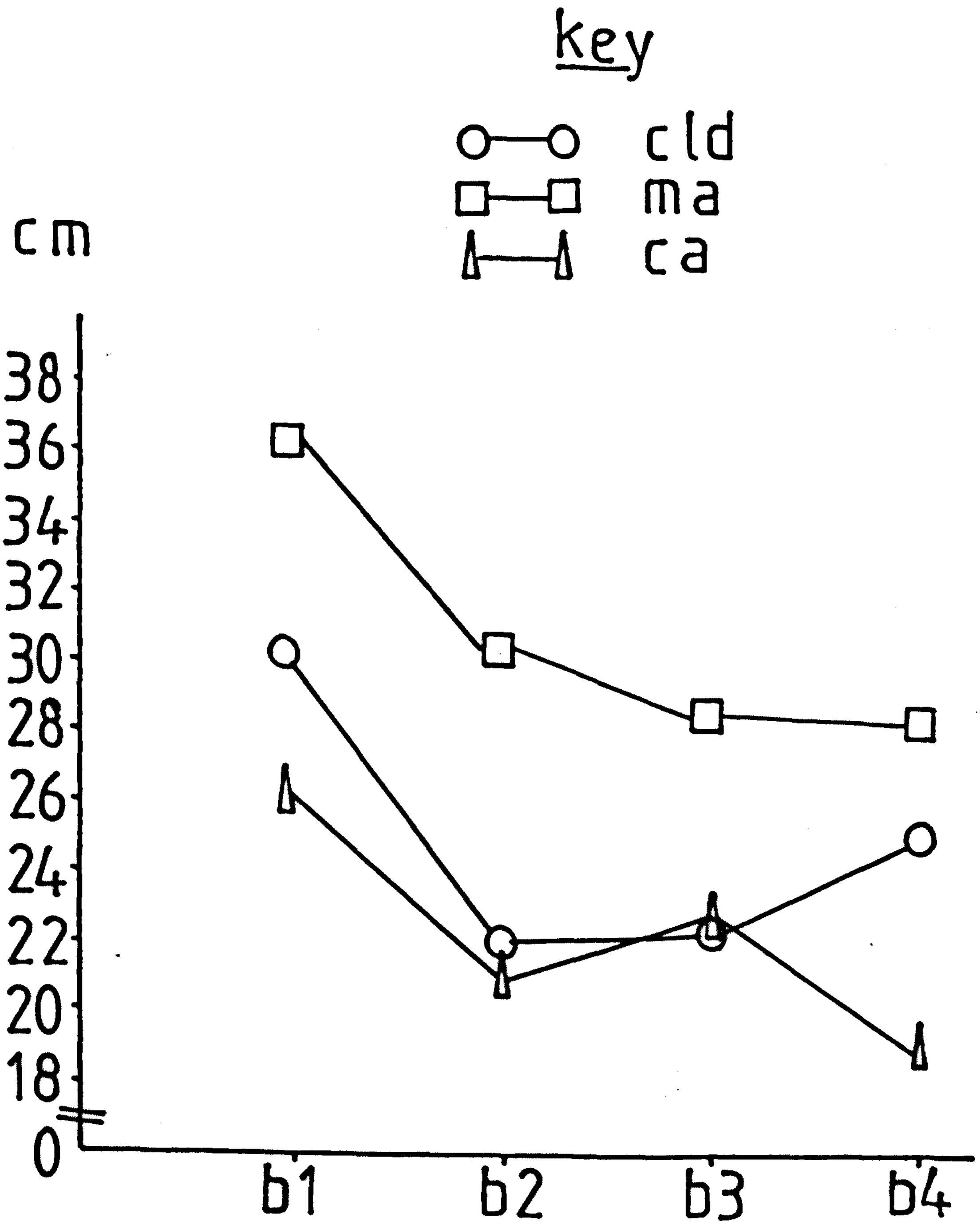
In the same way as for the linear slide experiment, the results of the ball throwing experiment will be considered in turn. The relative merits of AE, CE and VE as error scores were considered in the results section of the linear slide.

(a) 4 blocks of 10 trials

All three measures, AE, CE and VE, evidenced a reduction in error over blocks, and in all cases, the greatest reduction was between blocks 1 and 2, with relatively little difference between blocks 2, 3 and 4. This would indicate that all groups found the task relatively easy. The negatively accelerated shape of the learning or performance curves would suggest quick mastery of the requirements and demands of the task during the early trials, resulting in rapid improvement in performance with fewer improvements following. Apparently all groups have learned something, and the fact that no interactions were significant would seem to indicate that the nature of the change in performance was the same for all groups and practice conditions. Examination of the means shown in Table 6.52 and as seen in Figure 6.12 would appear to confirm this; although the absolute values may differ, the relative changes are similar in terms of the reduction between blocks 1 and 2 for all 3 groups.

With regard to differences between the 4 practice conditions, in all cases the widest practice band results in greatest error, for each of the 3 groups. It would appear to be the most difficult task of the four to master. Differences between practice conditions during

Figure 6.12: Performance of the 3 groups over the 4 practice trial blocks (AE), ball throwing task



the learning or acquisition phase have been found by other researchers (e.g. McCracken and Stelmach, 1977), and Schmidt (1975b) makes no prediction for schema as to what might happen during practice. Possibly if the acquisition trials were more numerous, the practice conditions might result in equal accuracy during the final block of trials.

Table 6.52: Mean error scores for the 3 groups over the 4 trial blocks (AE) ball throwing task

| | Block 1 | Block 2 | Block 3 | Block 4 |
|---|---|---|---|---|
| CLD | 30.28 | 22.34 | 22.47 | 24.46 |
| MA | 36.21 | 30.21 | 28.83 | 28.42 |
| CA | 26.10 | 21.63 | 22.72 | 19.00 |

With regard to the difference between the groups, the MA matched group appears to generate greater error than the two chronologically older groups, with no significant differences between the last two. The absence of any interaction suggests that this is consistently the case over the four practice blocks; examination of the means in Table 6.34 would appear to confirm this. On almost all occasions, the CA match is marginally more accurate than the children with learning difficulties, although not significantly so. The results for VE demonstrate the same trends; the MA matched group overall results in a mean VE of 32.41, whereas the CA matched group and the group with learning difficulties exhibit mean VE scores of 23.46 and 24.37 respectively. These results would appear to suggest that at least at this stage, the task is more chronological age related than mental age related. The greater amount of experience by children aged 12 years than those aged 8 years with ball games and pastimes may have an effect. However, this presupposes that the children are able to utilise these experiences in some way, in relation to the novel task. Generalisation of strategies, principles etc. by children with learning difficulties has not always been shown to occur.

(b) Transfer Distance 1, Trials 1-5, 6-10

The difference found between the groups at this stage resembles those found during the acquisition trials. AE and VE demonstrate the greater inaccuracy of the mental age matched group by comparison with the chronological age matched group and that with learning difficulties. The fact that the children with learning difficulties remain on a par with their chronological age matched peers suggest that they are able to transfer strategies, etc. to the new task in the same way as their peers. During the acquisition phase, the mean error scores, although not significant, of the group with learning difficulties were marginally greater than the chronological age matched group, and this trend remains apparent, as can be seen from Tables 6.29 and 6.35, for AE and VE respectively.

The absence of any differences in performance at Transfer Distance 1 as a function of practice condition, would suggest that all practice conditions enable transfer to the same degree. Examination of the means for AE in Table 6.12 suggests the lowest error is generated by practice condition 4, the constant practice schedule. However, the difference of 0.01 cm between conditions 4 and 3 (the narrow practice band) is insignificant, to say the least. Some support is, therefore, found for schema theory (Schmidt, 1975b) since a group not having practised at the distance is equally well able to perform accurately as the group which had experienced 40 attempts at the distance. Furthermore, no significant differences were found between any of the 4 conditions, suggesting width of practice band is immaterial although examination of the means in Table 6.12 indicates that the wider bands tend to result in marginally greater error. The fact that no interaction between practice condition and group was apparent suggests that all groups of children were equally capable of utilising the various practice experiences to engender transfer, i.e. of building up the schema on which to base future responses. This in turn would support the hypothesis that children with learning difficulties are capable of performing the cognitive exercises required to build up a schema as postulated by Schmidt (1975b). One further point is interesting in that, although when all groups are combined, practice condition 4 results in the greatest accuracy, when the groups are considered separately, in no case does practice condition 4 result in greatest accuracy. This can be seen from Table 6.53.

Table 6.53: Mean error scores for the 3 groups and 4 practice conditions at Transfer Distance 1 (AE), ball throwing task

| Group | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| CLD | 21.31 | 24.02 | 17.18 | 20.20 |
| MA | 28.29 | 25.67 | 26.02 | 25.72 |
| CA | 20.90 | 16.52 | 19.51 | 17.76 |

The results of the two blocks of five trials suggest a tendency for performance to deteriorate over trials, although not significantly so. This is apparent for all 3 statistical measures overall. When the 3 groups and 4 practice conditions are analysed, this trend, for AE, holds true for eight of the twelve subgroups, the exception being the MA and CA matched groups, practice conditions 1 and 2. The reason for this is not immediately explicable; although augmented feedback in terms of knowledge of results was not given, the subjects were able to view the target, the flight of the ball, their own movements and the result of the throw at all times. In this way, they would be able to evaluate their own performance. Subjectively, the tester observed that many of the subjects made comments to themselves or to her about their performance after a trial, such as "far too short" or "that was a good one, wasn't it?", apparently evaluating the trial. .Since vision was available, one might expect learning to continue. By the same token, the question of learning without knowledge of results cannot be considered here, since vision was not prevented. It could be argued that boredom was beginning to set in, although subjectively, this did not appear to be the case. Lack of motivation in the absence of precise knowledge of results may have been an influential factor, particularly if the subject could see that they were constantly scoring e.g. '50'.

### (c) Transfer Distance 1, Trial 1

The first attempt at a novel task is inevitably dependent on previous experience, or in Schmidt's (1975b) theory, the recall schema developed as a result of practice within the response class. The reason for analysing the results of the first trial is that it is the only trial which is entirely dependent on the previous practice. As the task is ballistic in nature, the visual knowledge of results acquired during that trial cannot be used to influence the result of the same trial, although it may be used as a basis for subsequent attempts from the novel distance, resulting in learning taking place. The first attempt from the novel distance is, therefore, the strictest measure of transfer, unaffected by possible learning. Since the transfer distance, 12 feet, is the same as that experienced by Practice Condition 4, Adams (1971) would predict that this group would be more accurate than the other three. The fact that this is not the case would tend to give limited support to schema theory (Schmidt, 1975b). The absence of any differences between the practice conditions is similar to that when all ten trials are considered, and can be interpreted in the same light.

The differences found between the 3 groups, with the mental age matched group exhibiting greater inaccuracy, reflects the same trend when all 10 trials are considered, and can be interpreted in the same light. When the means for the 3 groups are considered (See Table 6.38), the group with learning difficulties exhibits marginally less error than the chronological age match (AE of 14.95 and 16.77 respectively). Evidently, the children with learning difficulties are as able as their peers to utilise previous experience in adaptation to present requirements.

(d) Transfer Distance 2, Trials 1-5, 6-10

The apparent superiority of the children with learning difficulties and their chronological age matched peers over the subjects matched on mental age which was demonstrated during the learning phase and during Transfer Distance 1, is maintained at Transfer Distance 2 (16 feet). Examination of the means for both AE and VE confirms this. (See Tables 6.42 and 6.45).

Again, the children with learning difficulties would appear as able as their chronological matched peers to perform the task.

The differences found between the 4 practice conditions for AE must be interpreted with caution; by comparison with Tukey HSD test, the LSD test is less conservative and as such is more likely to result in the making of a Type 1 error, rejecting the null hypothesis it is in fact true. However, the tendency is for Condition 2 to result in the greatest error, and examination of the means suggests a natural division between conditions 1 and 3 together and 2 and 4 together (See Table 6.43), the latter resulting in the greatest error. Marginal support is, therefore, found for schema theory (Schmidt 1975b). However, the results are anomalous in that, when the three groups are considered separately, for the children with learning difficulties and the MA match, condition 4 results in greatest error, whereas for the chronological age match, it results in least error. This can be seen in Table 6.54.

Table 6.54: Mean error scores for the three groups and four practice conditions at transfer distance 2, (AE) ball throwing task

| Group | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| CLD | 25.09 | 36.33 | 26.69 | 38.57 |
| MA | 42.27 | 44.15 | 38.25 | 45.58 |
| CA | 25.65 | 31.87 | 28.95 | 24.45 |

The fact that there is a difference as a function of practice condition in error performance, would suggest that the children are not drawing entirely on previous days' or years' experience alone, and that the practice schedule they had experienced at the task earlier had also been influential on transfer to the second distance (16 ft.). The differences between the three groups may be explained partly in terms of previous years' experience, but this is apparently not the sole factor.

The reduction in error over trial blocks (trials 1-5, 6-10) found for AE is contrary to the trend exhibited for transfer distance 1. It was surprising in many ways to find no learning over the ten trials at transfer distance 1, since vision of performance and target was available throughout, such that the subjects were able to evaluate performance. The reduction in AE at transfer distance 2 over blocks would appear to confirm that visual feedback can be used to influence future responses, resulting in improvement. As can be seen from Table 6.55, this reduction of error is characteristic of all groups and practice conditions, implying that children of differing chronological age and intellectual abilities are all capable of this process.

It can be argued furthermore, that boredom is unlikely to have been the cause of poorer performance on trials 6-10 at transfer distance 1, since that block of trials was performed prior to the 10 attempts at transfer distance 2, in all cases. If boredom were a factor, performance could be expected to deteriorate consistently over the last 10 trials, which does not appear to occur. The errors may be greater at transfer distance 2 than at transfer distance 1, but this may be expected on the longer distance thrown and the fact of that a reduction in error at the final 5 trials would suggest that boredom is not a factor.

Table 6.55: Mean error scores of the 3 groups and 4 practice conditions over the 2 blocks of trials (1-5, 6-10) at transfer distance 2 (AE), ball throwing task

| | Practice Condition 1 | Practice Condition 2 | Practice Condition 3 | Practice Condition 4 |
|---|---|---|---|---|
| CLD $B_1$ | 25.62 | 38.36 | 27.39 | 40.54 |
| $B_2$ | 24.56 | 36.38 | 25.60 | 36.60 |
| MA $B_1$ | 47.88 | 46.54 | 40.92 | 48.93 |
| $B_2$ | 36.66 | 41.76 | 35.58 | 42.24 |
| CA $B_1$ | 29.90 | 36.86 | 30.48 | 26.42 |
| $B_2$ | 21.40 | 26.88 | 27.42 | 22.48 |

(e) Transfer Distance 2, Trial 1

The differences between the groups and practice conditions (AE) although not significant in the former case, reflect those trends apparent when all 10 trials are considered, and can be interpreted in the same light. Examination of the means in Table 6.49 suggest that the mental age matched group exhibits greater error than the other two groups, although not significantly so. With regard to the differences between practice conditions, condition 2 again exhibits greatest error, and the ordering of the means (2, 4, 3, 1) is again reflected here.

The effects for practice condition must be interpreted in a slightly different light than for transfer distance 1, since no group received constant practice at the second transfer distance. Schmidt (1975b) would predict more accurate performance by the variable practice groups, since variable practice forms the basis of schema. However, condition 4 does not result in the greatest error, with condition 2 producing the greatest, although conditions 1 and 3 result in less in accuracy than conditon 4. No real support is given for either Schmidt's (1975b) or Adams' (1971) point of view.

(f) General discussion and Conclusions

Overall, it would appear that on a discrete, ballistic, relatively closed task involving aiming balls at a target, children with learning difficulties are able to learn and perform the task at a level comparable to that of their chronological age matched peers of normal intelligence. Although on almost all occasions the mean error scores of the children with learning difficulties are marginally greater than those of their peers, at no time is the difference significant.
In contrast, the difference between these groups and the group matched with the group with learning difficulties on mental age, is significant throughout, with the exception of the first trial at transfer distance 2, and even in this case, the same trend is apparent. The effect for practice condition is such that it might be interpreted as giving tentative support so Schmidt's (1975b) schema theory since some generalisation is apparent, and practice condition 4 does not result in superior performance,even at transfer distance 1, novel to all variable practice groups and yet familiar to the constant practice condition, condition 4. The fact that no interactions between the

three groups emerge as significant for any of the analyses is interesting. It would suggest that difference, changes and trends found as main effects are consistent for all sub groups. For example, changes in performance over 4 trial blocks, found significant as a main effect, would appear to be the same for each of the 3 groups, the children with learning difficulties, and their chronological and mental age matches, such that the shape of the performance or learning curve is similar for all 3 groups.

It can, therefore, be tentatively concluded that children with learning difficulties are as capable as their age matched peers of learning ballistic, discrete ball throwing and aiming tasks in which no temporal impositions are placed on the individual by the environment in which and by the apparatus with which he is working. Their performance is considerably superior to that of children matched on mental age. This would appear to indicate that the task is chronological age related, rather than related to intellectual ability.

## V GENERAL DISCUSSION AND CONCLUSIONS - LINEAR SLIDE AND BALL THROWING TASKS

Certain similarities and contrasts are apparent in the nature of the two tasks attempted, as was stated at the beginning (Section II). When the results of the two experiments are considered together, again certain similarities and contrasts are apparent. The phases of the 2 experiments will be considered in turn.

### (i) 4 blocks of 10 trials

Whilst learning occurs in both tasks, certain differences between the two emerge. During the linear slide experiment the children with learning difficulties proved generally superior to the other two groups, whereas in the ball throwing experiment, the differences lay between the MA and CA matched groups, and the MA matched group and that with learning difficulties, the mental age matched group less accurate and the children with learning difficulties equal to their chronological age matched peers, but only just. Over the trial blocks, the interaction between group and blocks revealed differently shaped performance or learning curves for the children with learning difficulties when compared with their peers; the children with learning difficulties appear to take longer to make initial gains. In the ball throwing task, however, the relative shape of the curves for the 3 groups is similar, with no group x block interaction, the greatest gains for all groups being made between blocks 1 and 2. Possibly the ball throwing task is a task inherently more familiar to the subjects and so requires fewer cognitive operations to sort out the task demands and requirements, a process which one might expect to take longer for children with learning difficulties than those of normal intelligence.

Certainly, at this stage, the tasks appear to be more chronological age related than related to intellectual ability.

(ii) Performance at transfer task 1, trials 1-5,6-10

The main difference between the two tasks is the absence of vision in the linear slide task, and its presence in the ball throwing task.

Whilst one might account for the deterioration in performance over trials for the linear slide task, the trend for deterioration over trials in the ball throwing task is anomalous, and although boredom may have been a factor, it appears unlikely.

With regard to group performance, the group with learning difficulties and those matched on chronological age maintain superiority over the mental age matched group in both tasks, although in the case of the linear slide task, previous superiority by the children with learning difficulties during practice has given way to performance equal to tha of the chronological age matched group on transfer. Again, the tasks remain chronological age related in their demands.

Performance under the 4 practice conditions resulted in no differences on transfer 1 for either task, giving partial support for schema theory, and also indicating that all children were capable of the cognitive exercises required for the development of recall schema (Schmidt, 1975b). One further issue of interest is that on both tasks performance as a function of practice condition results in greater error (not significant, however) for the wide practice band than the middle width bands. This might be taken to mean that performance under these two conditions barely falls within the response class and does not contribute to the development of the recall schema in the same way as practice at the narrower bands.

(iii) Transfer task 1, Trial 1

For both tasks, performance on the first trial at transfer distance 1 will draw on previous practice experience. In neither task will vision/nonvision or absence of knowledge of results affect performance, nor is any correction of the ongoing response possible. The fact that differences emerge between the chronologically older groups and the younger group in both cases suggests that on this type of test the older groups are able to draw on these experiences to a greater extent (non-significant in the case of linear slide task). Possibly they have greater previous experience to call on. The fact that the results were significant for the ball throwing task and only apparent as trends for the linear slide task could also be taken to suggest that on the more familiar task, the older children are drawing on schema developed as a result of previous days' and years' experience, which is obviously greater for the older children. In the case of the linear slide task, this is not possible, since the task is completely novel.

The effects of practice condition on performance at Transfer Distance 1 reflects the results when all 10 trials are considered in both cases, giving some support for schema theory.

(iv) Transfer 2, Trials 1-5, 6-10

In both cases, the differences between the groups are such that the group with learning difficulties perform significantly more accurately than the group matched on mental age, suggesting that they are both tasks which are chronological age related than related to intellectual ability.

The reduction in error over trials is also characteristic of both tasks, although the situations are not directly comparable since vision was available during the ball throwing task, but not during this phase of the linear slide task. However, augmented knowledge of results, absent in both cases, would not appear to be essential for a decrease in error. All children would appear to be able to use other feedback information that is available.

(v) Transfer task 2, Trial 1

The results of the linear slide task indicate no differences between groups or practice condition. The significance of the practice condition demonstrates a trend for the ball throwing task for condition 2 to result in the greatest error, which is reflected by the data for the linear slide task (AE in both cases). With regard to group, both tasks reflect similar trends in turn reflecting analysis of the data when all 10 trials were considered.

(vi) General Conclusions

Certain similarities emerge when the data and results from the two discrete, ballistic and closed tasks are considered together.

One such feature is that on both tasks, learning and performance would appear to be chronological rather than mental age related. The difference between the two tasks as related to group performance is in the number of interactive effects present for the linear slide task, but absent for the ball throwing task. The longer time taken by the children with learning difficulties to make initial gains on the linear slide, compared with the CA and MA matched groups, is not apparent for the ball throwing task. This may be accounted for by the relative novelty of the linear slide task.

With regard to implications for theories of motor learning, the research suggests that rules for children of normal intelligence would appear to hold true for children with learning difficulties. Further, with regard to the theories of Adams (1971) and Schmidt (1975b) the results would appear to give limited support to the schema theory (Schmidt, 1975b) since in both cases, the group experiencing constant practice performs no more accurately than groups not having had the experience at that distance. The question of the nature of the response class remains unanswered in that no differences emerge between the practice conditions (for wide, narrow and medium practice bands), although there is a tendency for the wider bands to produce greater error.

Subjectively, all the children appeared to enjoy the tasks, and seemed motivated to do well. One difference was observed, however, between the three groups, during testing, particularly in the case of the ball throwing task. This was the large amount of time taken by the majority of the children with learning difficulties in preparation for each response. Many of them stood for a considerable length of time, checking their foot was up to the line, lining up the ball and swinging the throwing arm backwards and forwards before releasing the ball, on each occasion. No attempt was made to hurry the children, since the tasks were fundamentally without environmental demands. In no way was this length of preparation accounted for by the results. In view of these subjective observations, the next phase of the research employs tasks in which temporal demands are made by the environment.

# CHAPTER SEVEN

# AN INVESTIGATION INTO THE LEARNING OF TWO TRACKING TASKS BY CHILDREN WITH LEARNING DIFFICULTIES AND CHILDREN MATCHED WITH THEM ON CHRONOLOGICAL AGE AND MENTAL AGE

# I INTRODUCTION

Tracking can take many forms, but in all cases, the individual is required to move to a pattern or to points predetermined by the experimeter or apparatus. Poulton (1966) identifies five types of tracking:

(i) Pursuit tracking, in which the task is to keep a marker in time with a moving target.

(ii) Compensatory tracking, in which only one moving element is involved, and the task is to keep this element stationary at a point from which it tends to move away.

(iii) Acquisition or discontinuous step - function tracking, in which the target and marker begin together, the target then suddenly changes location and the task is to superimpose the marker on the target as quickly as possible, whereupon it moves again.

(iv) Unpaced contour tracking in which the target takes the form of a wiggly line along which the individual moves the marker in his own time.

(v) Paced contour tracking which is in principle the same as unpaced contour tracking, the only difference being that the target line is propelled at an externally controlled pace. The movement of the marker is at right angles to the direction of movement of the wiggly line.

The majority of research into tracking has focussed on pursuit and compensatory tracking, although it is with pursuit and paced contour tracking that the research here is primarily concerned. Poulton (1957) argues that pursuit tracking has a value in the study of everyday skills. He states that

> Pursuit tracking has two aspects which are common to a number of skills. First, it involves the acquisition of a moving target, as when an operative picks an object off a moving conveyor belt... And, second, pursuit tracking involves matching a function relating position and time, as in following a moving object with binoculars.
>
> (Page 467)

The research into pursuit tracking has often employed the pursuit rotor apparatus, which is generally a box-shaped piece of equipment, on top of which is a target which moves in a horizontal plane, often in the shape of a circle, on which the subject attempts to superimpose a stylus or marker. Accuracy is measured in terms of time on target. Research into tracking by children and adults with learning difficulties has been studied less intensively than that by persons of average intelligence, although certain aspects have been considered. The following areas will be considered, with reference to research using subjects with learning difficulties where applicable and available:-

(i) Tracking and Intelligence

(ii) Tracking and Age

(iii) Tracking relative to the size of target and speed of rotation

(iv) The predictability of the track

(v) Tracking and Sex

(vi) Practice schedules and reminiscence in tracking

(vii) Feedback in tracking

(viii) Praise and encouragement in tracking.

Whilst all these aspects of tracking are important, the central focus of this research is the effect of intelligence and age differences, and as a result of this, the main focus of the review of the literature on tracking is on the effects of intelligence and age. Rotation speed is also of concern, since two rotation speeds are used in the first experiment, using the pursuit rotor, and also track predictability, since this is a variable in the second experiment. Sex differences, practice scheduling and reminiscence, feedback, praise and encouragement are also relevant but perhaps less so, and mostly insofar as they reflect or refer to age and intelligence differences.

(i) <u>Tracking and Intelligence</u>

Much of the research into performance and learning of pursuit tracking by subjects with learning difficulties has compared their performance with that of subjects matched on chronological and/or mental age. In general, the research suggests that the performance of subjects of low intelligence is inferior to that of subjects of average intelligence.

Ellis, Pryer & Barnett (1960) tested acquisition and retention on a pursuit rotor task by subjects with a mean chronological age of 18.6

years and an IQ ranging from 38 to 75, with a mean of 61.2, and compared this with performance by subjects with a mean chronological age of 16.4 years, but average intelligence. During the acquisition trials, the latter group performed at a higher level in terms of percentage time on target than those of lower intelligence. Retention was tested after one or twentyeight days, and it was found that when the scores were adjusted in terms of amount originally learned, significant differences emerged between the intelligence groups, those of average intelligence having lost less than those of lower IQ. Retention over one day was superior to that over twenty-eight days with no significant group x retention interaction.

Similarly, Rarick, Dobbins and Broadhead (1976) examined pursuit rotor performance, and found that 9 year old children designated EMR performed at a lower level than children of the same age but of average intelligence. However, since only four trials of 15 seconds were given, and the mean time on target on these 4 trials taken as the measure, learning and retention were not considered.

Research by Jones & Ellis (1962) again using a pursuit rotor task, found performance by subjects with an IQ ranging from 60 to 75 and a chronological age ranging from 13 to 28 years significantly inferior to th of subjects of normal intelligence and chronological age of 14 to 16 years, over a series of 30 learning trials. Following a rest period, the difference between the groups increased markedly.

Ellis & Sloan (1957b) considered the relationship between performance on the rotor pursuit task and mental age. They took 3 groups of subjects, determined by mental age; 2.4 - 4.9 years, 5.1 -

7.8 years and 8.0 - 10.8 years. They found that the group with the lowest mental age did not improve with practice at the task, but that over 20 trials both other groups demonstrated an increase in time on target, the highest mental age group (8.0 - 10.8 years) marginally more so. The product - moment correlation between mental age and time on target was .43, a modest correlation.

Simensen (1973) found subjects of normal intelligence to perform at a higher level than subjects of the same age but with an IQ of 66.1 on a rotary pursuit task, during acquisition. After an eight week interval, no significant difference between the two groups was apparent in terms of amount retained. However, groups of subjects in the lower intelligence group who had been allowed to continue practising until they had achieved the level set by the groups of normal intelligence in the last 5 trials demonstrated greater retention after the 8 week interval than the subjects of average intelligence.

In total, the research done would appear to suggest that learning and performance by children with learning difficulties on a pursuit tracking task is inferior to that of their chronological age matched peers.

(ii) Tracking and Age

In general, the research suggests that both for children within the normal range of intelligence and those with learning difficulties rotary pursuit performance improves with age. Davol, Hastings & Klein (1965) found subjects of normal intelligence in a kindergarten, first, second and third grades, all to improve with practice on a rotary pursuit task; the results were such that the older children were more accurate throughout, the differences between the age groups increasing with practice trials. This is supported by Ammons, Alprin & Ammons (1955) who found a significant age effect overall when comparing groups of children of normal intelligence from school grades 3, 6, 9, 11 and 12. However, when girls only were considered, proficiency was found to decline between grades 9 and 12. Research by Davol & Breakell (1968) further confirms improvement in rotary pursuit performance with age for children within the range of normal intelligence; using two rotation speeds and subjects from two schools, designated lower class and middle class, age and rotation speed proved the most important factors, although the patterns differed between the two schools.

Rarick, Dobbins and Broadhead (1976) compared two age groups of subjects with learning difficulties on performance on a pursuit rotor task. The group with a mean age of 139.1 months performed more accurately than the younger group with a mean age of 101.3 months. Learning was not studied.

(iii) <u>Tracking relative to the size of target and the speed of rotation</u>

Again with subjects of average intelligence, Helmick (1951) investigated the effects of performance at a rotary pursuit task of target size and rotation speed. In terms of target size, the larger targets (1" and ¾") resulted in greater time on target scores than the smaller ones (½") at all speeds (50, 60 and 80 cpm), although the relationship between time on target and target size, linear to begin with, after trial 11 ceases to be linear and the curve levels out.

In terms of rate of rotation, the faster speeds generated generally lower time on target scores. Reminiscence remained unaffected by either variable. These findings are supported by Noble, Fitts & Warren (1955) who found an increase in root mean square (RMS) error and a decrease in time on target as cycle frequency increased. In this instance, however, the task was not rotary pursuit, but involved tracking a sinusoidal target line.

Further research by Davol, Hastings & Klein (1965) found faster speeds more difficult than slower ones, for children from kindergarten through third grade. A rotation speed of 33 rpm resulted in longer mean time on target than a speed of 45 rpm, and the significant trials x speed interaction found by Davol, Hastings & Klein (1965) indicates that the difference between the rotation speed increases with trials. This is confirmed by Horn (1975) who found longer time on target scores with slower rotation speeds, testing at 15, 30 and 45 rpm. Similar research by Davol & Breakell (1968) confirms longer time on target for slower rotation speeds.

(iv) The predictability of the track

Research in this area has been with subjects of average intelligence. Poulton (1957) compared the learning of predictable and unpredictable tracks. The tracks used were a series of 3 'W's side by side, with no gap between them, and the size of the 6 'V's was then systematically or randomly ordered resulting in a predictable or unpredictable track. He found that overshooting at the corners occured less when the position could be predicted than when it was random. Furthermore, he found that if visual information of the track was given before tracking, it was less effective than the visual-kinaesthetic information acquired during tracking.

## (v) Tracking and Sex

Much of the research into sex differences in tracking performance suggests superiority of males over females. Ammons, Alprin & Ammons (1955) found pursuit tracking performance of boys superior to that of girls, the difference increasing with age. Furthermore, performances of the girls declined from grade 9 to grade 12, whereas that of the boys continued to increase. Using subjects of average intelligence, Huang and Payne (1975) found evidence of superiority of male subjects over female subjects during early trials, and furthermore, this superiority increased over trials as the males evidenced a greater rate of improvement. McBride & Payne (1980), however, using a rotary pursuit tracking task found the sex difference to depend on the length of intertrial interval. Groups of subjects were given 60 trials of 30 seconds each, with intertrial intervals of 0, 5, 10, 20 or 40 seconds. The male superiority disappeared completely when the interval was greater than 5 seconds. McBride & Payne (1980) attribute this to the fact that males tend to generate and accumulate less reactive inhibition over trials than females, such that sex differences are a product of the temporal compositions of practice rather than heredity.

Research by Davol, Hastings & Klein (1965) suggests no sex differences exist for children between kindergarten and first grade classes. No interaction of sex with age, speed of rotation or trials suggests that this is consistent throughout. Davol & Breakell (1968) found no overall sex differences on a pursuit rotor task. Subjects were drawn from two schools, designated lower class and middle class, and a sex x sex of experimenter x speed interaction suggests that in the middle class school female subjects performed better with a female experimenter working at the faster speed (45 rpm), but better with a male experimenter at the slower speed (30 rpm). Mean time on target for the male subjects was approximately equal with examiners of both sexes. For subjects in the lower class school, both sexes appeared to perform better with a male experimenter. Thus, the only way in which sex appears to influence performance is through the sex of the examiner, and in this case only for middle class subjects. Males overall are not superior to females. Horn (1975) supports this view in that he found no significant effect for sex on the pursuit rotor task. However, time on target scores was found to be 2% higher for males than females for the slower speed (15 rpm), 16% higher at the medium speed (30 rpm) and 72% higher at the fastest speed (45 rpm). On reminiscence scores, males showed significantly greater reminiscence than females.

In terms of the research with children with learning difficulties, Rarick, Dobbins & Broadhead (1976) found the average performance of the boys superior to that of the girls, when young EMR children and those of normal intelligence are combined. However, the significant sex by disability interaction highlights the fact that it is the girls with learning difficulties who perform at a much lower level than the boys in the same disability group. The mean of the girls of average intelligence is marginally greater than that of the boys (3.49secs., compared with 3.44 secs.). Learning was not studied in this instance. Jones & Ellis (1962) and Simensen (1970) found superior performance by males over females, during a series of learning trials, reflecting much of the research findings using subjects of average intelligence.

(vi) Practice schedules and reminiscence in tracking

In research with subjects of average intelligence, on a variety of tasks, practice scheduling has been generally shown to be a performance rather than a learning variable (e.g. Adams & Reynolds, 1954; Stelmach, 1969). Massing practice will result in depressed performance during that time but on transfer to a more sympathetic, distributed regime, performance matches that of subjects having operated under that regime throughout.

Jones & Ellis (1962) using a pursuit rotor with two groups of subjects of average IQ and two groups with IQ ranging from 60 to 75, found that for both IQ groups, massed practice resulted in depressed performance during the acquisition trials. Following rest, both IQ groups demonstrated the reminiscence effect, suggesting that they are similarly affected by degree of distribution of practice in both cases. However, the difference between the IQ groups prior to rest is less than that after rest, although not significantly so, independent of practice schedule. This trend Jones & Ellis (1962) take to suggest that subjects of average intelligence demonstrate a greater build up of reactive inhibition during practice, resulting in greater benefit from the rest period. Similarly, Ellis, Pryer & Barnett (1960) found that although low intelligence (ranging from 38 to 75) and average intelligence groups benefitted from a 5 minute rest between two blocks of 20 trials, this was more so for the latter group, the results approaching significance.

Barnett & Cantor (1957) considered the effects of practice schedule on performance of a pursuit rotor task by subjects with a mental age ranging from 5 years 7 months to 10 years 2 months, and a mean chronological age of 27.4 years. Practice was given over two days, with 10 trials on each day. The subjects were allocated to one of four groups, differing in respect of the scheduling of the practice sessions, massed both days, distributed both days, massed on day 1 and distributed on day 2, and distributed on day 1 and massed on day 2. On day 1, distributed practice proved superior to the massed schedule, but the reminiscence effect on day two was significantly greater for the latter group. On the test trial following the two practice sessions and 5 minutes rest, no difference between the groups emerged suggesting that as for subjects of average intelligence, practice scheduling tends to influence performance rather than learning. In contrast, however, Baumeister, Hawkins & Holland (1966) evidenced a greater reminiscence effect for subjects with a mean IQ of 79.3 than for subjects of average intelligence, on a rotary pursuit task.

(vii) Feedback in tracking

Feedback and information about one's performance is known to be an important factor in learning. Bilodeau & Bilodeau (1961) suggest that it is

> the strongest, most important variable controlling performance and learning.
>
> (P.250)

The relative advantages of different types of feedback may well be task specific. However, using a pursuit rotor task, Noble & Noble (1972) found visual and on target auditory feedback to be superior to vision of target only and auditory on-target feedback only, when time on target was the criterion.

Simensen (1973) considered the effect of an immediate auditory error signal on rotary pursuit performance by subjects with a mean chronological age of 12 years 5 months and a mean IQ of 66.1 when compared with performance by children of the same chronological age but of average intelligence, under the same conditions. During acquisition, no effect for the error signal was apparent. Baumeister, Hawkins and Holland (1966) also used an auditory feedback signal but to indicate correct on-target performance. Two groups of subjects were compared, a group with a mean IQ of 79.3 and mean chronological age of 13.9 years, and a group with a mean chronological age of 14.0 years, all considered to be of average intelligence. Auditory feedback appeared to be equally beneficial to both groups. In terms of IQ group differences, initially the performance of those of low intelligence was below that of those of average intelligence, but with practice the initial superiority diminished. It is possible that since the speed of rotation was relatively slow, the latter group witnessed a ceiling effect on the task, reaching the asymptote early, and maintaining that level of performance.

Horgan (1980) considered the relative benefits to learning a pursuit rotor task of various types of feedback for mildly mentally retarded subjects with a mean chronological age of 141 months and a mean IQ of 66, ranging from 60 to 75. Seven groups were presented with differing types of feedback - visual/on target, visual/off target, auditory/on target, auditory/off target, tactile/on target, and tactile/

off target, and a control. The visual feedback was via a light on the stylus, the auditory feedback a buzzer and the tactile feedback through vibration in the stylus. Off target information failed to result in improvement over trials, whereas the control and all on target groups demonstrated greater accuracy. The auditory/on target information was significantly superior to the control and all off target information. The general implication is that at least for these subjects, positive information regarding success has benefits in learning. Possibly, it has additional motivational influences.

Holden & Corrigan (1980) considered velocity extrapolation and feed-back possibilities for subjects with a mean IQ of 65.2 and a mean chronological age of 16.2 years, and those matched with them on mental and chronological age. Using a pursuit rotor task, auditory feedback was present or withheld and designed to give information regarding proximity to the target, since the frequency increased as the stylus approached the target, both when the target was visible to the subject and under blindfolded conditions. When the target was visible, significant differences emerged between the performance of the chronological and mental age matched groups, the latter performing at a lower level, and the group with learning difficulties lying between the two. However, in the absence of target vision, the chronological and mental age matched groups demonstrated greater proximity to the target than the group with learning difficulties. When the target was not visible, auditory feedback resulted in more accurate tracking. Increasing the length of time during which the target was not visible had differential effects on the three groups. With feedback, when the intervals were relatively short, significant differences emerged between those with learning difficulties and their chronological age match: increasing the interval resulted in significant differences between the CA matched group and the two lower mental age groups. In the absence of auditory feedback, similar patterns emerge, the group with learning difficulties always inferior to the CA matched group, and significantly so at all but the shortest interval, but inferior also to the MA matched group at the two longest intervals. Holden & Corrigan (1980) suggest that the reason for poorer performance without feedback by those with learning difficulties is deficient velocity extrapolation, and that in the case of the presence of auditory feedback, mental age would appear to be the determinant.

(viii) Praise and encouragement in tracking

Ellis & Distefano (1959) examined the effects of verbal praise and encouragement on rotary pursuit performance by subjects with learning difficulties and found significant differences between a group receiving praise and one not doing so, in favour of the use of praise and urging. It is worth noting that at all times the comments were positive and at no time reflected disappointment on the part of the experimenter at the performance of the subject.

Ammons (1955), in a review of the variables involved in rotary pursuit tracking, states that care should be taken in the interpretation of many results and their generalisation, since the apparatus used varied considerably, and not all aspects were specified adequately. Since that time, quite possibly, the research has been more detailed, but the point remains valid.

## II PURPOSE OF THE TWO STUDIES

Continuing the theme of motor learning in children with learning difficulties and their mental and chronological age matched counterparts, the focus of this section is on the learning of two tasks, similar in that they have certain characteristics in common. All three groups follow the same programme, and it is proposed to investigate whether all are equally capable of learning the tasks and whether any differences emerge in terms of how they learn or the amount learned.

The two tasks used here, the pursuit rotor and the paced contour tracking tasks, both involve tracking predetermined courses at a rate imposed on the performer by the movement of the target. They are continuous tasks for the duration of each trial, the beginning and end imposed either by a timed period or by the length of the line or course to be followed. Both tasks, therefore, require that the performer learns to anticipate events. By comparison with the linear slide and ball throwing tasks, the pursuit rotor and paced contour tracking tasks are more 'open' in nature; the environment is moving, although in some cases predictably, and is therefore, imposing demands on the individual such that he must move in accordance with it. In terms of the task classification scheme postulated, both tasks fall into the category of environment moving, whole body stationary, body part(s) moving.

The experimental paradigm used within the tasks differs slightly. The pursuit rotor task involves two subgroups within the three school groups working at differing speeds, and acquiring the task after a series of 15 trials. The paced contour tracking task involves two subgroups again, but the variable manipulated is predictability of track, not speed of rotation. One group receives practice at 10 tracks all regular in nature, and identical; the second group receives practice at 10 tracks irregular in nature, and all different. This, to a certain extent, contributes to the issue of variable versus constant practice in relation to schema learning, as discussed in the previous chapter. Ten trials are given, and then a recall and a transfer trial after one week. The criterion measure for the pursuit rotor task is time on target, whereas the contour tracking task allows for more detailed analysis of errors. In both tasks, the data is subjected to analysis for differences between children with learning difficulties and their chronological and mental age matches, and between conditions within those groups. Consideration of individual data is also undertaken. Despite these similarities, the memory drum tracking study is not a mere replication of the previous one, in that two types of tracks are used, one regular and one irregular, and, secondly, they differ significantly in the way in which they allow for the analysis of errors. Use of pencil and paper in the second study provides a permanent record of trials and with it a more detailed subsequent analysis of results than the time on target information provided by the pursuit rotor task. These two fundamental differences are of concern in the following study. In terms of experimental paradigm, the three school groups, the group with learning difficulties and the CA and MA matched groups were randomly divided into two subgroups, one group attempting the regular track during practice and one group the irregular track. All children received ten trials on the first day and one recall trial five days later. The recall trial is then followed immediately by one transfer trial, attempting one type of track (regular or irregular) that had not been previously used. The effects of group and type of track on practice, recall and transfer were studied.

## III STUDY III: THE PURSUIT ROTOR TASK

The pursuit rotor task was employed as a task which would allow initial investigation of whether or not the observations made during the linear slide and ball throwing experiments regarding the length of time taken by the children with learning difficulties to execute the tasks would be a factor in a task in which temporal requirements were made by the environment or task. Comparisons were made between children with learning difficulties and their chronological and mental age matches and also between performance at different rotation speeds within these groups.

### (i) Method

#### (a) Subjects

30 boys and girls, all righthanded, were drawn from a local school for children with learning difficulties, with a mean chronological age of 12 years 10.5 months, and ranging from 12 years 3 months to 13 years 5 months. The mean IQ of the group was 67.17, and ranged from 46 to 79. Using the formula MA = $\frac{CA}{100}$ x IQ the resultant mental age was 8 years 7.8 months.

30 right handed boys and girls were drawn from a local junior school as a mental age match for the children with learning difficulties. The mean chronological age of the group was 8 years 8.4 months and ranged from 8 years 5 months to 9 years 4 months. All were considered by the teacher in charge to be from within the range of normal intelligence.

30 righthanded boys and girls were drawn from a local middle

school to act as a chronological age match for the children with learning difficulties. The mean chronological age of the group was 13 years 0 months and ranged from 12 years 4 months to 13 years 2 months. All were considered by the teacher in charge to be of average intelligence.

In all cases, the teacher in the school responsible for organising the release of the children was asked to exclude any children considered to have a physical or behavioural problem that might influence performance on the pursuit rotor task. In all groups, the ratio of boys to girls was approximately 2:1. Although sex difference was not of interest to this research, this was an attempt to control for any hereditary sex differences that might exist. Handedness was determined as the hand used to hold the pen when writing.

(b) Apparatus

The apparatus consisted of a pursuit rotor manufactured by Forth Instruments Ltd. A photograph of the equipment is shown in Figure 7.1. It comprised a metal framed box, 32.5 cms x 39 cms x 13 cms in height. The top surface, on which the target was located, was 31.5 cms square. On one side were located the control switches and read out panels, and at the opposite side were the sockets into which the stylus and power supply were directed. Inside the box was a turntable 29 cms in diameter which rotated in a clockwise direction and embedded within which was a line of 4 light bulbs covering a space of 8 cms in length and 1 cm in width located between the centre and edge of the turntable. This is shown in Figure 7.2.

Fig. 7.1: The pursuit rotor

Fig. 7.2: The turntable of the pursuit rotor

Over this turntable and resting on a ledge within the box were placed two pieces of clear glass. Between these sheets of glass was placed the target pattern, which comprised a sheet of plastic, blocked out with the exception of the target shape, a circle, which was white and allowed for the passage of light through that area only. The circle shape was 2 cm in width, and 12.75 cm in radius to the centre of the circle shape which was marked with a red dot. It was possible to rotate the turntable without illuminating the target, but when the lights were switched on, the patch of light was visible through the white area only, resulting in a patch of light approximately 1 cm x 2 cm moving around the circle. The speed of the turntable rotation was constant and could be varied from 1 circuit per 9 seconds at its slowest to 1 circuit per 0.5 seconds at its fastest. Calibration to a constant rate took approximately 10 minutes from switching on the electricity supply. The rotation speed was altered by means of the right hand control switch and was shown on the right hand display panel to .01 sec when the speed, target and count switches were also depressed. Sampling periods of 5, 10 or 20 seconds were possible, at the conclusion of which the time on target during that period was shown in the right hand display panel. Two red lights illuminated alternately for the duration of the sampling periods. Depression of the 'count' switch provided for display of cumulative time on target in seconds consecutive over sampling periods, but this was not used in this experiment. The 'audio' switch allowed for use of auditory feedback, again it was not used here. Depression of the 'target' switch allowed for illumination of the target lights. The controls and displays are shown in Figure 7.3.

Fig. 7.3: The display panel of the pursuit rotor

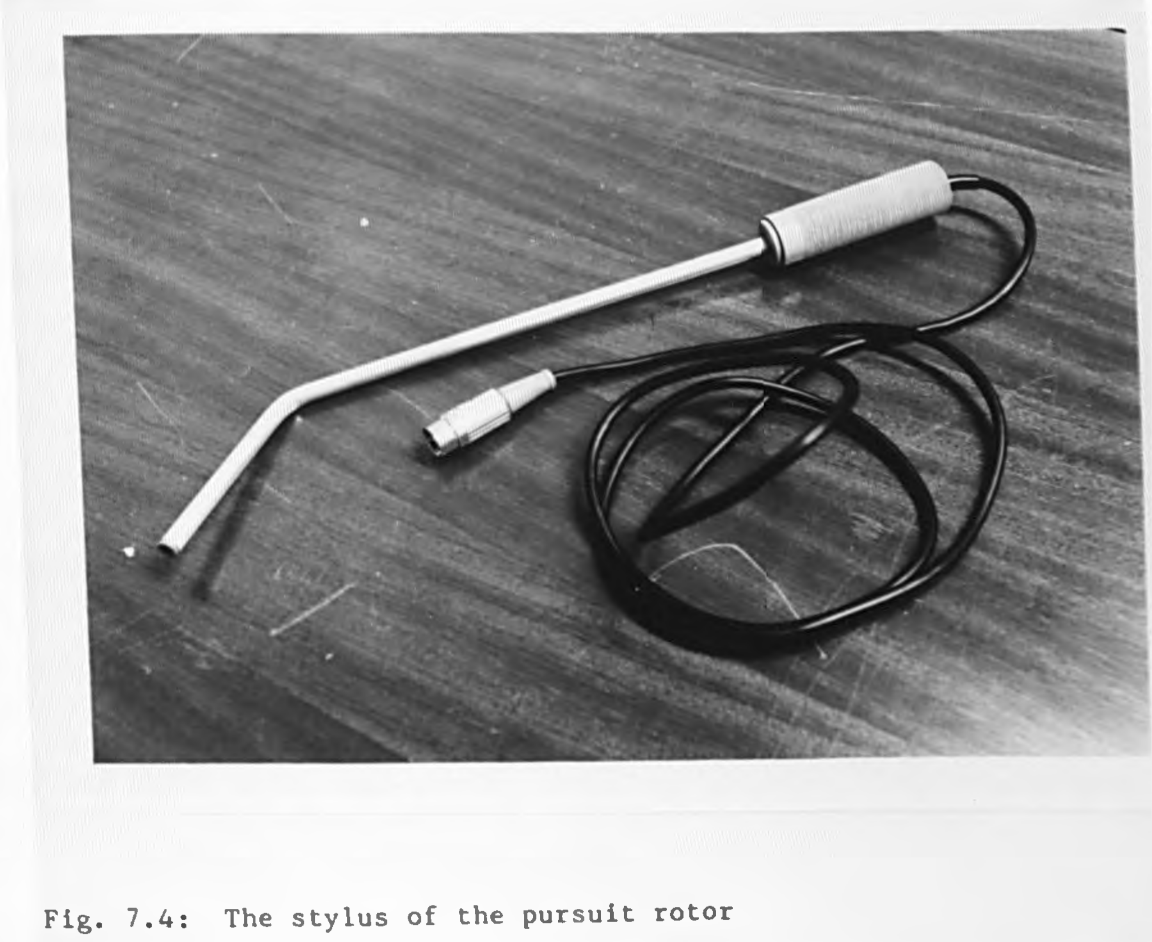


Fig. 7.4: The stylus of the pursuit rotor

Overall, the stylus was 40 cm in length, bent at an angle of $45^{o}$ at a point 32 cm along its length. The handle, 9.5 cm of the stylus length, was 2.5 cm in diameter and covered in hard plastic. The remaining 31.5 cm was metal, 0.75 cm in diameter, but hollow. The top of the stylus was plastic and embedded within it was a photoelectric cell. Contact between this photoelectric cell and the patch of light on the circle resulted in a recording of time on target (.01 seconds) on the right hand display panel at the termination of the sampling period. The stylus was attached to the pursuit rotor by means of a power cable, 1.5 m in length, from the end of the stylus handle to the socket at the back of the box. The weight of the stylus and cable was in all 150 grams. The stylus can be seen in Figure 7.4.

The pursuit rotor was placed on a table at a height suitable for the individual being tested and placed as close to the edge of the table as possible, by which the subject stood. The tester also kept a stopwatch on the table, by the apparatus, calibrated in .01 seconds, constantly going, in order to be aware of the passing of the test periods.

(c) <u>Design</u>

All testing was conducted within the school environment familiar to the subjects in a room allocated by the teacher in charge.

For all three groups, the children with learning difficulties (CLD) and their chronological and mental age matches, the subjects were assigned to one of two conditions. Since the variable employed was speed of rotation and recalibration took several minutes, it was not economical in terms of time to allocate subjects to conditions alternnately. For all three groups, the first 15 subjects worked with the slower rotation speed and the second 15 subjects with the faster rotation speed. It was necessary to find two rotation speeds as far apart as possible that would not generate floor or ceiling effects for any of the groups of children within the groups. For this reason, a small pilot study was conducted to find the two most suitable speeds. Six children with learning difficulties, who did not participate in the subsequent main experiment but from the same age group,acted as subjects. Speeds ranging from 1 rotation per 5 seconds to 1 rotation per 0.5 seconds were attempted by these subjects, some proving far too easy and thus presenting little challenge and others of which proved far too difficult. However, following the small pilot study with some children with learning difficulties, the rotation speeds were set at 30 rpm (1 rotation per 2 seconds) and 45 rpm (1 rotation per 1.33 seconds). The subjects were drawn from mixed ability classes and were taken alphabetically so it was considered unlikely that there would be any overall differences in ability between the subjects in the two subgroups within the school group.

The aim throughout was to keep the end of the stylus in contact with the moving patch of light. All subjects received three blocks of five trials, 15 trials in total, each trial lasting 20 seconds and with an intertrial interval of 20 seconds. The rest between practice blocks was achieved by two subjects working alternately for 5 trials, the second person waiting outside the testing room whilst the first practised.

Sixteen subjects per group were actually tested to allow for the rest/work pattern to remain constant throughout. The number per group was reduced to 15, since in one group, a subject unplugged the stylus, resulting in zero time on target over two trials and in another group, one subject proved uncooperative. The sixteenth subject in all subsequent groups was then disregarded.

This resulted in a 3 (group) x 2 (practice condition) x 3 (trial blocks) design, with repeated measures over the last factor.

(d) Procedure

The subjects were released from their classroom in pairs and the task was explained to them together. However, they were then tested individually.

The apparatus was shown to both subjects on entry into the testing room and the task then explained. They were told that a patch of light would move round the white circle at a constant rate, and their task was to try to keep the end of the stylus or pen touching the light all the time as it moved round. It was explained that the end of the stylus should be flat against the glass at all times, as it would not "score" if the end were at an angle against the surface. The target light was then switched on and allowed to be seen for the duration of one rotation, before being switched off again. They were told that they would hold the stylus in their right hand and begin with stylus end touching the red dot. They were told that they should move to the patch of light as quickly as possible after it came on and attempt to keep the stylus touching it until it was turned off. They were told that the experimenter would advise him that the light was about to come on by saying "ready" just before and "go" as it came on. They were told that the light could appear anywhere in the circle and not necessarily in the same place each time. Any questions asked by the subjects were then answered. They were told that at the end of each trial they would be told their score in terms of time on target (.01 secs) and it would be recorded on their individual score sheet (See Appendix 7, Sheet 3). They were then told that 10 seconds before the commencement of each trial, they would be told to place the stylus on the red dot. The second subject then left the room, whilst the first attempted five trials and they then changed over. Before the second subject began the task, he was asked if he remembered what he had to do, and any questions asked were answered. The subjects alternated until each had completed three blocks of five trials.

The rate of rotation was checked after testing each pair of subjec the glass surface was also wiped using a glass cleaning fluid to keep the surface clean, smooth, and free from grit and dust.

(ii) Results

The time on target (.01 seconds) was recorded for each individual. The following group analyses were then conducted.

(A) The mean time on target of each of the 3 blocks of 5 trials was calculated for each individual and the results subjected to a 3 (group) x 2 (practice condition) x 3 (trial blocks) analysis of variance.

(B) The standard deviation of the mean time on target of each of the 3 blocks of 5 trials was calculated for each individual and the results subjected to a 3 (group) x 2 (practice condition) x 3 (trial blocks) analysis of variance.

(C) The coefficient of variation of each of the 3 blocks of 5 trials was calculated for each individual. The group means for the two speeds were then calculated and examined.

Examination of the individual data was also conducted, although not subjected to analysis of variance in terms of

(D) Performance over 3 trial blocks in terms of time on target.

(E) The coefficient of variation over 3 blocks of 5 trials.

Each of these analyses will be considered in turn.

The tail probabilities will be stated as being significantat the .05, .01 or .001 level. Statement of the significance at the .001 level does not, however, preclude the fact that the tail probability may be much less, less than .0000, for example.

(A) Mean time on target over 3 blocks of 5 trials, group analyses

The mean time on target for each of the 3 blocks of trials on each subject were subject to a 3 (group) x 2 (practice condition) x 3 (trial blocks) anova with repeated measures on the last factor. Significant main effects for group ($F (2, 84) = 18.89$, $p < .001$), speed ($F (1, 84) = 123.09$, $p < .001$) and blocks ($F (2, 168) = 369.55$, $p < .001$) were found and in addition, a significant block x group interaction ($F (4, 168) = 5.98$, $p < .001$) and a blocks x speed interaction ($F (2, 168) = 23.58$, $p < .001$). No group x speed interaction was apparent. The table is shown in Appendix 3 (Appendix 3, Table 1).

Tests for simple main effects were carried out for the speed x blocks interaction (See Appendix 3, Table 2). Overall differences were evident for both speeds (fast speed, $F (2, 168 = 100.52$, $p < .01$; slow speed, $F(2, 168) = 289.9$, $p < .01$) and all three trial blocks (trial block 1, $F(1, 84) = 66.65$, $p < .C1$, Trial Block 2, $F(1, 84) = 126.28$, $p < .01$; Trial Block 3, $F(1, 84) = 145.23$, $p < .01$).

For all three trial blocks, the faster speed resulted in shorter time on target, as can be seen from Table 7.1.

Table 7.1: Mean Time on Target for the two rotation speeds over 3 trial blocks, pursuit rotor task

| Block | Slow rotation speed | Fast rotation speed |
|---|---|---|
| 1 | 4.435 | 1.238 |
| 2 | 7.129 | 2.735 |
| 3 | 8.193 | 3.525 |
| Mean | 6.586 | 2.166 |

With regard to the differences between trial blocks for the two speeds, posthoc analysis (Tukey HSD Test) revealed the following significant differences.

(i) For the slow speed between blocks 1 and 2 ($p < .01$)
blocks 1 and 3 ($p < .01$)
blocks 2 and 3 ($p < .01$)

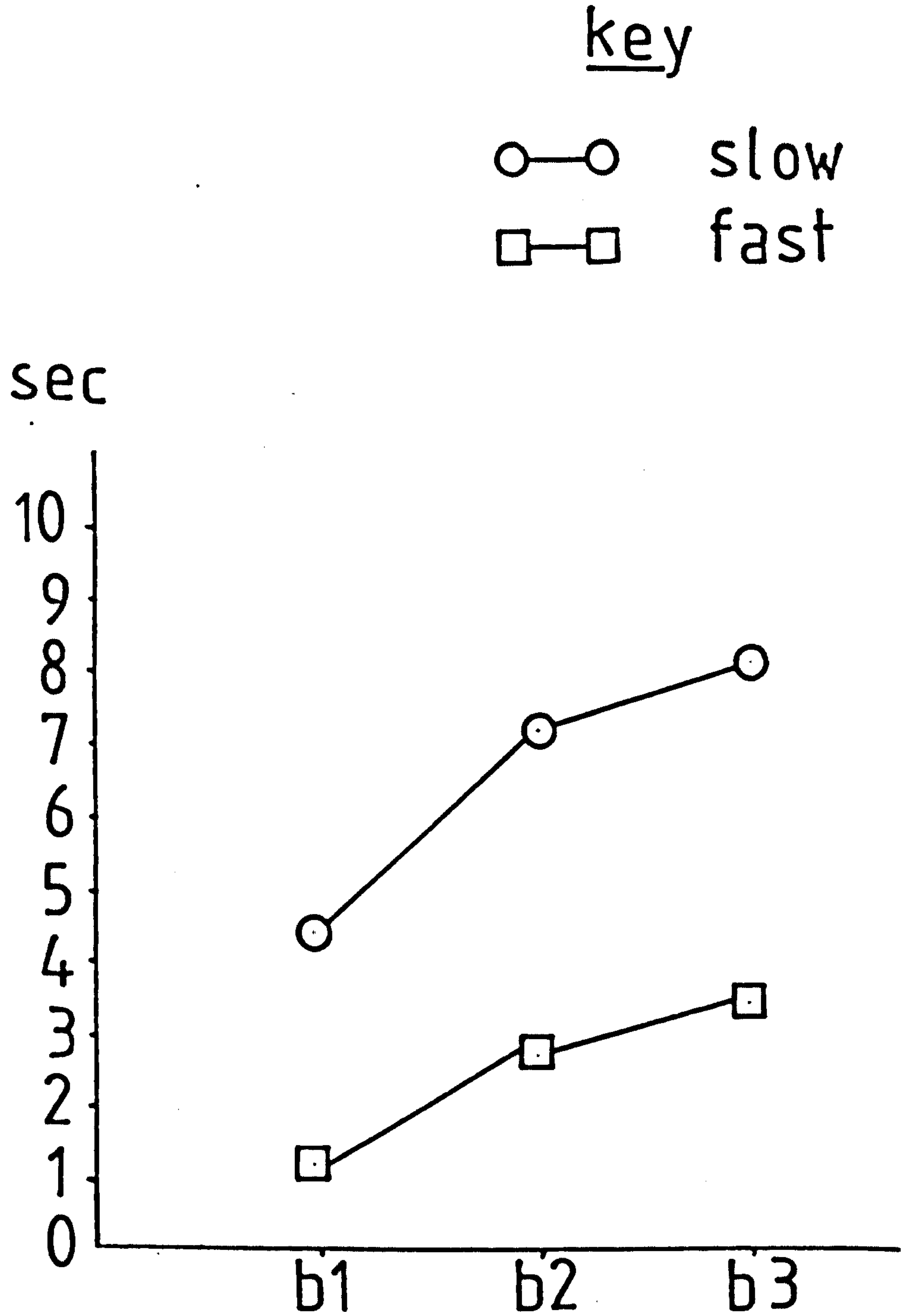
(ii) For the fast speed, between blocks 1 and 2 ($p < .01$)
blocks 1 and 3 ($p < .01$)
blocks 2 and 3 ($p < .01$)

(See Appendix 3, Tables 3 and 4).

Although all are significant, the effects of the interaction can be seen more clearly in Figure 7.5, where blocks 2 and 3 for the fast speed are relatively close in terms of mean time on target.

Tests for simple main effects were conducted on the significant group x block interaction. Overall differences were found for all trial

Figure 7.5 Mean time on target for the two rotation speeds, over 3 blocks of trials, pursuit rotor task



blocks and all groups (See Appendix 3, Table 5). Subsequent posthoc analysis (Tukey HSD) revealed the following specific differences:-

(i) On block 1, between CA and MA matched groups ($p < .01$)
CA and CLD groups ($p < .01$)

(ii) On block 2, between CA and MA matched groups ($p < .01$)
CA and CLD groups ($p < .01$)

(iii) On block 3, between CA and MA matched groups ($p < .01$)
CA and CLD groups ($p < .01$)

(iv) For the CLD between blocks 1 and 2 ($p < .01$)
1 and 3 ($p < .01$)
2 and 3 ($p < .01$)

(v) For the MA matched group, between blocks 1 and 2 ($p < .01$)
1 and 3 ($p < .01$)
2 and 3 ($p < .01$)

(vi) For the CA matched group, between blocks 1 and 2 ($p < .01$)
1 and 3 ($p < .01$)
2 and 3 ($p < .01$)

(See Appendix 3, Tables 6 to 11).

(B) <u>Standard Deviation of the mean time on target over 3 blocks of 5 trials, group data</u>

The standard deviation for the mean time on target over the 3 blocks was calculated for each of the subjects. A 3 (group) x 2 (practice condition) x 3 (trial blocks) analysis of variance, with repeated measures on the last factor, was then performed. Significant main effects for group ($F (2, 84) = 6.80$, $p < .01$, speed of rotation ($F(1, 84) = 73,32$, $p < .001$ and blocks ($F(2, 168) = 4.37$, $p < .05$) were found, and in addition a significant blocks x speed interaction ($F (2, 168) = 6.61$, $p < .01$). The anova table is shown in Appendix 3, Table 12.

With regard to the main effect for group, subsequent posthoc analysis using the Tukey HSD test revealed no significant differences between the three groups, (See Appendix 3, Table 13). Using the LSD Test, significant differences between the CA and MA matched groups emerged (See Appendix 3, Table 14), the required difference between the means just being equalled. However, care should be taken in the interpretation of these results, since the LSD test is not conservative, resulting in an increased likelihood of making a Type 1 error, rejecting the null hypothesis, when it is in fact true.

Tests of simple main effects were conducted on the significant blocks x speed interaction. The anova table is shown in Appendix 3, Table 15. Overall differences were found between speeds for all three trial blocks. (Block 1, $F(1, 84) = 69.04$, $p < .01$; Block 2, $F(1,84) = 27.13$, $p < .01$); Block 3 $F(1, 84) = 14.87$, $p < .01$), and between blocks for the slow speed only ($F (2, 168) = 10.67$, $p < .01$). For all blocks, the slower speed resulted in the higher standard deviations, as can be seen from Table 7.2.

Table 7.2: Mean standard deviations for the two rotation speeds over the 3 trial blocks, pursuit rotor task

| Block | Fast Speed | Slow Speed |
|---|---|---|
| Block 1 | 0.61 | 1.45 |
| Block 2 | 0.61 | 1.13 |
| Block 3 | 0.67 | 1.06 |

With regard to the difference between blocks for the slower speed of rotation, posthoc testing (Tukey HSD) revealed significant differences between blocks 1 and 2 ($p < .01$) and 1 and 3 ($p < .01$) (See Appendix 3, Table 16). The variability decreased over trial blocks particularly between blocks 1 and 2.

(C) Mean coefficient of variation over 3 blocks of 5 trials, group data, pursuit rotor task

The mean coefficient of variation for each individual was calculated, for the 3 blocks of 5 trials, using the formula

$$V = \frac{SD}{Mean} \times 100.$$

The results are shown in Tables 17-22. The mean for the groups on each block of trials was calculated, and can be seen in Table 7.3, and graphically in Figures 7.6 and 7.7.

Figure 7.6: Mean coefficient of variation of the 3 groups for the slow rotation speed over 3 trial blocks, pursuit rotor task

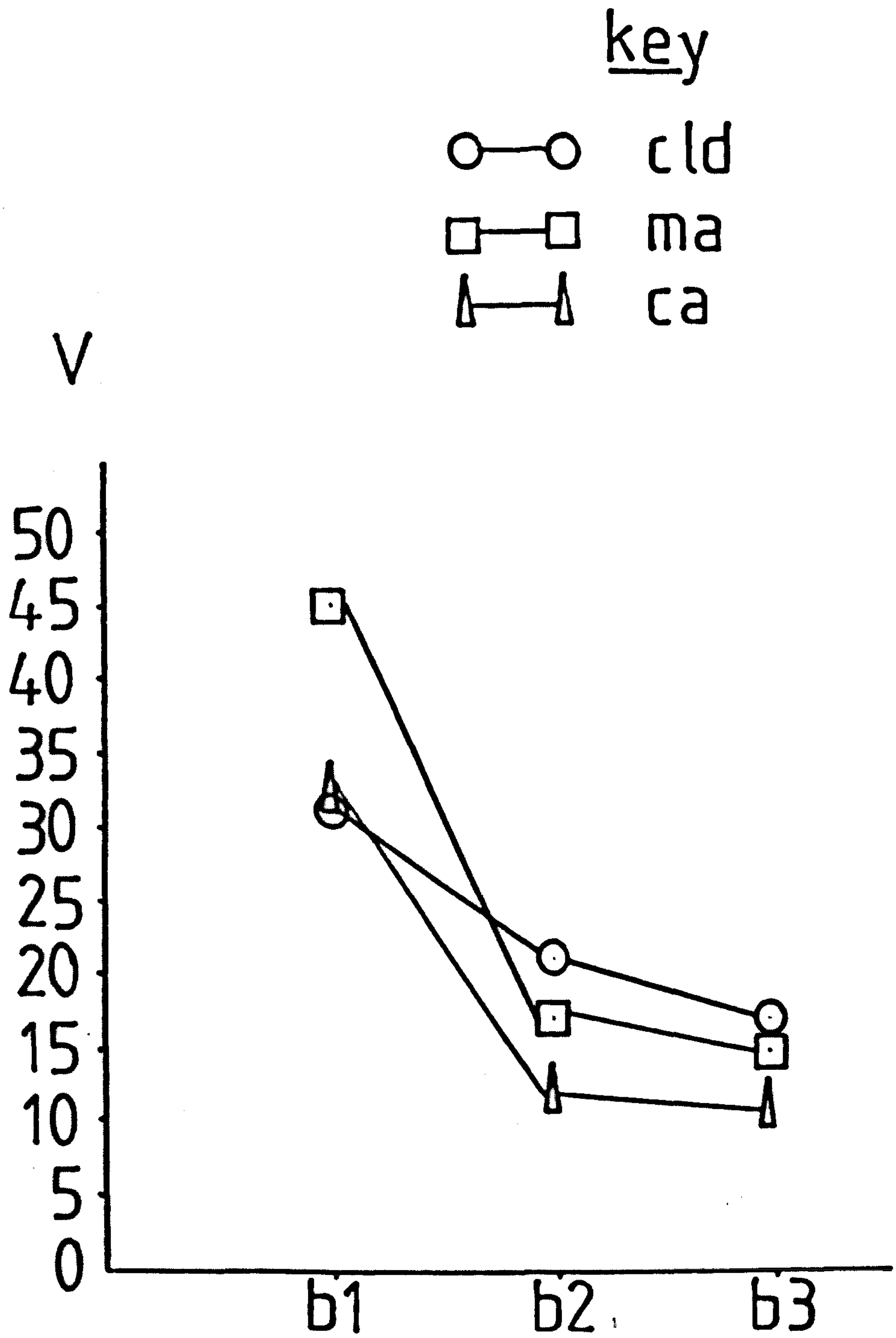


Figure 7.7: Mean coefficient of variation of the 3 groups over 3 trial blocks, fast rotation speed, pursuit rotor task

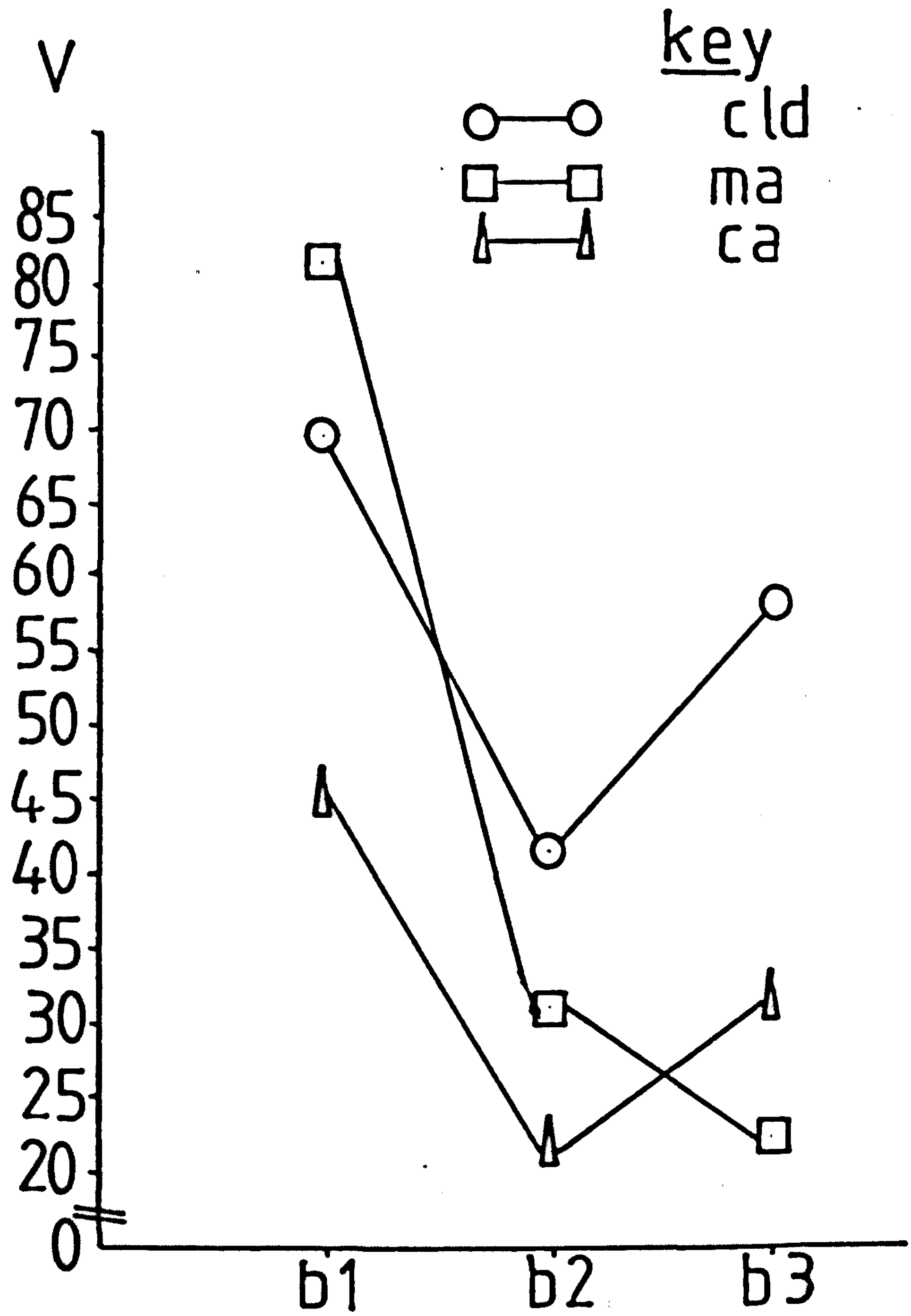


Table 7.3: Mean coefficient of variation (%) for the 3 groups and 2 rotation speeds over 3 blocks of trials, pursuit rotor task

| Rotation speed | Group | Block 1 | Block 2 | Block 3 |
|---|---|---|---|---|
| Slow | CLD | 30.87 | 21.60 | 17.79 |
| | MA match | 45.12 | 17.54 | 14.84 |
| | CA match | 31.87 | 12.78 | 11.64 |
| Fast | CLD | 69.75 | 42.04 | 58.67 |
| | MA match | 81.39 | 31.43 | 24.44 |
| | CA match | 44.97 | 21.16 | 31.40 |

No statistical analyses were conducted on the coefficient of variation, as it is a derived statistic and there is a tendency to move away from the original data when using second order factors, making the results meaningless or subject to erroneous interpretation. However, the coefficient of variation does enable the examination of the variability of the groups relative to their scores.

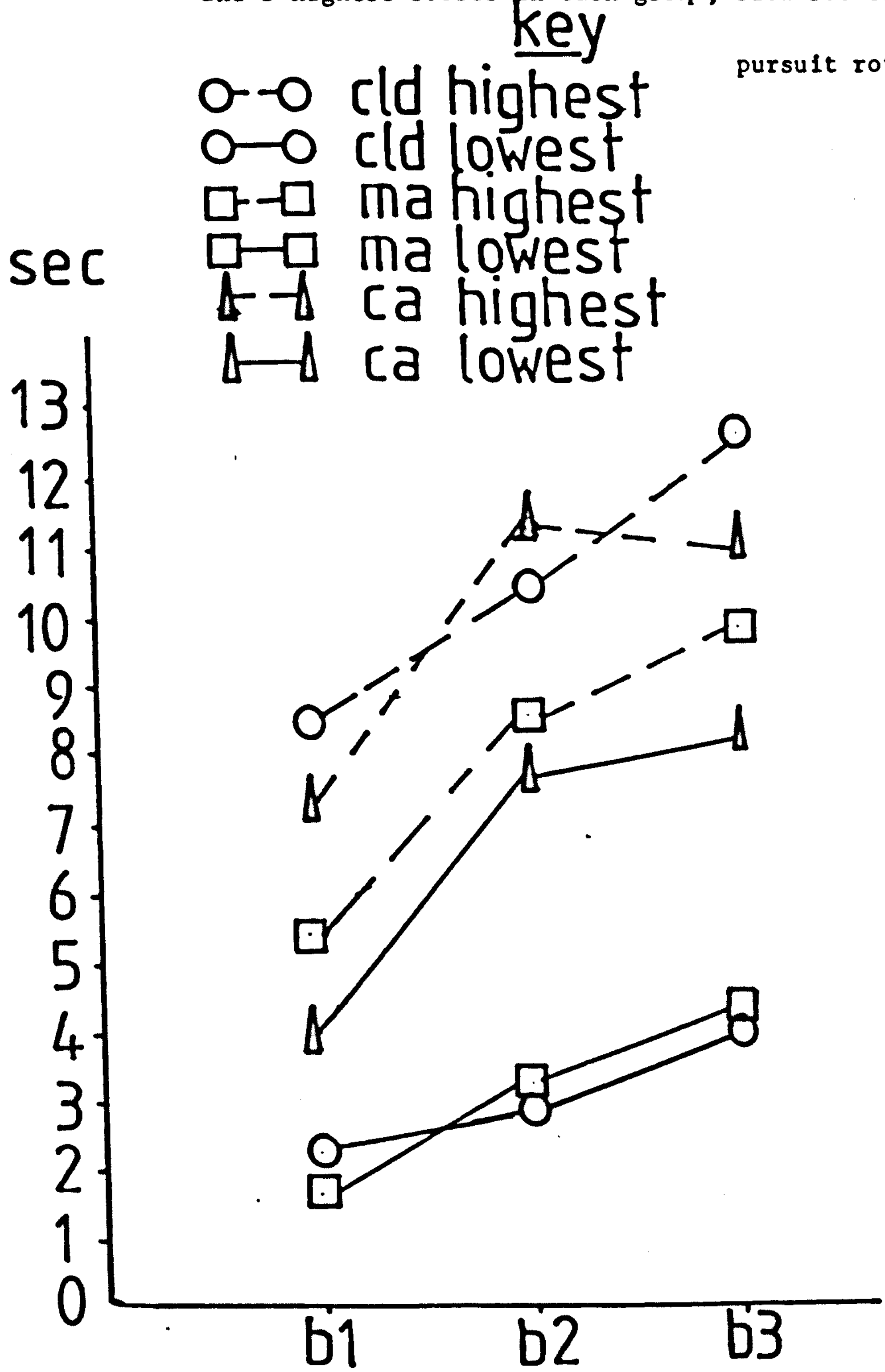
(D) Mean Time on Target over 3 blocks of 5 Trials, Individual Analyses

Subjective observation of the mean time on target data indicated great differences within the groups. The mean time on target over 3 blocks of 5 trials for the 3 groups and 2 rotation speeds for each individual is shown in Appendix 3, Tables 23-28. In order to gain some appreciation of the range and overlap of scores between groups, it was decided to take the three highest overall mean time on target and 3 lowest scores (from the right hand column in the Tables 23-28, Appendix 3) for each group. The 3 blocks of trials were then considered, and the mean time on target of the 3 individuals for each block calculated (See Appendix 3, Tables 29 and 30). The results for the slow rotation speed are shown in Table 7.4 and graphically in Figure 7.8. The results for the fast rotation speed are shown in Table 7.5 and graphically in Figure 7.9.

Taking the 3 highest and 3 lowest performers in each group does not provide full understanding of all the individuals in the group. However, it does give some indication of the range of performance level within the groups. This dissertation is concerned with learning, and therefore the use of the total performance measure as the criterion by which the six subjects per group were selected requires some explanation. Various criteria could have been used; if the amount learned, calculated as time on target for block 1 minus time on target for block 3, had been used, no measure of absolute level of performance would have been available. A second possibility was to take the mean time on target for the first, second or third block of trials only, using the 3 highest and 3 lowest recorded for that block only, thus being unrepresentative of overall performance. The decision was taken therefore to take the mean time on target overall as indicative of level of achievement, and then to plot the mean performance over 3 trial blocks of the 3 highest and 3 lowest achieving subjects in each group. Comparison of this method with use of the 3rd block time on target score shows that in fact 24 of the 36 subjects would have been selected by either criterion.

In the case of the individual analyses of the coefficient of variation, for which this method was also used, 18 of the 36 subjects

Figure 7.8: Mean time on target over 3 blocks for the 3 lowest and 3 highest scores in each group, slow rotation speed, pursuit rotor task



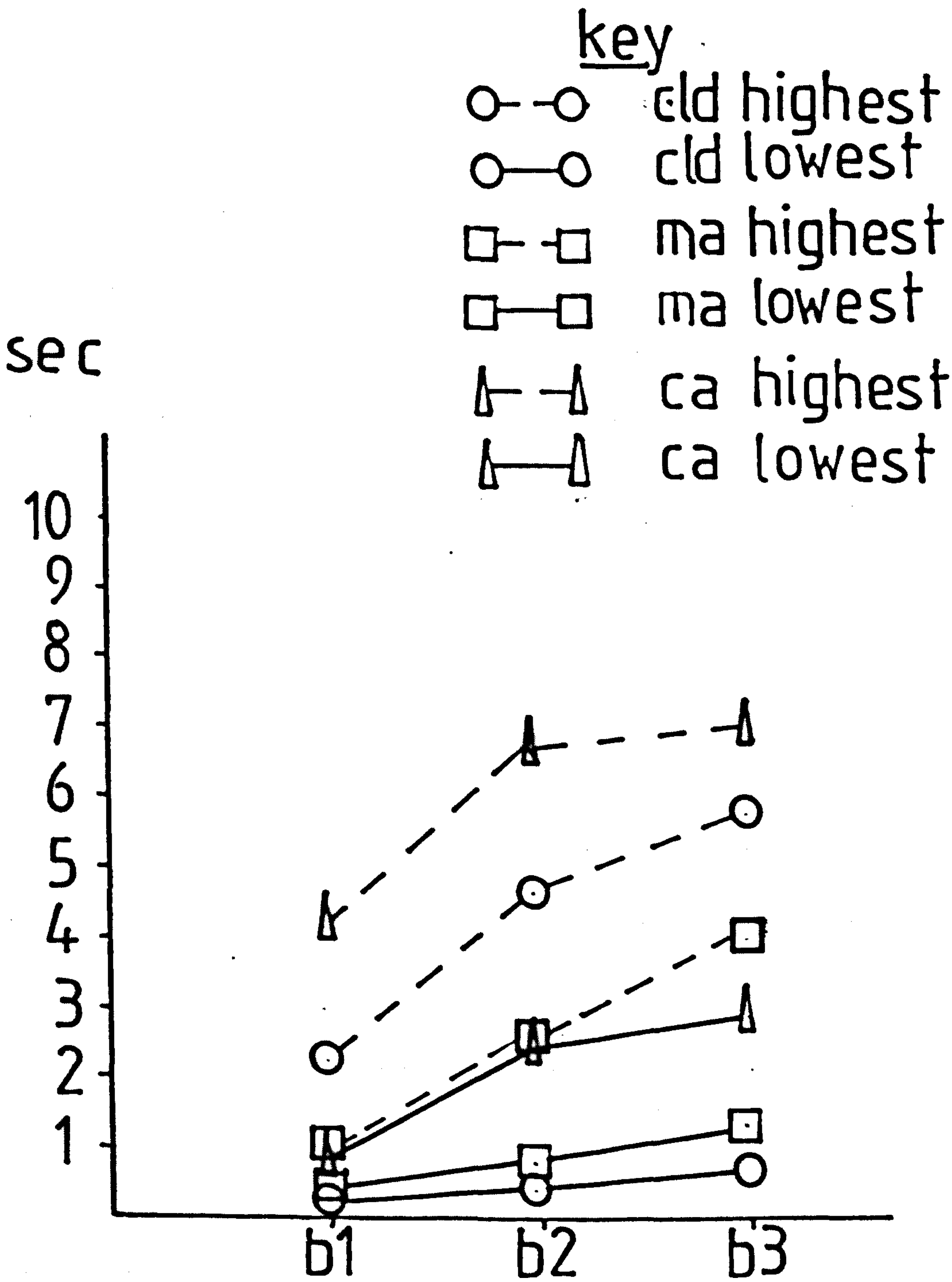



Figure 7.9: Mean time on target over 3 blocks for the 3 highest and 3 lowest scores in each group, fast rotation speed, pursuit rotor task

Table 7.4: Mean Time on Target for 3 highest and 3 lowest scoring subjects in each group, slow Rotation Speed, pursuit rotor task

| Group | Highest | | | Lowest | | |
|---|---|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | Block 1 | Block 2 | Block 3 |
| CLD | 8.40 | 10.44 | 12.59 | 2.25 | 2.87 | 4.04 |
| MA | 5.39 | 8.47 | 9.87 | 1.71 | 3.23 | 4.35 |
| CA | 7.35 | 11.32 | 11.04 | 4.05 | 7.64 | 8.27 |

Table 7.5: Mean Time on Target for the 3 highest and 3 lowest scoring subjects in each group, fast rotation speed, pursuit rotor task

| Group | Highest | | | Lowest | | |
|---|---|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | Block 1 | Block 2 | Block 3 |
| CLD | 2.34 | 4.75 | 5.83 | 0.10 | 0.31 | 0.59 |
| MA | 1.09 | 2.62 | 3.99 | 0.24 | 0.80 | 1.29 |
| CA | 4.19 | 6.76 | 6.92 | 0.81 | 2.45 | 2.90 |

were common to both selection criteria. However, in addition, two subjects classified as amongst the 3 highest in coefficient of variation using the overall mean would have been classified as being amongst the 3 with the lowest coefficient of variation if the final block score only had been used as the criterion.

In order to gain some insight into the way in which individual performance relative to the group might change over trial blocks, the mean time on target for each individual in the 3 groups wasplotted in terms of distribution and frequency of scores. This can be seen in Figures 7.10 and 7.11 for the slow and fast rotation speeds respectively.

(E) Coefficient of Variation of the 3 blocks of 5 trials, individual analyses

It is often argued that certain individuals, particularly those with learning difficulties, are more variable in their performance than others. The coefficient of variation gives a measure of within subject variability, regardless of actual score, or time on target, recorded. As for the individual analyses of the time on target data, the 3 highest and 3 lowest overall mean coefficient of variation in each group were taken, and the mean of these 3 individuals calculated over the 3 trial blocks. 'Highest' and 'lowest' were taken from the right hand column, Tables 17-22, Appendix 3. The results of the calculations are shown in Tables 7.6 and 7.7, for the slow and fast rotation speeds respectively, and graphically in Figures 7.12 and 7.13, The 3 highest and 3 lowest subjects' data are shown in Appendix 3, Tables 31 and 32.

Figure 7.10: Mean time on target of all subjects over 3 trial blocks, slow rotation speed, pursuit rotor task

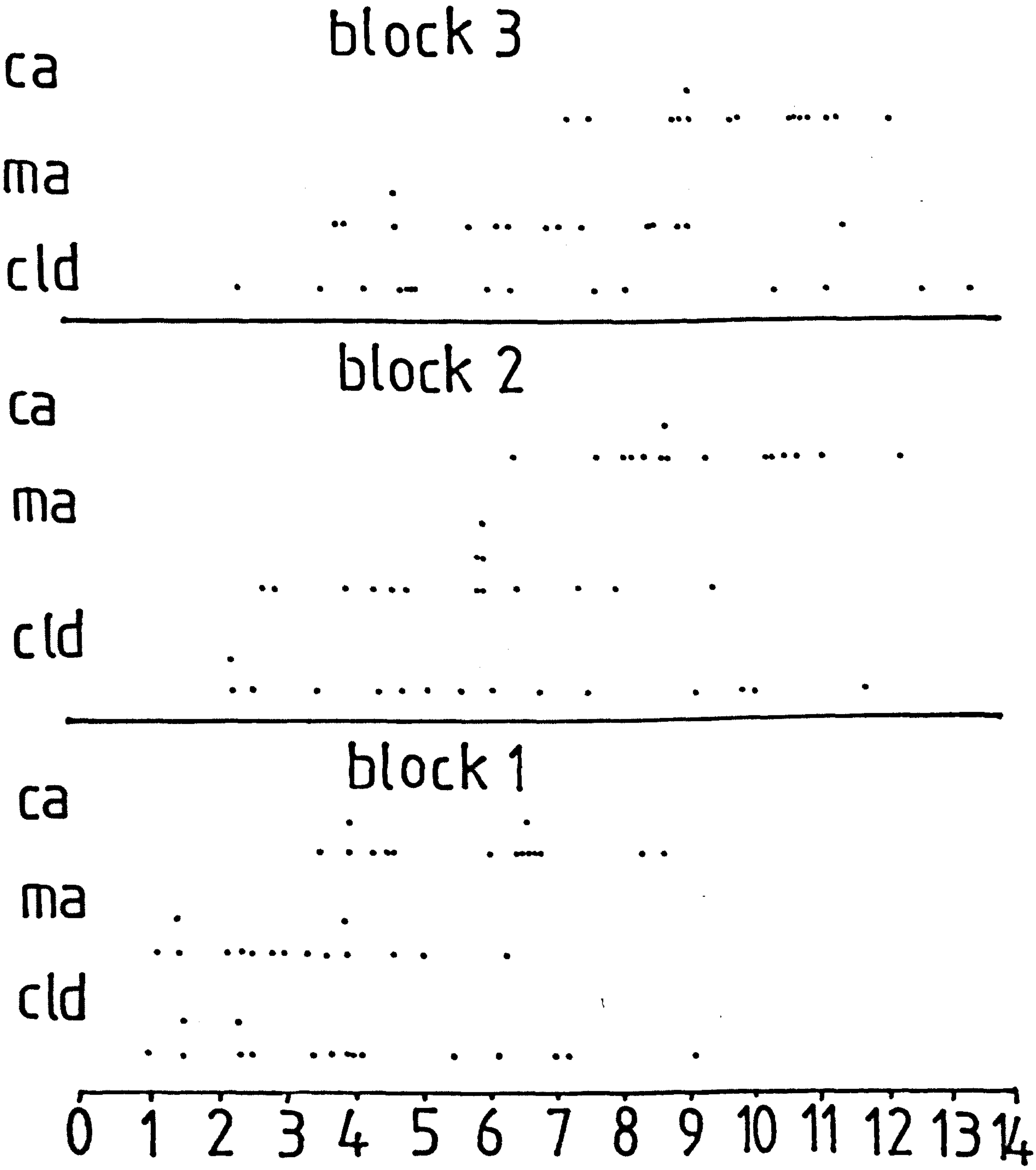
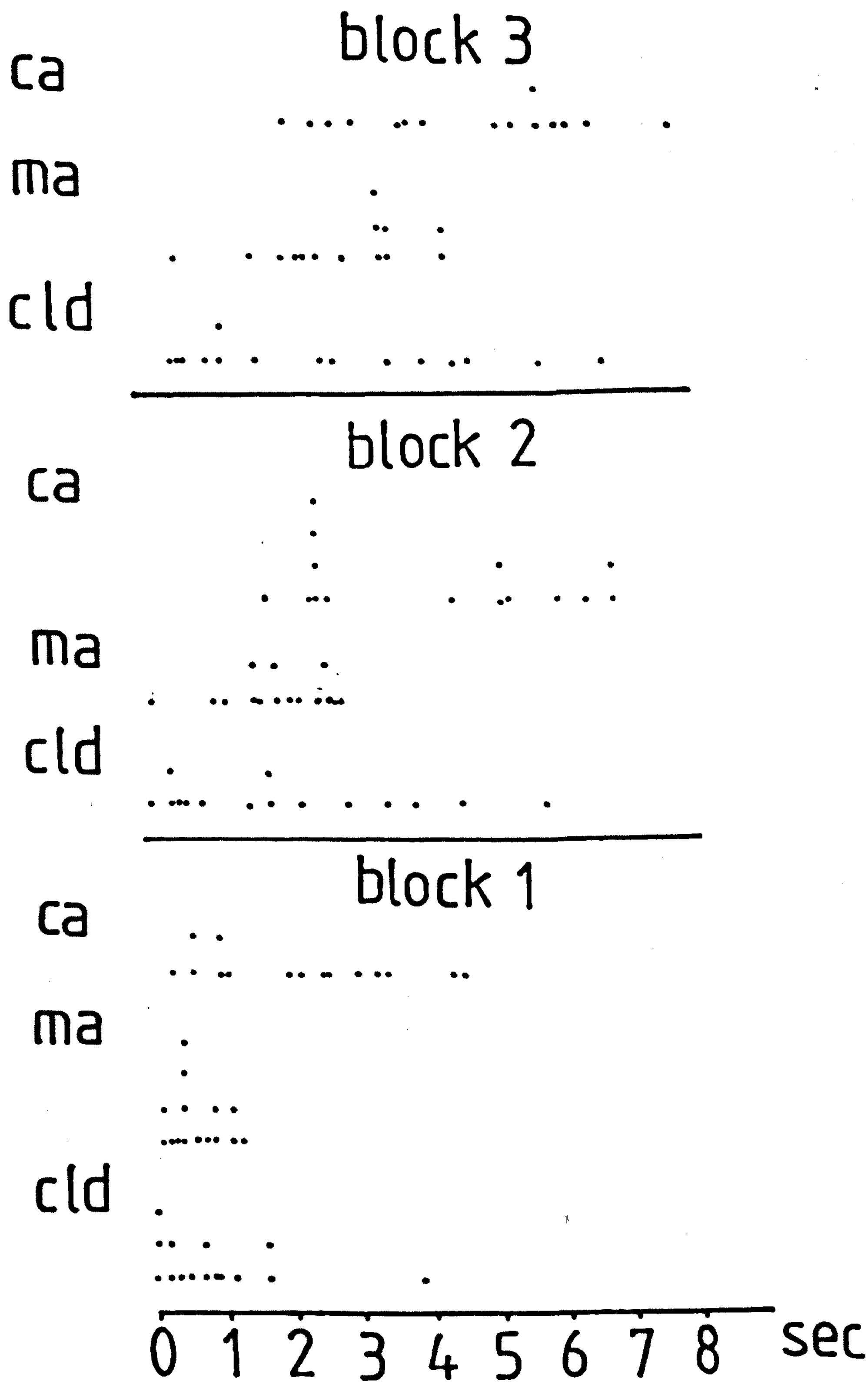


Figure 7.11: Mean time on target of all subjects over 3 trial blocks, fast rotation speed, pursuit rotor task



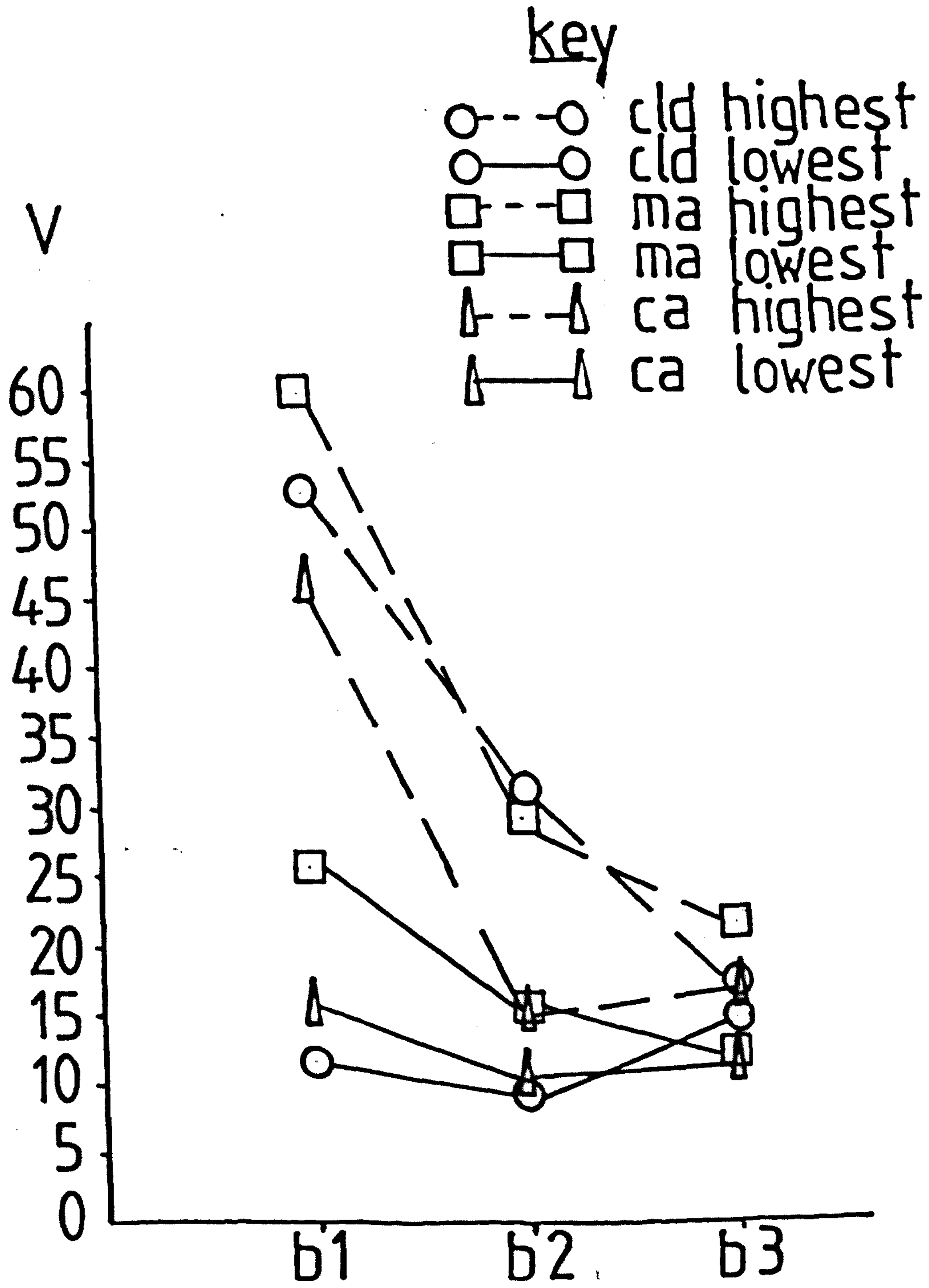



Figure 7.12: Mean coefficient of variation of the 3 most and 3 least variable subjects in the 3 groups, slow rotation speed, pursuit rotor task

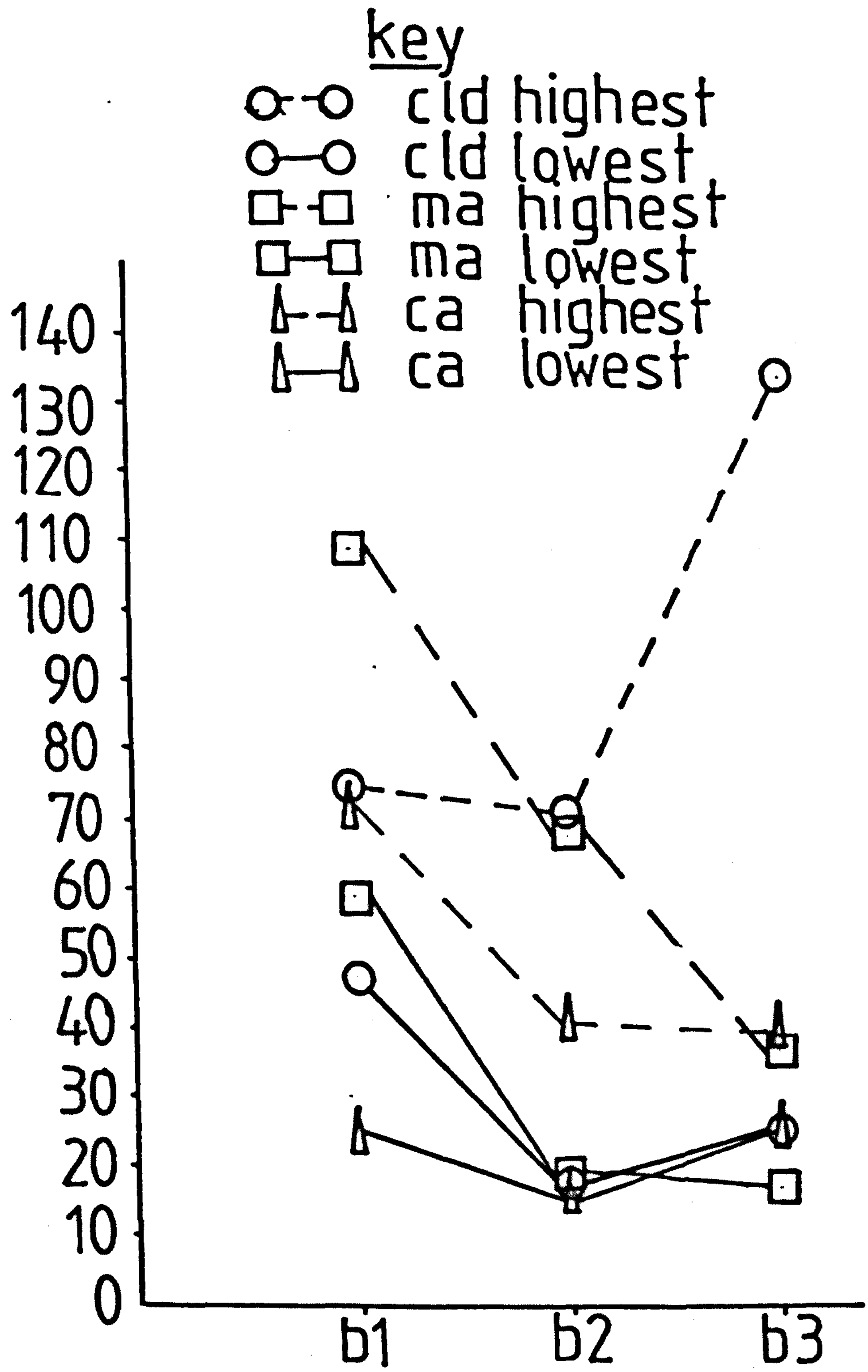



Figure 7.13: Mean coefficient of variation of the 3 most and 3 least variable subjects in the 3 groups, fast rotation speed, pursuit rotor task

Table 7.6: Mean Coefficient of variation for the 3 highest and 3 lowest 'V' scoring subjects in each group, slow rotation speed, pursuit rotor task

| Group | Highest | | | Lowest | | |
|---|---|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | Block 1 | Block 2 | Block 3 |
| CLD | 52.90 | 31.43 | 17.27 | 11.97 | 9.69 | 14.65 |
| MA | 59.58 | 29.06 | 21.39 | 26.17 | 15.39 | 12.01 |
| CA | 46.37 | 14.88 | 16.80 | 15.94 | 10.35 | 10.76 |

Table 7.7: Mean coefficient of variation for the 3 highest and 3 lowest 'V' scoring subjects in each group, fast rotation speed, pursuit rotor task

| Group | Highest | | | Lowest | | |
|---|---|---|---|---|---|---|
| | Block 1 | Block 2 | Block 3 | Block 1 | Block 2 | Block 3 |
| CLD | 71.96 | 71.40 | 132.94 | 47.31 | 18.22 | 25.54 |
| MA | 109.13 | 68.18 | 35.72 | 57.71 | 19.20 | 17.32 |
| CA | 69.92 | 40.88 | 40.09 | 24.10 | 15.69 | 25.19 |

A measure of the way in which individual variation changes over the 3 blocks, relative both to their own school group and to others can be seen by examination of Figures 7.14 and 7.15, which show graphically individual coefficients of variation over 3 blocks of trials for both slow and fast rotation speeds.

(iii) Discussion

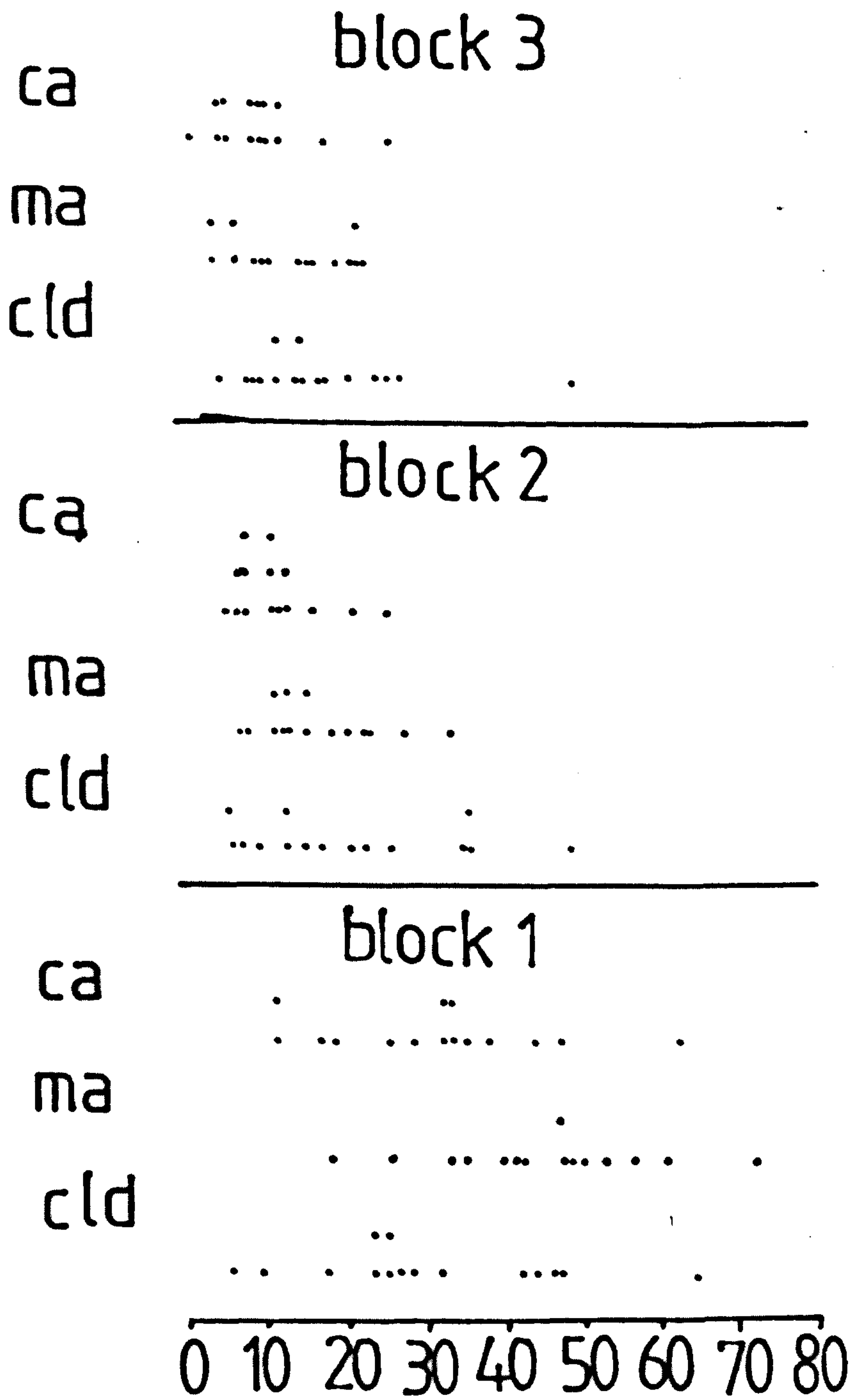
The discussion will take the same format as the results section, insofar as each of the analyses will be considered in turn. This will be followed by a general discussion.

(A) Mean time on target over 3 blocks of 5 trials, group analysis

Examination of the main effect for speed, and the absence of a group x speed interaction confirms that for all groups of children the slower speed resulted in longer time on target per 20 sec trial. This is in accordance with findings by other researchers using only subjects within the range of normal intelligence (e.g. Helmick 1951; Fitts and Warren, 1955). One can, therefore, conclude that as for subjects of average intelligence, children with learning difficulties find that following a slower moving target represents a relatively easier task.

The speed x block interaction is interesting, in that tests of simple main effects revealed significant differences between speeds on all three blocks, and between all blocks at both rotation speeds, all at .01 level of significance. Consideration of Figure 7.1 suggests that although all differences are significant and therefore posthoc analysis does not

Figure 7.14: Coefficient of variation of all subjects over 3 trial blocks, slow rotation speed, pursuit rotor task



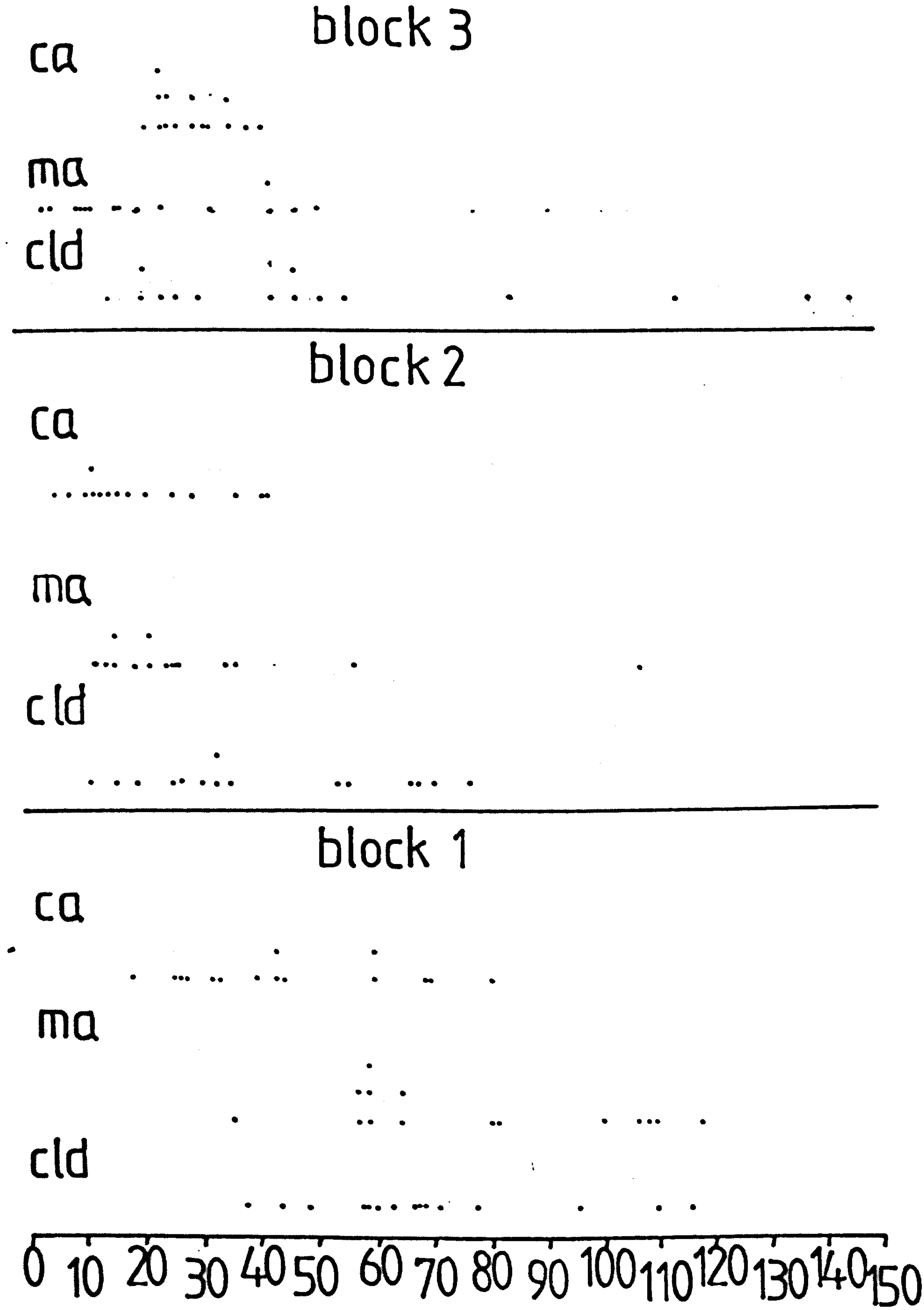
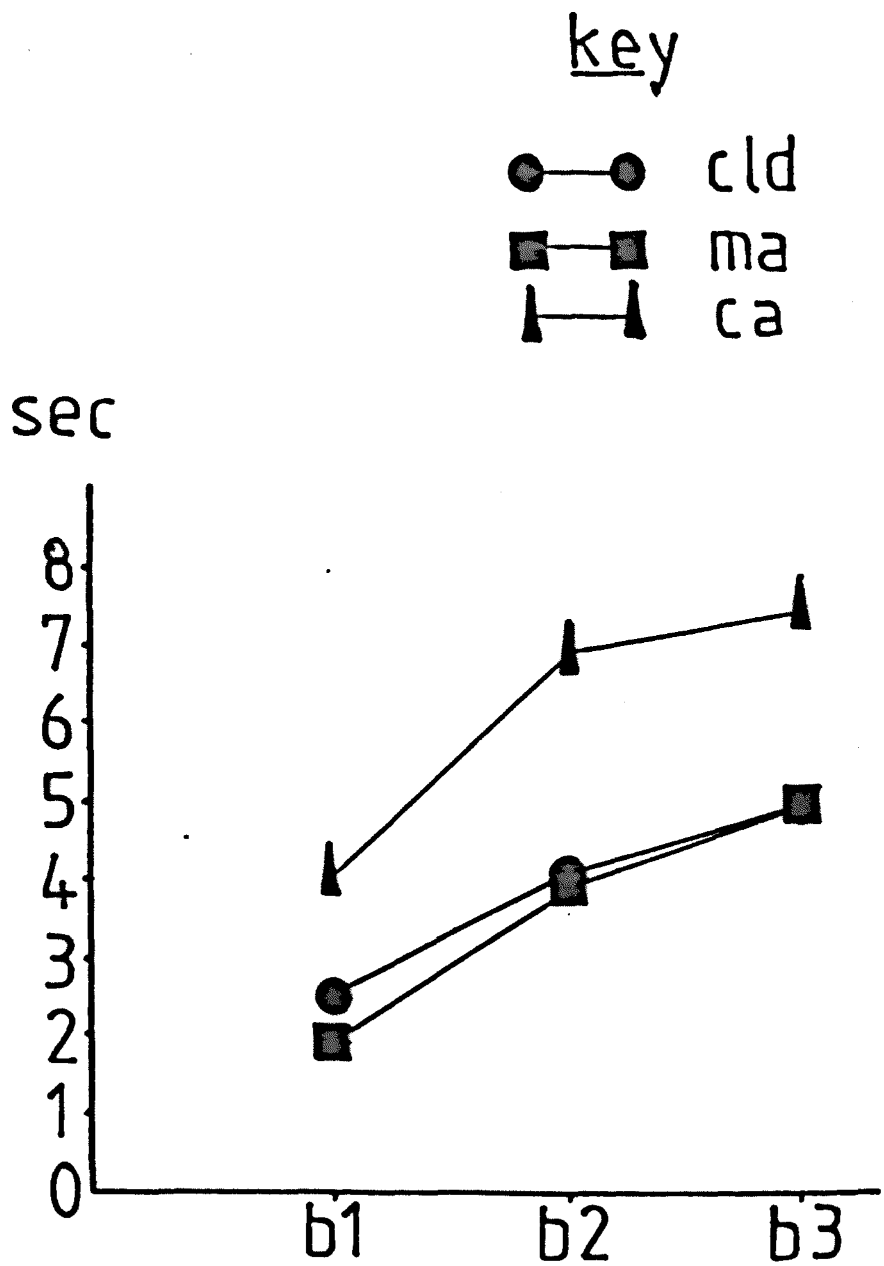



Figure 7.15: Coefficient of variation of all subjects over 3 trial blocks, fast rotation speed, pursuit rotor task

reveal any differential changes, the least significant difference lies between blocks 2 and 3 for the faster rotation speed. Improvement would appear to be taking place for both speeds of rotation over the 3 trial blocks, although the faster speed consistently produces less time on target. The absence of a significant block x speed x group interaction suggests that the improvement over blocks with regard to speed is consistent for all 3 groups.

Consideration of the significant group x block interaction indicates that all 3 school groups demonstrate improvement over the 3 trial blocks, differences emerging between blocks 1 and 2, 2 and 3, and 1 and 3 for all groups. The fact that the nature of the differences is the same for all groups suggests that the shape of the learning or performance curve is similar. This can be seen to be the case from examinations of Figure 7.16, all three groups exhibiting negatively accelerated curves. However, differences emerge between the groups at each of the 3 blocks, varying slightly in nature. The CA matched group is consistently superior to both lower MA groups, although on the first block the significance between the CA matched group and the children with learning difficulties is at the .05 level of significance, and between the CA and MA matched groups at the .01 level. The subsequent two trial blocks demonstrate differences between both the CA and MA matched groups and the CA matched group and the group with learning difficulties at the .01 level. This would suggest that the relative improvement of the group with learning difficulties over trial blocks is not as great as for the CA and MA matched groups. This is supported by examination of the group means in Table 7.8, which shows that not only does the difference between the group with learning difficulties and the CA matched group increase, but that whereas

Figure 7.16: Mean time on target of the 3 groups over 3 blocks of trials, pursuit rotor task



on the first two blocks, the ordering of the means is CA, CLD and MA in descending order, on the final block of trials the order becomes CA, MA, CLD, the mental age matched group equalling the group with learning difficulties in terms of mean time on target.

Table 7.8: Mean time on target for the 3 groups over 3 blocks of trials, pursuit rotor task

| Group | Block 1 | Block 2 | Block 3 |
|---|---|---|---|
| CLD | 2.52 | 4.07 | 5.04 |
| MA | 1.95 | 3.87 | 5.04 |
| CA | 4.05 | 6.89 | 7.49 |

The children with learning difficulties, as a group, do not appear to be able to improve their performance at the same rate as children within the range of normal intelligence, and one questions what might have followed if further periods of practice had been given. It must be noted that at no time during the testing period did any of the subjects become apparently bored or disinterested. They seemed to enjoy the task, and many subjects requested more trials. The performance of the subjects cannot be attributed, therefore, to lack of motivation.

(B) Standard deviation of the mean time on target over 3 blocks of 5 trials, group analyses

This measure was taken as an indication of the variability that individuals exhibit in their performance. It has been argued that children with learning difficulties are more variable in their performance than persons of average intelligence (e.g. Berkson and Baumeister, 1967). The main effect for group, however, revealed significant differences between CA and MA matched groups, the CA matched group exhibiting the greater mean standard deviation. The means can be seen in Table 7.9.

Table 7.9: Mean standard deviation for the 3 groups, pursuit rotor task

| CLD | MA | CA |
|---|---|---|
| 0.88 | 0.79 | 1.09 |

On first examination, the results would appear to indicate greatest variability by the CA matched group in contrast to findings by other researchers. However, the standard deviation scores should not be considered in isolation, but in conjunction with the mean time on target scores. Where the mean score is higher, there is a greater propensity for the deviation to be greater. If, for example, the mean score is 0.45, not as much variability can occur about this mean as if the score were 10.45. The percentage of, for example, 20% deviation would result in greater absolute deviation for the higher score. The mean time on target for the 3 groups is shown in Table 7.10.

Table 7.10: Mean time on target of the 3 groups, pursuit rotor task

| CLD | MA | CA |
|---|---|---|
| 3.88 | 3.61 | 6.14 |

As can be seen from this table, the CA matched group recorded the greatest mean time on target so that when this is taken into consideration, the higher standard deviation does not necessarily indicate that the CA matched group is relatively more variable in their performance. For a greater understanding of variability within subjects, the coefficient of variation is a more useful statistic since it takes into consideration mean time on target with standard deviation.

A similar argument can be put forward to explain the significant blocks x speed interaction. For all 3 blocks of trials, the slower rotation speed resulted in higher standard deviation scores, but again, as can be seen from Table 7.1, the slower rotation speed also resulted in greater time on target scores. With regard to the significant difference between blocks for the slower rotation speed, not evident for the faster rotation speed, examination of the mean time on target scores in Table 7.1 shows greater absolute differences between blocks for the slower speeds, and at a higher level, 4.4 to 8.2 secs. in comparison with 1.2 to 3.5. Similarly, the absolute standard deviation scores would be correspondingly higher for the slower speed.

(C) Mean coefficient of variation over 3 blocks of 5 trials, group data

General dissatisfaction with the standard deviation as a measure of variability led to the use of the coefficient of variation. This statistic gives a measure of relative variation in terms of percentage variability that the standard deviation about the mean represents. Taking the mean and the standard deviation into consideration for calculations dispense with the problems of using the standard deviation only.

The mean group coefficient of variation, as shown in Table 7.3 and Figures 7.6 and 7.7, raises some interesting points with regard to the differences that exist between the three groups and how the relationship between the groups changes over trial blocks.

For both rotation speeds, on block 1 the MA matched group demonstrates considerably greater variability than the two chronologically older groups. This might be anticipated, since they are younger, less experienced and the task may well present greater novelty to them, with the result that early attempts are somewhat of a 'hit and miss' affair. However, as they begin to master the task variability decreases, again as one might expect. The fact that the variability decreases to a much greater extent than that of the group with learning difficulties would suggest that the latter group is not mastering the task to the same degree. For both rotation speeds, the children with learning difficulties exhibit less variability on block 1 than the MA matched group but considerably more than them on the two subsequent blocks. Most, if not all, definitions of skill include consistency as one element and it is one which, from this data, the children with learning difficulties do not appear as a group to be exhibiting to the same extent as either their mental or chronological age matched peers. For both rotation speeds, the CA matched group demonstrates consistently less variability than the children with learning difficulties and generally less so than the mental age match group. For the slower rotation speed, it is interesting that their variability is almost the same as the children with learning difficulties on block 1, but decreases at a considerably faster rate as the novel task is mastered; in the initial stages, when the task is novel to all, variability is equal, but the learning process would appear to take place much faster in the case of children of average intelligence.

Possibly, if they had been given extra trials, the children with learning difficulties would have reduced their variability to the level of their CA matched peers. The data for the faster rotation speed, which perhaps represents the more difficult task, again demonstrates the superiority of the CA matched group over the other children, although in this case, it is right from the beginning. The interaction that occurs over blocks 2 and 3 between the CA and MA matched groups is interesting, although not immediately explicable. Possibly the CA matched group had achieved almost minimum possible variability on block 2 for a task of this difficulty, and this was followed by a decrement in performance, in terms of variability, or possibly their results represent one or two trials of high time on target which they could not sustain. However, both CA and MA matched groups exhibit considerably less variability than the group with learning difficulties.

One further point of interest is that as with the group differences, the trend for rotation speed differences is reversed. Using the coefficient of variation, it is the faster rotation speed that results in greater mean variability, whereas using the standard deviation only, it is the slower rotation speed. When the standard deviation only is considered, the mean time on target is higher and therefore the standard deviation will be higher; there is a greater propensity for it to be so. Taking both the mean and the standard deviation into consideration as is done in calculating the coefficient of variation, one would perhaps expect the variability of the two rotation speeds to level out and be approximately equal. However, the effect is greater than that; the variability for the faster rotation speed, as measured by the coefficient of variation, is in fact greater than that of the slow rotation speed. Not only is this point of interest to the present research but it is also an interesting comment on the relative merits of the two statistics, the standard deviation and the coefficient of variation.

Whist group mean coefficient of variation gives a measure of the mean variability of individuals, it does not give to the same extent an understanding of the relative variability that exists within the groups between individuals. It is therefore advantageous to consider individual performance both in terms of time on target and coefficient of variation, relative both to the school group to which they belong and to the other two groups, and the way in which this relationship might change over blocks of trials.

(D) Mean Time on Target over 3 blocks of Trials, Individual Analysis

Although, as has been stated this method of analysis does not provide conclusive statistical results, it does go some way towards enabling a general understanding of the differences that exist between individuals within groups categorised as belonging to certain groups. Visual examination of the data can provide some degree of understanding of this problem.

Consideration of Figure 7.8shows that for the slower rotation speed a greater difference exists between the 3 highest and 3 lowest performers in the group with learning difficulties than in either the CA or MA matched groups. In the case of the 3 poorest performers, the mean time on target of the children with learning difficulties is more or less equal to that of the MA matched group, and considerably lower than the CA matched group, this pattern remaining consistent over trial blocks. In the case of the 3 highest performers, the 3 subjects from the group with learning difficulties perform at a level that is equal if not superior to those from the CA matched group, both these group subjects demonstrating considerably greater time on target scores than the 3 highest scores in the MA matched group. These 3 subjects with learning difficulties at least, would be indistinguishable from their CA matched peers of average intelligence. It is the relatively greater numbers of low performers who adversely affect the group mean resulting in differences being found between children with learning difficulties and their CA matched peers, when group analyses are conducted. This pattern is similarly the case for a faster rotation speed, although not perhaps to the same extent. In the case of the 3 lowest performers, the time on target is consistently just below that of the 3 lowest scores in the MA matched group over the 3 trial blocks, both falling well below the mean time on target of the 3 poorest performers in the CA matched group. The 3 highest performers within the group with learning difficulties record a mean time on target well above that of the best of the MA matched group, but below that of the 3 highest performers in the CA matched group. Relative to the 3 highest and lowest performers in the CA matched group, the 3 highest performance subjects with learning difficulties fall in the middle of the 2 extremes, and as such, would, again, be indistinguishable from the CA matched group as a whole.

From this data, it would appear that there are certain dangers in the interpretation of group analyses, in that whereas the group analysis might suggest inferior performance by those with learning difficulties in comparison with the CA matched peers, consideration of the individual data implies that this is not characteristic of all subjects within the group. In the case of the children used in this experiment, at least 6 subjects with learning difficulties would appear to be able to perform a pursuit rotor task at a level indistinguishable from that of their peers of average intelligence.

Figures 7.10 and 7.11 give some indication of all subjects' performance over the 3 blocks of trials. Each 'point' represents one subject, resulting in 15 points per group per block of trials. It must be noted that as the subjects are not consistently ranked over trial blocks, position relative to others within the group does not remain constant; the subject registering the highest time on target on the first block, for example, does not necessarily register the highest time on target for block 2. Examination of Figure 7.10, representing data for the slow rotation speed, suggests that the range of scores on block one is greatest for the children with learning difficulties and least for the CA matched group, a characteristic that remains constant over the 3 blocks of trials, indicating a greater variation in the level of performance within the group with learning difficulties. On trial block 1, for the children with learning difficulties, there would appear to be a natural division between the 10 lowest performers and the 5 highest, of the latter at least 3 being indistinguishable from the CA matched group. In terms of low performance, however, at least 5 subjects with learning difficulties fall well outside the range of the CA matched group. For the MA matched group, on block 1, the natural division appears to fall between the 12 lowest and the 3 highest performers, the 3 highest performing not as well as the best of the chronologically older groups, but overlapping well into the middle of the range. The poorest performers of the MA matched group fall well behind the CA matched group poor performers, as one might expect of younger children; however, their performance level is virtually the same as the lowest performers of the group with learning difficulties, which again emphasises the point of just how far behind their peers of normal intelligence some children with learning difficulties fall.

Presentation of the second trial block data in this way results in a slightly different pattern. The range of time on target scores by the MA matched group and the group with learning difficulties has increased considerably, particularly in the case of the latter, whilst this is not true of the CA matched group. The natural division for the children with learning difficulties is between the worst 11 performers and the 4 best performers, all the latter group indistinguishable from the CA matched group, in essence a similar pattern to trial block 1. However, at the bottom end of the continuum, at least 7 subjects with learning difficulties fall well below their CA matched peers and 3 of those below their MA matched peers. The data of the MA matched group apparently represents a normal distribution with one or two outliers at each end, the majority falling in the middle. At least 3 of the MA matched group equal the level of performance achieved by the majority of the CA matched group.

Examination of the third block of trials shows an even greater range of scores for both the MA matched group and the group with learning difficulties, particularly for the latter. The natural division for the group with learning difficulties remains between the top 4 and bottom 11 performers, and it is interesting to note that 2 of the top performers in this group record a mean time on target score in excess of that of the best performer in the CA matched group. At the bottom end of the scale, however, at least 9 subjects with learning difficulties fall well below their CA matched peers, and 2 of these below their MA matched peers. In the case of the CA matched group, one subject records a mean time on target score at a level almost equal to that recorded by the top CA matched performers and those with learning difficulties, and 5 can be considered to fall within the range of the CA matched group.

In the case of the faster rotation speed, the picture is very similar and this is shown in Figure 7.11. On block 1, one of the subjects with learning difficulties performs at a level that is high even in comparison with the CA matched group, whereas the poorest performers with learning difficulties record mean time on target scores that are inferior even to the group matched on mental age. The range of scores recorded on trial block 1 is greater for the CA matched group, although the range for this group remains relatively stable over blocks, whereas for the MA matched group and the group with learning difficulties, particularly the latter, the range increases steadily over trial blocks. The MA group has a very small range, and as a group falls at approximately the lowest end of the CA matched performers, and in line with the majority of those with learning difficulties.

Examination of the data for block 2 presents again a similar picture to that for the slow rotation speed. At least 5 of the children with learning difficulties would appear to be indistinguishable from their CA matched peers, and at least 6 subjects with learning difficulties perform at a level well below that of all MA matched subjects except one. In general the main distinction is between the MA and CA matched groups, with some overlapping of subjects at the top end of the MA matched group and bottom end of the CA matched group. The data for block 3 again demonstrates that some subjects with learning difficulties, in this case at least 8, fall well within the range of the CA matched group, and the remaining 7 falling well below.

One point that the consideration of individual data highlights is the range of performance level within the group considered to have learning difficulties, which is apparently much greater than in groups of subjects of average intelligence, at least on a pursuit rotor task of this nature. One can tentatively suggest that on a task of this kind, the better performers with learning difficulties are able to perform at level equal to or better than that of their CA matched peers of normal intelligence. Possibly as many as a third of the subjects fall into this category. It would appear, therefore, to be unwise to make generalisations about or recommendations for children with learning difficulties as a group. Care should be taken to identify those individuals whose performance does not correspond to the group as a whole.

(E) Coefficient of variation over 3 blocks of 5 trials, individual analyses

Examination of the coefficient of variation in this way is an attempt to gain some appreciation of the differences that exist between individuals within groups and between groups. In fact, the pattern of behaviour that emerges is very similar in many ways to that of the time on target data.

From examination of Figure 7.12, the data for the slow rotation speed, it can be seen that the 3 children with learning difficulties exhibiting the lowest coefficient of variation in that group could be considered to be indistinguishable from the 3 subjects drawn from the

CA matched group as those with the lowest coefficient of variation. Indeed on the first two trial blocks, their mean coefficient of variation is below that of the CA matched subjects, the trend reversing only on the final block. On the first two trial blocks, both the children with learning difficulties and their CA match exhibit a coefficient of variation well below that of the 3 MA matched subjects having the lowest coefficient of variation in the group. On the third trial block, whilst the mean coefficient of variation of these subjects continues to decrease, that of the three with learning difficulties and the three CA matched subjects demonstrates an increase, particularly in the case of the children with learning difficulties; the net result is that the CA matched group remains superior, with least variability, whilst the subjects with learning difficulties have a greater mean coefficient of variation than the MA matched subjects.

With regard to the 3 subjects within each group that have the greatest coefficient of variation in each group, on the first trial block, the CA matched subjects exhibit a lower coefficient of variation than the children with learning difficulties, who in turn exhibit a lower mean coefficient of variation than the MA matched subjects. The variation of the subjects with learning difficulties and that of the MA matched group subjects is very close on the second trial block, the subjects with learning difficulties actually having a greater mean coefficient of variation, but the difference between these two groups and the mean of the 3 CA matched subjects increased considerably to approximately 15%. The third trial block sees a reduction in coefficient of variation for both subjects with learning difficulties and those drawn from the MA matched group, particularly for the former group, but an increase on the part of the 3 subjects drawn from the CA matched group, the result being that the coefficient of variation of the two chronologically older groups approximate each other. In all cases, the greater change in coefficient of variation occurs between blocks 1 and 2, resulting in negatively accelerated curves for the two lower mental age groups. From this data, similar conclusions can be drawn as from the time on target data; the better performers amongst the children with learning difficulties, if consistency is to be considered the criterion, perform at a level equal, if not better than that of their CA matched peers, whereas the poorest or least consistent individuals within that group perform at a level equal to or worse than that of their mental age matched counterparts. The range of level of performance within the group with learning difficulties is considerably greater than for the children of average intelligence and it is, therefore, perhaps unwise to make generalisations about or recommendations for the group as a whole. An appreciation of individual potential and abilities within the group, with particular reference to the task or skill, is required.

The data for the fast rotation speed demonstrates a similar pattern, shown in Figure 7.13. In the case of the mean of the 3 least variable subjects within each group, there is very little to distinguish between the 3 groups. The MA matched subjects begin by being the most variable, but by the 3rd block of trials are in fact the least variable; whereas those subjects drawn from the group with learning difficulties and from the CA matched group demonstrate a reduction in mean coefficient of variation between blocks 1 and 2, and a slight increase on block 3, unlike the MA matched subjects, for whom the coefficient of variation continues to decrease. Very little difference is apparent between the two chronologically older groups on the last two blocks of trials.

For the mean of the 3 most variable subjects in each group, greater differences between the 3 groups emerge. The CA matched subjects are least variable overall, demonstrating a larger decrease between blocks 1 and 2 than 2 and 3, but nevertheless decreasing continuously over trial blocks. The 3 MA matched subjects, as before, demonstrate high variability on trial block 1, but decreasing considerably over time, resulting in marginally less variability than the CA matched subjects on trial block 3. The 3 subjects with learning difficulties demonstrate a very different pattern of behaviour. On trial block 1, the mean coefficient of variation of these subjects is only just greater than the representatives from the CA matched subjects, and considerably less than the mean of the subjects from the MA matched group. However, the mean coefficient of variation of the 3 most variable subjects with learning difficulties for block 2 is virtually the same as for block 1, and on block 3, it increases dramatically, with a mean v of 133%, more than 90% in excess of the other 2 groups. This data again serves to emphasise the great variability of performance that is apparent within a group of children categorised as having learning difficulties on a task of this nature.

Figures 7.14 and 7.15 give some indication of the variability of performance of all subjects in all groups over the 3 trial blocks. Examination of Figure 7.15 containing the data for the slow rotation speed, shows that on trial block 1, the range of the coefficient of variation scores for the children with learning difficulties is very similar to that of their CA match, and in a similar position, in terms of absolute variability, on the x axis. Both groups are apparently less variable than the subjects of the MA matched group, although the range of variability within that group is more or less the same as for the other two groups. The data for trial block 2 presents a rather different picture, however. The amount of variability and the range of the coefficient of variation scores within the CA matched groups have both decreased markedly as have those on the MA matched subjects. The group with learning difficulties,however, has a much greater range than either of the other two groups, four subjects in particular exhibiting high coefficients of variation, the remaining 11 operating within the range covered by the CA matched subjects. On trial block 3, variability for most subjects in the groups continues to decrease, the range of scores for the group with learning difficulties again much greater, although this is solely the result of performance by one subject only. The coefficients of variation for the group as a whole have not fallen to the same extent as for the CA matched subjects, although the majority can be seen to be operating within the range shown by the CA matched subjects. Once again, it is in the range of performance level within the group with learning difficulties that is highlighted; some subjects are operating well within the range of children of normal intelligence of the same chronological age, whilst others perform at a considerably lower level, in some cases lower than their mental age matched equivalent.

The individual data for the faster rotation speed presents a slightly different picture, shown in Figure 7.15. On trial block 1, the range of the coefficient of variation scores within the 3 groups is very much the same but the distinction in terms of absolute level of performance is between the CA matched group, and the remaining two groups, both of whom demonstrate greater variability than the CA matched group. On trial block 2, the range of absolute level of variability decreases for the CA matched group, whereas the range of the children with learning difficulties and the MA matched group remains virtually as for trial one, block 1. In the case of the CA matched group, this is the result of one outlying subject, and were he not included, the range could be said to decrease as for the CA matched group. The general level of the coefficient of variation would appear to decrease for both lower MA groups, although not to the level of the CA matched subjects. On trial block 3, the range of the coefficient of variation for the group with learning difficulties increases dramatically, 4 subjects in particular demonstrating a very high level of variability. Furthermore, the absolute level of variability for the group does not appear to decrease. This latter factor is common also to the MA matched group, although it is true to say that the range is considerably smaller for this group than on Trial block 2. The data for the CA matched group is interesting in that the range of the coefficient of variation decreases markedly, but at an absolute levelactually increases. The upper limit set by the group remains the same, but the lower limit increases from a variability of approximately 5% to 23%. Possibly the task has a form of ceiling effect, such that it does not properly facilitate consistency to be maintained, particularly when performing at a high level, as could be said to be the case for the CA matched group, or at least for some of its constituent subjects. However, the main point remains true, that the range of level of performance within the group with learning difficulties is considerably greater than for the two groups of average intelligence, on this particular task.

## (F) General Discussion and Conclusions

Performance over 3 blocks of 5 trials on the pursuit rotor task, using two rotation speeds was measured, and the data subjected to both group and individual analysis, and the two measures of variability used both were present some contradictions.

The group analyses suggested that as a whole, on this particular task, which is taken as representative of those tasks in which the environment is moving, the whole body stationary and body parts are moving, children with learning difficulties perform at a lower level than children of the same age but of average intlligence, and more on a par which children matched with them on mental age. The statistical analyses strongly confirm this, when time on target is the criterion measure used. However, when individual data are considered, the pattern which is fairly consistent over both rotational speeds and trial blocks is such that whilst the implications of the group analyses are true for the majority of subjects having learning difficulties, it is far from true for all subjects. There would appear to be some children, possibly as many as a third of those tested here, who are able to perform at a level equivalent to that of their CA matched peers and in some cases as well as, if not better than, the best of the subjects within the group. It would appear to be inaccurate, therefore, to characterise all children with learning difficulties as poor performers on a pursuit rotor task of this nature and unwise to make recommendations and generalisations accordingly.

However, there is a body of children with learning difficulties who do appear to have faced problems in the execution of the task. This serves to confirm the subjective observations made during the testing sessions for the first two tasks, the linear slide and ball throwing tasks, that many of these children took a very long time in preparation for each trial and that these children would suffer a disadvantage when temporal restrictions were imposed by the environment. In the present experiment, the trial begins and terminates at a predetermined moment in time, unlike the first two tasks, and the target is constantly moving at a constant rate, again unlike the first two tasks, for which the target may have varied between trials, but remained stationary throughout the duration of each trial. Subjective observation during the testing sessions confirms this, in that many of the subjects with learning difficulties and their MA matched subjects took a comparatively long period of time to locate the patch of light on this ring and then to reach it. For many of these subjects, it was apparent that the temporal impositions made by the apparatus posed problems. Questions such as "Can you slow it down?" or "Will it get slower?" were not uncommon.

However, two points are common to all groups; the fact that the faster rotation speed resulted in less time on target and the fact that learning took place over trial blocks. This would appear to indicate no ceiling or floor effects to the task.

The contradiction that exists in terms of the variability within subjects measures. The standard deviation suggests greater variability on the part of the CA matched group, whereas use of the coefficient of variation indicates least variability on the part of this group. This is resolved when it is recalled that the standard deviation takes no account of the absolute time on target, and that it is the higher time on target scores recorded by the CA matched subjects, that give a greater propensity for relatively high standard deviations. The coefficient of variation is perhaps the more useful statistic, for this reason. Visual examination of the data suggests similar trends and differences between the 3 groups as for the time on target data. Some subjects perform at a level equivalent to subjects matched on chronological age but of average intelligence, whilst others perform at a level equivalent to those subjects matched on mental age and in some cases at a level below that of the poorest of the chronologically younger subjects. The point highlighted again is the range of performance within the group characterised as having learning difficulties.

Again, two features would, in general, appear to be common to all groups; the faster rotation speed results in greater within subject variability, and this decreases in general over trial blocks in both cases. This latter fact is confirmed by the group analyses conducted on the standard deviation data.

It is apparent that certain group differences do emerge, and that in general children with learning difficulties experience problems when confronted with a task of this nature, in which temporal impositions are made on the individual. However, this is not true of all subjects, either in terms of time on target or within subject variability. Possibly as many as one-third of subjects tested here would be indistinguishable from their peers of normal intelligence. However, it must be stressed that there is no attempt to state here that one-third of all children with learning difficulties are able to perform all tasks at a level equivalent to their peers. Each group of children must be considered individually, and furthermore, in relation to the task or skill to be mastered. Possibly, as more temporal impositions are made on the individual or greater body involvement is required, some or all of these children will be unable to maintain their level of performance relative to their peers of normal intelligence but the same age.

## IV STUDY IV: THE MEMORY DRUM TRACKING TASK

### (i) Method

#### (a) Subjects

Thirty right handed boys and girls were drawn from a local school for children with learning difficulties, with a mean chronological age of 12 years 5.1 months and ranging from 12 years 0 months to 12 years 11 months. Their I.Q. scores ranged from 55 to 79, with a mean of 67.7. Using the formula MA = CA/100 x IQ the resultant mean MA was 8 years 5 months.

Thirty right handed boys and girls were drawn from a local junior school to act as an MA match for the group with learning difficulties. The mean chronological age of the group was 8 years 5.7 months and ranged from 8 years 0 months to 8 years 11 months. All were considered to fall within the range of normal intelligence.

Thirty right handed boys and girls were drawn from a local middle school to act as a CA match for the group with learning difficulties. The mean chronological age of the group was 12 years 5.7 months and ranged from 12 years 0 months to 12 years 11 months. Again, all were considered to be from within the range of normal intelligence.

In all cases, the teacher in charge of the release of the children was asked to exclude any child with a physical or behavioural problem that might influence performance on the task.

#### (b) Apparatus

##### (i) The memory drum

The Memory Drum was manufactured by Campden Instruments, London. It was an electrical piece of equipment, of 240 volts, consisting of a drum within a box which rotated clockwise at one of two speeds, 3 rotations or 6 rotations per minute.

The outward appearance of the memory drum was that of a box, 21 cm x 32 cm x 19 cm in height. It consisted of metal, covered in navy blue plastic material, as can be seen in Figure 7.17.

As can be seen from Figure 7.17, one of the top corners was cut on the diagonal and on the flat surface was cut a "window" 15 cm x 10 cm in the centre. At the sides of the window were large nuts which held in place a further piece of metal behind the window. By sliding the nuts up and down, the size of the window could be narrowed to 1 cm. However, the presence of the nuts was found to interfere with the movement of the hand during tracking and for this reason, they were removed. The window was then narrowed for the purpose of this study to 2 cm by placing a piece of cardboard along the upper edge of the window, using adhesive tape to keep in place. In this way no impediment was apparent, and the placing of the cardboard along the upper edge meant that the lower edge, on which the hand could rest, remained firm. At the back of the box was a switch, the depression of which caused the rotation of the drum. Lifting the switch stopped the rotation. The top of the box was held to the base by hinges on the front edge. Lifting the top revealed the inner mechanisms. Inside the metal box was the drum, connected to the cogs and electronic apparatus which resulted in its rotation. The drum could be rotated at two speeds (3 or 6 rotations per minute), (although in this study only the faster one was used), which were achieved by movement of the handle on the mounting to the left or right, which employed differing sized cogs. The drum itself was 20.5 cm in

Fig. 7.17: Memory drum, general appearance

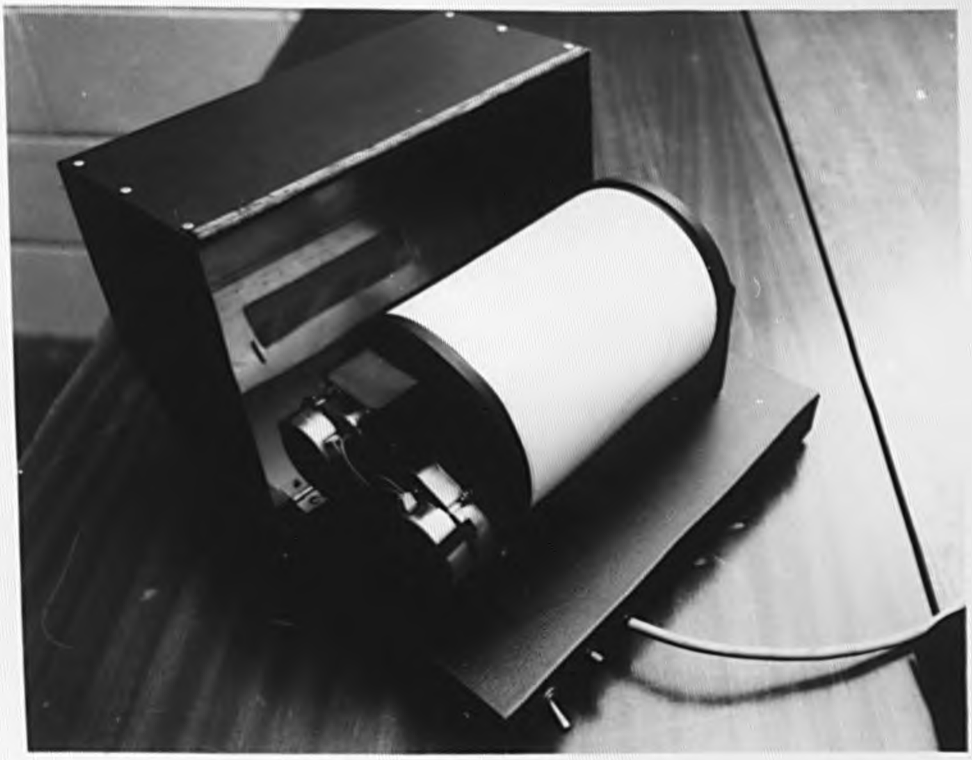


Fig. 7.18: Memory drum, internal mechanisms

width, with raised edges, such that the central area on which the paper was placed was 19 cm in width. The drum measured 14 cm in diameter. It was raised approximately 1 cm above the base in order to allow free rotation and placement of the paper on the drum. The drum rotated at a constant rate and the electrical and mechanical mechanisms were sufficiently stable that pressure by the pen onto the paper through the window did not result in a slowing down of the rate of rotation. The internal mechanisms of the drum can be seen in Figure 7.18. The drum was then placed on a table of a height suitable for the children being tested 6" away from the near edge of the table.

(ii) The tracks

The 12 tracks (1 regular and 11 irregular) were generated on the Amdahl computer, using one Ghost 80 graphics package. The program developed required the user to stipulate the x + y coordinates of successive peaks. This allowed the same program to generate any number of different curves. Each complete curve consisted of 5,000 points, which provided a very smooth curve when drawn on the graph plotter. The length of the x axis was 40 cm and the maximum amplitude of any curve was 9 cm. The 11 irregular curves were considered to be of approximately equal difficulty, since the total length of the line was within 1.5 cm (see Table 7.1 The difficulty level of the total trial could be varied by altering the number of peaks within the trial, and was finally determined following a pilot study with some children with learning difficulties of the same chronological age as those who subsequently took part in the experiment. The tracks used are shown in Appendix 5, along with those of 2 subjects. The quality of reproduction is not very good, as the sheets have been reduced and photocopied several times.

(c) Design

Each of the three school groups was randomly divided into two subgroups, approximately half boys and girls in each group. The first of these subgroups experienced ten trials tracking a regular sine curve track and the second experienced ten trials, one of each of ten different irregular tracks. Five days later, all children attempted one trial at the same type of track as previously experienced, followed by one trial at the type of track previously experienced by the other group. The design is shown in Table 7.11.

The eleven irregular tracks were all different, whereas the regular tracks were the same repeated over the ten practice and one recall trials. The effects of group and track on practice, recall and transfer were studied in several ways. It must be borne in mind that because of the nature of the tracks, the group attempting the regular track during practice actually attempted a longer line per trial than those attempting the irregular track. It could possibly be argued, therefore, that direct comparisons are not appropriate. However, all children spent the same length of time per trial. The time taken for one rotation of the drum, such that 40 cm of paper passed by the window. The line length and time per trial are shown in Table 7.12. The differences in line length are not that great, such when accumulated over the ten trials (all groups attempted equal length on recall and transfer) and for this reason it was decided to compare the effects of track.

Table 7.11: <u>Design of the Memory Drum Study</u>

| Group | Number of Subjects | Practice | | Recall | | Transfer | |
|---|---|---|---|---|---|---|---|
| | | Type of Track | No. of Trials | Type of Track | No. of Trials | Type of Track | No. of Trials |
| CLD | 15 | Regular | 10 | Regular | 1 | Irregular | 1 |
| CLD | 15 | Irregular | 10 | Irregular | 1 | Regular | 1 |
| MA | 15 | Regular | 10 | Regular | 1 | Irregular | 1 |
| MA | 15 | Irregular | 10 | Irregular | 1 | Regular | 1 |
| CA | 15 | Regular | 10 | Regular | 1 | Irregular | 1 |
| CA | 15 | Irregular | 10 | Irregular | 1 | Regular | 1 |

Table 7.12: Length of track and time per trial, memory drum study

| Type of track | Approximate length of line | Time per trial |
|---|---|---|
| Regular | 100 cm | 10 secs |
| Irregular 1 | 73 cm | 10 secs |
| Irregular 2 | 73 cm | 10 secs |
| Irregular 3 | 74 cm | 10 secs |
| Irregular 4 | 73 cm | 10 secs |
| Irregular 5 | 72.5 cm | 10 secs |
| Irregular 6 | 73 cm | 10 secs |
| Irregular 7 | 73 cm | 10 secs |
| Irregular 8 | 73 cm | 10 secs |
| Irregular 9 | 74 cm | 10 secs |
| Irregular 10 | 74 cm | 10 secs |
| Irregular Transfer | 73 cm | 10 secs |

(d) Procedure

All testing was conducted in a room allocated by the teacher in charge, in the school environment familiar to them. All the children were tested individually. On entry into the room, the apparatus was shown to the children. They then sat at the table and were given a red felt tipped pen, and the task explained.

The tester explained that she was going to put a piece of paper with a long wiggly line on it round the drum, which the child would be able to see through the window. This she then did and having closed the lid, drew the attention of the children to the line visible through the window. The tester then explained that when she pressed the switch at the back of the box, the line would start to move down the window. The children were then told to watch whilst the tester switched the machine on, and allowed the drum to rotate for approximately 5 cm, until the starting point was visible at the bottom of the window. It was then explained to the children that they were to begin with the pen on the starting point, and then try to keep their pen on or as close to the wiggly line as possible, as the line moved on. They were told that they should try to keep the pen on the paper all the time, as they would only "score" when the pen left a mark on the paper. They were told that they would receive ten trials to see how much they improved, and in addition whether or not all the lines would be the same shape. The children were asked if they understood what they were going to try and do, and any questions that they asked were answered. If the task appeared to be clearly understood, the children then placed their pen on the starting point, ready to begin. The tester said "Ready" and then turned the switch on, causing the drum to begin rotation. When the children reached the finishing line, the tester switched the drum off, and the children were then asked to lift the pen away. The tester then removed the paper from the drum and replaced it with the second track. This continued until all ten trials had been completed. The inter-trial test was naturally achieved,being the time taken to remove one track and replace it with another. Five days later, when the children received the recall and transfer trials, they were again tested individually. They were asked if they remembered what they had to do, and reminded of the task in general. Before the recall trial they were told that the track would be the same or similar to those attempted before, and before the transfer trial, they were told that this track would be rather different from those they had previously seen.

The twelve tracks attempted by the children were kept together, for future analysis.

(ii) Results

In order to give some insight into the type of attempts by the subjects, two randomly identified subjects' attempts are shown in Appendix 5, along with the percentage pen on paper, MM, RMS, 5 greatest RMS, subjective mark out of 10 and learning mark given for the trials. The quality of reproduction is not very good, as the sheets have been reduced and photocopied several times, having been used also for digitising and subjective marking. Several types of analysis were attempted, which can be broadly categorized into two types, each of which will be considered in turn:-

(A) Those analyses involving the digitising of the track made by the children, and subsequent analyses of the error.

(B) Subjective assessment of the tracks made by the children in relation to the track given.

## (A) Digitising of the data and subsequent analysis

The Ferranti Free Scan Digitiser was used. The digitiser consisted of a sensitive board and a sensor linked to the Systime computer. By moving the sensor into any given position on the table and pressing the appropriate entry button, the x + y values for that position are entered into the file on the computer. A photograph of the equipment is shown in Figure 7.19.

Each subject's trial was analysed separately. The paper on which the track was recorded was placed on the top of the board, as parallel with the bottom edge of the board as possible. The subject's file name was then entered into the computer, followed by the name of the desired track (REG 2, IONE, ITWO, ITHR, IFOU, IFIV, ISIX, ISEV, IEIG, ININ, ITEN, or IELE) and the trial number (1,2,3,4,5,6,7,8,9,10, 11 or 12). The sensor was then placed on the starting point of both the desired track and the subject's trial (the same point as the subject had been instructed to begin by putting his pen on that point) and this point was then entered into the file. The sensor was then moved slowly along the track produced by the subject, and as this was done automatically entered into the file were the y values (to the nearest 0.1 mm) for 160 points along the x axis, each 2.5 mm apart.

Provided the code of the calibration curve was recorded with the data, it was not necessary to digitise the calibration curve. This not only significantly reduced the time required for digitising but also reduced the amount of storage space required on the computer, which in any event amounted to 1.4 Mbytes.

Fig. 7.19: Ferranti free scan digitiser, used in the memory drum study

In some cases, the photocopying of the tracks had resulted in slight "stretching" of the track (up to approx. ·5 cm). For this reason, final entries were made into the subjects' file of the finishing point of the track, made by the subject and that of the desired track (y value). In the event of pen lifting, the letter z was typed in, which recorded the pen lifting in the subject's file until it was then entered again. The sensor then continued to record y values as before. The data for the 12 trials by each subject were kept in one file identified by his group (CA, CLD, MA), type of track attempted (Regular = 1, Irregular = 2) and his subject number (01-15), resulting in a name such as CA 104 DATA. Using a series of programs, the following operations took place:-

(i) Check that the curve title is one of the 12 listed (e.g. IFIV)

(ii) Search for and identification of instances of pen lifting.

(iii) Rotation of the subject's trial so that the end points of the desired track of the given trial match with those scored for the track typed.

(iv) Collation of subjects' data into six files, according to group (3) and type of track (2).

(v) Comparison of subject's y values with those stored for the given track, and calculation of deviation error, disregarding the points on which pen lifting occurred.

(vi) Calculation of mean MM error, RMS error, and 5 greatest RMS error scores for each trial of each subject, disregarding the points on which pen lifting occurred.

(vii) Calculation of number and percentage of instances of pen lifting.

The data, in terms of percentage time pen on paper, MM, RMS and 5 greatest RMS were then subjected to further group analysis, and each of these will be considered in turn.

The measures used - MM, RMS and percentage pen on paper

These measures of accuracy or error were selected as giving the overall best and most complete assessment of accuracy in an objective, mathematical and statistical sense.

Poulton (1962) in discussing various methods of scoring tracking, highlights the difference between error in terms of position and that in terms of time and between measures of error along the total track compared with measures taken at particular points along it. Hammerton (1981) states that:-

> Two measures are generally used which provide the bulk of the information required: these are the modulus mean error (MM) and the root mean squared error (RMS)
>
> (P.190)

Certainly these two measures, the RMS in particular, have been used extensively in tracking research (e.g. Mather & Putchat 1983; Noble, Fitts & Warren 1955) and has stood the test of time, when the dates of the two studies cited are compared.

Hammerton (1981) goes on to state that statistically the RMS is the preferred measure, although RMS and MM correlate together highly. It was decided that MM and RMS would both be analysed in order to examine whether both analyses did reflect similar trends. These two measures will also be considered in the light of percentage time pen on paper since, although this is not a measure of accuracy, it is relevant in that it may shed some light on overall orientation to the task. The two measures of accuracy, MM and RMS would then be taken as representative of objective assessment of error at an interval level before comparison with the subjective measures. It is accepted that there are several other methods of scoring, but it was considered that these adopted a viewpoint which was considered valuable by other researchers, which was objective and at an interval level of scoring, which considered the total trial and yet which might have some flaws.

No analysis along the x axis was attempted. This is because it was considered that any such analysis would fail to consider the total trial, as there would inevitably be occasions on which there was no track with which to compare the subjects' attempt, or no value for the subjects' attempt, particularly in falling short at the peaks.

(i) Percentage time pen on paper

These analyses were conducted in an attempt to understand whether or not all groups of children were equally capable of keeping the pen on the paper throughout the trials. They had all been instructed that they should attempt to do this, and that they could not "score" unless the pen was on the paper.

160 points along the x axis were digitised. When no mark was left by the pen on the paper, this was recorded in the data file. Subsequently, the percentage time of pen on paper was calculated for each trial, using the formula

$$\% = \frac{n}{160} \times 100$$

The results were then subjected to analyses of variance, to study the effect of group and curve on the following, each of which will be considered in turn.

(a) Performance over 10 practice trials

(b) Performance on the recall trial

(c) Performance on the transfer trial

(d) Performance over the recall and transfer trials.

It can be argued that analyses of variance are not suitable for this type of data; firstly, the mathematical operations mean that the data being used is far from the original data and therefore meaningless, and secondly, since there is a present maximum of 100%, the distribution of the scores is not normal, thus violating a prerequisition of analyses of variance.

Analysis of variance makes certain assumptions:-

(a) That the scale of the data is interval.

(b) That the scores in each sample are from normally distributed populations.

(c) That the sample taken is random.

(d) That the variances of the samples are equal (i.e. homogeneity of variance).

Games and Klare (1967) state that the assumption, regarding normality of distribution is not crucial and that the F test is accurate despite differing forms for the populations. Furthermore, they state that when the size of the samples is equal, the F test is quite robust with respect to the assumption of homogeneity of variance. Since the data is interval, and on the basis of these arguments, it is considered that there is a value in analysing the data in this way, since some comparison is necessary in order to establish whether the lower MM and RMS scores are achieved through a "trading off" strategy, lifting the pen in order to regain an improved position, or whether lifting of the pen and high error scores tend to go hand in hand. The percentage time on paper is ordinal data, and subjective observation of the group means indicate relatively few maximum scores, with the result that the normality of distribution may not be affected as severely as was feared. Bearing these points in mind the analyses will be taken in turn.

(a) Performance over 10 practice trials

The 3 (group) x 2 (curve) x 10 (trials) anova of percentage time of pen on paper over the practice trials resulted in significant main effects for group ($F(2, 84) = 4.79$, $p < .05$) and trials $F(9, 756) = 25.10$, $p < .001$) with interactions between trial and group ($F(18, 756) = 2.76$, $p < .001$) and between trial and curve ($F(9, 756) = 3.54$, $p < .001$).

In view of the interactions, the two main effects were disregarded. With regard to the significant trial x group interaction, tests of simple main effects revealed simple effects for the following:-

(i) For group on trial 1 ($F(2,84) = 20.16$, $p < .01$)

(ii) For group on trial 2 ($F(2,84) = 3.21$, $p < .05$)

(iii) For group on trial 4 ($F(2,84) = 3.61$, $p < .05$)

(iv) For trials for the group with learning difficulties ($F(9,756) = 14.45$, $p < .01$)

(v) For trials for the MA matched group ($F(9,756) = 14.71$, $p < .01$)

(See Appendix 4, Table 2).

Posthoc analysis of the differences between the groups on trials 1, 2 and 4 (Tukey HSD) revealed the following specific differences. On Trial 1, (i) between the CA matched group and the group with learning difficulties ($p < .01$); (ii) Between the CA and MA matched group ($p < .01$)

(See Appendix 4, Table 3).

On trial 2, no specific differences were evident.

(See Appendix 4, Table 4).

On trial 4, similarly no specific differences were evident, using the Tukey HSD Test.

(See Appendix 4, Table 5).

Use of the Fisher LSD Test also revealed no significant differences between groups at either trial 2 or trial 4.

(See Appendix 4, Tables 6 & 7)

This is perhaps not altogether surprising since the simple effects are only just significant and the overall difference is perhaps greater than the sum of the parts.

With regard to the differences between trials, significant for the groups with learning difficulties and the MA matched group, the following differences were found to be significant.

(i) For the group with learning difficulties, between trials

| | | |
|---|---|---|
| 1 and 2 ($p < .01$) | 1 and 3 ($p < .01$) | 1 and 4 ($p < .01$) |
| 1 and 5 ($p < .01$) | 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) |
| 1 and 8 ($p < .01$) | 1 and 9 ($p < .01$) | 1 and 10 ($p < .01$) |

(See Appendix 4, Table 8)

(ii) For the MA matched group, between trials

| | | |
|---|---|---|
| 1 and 2 ($p < .01$) | 1 and 3 ($p < .01$) | 1 and 4 ($p < .01$) |
| 1 and 5 ($p < .01$) | 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) |
| 1 and 8 ($p < .01$) | 1 and 9 ($p < .01$) | 1 and 10 ($p < .01$) |

(See Appendix 4, Table 9).

The mean percentage scores for the three groups over the 10 practice trials are shown in Table 7.13 and graphically in Figure 7.20. From this it can be seen that the trend is for the groups to be almost 100% pen on paper by the later trials. The majority of pen lifting would appear to occur on trial 1.

Table 7.13: Mean percentage pen on paper for the 3 groups over the 10 practice trials, memory drum tracking task

| Trial | CLD | MA | CA |
|---|---|---|---|
| 1 | 74.13 | 75.26 | 92.00 |
| 2 | 91.00 | 95.73 | 98.93 |
| 3 | 93.36 | 99.70 | 99.33 |
| 4 | 91.70 | 99.07 | 99.00 |
| 5 | 92.97 | 99.43 | 99.46 |
| 6 | 96.53 | 99.46 | 99.56 |
| 7 | 99.36 | 97.93 | 99.53 |
| 8 | 98.46 | 99.67 | 100.00 |
| 9 | 99.30 | 100.00 | 99.43 |
| 10 | 98.50 | 99.80 | 100.00 |

Tests of simple main effects were conducted on the significant trial x curve interaction. The following simple effects were found to be significant.

(i) For curve, on trial 1 ($F(1, 756) = 16.75$, $p < .01$)

(ii) For curve, on trial 2 ($F(1, 756) = 5.79$, $p < .05$)

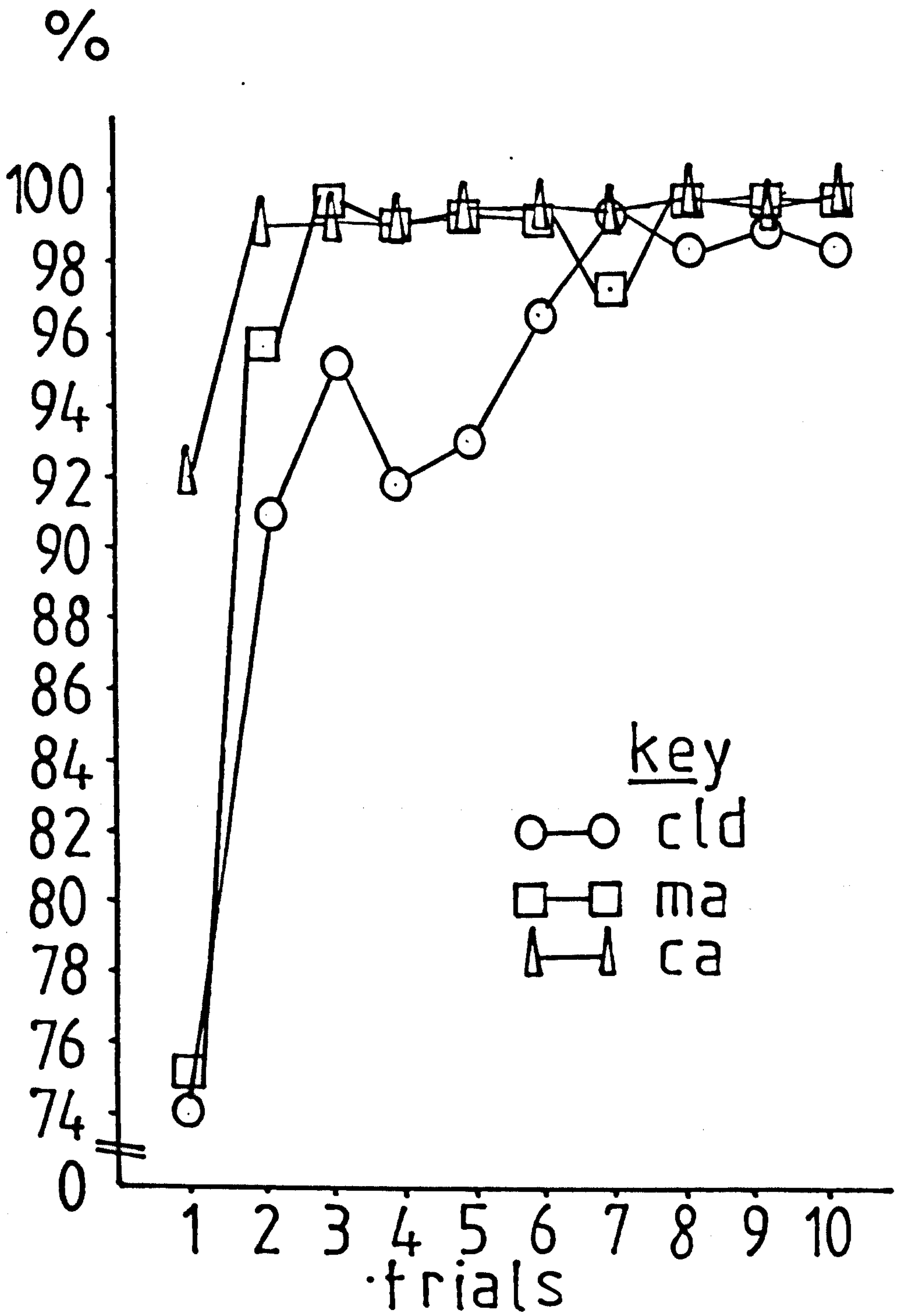



Figure 7.20: Percentage time pen on paper, for the 3 groups over the 10 practice trials, memory drum tracking task

(iii) For trials, for the regular track ($F(9, 756) = 20.84$, $p < .01$)

(iv) For trials, for the irregular track ($F(9, 756) = 8.17$, $p < .01$)

(See Appendix 4, Table 10).

With regard to the differences between the curves, significant on trials 1 and 2 only, it can be seen from Table 7.14, that on the subsequent trials percentage time pen on paper approximates 100%. On the two earlier trials, however, the picture is different; on the first trial, the regular track results in less time in contact with the paper, whereas on trial 2, this trend is reversed.

Table 7.14: Mean percentage time pen on paper for the two tracks over 10 practice trials (%), memory drum tracking task

| Trial | Regular Curve | Irregular Curve |
|---|---|---|
| 1 | 75.78 | 85.13 |
| 2 | 97.98 | 92.47 |
| 3 | 99.36 | 95.58 |
| 4 | 98.98 | 94.20 |
| 5 | 99.22 | 95.36 |
| 6 | 99.24 | 97.80 |
| 7 | 98.71 | 99.18 |
| 8 | 99.09 | 99.67 |
| 9 | 99.56 | 99.60 |
| 10 | 99.00 | 99.87 |

Posthoc analysis of the differences between trials for both curves (Tukey HSD) revealed the following specific differences.

(i) For the regular track, between trials

| | | |
|---|---|---|
| 1 and 2 ($p < .01$) | 1 and 3 ($p < .01$) | 1 and 4 ($p < .01$) |
| 1 and 5 ($p < .01$) | 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) |
| 1 and 8 ($p < .01$) | 1 and 9 ($p < .01$) | 1 and 10 ($p < .01$) |

(See Appendix 4, Table 11)

(ii) For the irregular track, between trials

| | | |
|---|---|---|
| 1 and 2 ($p < .05$) | 1 and 3 ($p < .01$) | 1 and 4 ($p < .01$) |
| 1 and 5 ($p < .01$) | 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) |
| 1 and 8 ($p < .01$) | 1 and 9 ($p < .01$) | 1 and 10 ($p < .01$) |

(See Appendix 4, Table 12).

The means for the two tracks over the 10 trials are shown in Table 7.14 and graphically in Figure 7.21. As can be seen, the trend is for increased time in contact with the paper over the 10 trials.

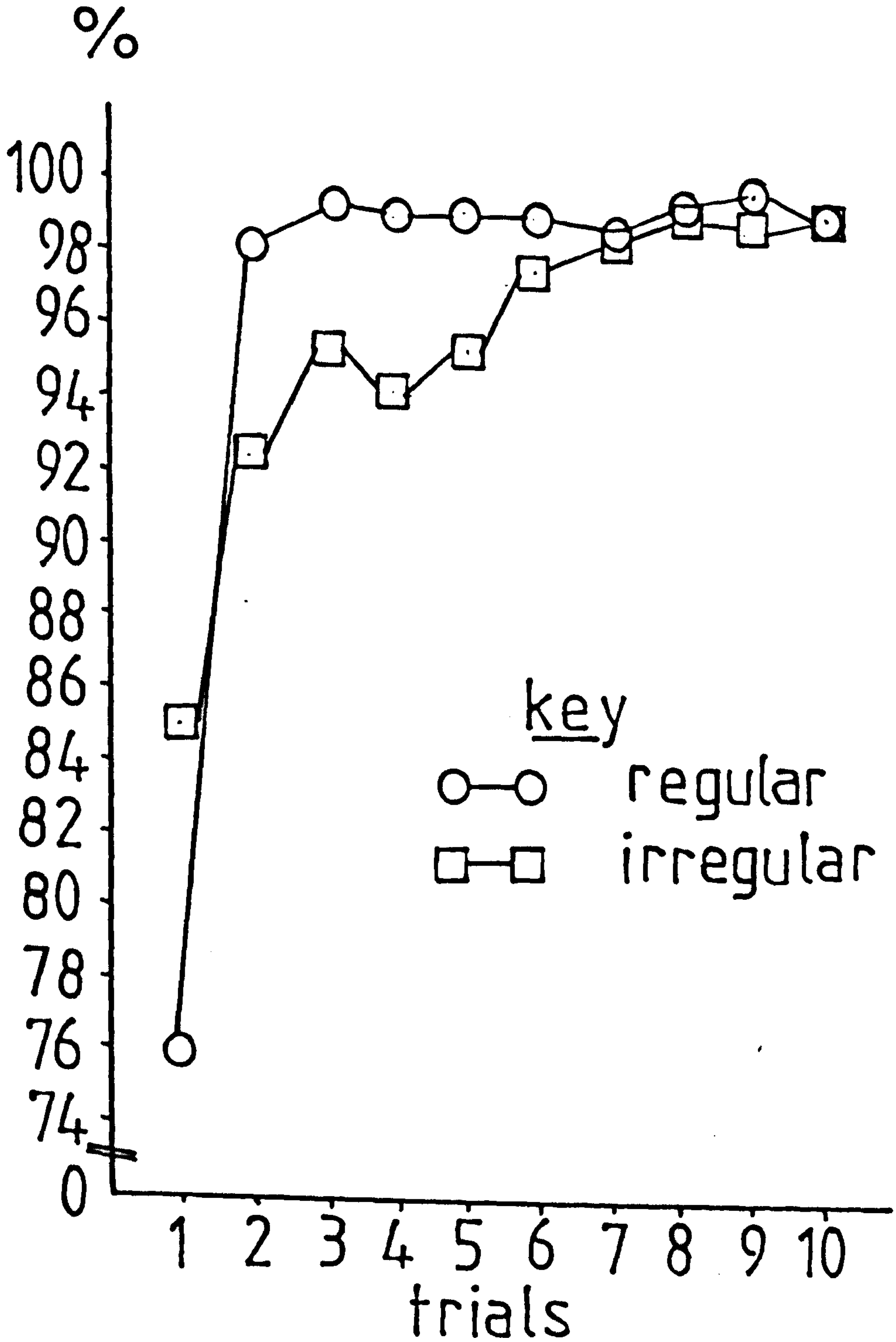
(b) <u>Performanceon the Recall trial</u>

The 3 (group) x 2 (curve) anova for percentage pen on paper on the recall trial revealed no significant main effects, nor any interactions (See Appendix 3, Table 13).

(c) <u>Performance on the Transfer trial</u>

The 3 (group) x 2 (curve) anova for percentage pen on paper on the transfer trial revealed a significant main effect for group only

Figure 7.21: Percentage time pen on paper over the practice trials for the two tracks, memory drum tracking task



($F(2, 84) = 3.99$, $p < .05$) and no interaction.

(See Appendix 4, Table 14).

Posthoc analysis (Tukey HSD) of the main effects for group revealed specific differences between the group with learning difficulties and the two remaining groups ($p < .05$), both of whom achieved 100% pen on paper.

(See Appendix 4, Table 15).

The means for the three groups are shown in Table 7.15.

Table 7.15: Mean percentage time pen on paper for the 3 groups on the transfer trial, memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 99.13 | 100.00 | 100.00 |

(d) Performance over the recall and transfer trials

The 3 (group) x 2 (curve) x 2 (trial) anova for percentage time pen on paper on day 2 revealed no significant main effects, but a group x trial interaction ($F(2, 84) = 3.16$, $p < .05$).

(See Appendix 4, Table 16)

Tests of simple main effects were conducted on the significant group x trial interaction. The only significant simple effect was for trials for the MA matched group ($F(1, 84) = 4.90$, $p < .05$)

(See Appendix 4, Table 17)

The means for the 3 groups and 2 trials are shown in Table 7.16. As can be seen, the MA matched group achieves 100% pen on paper on transfer, but not on recall. The means are also shown in Figure 7.22.

Table 7.16: Mean percentage time pen on paper on recall and transfer for the 3 groups, memory drum tracking task

| Trial | CLD | MA | CA |
|---|---|---|---|
| Recall | 99.70 | 99.03 | 100.00 |
| Transfer | 99.13 | 100.00 | 100.00 |

(ii) Modulus mean error

Following the digitising of the data, the modulus mean error of each track recorded (twelve per subject) was calculated using the formula

$$MM = \frac{\Sigma x}{n}$$

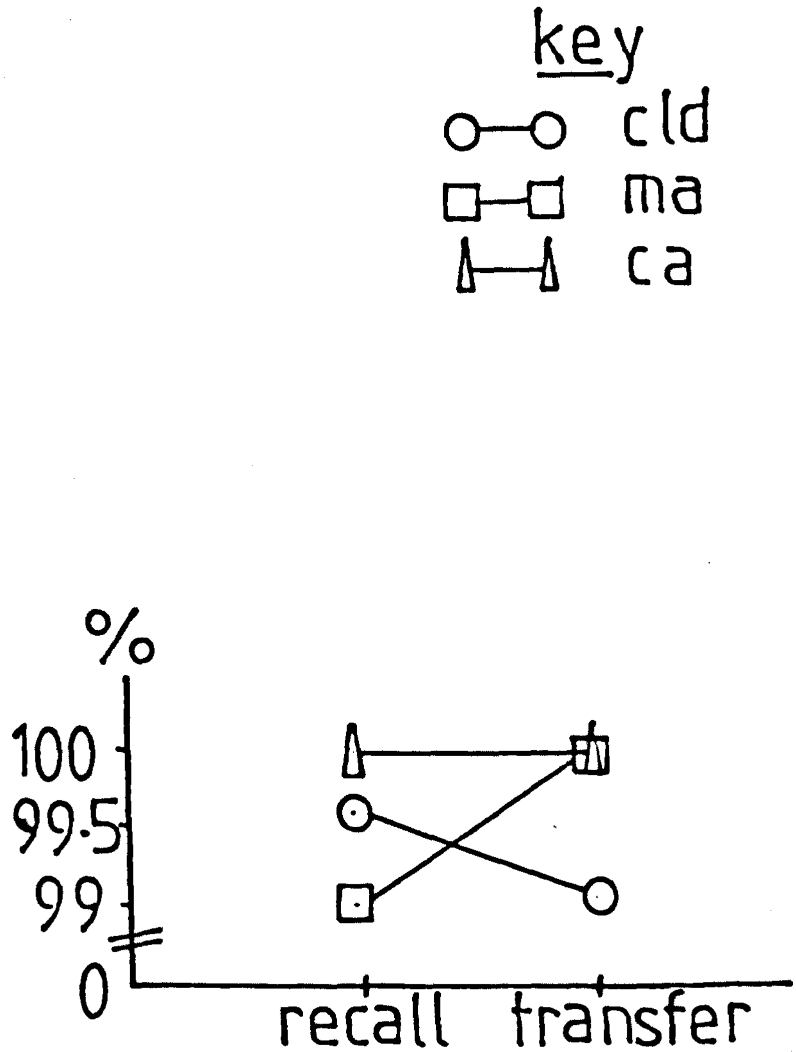
The results were then subjected to statistical analysis to determine the effects of group and track on the following, each of which will be considered in turn.

(a) Performance over the 10 trials, day 1.

(b) Performance on the recall trial, day 2.

(c) Performance on the transfer trial, day 2.

Figure 7.22: Mean percentage time pen on paper for the 3 groups on recall and transfer, memory drum tracking task



(d) Performance over the recall and transfer trials, day 2.

(a) Performance over the 10 practice trials, day 1

The 3 (group) x 2 (curve) x 10 (trials) anova for the modulus mean error revealed significant main effect for group ($F(2, 84) = 30.29$, $p < .001$), curve ($F (1, 74) = 19.08$, $p < .001$) and trials ($F (9, 756) = 34.42$, $p < .001$), and a significant group x track interaction ($F (9, 756) = 6.63$ $p < .001$).

(See Appendix 4, Table 18)

In view of the interactions, the main effects were disregarded and tests of simple main effects conducted on the two interactions.

With regard to the group x curve interaction, tests of simple main effects revealed the following overall differences.

(i) Between groups for the regular curve ($F(2, 84) = 28.20$, $p < .01$)

(ii) Between groups for the irregular curve ($F (2, 84) = 6.50$, $p < .01$)

(iii) Between curves for the group with learning difficulties ($F(1, 84) = 20.30$, $p < .01$)

(iv) Between curves for the MA matched group ($F(1, 84) = 6.60$, $p < .05$).

(See Appendix 4, Table 19).

Posthoc analyses (Tukey HSD) of the differences between the groups for the two types of curves revealed the following differences.

(i) For the regular curve, between the group with learning difficulties and the CA matched group ($p < .01$), the group with learning difficulties and the MA matched group ($p < .01$) and between the MA and the CA matched groups ($p < .01$)

(See Appendix 4, Table 20)

(ii) For the irregular curve, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 21)

The means for the three groups and two curves can be seen in Table 7.17 and in Figure 7.23. In both cases, the group with learning difficulties exhibits the greatest error and the CA matched group, the least.

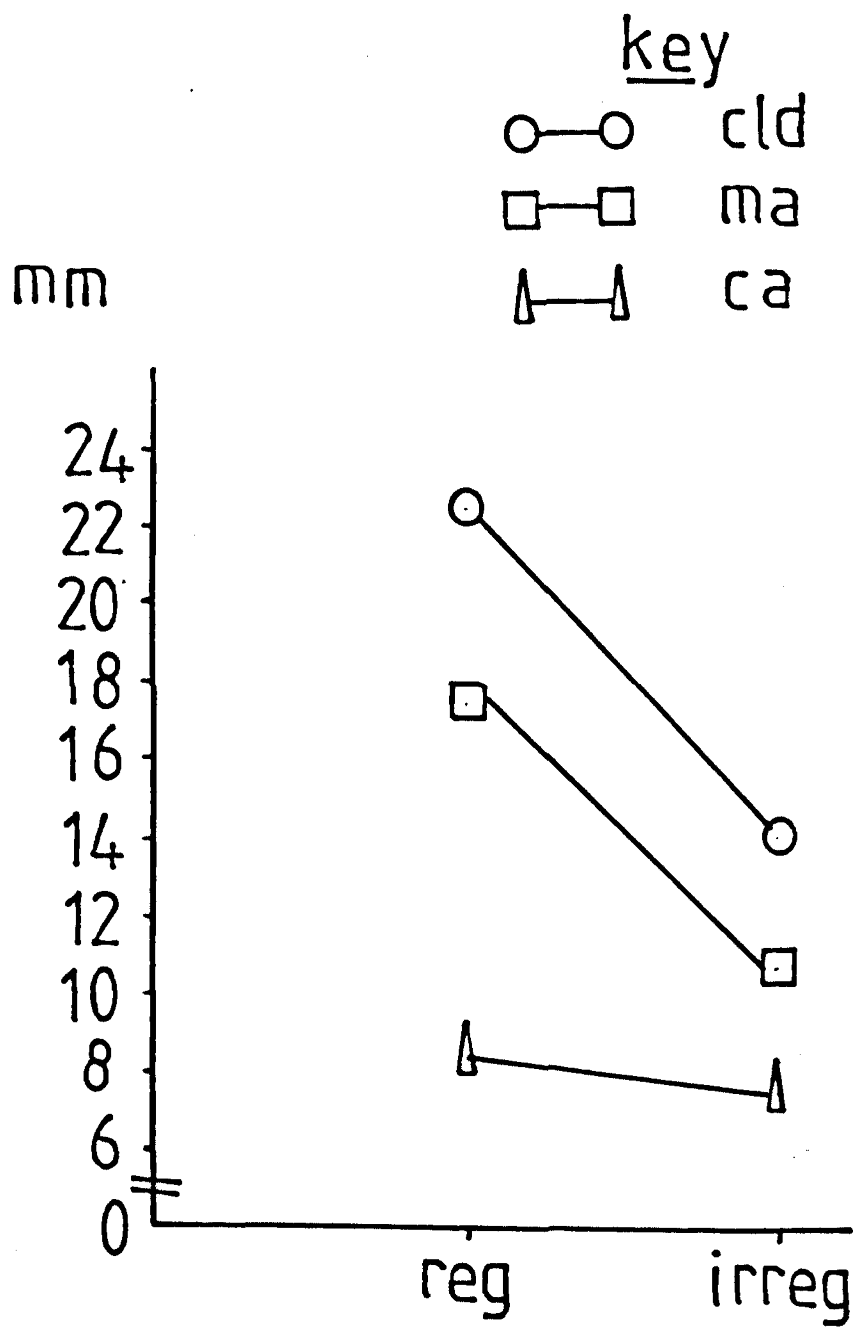
Table 7.17: Mean error (MM) for the 3 groups and 2 curves during practice trials, memory drum tracking task

| Curve | CLD | MA | CA |
|---|---|---|---|
| Regular | 22.39 | 15.40 | 8.45 |
| Irregular | 14.03 | 10.63 | 7.55 |

With regard to the effect for curve, significant for the group with learning difficulties and the MA matched group only, it can be seen from Table 7.17 that in both cases, the irregular track results in less error.

Tests of simple main effects were conducted on the trial x curve interaction, revealing the following overall differences.

Figure 7.23: Mean error (MM) of the 3 groups and 2 curves during practice trials, memory drum tracking task



(i) Between curves for trial 1(F(1, 84) = 59.90, p <.01)

(ii) Between curves for trial 2 (F(1, 84) = 19.35, p <.01)

(iii) Between curves for trial 3 (F(1, 84) = 11.34, p <.01)

(iv) Between curves for trial 4 (F(1, 84) = 9.11, p <.01)

(v) Between curves for trial 5 (F(1, 84) = 8.55, p <.01)

(vi) Between curves for trial 6 (F(1, 84) = 9.49, p <.01)

(vii) Between curves for trial 7, (F(1, 84) = 4.26, p <.05)

(viii) Between curves for trial 8 (F(1, 84) = 4.27, p <.05)

(ix) Between curves for trial 10 (F(9, 756) = 33.84, p <.01)

(x) Between trials for the regular curve (F(9, 756) = 33.84 p <.01)

(xi) Between trials for the irregular curve (F(9, 756) = 6.12, p <.01)

(See Appendix 4, Table 22)

Posthoc analysis (Tukey HSD) of the differences between trials for both types of curve revealed the following specific differences.

For the regular curve between trials

1 and 2 (p <.01) 1 and 3 (p <.01) 1 and 4 (p <.01) 1 and 5 (p <.01)

1 and 6 (p <.01) 1 and 7 (p <.01) 1 and 8 (p <.01) 1 and 9 (p <.01)

1 and 10 (p <.01)

2 and 5 (p <.01) 2 and 6 (p <.01) 2 and 7 (p <.01) 2 and 8 (p <.01)

2 and 9 (p <.01) 2 and 10 (p <.01)

3 and 7 (p <.05) 3 and 8 (p <.01) 3 and 9 (p <.01)

4 and 9 (p <.05)

(See Appendix 4, Table 23)

For the irregular curve between trials

1 and 3 ($p < .05$)    1 and 4 ($p < .05$)    1 and 5 ($p < .01$)    1 and 6 ($p < .01$)

1 and 7 ($p < .01$)    1 and 8 ($p < .01$)    1 and 9 ($p < .01$)    1 and 10 ($p < .01$)

2 and 10 ($p < .05$)

(See Appendix 4, Table 24)

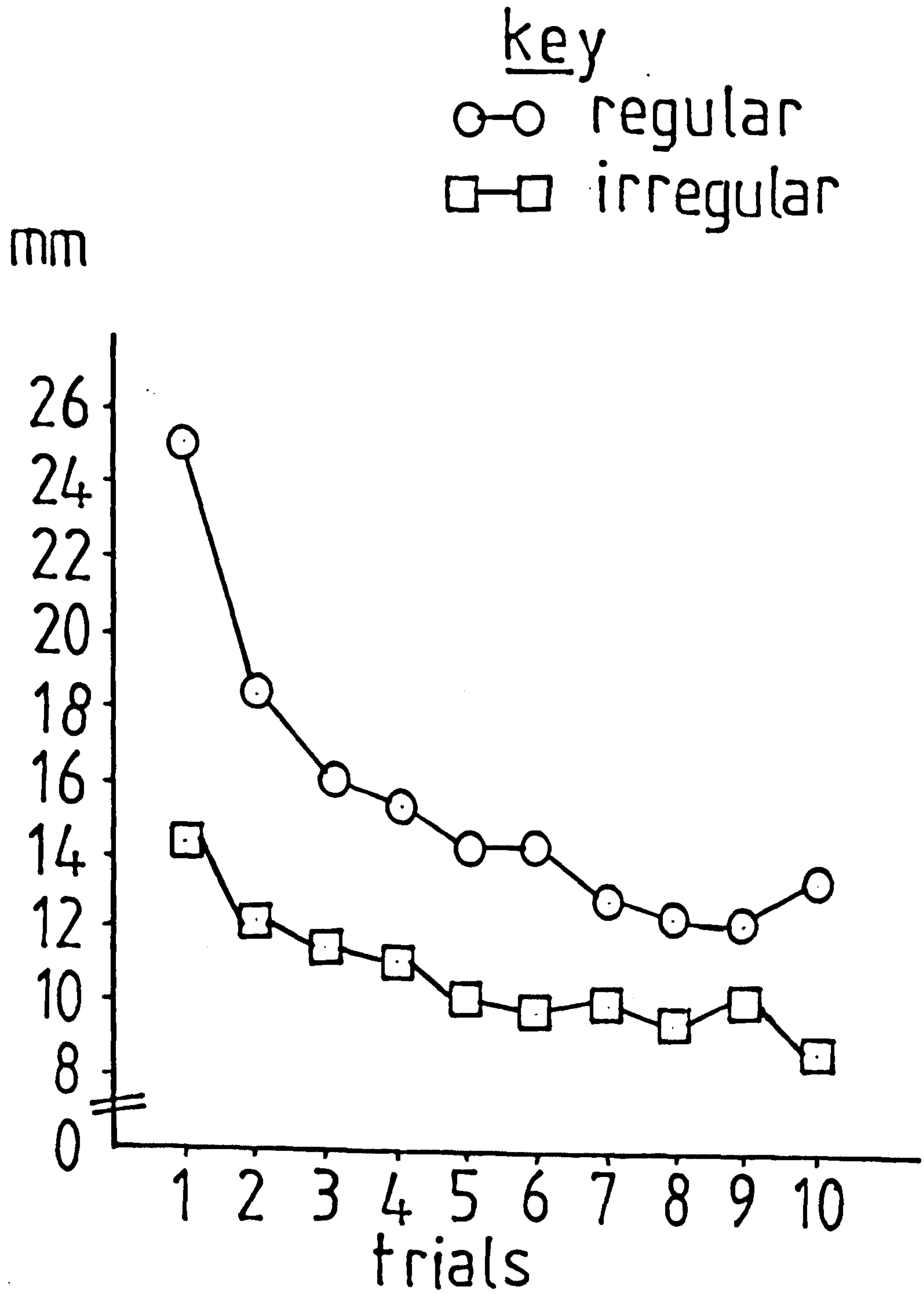
The mean error for the two types of curve and ten trials is shown in Table 7.18, and in Figure 7.24.

Table 7.18: Mean error (MM) for the 2 curves and 10 practice trials drum tracking task

| Trial | Regular curve | Irregular curve |
|---|---|---|
| 1 | 25.38 | 14.55 |
| 2 | 18.29 | 12.13 |
| 3 | 16.11 | 11.40 |
| 4 | 15.36 | 11.13 |
| 5 | 14.07 | 9.98 |
| 6 | 14.07 | 9.76 |
| 7 | 12.86 | 9.98 |
| 8 | 12.44 | 9.55 |
| 9 | 12.18 | 10.09 |
| 10 | 13.40 | 8.80 |

With regard to the differences between curves, significant for all trials with the exception of trial 9, it can be seen from Table 7.18 that in all cases, the regular curve results in the greater error.

Figure 7.24: Mean error (MM) for the 2 curves over 10 practice trials, memory drum tracking task



(b) Performance on the recall trial

The 3 (group) x 2 (curve) anova for modulus mean error on the recall trial revealed a significant main effect for group only ($F(2, 84) = 16.70$, $p < .001$) and no interaction.

(See Appendix 4, Table 25)

With regard to the main effect for group, posthoc analysis (Tukey HSD) revealed specific differences to exist between the group with learning difficulties and the CA matched group ($p < .01$), and the group with learning difficulties and the MA matched group ($p < .01$)(See Appendix 4, Table 26)

The means for the three groups are shown in Table 7.19, and as can be seen, the group with learning difficulties exhibits the greatest error.

Table 7.19: Mean error (MM) of the three groups on the recall trial, memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 14.11 | 7.57 | 5.50 |

(c) Performance on the transfer trial

The 3 (group) x 2 (curve) anova for modulus mean error on the transfer trial revealed significan main effects for both group ($F(1, 84) = 20.10$, $p < .001$) and curve ($F(1, 84) = 8.67$, $p < .01$), with no interaction between the two factors.

(See Appendix 4, Table 27)

With regard to the main effect for group, posthoc analysis (Tukey HSD) revealed specific differences to exist between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$). (See Appendix 4, Table 26)

As can be seen from Table 7.20, the group with learning difficulties exhibits the greatest error, and the CA matched group the least.

Table 7.20: Mean error (MM) of the 3 groups on the transfer trial, memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 13.70 | 8.23 | 5.53 |

With regard to the main effect for type of curve, it can be seen from Table 7.21 that those groups attempting the regular track on transfer (and irregular during practice and recall) generate greater error than those attempting the irregular track on transfer (and regular during practice and recall).

Table 7.21: Mean error (MM) for the two types of curve, on the transfer trial, memory drum tracking task

| R - IRREGULAR | I - REGULAR |
|---|---|
| 7.58 | 10.73 |

(d) Performance on the recall and transfer trials

The 3 (group) x 2 (curve) x 2 (trials) anova for modulus mean error on recall and transfer revealed a significant main effect for group ($F(2, 84) = 22.02$ $p < .001$), a trial x curve interaction ($F(2, 84) = 6.97$, p .01), and a group x trial x curve interaction ($F(2, 84) = 24.23$, $p < .01$). (See Appendix 4, Table 29).

In view of the three way interaction, the main effect and two way interaction were disregarded. Tests of simple main effects were conducted on the group x curve x trial interaction and the following simple effects found to be significant:-

(i) Between groups for the regular curve on recall ($F(2, 84) = 13.11$, $p < .01$)

(ii) Between groups, for the irregular curve on recall ($F(2, 84) = 6.83$, $p < .01$)

(iii) Between groups, for the regular curve on recall and irregular on transfer, on the transfer trial ($F(2, 84) = 3.87$, $p < .05$)

(iv) Between groups, for the irregular curve on recall and regular curve on transfer, on the transfer trial ($F(2, 84) = 15.21$, $p < .01$)

(v) Between recall and transfer for the group with learning difficulties attempting the regular curve on recall and the irregular curve on transfer ($F(1, 84) = 20.30$, $p < .01$)

(vi) Between recall and transfer for the group with learning difficulties, attempting the irregular curve on recall and the regular curve on transfer ($F(1, 84) = 14.47$, $p < .01$)

(vii) Between curves, for the group with learning difficulties on transfer ($F(1, 84) = 10.48$, $p < .01$)

(viii) Between curves for the MA matched group on transfer ($F(1, 84) = 27.46$, $p < .01$)

(See Appendix 4, Table 30)

The following interactions were also found to be significant.

(i) Group x trial, for the regular curve on recall, irregular curve on transfer ($F(2, 84) = 52.67$, $p < .01$)

(ii) Group x trial, for the irregular curve on recall, regular curve on transfer ($F(2, 84) = 67.10$, $p < .01$)

(iii) Group x curve, on recall ($F(2, 84) = 21.03$, $p < .01$)

(iv) Group x curve, on transfer ($F(2, 84) = 22.77$, $p < .01$)

(v) Trial x curve, for the group with learning difficulties ($F(1, 84) = 37.76$, $p < .01$).

(vi) Trial x curve, for the MA matched group ($F(1, 84) = 9.49$, $p < .01$)

(See Appendix 4, Table 30)

For the overall simple effects found for group at both recall and transfer, and for both types of curve, posthoc testing (Tukey HSD) revealed the following specific differences:

(i) On the recall trial, attempting the regular track, between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$).

(See Appendix 4, Table 31)

(ii) On the recall trial, attempting the irregular track, between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .05$).

(See Appendix 4, Table 32)

(iii) On the transfer trial, attempting the regular track on recall, and the irregular track on transfer, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 33)

(iv) On the transfer trial, attempting the irregular track on recall and the regular track on transfer, between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$).

(See Appendix 4, Table 34).

The means for the 3 groups, and two types of curve, on both recall and transfer are shown in Table 8.22, and graphically in Figure 7.25.

Table 7.22: Mean error (MM) for the 3 groups and 2 tracks on recall and transfer, memory drum tracking task

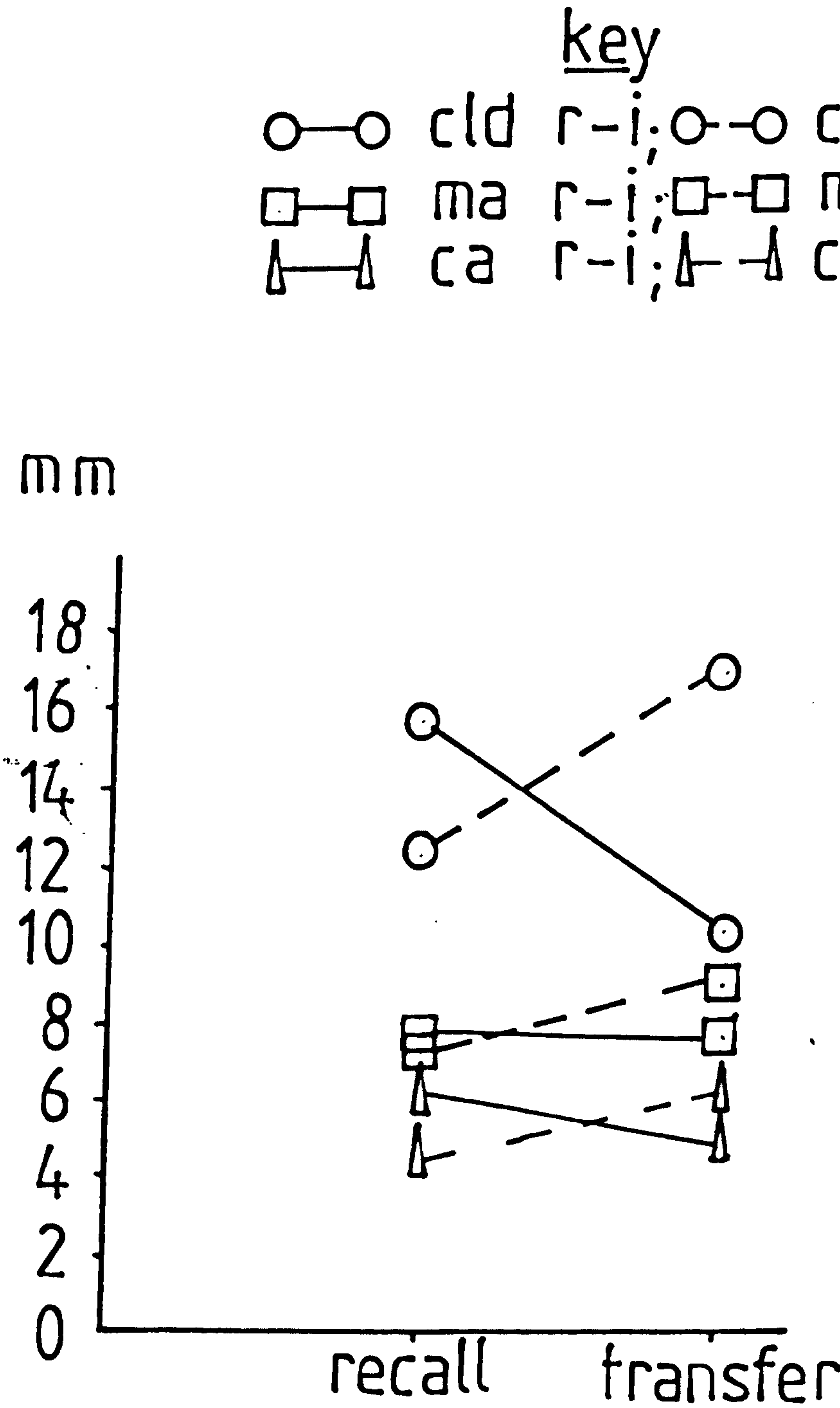
| | | RECALL | TRANSFER |
|---|---|---|---|
| CLD | R - 1 | 15.93 | 10.40 |
| | 1 - R | 12.33 | 17.00 |
| CA | R - 1 | 6.27 | 4.93 |
| | 1 - R | 4.73 | 6.13 |
| MA | R - 1 | 7.67 | 7.40 |
| | 1 - R | 7.47 | 9.07 |

With regard to the differences between recall and transfer, significant for the group with learning difficulties (both types of track) and the MA matched group, attempting the irregular curve on recall and the regular curve on transfer, it can be seen that the regular curve consistently results in greater error. This is similarly the case for the differences between curves on transfer, significant for the group with learning difficulties and the MA matched group only.

(iii) Root Mean Squared Error

Following the digitising of the data, the root mean squared (RMS) error of each track recorded (12 per subject) was calculated,

Figure 7.25: Mean error (MM) of the 3 groups and 2 types of track on recall and transfer, memory drum tracking task



using the formula

$$RMS = \sqrt{\frac{\sum x^2}{n}}$$

The results were then subjected to statistical analysis to determine the effect of group and track on the following, each of which will be considered in turn.

(a) Performance over 10 practice trials.

(b) Performance on the recall trial.

(c) Performance on the transfer trial.

(d) Performance over the recall and transfer trials.

(a) Performance over the 10 practice trials

The 3 (group) x 2 (curve) x 10 (trials) anova for performance over the practice trials (RMS) revealed significant main effects for group ($F(2, 84) = 30.24$, $p < .001$), curve ($F(1, 84) = 17.05$, $p < .001$), and trials ($F(9, 756) = 35.92$, $p < .001$) and significant interactions between group and curve ($F(2, 84) = 3.57$, $p < .05$) and between curve and trials ($F(9, 756) = 7.52$, $p < .001$).

(See Appendix 4, Table 35)

Posthoc testing (Tukey HSD) of the differences between the groups revealed the following specific differences.

(i) On the regular track, between the group with learning difficulties and the CA matched group ($p < .01$)

(ii) On the regular track, between the group with learning difficulties and the MA matched group ($p < .01$)

(iii) On the regular track, between the MA and CA matched groups ($p < .01$)

(See Appendix 4, Table 37)

(iv) On the irregular track, between the group with learning difficulties and the CA matched group ($p < .01$)

(See Appendix 4, Table 38)

The means for the 3 groups and 2 curves are shown in Table 7.23 and in Figure 7.26. As can be seen, the group with learning difficulties consistently registers the highest error and the CA matched group, the least.

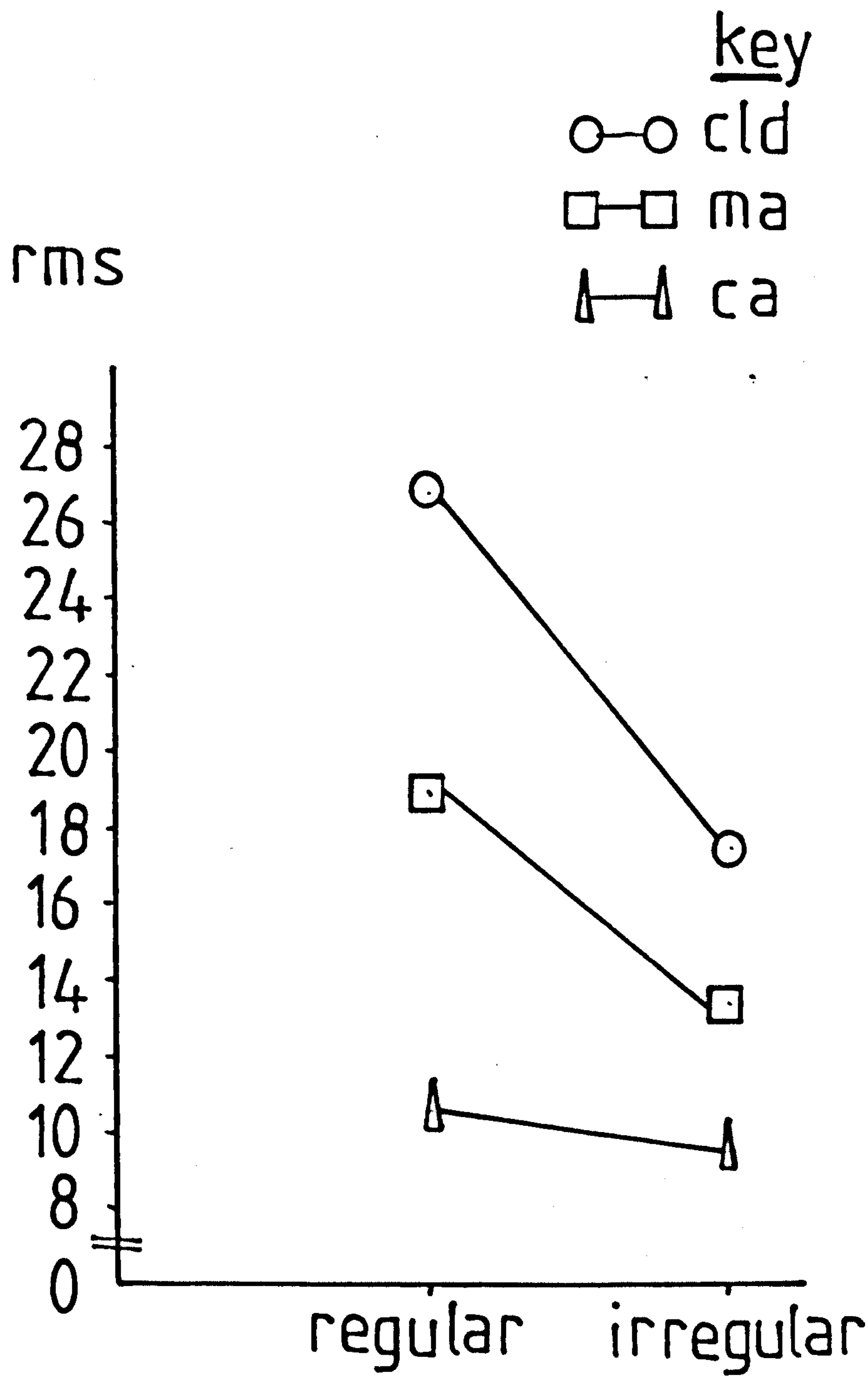
Table 7.23: Mean error (RMS) of the 3 groups and 2 curves during practice trials, memory drum tracking task

| Curve | CLD | MA | CA |
|---|---|---|---|
| Regular | 26.83 | 18.97 | 10.65 |
| Irregular | 17.59 | 13.52 | 9.68 |

It can be seen from Table 7.23 that the regular curve results in the greater error, although this is only marginal and insignificant in the case of the CA matched group.

Tests of simple main effects were also conducted on the curve by trial interaction. This revealed the following simple effects.

Figure 7.26: Mean error (RMS) of the 3 groups and 2 curves during practice trials, memory drum tracking task



(i) For curve on trial 1 ($F(1, 84) = 59.84$, $p < .01$)

(ii) For curve on trial 2 ($F(1, 84) = 20.47$, $p < .01$)

(iii) For curve on trial 3 ($F(1, 84) = 10.78$, $p < .01$)

(iv) For curve on trial 4 ($F(1, 84) = 7.45$, $p < .01$)

(v) For curve on trial 5 ($F(1, 84) = 6.72$, $p < .05$)

(vi) For curve on trial 6 ($F(1, 84) = 9.80$, $p < .01$)

(vii) For curve on trial 10 ($F(1, 84) = 7.79$, $p < .01$)

(viii) For trial on the regular curve ($F(9, 756) = 37.45$, $p < .01$)

(ix) For trials on the irregular curve ($F(9, 756) = 5.98$, $p < .01$)

(See Appendix 4, Table 39)

With regard to the effects for trials at both curves, posthoc testing (Tukey HSD) revealed the following specific differences.

(i) For the regular curve, between trials

1 and 2 ($p < .01$) 1 and 3 ($p < .01$) 1 and 4 ($p < .01$)

1 and 5 ($p < .01$) 1 and 6 ($p < .01$) 1 and 7 ($p < .01$)

1 and 8 ($p < .01$) 1 and 9 ($p < .01$) 1 and 10 ($p < .01$)

2 and 4 ($p < .05$) 2 and 5 ($p < .01$) 2 and 6 ($p < .01$)

2 and 7 ($p < .01$) 2 and 8 ($p < .01$) 2 and 9 ($p < .01$)

2 and 10 ($p < .01$)

3 and 7 ($p < .01$) 3 and 8 ($p < .01$) 3 and 9 ($p < .01$)

4 and 9 ($p < .05$)

(See Appendix 4, Table 40)

(ii) For the irregular curve, between trials

1 and 3 ($p < .05$) 1 and 4 ($p < .01$) 1 and 5 ($p < .01$)

1 and 6 ($p < .01$) 1 and 7 ($p < .01$) 1 and 8 ($p < .01$)

1 and 9 ($p < .01$) 1 and 10 ($p < .01$)

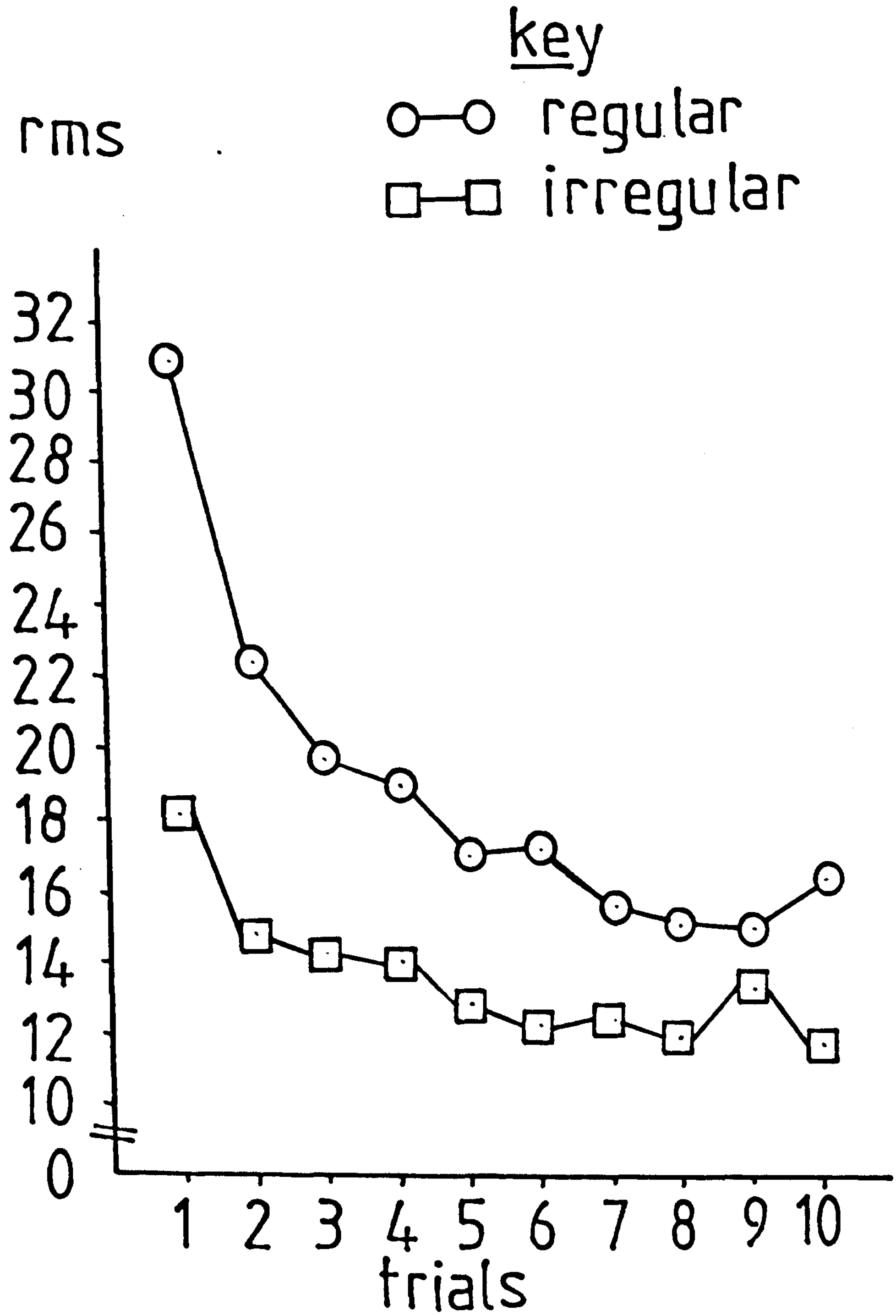
(See Appendix 4, Table 41)

The means for the ten trials and 2 curves are shown in Table 7.24, and it can be seen that in both cases the trend is for a decrease in error over trials. With regard tothe differences between curves, significant at trials 1, 2, 3, 4, 5, 6 and 10, it can be seen that the regular curve results in greater error. The error for the 2 curves and 10 practice trials is also shown graphically in Figure 7.27.

Table 7.24: Mean error (RMS) for the 2 curves and 10 practice trials, memory drum tracking task

| Trial | Regular Curve | Irregular Curve |
|---|---|---|
| 1 | 30.89 | 18.15 |
| 2 | 22.36 | 14.91 |
| 3 | 19.76 | 14.35 |
| 4 | 18.54 | 14.04 |
| 5 | 17.13 | 12.87 |
| 6 | 17.31 | 12.20 |
| 7 | 15.65 | 12.42 |
| 8 | 15.27 | 12.02 |
| 9 | 14.98 | 13.27 |
| 10 | 16.33 | 11.74 |

Figure 7.27: Mean error (RMS) for the 2 curves over 10 practice trials, memory drum tracking task



(b) Performance on the Recall Trial

The 3 (group) x 2 (curve) anova for RMS on the recall trial revealed a significant main effect for group only ($F(2, 84) = 18.35$, $p < .001$), and no interaction.

(See Appendix 4, Table 42)

With regard to the main effect for group, posthoc analysis (Tukey HSD) revealed specific differences to exist between the group with learning difficulties and the CA matched group ($p < .01$).

(See Appendix 4, Table 43)

As can be seen from Table 7.25, the group with learning difficulties exhibits the greater error and the CA matched group, the least.

Table 7.25: Mean error (RMS) of the 3 groups on the Recall Trial, memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 17.80 | 9.73 | 7.13 |

(c) Performance on the Transfer Trial

The 3 (group) x 2 (curve) anova for RMS on the transfer trial revealed significant main effects for group ($F(2, 84) = 19.72$, $p < .001$) and curve ($F(1, 84) = 7.17$, $p < .01$), but no interaction between the two.

(See Appendix 4, Table 44)

With regard to the main effect for group, posthoc testing (Tukey HSD) revealed specific differences to lie between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$).

(See Appendix 4, Table 45)

As can be seen from the group means in Table 7.26, the group with learning difficulties exhibits the greatest error and the CA matched group the least.

Table 7.26: Mean error (RMS) of the 3 groups on the Transfer Trial, memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 17.40 | 10.63 | 7.10 |

With regard to the main effect for curve, it can be seen from Table 7.27 that attempting the irregular curve on recall and the regular curve on transfer (I - R) results in greater error than attempting the irregular curve on transfer (R - I), when the transfer trial only is considered.

Table 7.27: Mean error (RMS) for the two curves on the Transfer Trial, memory drum tracking task

| R - I | I - R |
|---|---|
| 9.89 | 13.53 |

(d) Performance over the Recall and Transfer Trials

The 3 (group) x 2 (curve) x 2 (trials) anova for RMS on recall and transfer revealed a significant main effect for group ($F(2, 84) = 22.89$, $p < .001$), and interactions between trial and curve ($F(1, 84) = 21.57$, $p < .001$) and between group, curve and trial ($F(2, 84) = 5.96$, $p < .01$).

(See Appendix 4, Table 46)

In view of the three way interaction, the main effect and two way interaction were disregarded.

Tests of simple main effects were conducted on the 3 (group) x 2 (curve) x 2 (trial) interaction, which revealed the following overall differences.

(i) Between groups attempting the regular curve on recall ($F(2, 84) = 12.78$, $p < .01$)

(ii) Between groups attempting the irregular curve on recall ($F(2, 84) = 7.83$, $p < .01$)

(iii) Between groups, on the transfer trial, attempting the regular curve on recall and irregular curve on transfer ($F(2, 84) = 4.37$, $p < .05$)

(iv) Between groups on the transfer trial, attempting the irregular curve on recall and the regular curve on transfer ($F(2, 84) = 15.36$, $p < .01$)

(v) Between recall and transfer for the group with learning difficulties attempting the regular curve on recall and the irregular curve on transfer ($F(1, 84) = 17.12$, $p < .01$)

(vi) Between recall and transfer for the group with learning difficulties attempting the irregular curve on recall and regular curve on transfer ($F(1, 84) = 12.94$, $p < .01$)

(See Appendix 4, Table 47)

(vii) Between curves for the group with learning difficulties on transfer ($F(1, 84) = 9.39$, $p < .01$)

The following simple interactions were also found to be significant.

(i) Group x trials for the regular curve on recall and irregular curve on transfer ($F(2, 84) = 59.93$, $p < .01$)

(ii) Group x trial for the irregular curve on recall and regular curve on transfer ($F(2, 84) = 72.44$, $p < .01$)

(iii) Group x curve on recall ($F(2, 84) = 21.46$, $p < .01$)

(iv) Group x curve on transfer ($F(2, 84) = 22.93$, $p < .01$)

(v) Trial x curve for the group with learning difficulties ($F(1, 84) = 33.58$, $p < .01$).

(See Appendix 4, Table 47)

With regard to the simple effects found for group for both curves at both recall and transfer, posthoc testing (Tukey HSD) revealed the following specific differences.

(i) At the regular curve on recall, between the group with learning difficulties and the CA matched group ($p < .01$)

(ii) At the regular curve on recall between the group with learning difficulties and the MA matched group ($p < .01$)

(See Appendix 4, Table 48)

(iii) At the irregular curve on recall, between the group with learning difficulties and the CA matched group ($p < .01$)

(See Appendix 4, Table 49)

(iv) At the irregular curve on transfer (regular curve on recall), no specific differences.

(See Appendix 4, Table 50)

Using the LSD Test, the difference between the group with learning difficulties and the CA matched group was found to be significant ($p < .05$)

(See Appendix 4, Table 51)

(v) At the regular curve on transfer (irregular curve on recall) between the group with learning difficulties and the CA matched group ($p < .01$)

(vi) At the regular curve on transfer (irregular curve on recall), between the group with learning difficulties and the MA matched group ($p < .01$)

(See Appendix 4, Table 52)

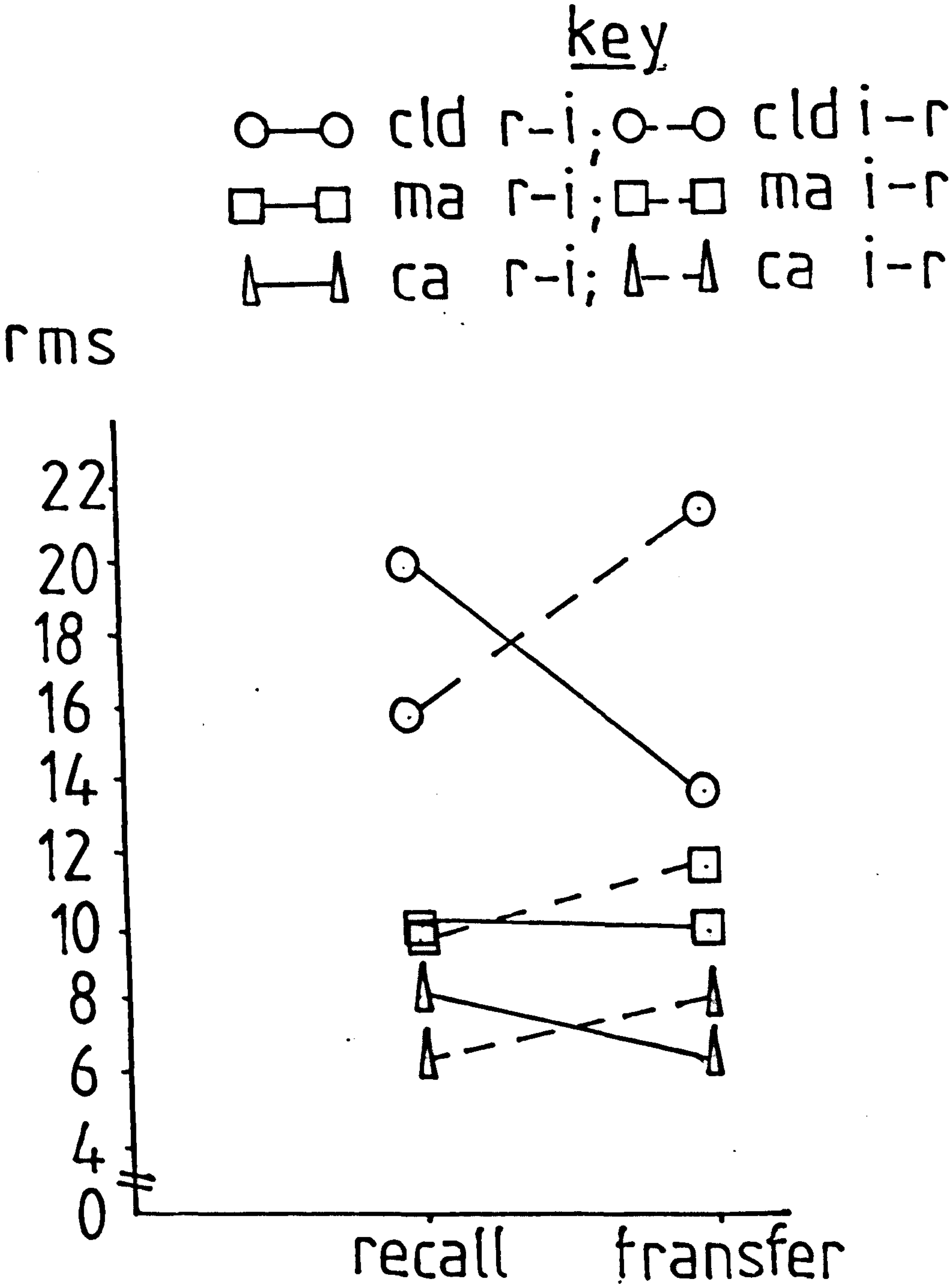
As can be seen from Table 7.28, the CA matched group generates the least error and the group with learning difficulties, the most. The results are also shown in Figure 7.28.

Table 7.28: Mean Error (RMS) for the 3 groups and 2 curves on Recall and Transfer, memory drum tracking task

| Group | | Recall | Transfer |
|---|---|---|---|
| CLD | R - 1 | 19.67 | 13.60 |
| | 1 - R | 15.93 | 21.20 |
| MA | R - 1 | 9.87 | 9.80 |
| | 1 - R | 9.60 | 11.47 |
| CA | R - 1 | 8.00 | 6.27 |
| | 1 - R | 6.27 | 7.93 |

With regard to the difference between recall and transfer, significant for the group with learning difficulties only, it can be seen from Table 7.28 that the amount of change in error is almost the same regardless of the order of curve presentation, but that the direction of the change between recall and transfer is dependent on the type of curve being attempted. This is highlighted by the further significant effect for curves for the group with learning difficulties on transfer.

Figure 7.28: Mean error (RMS) for the 3 groups and 2 curves on recall and transfer, memory drum tracking task



(iv) Analysis of the 5 greatest RMS error scores per trial

The five greatest RMS error scores on each trial were identified and the mean of these 5 calculated. The results were then subjected to analyses of variance. Since the MM and RMS analyses of the total track resulted in very similar trends and differences, it was considered unnecessary to repeat this exercise at this stage. Hammerton (1981), amongst others, recommends the use of RMS in preference to MM, and for this reason, RMS was selected.

The reason for the selection of five greatest error scores was that it was thought that it might give some insight into the question of whether or not children maintain a given level of accuracy over the entire trial, and whether or not the pattern is characteristic of all three groups of children tested here. One would logically expect the absolute value of the mean of the 5 greatest error scores to be significantly greater than that of the mean of the 160 scores used when the entire tra is considered. However, it is the relative increase that is significant here. If the mean of the 5 is reasonably close to that of the 160, then one could infer a given level of accuracy maintained over the trial, but if the mean of the 5 is very much greater than that of the 160, one could infer that the child has achieved a level of accuracy over part of the trial, which he is unable to maintain. The relative ability of the 3 groups to do this would be reflected in any changes in the pattern of significant differences found in the analyses of variance for the RMS (total curve) and RMS (5 greatest). If the pattern remains constant, with similar levels of singificance, one could infer all groups to be equally capable of maintaining performance over the trial, but if the pattern changes or the levels of significance alter, this may well not be the case. Five scores were taken for the mean measure, as it was thought that any more might not consider only the extreme examples and any less scores may be meaningless, as it would not really reflect one total movement.

The effects of track and group on the following were considered, each of which will be taken in turn.

(a) Performance over 10 practice trials.

(b) Performance on the recall trial.

(c) Performance on the transfer trial.

(d) Performance over the recall and transfer trials.

Following the statistical analyses, the discussion will consider these results in relation to those for the full trial, and the implications.

(a) <u>Performance over 10 practice trials</u>

The 3 (group) x 2 (curve) x 10 (trials) anova for performance over the practice trials revealed significant main effects for group ($F(2, 84) = 30.63$, $p < .001$), curve ($F(1, 84) = 13.20$, $p < .001$) and trials ($F(9, 756) = 23.99$, $p < .001$) and significant interactions between trial and group ($F(18, 756) = 1.66$, $p < .05$) and between trial and curve ($F(9, 750) = 8.18$, $p < .001$).

(See Appendix 4, Table 53)

In view of the interactions, the main effects were disregarded. Tests of simple main effects were conducted on the group x trial interaction, and the following simple effects found to be significant.

(i) Between groups on trial 1 ($F(2, 84) = 7.86$, $p < .01$)

(ii) Between groups on trial 2 ($F(2, 84) = 17.21$, $p < .01$)

(iii) Between groups on trial 3 ($F(2, 84) = 19.19$, $p < .01$)

(iv) Between groups on trial 4 ($F(2, 84) = 19.40$, $p < .01$)

(v) Between groups on trial 5 ($F(2, 84) = 16.90$, $p < .01$)

(vi) Between groups on trial 6 ($F(2, 84) = 14,48$, $p < .01$)

(vii) Between groups on trial 7 ($F(2, 84) = 14,84$, $p < .01$)

(viii) Between groups on trial 8 ($F(2, 84) = 16.31$, $p < .01$)

(ix) Between groups on trial 9 ($F(2, 84) = 21.49$, $p < .01$)

(x) Between groups on trial 10 ($F(2, 84) = 17.41$, $p < .01$)

(xi) Between trials for the group with learning difficulties ($F(9, 756) = 4.49$, $p < .01$)

(xii) Between trials for the CA matched group ($F(9, 756) = 9.58$, $p < .01$)

(xiii) Between trials fcr the MA matched group ($F(9, 756) = 13.28$, $p < .01$)

(See Appendix 4, Table 54)

With regard to the differences between groups, significant for all ten trials,posthoc analysis using Tukey HSD yielded the following results and differences.

(i) On trial 1, between no specific groups.

(See Appendix 4, Table 55)

(ii) On trial 2, between no specific groups.

(See Appendix 4, Table 56)

(iii) On trial 3, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 57)

(iv) On trial 4, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 58)

(v) On trial 5, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 59)

(vi) On trial 6, between no specific groups.

(See Appendix 4, Table 60)

(vii) On trial 7, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 61)

(viii) On trial 8, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 62)

(ix) On trial 9, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 63)

(x) On trial 10 between the group with learning difficulties and the CA matched group ($p < .05$)

For those trials on which use of the Tukey HSD test revealed there to be no specific differences, use of the Fisher LSD Test revealed the following results.

(i) On trial 1, no specific differences.

(See Appendix 4, Table 65)

(ii) On trial 2, between the group with learning difficulties and the CA matched group ($p < .05$) and between the MA and CA matched group ($p < .05$)

(See Appendix 4, Table 66)

(iii) On trial 6, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 67)

The means are shown in Table 7.29 and as can be seen, the ordering of the means is such that the CA matched group records the lowest error, and the group with learning difficulties, the greatest, over all trials. This can also be seen in Figure 7.29.

Figure 7.29: Mean error for the 3 groups over 10 practice trials (5 greatest RMS error scores), memory drum tracking task

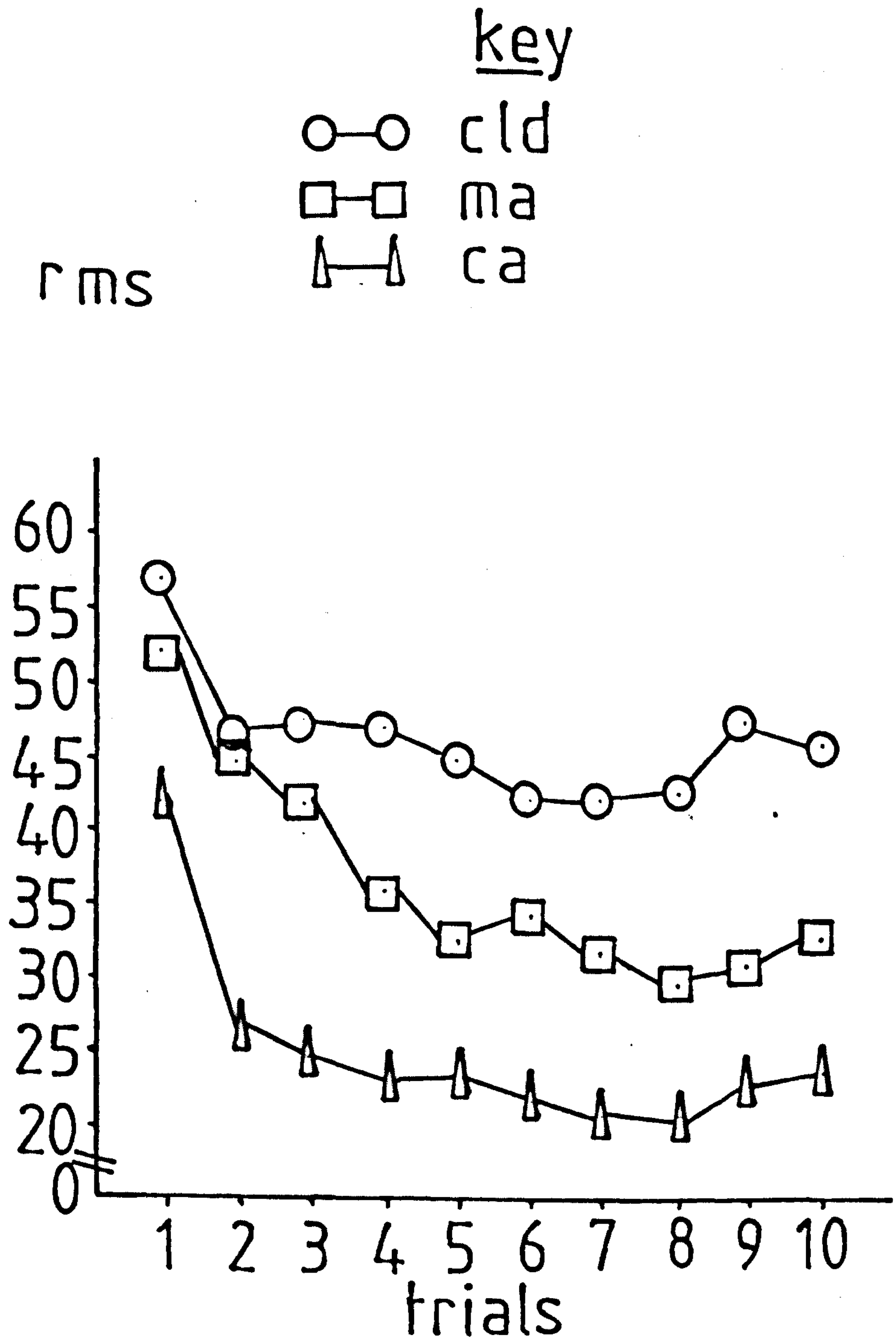


Table 7.29: Mean error for the 3 groups over the 10 Practice Trials (5 greatest RMS error scores) memory drum tracking task

| Trial | CLD | MA | CA |
|---|---|---|---|
| 1 | 56.86 | 52.26 | 41.97 |
| 2 | 47.65 | 45.00 | 26.80 |
| 3 | 47.56 | 41.76 | 24.53 |
| 4 | 47.27 | 36.00 | 23.20 |
| 5 | 45.33 | 32.70 | 23.13 |
| 6 | 42.36 | 34.68 | 21.76 |
| 7 | 42.36 | 32.26 | 21.30 |
| 8 | 42.60 | 29.40 | 20.67 |
| 9 | 47.43 | 30.70 | 22.56 |
| 10 | 46.07 | 32.70 | 23.40 |

With regard to the simple effects for trials, significant for all three groups, posthoc analysis (Tukey HSD) revealed the following specific differences.

(i) For the group with learning difficulties, between trials

1 and 2 ($p < .05$) 1 and 3 ($p < .05$) 1 and 4 ($p < .05$)
1 and 5 ($p < .01$) 1 and 6 ($p < .01$) 1 and 7 ($p < .01$)
1 and 8 ($p < .01$) 1 and 9 ($p < .05$)

(See Appendix 4, Table 68)

(ii) For the MA matched group, between trials

1 and 3 ($p < .01$) 1 and 4 ($p < .01$) 1 and 5 ($p < .01$)

1 and 6 ($p < .01$) 1 and 7 ($p < .01$) 1 and 8 ($p < .01$)

1 and 9 ($p < .01$ 1 and 10 ($p < .01$)

2 and 7 ($p < .01$) 2 and 8 ($p < .01$) 2 and 9 ($p < .01$)

2 and 10 ($p < .01$)

3 and 5 ($p < .05$) 3 and 7 ($p < .05$) 3 and 8 ($p < .01$)

3 and 9 ($p < .01$) 3 and 10 ($p < .05$)

(See Appendix 4, Table 69)

(iii) For the CA matched group, between trials

1 and 2 ($p < .01$) 1 and 3 ($p < .01$) 1 and 4 ($p < .01$)

1 and 5 ($p < .01$) 1 and 6 ($p < .01$) 1 and 7 ($p < .01$)

1 and 8 ($p < .01$) 1 and 9 ($p < .01$) 1 and 10 ($p < .01$)

(See Appendix 4, Table 70)

As can be seen from Table 7.29 and Figure 7.29,the trend is for a reduction in error over trials.

Tests of simple main effects were also conducted on the significant trial x curve interaction. The following simple effects were found to be significant.

(i) For curve on trial 1 ($F(1, 84) = 54.92$, $p < .01$)

(ii) For curve on trial 2 ($F(1, 84) = 24.05$, $p < .01$)

(iii) For curve on trial 3 ($F(1, 84) = 7.15$, $p < .01$)

(iv) For curve on trial 5 ($F(1, 84) = 7.77$, $p < .01$)

(v) For curve on trial 6 ($F(1, 84) = 6.60$, $p < .05$)

(vi) For trials on the regular curve ($F(9, 756) = 28.72$, $p < .01$)

(vii) For trials on the irregular curve ($F(9, 756) = 12.03$, $p < .01$)

(See Appendix 4, Table 71)

With regard to the simple effects for trials, significant for both types of curves, posthoc analysis (Tukey HSD) revealed the following specific differences.

(i) For the regular curve, between trials:-

| | | |
|---|---|---|
| 1 and 2 ($p < .01$) | 1 and 3 ($p < .01$) | 1 and 4 ($p < .01$) |
| 1 and 5 ($p < .01$) | 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) |
| 1 and 8 ($p < .01$) | 1 and 9 ($p < .01$) | 1 and 10 ($p < .01$) |
| 2 and 4 ($p < .01$) | 2 and 5 ($p < .01$) | 2 and 6 ($p < .01$) |
| 2 and 7 ($p < .01$) | 2 and 8 ($p < .01$) | 2 and 9 ($p < .01$) |
| 2 and 10 ($p < .01$) | | |
| 3 and 7 ($p < .05$) | 3 and 8 ($p < .01$) | 3 and 9 ($p < .01$) |

(See Appendix 4, Table 72)

(ii) For the irregular curve, between trials

| | | |
|---|---|---|
| 1 and 6 ($p < .01$) | 1 and 7 ($p < .01$) | 1 and 8 ($p < .01$) |
| 5 and 2 ($p < .01$) | 5 and 3 ($p < .01$) | 5 and 4 ($p < .01$) |
| 5 and 6 ($p < .01$) | 5 and 7 ($p < .01$) | 5 and 8 ($p < .01$) |
| 5 and 9 ($p < .01$) | 5 and 10 ($p < .01$) | |

(See Appendix 4, Table 73)

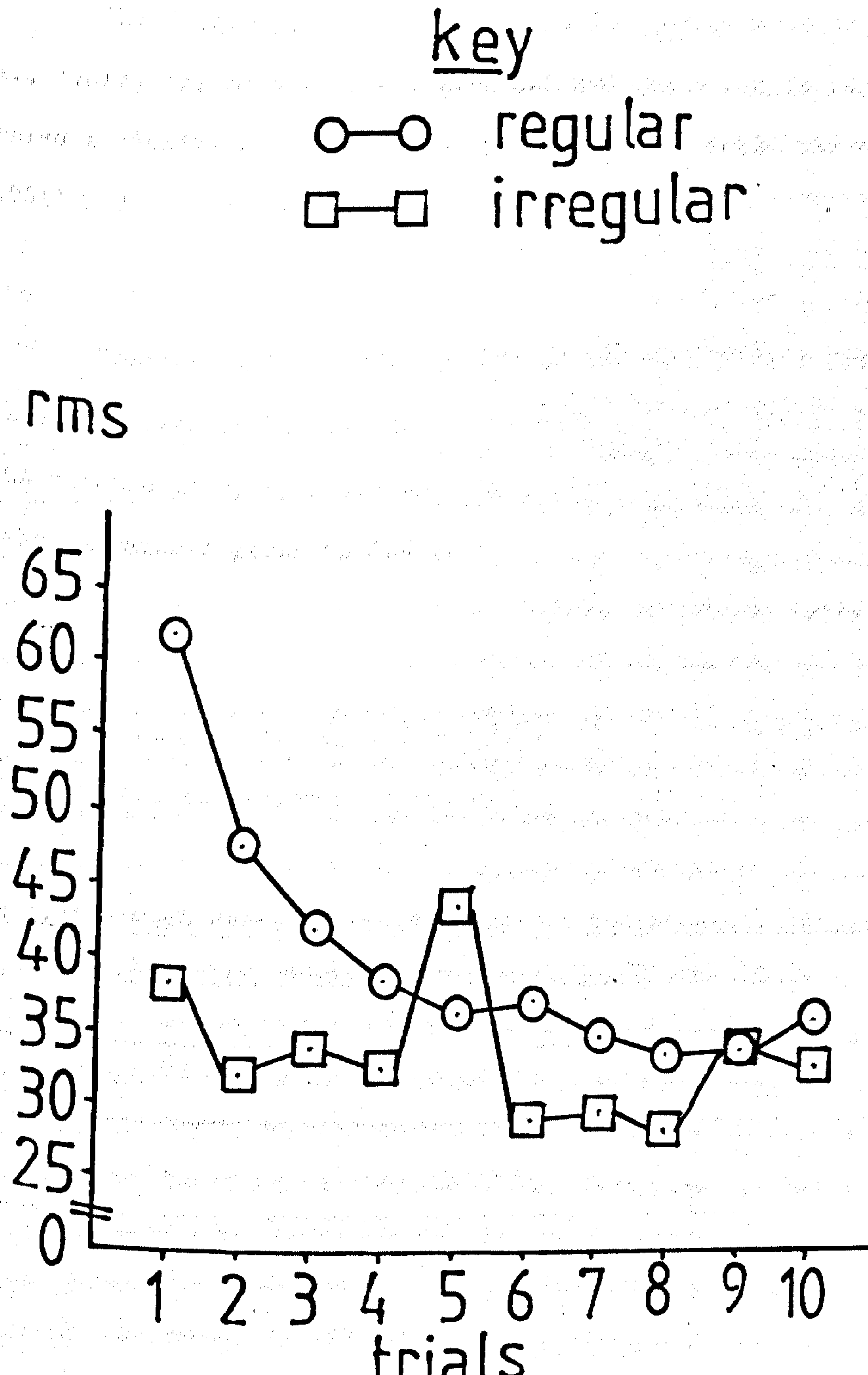
As can be seen from Table 7.30 and Figure 7.30, the trend is for a decrease in error over trials for both types of curve, with the exception of Trial 5 on the irregular curve, where a high error score is apparent.

Table 7.30: Mean error for the two curves over 10 practice trials (5 greatest RMS error scores) memory drum tracking task

| Trial | Regular Curve | Irregular Curve |
|---|---|---|
| 1 | 62.07 | 38.67 |
| 2 | 47.55 | 32.07 |
| 3 | 42.18 | 33.73 |
| 4 | 38.60 | 32.38 |
| 5 | 36.89 | 43.69 |
| 6 | 36.98 | 28.86 |
| 7 | 34.67 | 29.29 |
| 8 | 33.64 | 28.13 |
| 9 | 33.58 | 33.55 |
| 10 | 35.65 | 32.31 |

With regard to the differences between the two curves, significant on trials 1, 2, 3, 5 and 6 only, it can be seen from Table 7.30 that in general the irregular track results in less error, the exception being Trial 5, for which a high error is recorded for the irregular track.

Figure 7.30: Mean error for the 2 curves over the 10 practice trials (5 greatest RMS error scores), memory drum tracking task



(b) Performance on the recall trial

The 3 (group) x 2 (curve) anova for performance on the recall trial, taking the mean of the 5 greatest RMS error scores recorded revealed a significant main effect for group only ($F(2, 84) = 19.46$, $p < .001$) and no interaction.

(See Appendix 4, Table 74)

Posthoc analysis (Tukey HSD) of the main effect for group revealed differences between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$).

(See Appendix 4, Table 75)

As can be seen from Table 7.31, the CA matched group exhibits the least error and the group with learning difficulties, the greatest.

Table 7.31: Mean Error of the 3 groups on the Recall Trial (5 greatest RMS error scores), memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 40.27 | 24.06 | 18.37 |

(c) Performance on the Transfer Trial

The 3 (group) x 2 (curve) anova for performance on the transfer trial, taking the mean of the 5 greatest RMS error scores revealed significant main effects for group ($F(2, 84) = 21.19$, $p < .001$) and curve

($F(1, 84) = 6.55$, $p < .05$), with no interaction between the two.

(See Appendix 4, Table 76)

With regard to the main effect for group, posthoc analysis (Tukey HSD) revealed specific differences between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group (p .01).

(See Appendix 4, Table 77)

As can be seen from the means in Table 7.32, the group with learning difficulties exhibited the greatest error and the CA matched group, the least.

Table 7.32: Mean error for the 3 groups on the Transfer Trial (5 greatest RMS error scores), memory drum tracking task

| CLD | MA | CA |
|---|---|---|
| 42.56 | 26.83 | 18.50 |

Examination of Table 7.33 shows the difference between the error generated by the two curves. Those attempting the regular curve on transfer (having attempted the irregular curve on recall) (I - R) generate greater error than those attempting the irregular track on transfer (having attempted the regular track on recall (R - I).

Table 7.33: Mean error for the two curves on the Transfer Trial 5 greatest RMS error scores), memory drum tracking task

| R - I | I - R |
|---|---|
| 25.38 | 50.09 |

(d) Performance over the Recall and Transfer Trials

The 3 (group) x 2 (curve) x 2 (trials) anova for performance on recall and transfer taking the mean of the 5 greatest RMS error scores revealed a significant main effect for group ($F(2, 84) = 24.10$, $p < .001$), and interactions between trial and curve ($F(1, 84) = 23,82$, $p < .001$) and between group, curve and trial ($F(2, 84) = 5.42$, $p < .01$).

(See Appendix 4, Table 78)

In view of the three way interaction, the main effect and two way interaction were disregarded.

Tests of simple main effects were conducted on the group x curve x trial interaction, and the following simple main effects were found to be significant.

(i) For group, attempting the regular curve, on recall ($F(2, 84) = 11.37$, $p < .01$)

(ii) For group, attempting the irregular curve on recall ($F(2, 84) = 7.74$, $p < .01$)

(iii) For group, attempting the irregular curve on transfer, (having attempted the regular curve on recall) ($F(2, 84) = 5.88$, $p < .01$)

(iv) For group, attempting the regular curve on transfer (having attempted the irregular curve on recall) ($F(2, 84) = 17.63$, $p < .01$)

(v) For trials, for the group with learning difficulties, attempting the regular curve on recall and the irregular curve on transfer, ($F(1, 84 = 9.63$, $p < .01$)

(vi) For trials, for the group with learning difficulties, attempting the irregular curve on recall and the regular curve on transfer ($F(1, 84) = 21.74$, $p < .01$)

(vii) For curves, for the group with learning difficulties on transfer ($F(1, 84) = 9.44$, $p < .01$)

(See Appendix 4, Table 79)

The following interactions were also found to be significant.

(i) Group x trial, for the regular curve on recall, irregular curve on transfer ($F(2, 84) = 57.48$, $p < .01$)

(ii) Group x trial, for the irregular curve on recall, regular curve on transfer ($F(2, 84) = 90.55$, $p < .01$)

(iii) Group x curve on recall ($F(2, 84) = 19.97$, $p < .01$)

(iv) Group x curve on transfer ($F(2, 84) = 27.04$, $p < .01$)

(v) Trial x curve for the group with learning difficulties ($F(1, 84) = 36.33$, $p < .01$)

(vi) Trial x curve for the MA matched group ($F(1, 84) = 4.37$, $p < .05$)

(See Appendix 4, Table 79)

With regard to the differences between groups, significant for both curves on both trials, posthoc analysis (Tukey HSD) revealed the following specific differences.

(i) On recall, for those attempting the regular curve, between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .05$)

(See Appendix 4, Table 80)

(ii) On recall, for those attempting the irregular curve, between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 81)

(iii) On transfer, for those attempting the irregular curve (R-1), between the group with learning difficulties and the CA matched group ($p < .05$)

(See Appendix 4, Table 82)

(iv) On transfer, for those attempting the regular curve (1-R) between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$)

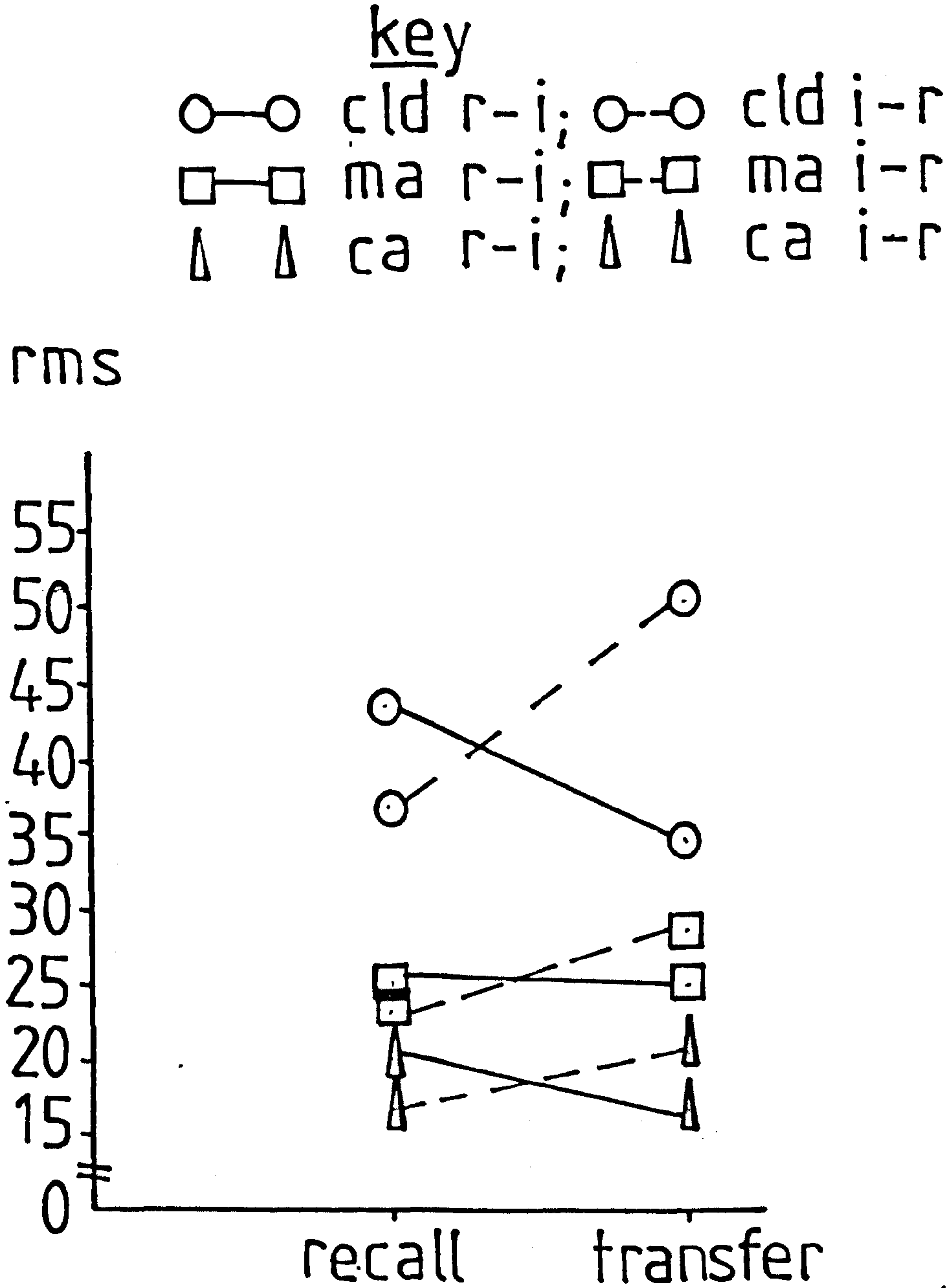
(See Appendix 4, Table 83)

As can be seen from Table 7.34 and in Figure 7.31 the CA matched group consistently exhibits least error, and the group with learning difficulties, the greatest.

Table 7.34: Mean error of the 3 groups and two curves on recall and transfer (5 greatest RMS error scores) memory drum tracking task

| Group/Curve | Recall | Transfer |
|---|---|---|
| CLD R - 1 | 43.67 | 34.52 |
| 1 - R | 36.87 | 50.60 |
| MA R - 1 | 24.80 | 25.00 |
| 1 - R | 23.33 | 28.67 |
| CA R - 1 | 20.07 | 16.60 |
| 1 - R | 16.67 | 20.40 |

Figure 7.31: Mean error for the 3 groups and 2 curves on recall and transfer (5 greatest RMS error scores), memory drum tracking task



With regard to the differences between trials, significant for both subgroups of the group with learning difficulties only, it can be seen from Table 7.24 that there is a marked change in the error over trials, the direction of change being dependent on the order in which the curves were attempted. Also significant was the difference between the two curves on transfer for the group with learning difficulties. Examination of Table 7.34 indicates that the subgroup attempting the regular track on transfer exhibits much greater error.

### (B) Subjective Assessment of the Tracks made by the Children in Relation to the Desired Path

#### Method

The twelve trials of each individual, each on a separate piece of paper, were stuck onto a piece of lining paper approximately 2 ft in width. They were placed in order from 1 to 10, recall and transfer, such that the observer would begin at his left with Trial 1. The beginning of each trial was at the bottom of the lining paper, finishing at the top edge. The ninety sheets of paper, one for the trials of each individual, were then pinned to a board fixed to the wall, in random order, such that the trials of one individual only were visible at any given time. Removal of the sheet then revealed another beneath it, so that all ninety could be examined without reference to another.

Two volunteer markers were responsible for the subjective assiessment, both postgraduate students having completed the MA degree in Physical Education in the Department of Physical Education, University of Leeds.

Considerable discussion took place between the two markers and the researcher regarding the criteria for marking. Areas of concern included

(i) Pen lifting.

(ii) Trials on which no attempt had been made to follow the given track.

(iii) Lags, where the track made was basically quite good, but fell behind the given track.

(iv) Falling short at the peaks.

(v) Overshooting at the peaks,

and the way in which these might offset against each other. Following these discussions, the two testers independently marked several trials generated by the researcher, continuing until the two testers had agreed on 10 consecutive trials. Marks were given out of 10 for each trial, and each trial was marked separately, without reference to the preceding one.

A second method of subjective assessment was also used, independently of that already discussed, in order to assess whether or not learning had taken place. Beginning with Trial 1, and automatically giving that trial a mark of 1, the tester proceeded to examine trial 2. If it was thought to be an improvement on trial 1, however small, the tester gave another mark, making 2. If the two trials were thought to be of an equal standard, the mark remained at 1 for the second trial and if the second trial was thought to be worse than the first, the mark was decreased, in this case to 0. The third trial was then examined in relation to trial 2, and this process continued until the 10 practice trials had all been assessed in this way. Once both testers were clear as to what was to be done, they proceeded to mark the tracks created by the subjects in the experiment. In all cases the marking out of 10 was done first, followed by the "learning" assessment. This was done because it was thought that the reverse order might influence the mark out of 10 given, as recollection of increasing or decreasing the mark might result in a higher or lower mark out of 10 being given accordingly. In both cases, the marks for each individual were recorded on a separate score sheet.

(See Appendix 7)

It will be noted that it is the child's name which appears on the sheet. All children were unknown to both markers, and it was feared that using a subject number might lead the marker to make subjective conclusions about the group to which he belonged, which may in turn influence the marks given.

When the two markers had completed the assessment of one child, the trials sheet was then removed by the researcher, revealing the next to be marked. Following the marking of each set of 15 subjects, the markers and researcher came together again to ensure that both markers were working along the lines agreed. Test trials generated by the researcher, were marked until 10 consecutive trials were given the same mark by both markers. In 2 of the 5 cases, this occurred on the first 10 trials given. The remaining two did not take very many more trials. The subjective assessment took 2 days and at the beginning of the second day, test trials, generated by the researcher were again given, a proportion of which had been used on the first day, in order to ensure that the overnight break did not influence the marking overall. Twenty-four test trials were required before agreement was reached on ten consecutive trials, and this agreed with the previous day's assessment. The two types of assessment were kept separate for future analysis.

(i) Marking out of 10

(a) Correlation of the two markers' assessments

An understanding of the extent to which the two markers agreed on their assessment of each trial was attempted in two ways.

(i) Of the 1080 trials assessed (90 subjects, 12 trials per subject), the marks for 581 were agreed by the testers, for 455 there was one mark difference between the testers and for 44 there was 2 marks difference. In no case was there a difference greater than 2. These figures and the percentages they represent are shown in Table 7.35.

Table 7.35: Agreement between the two markers on marks out of 10, memory drum tracking task

| | Number | % |
|---|---|---|
| Agree | 581 | 53.80 |
| 1 Mark Out | 455 | 42.13 |
| 2 Marks Out | 44 | 4.07 |
| Total | 1080 | 100.00 |

The means of the marks given by the two markers were calculated for future analysis and are as shown in Appendix 4, Table 84. Those trials on which the testers disagreed by two marks are denoted by an asterisk in that table.

(ii) Correlation between the marks given by the two markers, out of 10, using the Spearman Rank Correlation Coefficient.

Using random numbers and placing the 90 subjects in alphabetical order, 15 subjects were randomly identified. Tests of correlation between the two marks given for each trial were then conducted on each subject separately. The results are shown in Table 7.36.

(b) <u>Group analysis of the subjective assessments, marks out of 10</u>

Having obtained a reasonable and acceptable level of agreement between the two marks on the merit of the subjects' attempts, the means of the two markers' assessment was calculated for each trial of each subject (See Appendix 4, Table 84).

The two types of track attempted were then analysed separately, and the performance of the three groups at each of the following stages was analysed, using Kruskal-Wallis one way analysis of variance:

(i) The mean of the 10 practice trials

(ii) The recall trial

(iii) The transfer trial.

Each of these analyses will be considered in turn.

Table 7.36: Correlation between the marks given by the two testers for 15 randomly identified subjects (Spearman Rank Correlation Coefficient) Memory drum tracking task

| Subject No. | rs. |
|---|---|
| 5 | .71 |
| 10 | .88 |
| 26 | .31 |
| 28 | .95 |
| 34 | .68 |
| 35 | .89 |
| 48 | .80 |
| 52 | .77 |
| 53 | .98 |
| 56 | .71 |
| 61 | .54 |
| 65 | .35 |
| 70 | .50 |
| 86 | .37 |
| 90 | .80 |

(See Appendix 4, Tables 85-99)

(i) The mean of the 10 practice trials

The mean of the 10 practice trials was calculated for each subject. (See Appendix 4, Table 100)
It is conceded that this prevents an analysis of the effects of practice on performance, but this will be possible at a later stage using the second method of subjective assessment. Kruskal-Wallis does not allow for the use of two or more dependent measures. The results were then subjected to Kruskal-Wallis anova, each type of track independently.

With regard to the regular track the Kruskal-Wallis anova resulted in H = 28.88 and with df = 2, this indicates a significant difference between the groups ($p < .001$). (See Appendix 4, Table 101)

The sums of the rankings for each group are shown in Table 7.37, and as can be seen, the group with learning difficulties scores lower than the MA matched group which is again inferior to the CA matched group.

Table 7.37: Sum of the rankings for the 3 groups, mean of the practice trials, regular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 190.5 | 532.5 | 312.0 |

With regard to the irregular track, the Kruskal-Wallis anova resulted in H = 25.58, (df = 2, $p < .001$), indicating a significant difference between the groups. (See Appendix 4, Table 102)

The sums of the rankings for the three groups are shown in Table 7.38, and as can be seen, the ordering of the rankings is the same as for the regular track, with the CA matched group scoring highest, and the group with learning difficulties, the lowest overall.

Table 7.38: Sum of the rankings for the 3 groups,mean of the 10 practice trials, irregular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 205 | 521 | 309 |

(ii) The Recall Trial

The mean of the scores given by the two markers on the recall trial was calculated for each individual, (See Appendix 4, Table 84) and then taken as the dependent measure for the Kruskal-Wallis one way anova, taking the regular and irregular tracks separately.

With regard to the analysis for the regular track, the Kruskal-Wallis anova revealed a significant difference between the groups ($df = 2$, $H = 22.99$, $p < .001$). (See Appendix 4, Table 103)

The sums of the rankings are shown in Table 7.39, and as can be seen from the table, the group with learning difficulties overall ranks lowest, and the CA matched group the highest).

Table 7.39: Sum of the rankings for the 3 groups, recall trial, regular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 204 | 497 | 334 |

With regard to the analysis for the irregular track, the Kruskal-Wallis anova revealed a significant difference between groups (df = 2, H = 22.92, $p < .001$). (See Appendix 4, Table 104)

The sums of the rankings are shown in Table 7.40, and as can be seen, the trend is as for the regular track, with the group with learning difficulties ranking lowest overall, and the CA matched group ranking highest.

Table 7.40: Sum of the rankings for the 3 groups, recall trial, irregular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 213.5 | 506.0 | 315.5 |

(iii) The Transfer Trial

The mean of the scores given by the two markers on the transfer trial was calculated for each individual (See Appendix 4, Table 84) and this then taken as the dependent measure for the Kruskal-Wallis one way anova taking the two types of track separately.

With regard to the analysis for those performing the irregular track on transfer (irregular track during practices and recall), the Kurskal-Wallis anova revealed a significant difference between the 3 groups (H = 18.52, df = 2, $p < .001$). (See Appendix 4, Table 105)

The sums of the rankings are shown in Table 7.41, and as can be seen, the group with learning difficulties ranks overall far below either of the two other groups, the CA matched group in particular.

Table 7.41: Sum of the rankings for the 3 groups, transfer trial R-1 Group, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 179.5 | 479.0 | 376.5 |

With regard to the analysis for those attempting the regular track on transfer (irregular track during practice and recall), the Kruskal-Wallis anova revealed a significant difference between groups (H = 26.87, df = 2, $p < .001$) (See Appendix 4, Table 106)

The sums of the rankings are shown in Table 7.42, and as can be seen, the group with learning difficulties again ranks lowest overall and the CA matched group the highest.

Table 7.42: Sum of the rankings for the 3 groups, transfer trial, 1-R group, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 188.5 | 515.5 | 331.0 |

(ii) Marking for improvement over Trials 1- 10

(a) Correlation of the two markers' assessments

An understanding of the extent to which the two markers agreed on their assessment of learning was sought in the same way as for the marking out of 10. The dependent measure used throughout the subsequent analyses is the highest number reached by the individual during the ten trials.

(i) Of the 90 subjects' data assessed, the markers were in agreement in 26 of the cases, disagreed by 1 mark in 48 cases, and disagreed by 2 marks in 16 cases. This is shown in Table 7.43, along with the percentages they represent.

Table 7.43: Agreement between the two markers in terms of the amount of learning, memory drum tracking task

| | Number | % |
|---|---|---|
| Agree | 26 | 28.89 |
| 1 mark out | 48 | 53.33 |
| 2 marks out | 16 | 17.78 |
| Total | 90 | 100 |

The marks reached as judged by the two markers are shown in Appendix 4, Table 107, as is the mean of the two marks given.

(ii) Correlation between the highest marks reached, as judged by the two testers.

The highest mark reached by each subject using the second method of assessment was taken as the dependent measure and Spearman's Rank Correlation Coefficient used to calculate the extent of the correlation between the two marks given. This analysis yielded $r_s = .48$.

(See Appendix 4, Table 108)

(b) Group analyses of the learning assessment

Although the correlation between the two markers is not as high as for the assessment method whereby marks out of 10 are given, it was decided to continue with the group analyses.

The regular track and irregular track were considered separately, and Kurskal-Wallis one way anova used to test for differences between the 3 groups in each case. With regard to the regular track, Kruskal-Wallis anova revealed significant differences between groups ($H = 12.01$, $df = 2$, $p < .01$).

(See Appendix 4, Table 109)

The sums of the rankings are shown in Table 7.44, and as can be seen, the MA matched group overall resulted in the highest rankings, indicating a greater amount of improvement over trials, and the group with learning difficulties resulted in the lowest sum of rankings, indicating the least improvement.

Table 7.44: Sum of the rankings for the 3 groups, highest mark of the practice trials, regular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 307.5 | 358 | 389.5 |

With regard to the irregular track, the Kruskal-Wallis anova revealed significant differences between groups ($H = 10.87$, $df = 2$, $p < .01$).

(See Appendix 4, Table 110)

The sums of the rankings are shown in Table 7.45 and as can be seen, the pattern is similar to that for the regular track, with the MA matched group recording the highest overall rankings and the group with learning difficulties the least, although in this case, only marginally less than the CA matched group.

Table 7.45: Sum of the rankings for the 3 groups, highest mark of the practice trials, irregular track, memory drum tracking task

| CLD | CA | MA |
|---|---|---|
| 293.5 | 299 | 442.5 |

(C) Correlation between the subjective assessment (Marks out of 10) and the digitised data (RMS)

In an attempt to gain some insight into the question of whether the two methods of assessment of the accuracy of the subjects' attempts yield the same kind of results, a correlation between the two methods was conducted. The measure taken for the subjective assessment was the mean mark out of 10 of the 12 trials of each subject, for the mean of the two marks given. The measure taken for the digitised data was the mean RMS for the 12 trials of each subject. The regular and irregular tracks were considered separately, in the event that differences might emerge in the correlation for the two.

With regard to the regular track the Spearman Rank Correlation Coefficient that resulted was $r_s = .64$.

(See Appendix 4, Table 111)

In the case of the irregular track, the resultant Spearman $r_s = .72$

(See Appendix 4, Table 112)

(iv) Discussion

The discussion will take the same format as the results, with each analysis taken in turn. However, since examination of the MM and RMS analyses of the total trial indicate similar results, these two will be considered together.

(i) Percentage pen on paper

(a) Practice Trials

In terms of the ability of the children to keep the pen in contact with the paper throughout the trial, the CA matched group appears to be able to do this more or less from the beginning, and for this reason records no improvement over the trials. The two low MA groups, however, appear to find this more difficult, particularly on the first trial. It is almost as if the beginning of the trial took them by surprise, their immediate reaction being one of withdrawal. Subjectively, the tester observed this to be the case, despite the fact that the children had already seen the drum rotate a short distance during the time when the instructions were given. Examination of the means in Table 7.13 would suggest that the group with learning difficulties overcame the problem of pen lifting at a slightly slower rate than the MA matched group, although not significantly so.

The answer to the question of whether the children were deliberately employing the tactic of pen lifting in order to gain an improved position in relation to the track would appear to be in the negative. Analyses of the error as calculated by MM or RMS reveals the group with learning difficulties inferior to the CA matched group, and for the regular track inferior to the MA matched group, although these analyses will be considered in greater detail later, yet the group with learning difficulties also records lower percentage pen on paper. If pen lifting were being used as a deliberate tactic, one would expect the reverse trend, with less error for those exhibiting greater pen lifting. The percentage of pen off paper for the CA matched group, the group recording least error, is in general so small, less than 1% for 8 of the 10 practice trials, that it is difficult to envisage how pen lifting could have been of assistance. Furthermore, the subjective observation of the researcher indicates that the children did attempt to keep the pen on the paper, often apologising when they did not do so. Admittedly, when they returned the pen to the paper, they in general attempted to get as close to the desired track as possible, although they generally did this as quickly as possible, since they had been told that they would not 'score' unless the pen was leaving a mark on the paper.

Differences between the results for the two types of track also emerged, although in both cases improvement over the trials was evident. Figure 7.21 shows slightly different performance curves for the two types of track, the regular track initially results in greater pen lifting, but by trial 3, has virtually reached maximum, whereas the irregular track results in less pen lifting, but by trial 3, has virtually reached maximum, whereas the irregular track results in less pen lifting on trial 1, but it is only by trial 5 that the results approximate those of the regular track. No differences are apparent by the end of the practice session, indeed, it is only on the first 2 trials that the difference is significant, such that they enter the recall phase on a par in terms of percentage pen on paper.

(b) Performance on the Recall Trials

Just as the 3 groups and 2 types of track recorded a more or less equal percentage pen on paper by the end of the practice phase, similarly, on recall, no significant differences emerge. The surprise effect of the first trial experienced by the two low MA groups has disappeared; both groups would appear to be able to recall the task sufficiently to prevent this occurrence at this stage.

### (c) Performance on the Transfer Trial

The only significant effect to emerge at this stage is the inferiority of the group with learning difficulties to the remaining groups, both of whom achieve 100% pen on paper. Possibly the group with learning difficulties is in general less able to view the task as related to the previous one, resulting in another 'surprise' effect. This is possibly true of one or two individuals in the group whose results would then adversely affect the mean. However, the percentage pen on paper of 99.13% is considerably greater than that achieved early in practice; some transfer of orientation to the task must therefore have taken place, at least. The absence of any effect for type of track would suggest that the increased time pressure exerted by the regular track is not significant in terms of percentage pen on paper at this stage.

### (d) Performance over the Recall and Transfer Trials

The group x trial interaction which found a simple effect for the MA matched group is the only salient feature here. The CA matched group had virtually reached 100% pen on paper by recall, and therefore could not improve and the group with learning difficulties fails to reach 100% at all, with a slight decrease in percentage of pen on paper. Subjective observation would tend to suggest that the failure by the group with learning difficulties to achieve maximum time pen on paper is largely the result of one or two individuals within the group who did not appear to master the task at all.

### (e) General Discussion

Taken in conjunction with the MM and RMS analyses, these results would seem to suggest that the children did not employ pen lifting as a tactic to gain advantage. Furthermore, pen lifting would only appear to be a significant problem in the early stages of practice, before the task demands are fully clarified by the individual. The fact that this is a longer process for the group with learning difficulties might be expected. Once this is mastered, however, very little pen lifting occurs.

## (ii) Root mean squared (RMS) error and modulus mean (MM) error analyses

### (a) Performance over the 10 Practice Trials

Both the MM and RMS analyses suggest that learning is taking place over the 10 practice trials, although the nature of the improvement would appear to vary according to the type of track, regular or irregular, being presented, as indicated by the two trial x curve interactions. Both analyses suggest that the greatest reduction in error occurs between trials 1 and 2, for both types of track, resulting in negatively accelerated performance curves over the 10 trials.

(See Figure 7.24 and 7.27)

In the case of the irregular track, very little improvement occurs subsequent to this, although for the regular track, improvement continues through to approximately trial 5. The absence of any group x trial interaction suggests that this improvement is consistent for all groups of subjects.

With regard to the relative error generated by tracking the two types of track, the interaction and subsequent posthoc analyses suggest that, on the majority of trials, attempting the regular track results in the greatest error. This may be expected since the regular track exerts the greater time pressure, with a longer line to track in the same time period. However, the curve x group interaction suggests that this is not the case for all groups. For the CA matched group, there is apparently no difference between the two tracks, whereas for the two low MA groups, the regular track results in significantly higher error (RMS). Although it can be argued that the regular track exerts a greater time constraint, the track is also predictable, unlike the irregular track. The CA matched group would appear to be able to overcome the greater time constraint by taking advantage of the fact that it is possible to anticipate accurately the precise position of the track ahead, and therefore follow it more closely. The group with learning difficulties and the MA matched group do not apparently do this; they would appear to be taking each part of the line as novel, requiring time to process that information and respond to it resulting in a lag and therefore less accuracy. This could also account, at least in part, for the fact that although not always significantly so, the mean error of the group with learning difficulties is generally greater than that of the MA matched group; if both groups are failing to anticipate and are processing each piece of information as it comes, one might expect the group with learning difficulties to be slightly slower, since the operations involved are cognitive in nature, an area in which one might expect children with learning difficulties to fall behind.

Certainly, the group with learning difficulties performs consistently at a level lower than that of their CA matched peers, regardless of the type of track presented. On the regular track, they also fall behind the MA matched group, suggesting more strongly the problems they experience when time pressures are increased.

(b) Performance on the Recall Trial

For both the MM and RMS analyses, the sole effect is for group. In both cases, the group with learning difficulties performs at a level significantly lower than that of the CA or MA matched groups. Although during practice at the irregular track, they were not significantly inferior to the MA matched group, at the recall stage, their performance appears to have deteriorated, relatively speaking. Both analyses, the RMS in particular, reflect this trend. Comparison of the mean error for trial 10 and the recall trial suggests that the difference between groups is largely caused by the high error on the part of the group with learning difficulties. A reminiscence effect would appear to be present in all cases, except the group with learning difficulties. This is shown in Table 7.46, where the reminiscence effect is particularly evident for the MA matched group attempting the regular track.

It is interesting that the difference between the results for the two types of track has virtually disappeared at the recall stage, indicating that the children would appear able to cope equally well with both types of track. This is not quite so true of the group with learning difficulties, for whom a relatively large difference still exists.

Table 7.46: Mean error for practice trial 10 and the recall trial (RMS) memory drum tracking task

| Group/Track | | Trial 10 | Recall |
|---|---|---|---|
| CLD | R | 24.53 | 19.67 |
| | 1 | 15.67 | 15.98 |
| CA | R | 8.33 | 8.00 |
| | 1 | 8.87 | 6.27 |
| MA | R | 16.13 | 9.87 |
| | 1 | 10.67 | 9.60 |

(c) Performance on the Transfer Trial

Both MM and RMS analyses revealed significant effects for group and type of track. With regard to the difference between groups, the group with learning difficulties performs at a level significantly lower than either of the other two groups, in both cases. It would appear that they are less able to make the cognitive transformations necessary, since comparison of Tables 7.19, 7.20, 7.25 and 7.26 demonstrate that their mean error remains at the same level as for the recall trial, as does that of the MA and CA matched groups. However, they had not achieved the level achieved by the MA and CA matched groups during practice and recall, and this difference remains. Since they are performing at a level equivalent with recall and not with practice trial 1, it would appear that they are able to utilise previous practice and experience of the related task to assist in their performance at this transfer task.

With regard to the main effect for the type of track, it is again those attempting the regular track that generate the greater error, although as can be seen from Table 7.47, this is true to a much greater extent for the group with learning difficulties than the two matched groups.

Table 7.47: Error for the 3 groups and two types of track on transfer (MM) memory drum tracking task

| | R - 1 | 1 - R |
|---|---|---|
| CLD | 10.40 | 17.00 |
| MA | 7.40 | 9.07 |
| CA | 4.93 | 6.13 |
| $\bar{X}$ | 7.58 | 10.73 |

For the group with learning difficulties, the regular track would appear to present a more difficult task, presumably because of the greater temporal requirements.

(d) Performance over the Recall and Transfer Trials

For both analyses, three way interactions between group, track and trials were apparent. Differences between groups were evident at both stages, as already discussed. Differences between the error generated by the tracks on transfer is also evidenced as significant, for the group with learning difficulties in particular.

Of greater interest here, however, is the difference in the error generated on the two trials. It must be borne in mind that the nature of the type of track changes between recall and transfer, and it is the resultant change in error that is of interest. The change is in fact significant for the group with learning difficulties, although the direction of change over trials is consistent for all groups, larger error in the case of the regular track on transfer and less error in the case of the irregular track, which can be seen from Tables 7.22 and 7.28. The amount of change is minimal for the two matched groups.

The fact that the group with learning difficulties records significantly greater error for the regular track on transfer and less for the irregular track would appear to indicate their inability to predict events and act accordingly. Both subgroups are attempting a novel version of the task, so this alone cannot be the cause of the differential change. However, if the children are processing each part of the track as it appears and then acting on that information, one might expect greater error for the regular track, since it imposes greater time pressure, resulting in less time available.

However, it must again be noted that the group with learning difficulties is in some way utilising previous experience since the error generated is overall equal to that of recall rather than practice trial 1, in both cases, regular and irregular track. This is perhaps true to a greater extent of the irregular track on transfer, and it may be in some way connected with the ordering of the tasks, as much as any other factor.

(iii) Mean of the 5 greatest RMS error scores per trial

Interpretation of these results is necessary both independently and in the light of the analyses of the RMS error for the total trial.

(a) Performance over 10 Practice Trials

The analysis of variance revealed significant improvement for all groups over the 10 trials, the majority of the error reduction occuring between trials 1 and 2, particularly in the case of the two chronologically older groups. In the case of the MA matched group, significant improvement continues over the first three trials. This improvement is also demonstrated by the RMS error analysis for the total trial, although there is in that case, no trial x group interaction. Figure 7.31 demonstrates the similarity in improvement shown by the two analyses, although at different absolute levels.

With regard to the differences that exist between groups at this stage, the present analyses demonstrate the inferiority of the group with learning difficulties to the CA matched group on almost all trials, the difference between the group with learning difficulties and the MA matched group, and the CA and MA matched groups being nonsignificant. It is important to note, however, that on all trials the ordering of the means is such that the group with learning difficulties consistently demonstrates the greatest error and the CA matched group, the least. This is similarly the case for the total trial analysis as can be seen from Figure 7.32.

When the nature of the improvement for the 3 groups and 2 types of analysis are considered, certain features become apparent, although

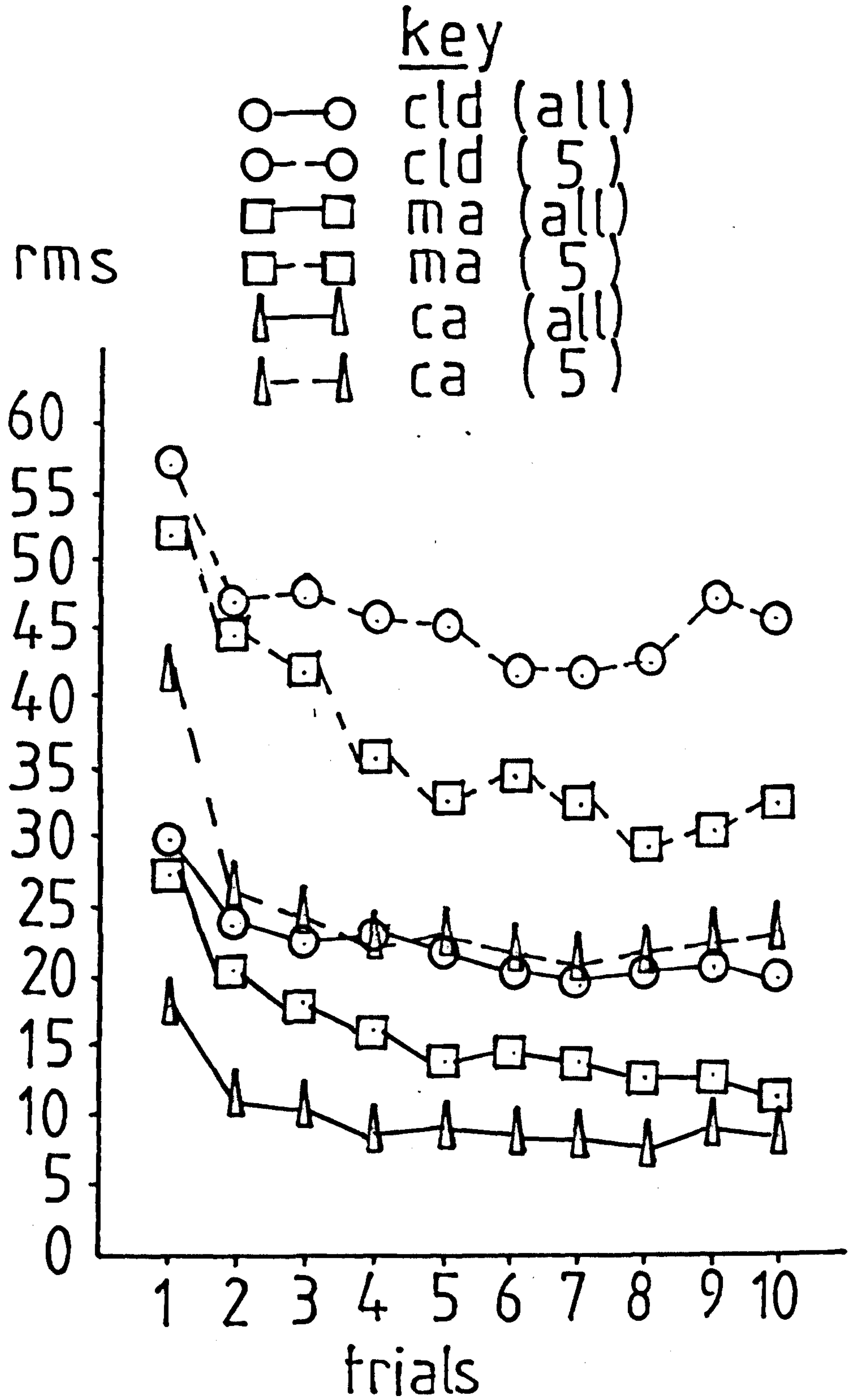



Figure 7.32: RMS (total) and RMS (5 greatest) error for the 3 groups over 10 practice trials, memory drum tracking task

these are largely subjective observations of the data. The improvement between trials 1 and 2 for the two analyses takes a slightly different form for the groups. In the case of the CA matched group, the improvement when only the 5 greatest error scores are considered is greater than when the total trial is considered, which would appear to suggest that the improvement is the result of improving the consistency over the trial, ironing out the large errors, although this probably results in a slightly less accurate reproduction over the rest of the track. In the case of the two remaining groups, both analyses result in similar types of improvement, indicating a reduction of the high error scores concurrent with improvement over the rest of the track. There is probably greater room for improvement over the rest of the track for these groups, since they are performing at a lower absolute level. In the case of the MA matched group analysis for the 5 greatest RMS error scores, improvement continues at a greater rate than when the total trial is considered, indicating that perhaps what is happening in this instance is the same as happened for the CA matched group over trials 1 and 2, that improvement is being generated by reduction of the greatest error "ironing out" of the track, possibly at the expense of slightly less accuracy over the rest of the track. However, for the group with learning difficulties, the picture is somewhat different in that the shape of the performance curve for the total trial after trial 2, is steeper than when the 5 greatest error scores only are considered. This would appear to indicate that the high error remains possibly in the form that it is only the "big mistake" in the trial, but that whilst overall accuracy is being improved, there still exists this lack of consistency within the trial itself. It may be that this is a problem for the group with learning difficulties caused by a short attention span, although it must be recalled that each trial lasts only 10 seconds. It could also be partly due to a slow reaction time, particularly if the information is not being anticipated, the change of direction resulting in greater error.

The track x trial interaction found significant for the analysis of the 5 greatest RMS error scores suggests improvement over trials by those attempting both types of track, although to a greater extent for those attempting the regular track largely because of the high initial error. The difference between the error for the two types of track is much more clear cut in the case of the total trial analysis, with no overlap between the two tracks and significant differences on 7 of the 10 trials. For the 5 greatest RMS error scores, significant differences exist on 5 trials only, with one of these being in the opposite direction (See Figure 7.29), and by trial 9 and 10 virtually no difference exists. Improvement for the regular track is relatively steep and would indicate early ironing out of errors, more so than in the case of the irregular track.

(b) Performance on the Recall Trial

The analysis of the 5 greatest RMS error scores on recall revealed the group with learning difficulties inferior to the two matched groups, a trend expected by the analysis of the total trial. Although the absolute level of the error is greater for the 5 RMS error scores, the relative increase of the 3 groups is of the same order, and furthermore, the levels of the significant effect for group are similar with an F statistic of 18.35 for the total trial analysis and 19.46 for the 5 point analysis. Both analyses suggest that at this stage the group with learning difficulties falls behind the MA matched group in terms of accuracy. Possibly the recall powers of children with learning difficulties are less than for children within the range of normal intelligence. The test period of 5 days is perhaps too long for such children.

(c) Performance on the Transfer Trial

The results for the 5 point analysis reflect consistently the trends found for the total trial analysis. Main effects for group and track were found, with the group with learning difficulties inferior to the two matched groups, and the regular track resulting in greater error than the irregular track. The levels of significance are also similar, F = 19.72 for the total trial and F = 21.19 for the 5 point analysis main effect for group; F = 7.17 and 6.55 respectively for the main effect for type of curve and furthermore, as for the recall trial, the relative increase in error is of the same order.

(See Tables 7.26 and 7.32)

The results, therefore, can be interpreted in the same light.

(d) Performance over the Recall and Transfer Trials

The analysis of the 5 greatest RMS error scores revealed identical main effects and interactions to the analysis of the total trial and can be interpreted in the same light. Furthermore, the levels of F, as shown in Table 7.48, are very similar.

Table 7.48: F Statistic for effects significant over Recall and Transfer total trial and 5 point analysis (RMS error) memory drum tracking task

| Source | Total Trial | 5 points |
|---|---|---|
| Group | 22.89 | 24.10 |
| Trial x Track | 21.57 | 23.82 |
| Trial x group x track | 5.96 | 5.42 |

The posthoc analyses also revealed similar differences, and examination of tables 7.28 and 7.34 demonstrates similarities in the order and relative magnitude of the changes in error.

(e) General Discussion: 5 point Analysis

Overall the analyses for the total trials and the 5 greatest error scores reveal similar trends. However, the 5 point analysis can be said to give some insight into the way in which the improvement over practice trials is brought about, and the way in which this might differ between groups. Further analysis would be necessary if one were to consider the way in which this might differ between individuals. It might also be valuable to consider, in future research, taking only a limited number of error points per trial, as it may be more economical in terms of the researcher's time and yet provide as complete a picture as total trial analysis.

(iv) <u>Subjective Assessment -Correlation between the two markers' marks out of 10</u>

In order to ensure as far as possible that the two markers were assessing each trial according to the same criteria, considerable time was taken in discussion and test beforehand. The fact that only 4.07% of marks given disagreed by 2 marks, on a point scale, is a reasonable assurance that this was the case, and a justification of the time spent beforehand. In the instance of correlation of marks for 15 randomly identified subjects, the majority resulted in at least moderately strong correlations. Even in the case of subject number 26, for whom $r_s = .31$,

(See Appendix 4, Table 87)

the lowest correlation, the markers agreed on 5 trials, disagreed by 1 mark on 6 trials, and only on 1 trial did they disagree by 2 marks. The use of the Spearman Rank Correlation Coefficient possibly has limitations in its use here, since it fails to give an understanding of the extent to which marks given agree, only of their rank order. A disagreement of marks at the top end of the scale, can result in disagreement in ranking lower down, even though the actual marks given at this stage agree.

The statement that over 53% of marks given agree, and over 42% disagree by 1 mark only is perhaps of greatest interest here. When dealing with subjective assessment in this way, with no absolutely fixed criteria by which to mark, it is extremely difficult to maintain a degree of objectivity and consistency, particularly when marking over 1000 trials. The methodology of criteria agreement, testing and checking is extremely important and a satisfactory, if not ideal, level would appear to have been achieved here.

(v) Subjective Assessment - Group Analysis, marks out of 10

One of the problems with the use of ordinal data is that no possible analysis allows for the factorial analysis of variance. For this reason, in this instance, separate analysis of the two types of track are undertaken. Furthermore, the Kruskal-Wallis anova, although giving an indication of the existence or otherwise of differences between the groups tested, does not allow for any formal posthoc analysis to determine the precise location of any differences, such as is possible with interval data using tests such as Tukey HSD. One is, therefore, left with inferences from observations of the ranking. One point of value, however, is that using the rank order enables the observer at a glance to see the relative position of individuals within the total sample, thus identifying individuals who may not be considered characteristic of the group to which they belong.

(a) Performance on the Practice Trials

For both types of track significant differences between groups emerge and observations of the sums of the rankings

(See Tables 7.37 and 7.38)

suggests that there may well be differences between all 3 groups, with the group with learning difficulties performing at a lower level than the MA matched group, which in turn performs at a lower level than the group matched on chronological age.

With regard to individual analyses, examination of Table A4.101 suggests that, for individuals, at least one child with learning difficulties, ranked 35, would be indistinguishable from his CA matched peers and several more are ranked at a level higher than many of the subjects in the MA matched group. For those attempting the irregular track, the picture is very similar, but with possibly three subjects with learning difficulties being indistinguishable from their CA matched peers. Similarly, there are also subjects within the MA matched group, who are ranked at a level within the range of the CA matched group.

However, in general, it would appear that as a group, the children with learning difficulties perform at a level lower than that of both their CA and MA matched peers, and the MA matched group below that of the CA matched group. Care should be taken in the generalisation of these inferences, however.

(b) Performance on the Recall Trial

Again, as for the practice trials, the group with learning difficulties appears to rank behind their MA matched peers, who in turn rank behind the CA matched group. With regard to the individual data, there would again appear to be at least one subject with learning difficulties, on the irregular track, who would be indistinguishable from his CA matched peers, and again some subjects who fare better than some of the MA matched subjects. Similarly, for the MA matched group, at least five subjects attempting the regular track and 3 subjects attempting the irregular track rank at a level well within the range of the CA matched group.

(c) Performance on the Transfer Trial

Once again, significant differences emerge between the groups, the group with learning difficulties performing at a relatively low level by comparison with both matched group, and the MA matched group ranking behind the CA matched group. Examinations of Tables 7.37, 7.38, 7.39 and 7.40 suggest that, relatively speaking, the group with learning difficulties is relatively less able to cope with transfer to the novel version of the task, than the other groups, since the sum of the rankings is less on transfer than on recall. The MA matched group, however, records an increase in the sum of rankings, resulting in a greater difference between the two groups.

With regard to individual data, at least two subjects attempting the irregular track and 2 subjects attempting the regular track from within the group with learning difficulties would appear indistinguishable from their CA matched peers, with other subjects ranking above some of the MA matched subjects.

(d) General Discussion

Overall, it would appear from the subjective analyses that the children with learning difficulties, as a group, perform consistently at a level below that of either their CA or MA matched peers. However, it must be noted that there are some subjects within that group who rank well within the range of the CA matched group, for whom the generalised statement would be untrue. The level of the data prevents any further insight into the nature of the differences, between the groups, although the inferiority of the group with learning difficulties has been considered in greater detail for the analyses of the interval data, and the results can be interpreted in the same light.

(vi) Subjective Assessment - Improvement Marking - Correlation between the Two Markers

The level of agreement about the existence of improvement over trials is not as high as for the previous subjective assessment. This may be expected, in that every mark given is dependent on comparison with the previous trial and disagreement about the existence of improvement on trial 2 for example, would affect the final mark reached, thus influencing 1/90 of the marks. In the previous assessment, each trial was marked independently and thus disagreement on a given trial would affect that trial only 1/1080 of the marks given. A second possible reason for less concurrence on the question of marks attained could be that the criteria were less well defined. The markers were instructed to increase the mark if there was any evidence of improvement, however small. In cases where subjects improved their proximity to the track down the sides of the peaks, at the expense of falling shorter at the peaks, it was a subjective assessment as to whether these two factors cancelled each other out, or one outweighed the other. It was this kind of decision which appeared to be the most difficult to make, as both markers remarked.

However, the fact that 28.89% of the subjects were agreed, and 53.33% were within one mark, despite the low correlation of .48, was taken as indicative of a reasonable degree of concurrence, and it was considered that group analysis would be valid.

## (vii) Subjective Assessment - Group Analysis - Improvement Marking

Firstly, it is necessary to point out that all subjects evidenced some improvement over trials, since all subjects recorded a mean of at least 2.5. As this is the mean and the two markers did not disagree by more than 2 marks on any occasion, all children must have been judged by both testers to have shown some improvement.

It was necessary again to use the Kruskal-Wallis anova, since the data is ordinal, with the result that the types of track were taken independently.

Both analyses revealed significant differences between groups, although examination of the rankings in Tables 7.44 and 7.45 suggests a slightly different pattern for the two types of track. In both cases, the MA matched group appears to continue improvement over trials. The group with learning difficulties and the CA matched group both lag behind, reaching lower marks, although possibly for differing reasons. A low 'high score' is a result of very little improvement, trial on trial. However good or bad an attempt trial 1 may be, it is automatically accorded 1 mark, and however marginal or great the increase in accuracy in trial 2, it is given a mark of 2. It may be that trial 2 is a great improvement on trial 1, such that very little improvement is possible thereafter, or it may be that there is considerable room for improvement, even after trial 2, which may or may not take place.

On the basis of the observations, both subjective and digitised, it could be argued that in the case of the group with learning difficulties, the low ranking is because of an inability to maintain improvement over trials, despite the fact that there is great room for improvement in most cases. In the case of the CA matched group, it is arguable that the low 'high score' is because following significant improvement, on, for example Trial 1 and 2, subsequent improvement is not as easy, since they have already achieved a high degree of accuracy. In the case of the MA matched group, it could be argued that they may begin at a level equal to that of the group with learning difficulties, but are able, unlike this group, to continue improvement until they reach the standard of the CA matched group, or at least approximate it. The actual "amount" of improvement is in no way quantified, and may or may not be equal in all cases.

However, one feature is evident; that improvement takes place on the part of all children. When this is also considered with the analyses for marks out of 10, it suggests that the group with learning difficulties is performing at a lower absolute level than either the CA or MA matched group, but making improvement.

(viii) Correlations between Subjective and Digitised Data

Correlations of .64 and .72 were found for the regular and irregular tracks respectively between subjective and objective assessment. Both of these can be considered to be moderately strong positive relationships accounting for 40.96% and 51.84% of the variance respectively. Restricting the range of one of the variables, as in the case here for the subjective marks out of 10 can reduce the level of correlation, a fact which should be borne in mind when interpreting the results.

The fact that the analyses for the regular and irregular tracks result in rather different levels of correlation is interesting. In the case of the RMS error, it is quite clear what is being measured - the deviation from the desired track, along the Y axis, as is shown in the diagram (Figure 7.33). However, a measure of error taken at points 1 and 2 on the curve will result in different RMS error scores although in fact the produced track is the same distance away from the desired track on both points if the measures taken were the shortest distance away from the point on the produced track to the desired track. The steeper the incline of the desired track the greater the relative difference there will be between the RMS error recorded at the two points, as can be seen in Figure 7.34, although at all times the shortest distance between the two lines remains equal.

Examination of the 12 tracks to be followed

(See Appendix 5)

shows that by the very nature of the tracks the inclines towards the majority of the peaks in the irregular are less steep than for the regular track. This perhaps explains in some way why the correlation between subjective and digitised assessment is greater for the irregular than the regular track (although the mean of eacy type of curve analysed contains one of the other type). It is postulated that in subjective assessment, the marker examines proximity to the track more in terms of shortest distance from the produced to the desired track rather than in terms of an RMS or MM error score. As the difference between RMS or MM error and shortest distance decreases with the gentler incline, one might expect greater correlation between subjective assessment and RMS error on the irregular track. This argument could furthermore, be used to explain partly the differences in error for the two types of track found during the MM and RMS analyses.

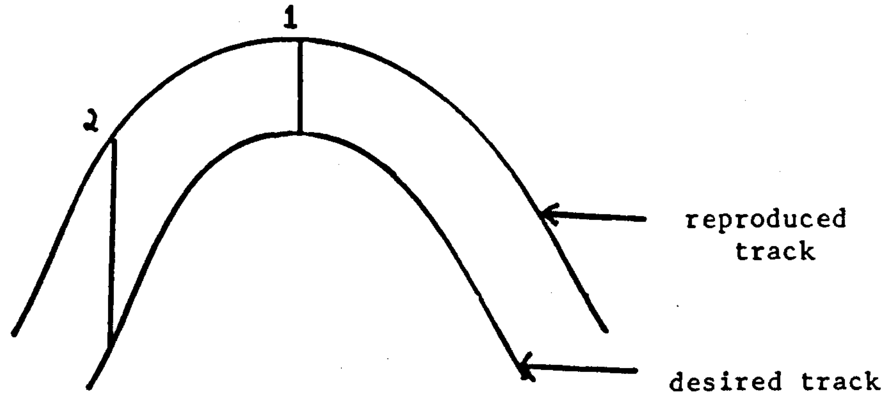



Figure 7.33: RMS analyses (i)

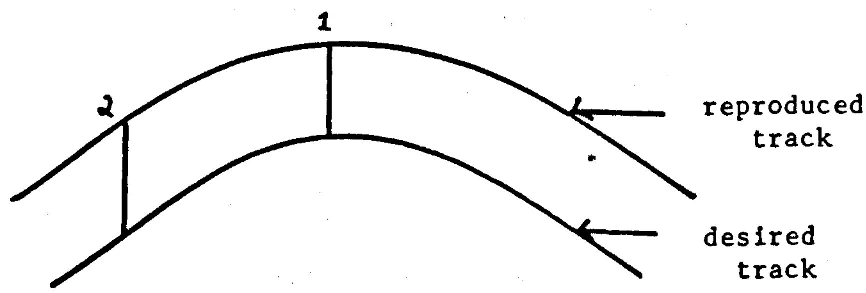



Figure 7.34: RMS analyses (ii)

It is possible that what is required for the objective digitising of data is some kind of weighting system whereby the differences between the RMS error at various points along the track are cancelled out. Suggestions have been made (e.g. Hammerton 1982) that it would be advisable to digitize data along the x axis as well as the y axis, but this is not really viable, since there may well be certain places where there is no track to assess,

(See Figure 7.35)

or no desired track along which to assess error.

(See Figure 7.36).

Henderson, Morris & Firth (1981) undertake subjective assessment of the spatial component involved in tracking by Down's syndrome children and matched retarded children, achieving inter-rater reliability of .90 to .96. They also measured the temporal component, using the CE and VE measures at the peaks, as well as noting pen lifting at the peaks and over the entire track. It would be interesting to examine the extent to which these measures reflect the measures used in the present research.

The point made, however, is that althoughthe RMS error is the generally accepted method of analysis, there are flaws in its use. Furthermore, it could be argued that subjective assessment in fact gives as good as, if not better indication of a 'good', 'bad' etc. attempt, although it must be acknowledged that the level of the information obtained prevents the detailed analysis possible with the digitized data.

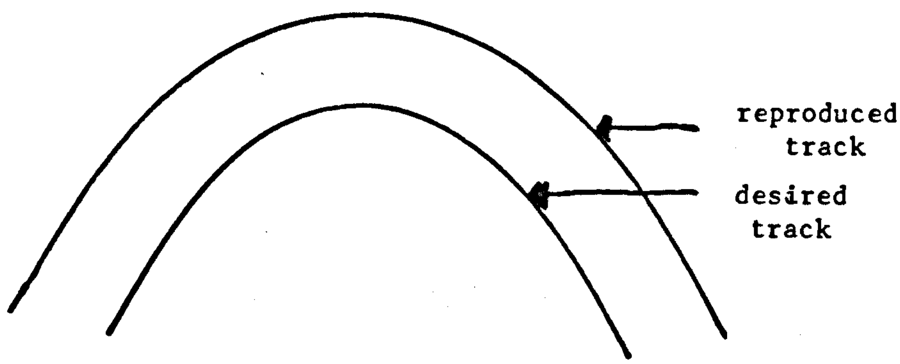



Figure 7.35: RMS analyses along the x axis (i)

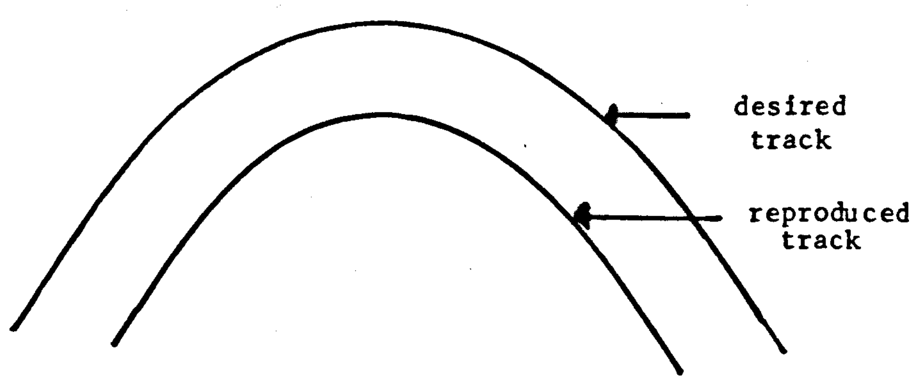



Figure 7.36: RMS analyses along the x axis (ii)

## (x) General Discussion and Conclusions

Taking the memory drum tracking task alone, one would infer that it is a task at which all 3 groups of children are able to improve, although the absolute level at which they perform differs. The group with learning difficulties would appear to be inferior certainly to their CA matched peers, as a group, and relative to their MA matched peers, at a level equal to or below them according to the phase of analysis. At no time does the group with learning difficulties exhibit a level of accuracy greater than the MA matched group.

Individual observations, however, would suggest that there may well be some subjects from the group with learning difficulties who are able to perform at a level such that they would be indistinguishable from their CA matched peers. With regard to the task itself, the differences that exist between the results for the two types of track are interesting. On the regular track, where the time pressures are greater, in general, the error tends to be greater. The CA matched group alone appears to be able to utilise the predictability and the anticipation it affords, to maintain their level of accuracy to equal that of the irregular track which is in essence unpredictable. Furthermore, it is on the regular track that the significant differences between the group with learning difficulties and the MA matched group emerge, suggesting further that the problems faced by the children with learning difficulties are fundamentally based in the temporal demands imposed on the individual by the task or environment.

The task used here has distinct advantages over the use of the pursuit rotor, since it allows for more detailed analysis of performance and error. However, in the analysis of the error, care should be taken in the selection of the method and criteria of measurement and assessment. Automatic accpetance of the RMS error as the index of error would appear to have certain drawbacks.

In general, however, on a task of this kind with total body stationary, body parts moving and environment moving, it can be tentatively stated that children with learning difficulties as a group perform at a level significantly below that of their CA matched peers, and on occasions significantly below their MA matched peers. However, caution should be taken in the generalisation of this statement to all children with learning difficulties, since there would appear to be certain individuals within the population of whom this is untrue.

## V PURSUIT ROTOR AND MEMORY DRUM TRACKING - GENERAL CONCLUSIONS

Both tasks were considered to fall within the classification postulated, into the category of environment moving, total body stationary, body parts moving. They provide a direct contrast to the two previous tasks, both of which allowed the individual to begin his attempt in his own time and move at his own speed, in that the environment, the apparatus and researcher imposed the beginning and end of each trial, for both tasks. In other respects, total and part body movement, all four tasks were consistent. The change in the pattern of difference should, therefore, be attributable to the change in environmental demands.

With regard to the differences between the groups, the main feature, common to both tasks, is the inferiority of the group with learning difficulties to the CA matched group and on occasions to the MA matched group. Logically, this would appear to be because of the temporal demands being made with which children from within the range of normal intelligence would appear more able to cope. Individual analysis, however, would suggest caution in the interpretation of these results, since there would appear to be individuals within the group with learning difficulties for whom this general statement is not true. This fact, together with the point made regarding the use of RMS error and MM error, would suggest that group analyses and use of generally accepted measures should not be undertaken without careful consideration of their meaning.

Since there appears, however, to be some changes in the differences between the groups when temporal demands are made by the environment, it remains to analyse any change in this pattern when greater body involvement is also required in a task which also makes temporal demands.

# CHAPTER EIGHT

# AN INVESTIGATION INTO THE LEARNING OF A COINCIDENCE TIMING TASK BY CHILDREN WITH LEARNING DIFFICULTIES AND CHILDREN MATCHED WITH THEM ON CHRONOLOGICAL AGE AND MENTAL AGE

# I INTRODUCTION

Coincidence timing and coincidence anticipation are terms used interchangeably by researchers to describe that which is defined by Nettleton and Smith (1980) as

> ... the ability of a performer to effect a motor response conicident with the arrival of a moving object.
>
> (Page 676)

Participation in fast ball games demands this ability; a tennis player, for example, needs not only to watch the ball moving towards him and in doing so predict the direction and speed of the ball, where it will bounce etc., but he needs also to decide the precise moment in time at which to initiate the stroke, allowing sufficient time for the back-swing and throughswing in order to make contact with the ball. Similarly, the team player in a game of hockey or rugby, for example, is required to time his movements and direction of movement in order to take or intercept a pass accurately. As Wade, Newell and Hoover (1982) state,

> Timing is an important component in skilled motor behavior simply because many actions are constrained by both temporal and spatial environmental demands; the nature of sport, leisure, and vocational activities often require efficient timing behavior.
>
> (Page 643).

However, despite this evident importance, the area has not been particularly well researched, particularly with regard to coincidence timing on the part of the children with learning difficulties.

Bard, Fleury, Carrière & Bellec (1981) identify three component processes involved in anticipation timing:

> ...(i) A sensory phase where a stimulus is detected in the visual field, followed by the tracking of this stimulus where the subject attempts to identify the speed and direction of the stimulus; (2) A sensory - motor integration phase, in which the individual, once having predicted the time and place of arrival of the stimulus, programs his motor response; and (3) an execution phase or motor response.
>
> (page 547)

They state that whereas for adults the second phase is generally well controlled, this is the area in which children seem to face problems, as can be witnessed by the young child's late grasping and catching movements, when a ball has been thrown to him, often hitting his chest before the response has been made.

Coincidence timing has been studied using a variety of tasks which often differ in their precise requirements. This may in part account for the differences which occasionally occur in terms of the results. The types of tasks used are basically four in number: firstly are those tasks which require a "push button" response to coincide with the arrival of an object at a particular point and in which there is no bodily involvement to organise; secondly, there are those tasks in which the individual is required to propel an object to coincide with another reaching a particular point, and in this case the individual needs to take into consideration the time taken for the object to move from the starting to the finishing point. Thirdly, there are those tasks which require some bodily involvement, such as those in which the individual is required to knock over a barrier with an arm, the individual here being required to think in terms of time and space; fourthly, are those tasks which require full body movement, such as in the following study, in which the entire body is passed through a photoelectric beam to coincide with a ball reaching the end of the chute. It is necessary to bear in mind these differences between the tasks, which, although they all attempt to examine coincidence timing, may influence the results.

Various aspects of and factors influencing coincidence timing have been studied, both in terms of learning and performance, which will be considered in turn. However, as is the case in many other research areas the experimental work done has largely been conducted using children and adults from within the range of normal intelligence as subjects. Whilst it is necessary to consider all facets of coincidence timing in order to gain complete understanding of what is involved, and as such all areas are important, the present research is concerned primarily with the effects on learning of intelligence and age, and because of this, these areas will be considered first, and throughout subsequent sections insofar as they interact with the aspect under discussion. Response complexity is also of considerable interest here, since in the following experiment the effects of two different types of gross motor response on accuracy of coincidence timing is considered. The aspects of coincidence timing that will be considered here are as follows:-

(i) Intelligence

(ii) Age

(iii) Response complexity

(iv) Sex

(v) Target Viewing time

(vi) Target Velocity

(vii) Practice schedules and learning.

(i) Intelligence and Coincidence Timing

Very few research studies have directly compared the coincidence timing behaviour of subjects from within the range of normal intelligence with that of subjects with learning difficulties. Wade (1980), however, conducted one such study, comparing the performance on a 'doughnut rolling' response to a moving target of three groups of children with a mean IQ of 71 and mean chronological age of 100 months, 130 months, and 155 months, with that of children matched with them on chronological age, but from within the range of normal intelligence. Three target velocities and three display periods were considered. No significant differences emerged between the two intelligence groups, either when target velocity was manipulated and viewing time held constant or when the situation was reversed. However, there were significant interactions between intelligence and other factors, which will be considered at a later time.

In contrast to these findings, McGown, Dobbins and Rarick (1973) found significant main effects for intelligence group. They examined accuracy and intra-individual variability on a coincidence timing task of children with an IQ (expressed in standard score form) ranging from -3.13 to -0.33, and a mean chronological age of 101.8 months with that of children from within the range of normal intelligence and a mean chronological age of 101.1 months. The task required the children to press a button and stop the target at the moment it reached a fixed stationary point towards which it was heading horizontally at a constant velocity of 2 ft per second. The intra-individual variability of the group with the lower IQ was significantly greater than that of the children of normal intelligence; McGown, Dobbins and Rarick (1973) state that on average it was approximately 1.8 times greater than that of the latter groups. Furthermore, in terms of absolute accuracy, the mean constant error (CE) of the children with learning difficulties was significantly greater than that of their peers of normal intelligence. McGown, Dobbins and Rarick (1973) go on to consider the relationships between CE and intra-individual variability, which were found to be nonsignificant, and suggest that it is not the case that the relatively low level of accuracy on the part of the children with learning difficulties is caused by the variability that exists in their individual performance.

These two items of research would at first appear to result in contradictory findings, although it may be that, for example, the particular target velocity and viewing period by McGown, Dobbins and Rarick (1973) combined to result in a difference similar to that found as an interaction in the case of the research by Wade (1980). The IQ x age x condition interaction found by Wade (1980) suggested that the youngest children with learning difficulties had greater than average problems with the slower speed, in this case 30 cm/sec. (approximately 1ft per sec) whereas at a speed of 90 cm/sec (approximately 3ft/sec), such children would appear no different from their chronological age matched peers. The target speed used by McGown, Dobbins and Rarick

(1973) of 2ft/sec falls somewhere between those used by Wade (1980) and results in different patterns of results. Furthermore, the type of response required may influence performance, and therefore results. The Wade (1980) study required the children to release a metal doughnut which rolled down a track in order to coincide with a moving target at the end of the track whereas the study by McGown, Dobbins and Rarick (1973) required a push button response, with no bodily involvement. The two tasks may be considered to be fundamentally different in nature.

Research related to intelligence differences and the other aspects of coincidence-timing under consideration, will be considered under the related headings.

(ii) Age and Coincidence Timing

The question that is under consideration here is whether or not coincidence timing improves with age.

Using subjects from within the range of normal intelligence, Dorfman (1977) compared the coincidence timing performance of six age groups (6-7 yrs, 10-11 yrs, 12-13 yrs, 14-15 yrs, and 18-19 yrs) over 60 trials on a task in which the subject was required to coordinate the interception of two dots on an oscilloscope. The 'target dot' moved in a vertical plane down the screen, and the aim was to initiate the 'cursor dot' so that it hit the target dot. During the last 20 trials, the target dot was masked from view 1 cm after appearing on the screen. Comparisons of AE, CE and VE between groups and over trials were then made. For AE, the older children recorded lower error scores than the younger groups with the exception of the two oldest groups, between whom no difference was found. Furthermore, the differences between the age groups increased over trials, the relative improvement of the older age groups being greater than that of the younger groups. Similar trends were reflected by the CE and VE analyses. Following the masking of the target dot, a marked decrement in performance was recorded for both AE and VE, but not for CE, although the decrement was true to a greater extent for the younger groups than the older age groups. Dorfman (1977) comments on the high level of performance by all groups, with even the youngest group evidencing a mean AE of 100 msec by trial block 8 (trials 35-40). However, when the target dot is masked, decrements occur to a greater extent for the younger children, possibly, he suggests, because the task then requires more cognitive functioning and operations, at which younger children are less competent.

Dunham (1977) also investigated coincidence timing behaviour from a developmental perspective, taking groups of children of ages 7 yrs, 8 yrs, 9 yrs, 10 yrs, 11 yrs and 12 yrs, and all apparently from within the range of normal intelligence. The task involved attempting to lift the foot off a spring switch in coincidence with the arrival of a ball at a target flag. Analysis of AE and CE in terms of time early or late revealed similar trends; for AE, age proved a significant variable, with the 7 yr olds performing at a level lower than all other groups; the 8 yr olds and 9 yr olds at a lower level than the 11 yr olds, and the 10 yr olds at a level lower than that of the 11 and 12 yr olds. Performance by all groups improved over the 5 trial blocks, specifically between blocks 1 and 2, 1 and 3, indicating early understanding of the task and fast improvement over trial blocks.

Alderson (1974) employed a linear motion prediction task with groups of 7, 10 and 13 year olds and adults, and found that the 13 year old age group responded in a fashion commensurate with that of the adults, but the younger age groups were found to be less accurate and more variable in their performance. The task itself involved prediction of the movement when a ball reached a given point, hidden behind a screen after it had been visible for part of its path. Performance on a ball catching task revealed similar trends.

Further research by Bard, Fleury, Carrière and Bellec (1981) confirms the findings of Dunham (1977) and Dorfman (1977), that coincidence timing behaviour improves with age. Using three tasks, two of which involved coincidence anticipation, with varying degrees of response complexity, a significant main effect was found for age, with regard to both spatial and temporal absolute error, posthoc analysis revealing the differences to lie between the 6 and 7 year old group and the 10 and 11 year old group for temporal AE, and between the 6 year old group and the 10 and 11 year old group and the 7 year old group for spatial AE.

Haywood (1980) compared the coincidence timing of four age groups, 7-9 years, 11-13 years, 18-32 years and 60-75 years on a task requiring the pressing of a button in time with the last of a series of lights, and found only the youngest group different to the rest, being less accurate (AE and CE) and having a greater VE. No difference was evident between the three older age groups.

Wrisberg and Mead conducted two studies (1981; 1983) examining the learning of coincidence timing by first grade children. The earlier study compared variable and constant practice in a task involving tapping a target barrier, and they found that all children improved with practice. The effects of the practice type will be considered later. The later study again revealed a decrease in error over practice blocks although the effects of practice schedule were apparent on transfer. These two studies would appear to give further evidence that children even at such an early age are capable of learning coincidence timing.

Wade (1980) compared the coincidence anticipation performance of children with a mean IQ of 71 (ranging from 54 to 86) with that of children from within the range of normal intelligence, matched with them on chronological age. Three age groups were studied with means of 100 months, 130 months and 155 months. The task was such that a target, a cartoon figurine, moved along a trackway from left to right, and the children attempted to hit the target by rolling an aluminium "dough-nut" at right angles to the trackway. AE, CE and VE in terms of distance from the coincident point was measured. No overall significant difference between the intelligence groups was apparent, but the age effect was significant for both,with the youngest group exhibiting the greatest AE, the oldest the least. Three target velocities were used and the significant IQ x age x target velocity interaction again suggests that there are developmental differences in the magnitude of error. The younger age groups for both levels of intelligence produced greater errors, but this was particularly the case for the younger children with learning difficulties, using the slowest target velocity; their mean AE was considerably greater than for all other groups. The results for CE did not prove significantly different as a result of age, although the younger children tended to make early responses. IQ, however, was significant, the group mean for the subjects from within the range of normal intelligence being +1.28 cm and for those with learning difficulties - 1.62 cm. The significant IQ x age x condition interaction showed the children with learning difficulties to have a relatively high CE for the slow target velocity in a manner similar to that for AE. For VE, no difference between intelligence groups was found, but age was a significant factor, the younger subjects exhibiting greater variability than the older groups. The significant age x target velocity interaction demonstrates that all age groups exhibit greater variability with slowest target velocity, the greatest increase being for the younger group.

In general, the research suggests that for all children regardless of intellectual ability, coincidence timing improves with age. Possibly, this reaches an asymptote in the early teens, although the effects may be compounded by the effects of such factors as target velocity and viewing period.

(iii) Response Compexity

Response complexity has most recently been studied within the context of reaction time, with concern for the way in which increased response complexity might affect both simple and choice reaction time, (Klapp 1974; Klapp, Wyatt and MacLingo 1974). However, the question of different types of response and their effect on accuracy of coincidence timing has received a little attention, although in the main, the research has been conducted using children and adults of normal intelligence as subjects.

Jensen, Picado & Morenz (1981) used a gross motor coincidence anticipation task, whereby undergraduate subjects ran from a designated starting point to coincide their run through a photoelectric beam with a ball reaching the end of a 20 ft. long chute. Two movement or timing patterns were used, termed 'long' and 'short', and the subjects followed one of these in response to the illumination of a green or red light in front of them. The AE analyses revealed that in general, the longer distance produced the greater error and the distance x sex interaction showed females to be less accurate than males on the longer distance, but not significantly so on the shorter run. These trends were supported by the CE and VE analyses. A second experiment, again with undergraduates, employed two shorter response distances and again the shorter distance was found to generate less error.

Bard, Fleury, Carrière & Bellec (1981) compared a fine motor response (pressing a button) with a gross motor response (throwing a ball at a target), the result of the response to coincide with the target reaching its terminal point. The button press response resulted in fewer timing errors than the throwing response over all six age groups studied (6, 7, 8, 9, 19 and 11 years).

Wade, Newell & Hoover (1982), working with subjects having an IQ ranging from 21 to 50, used two response requirements, a key press response and a response requiring the rolling of a metal 'doughnut' down a trackway, each of which they studied separately. The pressing of the key and the end of the doughnut run were to coincide with the target reaching a designated point. Although the two responses were not compared directly in terms of statistical analyses of errors, the subjects apparently made less error (AE) on the doughnut rolling task than the button press task. However, target viewing time and velocity were also manipulated and ironically the subjects were not able to complete all permutations of these for the 'doughnut' rolling response because the task was found to have a floor effect and as such was too difficult. These results are slightly anomalous. In terms of constant error (CE) recorded, it is the nature of the errors that changes with the response requirements; for the key press response, the responses were generally made too early, whereas for the doughnut rolling response the responses were usually initiated too late.

The research with children of normal intelligence would initially suggest that greater complexity of response generates greater error, although possibly this is not the case for all groups of persons, as witnessed by the research by Wade, Newell & Hoover (1982). Generalisation of research findings with subjects of normal intelligence to subjects of below average intelligence is not always wise. One further point that warrants consideration is the nature of the responses required. Two kinds of comparisons have been made here; gross with fine responses, and two types of gross response. Comparisons may also be needed between ballistic and controlled responses and along other dimensions before the picture is fully clear.

### (iv) Sex and Coincidence Timing

Some of the research done in this area is solely concerned with the effects of sex on accuracy of coincidence timing, although it is more often incorporated within research also concerned with other aspects of coincidence timing behaviour, as in some of the research already cited. In general, the trend would appear to suggest that males perform with greater accuracy than females.

Dorfman (1977), as part of the study already cited, found a significant effect of sex on performance (AE, CE and VE), with males superior to females; the largest difference between the sexes was found in the case of the two youngest age groups 6-7 year olds and 8-9 year olds and decreasing with increasing age. This sex difference is supported by the findings of Bard, Fleury, Carrière & Bellec (1981), who found boys more accurate than girls in terms of both spatial and temporal error. The errors by the girls for spatial accuracy decreased over the two testing sessions, however, whereas those of the boys remained stable. Bard, Fleury, Carrière & Bellec (1981), however, state

> ... this difference between boys and girls was only significant when the motor response was complex, i.e., when an arm throw must be executed alone or associated with information processing, the child having to answer to a moving stimulus. This put the girl in a ball-game situation, where boys might have acquired more experience. Thus the difference may be associated with a cultural bias rather than with a developmental and/or sex differences.
>
> (P.554)

Dunham (1977) also found significant sex differences, with boys more accurate than girls. In this case, there was no interaction with the target velocities used or trial/practice blocks.

Jensen, Picado & Morenz (1981) considered sex differences as part of a wider investigation into the effects of precision of knowledge of results on performance of a gross motor coincidence timing task, as described earlier. Undergraduate subjects ran one of two patterns, 'long' or 'short', to coincide their passage through a photoelectric beam with a ball reaching the end of a 20ft chute. Sex differences in favour of superior accuracy by males were found for the longer running pattern, but for the shorter distance no significant difference between the sexes was found, this trend being true for both AE and CE analyses. However, males generated less VE than females at both distances. When a shorter chute and shorter distances were used, no sex differences emerged for the AE, VE or CE analyses, although for CE, the males were significantly more on time than the females.

Wrisberg & Mead (1981) found no sex differences in first grade children on a coincidence timing task. The task was such that the children were to attempt to tap a target barrier coincident with the illumination of the last of a series of runway lights. The lights were illuminated at a constant rate, but practice was given either under a variable regime whereby four different stimulus velocities were attempted, or a constant practice regime, whereby only one of the four was experienced. This was again a fine motor response, using apparatus similar to that used by Wrisberg & Ragsdale (1979), who found no sex effect with university students when stimulus variability was high, but when the stimulus variability was low, the females were found to exhibit a significantly higher mean AE. Wrisberg & Ragsdale (1979) found a further interaction between sex and trial blocks, with females having greater AE than males on blocks 1, 2, 3 and 5, but not block 4. No significant effect for sex was apparent for the CE analyses.

A similar task, with a constant variable practice paradigm, was used by Wrisberg & Mead (1983) with first grade children and revealed a significant sex x group interaction, with females demonstrating a significantly greater AE than males only when the training phase was varied and randomly presented. On transfer to a novel velocity, AE and VE analyses revealed that performance relative to sex also depends on previous practice presentation. No effect for sex was found for CE. Wrisberg & Mead (1983) suggest that

> It is possible that young males favor stimuli which are rapid in nature. This would not be surprising in light of the fact that American culture often views sport experiences with fast speed stimuli as more appropriate for boys than for girls ..... An alternative explanation might be that males were more aroused by the novel task situation and the fast speed training. A resulting heightened anticipatory arousal would likely be contra-indicated during transfer performance with the less exciting yet demanding slow velocity. Support for this notion has come from Mendel (1965) who reported more frequent significant correlations between anxiety level and various types of performance for young males than for young females.
>
> (p.72)

Although at first it would appear that males perform with greater accuracy than females on coincidence timing tasks, the picture is not as clear as might be thought at first. Firstly, not all findings confirm this suggestion; secondly; other factors, such as target velocity and viewing time may be influential; and thirdly, it must be recalled that research done with children of normal intelligence is not always applicable to children with learning difficulties.

(v) Target Viewing Time

Ball catching is a common coincidence timing task, and a study of this by Whiting, Gill and Stephenson (1970) suggested that as the viewing period of the ball in flight increases, in their case from 0.1 to 0.4 seconds, the number of balls caught also increases. However, length of viewing period is not the only factor operating; the length of the occluded period and the position of the viewing period relative to the flight of the ball were also influential. Research by Whiting and Sharp (1974) varied the length of the occluded period from 0 to 320 msec, which was always followed by a 200 msec 'latency period' during which the ball was visible and at the end of which it was to be caught. Their findings suggested that the length of the occluded period does have an effect on catching performance, since the very short and very long occluded periods resulted in a smaller percentage of balls being caught. Since the viewing period immediately preceding the occluded period was held constant at 80 msec, the zero second occluded period did not allow sufficient time to move into the appropriate catching position (280 msec only); and the very long occluded periods presented problems in terms of time and velocity estimation. The combination of viewing and non-viewing periods would appear to be important.

Dorfman (1977), as part of the developmental study cited, noted a decrement in performance when vision of the target was prevented after 90 msec of movement. This was following 40 trials with full vision of the target, and was true of all age groups (6-7 years, 8-9 years, 10-11 years, 12-13 years, 14-15 years, 18-19 years), although particularly noticeable for the chronologically younger groups.

Wade, Newell and Hoover (1982) examined coincidence timing by subjects with a mean IQ of 40, ranging from 21 to 50, and between 22 years and 31 years in chronological age. Three target velocities were used (30.5, 61.0 and 91.5 cm/sec)and three preview distance conditions (30.5, 61.0 and 91.5 cm), with a task that involved attempting to press a telegraph key at the moment when the target reached a predetermined point. A main effect for preview period for CE was evident, the error scores ranging from 1.29 cm for the shortestexposure period to - 2.99 cm for the longest. In the second study by Wade, Newell and Hoover (1982) which involved a 'doughnut' rolling response, no CE differences were found between conditions. For VE, however, the longest period combined with the fastest target velocity resulted in greater variability with the shortest viewing period and the slowest target velocity resulting in the least variability. The data from the two experiments would appear confusing, since performances under the same velocity and exposure conditions provide different results. For experiment 1, an optimal viewing period would appear to exist, the 30.5 cm preview period, resulting in mean constant error approaching zero. Wade, Newell & Hoover (1982) suggest that

> "...slow responding...and an inability to inhibit responses...together produced both the late responses for the 30.5 cm. exposure and the early responses for the 61.0 cm. and 91.5 cm. exposures.
>
> (page 648)

They argue that this is supported by the higher VE, probably produced by greater variability in the early trials at the faster target velocity. Wade, Newell & Hoover (1982) further suggest

> A speculative possibility is that retarded subjects are insensitive to the kinematics (velocity & acceleration components) of the display; to the extent that this is the case, variables such as displacement and target velocity would not differentiate the appropriate cues. Gibson's (1979) perspective suggests an alternative explanation. In this interpretation the production of accurate motion - prediction responses requires a sensitivity to the dynamics (mass and force components) of the display rather than the kinematics. In the present setting, the rate of change of the optic array, and possibly the texture grading, may provide the necessary information directly to subjects.
>
> (p.648)

Earlier research by Wade (1980) using the same apparatus and the 'doughnut' rolling response, included comparisons between children with an IQ ranging from 54 to 86, of 3 age groups (means of 100.3 months, 120 months and 155.8 months) and children from within the range of normal intelligence matched with them on chronological age. Two target viewing conditions were used, ⅓ and ⅔ covered, and for AE, no difference was found between the intelligence groups,but for all subjects a significant effect for target preview was apparent, in that the longer the target viewing period, the greater the timing accuracy. Only for the 9-11 year olds, on trial block 5 was this trend reversed.

The findings suggest, therefore, that for subjects of normal intelligence, longer viewing periods are advantageous in terms of timing accuracy although this is also influenced by its proportion in relation to overall flight, and its position within the flight or target movement. There would appear to be optimum viewing times, although these are dependent on other factors. Although the position with children having learning difficulties is less well researched, the pattern would appear to be similar.

(vi) Target Velocity

The effect of the velocity of the target with which the subject attempts to coincide his response on accuracy of timing that response has received some attention, although once again, much of the research conducted has employed as subjects children and adults from within the range of normal intelligence.

Dunham (1977), in the research already cited, with 6 age groups of children of normal intelligence, used four target velocities, such that the 'car' ran the length of the track in 2.0 seconds (slow), 1.25 seconds (medium slow), 0.90 seconds (medium fast), or 0.75 seconds (fast). The AE results recorded no significant effect for rate, with the faster speeds resulting in no more error than the slow ones, but the CE analyses revealed less error for the two slower rates than the two faster rates. A significant sex x rate interaction was caused by the fact that for the medium fast rate, females recorded a relatively higher mean error.

Bard, Fleury, Carrière & Bellec (1981), however, found children more accurate in timing when the target moved at a velocity of 150 cm/sec than when it moved at a rate of 75 cm/sec. The suggest that for the fast velocity, subjects preprogrammed a response

> ... but when a low velocity stimulus was
> presented, subjects reorganized their

> response and this reorganization resulted in larger errors. Indeed, inaccurate evaluation of low velocity constantly resulted in the following pattern: the child stopped his initial movement, then he initiated a second movement and this throw was always late on the target.
>
> (p.554)

Similarly, Wrisberg & Mead (1981) found lower AE and CE for a faster moving target (358 cm per second) than with a slower velocity (224 cm per second), although this was not the case for VE. In this research, first grade children acted as subjects, and had previously experienced constant or variable practice of velocities. The difference found between velocities was consistent over groups, regardless of the nature of the previous practice. A similar experimental design was used subsequently, again by Wrisberg and Mead (1983), whereby subjects received constant fast speed training, constant slow speed training, varied speed practice with random presentation, or varied speed practice with presentation blocked. A fifth group acted as a control group. Two transfer speeds were used, 134 and 358 cm/sec, and on transfer, the slower speed resulted in greater AE and VE, with the mean CE for the slower velocity being -3 msec and for the faster velocity +25 msec, so the pattern was slightly different. Wrisberg and Mead (1983) state that the reason for the high positive CE is because the responses were made consistently late, whereas for the slower velocity, they were more evenly distributed about zero.

Wade (1980) used three target speeds (152.4 cm per sec, 91.4 cm per sec and 30.5 cm per sec) with children of IQ ranging from 54 to 86, and of three age groups, 100 months, 130 months and 155 months.

Children from within the range of normal intelligence were matched with them on chronological age. For the AE data, target velocity again proved a significant source of variation, with mean error scores of 5.30 cm for the fastest velocity, 3.12 cm for the middle velocity, and 8.71 cm for the slowest velocity. There was also an IQ x age x target velocity interaction, such that the low IQ group appeared to generate inordinate error on the slowest target velocity, and an age x target velocity x blocks interaction such that the youngest children with learning difficulties recorded a much smaller error reduction over blocks on the slower speed. The CE analyses revealed a significant main effect for target velocity, the means being 2.25 cm for the fastest speed - 1.8 cm for the middle speed and - 2.59 cm for the slowest speed. The VE analyses showed the faster speeds to generate less variability.

Wade, Newell & Hoover (1983) had subjects with an IQ of between 21 and 50 perform a coincident timing task with three target velocities of 30.5 cm per sec, 61 cm per sec and 91.5 cm per sec. Two complexities of response were used and the analyses for VE suggest increased variability with increased target velocity apparently in contrast with the previous research, although it must be noted that the velocities used are different and the IQ range is much greater here than in the research by Wade (1980). The middle speed errors approximate zero CE, but increase for the fast and slow speeds.

Shea & Gabbard (1979), using a coincident timing task with undergraduates, suggest that rapid responses have similar spatial temporal structures, but that for slower responses these structures alter. The 1000 msec. response resulted in significantly greater error than either the 500 msec. or 250 msec. response. Furthermore, the analyses for the four segments of the movement response indicate steady variability of speed for the 500 msec. and 250 msec. responses, but for the 100 msec. response, segment 4 was more variable than segment 1, both of which were more variable than segments 2 and 3.

Target velocity would appear to be a factor in accuracy of coincidence timing, although it does not appear to be independent of other factors such as target preview time, and mode of response. Furthermore, the subjects under study should be considered, as children and adults, of normal intelligence and those with learning difficulties may respond differently to changes in the velocity or to different velocities overall. Once again, generalisation of research findings to children with learning difficulties is perhaps unwise.

(vii) Practise Scheduling

The effect of various practice schedules on the learning of a coincidence timing task has been studied, although again with children and adults from within the range of normal intelligence. The paradigm generally used is to give different practice schedules whereby to acquire the skill and then to test this ability on a novel but related task.

Wrisberg & Ragsdale (1979) gave four groups of student volunteer subjects 40 trials during which response requirements and stimulus variability varied from high to low. High response requirements involved a button press with the non preferred hand, whereas low response requirements involved visually tracking the target movement only. High stimulus variability involved the presentation of four stimulus velocities (2235, 3159, 4917 and 5812 mm. per sec), randomly presented, and low stimulus variability, the presentation of one of these four velocities only. Following these 40 training trials all subjects were presented with a novel target speed and were required to respond by pressing the button with the preferred hand. The AE analyses revealed lowest error by those who had received training with high stimulus variability and high response requirements, this being significantly lower than the other groups.

Using first grade children as subjects, Wrisberg & Mead (1981) compared transfer performance by subjects having received practice with four stimulus velocities, constant practice with one of the four velocities only, or no practice at all. On the two transfer stimulus velocities, the main effect for groups revealed significantly lower AE for the constant practice group than the no practice group, but no difference between the variable practice group and the no practice group or constant practice group. Unlike the findings of Wrisberg & Ragsdale (1979) working with adults, these findings suggest that with children, variability of practice may not be the best way of acquiring a skill. They suggest that

> Data from the present study additionally suggest the importance of experience in coincidence-anticipation settings in promoting the development of timing skill in children.
>
> (p.605)

Wrisberg & Mead (1983) conducted further research into the role of practice scheduling in learning a coincidence timing task by children. 4 groups of first grade children were given a total of 96 trials with stimulus speeds varying in that they were slow (179 cm per sec),fast (31 cm per sec), varied with random presentation (179, 224, 268 and 313 cm per sec) or varied with blocked presentation. Two transfer tasks using stimulus speeds of 134 cm per sec and 358 cm per sec were then given. For the slower of these speeds those having received slow stimulus speed training and varied block training generated significantly less error than those having received fast training. No group differences emerged for the faster transfer velocity. With regard to VE, the group trained with the fast speed was significantly less consistent than the group having received varied blocked training on the slower transfer velocity. They recommend therefore, that any training given should focus on slower stimulus target speeds and employ a blocked presentation approach when variable practice is being given.

The results of the research in this area are in many ways anomalous. Differences emerge between adults and children and the way in which they appreciate practice, with the result that generalisations are not wise. Similarly, generalisations to populations with learning difficulties from research with subjects of average intelligence may well be misleading.

Although in many cases, the research findings are anomalous, the importance of the aspects of coincidence timing discussed here remains evident. It would appear that in many cases, the factors do not influence performance independently of one another and that a combination of influences is at work. Working with different age groups also makes the results less clear. It is the effects of age and intelligence on coincidence timing with which the research is primarily concerned here and even in those two areas, the findings occasionally appear anomalous. Research regarding intelligence differences employs differing types of tasks which are in turn different in nature to the task employed in the following study. The anomalies present in the studies cited would counsel against generalisation to a task of yet another different kind. Furthermore, the interactions with other elements, such as target velocity, make any predictions dubious to say the least. With regard to the research findings related to age, the suggestions are perhaps clearer; regardless of intellectual ability or the nature of the task used, coincidence timings appear to improve with age. One might anticipate differences therefore, between the two matched groups from within the range of normal intelligence that participate in the following study in favour of the chronologically older subjects.

## II PURPOSE OF THE COINCIDENCE TIMING STUDY

The focus of the present research, as has already been stated, is motor learning in children with learning difficulties and their mental and chronological age matched counterparts. For this reason, as before, three school groups of children matched in this way will be studied using the same experimental paradigm in order to investigate whether all are equally capable of learning the task or whether any differences between the groups emerge.

The coincidence timing task used here is an example of a task falling into the category of environment moving, whole body moving, body parts stationary (in that they are only moving insofar as they assist the whole body movement and are not required to perform any additional independent task), according to the classification model postulated in Chapter Four. Much of the research cited in the preceding section in relation to coincidence timing does not employ a task of this kind, in that the required response does not involve total body movement. Generalisations to and predictions for this study are, therefore, not entirely applicable. The task response used in the following study involves the children attempting to coincide their movement through a photoelectric beam with a ball reaching the end of a 20 ft chute. As such, it is a gross motor task and since the environment, the ball, is in motion, and the child is effectively making his response to that environment, the task can be deemed to be relatively "open". The environment is making temporal demands on the individual, and he is therefore not at liberty to determine the onset of his response, at least if he is to be successful. It must be noted, however, that the ball travels at a constant speed, consistent over all trials, and that during practice the child begins his response from the same point. The environment is therefore predictable,making the task more 'closed' in nature than if different weight balls resulting in different speeds down the chute were used, or if varying lengths of chute were used, or if the children varied their starting point.

Throughout the experiment, two response patterns were used, and during practice half of each group attempted one response pattern only. The different response patterns resulted in slightly different types of task. The short response pattern involves jumping, two feet together, through the photoelectric beam from a line 1ft. behind it, whereas the long response pattern involves the children running from a line 13 ft away from the beam, and then leaping through the beam as they reach it. Both responses can be categorised as discrete, in that they have a clear starting point, and both finish after passage through the beam. However, in the case of the short response pattern, the response can be seen as ballistic in nature, since once the child has left the floor and thus initiated his response, he is unable to draw back, slow down, or influence that response in any way. In the case of the long response pattern, however, the child can vary his speed of run, for example, by slowing down if he feels he began too early or too fast, and thus control his ongoing response right up to the moment when he takes off from the floor to leap through the beam. In this way, the long response patterns can be classified "controlled", at least by comparison with the short response pattern.

In terms of experimental paradigm, the three school groups were divided into half, each attempting one response pattern only. All children received a total of 60 trials at that task on one day, and on the following day, attempted 10 further trials of the same pattern, followed by 10 trials from the other distance. Learning and recall were measured, and on transfer, the ability of the children to utilise previous experience at the related task during the attempts at the novel task.

III STUDY V: THE COINCIDENCE TIMING TASKS

(a) METHOD

(i) Subjects

30 boys and girls were drawn from a local school for children with learning difficulties. The mean chronological age of the group was 13 years 3 months and ranged from 12 years 5 months to 14 years 4 months. The mean IQ of the group was 65, ranging from 52 to 79. Using the formula $MA = \frac{CA}{100} \times IQ$, this resulted in a mean mental age of 8 years 8 months.

30 boys and girls were drawn from a local junior school to act as a mental age match for those with learning difficulties. The mean chronological age of this group was 8 years 10 months, and ranged from 8 years 4 months to 9 years 3 months. All were considered by the class teacher to be within the range of normal intelligence.

30 boys and girls were drawn from a local middle school to act as a chronological age match for those with learning difficulties. The mean chronological age of this group was 13 years 0 months, and ranged from 12 years 6 months to 13 years 5 months. All were considered by the class teacher to be from within the range of normal intelligence.

In all cases the teacher in the school responsible for the release of the children was asked to exclude any children with physical or behavioural problems that might affect performance on the task.

(ii) Apparatus

The apparatus used was similar to that described by Picado (1978). It was manufactured by Headingley Scientific Instruments Ltd., Leeds. A general view is shown in Figure 8.1.

It consisted of a chute 20 feet in length down which any ball approximately the size of a tennis or lacrosse ball would roll freely, the time taken to cover the length of the chute determined by the weight of the ball. The chute itself comprised 4 lengths of plastic drainpipe tubing 3 in. in diameter and each 5 ft. in length, which were joined together, again using drainpipe tubing, to form the 20 ft. length, which could be transported separately to the schools. The upper side of all pieces was removed, as much as possible without the pipe resulting in a "bowed" shape, with the result that the ball could be seen for most of its path down the chute. Once assembled, the chute rested on four metal poles slotted into wooden bases and was 7 ft. 3 in. high at its highest point, descending to 1 ft. in height at its lowest point, the final five ft. length being parallel with the ground. The angle of descent of the first 15 feet was 24 degrees, forming an angle of 166 degrees with the final 5 feet.

The ball release mechanism at the top of the chute is shown in Figure 8.2. It was electrically controlled from the control box. Pressing a button on the control box resulted in the small piece of plastic which had held the ball in place at the top of the chute (put there by one of the testers) being raised out of the chute, thus allowing the ball to roll freely down. The control mechanism allowed

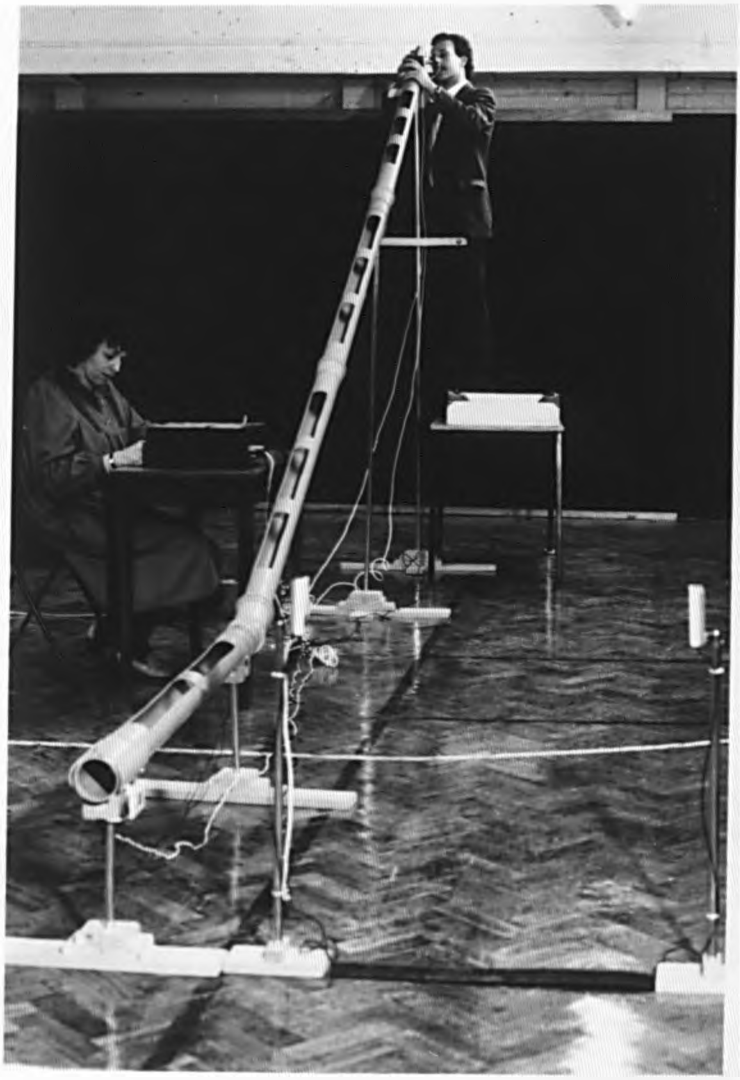


Fig. 8.1: The coincidence timing apparatus

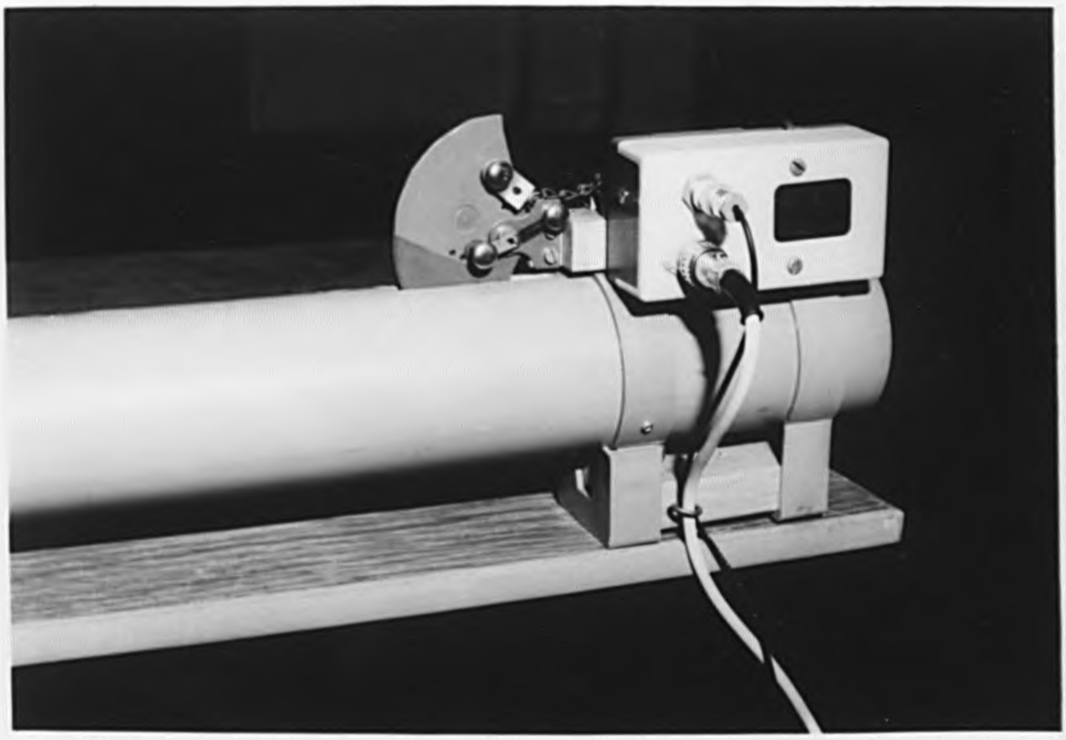


Fig. 8.2: The ball release mechanism for the coincidence timing apparatus


Fig. 8.3: The control panel for the coincidence timing apparatus

for a chosen delay of up to 8 seconds from the button press to the release of the ball, although in this study a 1 second delay only was used.

On the highest metal post, at a height of 5 feet was placed a crossbar 18" in width, on which were green and red lights, 15" apart, at the left and right sides respectively, as viewed when looking at the chute from the bottom end. These could be used to indicate different response requirements, but for this study, the green light only was used and was illuminated as the ball was released.

At the bottom end of the chute were positioned photoelectric cells, 1" and 8" from the end of the chute, and through which the ball was forced to pass. When the ball passed each of the photoelectric cells, the respective clock on the control box stopped, given a measure of the time taken for the ball to travel to that point from the moment of release (.001 sec.). In this study, only the second photoelectric cell and ball travel time were used. This is termed the target coincidence point. The reason for the two photoelectric cells was to give a time span of a few milliseconds during which to coincide the response, since a small degree of error is probably permissable in most tasks requiring coincidence timing. However, a small pilot study with some children with learning difficulties revealed that the task was not as well understood when it was explained in these terms, with the result that it was decided to use the one travel time only. The balls were placed singly in the top of the chute by one of the testers, and after each ball release, the mechanism was primed again before insertion of the next ball.

Two photoelectric cells were mountedon metal posts such that they were 27" from the ground and joined by wires that ran under a rubber strip 3" wide and 2 ft. in length which separated the bases of the posts and resulted in the photoelectric cells being 2 ft. 8 ins. a These were also connected electrically to the control box and passage of an object through the photoelectric beam resulted in the stopping of a clock that recorded time between ball release and movement through the beam (.001 sec.). The posts were placed level with the target coincidence point on the right hand side of the chute as viewed when facing the chute from the lowest end. The apparatus allowed for the use of two such photoelectric beams, with the red and green lights on the upright, although in this experiment, one only was used. Lines were marked in chalk or tape on the floor 1 ft. and 13 ft. from the centre of the rubber strip, behind which the children stood facing the chute, ready to begin each trial.

A table was placed on the left hand side of the chute approximately half way along, at which one tester sat and on which were placed the control box and score sheets. The control box is shown in Figure 8.3. As can be seen, four clocks are shown, the two ball time clocks, the subject time clock, and the delay clock. To the right of the delay clock is the counter indicating the chosen length of delay, and below it two switches for the red and green lights. These are switched to initiate ball release, and the lights then illuminated on ball release. In the centre is the reset button, and above it a small red light which illuminates followingball release, indicating that the veent has occurred.

A second tester stood on a high table or gymnastics box at the top end of the chute in order to be able to reach easily to prime the release mechanism and place the ball in the end of the chute. Bright yellow tennis balls were used, and kept in a box on the high table after collection by the children in a canvas bag.

(iii) Design

For all three groups, the children with learning difficulties and their chronological and mental age matches, the 30 children were assigned to one of the two practice conditions, differing in terms of the response required. Research findings related to sex differences are not all in agreement, but in order to prevent this being a confounding variable, each group consisted of approximately half male and half female subjects. Two groups of 15 subjects were established in this way.

The aim for all subjects, regardless of group membership, was to coincide their movement through the photoelectric beam and over the rubber bar with the reaching of the ball at the photoelectric cells at the end of the chute. All subjects received 60 practice trials in total, 3 blocks of 10 trials in the morning (30) and 3 blocks of 10 trials in the afternoon (30), with a rest between blocks to collect the 10 balls that had rolled down. Following the practice trials, the subjects returned the following morning and attempted ten recall trials, identical in requirements to those of the previous day, followed by ten transfer trials requiring the response pattern not yet experienced. This is shown in Table 8.1.

*Table 8.1: Design of Coincidence Timing Study*

| Group | No. of subjects | Response pattern during practice | No. of recall trials | Response Pattern on recall | No. of recall trials | Response pattern on transfer | No. of transfer trials |
|---|---|---|---|---|---|---|---|
| CLD | 15 (13)* | Short | 60 | Short | 10 | Long | 10 |
| CLD | 15 (12) | Long | 60 | Long | 10 | Short | 10 |
| MA | 15 (15) | Short | 60 | Short | 10 | Long | 10 |
| MA | 15 (14) | Long | 60 | Long | 10 | Short | 10 |
| CA | 15 (14) | Short | 60 | Short | 10 | Long | 10 |
| CA | 15 (15) | Long | 60 | Long | 10 | Short | 10 |

*Due to absenteeism on day 2, the numbers in the groups were reduced to those shown in brackets.

All testing was conducted in the gymnasium or dining room in the school environment familiar to the children, as arranged by the teacher in charge.

The effect of group and response pattern over the six blocks of practice trials, the two practice sessions (morning and afternoon) the recall and transfer blocks and the first recall and transfer trials were analysed.

(iv) Procedure

The children were tested individually. The apparatus was shown to them on entry into the testing room, the tests were introduced and the task explained. The children were told that their aim was to pass through the lights at the exact moment that the ball reached the light just inside the end of the chute. They were shown the way in which the red photoelectric cell light on the upright went out when something went between the beam. They were then shown the way in which the ball ran down the chute: the tester pressed the button on the control box and the children were then able to watch one ball roll down. It was explained that the tester would say "ready" 1 second before the ball started on its path and that the green light would come on when the ball set off. They could set off any time after that. Regardless of response pattern required during practice, all children were asked to stand, feet up to the 1 ft line and jump, feet together, and hands held behind their back, over the rubber strip. They were then asked to stand with one foot up to the 13 ft. line, and to run and leap over the rubber strip.

Once the tester was satisfied that they were capable of both tasks, the children were then shown the line from which to begin the practice trials. It was explained that they would receive ten trials, and then collect the balls, so to let them run against the walls, provided they were not in their path. They were told that they would receive 60 trials in total, 30 in this session and 30 in the afternoon, and some more the following day. Any questions asked by the children were answered, and once it was clear that the task was understood, the child and tester took their places, and the trials began. Following each trial, the children were told their error in msec "too early" or "too late", and their total subject time and ball time were recorded on their individual score sheet (see Appendix 7, sheet 6) in - or + msec accordingly. Following each trial, the children returned in their own time to their allocated starting line, other than whey they were told to collect the balls and replace in the box on the high table.

(b) RESULTS

The relative merits of AE, CE and VE were discussed in the Results section of the study using the linear slide task (Chapter 6). The same holds true here. AE, CE and VE were computed in all cases where applicable, and the effects of group and response pattern of the following were examined. All error scores are stated in milleseconds (msec).

(A) Performance over six blocks of trials, day 1.

(B) Performance over the two practice sessions, morning and afternoon, day 1.

(C) Performance on the recall block of trials, day 2.

(D) Performance on the 1st trial of the recall block, day 2.

(E) Performance on the transfer block of trials, day 2.

(F) Performance on the 1st trial of the transfer block, day 2.

(G) Performance over the recall and transfer blocks, day 2.

(H) Performance of the first attempts on the recall and transfer blocks, day 2.

With the exception of analyses (D), (F) and (H) for which VE is not a viable statistic, analyses of variance were conducted for AE, CE and VE in all cases. The levels of significance, stated and accepted, will be .05, .01, and .001, although this does not preclude the existence of a significance greater than .001.

(A) Performance over 6 blocks of 10 trials, day 1

The mean error score (AE, CE and VE) for the 6 blocks of practice trials was computed for each subject, and the results subjected to a 3 (group) x 2 (response pattern) x 6 (blocks) anova with repeated measures on the last factor, in all cases, each of which will be considered.

(i) AE

The 3 (group) x 2 (response pattern) x 6 (blocks) anova for AE revealed significant main effects for group ($F(2, 77) = 11.10$, $p < .001$), and trial blocks ($F(5, 385) = 19.39$, $p < .001$), with no significant interactions (see Appendix 6, Table 1).

With regard to the main effect for group, subsequent posthoc testing (Tukey HSD) revealed specific differences between children with learning difficulties (CLD) and their chronological age (CA) match ($p < .01$), and between CLD and their mental age (MA) match ($p < .05$), the group with learning difficulties exhibiting much greater error overall (see Appendix 6, Table 2). The means for the three groups are shown in table 8.2.

Table 8.2: Mean error for the 3 groups during practice trials, (AE) coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 52.94 | 34.11 | 23.74 |

Subsequent posthoc testing (Tukey HSD) of the significant effect for trial blocks, revealed the following specific differences, all at the .01 level of significance: between blocks 1 and 2, 1 and 3, 1 and 4, 1 and 5, 1 and 6, 2 and 5, 2 and 6. (See Appendix 6, Table 3). The means for the six blocks are shown in Table 8.3 and as can be seen, the greatest reduction in error occurs between the first two blocks.

Table 8.3: Mean error over 6 practice trial blocks, (AE) coincidence timing task

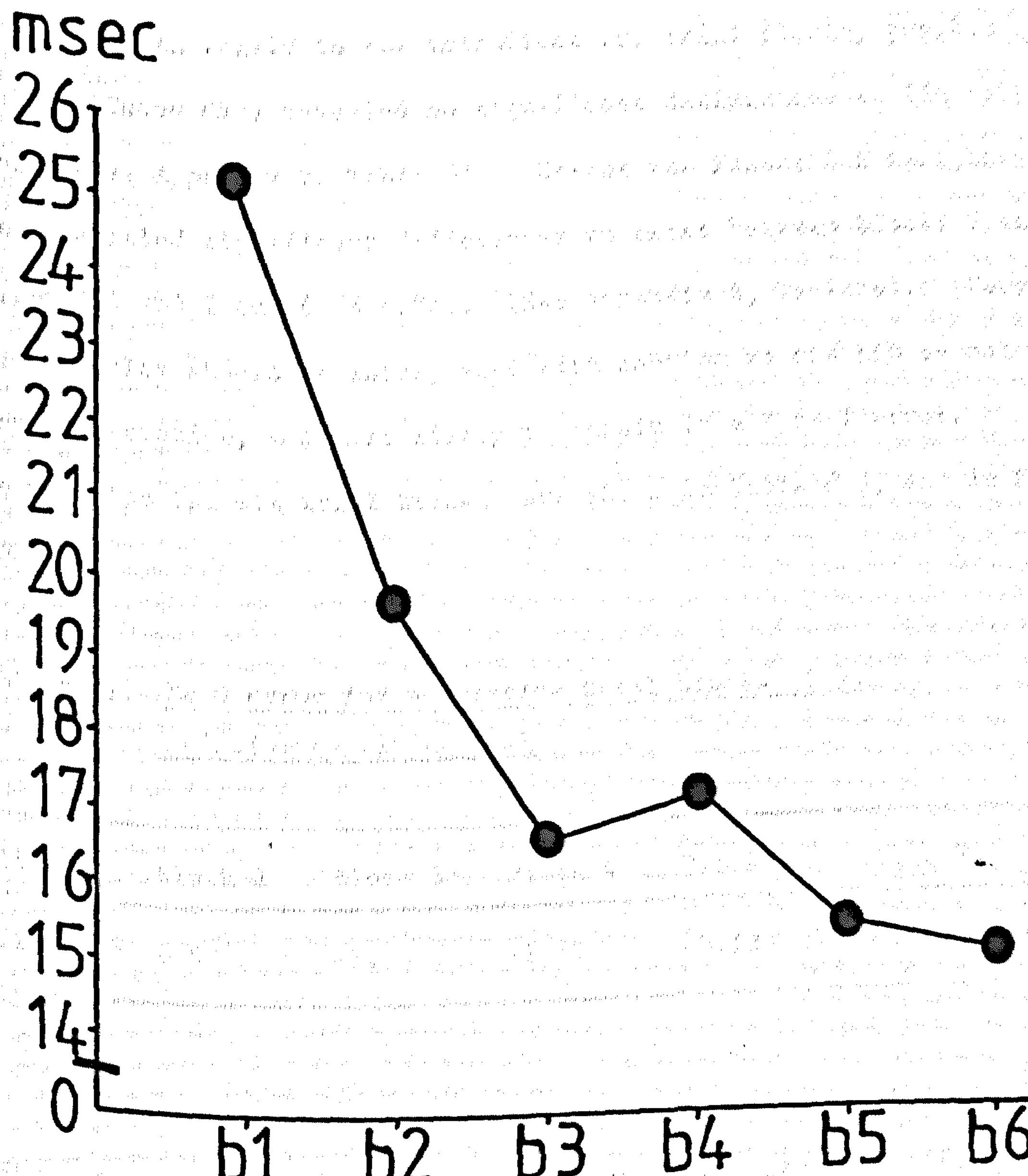
| Block 1 | Block 2 | Block 3 | Block 4 | Block 5 | Block 6 |
|---|---|---|---|---|---|
| 29.17 | 19.68 | 16.64 | 17.06 | 15.41 | 14.97 |

These results can also be seen in Figure 8.4

(ii) CE

The 3 (group) x 2 (response pattern) x 6 (trial blocks) anova for CE revealed significant main effects for response pattern

Figure 8.4: Performance over 6 practice trial blocks (AE), coincidence timing task



($F$ (1, 77) = 9.01, $p < .01$) and blocks ($F$ (5, 385) = 2.28, $p < .05$) and a significant group x response pattern interaction ($F$ (2, 77) = 4.83, $p < .05$). No main effect for group was evident (See Appendix 6, Table 4).

With regard to the main effect for trial blocks, posthoc testing (Tukey HSD) revealed no significant differences to lie between blocks (See Appendix 6, Table 5). Use of the Fisher LSD test, however, revealed significant differences to exist between blocks 2 and 6 ($p < .01$) and 1 and 6 ($p < .05$). (See Appendix 6, Table 6). However, these results should be interpreted with caution as the LSD is not very conservative, and more likely to result in a Type 1 error. The means for the six trial blocks are shown in Table 8.4, and in Figure 8.5.

Table 8.4: Mean error for 6 practice trial blocks (CE), coincidence timing task

| Block 1 | Block 2 | Block 3 | Block 4 | Block 5 | Block 6 |
|---|---|---|---|---|---|
| 0.25 | 0.60 | -1.60 | -1.80 | -3.12 | -4.89 |

Tests of simple main effects were conducted on the significant group x response pattern interaction. The only overall significance was for children with learning difficulties, between response patterns ($F$ (1, 385) = 15.24, $p < .01$) (See Appendix 6, Table 7). The means for the groups and response patterns are shown in Table 8.5 and in Figure 8.6.

Figure 8.5: Mean performance over 6 trial blocks (CE), coincidence timing task

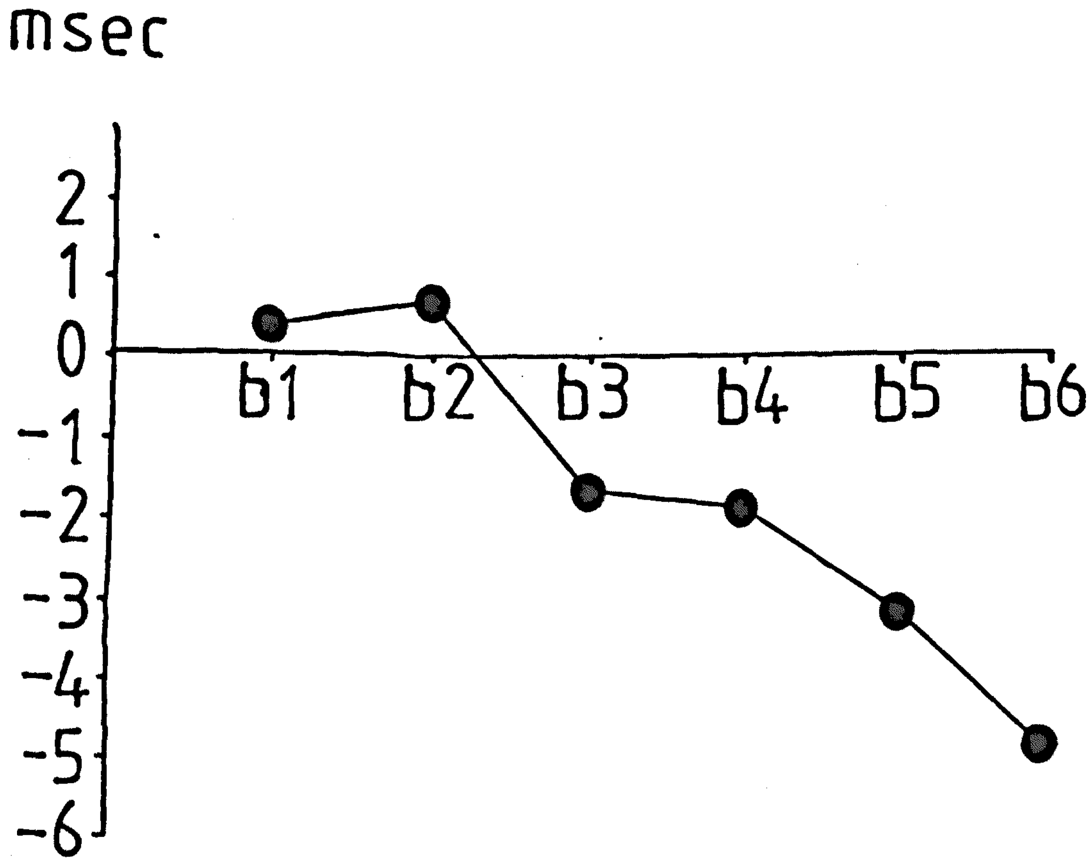


Figure 8.6: Performance of the 3 groups at the 2 response patterns during practice trial blocks (CE), coincidence timing task

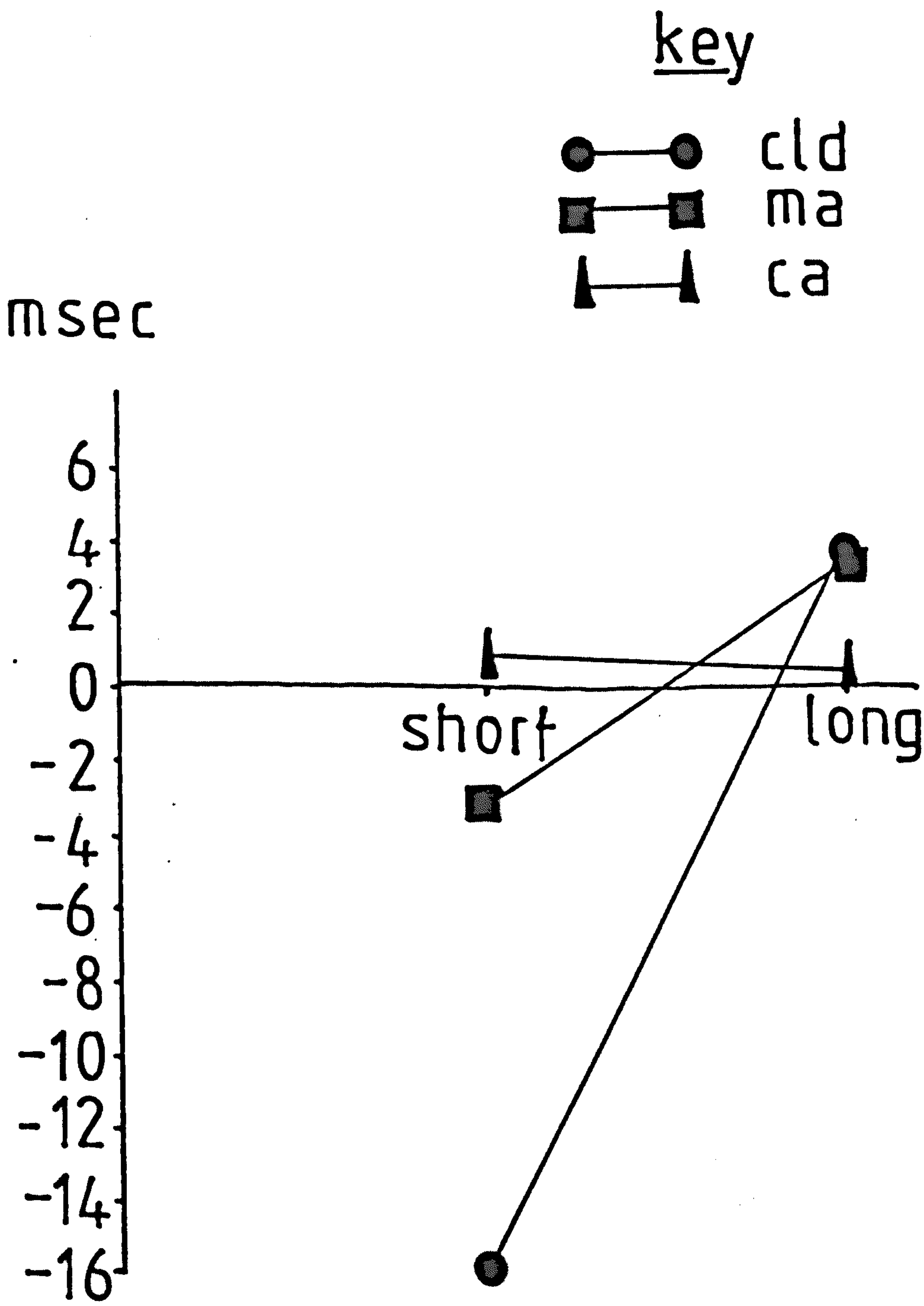


Table 8.5: Mean error for the 3 groups and 2 response patterns during practice trials(CE) coincidence timing task

| Group | Short response pattern | Long response pattern | |
|---|---|---|---|
| CLD | -15.93 | 3.56** | $p < .01$ |
| MA | -3.06 | 3.45 | |
| CA | 0.95 | 0.16 | |

(iii) VE

The 3 (group) x 2 (response pattern) x 6 (trial blocks) anova for VE revealed significant main effects for group ($F (2, 77) = 12.83$, $p < .001$) and trial blocks ($F (5, 385) = 17.13$, $p < .001$). The main effect for response pattern approached significance ($F (1, 77) = 3.86$, $p < .0531$). No interactions proved significant. (See Appendix 6, Table 8).

Posthoc analysis of the significant main effect for group (Tukey HSD) revealed specific differences between the group with learning difficulties and their CA matched group ($p < .01$), and between the MA and CA matched groups ($p < .01$) (See Appendix 6, Table 9). The mean VE for groups are shown in Table 8.6,and as can be seen the group with learning difficulties exhibits the greatest mean VE.

Table 8.6: Mean error of the 3 groups during practice trial blocks (VE) coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 24.07 | 19.79 | 13.35 |

With regard to the significant main effect for trial blocks, posthoc testing (Tukey HSD) revealed specific differences between blocks 1 and 2 ($p < .01$), 1 and 3 ($p < .01$), 1 and 4 ($p < .01$), and 1 and 5 ($p < .01$), 1 and 6 ($p < .01$), and between blocks 2 and 5 ($p < .05$) and 2 and 6 ($p < .05$). (See Appendix 6, Table 10). The mean VE over the six blocks is shown in Table 8.7, and as can be seen, variable error tends to decrease over blocks.

Table 8.7: Mean error over the 6 practice trial blocks, (VE) coincidence timing task

| Block 1 | Block 2 | Block 3 | Block 4 | Block 5 | Block 6 |
|---|---|---|---|---|---|
| 26.22 | 19.95 | 17.05 | 18.58 | 16.06 | 15.54 |

(B) Performance over the two practice sessions, morning and afternoon, day 1

Observation of the mean error scores for the six trial blocks suggested a general decrement in performance between blocks 3 and 4, before and after the lunch time break. It was therefore decided to consider the two sessions and compare performance when three blocks were combined, to see whether or not the afternoon session witnessed any overall improvement on the morning session. The mean AE, CE and VE of each of the sessions of 30 trials were calculated for each individual and the results subjected to a 3 (group) x 2 (response pattern) x 2 (practice session) anova with repeated measures on the last factor, in all cases, each of which will be considered in turn.

(i) AE

The 3 (group) x 2 (response pattern) x 2 (practice session) anova for AE revealed significant main effects for group (F (2, 77) = 11.39, $p < .001$), and practice session (F (1, 77) = 24.19, $p < .001$, and a significant group x practice session interaction (F (2, 77) = 3.83, $p < .05$). No effect for response pattern was apparent. (See Appendix 6, Table 11).

Tests of simple main effects were conducted on the significant group x practice session interaction. Overall significant effects were found for groups at both practice sessions ($p < .01$) and between practice sessions for the group with learning difficulties ($p < .01$) and the MA matched group ($p < .01$) only (See Appendix 6, Table 12). Subsequent posthoc analysis of the differences between groups during the morning practice session (Tukey HSD) revealed specific differences only between the group with learning difficulties and the CA matched ($p < .01$), the group with learning difficulties exhibiting the greatest error,and the CA matched group, the least (See Appendix 6, Table 13). Posthoc analysis (Tukey HSD) of the difference between the groups in the afternoon session revealed significant differences between the group with learning difficulties and the CA match ($p < .01$) only the former exhibiting the greatest error. (See Appendix 6, Table 14). The group means for the two practice sessions are shown in Table 8.8 and in Figure 8.7.

Table 8.8: Mean error of the 3 groups for the two practice sessions (AE), coincidence timing task

| Practice Session | CLD | MA | CA |
|---|---|---|---|
| AM | 29.91 | 19.75 | 11.86 |
| PM | 22.77 | 14.43 | 10.79 |

The differences between practice sessions was significant for the group with learning difficulties only. In all cases the error decreases over time, although this is only marginally so for the CA matched group.

(ii) CE

The 3 (group) x 2 (response pattern) x 2 (practice session) anova for CE revealed significant main effects for response pattern ($F(1, 77) = 7.16$ $p < .01$) and practice session ($F(1, 7) = 4.48$ $p < .05$) and a significent group x response pattern interaction ($F(2, 77) = 3.34$, $P < .05$) (See Appendix 6, Table 15).

With regard to the maineffect for practice session, the means for the two sessions are shown in Table 8.9. Evidently, the second session, held in the afternoon, results in greater negative CE.

Figure 8.7: Performance of the 3 groups over the 2 practice sessions (AE), coincidence timing task

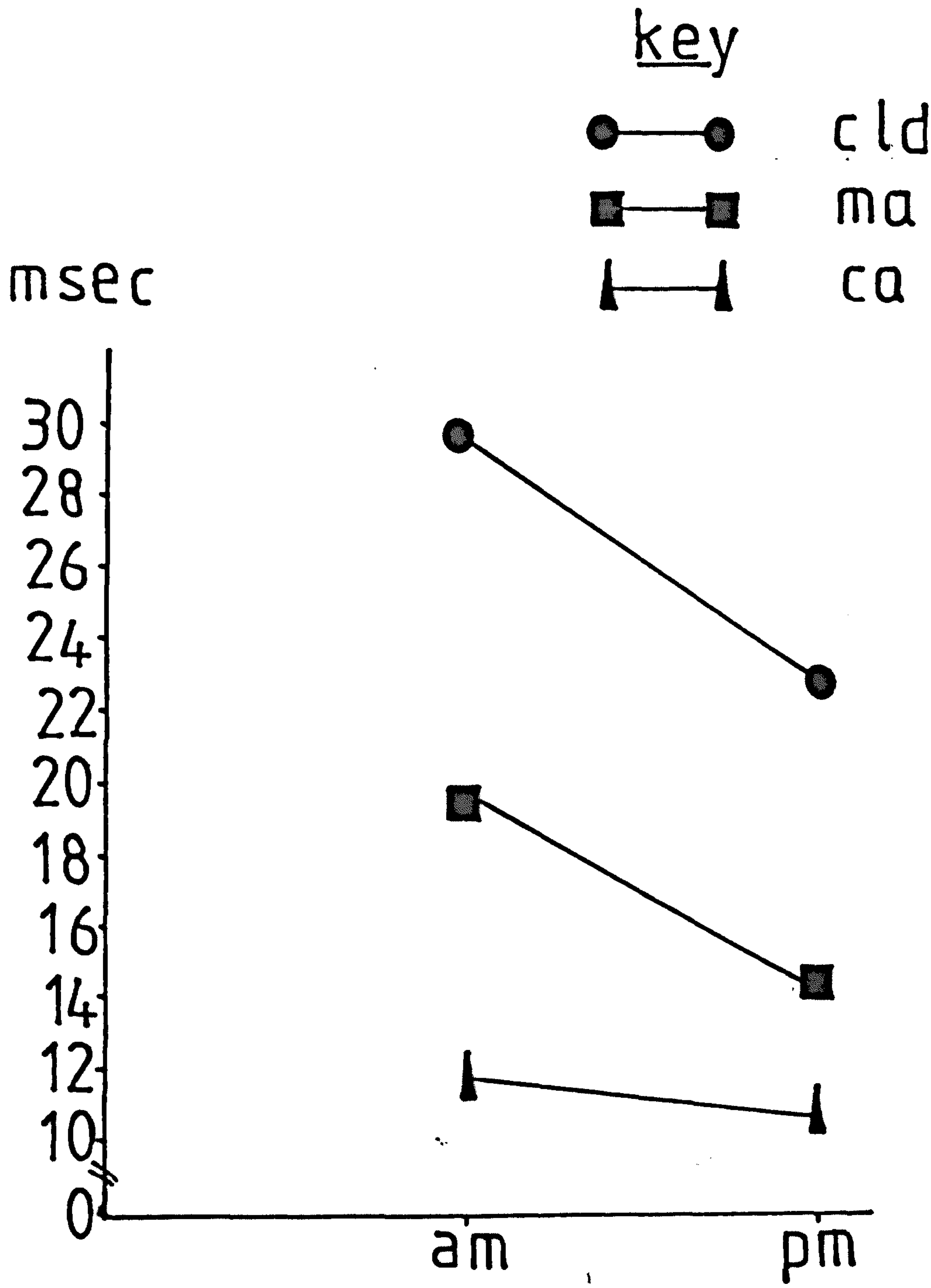


Table 8.9: Mean error for the two practice sessions, (CE), coincidence timing task

| AM | PM |
|---|---|
| -0.15 | -2.59 |

The main effect for response patterns was disregarded and tests for simple main effects conducted on the significant group x response pattern interactions. One simple main effect only was significant, for response pattern by the groups with learning difficulties ($F\ (1,\ 77) = 5.64,\ p < .05$). (See Appendix 6, Table 16). The means for the response patterns by all groups areshown in Table 8.10.

Table 8.10: Mean error for the 3 groups and 2 response patterns (CE) during practice, coincidence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| Short | -13.40 | -2.89 | 0.95 |
| Long | 3.56 | 3.24 | 0.16 |

In the case of the group with learning difficulties, and to a lesser extent, the MA matched group,' the short pattern results in greater negative error, and the long response pattern in positive error.

(iii) VE

The 3 (group) x 2 (response pattern) x 2 (practice session) anova for VE resulted in significant main effects for group ($F (2, 77) = 10.52$ $p < .001$) and practice session ($F (1, 77) = 22.05$, $p < .001$), with no effect for response pattern nor any interactions. (See Appendix 6, Table 17).

Subsequent posthoc analysis (Tukey HSD) of the significant main effect for group revealed significant differences specifically between the group with learning difficulties and the CA matched group ($p < .01$), and between the group with learning difficulties and the MA matched group ($p < .05$). The means for the 3 groups are shown in Table 8.11. (See Appendix 6, Table 18).

Table 8.11: Mean error for the 3 groups, during practice sessions (VE), coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 28.10 | 21.02 | 14.57 |

With regard to the main effects for practice sessions, the means are shown in Table 8.12. As is clear, variability decreases with practice.

Table 8.12: Mean error for the 2 practice sessions (VE), coincidence timing task

| AM | PM |
|---|---|
| 24.02 | 17.93 |

(C) Performance on the block of recall trials, day 2

The mean AE, CE and VE of the block of 10 recall trials were calculated for each individual and the results subjected to a 3 (group) x 2 (response pattern) anova in all cases, each of which will be considered in turn.

(i) AE

The 3 (group) x 2 (response pattern) anova for AE revealed significant main effects for group ($F(2, 77) = 8.42$, $p < .001$) and response pattern ($F(1, 77) = 6.20$, $p < .05$) and a significant group x response pattern interaction ($F(2, 77) = 3.36$ $p < .05$) (See Appendix 6, Table 19).

The two main effects were disregarded and tests of simple main effects conducted on the group x response pattern interaction. Overall significant differences were found between groups for the short response pattern ($F(2, 77) = 3.96$, $p < .05$) and between response patterns for the group with learning difficulties ($F(1, 77) = 11.74$, $p < .01$) (See Appendix 6, Table 20). Subsequent posthoc analyses (Tukey HSD) revealed the significant differences to lie between the group with learning difficulties and their CA match ($p < .01$) and between the group with learning difficulties and the MA matched group ($p < .05$), the group with learning difficulties exhibiting the greatest error. (See Appendix 6, Table 21). The means for the 3 groups and 2 response patterns are shown in Table 8.13 and in Figure 8.8.

Figure 8.8: Performance of the 3 groups at 2 response patterns on recall, day 2 (AE), coincidence timing task

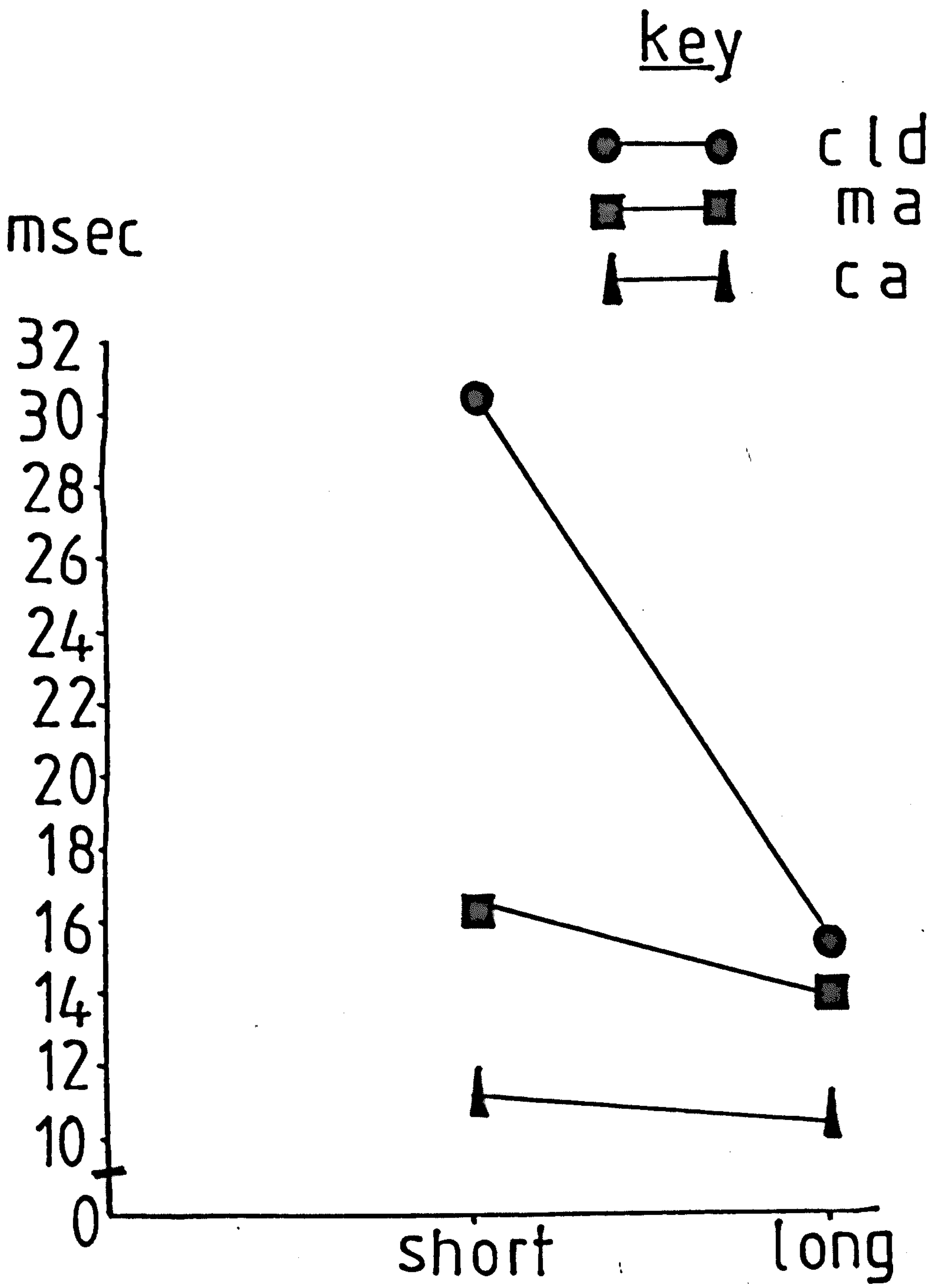


Table 8.13: Mean error of the 3 groups and 2 response patterns on recall (AE) coincidence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| Short | 30.58 | 16.40 | 11.29 |
| Long | 15.65 | 14.14 | 10.67 |

With regard to the difference between response patterns found for the group with learning difficulties, as can be seen from Table 8.13, the short pattern results in significantly greater error. The trend remains the same for the two matched groups, although to a much lesser extent.

(iii) CE

The 3 (group) x 3 (response pattern) anova for CE resulted in significant main effects for group ($F (2, 77) = 3.34$, $p < .05$) and response pattern ($F (1, 77) = 11.21$, $p < .01$) and a significant group x response pattern interaction ($F (2, 77) = 3.16$, $p < .05$). (See Appendix 6, Table 22).

The two main effects were disregarded and tests of simple main effects conducted on the group x response pattern interaction. Overall significant simple main effects were found for groups on the short response pattern ($F (2, 77) = 6.61$, $p < .01$) and for response pattern for the group with learning difficulties ($F (1, 77) = 14.26$, $p < .01$). (See Appendix 6, Table 23). Subsequent posthoc analysis (Tukey HSD) of the significant effect for group on the shorter response pattern revealed specific differences between the group with learning difficulties and the MA matched group ($p < .05$). (See Appendix 6, Table 24), the group with learning difficulties exhibiting the greatest error. The means for the 3 groups and 2 response patterns are shown in Table 8.14 and in Figure 8.9.

Table 8.14: Mean error of the 3 groups and 2 response patterns on recall (CE), coincidence timing task

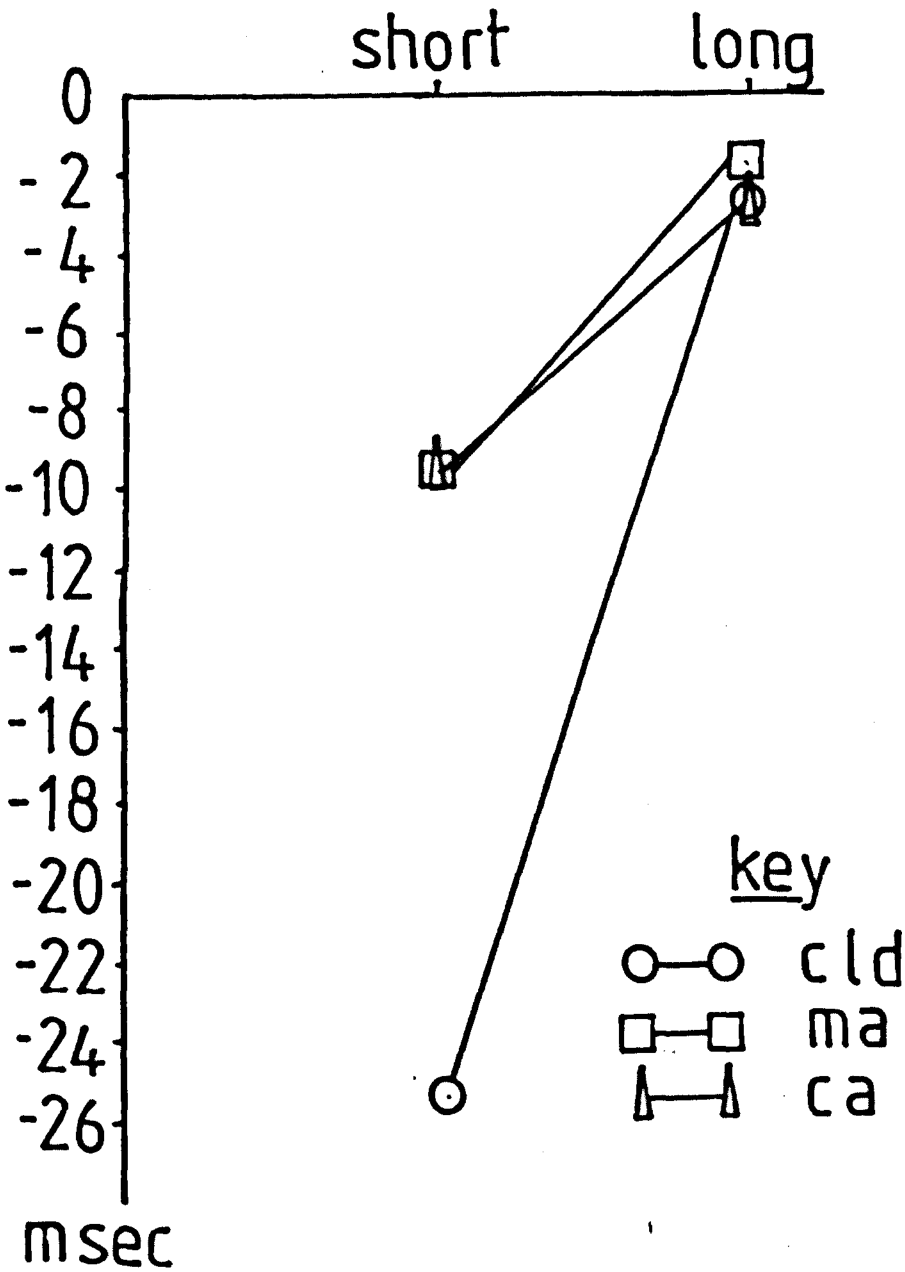
| Response Pattern | CLD | MA | CA |
|---|---|---|---|
| Short | -25.28 | -9.60 | -5.37 |
| Long | -2.70 | -1.79 | -2.73 |

With regard to the effect for response pattern found for the group with learning difficulties, it can be seen from Table 8.14 that the short pattern results in greater error. This trend is reflected by the 2 matched groups, although to a much lesser extent. In all cases, the error scores are negative.

(iii) VE

The 3 (group) x 2 (response pattern) anova for VE revealed significant main effects for group ($F (2, 77) = 7.89$, $p < .001$) and response pattern ($F (1, 77) = 9.08$, $p < .01$) and a significant group and response pattern interaction ($F (2, 77) = 3.23$, $p < .05$) (See Appendix 6, Table 25).

Figure 8.9: Performance of the 3 groups and 2 response patterns on recall (CE), coincidence timing task



The two main effects were disregarded and tests of simple main effects conducted on the group x response pattern interaction. Significant simple main effects were found for groups at the short movement response ($F_{(2, 77)} = 10.53$, $p < .01$) and for response pattern for the group with learning difficulties ($F_{(1, 77)} = 11.52$, $p < .01$) (See Appendix 6, Table 26). Subsequent posthoc analysis (Tukey HSD) of the differences between groups on the short response pattern revealed specific differences between the group with learning difficulties and the CA matched group ($p < .01$), the former demonstrating the greatest error (See Appendix 6, Table 27). The means for the three groups and 2 response patterns are shown in Table 8.15 and in Figure 8.10.

Table 8.15: Mean error of the 3 groups and 2 response patterns on recall (VE) coincidence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| Short | 22.90 | 16.71 | 10.50 |
| Long | 13.42 | 12.09 | 10.70 |

With regard to the effect for response pattern found for the group with learning difficulties, it can be seen from Table 8.15 that the short movement pattern results in much greater VE than the long pattern for these children.

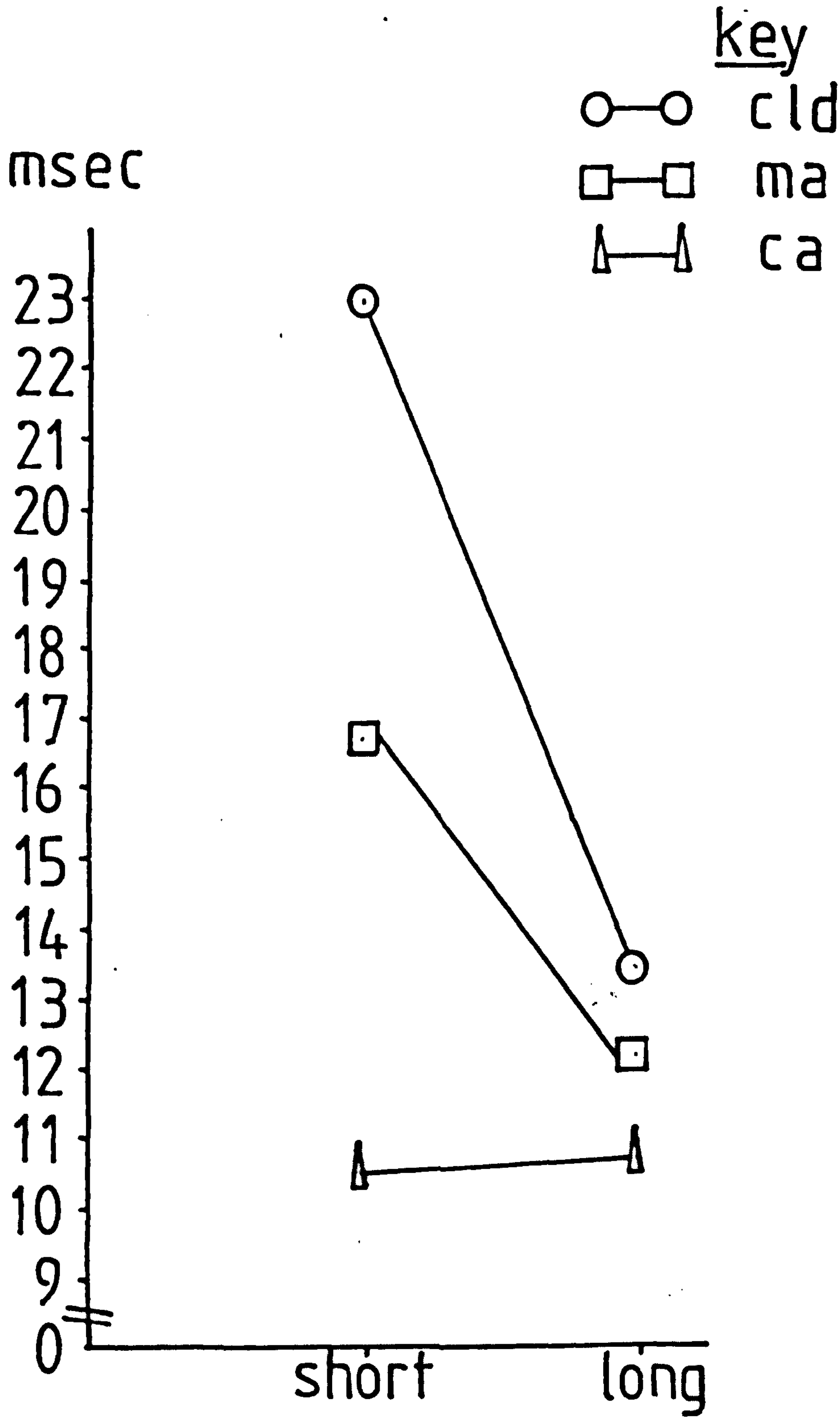



Figure 8.10: Performance of the 3 groups at 2 response patterns on recall (VE), coincidence timing task

(D) Performance on the 1st recall trial, day 2

The first attempt on day 2 was taken as an AE and a CE score, and the results subjected to a 3 (group) x 2 (response pattern) anova in both cases. VE is not a viable statistic. The reason for taking the first score in this way is that it is the only one of the 10 recall trials that is entirely dependent on the previous day's practice. The remaining 9 trials, and hence the mean, may be influenced by the preceding recall trial(s). The first score is the only real test of recall.

(i) AE

The 3 (group) x 2 (response pattern) anova for AE revealed significant main effects for group ($F(2, 77) = 7.17$, $p < .01$) and response pattern ($F(1, 77) = 5.22$, $p < .05$). The interaction between the two factors was not significant (See Appendix 6, Table 28).

With regard to the main effect for group, subsequent posthoc testing (Tukey HSD) revealed specific differences between the group with learning difficulties and the CA matched group ($p < .01$), the former exhibiting the greatest error (See Appendix 6, Table 29). The means for the 3 groups are shown in Table 8.16.

Table 8.16: Mean error of the 3 groups on the 1st recall trial (AE), coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 22.75 | 16.36 | 9.18 |

Consideration of the significant main effect for response pattern indicates that the short response pattern results in the greatest error overall, although this is not in fact the case for the CA matched group, as can be seen from Table 8.17.

Table 8.17: Mean error of the 3 groups and 2 response patterns, 1st recall trial (AE), coincidence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| Short | 29.00 | 20.73 | 8.50 |
| Long | 16.50 | 12.00 | 9.90 |

(ii) CE

The 3 (group) x 2 (response pattern) anova for CE revealed significant main effects for group ($F (2, 77) = 5.08$, $p < .01$) and response pattern ($F (1, 77) = 15.24$, $p < .01$) and a significant group x response pattern interaction ($F (2, 77) = 3.20$, $p < .05$). (See Appendix 6, Table 30).

The two main effects were disregarded and tests of simple main effects conducted on the significant group x response pattern ($F (2, 77) = 7.22$, $p < .01$), and for response pattern both for the group with learning difficulties ($F (1, 77) = 8.52$, $p < .01$) and for the MA matched group ($F (1, 77) = 12.62$, $p < .01$) (See Appendix 6, Table 31). Subsequent posthoc analysis (Tukey HSD) of the differences between groups revealed specific differences between the group with learning difficulties, and the CA matched group ($p < .01$) and between the MA and CA matched groups ($p < .05$). (See Appendix 6, Table 32). The means of the 3 groups and two response patterns are shown in Table 8.18 and Figure 8.11.

Table 8.18: Mean error of the 3 groups and 2 response patterns on the 1st recall trial (CE), coincidence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| Short | -27.46 | -20.73 | -3.79 |
| Long | -7.83 | 1.43 | -2.27 |

With regard to the significant simple main effect for response pattern for both the group with learning difficulties and the MA matched group, it can be seen from Table 8.18 that both these groups demonstrate similar trends, in that the error for the short response pattern is greater than for the long pattern, and in the case of the MA matched group, negative rather than positive. This is evidently not the case for the CA matched group.

(E) Performance on the transfer block of trials, day 2

The mean AE, CE and VE for the block of trials at the novel distance on day 2 was calculated for each individual and the results subjected to a 3 (group) x 2 (response pattern) anova in all cases. It must be noted that the response patterns are now opposite to those which the subjects have previously experienced,

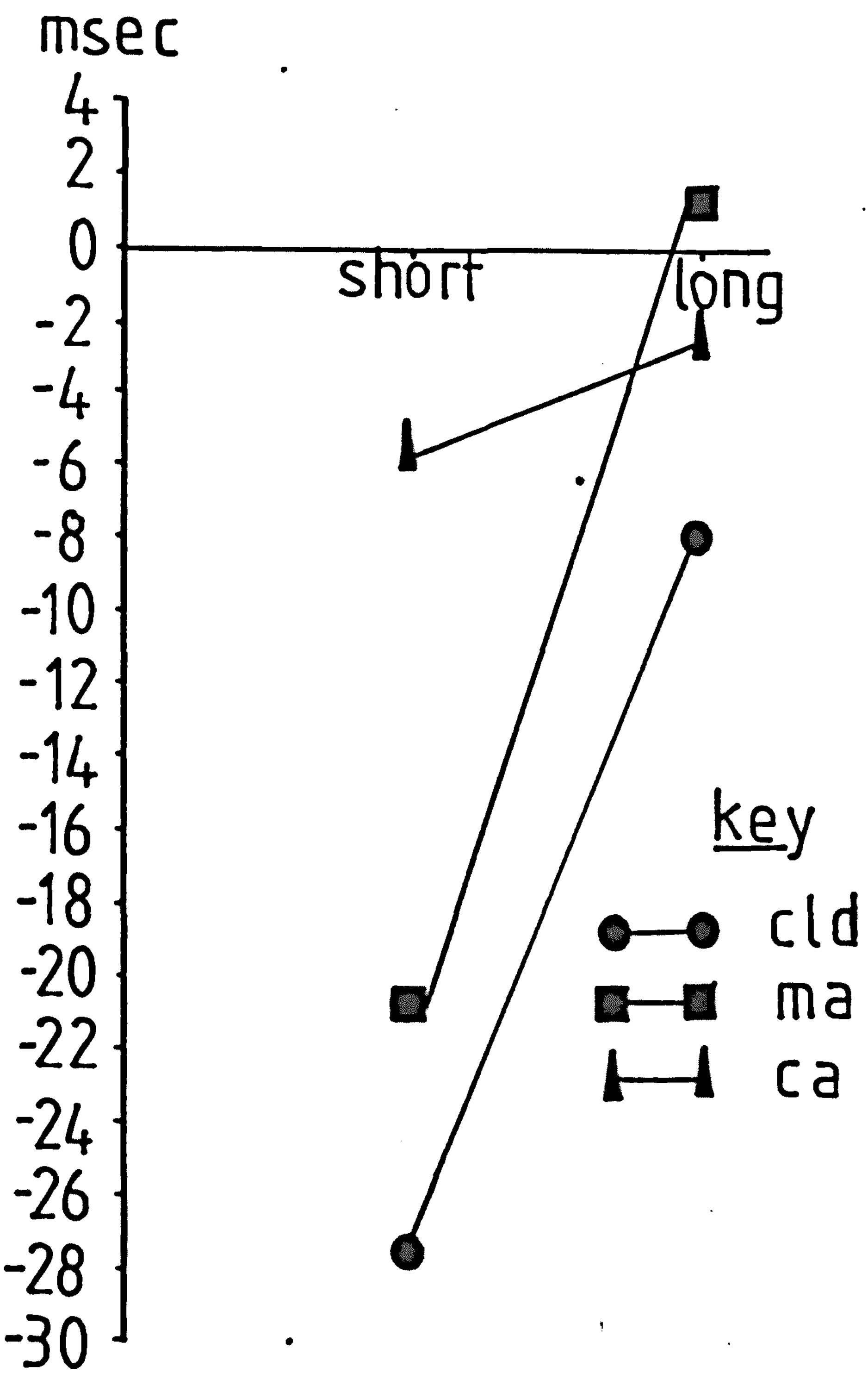



Figure 8.11: Performance of the 3 groups and 2 response patterns on the first recall trial (CE) coincidence timing task

in that those who have previously attempted the long response pattern now attempt theshort and vice versa. In terms of labelling, the groups will be designated L - S (long-short) for the former and S - L (short-long) for the latter.

(i) AE

The 3 (group) x 2 (response pattern) anova for AE revealed a significant main effect for group only ($F(2, 77) = 15.10$, $p < .001$). No effect for response pattern nor any interaction proved significant. (See Appendix 6, Table 33).

Posthoc analysis of the significant main effect for group (Tukey HSD) revealed specific differences between the group with learning difficulties and the CA matched group ($p < .01$) and between the CA and MA matched groups ($p < .01$). (See Appendix 6, Table 34), the group with learning difficulties exhibiting the greatest error, as can be seen from Table 8.19.

Table 8.19: Mean error of the 3 groups on the transfer trials, (AE) coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 39.69 | 32.99 | 14.32 |

(iii) CE

The 3 (group) x 2 (response pattern) anova for CE revealed a significant main effect for response pattern ($F (1, 77) = 104.65$, $p < .001$) and a significant group and response pattern interaction ($F (2, 77) = 13.13$, $p < .001$) (See Appendix 6, Table 35).

The main effect for response pattern was disregarded and tests of simple main effects conducted on the group and response pattern interaction. Overall simple effects were found for the following:-

(i) For group, at the long response pattern (S-L)($F(2, 77) = 7.71$, $p < .01$)

(ii) For group, at the short response pattern (L-S) ($F (2, 77) = 6.24$, $p < .01$)

(iii) For response pattern by the group with learning difficulties ($F (1, 77) = 76.52$, $p < .01$).

(iv) For response pattern by the MA matched group ($F (1, 77) = 45.18$, $p < .01$)

(v) For response pattern by the CA matched group ($F (1, 77) = 4.18$, $p < .05$)

(See Appendix 6, Table 36).

Posthoc analysis (Tukey HSD) of the differences between groups for the long response pattern (S-L) revealed specific differences between the group with learning difficulties and the CA matched group ($p < .01$)and the MA and CA matched groups ($p < .01$), the groups with learning difficulties exhibiting the greatest error, and the CA matched group the least. (See Appendix 6, Table 37). The means are shown in Table 8.20. Posthoc analysis (Tukey HSD) of the differences between groups for the short response pattern (L-S) revealed significant differences between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .05$). The means are shown in Table 8.20. (See Appendix 5, Table 38) and in figure 8.12.

Table 8.20: Mean error of the 3 groups and 2 response patterns on the transfer trials (CE) coincidence timing task

| Response Pattern | CLD | MA | CA |
|---|---|---|---|
| S-L | 35.86 | 31.99 | 7.66 |
| L-S | -35.92 | -19.21 | -7.90 |

With regard to the effect for response pattern, significant for all groups, although to a lesser extent for the CA matched group ($p < .05$), it can be seen from Table 8.20 that the pattern is consistent for all groups. The subjects moving from the long pattern to the short response pattern tend to be late in their response.

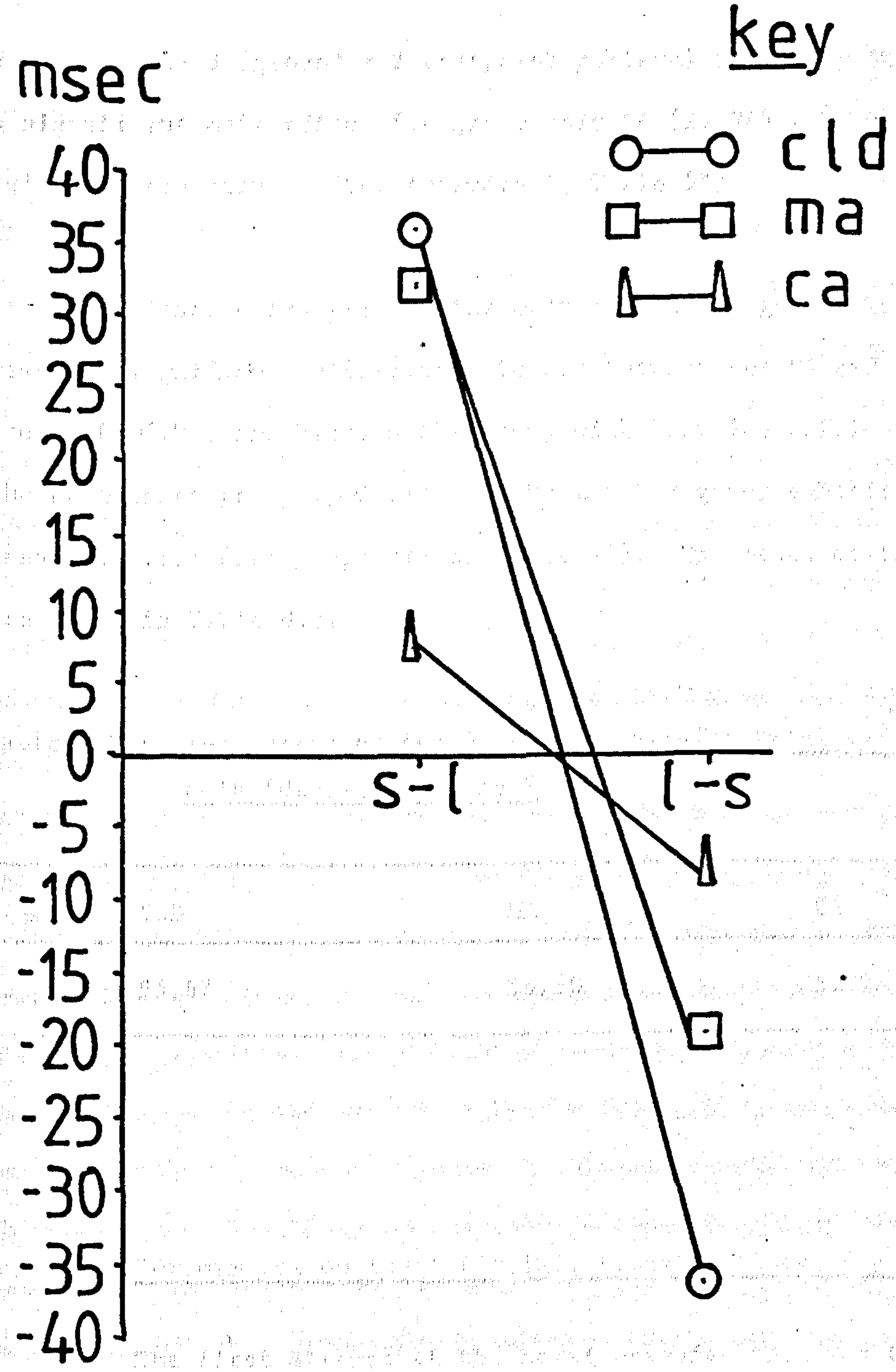



Figure 8.12: Performance of the 3 groups at 2 response patterns, transfer trials (CE), coincidence timing task

(iii) VE

The 3 (group) x 2 (response pattern) anova for VE revealed a significant main effect for group only ($F (2, 88) = 14.60$, $p < .001$) and no interaction. (See Appendix 6, Table 39).

Posthoc analysis of the main effect for group (Tukey HSD) revealed significant differences to lie between the MA and CA matched groups ($p < .01$) and between the group with learning difficulties and the CA matched group ($p < .01$), the MA matched group exhibiting the greatest error (See Appendix 6, Table 40). The means of the 3 groups are shown in Table 8.21.

Table 8.21: Mean error of the 3 groups, transfer trial (VE), coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 55.67 | 56.30 | 31.98 |

(F) Performance on the 1st trial, transfer block, day 2

The first attempt at the novel transfer task was taken as an AE and CE score, and then subjected to a 3 (group) x 2 (response pattern) anova in both cases. VE is not a viable statistic. The reason for this analysis is that the first trial is the only one that is wholly dependent on previous practice at the related task. Subsequent trials and therefore the mean of the block of ten may be influenced by practice during these trials. Each of the analyses will be considered in turn.

(i) AE

The 3 (group) x 2 (response pattern) anova for AE revealed a significant main effect for group only ($F(2, 77) = 6.16$, $p < .01$) and no interaction (See Appendix 6, Table 41).

Subsequent posthoc analysis (Tukey HSD) of the main effect for group revealed the only significant difference to lie between the group with learning difficulties and the CA matched group ($p < .01$). (See Appendix 6, Table 42). The means for the 3 groups are shown in Table 8.22.

Table 8.22: Mean error of the 3 groups, transfer trial 1 (AE) coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 56.00 | 42.25 | 18.76 |

(ii) CE

The 3 (group) x 2 (response pattern) anova for CE revealed a significant main effect for response pattern ($F(1, 77) = 47.02$, $p < .001$) and a significant group x response pattern interaction ($F(2,77) = 8.14$, $p < .001$). (See Appendix 6, Table 43).

The main effect for response pattern was disregarded and tests for simple main effects conducted on the group x response pattern interaction. Significant overall effects were found as follows:-

(i) For groups, attempting the long response pattern (S-L) ($F(2, 77) = 5{,}62$, $p < .01$).

(ii) For groups, attempting the short response pattern (L-S) ($F(2, 77) = 3.61$, $p < .05$).

(iii) For response pattern for the group with learning difficulties ($F(1, 77) = 38.77$, $p < .01$).

(iv) For response pattern,for the MA matched group ($F(1, 77) = 21.03$, $p < .01$).

(See Appendix 6, Table 44).

Subsequent posthoc analysis (Tukey HSD) of the differences between groups revealed the following specific differences.

(i) For the long response pattern between the group with learning difficulties and the CA matched group ($p < .05$).

(See Appendix 6, Table 45)

(ii) For the short response pattern (L-S) between the group with learning difficulties and the CA matched group ($p < .05$) and the MA and CA matched groups ($p < .05$).

(See Appendix 6, Table 46).

The means for the 3 groups and 2 response patterns are shown in Table 8.23, and in Figure 8.13.

Figure 8.13: Performance of the 3 groups at 2 response patterns, transfer trial 1 (CE), coincidence timing task

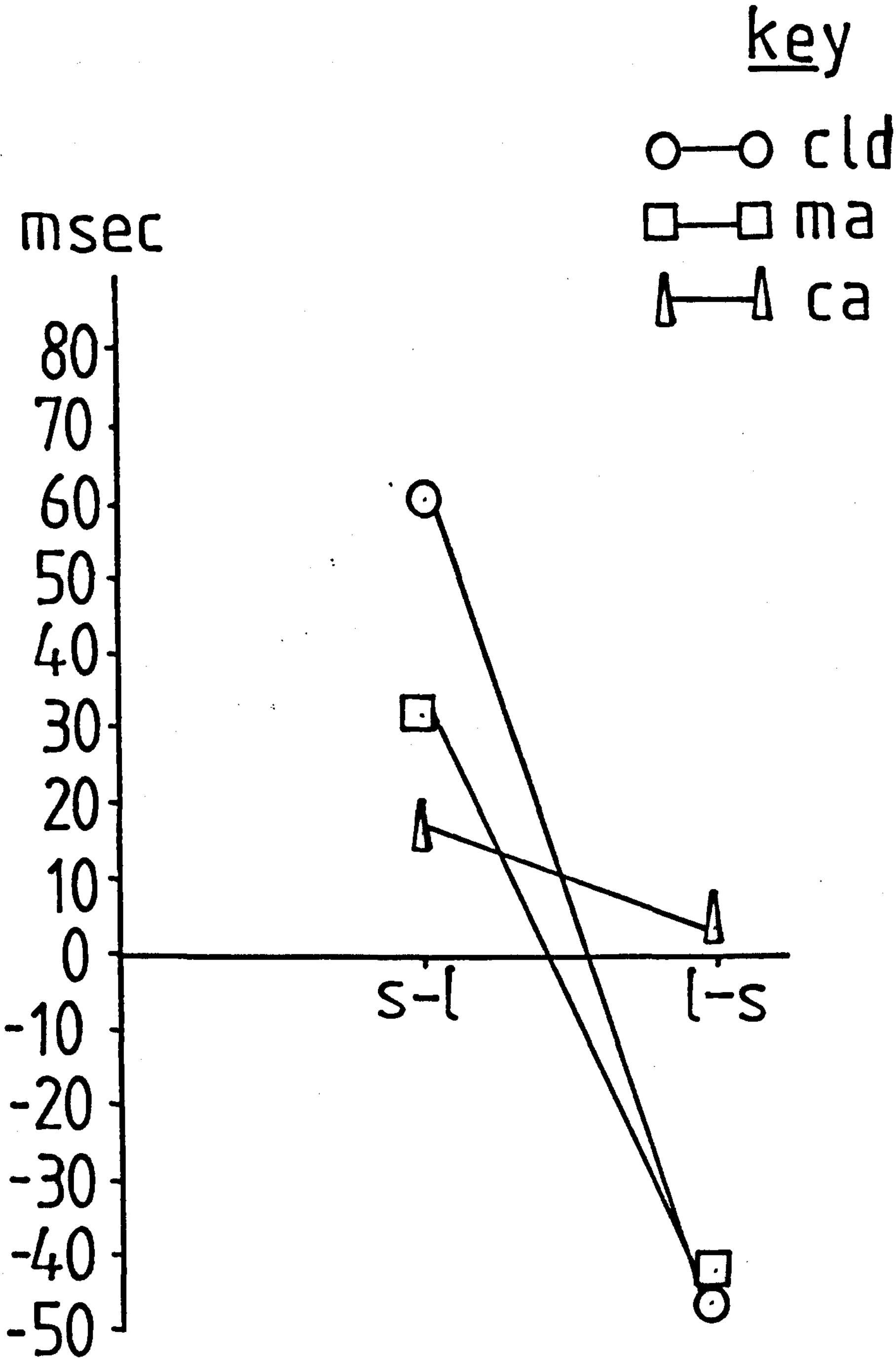


Table 8.23: Mean error of the 3 groups and 2 response patterns, 1st transfer Trial (CE), Coincidence timing task

| Response Pattern | CLD | MA | CA |
|---|---|---|---|
| S-Long | 61.77 | 32.20 | 17.64 |
| L-Short | -46.25 | -41.64 | 3.20 |

With regard to the differences found between response patterns for the groups with learning difficulties and the MA matched group, it can be seen from Table 8.23 that novel experience of the short response pattern resulted in highly negative CE scores, indicating responses made too early, whereas novel experience of the long response pattern resulted in highly positive CE scores, indicating responses made too late.

## (G) Performance over the recall and transfer blocks of trials, day 2

The purpose of this analysis was to determine any change in performance between the recall and transfer blocks of trials as a function of group or response pattern. Some findings were found to be a replication of those when the test and transfer blocks were considered separately. However, those analyses were not disregarded since certain features emerged from those analyses which were lost when the two blocks were considered together.

The mean AE, CE and VE for each block of 10 trials on day 2 was calculated for each individual and the results subjected to a 3 (group) x 2 (response pattern) x 2 (blocks) anova in all cases. Each of these will be considered in turn.

(i) AE

The 3 (group) x 2 (response pattern) x 2 (blocks) anova for AE revealed significant main effects for group ($F(2, 77) = 18.80$, $p < .001$) and blocks ($F(1, 77) = 36.73$, $p < .001$) and a significant group x block interaction ($F(2, 77) = 5.19$, $p < .01$). (See Appendix 6, Table 47).

The two significant main effects were disregarded and tests of simple main effects conducted on the group x block interaction. The following simple main effects were found to be significant.

(i) For group on the recall block ($F(2, 77) = 4.09$, $p < .01$)

(ii) For group on the transfer block ($F(2, 77) = 18.57$, $p < .01$)

(iii) For block on the part of the group with learning difficulties ($F(1, 77) = 12.75$, $p < .01$)

(iv) For block on the part of the MA matched group ($F(1, 77) = 17.86$, $p < .01$)

(See Appendix 6, Table 48).

With regard to the differences between groups on the recall and transfer blocks, similar differences were found when these blocks were analysed separately. Posthoc testing revealed the differences to lie specifically between the group with learning difficulties and the CA match ($p < .01$) and the group with learning difficulties and the MA match overall ($p < .01$) (Tukey HSD) (See Appendix 6, Table 49).

With regard to the differences between groups on transfer, posthoc testing (Tukey HSD) revealed the differences to lie between the group with learning difficulties and the CA matched group ($p < .01$) and the MA and CA matched groups ($p < .01$) (See Appendix 6, Table 34).

The mean for the 3 groups on recall and transfer are shown in Table 8.24 and in Figure 8.14.

Table 8.24: Mean error of the 3 groups on recall and transfer (AE), coincidence timing test

| | CLD | MA | CA |
|---|---|---|---|
| Recall | 23.11 | 15.22 | 12.09 |
| Transfer | 39.69 | 32.99 | 14.32 |

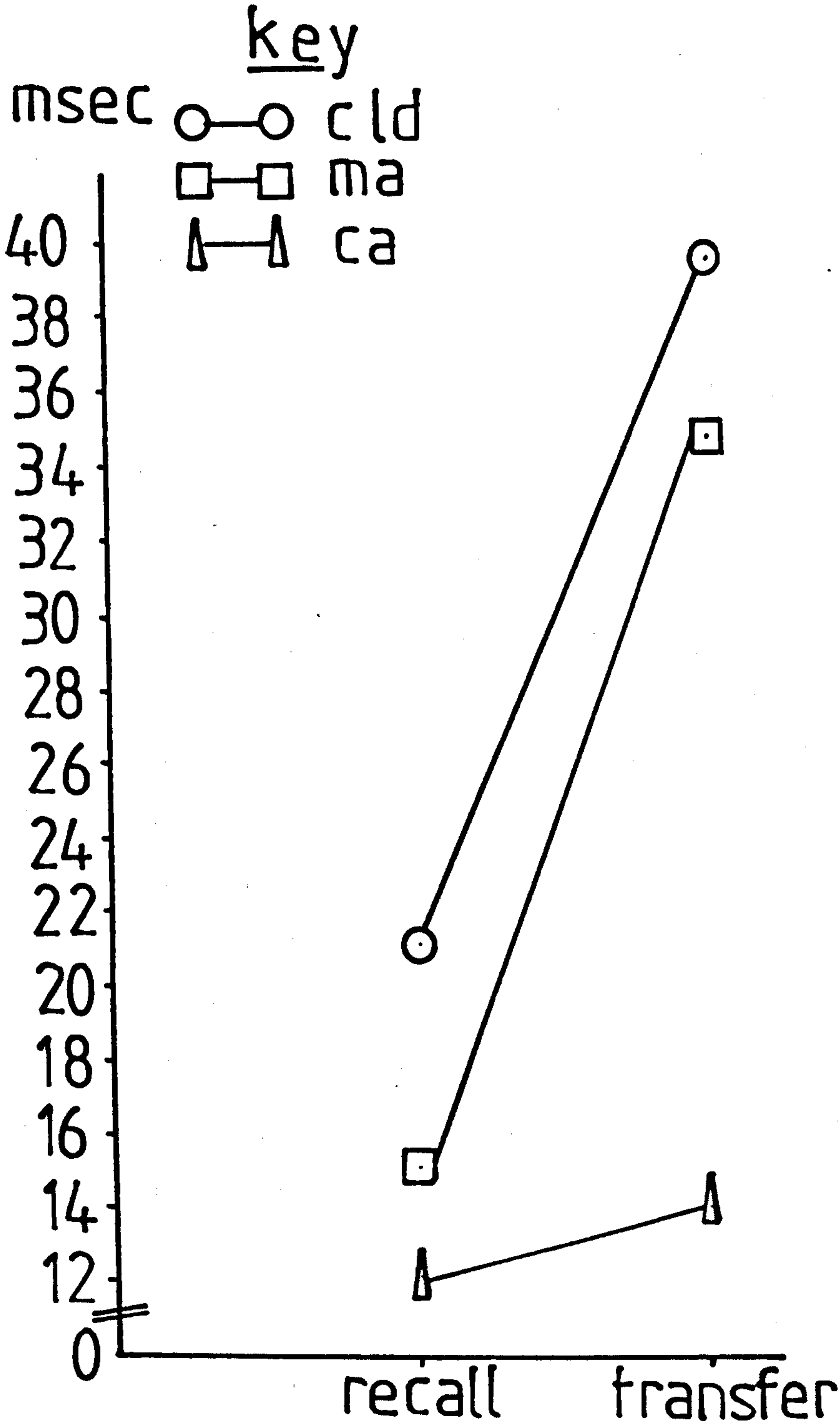



Figure 8.14: Performance of the 3 groups over the recall and transfer trial blocks (AE), coincidence timing task

With regard to the differences found between recall and transfer for the group with learning difficulties and the MA matched group it can be seen from Table 8.24 that both groups exhibit considerably less accuracy on the transfer task than the recall task. The difference between the two blocks for the CA matched group is marginal.

(ii) CE

The 3 (group) x 2 (response pattern) x 2 (blocks) anova for CE revealed significant main effects for response pattern ($F (1, 77) = 34.42, p < .001$) and blocks ($F (1, 77) = 15.09, p < .001$) and significant interactions between group and response patterns ($F (2, 77) = 3.57, p < .05$), between response pattern and blocks ($F (1, 77) = 123.58, p < .001$) and between group response pattern and blocks ($F (2, 77) = 17.94, p < .001$). (See Appendix 6, Table 50).

The main effects and two-way interactions were disregarded and tests of simple main effects conducted on the group x response pattern x blocks interaction. The following simple main effects were found to be significant:

(i) Between groups performing the short response pattern, on recall ($F (2, 77) = 4.58, p < .05$)

(ii) Between groups performing the long response pattern, on transfer (S-L) ($F (2, 77) = 6.88, p < .01$)

(iii) Between groups performing the short response pattern on transfer (L-S) ($F (2, 77) = 10.07, p < .01$).

(iv) Between response patterns for the group with learning difficulties, on recall ($F(1, 77) = 9.89$, $p < .01$)

(v) Between response patterns for the group with learning difficulties, on transfer ($F(1, 77) = 99.59$, $p < .01$).

(vi) Between response patterns for the MA matched group, on transfer ($F(1, 77) = 59.02$, $p < .01$).

(vii) Between response patterns for the CA matched group on transfer ($F(1, 77) = 5.45$, $p < .05$)

(viii) Between blocks for the group with learning difficulties performing the short response pattern on recall and long response pattern on transfer ($F(1, 77) = 89.05$, $p < .01$)

(ix) Between blocks for the group with learning difficulties performing the long response pattern on recall and short response pattern on transfer ($F(1, 77) = 24.27$, $p < .01$).

(x) Between blocks for the MA matched group performing the long response pattern on recall and short response pattern on transfer ($F(1, 77) = 7.66$, $p < .01$)

(xi) Between blocks for the MA matched group performing the short response pattern on recall and long response pattern on transfer ($F(1, 77) = 47.54$, $p < .01$)

(See Appendix 6, Table 51).

The following simple interactions were also found to be significant:-

(i) Group x response pattern on recall ($F(2, 77) = 8.25$, $p < .01$)

(ii) Group x response pattern on transfer ($F(2, 77) = 83.66$, $p < .01$)

(iii) Group x block for short response pattern on recall and long response pattern on transfer ($F(2, 77) = 18.24$, $p < .01$)

(iv) Group x block for long response pattern on recall and short response pattern on transfer ($F(2, 77) = 77.84$, $p < .01$).

(v) Response pattern x block for the group with learning difficulties ($F(1, 77) = 140.99$, $p < .01$)

(vi) Response pattern x block for the MA matched group ($F(1, 77) = 80.40$, $p < .01$)

(vii) Response pattern and block for the CA matched group ($F(1, 77) = 7.31$, $p < .01$)

(See Appendix 6, Table 51).

The differences found between groups on both recall and transfer and between response patterns for both these blocks have been considered earlier when the two blocks were taken separately. The following specific differences were found to be significant.

(i) On recall, performing the short response pattern between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$)(See Appendix 6, Table 24).

(ii) On transfer, performing the long response pattern (S-L) between the group with learning difficulties and the CA matched group ($p < .01$) and MA and CA matched groups ($p < .01$) (See Appendix 6, Table 37).

(iii) On transfer, performing the short response pattern (L-S) between the group with learning difficulties and the CA matched group ($p < .01$) and the group with learning difficulties and the MA matched group ($p < .01$) (See Appendix 6, Table 38).

(iv) For the group with learning difficulties on recall, greater error for the short response pattern (See Table 8.14).

(v) For the group with learning difficulties on transfer large negative error for the L-S group and large positive error for the S-L group (See Table 8.20).

(vi) For the MA matched group on transfer, large negative error for the L-S group and large positive error for the S-L group (See Table 8.20).

(vii) For the CA matched group on transfer, negative error for the L-S group and positive error for the S-L group (See Table 8.20).

With regard to differences between blocks, the means for the groups and response patterns are shown in Table 8.25 and in Figure 8.15.

Table 8.25: <u>Mean error for the 3 groups and 2 response patterns on recall and transfer</u>

| Group | Response Pattern | Recall | Transfer |
|---|---|---|---|
| CLD | S - L | -25.27 | 35.86** |
| | L - S | -2.70 | -35.92** |
| MA | S - L | -9.60 | 31.99** |
| | L - S | -1.79 | -19.21** |
| CA | S - L | -5.37 | 7.66 |
| | L - S | -2.73 | -7.90 (**$p < .01$) |

The four found to be significant are marked and it can be seen that for both low MA groups performing the short response pattern on recall and the long response pattern on transfer that the error changes in nature from negative to highly positive, whereas for

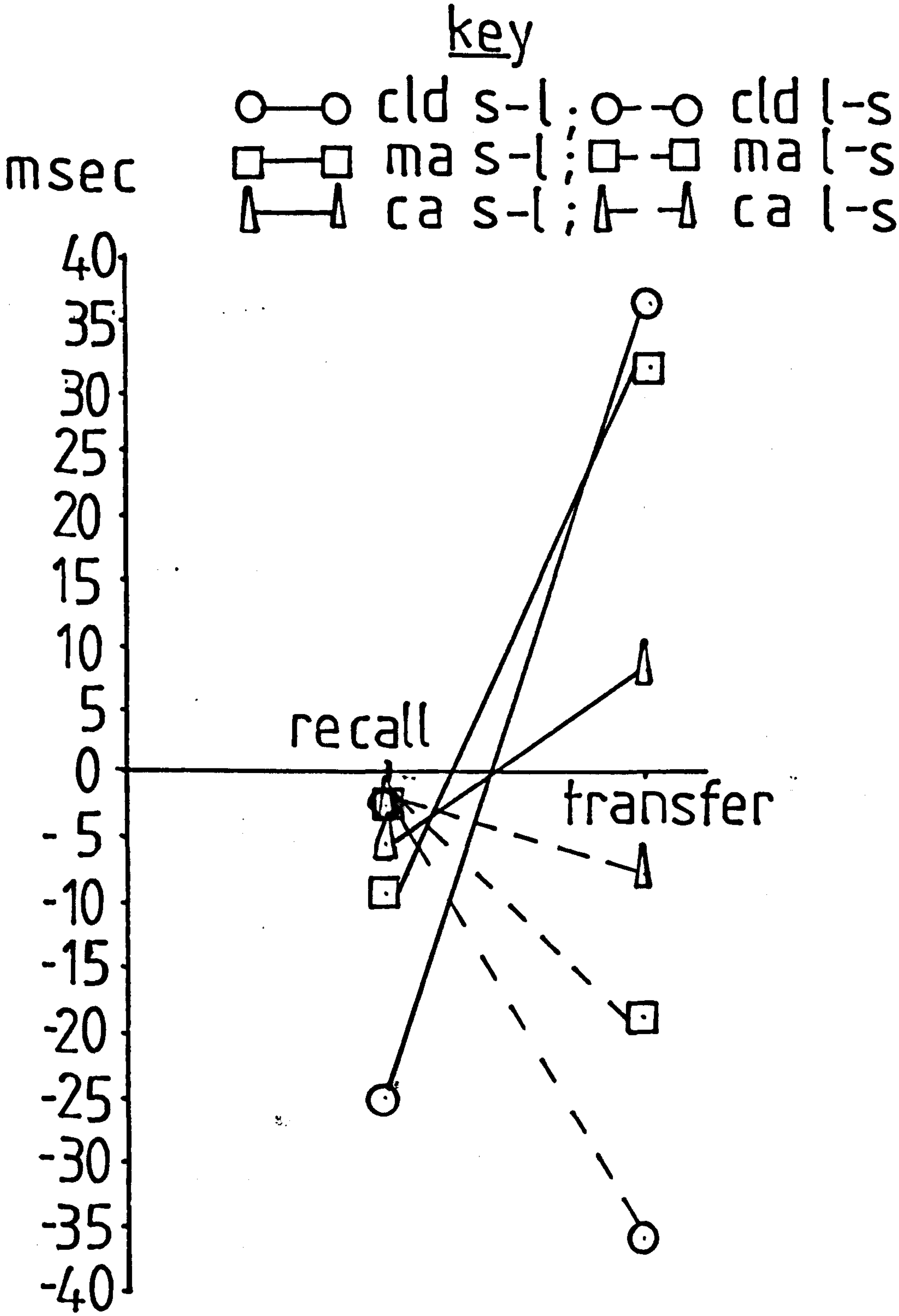



Figure 8.15: Performance of the 3 groups and 2 response patterns over recall and transfer trial blocks (CE), coincidence timing task

those attempting the long response pattern first, the direction of change is reversed.

(iii) VE

The 3 (group) x 2 (response pattern) x 2 (blocks) anova for VE revealed significant main effects for group ($F (2, 77) = 18.55$, $p < .001$) response pattern ($F(1, 77) = 4.52$, $p < .05$) and blocks ($F (1, 77) = 61.92$, $p < .001$), and a significant group x block interaction ($F (2, 77) = 4.11$, $p < .05$). (See Appendix 6, Table 52).

Subsequent examination of the main effect for response pattern demonstrates greater VE for the short response pattern on recall, long response pattern on transfer than for the long response pattern on recall, short response pattern on transfer. This trend is consistent for all three groups, as can be seen from Table 8.26.

Table 8.26: Mean error for the 3 groups and 2 response patterns, day 2, (VE), coindicence timing task

| Response pattern | CLD | MA | CA |
|---|---|---|---|
| S - L | 25.39 | 22.71 | 13.93 |
| L - S | 20.61 | 19.84 | 12.66 |

The main effects for group and block were disregarded and tests of simple main effects conducted on the significant group x block interaction. The following simple main effects were found to be significant:-

(i) Between groups on recall ($F(2, 77) = 5.69$, $p < .01$)

(ii) Between groups on transfer ($F(2, 77) = 19.39$, $p < .01$)

(iii) Between Blocks for the group with learning difficulties ($F(1, 77) = 13.98$, $p < .01$)

(iv) Between blocks for the MA matched group ($F(1, 77) = 33.78$, $p < .01$)

(v) Between blocks for the CA matched group ($F(1, 77) = 5.14$, $p < .05$)

(See Appendix 6, Table 53).

Previous analysis of the differences between groups on transfer demonstrated significant differences between MA and CA matched groups ($p < .01$) and the group with learning difficulties and CA matched group ($p < .01$) (See Appendix 6, Table 40). Posthoc analysis of the difference between groups on recall (Tukey HSD) revealed a significant difference between CLD and CA only ($p < .05$) (See Appendix 6, Table 54).

With regard to the differences found between blocks for all three groups, the means are shown in Table 8.27 and in Figure 8.16.

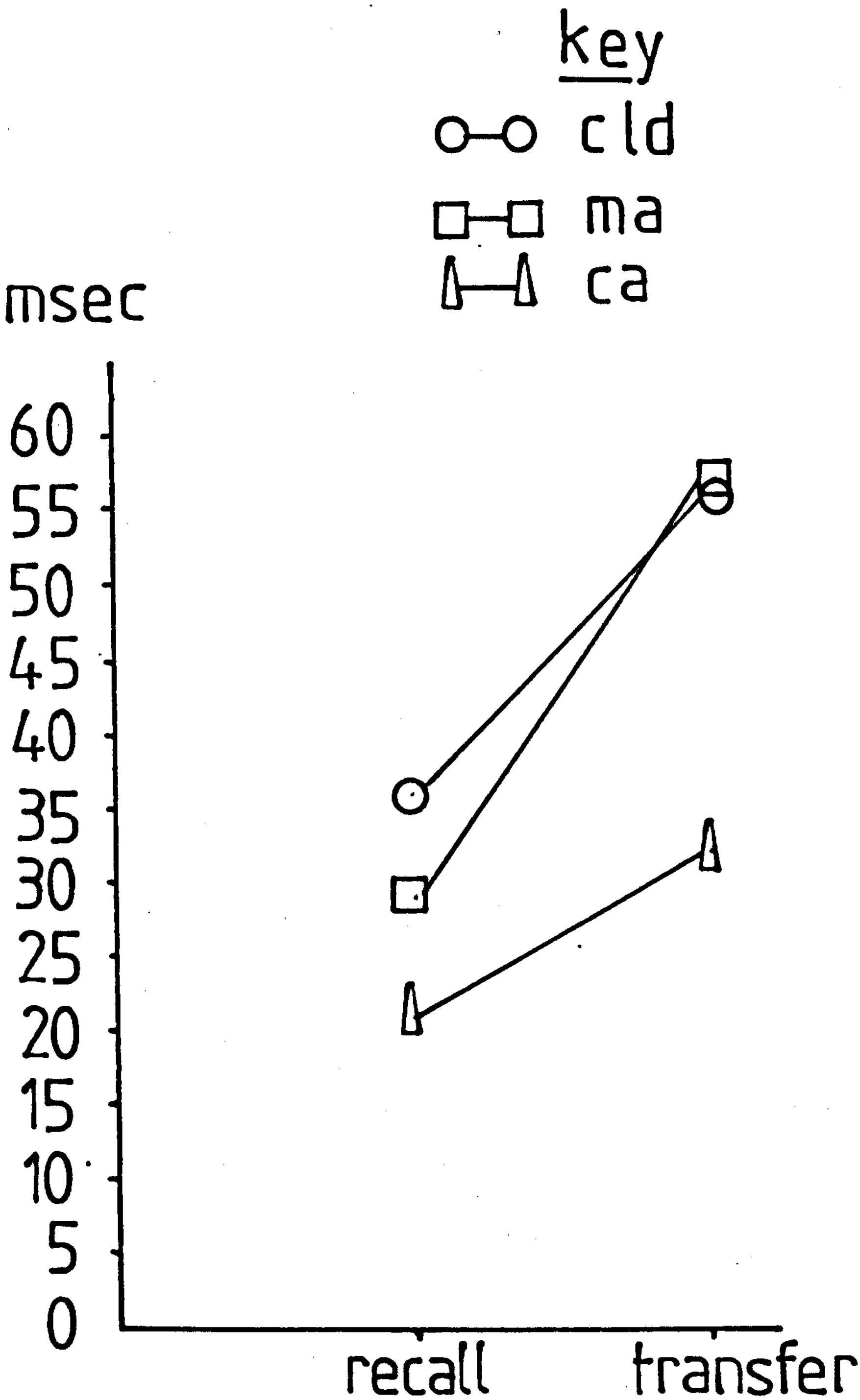



Figure 8.16: Performance of the 3 groups over the recall and transfer blocks (VE), coincidence timing task

Table 8.27: Mean error of the 3 groups over recall and transfer trials, (VE), coincidence timing task

| TrialBlock | CLD | MA | CA |
|---|---|---|---|
| Recall | 36.32 | 28.80 | 21.18 |
| Transfer | 55.67 | 56.30 | 31.98 |

As can be clearly seen, VE increases on transfer particularly in the case of the group with learning difficulties and their MA matched group.

(H) Performance on the 1st recall and 1st transfer trials, day 2

The purpose of these analyses was to compare performance unaffected by previous trials on that day with performance on a novel task unaffected by previous attempts at that task. The first score of each of the trial blocks on day 2 was taken and used both as AE and CE and subjected to a 3 (group) x 2 (response pattern) x 2 (blocks) anova in both cases. VE is not a viable statistic.

(i) AE

The 3 (group) x 2 (response pattern) x (trials) anova for AE revealed significant main effects for group ($F(2, 77) = 10.91$, $p < .001$) and trials ($F(1, 77) = 23.39$, $p < .001$). No effect for response pattern nor any interaction was significant. (See Appendix 6, Table 55).

With regard to the main effect for group, posthoc analysis (Tukey HSD) revealed specific differences to exist only between the group with learning difficulties and the CA matched group ($p < .01$), the former exhibiting the greatest error. (See Appendix 6, Table 56). The means for the three groups are shown in Table 8.28.

Table 8.28: Mean error of the 3 groups, 1st recall and transfer trials (AE), coincidence timing task

| CLD | MA | CA |
|---|---|---|
| 39.37 | 29.31 | 13.97 |

The means for the two trials on day 2 can be seen in Table 8.29. As can be seen, the error recorded for the first transfer trial is considerably greater than that recorded for the first recall trial.

Table 8.29: Mean error for the 1st recall and transfer trials (AE), coincidence timing task

| 1st recall trial | 1st recall trial |
|---|---|
| 15.92 | 38.23 |

(ii) CE

The 3 (group) x 2 (response pattern) x 2 (trials) anova for CE revealed significant main effects for response pattern ($F\ (1, 77) = 21.92$, $p < .001$) and trials ($F\ (1, 77) = 9.38$, $p < .01$) and interactions between groups and response pattern ($F(2, 77) = 3.91$, $p < .05$), between trials and response pattern ($F\ (1, 77) = 70.24$, $p < .001$) and between group response pattern and trials ($F(2, 77) = 12.17$, $p < .001$) (See Appendix 6, Table 57).

In view of the three way interaction, the main effects and two way interactions were disregarded. Tests of simple main effects were then conducted on the group x response pattern x trials interaction. The following simple main effects were found to be significant.

(i) Between groups for those attempting the short response pattern on transfer (L - S) ($F(2, 77) = 9.80$, $p < .01$).

(ii) Between groups for those attempting the long response pattern on transfer (S - L) ($F\ (2, 77) = 6.27$, $p < .01$).

(iii) Between response patterns for the group with learning difficulties on transfer ($F\ (1, 77) = 67.41$, $p < .01$).

(iv) Between response patterns for the MA matched group on transfer ($F\ (1, 77) = 36.56$, $p < .01$).

(v) Between trials for the group with learning difficulties performing the long response pattern on recall and short response pattern on transfer (L - S) ($F$ (1, 77) = 9.47, $p < .01$).

(vi) Between trials for the group with learning difficulties performing the short response pattern on recall and long response pattern on transfer (S - L) ($F$ (1,77) = 55.43, $p < .01$).

(vii) Between trials for the MA matched group performing the short response pattern on recall and long response pattern on transfer (S - 1) ($F$ (1, 77) = 22.44, $p < .01$).

(viii) Between trials for the MA matched group performing the long response pattern on recall and short response pattern on transfer (L - S) ($F$ (1, 77) = 13.86, $p < .01$).

(See Appendix 6, Table 58).

The following simple interactions were also found to be significant:-

(i) Group x trials for the short response pattern on recall, long response pattern on transfer ($F$ (2, 77) = 47.06, $p < .01$).

(ii) Group x trials for the long response pattern on recall, short response pattern on transfer ($F(2, 77) = 17.87$, $p < .01$).

(iii) Group x response pattern on recall ($F(2, 77) = 4.20$, $p < .05$).

(iv) Group x response pattern on transfer ($F(2, 77) = 54.27$, $p < .01$).

(v) Trials x response pattern for the group with learning difficulties ($F(1, 77) = 90.83$, $p < .01$).

(vi) Trials x response pattern for the MA matched group ($F(1, 77) = 46.63$, $p < .01$).

(vii) Trials x response pattern for the CA matched group ($F(1, 77) = 4.32$, $p < .05$).

(See Appendix 6, Table 58).

Posthoc analysis of the differences between groups performed earlier (Tukey HSD) revealed the following specific differences:-

(i) Between the group with learning difficulties and the CA matched group ($p < .05$) and the MA and CA matched groups ($p < .05$) performing the short response pattern (L-S), transfer trial 1. (See Appendix 6, Table 46).

(ii) Between the group with learning difficulties and the CA matched group ($p < .05$) performing the long response pattern (S-L), transfer trial 1. (See Appendix 6, Table 45).

With regard to the simple main effect for response pattern for both the group with learning difficulties and the MA matched group on transfer, it can be seen from Table 8.30 and Figure 8.17 that the trend is consistent for both groups, and is such that those attempting the short response pattern on transfer exhibit high negative rror, whereas those attempting the long response pattern record a high positive error score.

Examination of Table 8.30 and Figure 8.17 give some insight into the effect for trials found for both response patterns for both low MA groups. In all cases the CE score deviates from zero to a greater extent on transfer than on recall and in three of the four cases in the opposite direction.

Table 8.30: Mean error for the 3 groups and 2 response patterns on 1st recall and transfer trials (CE)

| Group | Response pattern | 1st recall trial | 1st recall trial |
|---|---|---|---|
| CLD | S-L | -27.46 | 61.77 |
| | L-S | -7.83 | -46.25 |
| MA | S-L | -20.73 | 32.30 |
| | L-S | 1.43 | -41.64 |
| CA | S-L | -3.79 | 17.64 |
| | L-S | -2.27 | 3.20 |

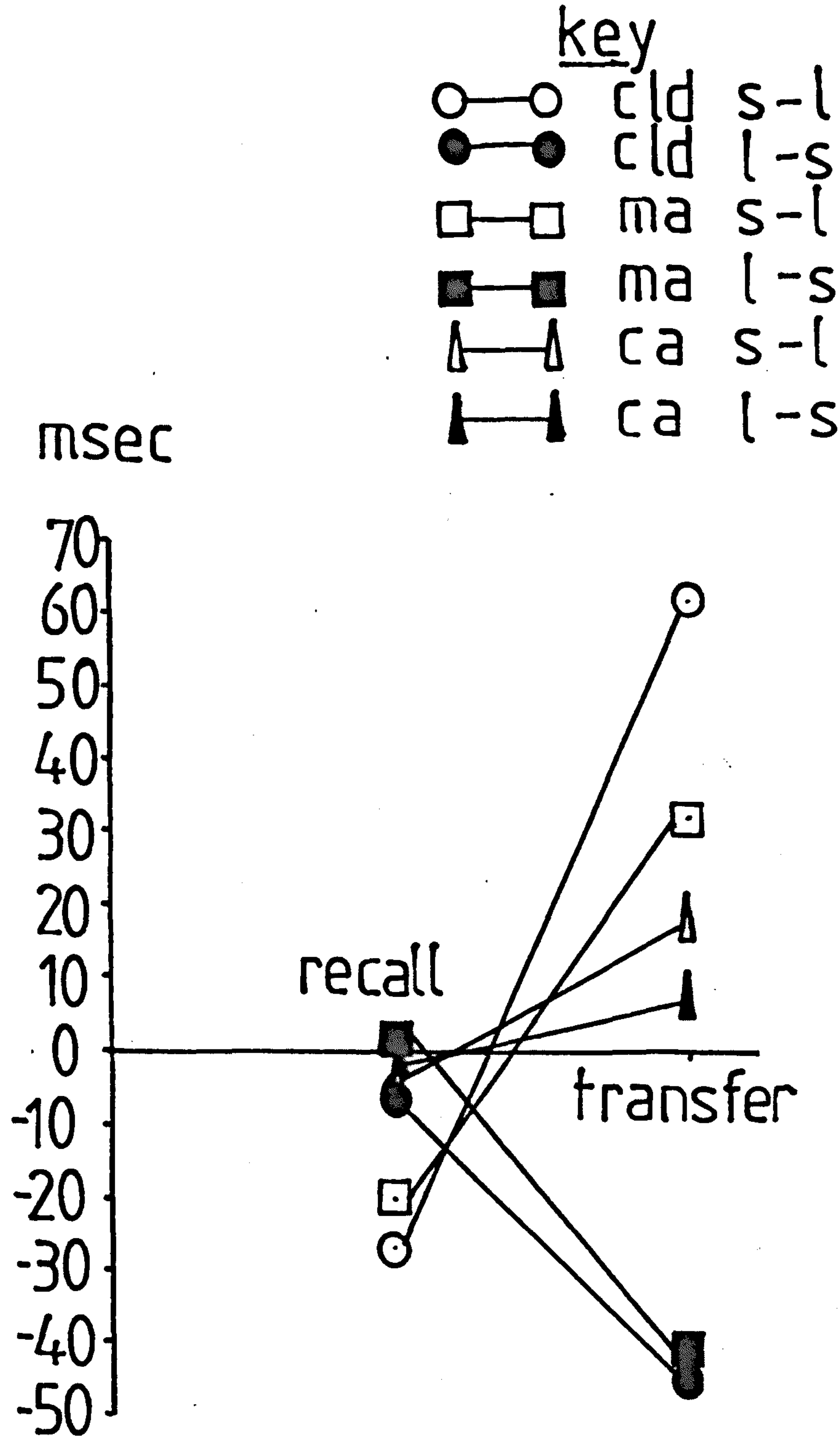



Figure 8.17: Performance of the 3 groups and 2 response patterns over 1st recall and transfer trials (CE), coincidence timing task

(c) DISCUSSION

The discussion will take the same form as the results section, insofar as each of the analyses will be considered in turn, although there will also be a general discussion in conclusion.

(A) <u>Performance over six blocks of 10 trials, day 1</u>

For both AE and VE, some evidence of improvement and reduction in error is seen to occur over time. For CE, the pattern is rather different, in that error does not approximate zero with progressive trial blocks, but would appear to indicate that, overall, the subjects arrived increasingly early at the coincident point. The fact that the values of CE are very small in comparison with the AE scores would indicate a cancelling out effect of positive and negative scores. This is possibly the effect of two response patterns, since the error scores for one (long) are generally positive and those of the other (short) generally negative. However, consideration of AE and VE suggests that some learning is taking place, particularly during the early stages, since in both cases, the significant differences are between block 1, and the remaining 5 blocks, and to a lesser extent between blocks 2 and 5 and 2 and 6. The fact that learning takes place at all is in accordance with other research findings (e.g. Dorfman, 1977; Dunham, 1977, Wrisberg and Mead, 1981 and 1983). The kind of performance or learning curve that results can be termed negatively accelerated (see Figure 8.4), indicating that the children concerned are managing to sort out the task requirements early, and make fast initial progress. The absence of any group x trial blocks or response pattern x trial blocks interaction suggests this is the case for all groups of children in the study, although some are performing at a higher level than others.

The difference between the groups found for both AE and VE suggest that the group with learning difficulties is less able than the two other groups to cope with the task. In both cases, the group with learning difficulties falls very much behind their CA matched peers, and also some way behind their MA matched peers. The very high mean AE scores recorded for the group with learning difficulties by comparison with the two remaining groups suggest that the two matched groups are more related to each other than to the group with learning difficulties. The inferior performance by the group with learning difficulties would not appear to be supported by the findings of Wade (1980). However, it must be noted that the types of response required by the two tasks are very different, and although they both involve coincidence behaviour, this may account for some of the differences found. Variability of performance by children with learning difficulties on coincidence timing tasks has been studied by McGown, Dobbins and Rarick (1973), who found such children more variable in their performance than children from within the range of normal intelligence, a finding that would appear to be supported by the study.

The difference found for CE between the two response patterns is interesting in that for the group with learning difficulties at least, it would appear that the short movement pattern generates a response made too early. The longer response pattern, however, results in arrival at the coincidence point too late. Almost significant is the main effect for response pattern for VE ($p < .0531$), which shows greater VE for the short response pattern (20.77) than for the long response pattern (17.37). This is in contrast to the findings of Jensen, Picado and Morenz (1981) who found no differences in variability between movement response varying in distance. However, their shorter distance did not result in the same kind of "ballistic" response employed in the present study.

In general, it can be tentatively suggested that although all groups are apparently capable of improvement in the task, the group with learning difficulties performs at a level much lower in terms of accuracy of time than their MA or CA matched peers, on this coincidence timing task.

(b) Performance over the 2 practice sessions, morning and afternoon, day 1

The results of the analyses when the data is blocked into two sessions are similar to those when the six blocks of trials were considered.

With regard to the differences that exist between groups, both AE and VE show the group with learning difficulties to be performing at a lower level than their CA matched peers, and in the case of VE, worse than their MA matched peers. The difference between the two groups from within the range of normal intelligence but of differing chronological ages is in accordance with research findings elsewhere (e.g. Dorfman, 1977; Dunham, 1977, Bard, Fleury, Carrière and Bellec, 1981).

The differences between the groups are highlighted by this analyses, since (for AE) for the CA matched group, no difference was found between the two sessions, and the mean AE score recorded by these children for the morning session is considerably less than that achieved by either of the low MA groups at any time. The CA matched group would appear to have reached maximum performance over the first three blocks of trials; the afternoon session takes the form more of consolidation of the task learned. This will have particular relevance for the trials on day 2, when the research findings concerning overlearning (e.g. Melnick 1971) are considered. Overlearning is generally found to aid in subsequent recall, so if it is the case that the CA matched group has effectively overlearned the task, one might expect considerably better recall by these subjects on the following day.

The CE analyses, as for the analysis of the six trial blocks, show increased negative error over time. The high negative error recorded by the group with learning difficulties performing the short response pattern is again influential in the resulting difference between response patterns for that group.

In general, the results of the analysis of the two practice sessions can be interpreted in the same light as the analyses of all six trial blocks.

(c) Performance on the block of recall trials, day 2

The results for AE, CE and VE demonstrate a similar pattern. In all cases, there is a significant group x response pattern interaction with significant differences between groups emerging for the shorter response pattern only. In all cases, it is the group with learning difficulties that appears to generate by far the greatest error, significantly inferior to the CA and MA matched groups in both AE and to the CA matched group in terms of VE. Apparently, the group with learning difficulties experiences greater problems at this stage with the task than the other two groups.

The significant effect for response pattern for the group with learning difficulties, for whom the mean error for the short response pattern is very large in all cases, would suggest that it is this response with which these children have particular difficulty. The task itself involves waiting for some considerable length of time before initiating a response. In some ways, this situation is analogous to that in which subjects are required to make a coincidence response to a slow moving target, in that such a task also necessitates waiting some time before responding. Research findings by such as Wade (1980) and Wrisberg and Mead (1981) suggest that such children experience greater problems with slow moving targets, generally responding too early. The same holds true in this experiment: the group with learning difficulties in particular generate significantly greater error on the short response patternfor all statistics, and comparison of the mean for AE (30.58) with that for CE (-25.28), since there is little difference between them, suggests that the majority of the responses are made too early.

Since the group with learning difficulties performed at a lower level than the two matched groups during practice, one cannot reasonably expect them to equal them on recall. If one takes the mean of trial block 6, day 1 and compares it with that of the recall block, some measure of percentage recall may be gained.

Table 8.31: Performance on practice block 6, recall block and percentage gain (AE), coincidence timing task

| Group | Block 6 | Recall Block | Percentage forgotten |
|---|---|---|---|
| CLD | 21.72 | 23.11 | -6.40% |
| MA | 12.93 | 15.26 | -18.02% |
| CA | 10.92 | 11.03 | -1.01% |

As can be seen, the relative forgetting is least by the CA matched group but greatest by the MA matched group, suggesting that the amount of learning recalled is greater for the group with learning difficulties than the MA matched group, although comparison of the absolute scores states the group with learning difficulties to be inferior. In terms of amount recalled, this is not the case.

(D) Performance on the 1st recall trial, day 2

In this study, the first trial on day 2, the first recall trial, is the only real test of memory or recall, since it is in the only trial entirely dependent on the previous day's practice. All subsequent trials may be the result of further practice on day 2, and therefore not a true test of recall alone. Vision was available throughout the task and on all trials and this fact enhances the possibility of improvement over the ten recall trials, the mean of the ten trials therefore being influenced by such learning. On the whole, however, the results of the analyses taking all ten trials and the first alone, suggest similar trends.

Unlike the analysis for the ten trials, the results of the AE and CE analyses here differ slightly in that no group x response pattern interaction is evident for AE. However, the main feature is again evident, the high error scored by the group with learning difficulties. As was discussed in the previous section, this might be expected since they recorded higher error scores on day 1. The group means for recall trial 1 and trial block 6 are shown in Table 8.23, and as can be seen, the relative increase in error is greater for the MA match than for the group with learning difficulties. The CA matched group actually demonstrates improvement on recall.

Table 8.32: Performance on trial block6, and first recall trial and relative loss/gain (AE), coincidence timing task

| Group | Trial block 6 | 1st Recall Trial | % Loss/Gain |
|---|---|---|---|
| CLD | 21.72 | 22.75 | -4.7% |
| MA | 12.93 | 16.37 | -26.6% |
| CA | 10.92 | 9.19 | +15.84% |

Based on this table, the implication is that whilst one acknowledges that the group with learning difficulties has not mastered the task to the extent of the two remaining groups, as witnessed by the significantly greater error during practice, they do appear to be more capable of recall of the task learned than those children matched with them on mental age. However, in no way do they match up to the group matched with them on chronological age.

The differences found between response patterns at this stage are consistent with those found when all ten trials were considered, and can be interpreted in the same light. With regard to AE, the short response pattern results in the greater error, and in the majority of cases the responses would appear to be made too early, as witnessed by the negative CE scores.

(E) Performance on the transfer block of trials, day 2

The question at issue here is whether or not the children are able to utilise previous experience of seeing the ball roll down the chute and make a response to it that is somewhat different to that practised on day 1. Whilst the stimulus remains constant, the response must be altered, in order to be successful. Given that there appear to be differences in terms of error, amount and direction generated between groups and between response patterns during practice and recall, the question is further posed as to whether these trends remain or alter in some way on transfer.

Certainly, in terms of group differences, there remain differences between the groups. However, the pattern changes slightly, in that during practice and recall, differences have tended to emerge between the group with learning difficulties and the two remaining groups, whereas on transfer, the differences tend to lie between the two younger MA groups and the older MA group, with little difference apparent between the first two. Furthermore, with regard to the VE analysis, it is the first occasion in this study on which the mean error score for the MA matched group has exceeded that of the two chronologically older groups, albeit only marginally. The CA matched group remains superior throughout. The MA matched group would appear to find the transfer task differentially more difficult.

The question of the value of the previous practice experience in attempting the transfer task should also be considered. Comparisons between recall and transfer will be made in subsequent sections, but the means for the first trial block on day 1 and the transfer block on day 2 are shown in Table 8.33, and from this it can be inferred that only the CA matched group would appear to have benefitted from the 60 trials on day 1 and 10 recall trials on day 2 (AE).

Table 8.33: Performance on the first trial block, day 1 and the transfer trial block, day 2 (AE), coincidence timing task

| Trial block | CLD | MA | CA |
|---|---|---|---|
| Trial block 1 day 1 | 37.29 | 24.25 | 15.60 |
| Transfer Block day 2 | 39.69 | 32.98 | 9.32 |

For both the group with learning difficulties and the MA matched group, the mean error scores are actually higher on transfer, than on the first trial block. One could tentatively suggest that previous practice with a different response pattern is having an interfering or negative transfer effect for the two low MA groups. They are apparently unable to sort out the different task requirements, and possibly continue using as inappropriate cues during the transfer phase those used during recall and practice. It could be argued that the higher error scores on the final trial block are the result of boredo

However, this is thought to be unlikely, since all groups appeared to continue enjoying the task.

The differences found between the response patterns are in the direction expected, with the short response resulting in greater negative CE, indicating a response made too early, and the long response pattern resulting in error scores either positive (for the group with learning difficulties and the MA matched group) or negative, but to a lesser extent, (for the CA matched group). What would appear to be happening here is that the two low MA groups in particular are using the cues that they found to be successful for the first movement response pattern, and applying them with relatively little modification to the present response pattern. The CA matched group is apparently more able to modify the use of the cues to the novel task. The actual differences between the values of the error scores for the two response patterns is very much greater than at any stage so far; the trends remain the same, but are accentuated, presumably by the application of inappropriate cues.

(E) Performance on the first transfer trial, day 2

The first attempt at the novel, but related, task is the only real measure of the generalisation of previous experience and practice to the present task. Taking the mean of all 10 transfer trials will not give such a clear indication since trials 2 to 10 are possibly influenced by practice of the transfer task itself, thus influencing the mean of the trial block. The first trial is the only one entirely dependent on previous experience, and because of this, there is value in its consideration. However, in spite of these arguments, in this instance the two analyses reflect similar trends, in some respects, and can be interpreted in the same light.

The group differences again suggest superior performance by the CA matched group, with the group with learning difficulties exhibiting the highest score errors for both AE and CE. The differences between response patterns in terms of CE for the two low MA groups are again in the direction expected with the short response pattern resulting in negative scores and the long response pattern resulting in positive scores. The CA matched group appears even at this stageto have considered previous experience and the modifications necessary to ensure success at the present task.

(G) Performance over the recall and transfer blocks, day 2

The main focus of interest here is the change in performance over the two trial blocks on day 2. The analyses in terms of group and response pattern have largely been considered in previous sections which related to one trial block only.

Both the AE and VE analyses revealed a decrement in performance by the group with learning difficulties and the MA matched groups over blocks, at a high level of significance. Only the VE analysis revealed any decrement for the CA matched group ($p < .05$ only). As can be seen from Tables 8.24 and 8.26, the decrement for the low MA groups is of quite a high order, particularly for the MA matched group, for whom the increase in both cases approximates 100%. It would appear from this that such children are not able to utilise previous experience on the novel task, although it could be argued that in fact this is less true of the group with learning difficulties than the MA matched group, since the AE increase for the former group is in the order of 72% by comparison with the 92% increase for the MA matched group. This is true also for the VE increases, 53.28% for the group with learning difficulties and 95.49% for the MA matched group.

The CE analyses are also interesting here, in respect of the nature of the changes that take place. Overall, the error deviates from zero to a greater extent on transfer than on recall, presumably the result of a novel task. In addition, at least for the two low MA groups, the direction of the CE score alters as a function of the response pattern. For the group attempting the long response pattern on recall and short response pattern on transfer, the error changes from slightly negative to highly so, arriving too early at the coincidence point. The error pattern is reversed for those attempting the response patterns in the reverse order, with highly positive error scores for the long response pattern on transfer. These patterns are similar to those found during practice for the two response patterns, although possibly they are more accentuated here, since some negative transfer is apparently occurring from the response pattern attempted. The CA matched group remains superior, alone in their ability to make the cognitive exercises and transformations necessary to successful performance on transfer.

(H) Performance on the 1st recall and 1st transfer trials, day 2

The analyses done here generally reflect the trends of those discussions in the previous section. This might be expected since the individual score analyses of the two blocks separately also reflected the trends of those when the mean of the ten trials was taken. For this reason, many of the results can be interpreted in the same light.

The AE analyses show clear distinctions between groups and between trial blocks, the group with learning difficulties again exhibiting the greatest error, and performance deteriorating from recall to transfer. For CE, the difference between recall and transfer is again only found for the two low MA groups, and again, the direction of the error is a function of the response pattern being attempted. These trends were all evident when the means of both recall and transfer trial blocks were considered.

(J) General discussion and Conclusions

Throughout the three phases of this study, the practice trials, the recall trials and the transfer trials, the group with learning difficulties is performing at a lower level than both groups matched on CA and MA, recording the highest error scores in all cases bar one. Although it is in contrast to the findings of Wade (1980), McGown, Dobbins and Rarick (1973) found greater variability by low intelligence subjects, and it must be recalled that the tasks used by neither Wade (1980) nor McGown, Dobbins and Rarick (1973) would fall into the same category as the task employed in this study. This fact alone may account for the anomalies present. The differences between the MA and CA matched groups may be anticipated on the basis of previous findings related to age differences (e.g. Dorfman, 1977; Dunham, 1977) although again, the tasks used are fundamentally different to that employed here. There can be no real doubt that on this particular task at least the children with learning difficulties fall well behind their peers. This is not to say that this is the case for all the children within that group, as there may well be an overlap, but as a group it most certainly is true. However, one also needs to consider the amount recalled in relation to previous learning, and the amount of transfer in relation to such. When this approach is taken, although the group with learning difficulties in no way matches their unmatched peers, they would appear to fare well in comparison with their MA matched peers. Greater increases in error are exhibited by the latter group on day 2 than either of the two chronologically older groups. However, the group with learning difficulties remains at a lower absolute level of performance than the two matched groups.

The fact that all groups are capable of learning is witnessed by the improvement of all groups over the six trial blocks, although the nature of the resultant learning curves differs according to group when the two practice sessions alone are considered. Learning has been shown to occur by other researchers using coincidence timing tasks, many of a different type (e.g. Wade, 1980; Wrisberg & Mead, 1981, 1983). The CA matched group really exhibits no improvement over the final three blocks, with a possible ceiling effect to the task, although subsequent lower error scores on day 2 would suggest that this is not the case.

With regard to the differences between response patterns, the effects are considerably more evident for the low MA groups than for the CA matched group. The short response pattern consistently results in responses being made too easy, whereas the long response pattern results in responses being made too late. This is the case regardless of the phase of the study. The CA matched group alone, having mastered one pattern, is apparently able to utilise information from the previous experience and modify the use of the cues accordingly, on transfer.

Jensen, Picado & Morenz (1981), using a gross motor coincidence timing task with undergraduates, found that a shorter movement pattern resulted in less error than a large one. However, the nature of the shorter pattern was very different from the one employed here, in that the present response is ballistic; having jumped into the air, the individual cannot influence his response any further. The short response pattern used by Jensen, Picado & Morenz (1981) was similar to the long one used in the present study, in that there was an opportunity for modification of the response along the way. It differed from the longer response pattern only in terms of distance covered.

With regard to the use of previous experience, the CA matched group alone appears to have been able to build up a picture of the task during practice and then perform the cognitive exercises necessary to ensure success at the new task. For both the group with learning difficulties and the MA matched group the error recorded on transfer was even greater than during the first trial block on day 1 suggesting inappropriate application of cues learned.

On the basis of this study, one can tentatively suggest that for this task at least,and possibly for other tasks falling within the category of environment moving, whole body moving, children with learning difficulties, as a group, perform at a lower level of skill than groups of children matched with them on chronological and mental age. This is not to say that this is true of all children falling within that group, since there may well be some overlap between the groups.

# CHAPTER NINE

## SUMMARY AND CONCLUSIONS

The first three chapters considered the information available regarding children with learning difficulties, defined as having a measured IQ of between 50 and 75, in respect of their level of performance and learning of motor skills. A considerable amount of information is available both for children with learning difficulties and for children from within the range of normal intelligence regarding the performance of motor skills, but there is a general dearth of information regarding the learning of motor skills by children with learning difficulties. The result is that information principles etc. are borrowed from the research into verbal learning and verbal behaviour, from the work of such as Borkowski and Wanschura (1974), Brown (1974) and others. It is against this background of research that the present investigation was undertaken.

It was suggested that what was required was a systematic approach to learning by children with learning difficulties, and one way by which this might be achieved may be by task classification. Several task analyses and classifications were considered (e.g. Poulton, 1957; Fitts, 1965, Gentile, Higgins, Miller & Rosen, 1975), and a task classification scheme was proposed which focussed on the mobility or stability of the environment, person and body parts, such that the determining feature was that any one or a combination of these elements could be deemed to be in motion whilst the remaining element(s) remained stationary. It is not suggested that this is the sole classification scheme that could be useful, but it was proposed as one which appeared to have certain value in that it focussed on commonalities that were not in any way artificial and unrelated to the individual attempting the task. Tasks were then selected as representative of categories within this classification and groups of children with learning difficulties and those matched with them on mental and chronological age were examined in respect of their learning of the tasks. It was argued that this might result in a systematic approach to the study of motor learning in children with learning difficulties.

The first two tasks, the linear slide task and the ball throwing task, were selected as representative of the category of 'environment stationary, whole body stationary, body parts moving'. The results were such that at the linear slide task the group with learning difficulties appeared to perform in general at an even higher level than those matched with them on CA and MA, particularly the latter, during the practice phase, and at a level equal to the CA matched group and above the MA matched group on transfer to a novel version of the task, at least with respect to AE analyses. Although the group with learning difficulties does not appear inferior on transfer, it can be argued that relative to their practice performance they fare less well than their peers of normal intelligence, since they have effectively come down to their level of performance, having been performing above it previously. Precisely what is or should be transferred to the novel task is not clear, but it would appear that this is the area in which children with learning difficulties experience greatest problems. The ball throwing task shows the group with learning difficulties are able to almost equal the level of performance set by their peers of normal intelligence throughout, since the analyses, at least for AE, show nonsignificant differences at each stage. The mean values are always slightly greater, however, for the group with learning difficulties than for the CA matched group.

The third and fourth tasks, the pursuit rotor and memory drive tasks, were selected as representative of the category of environment moving, whole body stationary, body parts moving. On the pursuit rotor task, the groups with learning difficulties performed at a level equal to that of the group matched on MA, both of these groups being inferior to the group matched on CA. No transfer design was employed in the pursuit rotor task, since it was meant more as a test of subjective observations made during the testing of the first two tasks, and, as such, as a test of the task classification scheme. In the memory drum task, the level of performance of the group with learning difficulties again fell behind the CA matched group in terms of absolute level of performance and in some cases behind the MA matched group, this trend being reflected at all stages - acquisition, recall and transfer.

For both these studies, and to a greater extent in the case of the pursuit rotor task, individual analyses were considered, since subjective observation would indicate that some subjects, at least, categorized as having learning difficulties appeared to perform at a level equal to if not better than their CA matched peers. On the basis of this, caution is advised in respect of the interpretation and generalisation of results from group analyses. With regard to the memory drum study, several types of analysis were undertaken, with merits and flaws apparent for both the mathematical measures and the subjective assessments taken.

The final task, the coincidence timing task, was selected as representative of the category of environment moving, whole body moving, body parts stationary, insofar as the body parts were only moving in order to assist whole body movement and not performing a separate function. At all stages of this study, on acquisition, recall and transfer, the group with the learning difficulties fell significantly behind both CA and MA matched groups performing at a significantly lower level. With this level of complexity of skill, children with learning difficulties, as a group, appear less able to cope with the task, although learning is evident.

The studies conducted here would appear to give some support for a systematic approach to learning, since it highlights possible reasons for different research findings and provides a broader picture of learning by children with learning difficulties than do isolated studies. Both the resources of the individual and the demands of the task require consideration while examining learning, with the result that generalisation of principles etc. to populations with different resources or to tasks with different demands may well be inaccurate. The five studies, individually and together, highlight certain issues, each of which needs to be considered in turn.

## THE TASK CLASSIFICATION SCHEME

The need for a task classification scheme was outlined in Chapter Four. It is one way of giving structure to research of this kind, and enabling a more systematic approach to the point at issue, which in this case is the learning of motor skills by children with learning difficulties and children matched with them on chronological and mental age.

The classification postulated and the tasks selected focus on the stability or otherwise of the environment, the body and the body parts. The findings of the studies conducted here would tend to support this type of classification, since groups of children of similar age and ability perform and learn relatively differently on the different types of tasls. It could be argued that in order to establish any conclusive differences in the performance of the tasks by the three groups, the same subjects should be used in all five tasks. Only then could one attribute any differences in performance on the task to the demands of the task and not to any individual differences. However, the subjects were drawn randomly, and there is no reason to suppose that the resources of the groups differ significantly, insofar as they are all either with learning difficulties and aged on average 12-13 years, or matched with those of chronological age or mental age. It must be therefore, that the crucial factor is the demands placed on the individual by the tasks themselves.

The question of the imposition of temporal requirements certainly appears to be a problem for many children with learning difficulties. It would appear to be one line of study which warrants investigation in terms of the way in which temporal demands influence the total task demands, and the way in which this factor affects individuals, and groups of individuals differentially.

Although the task classification scheme proposed would appear to have some value, it is in no way suggested that it is the only one that would provide a framework within which to work, or that it covers all dimensions of tasks. It may be that other or more dimensions should be considered, accounting for different or more subtle differentiation between tasks. However, care should be exercised in that overzealous inclusion of all possible dimensions taken to the extreme, may result in one or two tasks per category. In this case, no great value of classification has been achieved; a segmented rather than a structured framework is the result. Commonalities between tasks would appear to be as important as are the differences between them, particularly if in research and experimental work the findings indicate similarities in terms of results for individuals attempting tasks classified as similar.

It would appear, in general, that the task classification scheme proposed for use here has provided a reasonable structure within which to work. The advantages of bringing together a series of studies within a framework of this kind rather than conducting isolated studies, is that it enables a broader, more cohesive, overview of the major issues, which here is seen to be motor skill learning in children with learning difficulties and their CA and MA matched counterparts. As such, it has assisted not only in highlighting differences and similarities between tasks, but also differences and similarities between the three groups of children.

THE EXPERIMENTAL PARADIGMS

The experimental designs employed in the five studies differ in various ways:

(i) 2 of the 5 studies employ a recall phase.

(ii) The length of the practice-recall rest interval varies.

(iii) 4 of the 5 studies employ a transfer design.

(iv) The length of the practice-transfer or recall-transfer rest interval varies.

(v) The number of practice trials given in each study varies.

(vi) The organisation of the testing, the inter-trial interval and overall structure of the practice session varied.

(vii) The exact nature of the practice given varies both within the studies and over the five studies.

The value of these different elements of design within the studies is in reflecting different aspects of the learning process. At the same time, because the tasks themselves are embedded within the structured framework, the processes studied are seen as aspects of the total learning process.

As a result of these factors certain features are highlighted. The length of the practice phase given has significance. Enough practice needs to be given in order that the children should overcome the major problems of the task, and basically 'master' the skill. However, the effect of a given length of practice session on the three groups employed here may well be different. The CA matched group may be expected to master a given level of accuracy, skill etc. in a shorter period of time, with the result that any further practice is presenting the opportunity for overlearning. The significantly beneficial effects of overlearning or at least recall of the task have been demonstrated by reseaarch both with subjects with learning difficulties and from within the range of normal intelligence (e.g. Melnick, 1971; Chasey, 1971; Chasey, 1977). The result may be therefore that any superiority at the recall phase on the part of such groups may be partly attributable to the possibility of overlearning. One questions what differences may have emerged at the recall phase if all groups of children were allowed to continue practice until a criterion level had been reached.

The use of recall and transfer phases are important, since in some cases, particularly on the transfer phase, different patterns emerge between groups or practice conditions, for example. Schmidt (1982) argues that a transfer phase is essential in studying learning if one is to discover what exactly is being learned. Recall will assess only whether the specific task details and demands have been acquired and retained, whereas a transfer phase will enlighten as to whether any principles, strategies etc. have been developed. That this occurs, Schmidt (1982) argues is essential, since experiences in life are not repeated exactly and would require learning on each occasion if only specific task details were learned. Using both recall and transfer in this way, it is possible not only to assess recall or transfer as such, but also relative recall and transfer. Furthermore, the process assists in shedding light on the relative benefits of, for example, practice condition, which in turn may develop one's understanding of the learning process. One aspect that warrants consideration in the designing of a transfer phase is the precise nature of the task, since the proximity and nature of the relationship between that version of the task and the practice version(s) may influence the results, particularly relative to the different groups tested.

The length of the intervals between practice and recall, recall and transfer, and practice and transfer are also significant. One might expect greater recall over a shorter period of time; the effects of overlearning may be significantly increased over longer periods of rest; the 'schema' as proposed by Schmidt (1975b) developed as a result of practice may be less diverse in some groups of children than others, particularly if not as well developed and over long periods of rest, the relationships more easily forgotten, with less possibilities of transfer. These factors, amongst others, should be taken into consideration particularly when comparing studies employing different rest intervals.

The nature of the practice given may well be influential. To state that practice was variable or constant, and in particular to then compare the results with other studies employing variable or constant practice, may be unsound. Such factors as the dimension along which the practice was varied, the extent to which it had been varied, both in terms of the numbers of instances and their 'separateness', as well as the ordering of the practice may be more influential than the mere fact that it was varied in the first place.

Whilst the task classification scheme may be one method of comparison of the learning of motor skills, these other features also require consideration. They fundamentally constitute task demands and should be considered in this light. It would possibly be worthwhile to standardise all procedural variables and to then compare learning and performance over different types of tasks, although in some cases this may be impractical. It would perhaps provide a better analysis of the task classification scheme, but possibly not such a value in terms of examining the learning of motor skills.

THE RELATIVE PERFORMANCE OF THE THREE GROUPS OF CHILDREN AND THE EFFECT OF PRACTICE CONDITION

The relative performance of the three groups of children varies according to the type of task being presented and attempted. At the tasks in which no temporal demands are being made, the group with learning difficulties performs at a level equal to if not in excess of the group matched with them on chronological age, at least during the acquisition phase. Their ability to perform at such a relatively high level must in part be due to the great enthusiasm observed. This may partly be a function of the school, since the overall impression that one gets on visting the school is the enthusiasm, enjoyment and hard working nature of both staff and pupils. However this is not the only factor, since on subsequent tasks, pupils from the same school are not able to match the level of performance of their peers of normal intelligence. Even on transfer to a novel version of the linear slide task in particular, one group with learning difficulties does not maintain the superiority. This would appear to suggest that even on a task in which no temporal demands are made, generalisation of principles etc. from a previous similar and related task is the area of operation in which groups of children with learning difficulties appear to experience difficulties.

Much of the research into verbal learning suggests that transfer is the area in which children with learning difficulties experience difficulties

Kellas, Ashcraft & Johnson (1973), for example, found beneficial effects of rehearsal training, although to a much greater extent when the children were retested using the same material rather than a new set. A similar absence of transfer was found by Bilsky, Evans & Gilbert (1972) and Bilsky (1976), although research by Burger, Blackman and Tan (1989) indicated that following a training programme both children with learning difficulties and children of normal intelligence performed better on transfer taks than those having received no such training programme, with no difference between the intelligence groups. However, these findings are in the minority, and the majority of findings suggest that although techniques such as associative clustering and mnemonic elaboration can be induced in children with learning difficulties, transfer to novel tasks or lists is relatively small.

With regard to motor skill learning, some research (e.g. Porretta, 1982) has suggested that such children are able to make the extractions necessary to the development of schema as proposed by Schmidt (1975b) since variable practice has proved superior to constant practice on transfer to a novel version of the task. The findings are similar here. On the linear slide task, the AE trends are similar for all groups of children, but at transfer distance 1 very much accentuated for the group with learning difficulties, with the constant practice significantly inferior to the narrow band of variable practice, and on transfer distance 2, no significant differences between the practice conditions. It may be that the precise nature of the variable practice beneficial to the three groups is different. In the case of the group with learning difficulties, the narrow band of practice is superior and one can envisage that the relationships between such experiences and one close to it would be easier to comprehend than more distant experiences if this is indeed the way in which practice should be varied. Similar results are apparent for the AE analyses on the ball throwing task; no differences emerge between practice conditions on transfer distance 1, but on transfer distance 2, the constant practice group fares less well than two of the variable practice groups, although not significantly so.

On the basis of these findings, one is led to conclude tentatively that a group with learning difficulties is capable of making the cognitive extractions etc. necessary to develop the schema as proposed by Schmidt (1975b). However, from the fact that, relatively speaking, their level of performance deteriorated on transfer by comparison with those marked on chronological age, one could infer that they execute these exercises less efficiently.

The analyses for the pursuit rotor and memory drum tasks suggest that the level of performance of the group with learning difficulties is significantly lower than that of a group of subjects matched with them on chronological age, and often at a level lower than that of subjects matched with them on mental age. The main differences between these tasks and the previous two is the temporal demand made by the environment; the children are no longer free to make the necessary responses in their own time, but must begin and finish to order. This imposition would appear to affect the children with learning difficulties as a group, much more adversely than the groups matched on chronological and mental age. Furthermore, the findings for the memory drum study in particular would appear to suggest that the greater the temporal imposition, the more significant the effect of such on the group with learning difficulties, since it is on the regular track (in which there are greater temporal demands) that the group with learning difficulties falls significantly behind the level set by the MA matched group.

On the coincidence timing task, the group with learning difficulties consistently performs at a level significantly worse than both matched groups. In this instance, not only are external temporal requirements being imposed, but the degree of body involvement is much greater. The child is requested to move his whole body through space, but these requirements are less demanding than the temporal ones. It was checked that all children were able to meet the spatial requirements without practice, prior to the commencement of testing. However, it is possible that although all children were able to meet this requirement, for some children it required some attention throughout, such that they were not able to devote total attention to the temporal requirements. Preferences for sequential processing by children of low IQ were demonstrated by such as Das & Cummins (1978) and this may also be an influential factor.

The measurement of the relative effect of previous practice on performance of the novel transfer task is possibly less illuminating in the two final studies than in the first two tasks, since the group with learning difficulties performs at a level significantly lower than CA and MA matched groups during acquisition and recall, and merely continues to do so on transfer. One cannot reasonably expect improvement or superiority on transfer by such a group, particularly since even in the less temporally demanding tasks, it is the transfer phase at which their performance is relatively depressed. It would appear, however, from the results on transfer that some benefit has been gained from the previous practice, since the group is performing at a level higher than in theearly trials of the practice session, although again the group with learning difficulties fares less well than the two matched groups, suggesting less efficient transfer on their part. This would appear to lend some support to the findings of the first two studies, which would suggest the possibility of transfer on the part of children with learning difficulties, but to a lesser extent than for children from within the range of normal intelligence.

From these studies, two main features become apparent regarding the relative ability of the three groups of children to learn motor tasks. The first part is that the imposition of temporal requirements would appear to have a greater effect on children with learning difficulties than on children from within the range of normal intelligence. Secondly, with regard to the way in which learning takes place in children with learning difficulties, the findings would suggest that this may be in the same way as for children of normal intelligence, but to a more limited extent. In many ways, this is reflective of the analyses of performance in children with learning difficulties by Dobbins & Rarick (1975) who found a similar factor structure to that of children of normal intelligence for motor performance, but the children with learning difficulties performing on a lower level in general. Such children appear to be able to transfer skills, principles etc. but less efficiently. It may be that the relationship between practice and transfer must be much closer and more direct for such children than for children from within the range of normal intelligence, of the same age.

GROUP AND INDIVIDUAL ANALYSIS

The standard deviation gives some statistical indication of the variability of scales that exists inside a group, and in some of the groups studied and experiments conducted these were quite high, more so in some cases than others. Subjective observation whilst testing also suggested that there was a great deal of variability within the groups. In the pursuit rotor task, for example, within a given group, there were found to be children who performed at a level consistent with the mean for the group, but a few subjects who performed at a level outside that range, either significantly better or significantly worse. This was particularly the case in the groups characterised as having learning difficulties.

The examination of individual data may, therefore, have a part to play in the understanding of learning on the part of these children. In this research, individual data was examined by simple observation in the case of the pursuit rotor study, and revealed that whilst there certainly were group trends indicating the inferiority of the children with learning difficulties as a group, there were within that group, certain individuals who, on the basis of the results they achieved, would be indistinguishable from those matched with the group on chronological age, but from within the range of nominal intelligence. Furthermore, many individuals with learning difficulties performed at an absolute level higher than the majority of the group matched on mental age. It would appear possible that there is a hard core of subjects with learning difficulties performing at a very low level, who never really mastered the taskand consistently adversely affect the mean of the whole group. Although group trends do exist, it may well be unwise to make generalisations to the entire population with learning difficulties, particularly with regard to the development of training programmes designed to improve learning of motor skills. It is arguable that, particularly in the case of training or remedial programmes, what is required is an individual approach in preference to a group approach.

SUBJECTIVE AND OBJECTIVE ASSESSMENT

One of the major advantages of objective mathematical measurement over subjective assessment is that it results in interval data, which is useful in terms of statistical analysis in that it allows a more detailed understanding of the factor involved, since a greater range of analyses is available. However, these analyses should be undertaken in the light of the understanding that what is being assessed by such measures is that which it is desired to assess. In the event that this is not the case, the value of such mathematical measures decreases.

An attempt at understanding whether mathematical and subjective assessments measure the same factors or whether or not this was desirable was undertaken in the memory drum study. It was suggested that in fact although the correlation between the two was moderately strong, the disagreement existed because they were not basically measuring the same thing, and whilst both measured accuracy, the definition of accuracy was different for the two measures.

Further consideration was given to the value of the generally accepted measures, the modules mean error and root mean square error with suggestions that they may well have flaws or limitations.

It is not intended that, at this stage, subjective assessment should replace the objective mathematical measurement. However, it is considered that it has a part to play in the total analysis.

CONCLUDING REMARKS

In conclusion it can be said that from the five studies conducted, certain features about the learning of motor skill on the part of children with learning difficulties and those matched with them on chronological and mental age emerge. Firstly, as a group, there are types of tasks on which children with learning difficulties are able to perform at a levelequivalent to that of children of the same chronological age but within the normal range of intelligence. At the same time, however, there are other types of tasks at which they are unable to learn to a level comparable with those matched on chronological age but superior to those matched on mental age, and yet again tasks in which their level of learning will be inferior to both matched groups. This assumes a consistent length of practice for all groups. The dimensions along which these types of tasks can be identified are that of the degree of temporal control exercised by the environment and the degree of body involvement required.

As individuals, however, the picture may be very different, such tha whilst some individuals may be indistinguishable from their chronological age matched peers from which the range of normal intelligence on a few, many or all types of tasks, other individuals will perform at a level well below their peers matched on mental age on a few, many or all types of tasks. It would appear that children with learning difficulties are not a homgenous group. One might expect differences to emerge between such a group and a group of the same age from within the range of normal intelligence, because cognition is an integral part of learning motor tasks, and this is the area in which children with learning difficulties experience problems. Whilst this may be true, it is possible that such children have, in fact, disabilities in specific areas of operation which may or may not relate to the task they are learning, with the result that some individuals, on some or all types of tasks, are able to perform at a level equal to that of their peers matched on chronological age.

With regard to the way in which learning is brought about, the individual/group relationship may be similar. As a group, it would appear that children with learning difficulties are able to execute the cognitive exercises necessary for the development of schema in the same way as children of the same age but from within the range of normal intelligence and to engender some transfer to a normal version of a task, although, as a group, they appear to do this less efficiently. As individuals, some may be able to do so as well as their peers, whilst others are very limited in their ability to do so. The nature of the task is also a consideration here.

Future research could prove valuable in a number of areas, including

(i) A more detailed examination of the way in which motor tasks differ, as a basis for a systematic investigation of motor learning and performance.

(ii) A greater understanding of the amount and nature of the variability that exists within groups, particularly those with learning difficulties.

(iii) A systematic approach to the understanding of motor learning, standardising all the variables relative to the experimental paradigm and design.

(iv) The identification of individuals with particular difficulties in learning a particular type of task, the reasons for such problems, and the development of a training programme to assist in overcoming these problems.

(v) Careful consideration of the meaning of the measures taken as indices of success, accuracy etc. and their relative merits.

In following any of these lines of investigation with regard to children with learning difficulties, researchers should be mindful, above all, that a child designated as having learning difficulties will not necessarily learn and perform motor skills at a level below that of his peers of the same age but from within the normal range of intelligence.

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